Investigating the dynamic impacts of public debt on economic growth in the Democratic Republic of Congo: a case of quantile on quantile regression

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Université Officielle de Bukavu

2024

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Abstract: From the early 1980s until the late 2000s, the Democratic Republic of Congo (DRC, thereafter) was in severe debt distress, which resulted in debt relief under the Heavily Indebted Poor Countries (HIPC) initiative. Surprisingly, the DRC's debt-to-GDP ratio increased significantly from around US$6.4 billion in 2019 to US$10.4 billion in 2022. With this in mind, we investigated the long-term impacts of public debt on growth by examining whether the debt-growth link is time-varying and state-dependent. Unlike the existing literature on country-specific studies that use parametric approaches, we employed the novel non-parametric Quantile-on-Quantile Regression (QQR) framework to uncover the non-linearity of the effect of public debt on growth using data covering the period 1970-2022. The results revealed asymmetric effects of public debt on growth across GDP growth quantiles. Specifically, we found positive impacts of public debt in lower quantiles (0.05-0.3) and middle quantiles (0.4-0.6) of GDP coupled with lower quantiles of Debt-to-GDP ratio (0.05-10). Moreover, the slope coefficient becomes negative in almost all quantiles of GDP coupled with the lower quantiles (0.2-0.3), middle quantiles (0.4-9.6), and higher quantiles (0.7-0.95) of Debt-to-GDP ratio. To check the robustness of our results, we used Markov Switching (MS) regression and the results were consistent with those of the QQR approach. Policy implications for robust growth in the DRC are provided.

Keywords: Public debt, Economic growth, Threshold model, QQR model

JEL classification: C23, E62, F34, H63, O11

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1. Introduction

In recent years, the relationship between public debt and economic growth has attracted the attention of several scholars and policymakers around the world. This is because debt is a double-edged sword. When used wisely and in moderation, it significantly improves the well-being of the country (Checherita-Westphal and Rother, 2011; Law, 2021). It also acts as a destructive factor, particularly for economic growth, if it is misused (Cecchetti et al. 2011), whether the country is developed or underdeveloped. Specifically, at the household and business level, overindebtedness leads to bankruptcy (Cecchetti et al. 2011). Likewise, at the national level, excessive debt undermines the government's ability to provide essential services to its citizens. Excessive debt can squeeze a government's budget to the point where crucial services—like healthcare, education, and infrastructure—suffer. It also prevents the financing of productive public investments, which can lead to a reduction in the production capacity of goods and services for an economy (Cecchetti et al. 2011).

Understanding the issue of public debt versus fiscal sustainability is crucial for robust and sustained economic development in developing economies. Since the role of the state is to ensure debt sustainability, economic theory predicts that high levels of public debt could have adverse effects on growth (Modigliani, 1961; Diamond, 1965). However, in recent years, the ideas of a debt-to-GDP ratio threshold and the non-linear impacts of public debt on economic growth have received considerable research attention. This is because policymakers want to know the public debt threshold to craft policies that keep debt within manageable levels, ensuring that the economy remains stable and that the government can continue to fund essential services without excessive borrowing (Rahman et al, 2019). The seminal work of Reinhart and Rogoff (2010) presents a more elaborate framework studying the long-term impact of public debt on the economic growth of countries. The two authors show that, even if the link between public debt and the growth of an economy seems relatively weak at certain levels of debt, debt is particularly linked to weak growth when it exceeds 90% of GDP.

Several subsequent studies (Cecchetti et al., 2011, Checherita-Westphal and Rother, 2012, and Baum et al., 2013) directly referred to Reinhart and Rogoff (2010) in calling out for urgent fiscal consolidation measures to achieve significant control of public debt (Checherita and Rother 2010; Konzelmann 2014; Law et al 2021). Nonetheless, other researchers have reexamined the debt-growth relationship and found different results, making the debate inconclusive. In a sample group of 71 developing countries for example, Law et al (2021) found a threshold debt value of 51.65 percent, which is much lower compared to the previous literature. Moreover, studies that employed single-country approach report conflicting results on the threshold value. In Zimbabwe for instance, Mupunga and le Roux (2015) used a quadratic debt model and estimated a debt-to-GDP ratio threshold of between 45% and 50%, while Omotosho et al. (2016) finds 73.7% for Nigeria, Chikalipah (2021) reports 40% for Zambia, and Ndoricimpa (2022) finds a robust debt threshold of 37% for South Africa. This opens new research opportunities to reconcile the inconsistency in the literature.

Additionally, most empirical findings on the debt-growth relationship are restricted to the traditional parametric econometric approaches (Omotosho et al, 2016; Chikalipah, 2021; Ndoricimpa, 2022). However, parametric estimators are not robust to outliers and they usually fail to integrate the time-varying nature of the slope coefficient (Dzator and Acheampong, 2020). Consequently, understating the impact of public debt on economic growth requires an improved novel econometric procedure that is robust to data outliers and that can account for slope heterogeneity.

Against this background, this study seeks to reinvestigate the dynamic impacts of public debt on economic growth in the case of DRC. The main objective of this study is to elucidate the intricate interconnections between public debt and economic growth by providing substantial contributions to the policymakers, professionals in the field, and academic community. In so doing, our study contributes to the literature in different ways. To the author' best knowledge, this is the first study to empirically investigate the debt-growth nexus in the DRC, a low-income country that has experienced major economic challenges throughout the period studied, and which has not been widely studied on this topic. Understanding the dynamics of public debt and its effect on growth for the DRC is crucial for several reasons: (1) since 2019, public debt increased from US$6.4 to US$10.4 billion (14.58% of GDP) in 2022. This may seem modest, but for a poor country like the DRC, it is extremely high. The country's debt capacity is limited by its low repayment possibilities due to low revenue mobilization[2] and vulnerability to fluctuations in commodity prices. If there are no orthodox public debt management mechanisms, there is a risk plunging back into a difficult financial situation similar to the years before 2010. Consequently, the current dynamics of positive and robust economic growth achieved since 2010 may risk being affected by the ongoing growing public debt. Moreover, DRC is one of the poorest countries in the world despite its enormous natural resources endowment. According to the PovCalnet database, 78.94% (or 73.3 million) of the population lives with less than $2.15 per day in 2022. Since high levels of public debt can lead to increased poverty in developing countries, as

[2] According to the report from the Ministry of Budget relating to the 2022 financial year, public finances reveal the level of tax pressure located at 14% in 2022, compared to 11% in 2021. Indeed, the tax pressure in the DRC remains well below the average for sub-Saharan Africa that is around 18% of GDP (https://www.budget.gouv.cd/wp-content/uploads/budget2024/projet/document_11_depenses_fiscales_2022_impr.pdf).

theoretically postulated (Addison and Rahman, 2004; Addison, 2006), the government needs to comprehend all the dynamics of public debt in relation to growth prospect. Doing so will allow the government to exercise cautionary measures when contracting excessive debt, prioritize debt sustainability and avoid negative effects on growth and poverty.

Additionally, this study contributes to literature by investigating the debt-growth relationship using the novel QQR technique as recently developed by Sim and Zhou (2015). Most existing studies employed parametric techniques. They mainly focused in determining a single threshold point where excessive debt harms growth. Here, we hypothesize that the impact of public debt on growth is time-varying and state-dependent. To assess these hypotheses, we deploy the QQR and MS regression approach. To our knowledge, this is the first study to use the QQR method to analyze the dynamics of public debt on growth in the context of a single country study. The use of QQR method is advantageous because it is robust to outliers and could account for time-varying slope. Furthermore, unlike conventional linear regression approaches used in prior literature that primarily examine conditional means, the QQR method provides the ability to model and analyze the associations of conditional quantiles of public debt with those of GDP growth. Since empirical evidence regarding the debt-growth nexus using QQR approach is scarce, this study's findings could play a pioneering role in the debate regarding the dynamics of public debt, fiscal sustainability and sustained economic growth, especially within a poor developing economy. Finally, this study is relevant for policy since the findings will contribute to the DRC's formulation and implementation of public reforms for future and robust growth.

The remaining sections of this study are outlined as follows: a brief history of public debt in DRC is provided in Section 2, the theory and literature survey is presented in Section 3. Section 4 presents the methodology and data, while Section 5 presents and discusses the empirical findings. Finally, section 6 provides the conclusion of the study.

2. A brief history of public debt in DRC

As in most African countries, the history of public debt in the DRC dates to the 1970s. The DRC, which became Zaire in 1971, experienced a financial crisis. There was an urgent need for financial facilities to adjust the country's balance of payments and carry out major economic and development projects (Debt justice, 2017). The sovereign debt during this period amounted to approximately $342 million and corresponded to loans taken out from private and multilateral organizations guaranteed by mineral resources. The year 1974 was marked by the fall in the price of copper, Zaire's main export raw material, which made it more difficult to repay loans. In 1976, Zaire could not meet its debt repayment obligations. The International Monetary Fund (IMF) stepped in to implement its austerity program. The country's public debt will increase further when the United States decides to increase its interest rate in 1980. The debt service exceeded 50% of the country's domestic production during the years 1983-1989 and the general public debt reached a peak of 258% of GDP (equivalent to 12.155 billion current US dollars) in 1999 (IMF)[3]. To enable many poor countries to alleviate their debt burdens, the HIPC initiative was proposed in 1996 at the joint initiative of the IMF and the World Bank (WB)[4]. In July 2010, the executive boards of the WB and the IMF approved an irrevocable debt relief for the DRC. The country became the 26th Regional Member Country (RMC) of the WB group to reach the completion point under the HIPC Initiative. The country was eligible for a total debt relief of $7,252 million as of end-December 2002, including $1,009.7 million from the Bank Group (African Development Bank, 2011). Precisely, the DRC's debt was reduced from $13.704 billion to $2.931 billion between December 2004 and July 2010.

However, according to recent figures from la Direction Générale de la Dette Publique (DGDP)[5], the public debt of the country has increased by $3 billion over the past three years. It increased from $7,385.03 billion in 2021 to $10,542.81 billion in 2023. During the same period, the external debt of the DRC grew by nearly $2 billion in three years, from $4,867.98 billion in 2021 to $6,829.72 billion in 2023. Meanwhile, the internal public debt of the country increased from $2,517.05 billion in 2021 to $3,713.09 billion in 2023. As of December 2023, the IMF estimates the general public debt of DRC around 14,58% of GDP ($10,57 billion), exceeding a bar of 10 billion dollars. Hence, the DRC regained its seat on the HIPC.

3. Theory and literature survey

3.1. Theoretical literature

Economic theory tends to highlight the negative relationship between public debt and economic growth. Modigliani (1961) argues that the national debt constitutes a burden on future

[3] The IMF database provides the general government debt data for several countries in the World, including DRC. It is well documented that in 1999, the public debt reached a higher level of 268% of GDP (https://www.imf.org/external/datamapper/GG_DEBT_GDP@GDD/SWE)

[4] To be eligible a country should: (a) have an average per capita income of less than $780 per year; (b) having undertaken reform programs with the support of the IMF and the World Bank; (c) have an unsustainable debt after the application of traditional relief mechanisms, that is to say after the application of the Naples terms, i.e. a reduction of 67% of the Net Present Value (NPV) of the debt eligible for the Paris Club; (d) the ratio NPV of debt/Exports of goods and services must represent more than 150%; (e) the ratio Debt service/Exports of goods and services must be greater than 20%; (f) the ratio Exports of goods and services/GDP of 30%; (h) the ratio Tax revenue/GDP must be equal to 15%.

[5] La Direction Générale de la Dette Publique (DGDP) is the agency responsible (within the Ministry of Finance) with the analysis and management of the public debt portfolio. The data presented above comes mainly from the managed public debt database by the "DGDP" under SYGADE 6. They are completed by information provided by the Sino-Congolese Program Coordination Office, the Central Bank of Congo "BCC" and GÉCAMINES, which contracted the external debt without the guarantee of the state (https://risquepays.gouv.cd/statistics/wp-content/uploads/2023/06/Bulletin-Statistique-de-la-dette-publique-n162022-1.pdf).

generations, manifested in the form of a reduced flow of income from a lower stock of private capital. In explaining his theory, he considered only one case where this burden could be offset in part or in full, where debt finances public spending that could contribute to the real income of future generations, such as productive public infrastructure. Similarly, Diamond (1965) emphasizes the negative effect of debt on growth due to the negative effect of taxes on capital stock. He concludes that, due to the impact of taxes required to finance interest payments, both public and private debt reduce taxpayers' disposable consumption over their lifetime, as well as their savings, and therefore the capital stock and future economic growth. In a simple theoretical model integrating the state budget constraint as well as debt financing, Adam and Bevan (2005) find that an increase in productive public spending, financed by an increase in the tax rate, will not promote growth only if the level of the State's public debt is sufficiently low. There are several other channels through which debt impacts growth. These include total factor productivity, as proposed by Patillo et al. (2004), or increased uncertainty about future policy decisions, with a negative impact on investment and, even more, on growth, as in Agénor and Montiel (1996).

3.2. Empirical evidence

The empirical literature on the impact of public debt on economic growth is extensive and varied, reflecting the complexity of the relationship between these two variables. More recent studies confirm the existence of a non-linear impact in the form of an inverted U—shaped relationship between public debt and economic growth (Chen et al, 2017; Law et al, 2021; Medina et al, 2020). Initially, public debt can boost economic growth by increasing aggregate demand and financing productive investments. However, beyond a certain threshold, the negative effects of high debt levels, such as increased interest payments and reduced private investment, start to outweigh the benefits. Pattillo et al. (2002) used a sample of 93 developing countries over the period 1969-1998 and found that the impact of external debt on GDP per capita growth is negative for the net present value of debt levels above 35-40%. Reinhart and Rogoff (2010) examined the impact of public debt on growth for a sample of 20 advanced countries and found a common threshold of 90% debt-to-GDP ratio for which debt has a negative effect on growth.

Several authors have contested the result of Reinhart and Rogoff (2010) estimating that countries are heterogeneous on several factors, which can lead to heterogeneous public debt thresholds. Thus, an emerging empirical literature has reconsidered the concave nonlinear relationship between public debt and growth and takes into account various econometric issues, such as causality or simultaneity bias and factor heterogeneity. Shal et al (2024) deployed a dynamic panel threshold model on a sample of developing countries over the years 1990-2020 and study the threshold effects of public debt on economic growth. One of the peculiarities of the Shal et al (2024) study is that they went a step ahead and classified countries into lower-middle-income and upper-middle-income economies in order to check the threshold level heterogeneity. Their findings revealed that public debt negatively hinders growth beyond the thresholds of 50.243% and 62.646%, respectively for the two income groups, thus indicating differences in the threshold levels between the two subsamples. Moreover, Yousaf and Aziz (2024) used dynamic panel threshold model and other econometric techniques and found the threshold to be 56% of GDP, beyond which public debt hampers growth. Law et al (2021) used a dynamic panel threshold technique on a sample of seventy-one developing countries from 1984 to 2015 and found threshold debt value of 51.65%.

Furthermore, a few studies presented positive effect of public debt on growth, thus, contradicting those who have supported the adverse effect of debt on GDP growth. Remarkably, Minea and Parent (2012), used panel smooth threshold regression (PSTR) models and reported a convex relationship between debt and growth. Precisely, the two authors found the debt effect negative below a high debt threshold of 115% and positive above this threshold. Moreover, Tung (2022) considered a case of 12 emerging economies between 1980 and 2015 and found that public debt exercises a positive effect on economic growth.

In line of heterogeneous threshold effect, some authors have considered the approach of country-specific studies. For example, Medina et al (2020) investigate the impact of public debt on economic growth for Mexico during the 1994–2016 periods. They found that public debt negatively affect economic growth when it exceeds the threshold in the debt-to-GDP ratio of 27%. Bentour (2021) applied the kink regression method of Hansen (2017) to study the existence of possible threshold effects in the link between public debt and growth in 20 advanced countries. Its conclusions contradict the hypothesis of a debt threshold common to all countries. The author concluded by showing that whenever a threshold exists, it is specific to a country rather than a common rule applicable to all.

A small but growing number of studies have been carried out for certain African countries. For example, Chikalipah (2021) investigated the impact of the sovereign debt-growth relationship in Zambia during the period between 1970 and 2017, by employing both the linear and non-linear specifications. The study results revealed evidence for a non-linear relationship, with an estimated threshold of around 40% of the debt-to-GDP ratio. Ndoricimpa (2022) applied the kink regression framework in investigating the sovereign debt effect on growth in South Africa on a sample period between 1961 and 2019. The findings revealed a robust debt threshold of 37% over which debt was harmful to growth in the country.

As this literature review shows, the results of existing studies are contradictory and still inconclusive, with some research reporting either a decreasing or increasing impact of public debt on GDP growth. The results of previous studies are surrounded by greater uncertainty and can have dangerous consequences when translated into policy decisions. Given these conflicting empirical findings, further studies are needed to reconcile the inconsistencies in the literature. Besides, most empirical studies on the relationship between public debt and growth are limited to traditional parametric econometric models (Ndoricimpa, 2022; Checherita-Westphal and Rother, 2012, and Baum et al., 2013). Parametric estimators may not be robust to outliers and sometimes do not take into account slope heterogeneity (Dzator & Acheampong, 2020). Therefore, underestimating the effect of public debt on growth requires a new advanced econometric approach, robust to outliers and which could take into account the time-varying and state-dependent effects. Additionally, the DRC is highly integrated with the rest of the world and plays an important role in the international commodity market, essential to global economic growth. To our knowledge, there is no study on the relationship between public debt and economic growth in the DRC. Consequently, this study contributes to the literature by applying the novel non-parametric QQR approach to study the link between public debt and economic growth in the DRC for 1970-2022 while controlling for physical capital, labor, inflation and the rate of exchange.

4. Methodology and data

4.1. Empirical model

In this study, the short and long term impacts of public debt on growth are modelled within the framework of the augmented Solow–Swan growth regression model (Solow, 1956; Swan, 1956). The Solow–Swan growth model is augmented with the debt-to-GDP ratio as the main variable of interest and a set of additional control variables to avoid the bias associated with the omission of variables bias. Hence, our analysis focuses on the coefficient of debt, which estimates the impact of public debt on growth in the DRC. The full model specification is as follows:

$$y_t = [A_t Labour_t]^{\alpha} Capital_t^{\beta} Z_t^{(\varphi=1-\alpha-\beta)} \quad (1)$$

where y_t denotes the aggregated output produced in time t, $Capital_t$ is the stock of physical capital, $Labour_t$ is the total labour force, A_t is the labour-augmenting technological progress or production knowledge (also known as total factor productivity)[6], and Z_t is a vector of variables including public debt and other control variables such as annual inflation rate and the US-CDF[7] exchange rate. The couple $A_t Labour_t$ represents effective labour. φ, α and β are elasticities to be estimated. We simplified the model by linearizing Eq. (1) as:

$$GDP_t = \alpha Labour_t + \beta Capital_t + \delta Debt_t + \pi Inflation_t + \vartheta Exchrate_t + \varepsilon_t \quad (2)$$

where GDP_t represents the growth rate of Gross Domestic Product, $Labour_t$ and $Capital_t$ are number of persons employed in millions and capital stocks at currents PPPs (in 2017 million US$), respectively. $Inflation_t$ and $Exchrate_t$ are the rate of inflation and exchange, while ε_t is the stochastic error term. From equation (1), we maintain two possible mechanisms by which debt accumulation can affect economic growth. Firstly, as many developing countries, DRC has an underdeveloped bond market. Most infrastructure projects and budget deficit are financed mainly by bilateral and multilateral debt. Thus, public debt can stimulate/hinder growth through public spending channel. Secondly, the literature assumes that when public debt exceeds a certain threshold, the effect on growth becomes negative (Hansen, 2017). It is often argued that low/high public debt rate is associated with high/low economic growth (Ndoricimpa, 2022).

4.2. Analytical techniques

4.2.1. Quantile-on-Quantile Regression (QQR)

In this study, we used the Quantile-on-quantile regression (QQR) technique to capture the dynamic impacts of public debt on GDP growth in the DRC. This technique was introduced for the first time by Sim and Zhou (2015). It captures the tail and current nonlinear effect in an ad hoc way between the dependent and independent variable. It also offers an in-depth comprehension of the state-dependent and tail effect of the independent variable over the conditional quantiles of the dependent variable. These characteristics make the estimated results from this technique robust in the presence of variable dependency and model misspecification as it resorts specific associations of the distributions of both variables (dependent and independent variable), and that the relationship is statistically significant or not (Adebayo et al. 2022). Furthermore, QQR approach account for the shocks on X that may determine the nexus between Y and X. For instance, a positive/negative endogenous or exogenous shock on X may provide heterogeneous results (small or big) on the variation of Y. Thus, the impact of X on Y using QQR technique is asymmetrical and the magnitude of the coefficient is heterogeneous across quantiles of both variables under observation.

[6] For more details on the production function specification, see Espoir and Ngepah (2020a 2020b).
[7] CDF stands for Congolese Frank

To investigate the variation in the ϑ^{th} quantile of GDP based on the δ^{th} quantile of Debt as well as quantile of other control variables, an unknown local linear regression can be estimated using the first-order Taylor expansion. The QQR model for the relationship between the quantile of the dependent variable (GDP) and the quantile of the independent variable (X) can be written as follows:

$$\underbrace{GDP_t = \emptyset_0(\vartheta, \delta) + \emptyset_1(\vartheta, \delta)(X_t - X^\delta)}_{*} \; + u_t^\vartheta \tag{3}$$

where δ_1, δ_2, …, δ_n represent the quantiles of X_1, X_2… X_n, respectively, and ϑ_1, ϑ_2, …, and ϑ_n represent the quantiles of GDP. The relationship between the quantile of GDP and X is captured by the shaded area (Alola et al. 2023). In Equation (3), the ϑ_n conditional quantile of Y is depicted by (*). Given that the QQR method is a non-parametric regression approach it requires one to specify the bandwidth size that will determines the estimated parameters optimally. In this work, we set the bandwidth to 0.05 as recommended by Sim and Zhou (2015). It is worth noting that the bandwidth conditions the smoothness of the corresponding approximation of the parameters as it determines the scale of the neighborhood surrounding the target point. A larger bandwidth means a higher risk of estimation distortion, while a reduced bandwidth indicates a higher risk of prediction uncertainty (Adebayo et al. 2022).

In estimating equation (3), X_t and X^δ are replaced by the conjugates $\widehat{X_t}$ and $\widehat{X^\delta}$. Subsequently, the coefficients $\emptyset_0$ and $\emptyset_1$ as standing in equation (3), are allocated by φ_0 and φ_1, and are anticipated by localized linear regression. These coefficients are determined by completing the following technique of optimization, which is as follows:

$$min_{\varphi_0,\varphi_1} \sum_{i=1}^{n} \rho_0\left[GDP_t - \varphi_0 - \varphi_1(\widehat{X_t} - \widehat{X^\delta})\right] \text{ x } K\left(\frac{F_n(X_t) - \delta}{h}\right) \tag{4}$$

where the quantile loss function is represented in equation (4) by ρ_0(u) that is expressed by ρ_0(u) $=u(\vartheta - I(u < 0))$. We represent a usual indicator function of a given identifier, K() and h denote the parameters of the kernel function and bandwidth, respectively. To weigh the observations in the X^δ neighborhood, we utilized the Gaussian kernel density function, which is commonly applied function in economics and finance due to its simplicity, computation, and reliability. The weights are inversely proportional to the distance between the analytical distribution function $\widehat{X_t}$, given by $F_n(\widehat{X_t})=\frac{1}{n}\sum_{i=1}^{n} I(\widehat{X_k} > \widehat{X_t})$ and the distribution function value that correspond with the X^{δ} illustrated by δ. When estimating the model the bandwidth determines the smoothness of the approximated parameter. This is because it defines the scale of the neighborhood surrounding the target point. A broader bandwidth recommends a higher risk of estimation distortion, while a smaller bandwidth illustrates a higher risk of prediction uncertainty. In this study, a bandwidth parameter h = 0.05 was used as recommended by Sim and Zhou (2015).

4.2.2. The Markow switching dynamic regression (MSDR) growth model

For the robustness of our study findings, we performed the MSDR framework to test whether the elasticity of GDP growth with respect to changes in the debt-to-GDP ratio is regime dependent. If the slope coefficient varies across regime, then the QQR results will be considered as robust. MSDR is one of the MS frameworks used to model data exhibiting various dynamics across unobserved regimes/states via regime-dependent parameters (Mills and Wang, 2006; Guidolin, 2011a, 2011b, Espoir et al, 2024). As Garcia and Perron (1996) point out, this technique is generally used to adapt to phenomena involving several regimes, such as structural breaks due to economic crises or political reforms. The process of transitions between two unobserved regimes follows a process known in the literature as the "Markov chain". Thus, the procedure allows for changes in the model variance, intercept and explanatory variables (Klarl, 2020 Espoir et al 2024). Following Espoir et al. (2024), we considered unobserved regimes that follow a Markov chain process, then GDP growth is modeled as a constant and a regime-dependent covariate for regimes *r* as:

$$GDP_t = \beta_0^{r_t} + \beta_1^{r_t} Debt_t + \varphi^{r_t} Z_t + u_{r_t}, \quad t \in \mathbb{Z} \tag{5}$$

$$u_{r_t} \sim N\left(0, \sigma_{r_t}^2\right) \tag{6}$$

$$\sigma_{r_t}^2 = k \sum_{r=1}^{k} \sigma_r^2, \sum_{r=1}^{k-1} \sigma_r^2 > 0 \tag{7}$$

$$\beta_0^{r_t} = \sum_{r=1}^{k} \beta_0^r \tag{8}$$

where GDP_t and $Debt_t$ in Eq. (5) represent the growth rate of GDP and ratio of debt-to-GDP respectively, and z_t represents a vector of regime-dependent control variable (physical capital labour, inflation and exchange rate). u_{r_t} is an identically and independently distributed error term with zero mean and $\sigma_{r_t}^2$ regime-dependent variance, *r* denotes the number of regimes with $r = \{1,2,\dots,k\}$[8]. $\beta_0^{r_t} = \beta_0^1$ when r_t=1, $\beta_0^{r_t} = \beta_0^2$ when r_t=2…, $\beta_0^{r_t} = \beta_0^k$ when $r_t = k$. Similarly, $\beta_1^{r_t} = \beta_1^1$ when r_t=1, $\beta_1^{r_t} = \beta_1^2$ when r_t=2,…, $\beta_1^{r_t} = \beta_1^k$ when $r_t = k$. In the MS model, the

[8] Note that it is not possible to observe the regime variable r_t as it evolves according to a Markov-Chain on S.

probability distribution is expected to follow a logistic distribution (Chen and Shen, 2007; Hamilton, 1994). The corresponding (N × N) matrix of transition probabilities is given as:

$$p = \begin{bmatrix} p_{11} & p_{21} & p_{31} & \cdot & \cdot & \cdot & p_{k1} \\ p_{12} & p_{22} & p_{32} & \cdot & \cdot & \cdot & p_{k2} \\ p_{13} & p_{23} & p_{33} & \cdot & \cdot & \cdot & p_{k3} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ p_{1k} & p_{2k} & p_{3k} & \cdot & \cdot & \cdot & p_{kk} \end{bmatrix}, \sum_{j=1}^{k} P_{i,j}=1 \quad (9)$$

Entries in the transition probabilities columns must total unity[9]. We use the diagonal probabilities $P_{i,j}$ to determine the persistence of each state i (Klarl, 2020). We then put our focus on the estimated coefficient $\beta_1^{r_t}$ as it provides the debt effect in both regimes. MSDR technique provides unbiased point estimates using maximum likelihood procedure. We specified the $\log L(\gamma)$=($\beta_k^{r_t}, \varphi, P_{i,j}, \sigma_{r_t}$)$\forall i, j$ to maximize the log likelihood of the estimated models.

4.2.3. Granger causality-in-quantiles approach

After establishing the impact of the independent variables on growth, the causality test was performed using Granger causality-in-quantiles approach. The non-causality test in conditional quantiles corresponds to the following:

$$Fy_t(\delta|X,Y)_{t-1} = Fy_t(\delta|Y_{t-1})), \forall\delta \in [0,1] \quad (10)$$

where $Fy_t(\delta|\tau)$ is the δ^{th} quantiles of $Fy_t(.|Y_{t-1})$. Given the specification in equation (3), it is can be said that X_t does not Granger cause Y_t in all quantiles.

To test for causality between X and Y, the quantile regression technique developed by Koenker and Bassett (1978, 1982) is used and the quantile causality is executed for different quantiles range (0.10-0.90). The sup-Wald statistical test suggested by Koenker and Machado (1999) is then calculated and applied to assess the null hypothesis of no Granger causality between X and Y.

[9] It is important to also mention that the elements that constitute P are all non-negative and the total weight of each column sums to 1. To avoid some numerical complications that may occur because of $\sum_{j=1}^{k} P_{i,j}$=1, we estimate functions of $P_{i,j}$ through normalizing $P_{i,k}$ such that: $P_{i,j} = \frac{\exp(-q_{ij})}{1+\exp(-q_{i1})+\exp(-q_{i2})+\cdots+\exp(-q_{i,k-1})}$

Equation (11a) and (11b) present the conditional quantiles for non-causal relationships between X and Y as follows:

$$Y_t = \beta_0(\delta) + \sum_{\beta=1}^{n} \beta_i(\delta) Y_{t-\beta} + \sum_{\alpha=1}^{m} \alpha_j(\delta) X_{t-\alpha} + \varepsilon_{y,t} \quad (11a)$$

$$X_t = \omega_0(\delta) + \sum_{\beta=1}^{n} \omega_i(\delta) X_{t-\beta} + \sum_{\alpha=1}^{m} \varphi_j(\delta) Y_{t-\alpha} + \varepsilon_{y,t} \quad (11b)$$

The Wald statistic for a specific quantile δ to assess null hypothesis H_0: $\beta(\delta) = 0,\ \forall\delta \in [0,1]$ is computed as:

$$W_T(\delta) = \frac{T\hat{\beta}_T(\delta)'(M\hat{\tau}(\delta)M)^{-1}\hat{B}_T(\delta)}{\delta(1-\delta)} \quad (12)$$

where $\hat{\tau}(\delta)$ is a consistent estimator $\tau(\delta)$ and represents the variance-covariance matrix of M (m*n such that $\beta(\delta)$). Also note that, the calculation of the Wald statistics follows the weak convergence test given by the following:

$$W_T = \left\| \frac{Q_m(\delta)}{\sqrt{\delta(1-\delta)}} \right\|^2 \quad (13)$$

where $Q_m(\delta)$= $[\delta(1-\delta)]^{1/2}$ N(0,I_m) is a vector of n independent Brownian bridges, and the weak limit is the sum of squares of n independent Bassel process. Koenker and Machado (1999) suggested assessing the null hypothesis H_0: $\beta(\delta) = 0,\ \forall\delta \in [0,1]$ using the Wald suprema statistic whose asymptotic distribution is given as follows:

$$\sup_{\delta \in T} W_T \rightarrow \sup_{\delta \in T} \left\| \frac{Q_m(\delta)}{\sqrt{\delta(1-\delta)}} \right\|^2 \quad (14)$$

However, the aim is to test non-causality across different quantile ranges. It is then essential to define a regular quantile interval of length k from p to q (p =δ_1<……<δ_q=k) and then execute a quantile regression for every δ_m. Finally, the supremum of the Wald statistics is calculated based on the quantile regression as follows:

$$supW_T = supW_T(\delta_m), m = 1,2, \ldots, k \quad (15)$$

4.3. Data and variable measurement

We constructed a dataset going from 1970 to 2022, that is, n= 53 observations. In what follows, we proceeded by providing a summary of the dataset, variables measurement, and some descriptive analyses (Tables A1 and A2 in the appendix). According to the summary statistics in Table A2, the highest average value is observed for physical capital, followed by the inflation rate. The standard deviation of physical capital has the most spread distribution and the greatest volatility than all other variables. Additionally, we used quantile-on-quantile plots (Q-Q plots) to explore further the normality of our time-series. Basically, the Q-Q plot is a graphical representation that helped us evaluate the distribution of the series relative to the theoretical distribution such as normal. In a quantile plot, the value of each variable is plotted against the fraction of the data point that has values less than that fraction. In the plot, the red diagonal line is a reference line. For example, if the GDP growth values are rectangularly distributed, all the data would be plotted along the red line. Therefore, one would conclude that this specific variable is normally distributed. From Figure (1), we observe that the plot of public debt data points from the straight line is not normally distributed. This is because there is a deviation of the data points from the straight line, especially for the middle and high quantiles. Likewise, the plots of the remaining variables also display a substantial deviation from the straight red line. While GDP growth and physical capital stock appear to be negatively skewed; labor, inflation and foreign exchange rate are positively skewed.

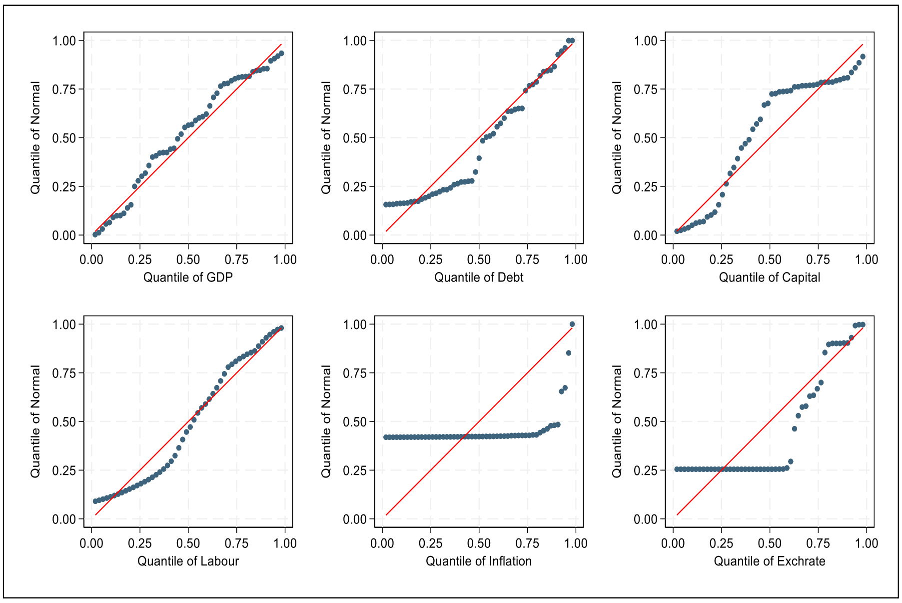

Fig. 1: Q-Q plots of the variables

5. Empirical results and discussion

5.1. (Non)linearity test results

To determine the marginal effect of the association between two variables, it is crucial to start by carrying out a linearity test. This allow resorting the variables' linearity characteristics as the utilization of linear models on the non-linear data or non-linear models on the linear data may lead to misleading outcomes. Thus, we utilised the Broock-Dechert-Scheinkman (BDS) (Broock et al., 1996) test to determine the (non)linearity features of the series as in Wang et al. (2023) and Alola et al. (2023). We reported the results of the BDS test in Table 2. It is important to mention that the estimated statistic assess the null hypothesis of linearity of series. As can be observed in Table 2, at the 1% significance level the null hypothesis is rejected for all variables in all the six embedded dimensions. This finding corroborates the results of non-normality of the Q-Q plots presented in Figure 1. Henceforth, we concluded from the findings that all the six variables display non-linearity and the QQR framework is the most appropriate for this study because of it capabilities of accounting for both non-normality and nonlinearity of the series.

Table 2: The BDS results for non(linearity) test

Variables	$\mathcal{M} = 2$	$\mathcal{M}$=3	$\mathcal{M}$=4	$\mathcal{M}$=5	$\mathcal{M} = 6$
GDP	7.500***	7.440***	8.320***	8.095***	7.937***
Debt	11.262***	11.177***	11.145***	10.665***	10.295***
Capital	16.075***	16.076***	16.093***	16.212***	16.465***
Labour	37.557***	35.985***	34.513***	33.179***	31.969***
Inflation	6.488***	6.447***	6.405***	6.343***	6.301***
Exchrate	16.089***	14.865***	13.781***	12.829***	12.005***

Note: $\mathcal{M}$ stands for the embedding dimension. ***, **, and * indicate the level of significance (1%, 5%, and 10% levels, respectively) at which the null hypothesis that the relevant variable is independent and identically distributed is rejected.

5.2. Quantile-on-quantile regression results and discussion

The main findings of the empirical procedure regarding the impact of public debt, physical capital, labour, inflation, and exchange rate on GDP growth are revealed in this section. We started by focusing on the relationship of the key interest, which is the impact of public debt on GDP growth. Figure 2 shows the QQR slope coefficients, $\emptyset_1(\vartheta, \delta)$, which represents the marginal impact of the δ^{th} quantile of Debt-to-GDP ratio on the ϑ^{th} quantile of GDP growth, at different values of ϑ and δ for the DRC. The slope coefficient (marginal effect) varies across quantile and ranges from -1 to 5. We observe that the impact of Debt-to-GDP ratio on GDP growth is positive in lower quantiles (0.05-0.3) and middle quantiles (0.4-0.6) range of GDP coupled with lower quantiles of Debt-to-GDP ratio (0.05-10). Moreover, the estimated slope coefficient is negative in almost all quantiles of GDP coupled with the lower quantiles (0.2-0.3), middle quantiles (0.4-9.6) and higher quantiles (0.7-0.95) of Debt-to-GDP ratio. These findings show that both positive and negative impacts exist between public debt and GDP growth in the DRC. Specifically, the findings indicate that the positive impact is strong and positive when the Debt-to-GDP ratio is between below the quantile range of 0.05-0.10. When the ratio jumps above this range, the impact of public debt on GDP growth becomes strong and negative for the rest of the graph area. These outcomes comply with the study of Mupunga and le Roux (2015) for Zimbabwe (threshold between 45% and 50%), Omotosho et al. (2016) for Nigeria (threshold of 73.7%), Chikalipah (2021) for Zambia (threshold of 40%), Ndoricimpa (2022) for South Africa (threshold of 37%), who used parametric kink regression techniques. All these studies established a negative impact when the Debt-to-GDP ratio exceeds the threshold value. Our findings have several implications in terms of public policies related to government debt and long-run growth objectives. First, the DRC government should strive to maintain the public debt rate in the range below 20% of GDP to avoid the adverse impacts of over-indebtedness. Secondly, the implementation of public reforms in the field of finances that would lead to the broadening of the tax base to finance government expenditure from own resources. These budgetary consolidation measures should contribute to controlling the stock of public debt so that it does not explode, at the risk of becoming harmful to economic activity. Third, the Government should strengthen transparency in the management of funds allocated to investment projects through borrowing. Indeed, the establishment of solid accountability mechanisms is essential to escape the traps of excessive debt. Compliance with these recommendations should thus lead to financial prudence in the development of debt policies, which will promote rapid and sustained growth of economic activity in the DRC.

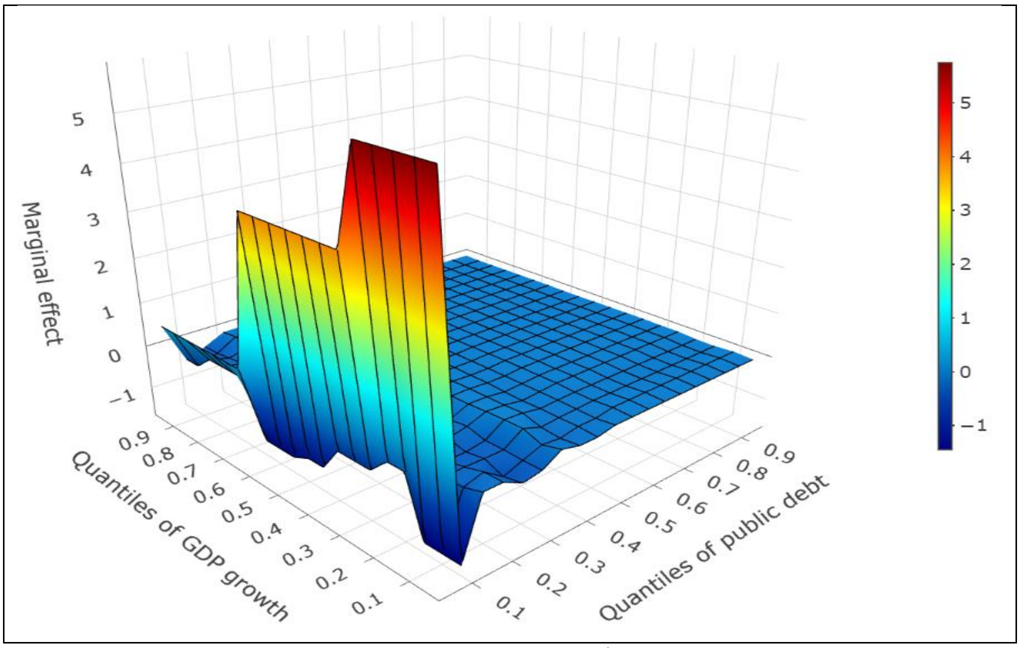

Figure 2: Quantile-on-Quantile slope coefficient of Debt/GDP ratio on GDP growth in the DRC.

Regarding the impact of the control variables, the results of their connection to GDP growth rate are presented in Figure 3. As can be seen, Figure 3a shows that the marginal effect of physical capital on GDP growth is negative, and this effect is quite strong at lower and medium quantiles (0.05–0.6) of GDP growth, whereas it decreases and becomes positive at higher quantiles (0.7–0.95) of GDP growth. Empirically speaking, this result reveals that an increase in physical capital investment increases GDP growth rate in the DRC, particularly during economic boom periods. This finding aligns with the African Development Bank report (AfDB, 2018), which indicates that the acceleration of economic growth from 2002 is largely due to increasing gross fixed capital formation specifically in the mining sector. In 2023 the mining sector grew by 15.4% contributing around 70% to overall growth (According to the World Bank (2024) report). Thus, it is clear that the investment in physical capital determines the level of the economic activity in the DRC and the government should accelerate public reforms that aim at sustaining the current positive momentum of the economic activity.

Figure 3b presents the results of the effect of labour on GDP growth rate. The impact of labour is strong and positive at the higher quantiles (0.7-0.95) of labour and high quantiles (0.8-0.95) of GDP growth. This outcome is not surprising given that the DRC's economy since 1960 remains labour intensive economy where 75% of the labour force is employed in the agriculture sector (Akitoby and Cinyabuguma, 2004; IOE, 2023, Espoir et al, 2024). While the growth rate in extractive industries decreased from 22.3% in 2022 to 15.4% in 2023, the growth in nonextractive sectors shows resilience and rose from 3.1% in 2022 to 3.6% and was mainly driven by agriculture (AfDB, 2024). Nevertheless, the contribution of the agriculture sector to overall growth of the economy is still low given the country potential. Agricultural development has been hampered by many factors, including the deterioration of the rural feeder road network; the dislocation caused by the Zairanization measures of 1973-1974, the country's political crisis of the 2000s; inadequate credit for small farmers; insufficient foreign exchange for agriculture material imports; insufficient storage and other marketing facilities; and uncertainties created by government pricing policies. Thus serious public policy reforms have to be undertaken for removing all the distortions surrounding the explosion of this sector.

Furthermore, Figure 3c shows the impact of inflation on GDP growth, which is negative and strong at most of the association of quantiles of inflation rate and GDP growth. However, the result shows strong evidence of negative impact of inflation on GDP growth in the higher quantiles (0.7-0.95) of inflation and higher quantiles of GDP growth (0.7-0.95). This result is in line with the findings of Yemba et al, (2020) who showed that an inflation rate beyond the threshold of 17,2% will adversely affect economic growth in DRC. Finally, Figure 3d exhibits the impact of exchange rate on GDP growth. As can be seen in this figure, the effect of exchange rate on GDP is positive in all quantiles (0.05-0.95). However, the estimated slope coefficients are weak (averaging zero) in almost all the quantiles of the combination of exchange rate and GDP growth. This finding is in line with Ndou et al, (2024) for South Africa.

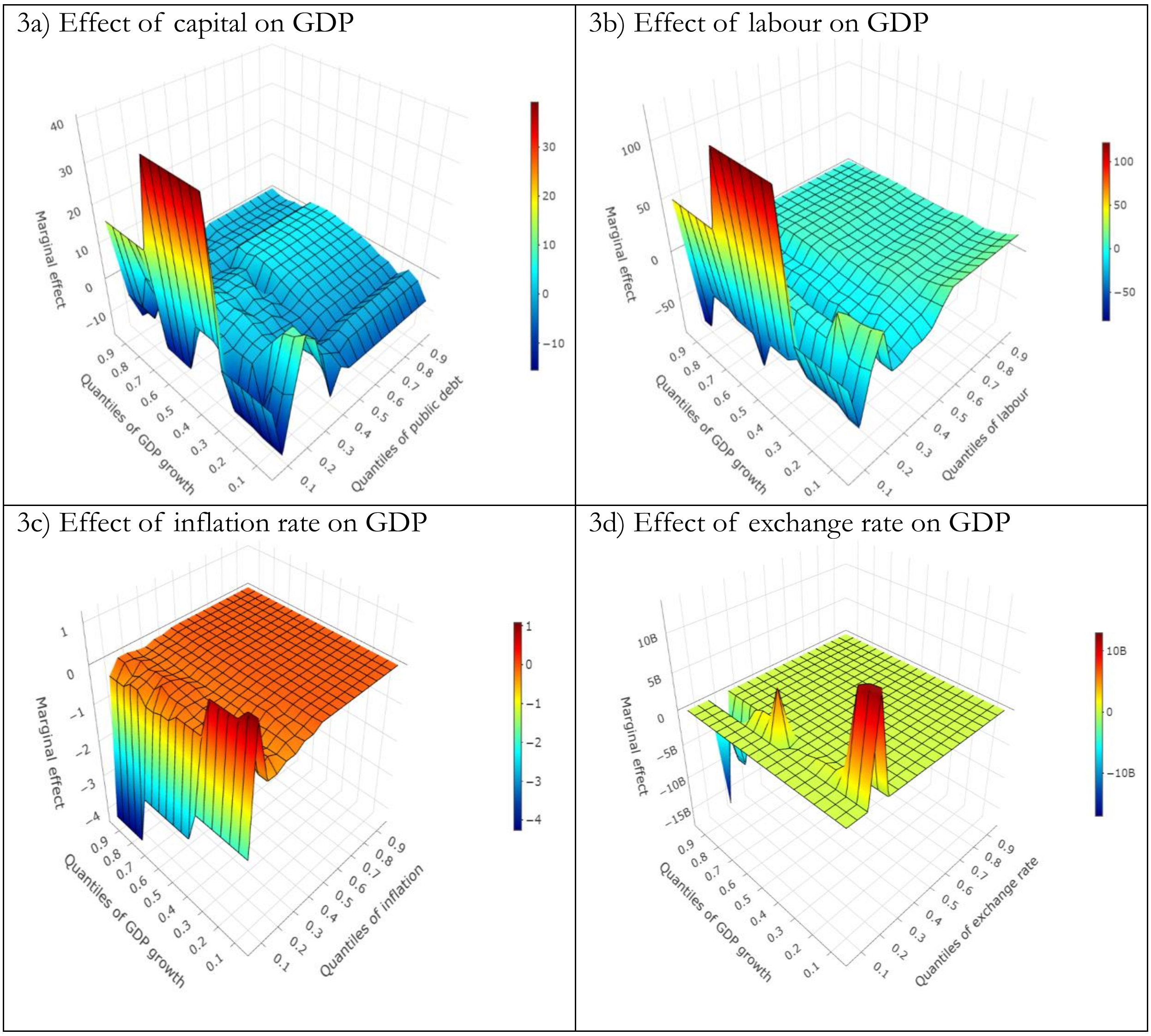

Figure 3: Quantile-on-Quantile (QQ) results of the slope coefficients of physical capital (3a), labour (3b), inflation (3c) and exchange rate 3(d) on GDP growth in the DRC.

5.3. Robustness check for the QQR results

The MS approach can be viewed as an exchange technique for the QQR model because it enables the model slope coefficients to vary across regimes. We employed the MSDR model (Klarl, 2020 Espoir et al 2024), a MS technique that allows to model data presenting substantial dynamics across unobserved regimes through regime-dependent parameters (Mills and Wang, 2006). Figure 4 presents the time-trend of the public debt/GDP ratio over the period 1970-2022. From this figure, we observed in the data the configuration of two possible public debt regimes in the DRC. The period from 1970 to 1982 and from 2011 to 2022 corresponds to the low debt/GDP ratio regime (regime 1), and the period from 1983 to 2010 corresponds to the high debt/GDP ratio regime (regime 2). On average, the debt-to-GDP ratio is 34.77% between 1970 and 1982, 118.89% between 1983 and 2010, and 17.48% between 2011 and 2022. The low debt-to-GDP ratio over the last decade is mainly attributed to debt relief efforts undertaken at the end of 2010 and recent improvements in public revenue mobilization, which have made it possible to service the debt. In Figure 4, we observed two different patterns of Debt-to-GDP ratio over the entire sample period. Thus, using non-linear regime-switching estimators is more appropriate to capture the dynamic nature of public debt and its effects on growth in the DRC.

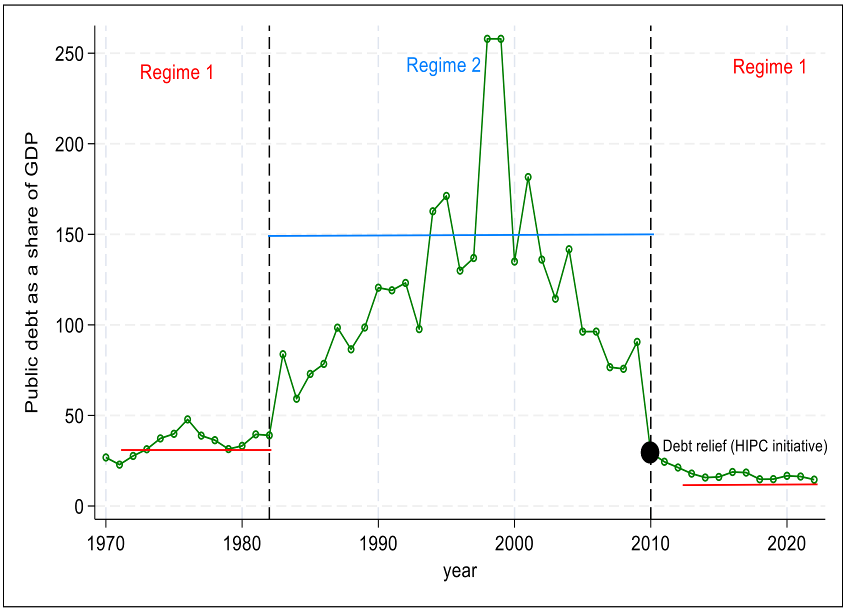

Fig. 4: Time trend of the general government debt as a share of GDP (1970 to 2022).

Table 3 shows the estimated marginal effects of the independent variables on GDP growth. In model 1 of this table, the regression of public debt on GDP is carried out without controlling any variable. Furthermore, it is important to mention that the estimated marginal effects for the MSDR model imply that regime 1 categorizes the low GDP growth regime while regime 2 categorizes the high GDP growth regime. The result shows a regime-shifting behaviour of GDP growth. Precisely, the result indicates a positive marginal effect (0.00377) of GDP in regime 1 although not significant and a significantly negative marginal effect (-0.0131) at the 5% significance level in regime 2. This result confirms the presence of the time-varying and regime-dependent effect of debt on growth in the DRC. Model 2 in Table 3 presents the full specification of equation (2), where the control variables are included in the regression. This model is superior to model (1) because it generated the highest log likelihood value (-125.0605) and the lowest AIC value (276.1347). Similar to model (1), the result shows a regime-switching behaviour of GDP growth in which a positive and significant (0.0463) marginal effect of GDP is observed in regime 1 and a significant negative marginal effect (-0.0361) is observed in regime 2. The two regime-dependent marginal effects are statistically significant at the 1% level. This result implies that an increase in public debt is favorable to growth when the debt/GDP ratio is low and anti-growth when the ratio is high. This outcome corroborates the QQR results which show a negative impact of public debt above the quantile interval between 0.05 and 0.3. The remaining independent variables also exhibit regime-switching behavior.

Table 3: Estimated coefficients for the MSDR growth model

Variables	Model (1)	Model (2)
Regime 1 (low)		
L.gdp	0.890***	0.921***
	(0.0868)	(0.1177)
Debt	0.00377	0.0463***
	(0.00782)	(0.02161)
Capital		-2.6290
		(2.3984)
Labour		-0.4194
		(4.3884)
Inflation		0.0004***
		(0.00011)
Exchrate		0.0071***
		(0.00322)
Constant	-3.654***	25.0244
	(0.813)	(25.4754)
Regime 2 (high)		
L.gdp	0.477***	0.209
	(0.0739)	(0.1693)
Debt	-0.0131**	-0.0361***
	(0.00622)	(0.01558)
Capital		-4.485
		(3.14237)
Labour		10.726**
		(5.2563)
Inflation		-0.0027***
		(0.00077)
Exchrate		-0.0056***
		(0.00321)
Constant	4.491***	34.442
	(0.589)	(32.2703)
P11	0.4762***	0.39177***
P22	0.6395***	0.52771***
$P(r_t=1)$	0.4762	0.3917
$P(r_t=2)$	0.5237	0.6082
Observations	52	52
Model selection criteria		
Log likelihood	-129.0673	-125.0605
AIC	284.1209	276.1347
Expected duration of the regimes (in months)		
Regime 1	22.9	19.73
Regime 2	33.3	25.41

Notes: The *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels.

5.4. Granger causality-in-quantiles results

The causality results between GDP growth and all the independent variables in this study are presented in Table 4. This table shows the sup-Wald statistics by quantile for the bivariate combinations between GDP and public debt, physical capital, labour, inflation and the exchange rate. To be more specific, panel (A) of Table 4 presents the results of the non-causality test when GDP growth is the dependent variable and panel B shows the reverse causality (when GDP is the independent variable). The low quantile [0.1-0.3] indicates the regime in which the debt-to-GDP ratio is low while the medium [0.4-0.6] and high [0.75-0.95] quantiles indicate the regime in which the debt/GDP ratio is high. However, the null hypothesis that public debt has non Granger effect on GDP growth is rejected for the middle (0.5-0.6) and upper (0.7-0.9) quantiles, as the sup-Wald statistics show. This suggests that public debt does not influence GDP growth when the debt-to-GDP ratio is low, but that it has an impact on economic activity when the debt-to-GDP ratio is high. Furthermore, the results in Panel B show that GDP growth influences public debt in almost all quantiles, except the low quantiles (0.10 and 0.4). Both results imply bidirectional Granger causality.

The two-way non-causality results on physical capital and GDP growth in both panels of Table 3 indicate no Granger causality because the sup-Wald statistics are not significant in all quantiles. This means that physical capital and GDP growth are not Granger related. Focusing on the quantile causality of labour on GDP growth, the null hypothesis cannot be rejected in low quantiles (0.10-0.30), except for medium quantiles (0.4-0.6) and higher (0.7-0.9) with a significance of 10%. This implies that employment contributes significantly to economic activity in the DRC. Meanwhile, the results of panel B for GDP to labour show that the null hypothesis is strongly rejected with 10% significance in all quantiles except the middle quantiles (0.4-0.5). This therefore implies that growth in economic activity is an important driver of employment in the country. The government is expected to maintain a positive trend to absorb more unemployment and reduce the country's high poverty rate.

Furthermore, regarding the quantile causality between inflation and GDP (Panel A), the null hypothesis can only be rejected for the low quantiles (0.10-0.30) while it is rejected for the medium (0.5-0.6) and high quantiles (0.7-0.9). This suggests that inflation drives GDP growth when rates are moderate or high rather than when they are low. This result confirms the findings of Yemba et al (2020), who highlighted the need to keep the inflation rate below 17.2% to avoid negative effects. Concerning the causality from GDP to inflation, the results of panel B indicate that the null hypothesis cannot be rejected because the Sup-Wald statistics are not statistically significant in all quantiles. This implies that GDP growth does not stimulate inflation in the DRC.

Table 4: Quantile causality results

	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
Panel A: δ pair (δ , 1 _ δ) GDP is the dependent variable									
Debt $\nRightarrow$ GDP	-2.159361	-2.372778	-2.828767	-3.636032	-5.777483***	-6.566863***	-4.542867**	-7.322887***	-9.028323***
	(0.30981819)	(0.32948693)	(0.28013732)	(0.17589799)	(0.03542076)	(0.02601294)	(0.07738675)	(0.01740539)	(0.01475768)
Capital $\nRightarrow$ GDP	-1.269719e-02	1.508050e-02	1.669988e-02	-1.054253e-02	-3.726271e-03	7.416578e-05	1.716431e-03	2.617294e-03	7.335763e-03
	(0.5948333)	(0.5557882)	(0.4427460)	(0.5485539)	(0.8283072)	(0.9964037)	(0.9080304)	(0.8387448)	(0.5201087)
Labour $\nRightarrow$ GDP	-0.004300246	0.015841925	0.023832274	0.05955649***	0.036727702**	0.032113875*	0.026524702	0.031009908**	0.03385963***
	(0.83267419)	(0.50184549)	(0.32351667)	(0.02303185)	(0.06483378)	(0.08462608)	(0.11017806)	(0.03367579)	(0.01385217)
Inflation $\nRightarrow$ GDP	-2.557932	-3.787707	-5.662030*	-5.950297	-12.501920**	-15.288295**	-37.112829***	-85.282681***	-127.41114***
	(0.428073647)	(0.235633194)	(.0863953524)	(0.113295466)	(0.063954918)	(0.059126993)	(0.023831989)	(0.002439425)	(0.000442432)
Exchrate $\nRightarrow$ GDP	-4.793586e-14	5.617026e-12	2.029368e-11	3.543650e+01	4.19883e+01*	4.7115e+01**	6.624e+01***	6.038e+01***	8.411e+01***
	(1.000000000)	(1.000000000)	(1.000000000)	(0.145511955)	(0.082141848)	(0.033059929)	(0.000996086)	(0.000571006)	(0.000249112)
Panel A: δ pair (δ , 1 _ δ) GDP is the independent variable									
GDP $\nRightarrow$ Debt	-0.04366147	-0.06724253**	-0.03858629*	-0.03235878	-0.03769391*	-0.04288555**	-0.0360634*	-0.0382239***	-0.0414530***
	(0.15082522)	(0.03541631)	(0.06680910)	(0.13098455)	(0.07425579)	(0.03499470)	(0.06374139)	(0.02325671)	(0.00594882)
GDP $\nRightarrow$ Capital	-2.3226323	-3.5672668	-1.1427879	1.1398258	2.3555723	3.2943162	2.8716999	0.2183006	-0.1964649
	(0.5420207)	(0.3435013)	(0.7710064)	(0.7829691)	(0.5823656)	(0.4257328)	(0.4491239)	(0.9502049)	(0.9489390)
GDP $\nRightarrow$ Labour	11.805422***	6.591256**	8.296794***	4.719567	4.888467	6.447882**	6.276570**	4.338230*	3.363565
	(0.00669043)	(0.05753736)	(0.01811602)	(0.14256796)	(0.13383070)	(0.04818454)	(0.03846742)	0.09497922	(0.15885748)
GDP $\nRightarrow$ Inflation	-0.0014607030	-0.0022285250	-0.0001705218	-0.0001980096	-0.0002650123	-0.0003213052	-0.0003988944	-0.0004262492	-0.00046234*
	(0.81557591)	(0.75448653)	(0.61503292)	(0.60041532)	(0.49988351)	(0.39361522)	(0.23698091)	(0.14353434)	(0.07858239)
GDP $\nRightarrow$ Exchrate	0.00664710***	0.00594678***	0.00552490***	0.00392044**	0.00490672**	0.00664738***	0.00514960**	0.00305716	0.00299717*
	(0.000136530)	(0.001737029)	(0.007580424)	(0.058151763)	(0.041298266)	(0.019352564)	(0.036524070)	(0.123365528)	(0.097692307)

Notes: The reported statistics are the sup-Wald. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

The results for the causality between the exchange rate and GDP are similar to those for the causality between inflation and GDP. More precisely, the result (part A) indicates that the null hypothesis of Granger non-causality cannot be rejected for low quantiles (0.1-0.4), except for medium quantiles (0.5-0 .6) and higher (0.7-0.9). Concerning the causality going from GDP to the exchange rate, the result of panel B shows that the null hypothesis of Granger non-causality can only be rejected in a single quantile (q=0.8). These results suggest bidirectional causality between the exchange rate and GDP growth, particularly in the upper quantiles of both variables. Now, all these results offer useful information for policy makers to design policies that will promote and support growth based on the behaviour of these macroeconomic variables.

6. Conclusion and policy implications

The aim of this study was to investigate the dynamic impacts of public debt on economic growth in the Democratic Republic of Congo (DRC). We used an augmented Solow-Swan growth model to achieve this research objective. Specifically, we utilised newly developed econometric techniques to ascertain the time-varying and state-dependent impact of public debt (proxied by Debt-to-GDP ratio), physical capital, labour, inflation, and exchange in DRC using data spanning 1970 and 2022. We obtained the slope coefficients of the model using the novel nonparametric quantile-on-quantile regression (QQR) technique. Unlike conventional linear regression approaches used in prior literature that primarily examine conditional means, the QQR technique offers the ability to model and analyze the associations of conditional quantiles of public debt with those of GDP growth, thus providing a more detailed explanation of the overall structure of dependence between the two variables. To the author' knowledge, no previous study has examined these associations in the DRC. Besides, it is also important to mention that no previous studies have explored these associations using the QQR approach.

To discover the dynamic impacts of public debt on GDP growth, we started by examining the linearity of the variables studied using the BDS test. We did so to avoid misleading outcome linked to the utilization of linear models on the non-linear data or non-linear models on the linear data. The null hypothesis of linearity of series was strongly rejected by the estimated statistics at the 1% level of significance, thus suggesting the use of nonlinear model as we did. Furthermore, the results of the QQR model illustrated: (i) the asymmetric effects of public debt on growth across GDP growth quantiles. Specifically, we found positive impacts of public debt in lower quantiles (0.05-0.3) and middle quantiles (0.4-0.6) of GDP coupled with lower quantiles of Debt-to-GDP ratio (0.05-10). Moreover, the slope coefficient becomes negative in almost all quantiles of GDP coupled with the lower quantiles (0.2-0.3), middle quantiles (0.4-9.6) and higher quantiles (0.7-0.95) of Debt-to-GDP ratio; (ii) a is negative effect of physical capital at lower and medium quantiles (0.05–0.6) of GDP growth and positive impact at higher quantiles (0.7–0.95) of GDP growth; (iii) a positive impact of labour at the higher quantiles (0.7-0.95) of labour and high quantiles (0.8-0.95) of GDP growth; (iv) a negative impact of inflation on GDP growth in the higher quantiles (0.7-0.95) of inflation and higher quantiles of GDP growth (0.7-0.95); (v) a positive impact of exchange rate in all quantiles (0.05-0.95). To verify the reliability of these results, we used the Markow switching dynamic regression (MSDR) growth model. The results were consistent with those from the QRR model, since they show a regime-switching behaviour of GDP growth in which a positive and significant (0.0463) marginal effect of GDP was observed in regime 1 and a significant negative marginal effect (-0.0361) in regime 2.

The results suggest that policy makers should take into account the public debt situation when designing and implementing macroeconomic policies related to economic activities. Given that public debt worsens economic growth at medium and high quantiles, DRC policymakers should not underestimate the impact of public debt on growth. Public debt should be integrated into the design and implementation of a political framework of macroeconomic and human development objectives. Failure to incorporate public debt into economic growth forecasting models and macroeconomic policies could hamper the DRC's efforts to achieve the UN Sustainable Development Goals 1 (no poverty), 8 (decent work, and economic growth, and 10 (reduced inequalities). Given the negative impact of public debt on GDP growth, as evidenced in this study, we recommend the following. First, the DRC government should strive to maintain the public debt rate in the range below 20% of GDP to avoid the adverse impacts of over-indebtedness. Secondly, the implementation of public reforms in the field of finances that would lead to the broadening of the tax base to finance government expenditure from own resources. These budgetary consolidation measures should contribute to controlling the stock of public debt so that it does not explode, at the risk of becoming harmful to economic activity. Third, the Government should strengthen transparency in the management of funds allocated to investment projects through borrowing. Indeed, the establishment of solid accountability mechanisms is essential to escape the traps of excessive debt. Compliance with these recommendations should thus lead to financial prudence in the development of debt policies, which will promote rapid and sustained growth of the economic activity in the DRC.

However, future research is needed due to the following limitation. Our study examines the effect of public debt on economic growth without considering other political and social aspects of the country's economic activity. A recent study showed that political dynamics have a disparate effect on economic growth and sustainable well-being in developing countries (Kou and Yasin, 2024). For this reason, future researches can extend this study by incorporating the impact of political instability, corruption and the rule of law on economic growth in DRC.

Appendix

Table A1: Variables and sources

Variables	Measurement	Source
GDP	Annual percentage growth rate of GDP at market prices based on constant local currency.	WDI
Debt	General Government debt percent of GDP	IMF
Capital	Capital stock at current PPPs (in mil 2017 US$)	PWT
Labour	Number of persons engaged (in millions)	PWT
Inflation	Inflation as measured by the consumer price index (annual %)	WDI
Exchrate	Exchange rate, national currency against US Dollars	PWT

Note: this table presents the measurement and data source of the variables used in our estimation framework. As it is indicated in this table, WDI denotes World Development Indicators, IMF is International Monetary Fund, and PWT represents the Penn World Tables (PWT) version 10.1.

Table A2: Descriptive statistics

Variables	N. Obs	Mean	Std. Dev	Minimum	Median	Maximum	Kurtosis
GDP	53	1.487	5.312	-13.469	2.350	9.470	2.955
Debt	53	75.301	60.200	14.580	59.241	257.925	4.122
Capital	53	199036.9	59201.59	76877.74	230231.9	280960.6	2.123
Labour	53	15.087	5.821	7.405	14.506	27.4158	2.031
Inflation	53	674.995	3304.365	0.744	29.469	23773.1	46.823
Exchrate	53	311.548	472.288	1.67e-12	0.041	1647.76	3.900

Note: This table reports the summary statistics of our variables for the full sample of over 48 annual observations.

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