HEC MONTREAL

The Contribution of GDP-linked Bonds to Addressing Debt Burden in Emerging Economies

Evidence From a Quasi-Experimental Study

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“ What [...] if it was impossible to invest capital at a fixed rate of interest, and everyone instead collected variable dividends depending on the net income of the firm; if it was impossible to hire labour at a fixed salary or wage, but all [...] workers were *paid instead with a share of the firm's output*? In this case, why should there be *crises*? ”

— Luigi Einaudi, “Debiti” in La Riforma Sociale (1934)

Résumé

La viabilité de la dette publique joue un rôle crucial dans les perspectives de croissance, en particulier pour les pays émergents comme la Côte d'Ivoire, l'une des économies à la croissance la plus rapide et la plus importante de l'Union Économique et Monétaire Ouest-Africaine (UEMOA). Considérant l'exposition du pays aux chocs macroéconomiques, notamment face aux enjeux que présentent la transition climatique et démographique en vue, aggravée par le manque de mécanismes d'atténuation des risques robustes, cette thèse évalue le degré de viabilité que les titres de créance conditionnels, tels que les obligations indexées au PIB, pourraient offrir aux économies émergentes soumises à des pressions budgétaires. Contrairement à la littérature existante qui emploie des simulations de Monte Carlo, nous appliquons la méthode des Double Différences, développée par Snow (1849), à un panel de données annuelles sur la dette publique brute de sept pays africains, dont la Côte d'Ivoire, couvrant la période de 2002 à 2022, et extraites de la base de données du Fonds Monétaire International et de la Banque Mondiale. Par ailleurs, notre analyse teste directement l'hypothèse sous-jacente du cadre théorique en documentant l'effet stabilisateur des obligations indexées au PIB par le biais de tests de Dickey-Fuller augmentés. Celle-ci comporte trois contributions principales. Premièrement, elle révèle que le fait de substituer la dette publique conventionnelle à une dette indexée au PIB diminue considérablement la variation du ratio d'endettement, ce qui est conforme aux conclusions tirées dans les écrits théoriques selon lesquelles les obligations indexées au PIB stabilisent le ratio d'endettement. Nous montrons également que l'effet de l'introduction des obligations indexées sur le PIB est plus prononcé et économiquement significatif lorsque le coefficient d'indexation est faible (0,01) et que l'encours de la dette publique indexée au taux de croissance nominal du pays représente au moins 30 pourcents. Ainsi, nous appuyons la mise en place d'obligations indexées au PIB pour immuniser les économies émergentes contre les chocs macroéconomiques et promouvoir une gestion viable des finances publiques.

Mots clés: Produit Intérieur Brut (PIB), obligations indexées au PIB, viabilité de la dette publique, titres de créance conditionnels, Fonds Monétaire International (FMI), économie politique, Étude quasi-expérimentale, Union Économique et Monétaire Ouest Africaine (UEMOA)

Abstract

Public debt sustainability plays a crucial role in shaping growth perspectives, particularly for emerging countries such as Côte d'Ivoire, one of the fastest growing and largest economies in the West African Economic and Monetary Union (WAEMU). Considering the country's exposure to macroeconomic shocks in light of current and emerging climatic and demographic pressures, compounded by the lack of robust risk mitigation mechanisms, this thesis assesses the degree of sustainability that state-contingent debt instruments such as GDP-linked bonds could offer to emerging economies under budgetary pressures. Departing from the traditional use of Monte Carlo simulations in the existing literature, we apply a Difference-in-Differences regression methodology developed by Snow (1849) to a general gross public debt annual panel data of seven African countries, including Côte d'Ivoire, spanning from 2002 to 2022, and retrieved from the International Monetary Fund and World Bank databases. Furthermore, our analysis directly tests the underlying hypothesis of the theoretical framework by documenting the stabilizing effect of GDP-linked bonds through augmented Dickey-Fuller tests. The latter entails three main contributions. First, it reveals that substituting away from conventional public debt towards GDP-linked debt significantly decreases the change in the debt ratio, which is consistent with findings in the theoretical literature that GDP-linked bonds stabilize the debt ratio. We also demonstrate that the effect of the introduction of GDP-indexed bonds is more pronounced and economically significant when the indexation coefficient is low (0.01), and the public debt stock indexed to the country's nominal growth rate represents at least 30 percent. We therefore support the implementation of GDP-linked bonds to hedge emerging economies against macroeconomic shocks and promote sound public finance management.

Keywords: Gross Domestic Product (GDP), GDP-linked bonds, public debt sustainability, International Monetary Fund (IMF), political economy, quasi-experimental study, West African Economic and Monetary Union (WAEMU)

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Acronyms and Abbreviations

ADF	Augmented Dickey-Fuller
BCEAO	Banque Centrale des États de l'Afrique de l'Ouest (*Central Bank of West African States*)
bps	Basis points
BTP	Buoni del Tesoro Poliennali (*Multi-Year Treasury Bonds*)
CLBs	Commodities-linked bonds
COVID	Coronavirus Disease
COVID-19	Coronavirus Disease of 2019
DF	Dickey-Fuller
DID	Difference-in-Differences
DSA	Debt Sustainability Analysis
DSSI	Debt Service Suspension Initiative
EMEs	Emerging Market Economies
FEs	Fixed Effects
GDP	Gross Domestic Product
GLBs	GDP-linked Bonds
G20	Group of Twenty
HIPC	Heavily Indebted Poor Countries
IMF	International Monetary Fund
MDRI	Multilateral Debt Relief Initiative
OECD	Organisation for Economic Co-operation and Development
PVBC	Present Value Budget Constraint

SC	Synthetic Control
SCDIs	State-Contingent Debt Instruments
SCM	Synthetic Control Method
SDID	Synthetic Difference-in-Differences
UN	United Nations
WAEMU	West African Economic and Monetary Union

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1 Introduction

Since the initiative to cancel the debt of the Heavily Indebted Poor Countries (HIPC), the need to activate mechanisms for restructuring public debt[1] has resurfaced at the forefront of international attention. In this regard, it is worth noting that despite the recent G20 Debt Service Suspension Initiative (DSSI) in 2020 and the Common Framework for Debt Treatments which had enabled a deep restructuring of the debt, the ongoing and more pressing necessity of pursuing a solution shows that public debt management is more complex than initially envisioned. Specifically, in the midst of the prevailing uncertainties of the present macroeconomic climate, the contraction of additional debt threatens public finance sustainability[2] and constrains growth prospects, by creating significant budgetary pressure, especially in African developing countries. More than twenty African countries are at significant risk of experiencing debt distress and eleven are currently in distress, as recently identified by global financial organizations (IMF, 2024). Furthermore, we registered two insolvent African countries: Zambia and Ghana in 2020 and 2022, respectively, and several countries that undertook efforts to restructure their debt including Ethiopia and Chad during this period. These cases are instructive and collectively urge us to entertain the possibility that the problem might be rooted in the inflexibility of traditional debt instruments and in the inadequacy of the strategies that have been adopted thus far to manage debt repayment challenges. Thus far, debt restructuring processes remained a short-term, slow, costly, and insufficiently transparent remedy. Moreover, the public debt structure (Chamon and Mauro, 2005) across the continent which presents particularly burdensome characteristics(UN Trade and Development, 2024), adds another layer of risks. As a matter of fact, in the sub-Saharan region, specifically, 40 percent of public debt is held by international lenders and more than 60 percent of the latter is denominated in US dollars (Kemoe *et al.*, 2023). This reliance on foreign currency debt (African Export-Import Bank, 2024) exposes the continent to exchange rate risk, which makes the debt refinancing and potential restructuring process more complex and uncertain. These challenges are exacerbated for emerging African countries, in particular, considering that many of them lack the resources and strategies necessary to effectively manage and mitigate risks. Besides, the propensity of African government securities to have short-term durations exposes them to substantial liquidity risks, especially during periods of decline in economic activity. Preventing future debt crises would require refining current debt instruments and adopting a holistic and

[1] **Public debt** (also known as *"sovereign debt")* is defined as the total amount that a government owes to its domestic creditors and foreign lenders including institutions, banks and individuals. It covers the liabilities incurred by a government through borrowing, including bonds issued at the domestic and international scale, and additional forms of debt instruments.

[2] **Public finance sustainability** (also referred to as "***fiscal sustainability***") is the ability of a government to sustain its current spending, tax and other policies in the long run without threatening government solvency or defaulting on some of its liabilities or promised expenditures. **Debt sustainability** is a component of public finance sustainability and refers to a condition in which the debt-to-GDP ratios are stationary and mean-reverting. In simple terms, a country's public debt is considered sustainable if incremental changes in this ratio move back towards the mean in the medium and long term (Bohn, 1998; Lukkezen and Rojas-Romagosa, 2013) and if the government is able to meet its future obligations without exceptional financial assistance or going into default (Hakura, 2020).

macroprudential borrowing approach (Blanchard *et al.*, 2013) that considers the arising risks and the structural inadequacies of the sovereign debt structure in emerging African countries. As a matter of fact, there is an increased consensus on the need for reform (African Development Bank Group, 2024; Mottley, 2024) and instruments that allow countries to minimize risks associated with increasing indebtedness (Blanchard *et al.*, 2013). The International Monetary Fund (IMF) prompted some African countries, such as Senegal, to undertake bold and prompt action to place public debt on a declining path (IMF, 2023; 2024).

GDP-linked securities are state-contingent debt instruments (SCDIs) (IMF, 2017) that have been issued, thus far, by countries with difficulties in servicing their debts, ranging from Latin American countries during the 1980s debt crisis to Bulgaria, Argentina, Greece, and Ukraine in 1994, 2005, 2012 and 2015, respectively, within a debt restructuring context. Initially advocated by Shiller (1993), and supported by Borensztein and Mauro (2004), the idea of GLBs has been extended by other economists who argued that the benefits from growth-indexed bonds could be mainly meaningful for countries with a relatively high debt ratio (Blanchard *et al.*, 2016). In our case, considering the massive recurring episodes of debt restructurings in Africa (Brooks *et al.*, 2014) and upcoming risks, we posit that exploring this alternative in the case of emerging African countries, with a proactive and preventive approach rather than a mitigative post-event framework, could unveil new pathways to achieve sustainable debt. The body of research approached the subject of GLBs from a flawed and limited perspective. Previous works from seminal contributors propose a debt indexation to nominal GDP level (Shiller, 1993; Obstfeld and Peri, 1998) and real growth rate (Borensztein and Mauro, 2004), however this strategy does not provide an optimal hedge against macroeconomic risks. Moreover, their methodological approach was, to some extent, not well anchored in real-world contexts. Indeed, the growing literature covering the topic of GLBs is dominated by research using Monte Carlo methods and considering hypothetical small open economies (Borensztein and Mauro, 2004; Durdu, 2007; Hatchondo and Martinez, 2012; Barr *et al.*, 2014; Kim and Ostry, 2021), advanced economies (Benford *et al.*, 2016; Cabrillac *et al.*, 2017) and currency unions (Brooke *et al.*, 2013; Carnot and Sumner, 2017; Bonfim and Pereira, 2018). By deriving inferences on the impact of GDP-linked debt from stochastic Monte Carlo simulations of the debt ratio, most of these studies failed to account for the effect of GLBs in situations comparable to historical economic shocks and crises, particularly extreme tail events. Overall, the standard approaches used by scholars to estimate the effects of GLBs on debt ratio are unsuitable. These gaps leave a critical space for the exploration of another indexation design (Pina, 2022) and more plausible representations of the effects of these financial instruments on the debt burden, especially in African emerging countries, where the GDP growth rate exhibits significant changes over time.

In this thesis, we aim to address gaps in the literature and investigate how GDP-linked bonds[3] could contribute to preventing a new spiral or escalation of debt-related vulnerabilities,

[3] **GDP-linked bonds** fall within a category of state-contingent government debt securities for which repayments are tied to parameters related to the Gross Domestic Product (GDP) of the issuing country (Bowman and Naylor, 2016).

without compromising the development process and growth perspectives of the emerging countries. Their crucial lack of access to sufficiently robust instruments to deal with adverse shocks motivates our focus on countries like Côte d'Ivoire in our investigation. We contemplate whether, in this country, the implementation of a debt servicing model contingent upon the repayment ability of a country is likely to ease debt vulnerabilities. Overall, focusing on the comparative analysis of Côte d'Ivoire and other emerging countries, we aim to address the following key questions: What implications does a GDP-linked bonds framework have for debt sustainability compared to a conventional debt framework? How could African emerging countries initiate a process of inflection of the level of debt as recommended by international organizations? In particular, to what extent should traditional debt instruments and GDP-linked bonds be combined to meet the debt reduction goal?

This thesis responds to the urgent call made by policymakers and international financial entities for evidence on effective approaches to address the issue of debt sustainability. Our findings are projected to provide valuable input for policy formulation in African emerging countries and comparable regions. Furthermore, by opening up a new dimension to debt relief research, it addresses the limits of the literature and make one broader scholarly contribution. Specifically, we extend the empirical debate surrounding GDP-linked debt by demonstrating, theoretically and especially empirically, the implications of the implementation of GDP-indexed bonds in the prevention of repetitive and costly crises of public debt in emerging African countries. While the debt reduction effects of GLBs constitute a major part of our investigation, unlike previous studies, our primary concern is not merely the debt level but the capacity to refinance it and to cope with future unpredictable events, which is strengthened by the additional margin for maneuver that debt reduction offers.

Given these considerations, the main innovations in this thesis are the application of an Augmented Dickey-Fuller (ADF) test and a quasi-experimental Difference-in-Differences (DID) method (Snow, 1849) to public debt data. The latter approach allows us to estimate the degree of fiscal flexibility that the implementation of GDP-linked debt could potentially allow in a given country compared to other countries that rely on conventional bonds. Such technique has not been applied thus far in the literature surrounding GDP-linked bonds, to the best of our knowledge. In this framework, Côte d'Ivoire serves as the *treated* country where we simulate the introduction of GDP-linked bonds, while Kenya and other comparable African emerging countries (Ethiopia, Rwanda and Senegal) serve as *control* countries relying on conventional debt instruments. By using Côte d'Ivoire and other African countries, we aim to offer a new and broader perspective on the application and potential impacts of GLBs in a less explored economic context. Moreover, in contrast to earlier research that exclusively put the emphasis on stochastic projections, we adopt a retrospective methodology by simulating how the introduction of GDP-linked bonds would have affected the change in the debt-to-GDP ratio if they were introduced in previous years. This approach contributes to grounding our analysis in real-world data, making our findings more concrete and applicable for future recommendations on public debt management.

In our attempt to elucidate key implications for policymakers considering alternative debt financing options in a rapidly changing economic environment, we focus on a particular group of countries and employ different quantitative methods. Our sample consists of seven African developing countries that were recurrently identified as qualifiable for the key debt relief programs[4] that were elaborated over the past two decades. Our panel data spans from 2002 through 2022, covering the two major financial crises[5] that were experienced on a global scale. First, we provide evidence that the parallel trend assumption is consistent with our panel data. Then, we employ a Difference-in-Differences (DID) methodology to illustrate the average effect of the implementation of GDP-linked bonds on the change in the debt ratio. We also perform a series of robustness checks to assess the validity of our results. Subsequently, we conduct forecasts of the debt-to-GDP ratio based on deterministic models from 2022 to 2032. With several assumptions considered and all things equal, we predict that, under specific circumstances and when designed properly, GDP-linked bonds could potentially contribute to decreasing debt burden, improving solvency, and providing additional space for new borrowing. We hold the view that the use of these instruments is now imperative in the transitional phase of African emerging countries. Based on our quasi-experimental study with our selection of seven African emerging countries, with a focus on Côte d'Ivoire, we reached the following main conclusions:

First, our findings demonstrate that the implementation of GDP-linked bonds might contribute to debt stabilization.

Second, our Difference-in-Differences approach reveals that this reform could significantly decrease the variability of the debt ratio.

Finally, evidence from our quasi-experimental study supports the conclusion that, in Côte d'Ivoire, at the very least, more than one-third of the public debt stock should be indexed to nominal GDP growth rate for the effect of the implementation of GDP-linked bonds to be substantial.

The remainder of the thesis is structured as follows: Section 2 briefly covers the historical context that paved the way for the emergence of proposals for state-contingent debt instruments. Section 3 presents a review of the previous literature on GDP-linked bonds, namely the rationale, benefits, and costs of linking sovereign debt to GDP growth, including the arguments against this approach. Section 4 presents our experimental design including the creation of the GDP-linked bonds, the date of the experiment, and the main hypotheses. Section

[4] 1996: Heavily Indebted Poor Countries (HIPC) Initiative,
2005: Multilateral Debt Relief Initiative (MDRI),
2020: Debt Service Suspension Initiative (DSSI).

[5] 2010, 2019-2020.

5 provides an overview of the data used in the model, and the collection process, including their sources. In this section, we also explain the choice of methodology and statistical techniques used in the study. Section 6 outlines the main results obtained from the different econometric approaches employed. Section 7 provides an interpretation and discussion of the results. Section 8 offers some concluding remarks by summarizing the main results and discussing their implications for public debt management. In this section, we also highlight the limitations of the study, specifically, the constraints encountered and their potential effects on the results and, finally, we provide recommendations for policymakers and future research. The Appendix encloses summary statistics and additional figures and tables including results from robustness checks. This section also briefly encompasses previous applications and failures of these financial instruments, and specifically, discusses the design and historical performance of similar instruments such as the GDP-indexed warrants in Argentina in 2005 and Greece in 2012.

2 The Intersection between GDP-linked Bonds and the Imperative for Reform

Initial discussions surrounding state-contingent debt instruments (SCDIs) arose following the debt crisis of the 1980s. The premise was that the indexation of debt to endogenous indices mirroring market conditions such as export revenues (Bailey, 1983), GDP, or prices of major commodities (Krugman, 1988; Froot *et al.*, 1989) might offer a promising solution to address some of the deficiencies in traditional debt instruments.

Krugman (1988) advocated that a potential solution to debt stabilization could lie in state-contingent claims. The underlying intuition is that linking debt repayments to the economic performance of the sovereign borrower could possibly decrease its debt burden in times of economic decline and mitigate the adverse impacts of a debt overhang[6]. The main insight from his research was that the indexation of debt to the state of nature of the given country proved to provide more incentive to the country to pursue economic adjustments to enhance and reinforce its likelihood of fulfilling debt payments than conventional debt arrangements (Krugman, 1988). The theory of state-contingent claims has subsequently been translated into practice through the introduction of Brady bonds between 1989 and 1997, within the framework of debt restructuring of the several Latin American countries that defaulted. The Brady Plan was designed to provide debt relief to these emerging countries by enabling commercial banks to convert their claims on debtor countries into bonds backed by U.S. Treasury zero-coupon bonds as collateral. These warrants rewarded investors with contingent upside payments, tied to a pre-determined economic variable. In other words, under such contracts, coupon payments were increasing at specified GDP thresholds instead of closely mirroring GDP trends. This innovation paved the way for greater research. Notably, Shiller (1993) instigated a renewed interest in the topic of GDP-linked debt instruments by advocating that they could hedge exogenous risks and redistribute risks among the stakeholders when designed properly.

Practical Applications of GDP-Linked Debt Instruments

GDP-linked securities have, historically, been issued in the context of debt restructurings, from the Brady bond exchanges that began in 1989 to the more recent cases of Argentina, Greece, and Ukraine. The case of Argentina (refer to Appendix B) emphasized a trade-off between the appeal of the GDP-linked warrants to investors and their payment burden. The structure of the payments was made in a way that any payment missed in any given year due to slow growth was deferred to the next period, making the payment even more inconvenient for the country. In contrast, as Griffith-Jones and Hertova (2013) argued, the structure of the Greek warrants (Appendix B) was more beneficial to the debtor country relative to the investors. Consequently,

[6] **Debt overhang** refers to a situation in which a government incurs debt at such a high level that they are unable to sustain future investments.

they drew minimal interest from lenders, especially because the short-term growth outlook was not promising. Moreover, the payment structure in Argentina and Greece failed to take inflation and exchange rate changes into account.

3 Literature Review

In key academic contributions, the trade-offs, costs, and design of GDP-linked debt — as a countermeasure to macroeconomic fluctuations — have been subjects of long-standing discussion.

3.1. Rationale for Indexing Public Debt to GDP-derived metrics

The literature provides multiple arguments to defend the logic behind indexing debt to GDP metrics—particularly the growth rate. The ability of a country to manage its debt sustainably is intrinsically linked to its economic growth trajectory, which affects its capacity to repay (Borensztein and Mauro, 2004). When considering the issuance of state-contingent debt, the latter observation implies that Gross Domestic Product (GDP) growth rate represents a compelling indexation metric. Several studies prove that economic expansion has direct repercussions on the capability of a country to service its debt obligations over both the short and long run (Barro, 1979; Bohn, 1998, 2005). Easterly (2001) shows that declines in growth rate add considerable pressure at certain debt levels by decreasing primary surpluses and tax revenues. As logic would suggest, his study revealed that growth is a significant and robust predictor of debt crises. Besides, declining GDP aggravates debt overhang, a high debt level that discourages investment and prompts restructurings to restore economic incentives (Krugman, 1988). More recently, Keynesian economists posited that concerns regarding debt levels arise whenever interest rates exceed economic growth rates in the long run (Blanchard, 2019).

3.2. Proposals of Indexation Designs

Acknowledging the role of the time horizon and GDP level in shaping debt repayment potential, Shiller (1993) proposed the issuance of longer-maturity debt instruments, if possible, perpetual, for which both coupon and principal payments are indexed to the nominal GDP level. The indexation to nominal levels takes inflation into account, as a result, it further covers lenders against inflation. Besides, the rationale behind the use of long-term debt lies in the notion that a long horizon provides more flexibility and time for carrying out countercyclical fiscal measures in times of recession. Moreover, long bonds involve a lower default risk as they somewhat limit the variance of the expected value of the debt (Acalin, 2018). One of the disadvantages of tying debt to GDP level rather than GDP growth rate is that it does not enable debt payments to decrease during periods of economic downturns, hence, making the desired countercyclical benefits less pronounced.

On the other hand, Borensztein and Mauro (2004) suggested that only the coupon payments should be indexed to real GDP growth, and the principal payment should remain fixed. However, indexing debt to real GDP growth might minimize the ability to pay of the government in inflationary circumstances. In accordance with our framework, the model of

Borensztein and Mauro (2004) was calibrated using historical data from multiple countries to reflect realistic economic conditions and debt structures. They performed a sensitivity analysis where different scenarios were explored, such as varying the proportion of GDP-linked bonds and examining different economic growth rates to evaluate their impact on debt sustainability and default risk (Borensztein and Mauro, 2004). In this study, our simulations rely on a payment structure that combines both approaches (Shiller, 1993; Borensztein and Mauro, 2004) to guarantee an optimal indexation. Specifically, we attach the coupon to the nominal GDP growth.

3.3. Advantages of GDP-Linked Bonds: Theoretical and Empirical Evidence

Shiller (1993) argued that adjusting the burden of public debt to the economic situation of the country through the means of GDP-linked bonds could offer "insurance" against the risks associated with public debt. In line with the view of other advocates of state-contingent debt, he pointed out the fact that this innovation would reduce the debt servicing costs during a recession, and consequently decrease the probability of experiencing a crisis. GLBs offer a countercyclical buffer that protects countries against economic shocks (Borensztein and Mauro, 2004). According to Borensztein and Mauro (2004), adopting GDP-linked bonds could prevent debt from reaching high paths in the future and lower fiscal deficits. This improvement in fiscal balance is attributed to the smoother debt service payments, which reduce the need for drastic fiscal adjustments during economic downturns. Their analysis shows that GDP-linked bonds can significantly enhance debt sustainability. For instance, their sensitivity analysis revealed that during the Tequila crisis that occurred in 1994, the use of GLBs in Mexico could have lowered the coupon rate to nearly zero. Other estimations show that GLBs could reduce the cost of borrowing in countries with high levels of economic volatility (Griffith-Jones and Sharma, 2006) More recently, central banks such as the Bank of England have been active in exploring the potential for such instruments (Benford *et al.,* 2016). GLBs offer potential benefits for both sovereign issuers and investors. Contributing to the literature on the benefits of GLBs for issuing sovereigns, Papavassiliou *et al.* (2024) found that GLBs were valuable from the investor's perspective, as they represent a new asset class with diversification potential. Using the generalized method of moments regressions, they could determine that adding bonds with coupon payments indexed to GDP to the portfolio increases both the Sharpe and the downside Sharpe ratios by up to 3 percentage points above the benchmark. Their advantages remain consistent across the different risk premium estimates found in the existing literature and are robust to randomized tests (Papavassiliou *et al.,* 2024). For issuers, these instruments can provide a more sustainable debt structure by reducing the pro-cyclicality of debt service payments (Chamon and Mauro, 2005). This could improve public debt management throughout economic fluctuations. For investors, GLBs present an opportunity to diversify their portfolios with a new class of assets that are less correlated with traditional financial instruments. They would also benefit from the decreased likelihood of default and debt crisis, which lead to burdening restructuring negotiations. Although the pricing of these bonds might be more complex due to the uncertainty in future GDP growth paths, the risk-sharing benefits (Emter and Herzberg, 2018) between sovereign borrowers and investors could make these bonds an attractive investment, particularly for those seeking exposure to emerging market economies. Despite their challenges, these instruments could play an important role in improving global financial stability, especially if they are supported by sound economic policies and international institutions that can help mitigate the associated risks (Chamon and Mauro, 2005). Hatchondo and Martinez (2012) formulated a theoretical framework of a small open economy subject to countercyclical default risk, with risk-neutral investors. They found that indexed debt induces welfare gains, which could be explained by the resulting consumption smoothing, increasing the ability of the government to contract debt, and neutralization of default risk. Önder (2023) showed an optimal GDP-linked bonds agreement contract in which the welfare gains of the government increased by a minimum of 2 percent. He designed two types of contracts —floored and unfloored —which both drove welfare gains. However, he found that higher gains could be obtained when the payments were not floored nor suspended during economic downturns. Finally, he established that such instruments provide a hedge for countercyclical policies.

3.4. Challenges, Drawbacks, and Costs related to GDP-linked bonds Issuance

A major concern related to GLBs, among investors, is the plausibility of moral hazard, which translates to a situation where governments might be less incentivized to seek growth opportunities in order to decrease their debt responsibilities (Chamon and Mauro, 2005). Griffith-Jones and Hertova (2013) argue however that this argument does not stand on a political standpoint and that, in practice, it is impossible to maintain low growth levels in the long run voluntarily. Benford *et al.* (2016) also discussed challenges relating to the potential manipulation and the prompt availability of the GDP data. A study conducted for 66 countries from 1983 to 2006 found that most historical GDP revisions were relatively negligible (Williamson, 2017). Nevertheless, the investigation revealed that, out of 740 observations, 41 atypical revisions to the real GDP across 38 countries were observed between 1981 and 2000, a period during which the data were deemed accurate.Williamson (2017) argues that GDP adjustments could be countered by establishing a general formula for GDP measurement in the bonds' agreement, by adding any increments in the GDP to the previous formula, or by adjusting payments to potential revisions. Besides, another major apprehension for investors is the risk entailed by this new instrument. The essence of GLBs is the strategic reallocation of sovereign risk to investors (Shiller, 1993). However, this aspect raises an important issue since risk-averse lenders tend to prefer the certainty guaranteed by conventional bonds rather than being exposed to the fluctuations of the country's future economic performance. As a result, when considering such instruments, they would require a higher risk premium that would be taken into account in the pricing of the GLBs.

Another significant challenge is related to the accuracy of the structure and the pricing of these bonds. In terms of cost, according to a few economists, the estimated risk premium demanded by risk-averse investors for holding GDP-linked bonds could range from 40 to 150 bps (Borensztein and Mauro, 2004; Costa *et al.*, 2008; Kamstra and Shiller, 2009; Pisani-Ferry *et al.*, 2013; Barr *et al.,* 2014; Blanchard *et al.,* 2016). Additionally, nations with weak governance frameworks may face higher borrowing expenses, as financial specialists would require a premium to reimburse for the potential for information adjustment (Benford *et al.*, 2016). In parallel, for similar instruments issued in the real world, notably GDP-linked warrants, Igan *et al.* (2022) documented a high, persistent, and procyclical risk premium; taking values of 12.5 percent, 4.25 percent, and 6.65 percent in Greece, Ukraine, and Argentina, respectively. The overall cost of the premium of GLBs, relative to traditional bonds, takes into account the following components: novelty premium, liquidity premium, GDP growth risk premium, and default premium (Blanchard *et al.*, 2016). Costa *et al.* (2008), using a Monte Carlo methodology to calculate the expected net present value of payments, found that the residual premium paid by these warrants over standard bonds declined significantly by approximately 600 basis points between 2005 and 2007, indicating that a substantial part of the risk premium of GLBs is mainly attributed to novelty risk which will eventually decrease in the short run. Furthermore, the default risk component of the overall risk premium dissipates as the insurance mechanism of GLBs reduces the probability of default (Chamon and Mauro, 2005; Barr *et al.,* 2014; Blanchard *et al.*, 2016). Borensztein and Mauro (2004) argue that this reduction of the default risk would occur exclusively under the condition that GDP-linked debt securities constitute a substantial share of the public debt of a given country. Consistently with this view, Chamon and Mauro (2005) emphasize on the need for a liquid and transparent market for the GDP-linked bonds to emerge as a successful tool.

Overall, despite the flaws, costs and apprehensions related to GDP-linked bonds highlighted in the literature, we maintain an optimistic perception of these instruments and argue that their potential to contribute to debt viability lies in the optimality of the indexation approach. Besides, to maximize the effectiveness of these instruments, we can draw lessons from concrete applications of similar instruments such as GDP-linked warrants in the 1980s in Latino-American countries, and more recently in Argentina and Greece. Particularly, in light of the current and upcoming risks faced in African Emerging Market Economies (EMEs), we attempt to investigate the potential impact of GLBs in addressing the macroeconomic challenges of those specific countries, hereby filling a crucial gap in the related literature.

4 Experimental Design

4.1. Purpose

The aim of this experiment is to evaluate the potential causal effects of both a complete and a partial embrace of GDP-linked bonds on the debt-to-GDP ratio in an emerging West African country. To achieve this, first, we simulate the introduction of these instruments in 2009 and compare their performance to the actual performance of conventional debt in Côte d'Ivoire. Simulating the implementation of GLBs and estimating their potential effect on debt dynamics might pose significant challenges considering that such bonds might induce macroeconomic changes and policy decisions that are hard to anticipate. However, to pave the way for developing these instruments as part of public debt management strategies, we attempt to generate a rough idea of their potential impact by grounding our quasi-experimental study on a few assumptions and using a well-considered methodology.

First, we determine the adequate metric for the indexation between GDP growth rate and GDP level, and whether to apply nominal or real terms. Then, we calculate the indexation-adjusted interest rate, using arbitrary risk premium and indexation coefficient. Finally, we perform the simulation by adjusting the debt-to-GDP ratio of Côte d'Ivoire to reflect the effects of full-scale and partial conversions to GDP-indexed debt in 2009. In the remaining subsections, we explain the underlying assumptions of our simulation and our expected outcome from this study.

4.2. Choice of Index

As opposed to previous research (Shiller, 1993; Borensztein and Mauro, 2004), in our analysis, we choose to index public debt on the difference between the nominal GDP growth rate and the baseline nominal growth rate. One argument in favor of the nominal GDP growth rate is that it may be more suitable for emerging economies where the government seeks to buffer debt payments during downturns. Indexing debt on this differential helps control the pace of debt accumulation relative to the country's economic growth and aligns more with debt sustainability objectives. Indeed, since African EMEs tend to experience high economic volatility, tying debt servicing costs to the change from the baseline growth rate could provide more flexibility to governments during times of economic distress.

4.3. Indexation Formula

Drawing lessons from previous real-world implementations of GDP-Linked debt instruments, and building on the approach of Borensztein and Mauro (2004), we determine the interest rate under indexation as follows:

$$i_t^{GLB} = i_t + \lambda \times (g - \overline{g}) + \theta_{GLB} \qquad \textbf{(4.1)}$$

where i_t represents the base interest rate; the nominal interest on plain vanilla bonds. λ denotes the indexation coefficient and g represents the nominal GDP growth rate and $\overline{g}$ represents the average GDP growth rate in Côte d'Ivoire between 2002 and 2008. In contrast, Borensztein and Mauro (2004) multiplied the indexation coefficient by the difference between the real GDP growth rate and a benchmark GDP growth rate that, according to them, should be determined and agreed to by all parties involved in the contract before the bond issuance. To simplify our research and simulations, we use the average GDP growth rate. The parameter θ_{GLB} represents the risk premium on GDP-linked bonds. The optimal indexation coefficient λ^* is a coefficient that achieves the lowest variance of the change in the debt-to-GDP ratio. We consider that determining an optimal indexation coefficient is a complex task in practice since the variance of the change in the debt-to-GDP ratio depends on several factors. For simplicity, we choose an arbitrary baseline indexation coefficient equal to 0.01. Then, we perform sensitivity tests with indexation coefficients set to 0.03 and 0.07.

4.4. Risk Premium Assumptions

One of the most critical determinants of the cost of GLBs is their risk premium which fluctuates in proportion to the perceived risk of the investment or market, especially political and economic stability. In line with previous studies, we presume that this new class of bonds will, in practice, have a high premium in contrast to more traditional bonds. Given that these bonds give higher exposure to economic fluctuations, we can expect a relatively high risk premium, particularly during times of severe economic instability or market turmoil. In the absence of credit ratings for Côte d'Ivoire for the period 2002-2008, we hypothesize that the country was facing moderate economic uncertainty and default risk by the end of the year 2008, within our quasi-experimental study. We use an arbitrary risk premium (θ_{GLB}) of 2 percentage points in our basic model. To assess the sensitivity of our results to risk premium values, we evaluate two additional models; one in which the risk premium is equivalent to 400 basis points and the other with a null risk premium.

4.5. Simulating the Issuance of GDP-Linked Bonds in Côte d'Ivoire in 2009

The standard equation[7], employed by many scholars including Benford *et al.* (2016), illustrating the change in the debt-to-GDP ratio related to conventional debt is defined as:

$$\Delta d_t^c = d_t^c - d_{t-1}^c = \frac{i_t - g_t}{1+g_t} d_{t-1}^c - pb_t + \varepsilon_t \quad \textbf{(4.2)}$$

where d_t^c and d_{t-1}^c represent the general government gross debt-to-GDP ratio in year *t* and *t-1,* respectively. Additionally, i_t represents the nominal interest on outstanding debt in year t and g_t represents the nominal GDP growth rate in year *t*. Finally, pb_t represents the government primary balance as a proportion of GDP in period *t*, and ε_t refers to any other exogenous adjustments and shocks to the debt stock in year *t*. This term also captures shocks of exchange rate shocks. For simplicity, we assume that it is non-stochastic, similarly to Benford *et al.* (2016).

In accordance with the literature (Benford *et al.*, 2016), we approximate the change in the debt-to-GDP ratio observed within a regime of GDP-linked bonds as follow:

$$\Delta d_t^{GLB} = \frac{i_t^{GLB} + \theta_{GLB}}{1+g_t} d_{t-1}^{GLB} - pb_t + \varepsilon_t \quad \textbf{(4.3)}$$

where Δd_t^{GLB} represents the change in the debt-to-GDP ratio for GDP-linked bonds in year *t*, and i_t^{GLB} is the nominal coupon on GDP-linked debt, and θ_{GLB} represents the GDP risk premium. For simplicity, we assume that the risk premium θ_{GLB} is equal to zero. d_{t-1}^{GLB} represents the lagged general government gross debt-to-GDP ratio. The other variables were defined previously.

In order to simulate the introduction of GLBs in Côte d'Ivoire, we recalibrated the debt ratio as follow:

$$d_{t,CIV} = \begin{cases} d_t, & if\ t < 2009 \\ d_{t-1} \times (1 + (i_t^{GLB} + \theta_{GLB})) - pb_t, & otherwise \end{cases} \quad \textbf{(4.4)}$$

where $d_{t,CIV}$ denotes the debt ratio in Côte d'Ivoire in the framework of our study. It represents the recalibrated debt ratio that takes into account the transition to GLBs in Côte d'Ivoire in 2009, and d_t is the conventional debt ratio.

[7] The equation that we adopt has been widely used in the literature related to public debt and GDP-linked bonds, namely Benford *et al.* (2016), Blanchard et *al.* (2016), Carnot and Sumner (2017) and Cabrillac *et al.*(2017).

4.6. Assumptions

It is undeniable that the fundamentals of the debt-to-GDP ratio such as the primary balance and the GDP level, are affected by the change in the debt structure, whether through direct or indirect channels. However, for the causal effect of GLBs to be conceptually sound and easily estimated, it is essential to assume specific conditions regarding the values of these parameters that we cannot anticipate. As a matter of fact, forecasting primary balance presents significant challenges due to changing political decisions, economic uncertainties, and external shocks, especially for developing countries. Considering the lack of available forecasts for the countries under consideration, throughout the simulation period, for simplicity purposes, we do not take into account the potential variations in the nominal GDP level after the adoption of GLBs and follow the same trajectory to that observed after 2009 in Côte d'Ivoire (Borenzstein and Mauro, 2004). Additionally, we do not take into account the changes in the borrowing practices that may occur with the introduction of GDP-linked bonds (Benford *et al.*, 2016). Indeed, the incremental fiscal space resulting from the adoption of GLBs could stimulate the sovereign to expand debt acquisition. In our analysis, to isolate the impact of the instruments and for simplicity purposes, we assume that the Ivoirian government does not change its borrowing patterns. Furthermore, we assume that the benchmark interest rate used to calculate the interest rate of GLBs is equal to 5 percent, slightly above the peak interest rate of 4 percent recorded by Côte d'Ivoire between 2002 and 2008. Grounding our model in these assumptions will allow us to bypass the complexities of modeling such an innovative debt structure, and to refine the interpretation of our experimental results.

4.7. Thesis

The intuition behind our experimental approach is straightforward. In line with the theory that GLBs offer a natural hedge against adverse shocks, we argue that if GDP-linked debt instruments had a significant share in the debt strategy of African emerging countries, their debt ratio could have been controlled and plausibly maintained at a level that surpasses sustainability standards. In addition to some developed countries for which it is already verified, we extend this theory to emerging African countries.

5 Data and Methodology

The body of literature related to GDP-linked bonds estimates the impact of these instruments through an approach that does not entirely encompass the complexities of real-world shocks, especially in emerging countries. To correct this omission, we measure the extent of sustainability that this structural reform could enable, by using an Augmented Dickey-Fuller (ADF) method (Said and Dickey, 1984). Then, we proceed with a retrospective Difference-in-Differences analysis (Snow, 1849). For additional insights, we perform stress testing with different scenarios of growth shocks (refer to Appendix D1). In this section, we describe the variables used in our model, their sources and the methodology used to assess the effects of a transition to GLBs in Côte d'Ivoire.

Data

Overview

We compile data on an annual basis from different sources spanning the years 2002 to 2022. Data availability and consistency across all variables during this period reinforce the reliability of our analysis. Moreover, this sample period captures several economic cycles, including the global financial crisis of 2008 and the COVID-19 pandemic, providing a robust view of economic trends and enabling a comprehensive analysis of the impacts of external shocks on the main parameter under study: public debt-to-GDP ratio. The central variable for our analysis is the general government debt, considering that standard Debt Sustainability Analyses (DSA) produced by the IMF for low-income, emerging and advanced economies typically focuses on this specific variable (Nicholls and Peter, 2014). The general government gross debt, the real GDP growth rate, the interest paid on public debt and the government primary balance were retrieved from the database of the International Monetary Funds (IMF). The general government gross debt, the interest paid on public debt and the government primary balance are expressed in nominal terms and as a share of GDP. The real GDP growth rate is expressed as annual percent changes. The inflation rate was retrieved from the World Bank database (Table C1). Our treated country, Côte d'Ivoire, belongs to the West African Economic and Monetary Union (WAEMU) and is, therefore, subject to rules governing fiscal policy, such as deficit limits or balanced budget requirements. These constraints can impede the country from implementing appropriate fiscal measures to reduce debt levels when necessary. Besides, Côte d'Ivoire experienced political instability and conflict in the years leading up to 2009, the chosen treatment year. The latter marks a period of recovery, allowing for a clearer assessment of how the introduction of GDP-linked bonds can affect debt dynamics in a post-conflict setting.
After years of political instability, Côte d'Ivoire has seen significant economic growth (Direction Générale du Trésor, 2024). Bonds indexed to its growth rate could help the country manage its

debt sustainably as it continues to rebuild and grow its economy. As a major exporter of agricultural products, the Ivoirian economy is somewhat vulnerable to commodity price fluctuations along with other adverse macroeconomic, environmental, and political shocks that can potentially threaten the sustainability of debt-to-GDP ratio. If designed properly, GLBs could provide a more *stable* and *predictable* debt service framework for an emerging country like Côte d'Ivoire.

Our sample of control countries for this study consists in Benin, Burkina Faso, Ethiopia, Kenya, Rwanda and Senegal. We select these countries for this study based on data availability and similarities with the Ivorian economy, in terms of debt structure and growth prospects. Specifically, Benin, Burkina Faso, and Senegal are part of the West African Economic and Monetary Union (WAEMU), which shares a common currency with Côte d'Ivoire, facilitating comparable economic policies and practices. Additionally, Kenya, Rwanda, and Senegal are three emerging African economies exhibiting a similar debt composition as Côte d'Ivoire, as they similarly issue Eurobonds, which positions them as relevant counterparts in this analysis.

Raw Data Analysis

Figure C1, provides insight into general government gross debt ratios, which exhibit parallel trends across the different countries. As illustrated in Figure C4, inflation rates take extreme values for Ethiopia with values above 30 percent in 2008, 2012 and 2022; and in Kenya, where inflation rate exceeds 20 percent in 2006 and 2009. For other countries in the panel, the dynamics of inflations rates are less erratic and fluctuate between minus 7 percent and 11 percent. Figure C5 shows that Kenya pays relatively high and increasing interest on public debt since 2002, followed by Côte d'Ivoire. Other countries in our sample exhibit an increasing trend. Overall, we observe some heterogeneity across our sample countries.

Data Cleaning and Processing

As accessible databases do not provide public debt interest rates nor nominal GDP growth rates for the selected countries, which are necessary for conducting the simulations, we derive them from available data. First, we determine the interest rate by dividing the interest paid on public debt by the gross general government debt to GDP ratio:

$$i \approx \frac{Interest\ Paid\ on\ Public\ Debt}{Gross\ General\ Government\ Debt}$$

Then, we derive the nominal GDP growth rate from the following equation:

$$1 + g_{nominal} = (1 + g_{real}) \times (1 + inflation)$$

$$g_{nominal} = (1 + g_{real}) \times (1 + inflation) - 1$$

Considering that we are working with a restricted sample, we choose not to remove outliers as their removal could introduce greater distortion and inconsistencies to our outcomes. We linearly transform the rates and ratios by dividing them by 100 to reduce scale discrepancies and standardize data for comparison. We recalibrate the debt-to-GDP ratio, as of 2009, for Côte d'Ivoire exclusively, to simulate the implementation of GDP-linked bonds, as described in *Equation* ***4.4***.

Main Variables Summary

We segment the summary statistics into two samples. Table 1.1 presents summary statistics for the treated country, Côte d'Ivoire, while Table 1.2 presents summary statistics for the sample of 126 observations drawn from the control countries: Kenya, Benin, Burkina Faso, Ethiopia, Rwanda and Senegal. A substantial part of the public debt of Côte d'Ivoire is external and denominated in U.S. dollars (USD) and euros (EUR), as the country borrows essentially in these major international currencies (Table 1.1). It is therefore appropriate to include the change in exchange rates in our model if they are not stable over time. On one hand, we note that Côte d'Ivoire's local currency, the CFA franc (XOF), is pegged to the euro. As a result, the EUR/XOF exchange rate remains relatively stable throughout the period under study. Hence, we focus on analyzing the change of the USD/XOF to determine its magnitude before introducing it to our model. The summary statistics show that the average change in the exchange rate is approximately equal to zero. Consequently, we omit this variable from our model as it is fairly negligible.

TABLE 1.1 — Summary Statistics

Côte d'Ivoire

Variables	Obs.	Mean	Median	SD	Min	Max
Year	21	2012	2012	7.23	2002	2022
Interest Paid on Public Debt	21	0.01	0.01	0.00	0.01	0.02
Nominal Interest Rate	21	0.03	0.03	0.01	0.02	0.05
Real GDP Growth Rate	21	0.04	0.03	0.04	-0.05	0.11
Nominal GDP Growth Rate	21	0.06	0.06	0.04	-0.01	0.14
Inflation Rate	21	0.02	0.02	0.02	-0.03	0.06
General Government Gross Debt	21	0.44	0.46	0.12	0.25	0.63
Government Primary Balance	21	-0.01	-0.01	0.02	-0.05	0.01
ΔUSD/XOF	21	-0.00	-0.00	0.01	-0.02	0.01

Sources: IMF; World Bank Databases and Author's calculations.
Notes: This table summarizes the descriptive statistics for the variables for Côte d'Ivoire which represents our treatment country in which we simulate the introduction of GDP-linked bonds.

TABLE 1.2 — Summary Statistics

Benin, Burkina Faso, Ethiopia, Kenya, Rwanda, Senegal

Variables	Obs.	Mean	Median	SD	Min	Max
Year	126	2012	2012	6.08	2002	2022
Interest Paid on Public Debt	126	0.01	0.01	0.01	0.00	0.05
Nominal Interest Rate	126	0.03	0.02	0.02	0.01	0.08
Real GDP Growth Rate	126	0.06	0.06	0.03	-0.03	0.13
Nominal GDP Growth Rate	126	0.12	0.10	0.09	-0.02	0.45
Inflation Rate	126	0.06	0.04	0.07	-0.05	0.35
General Government Gross Debt	126	0.42	0.40	0.19	0.08	1.07
Government Primary Balance	126	-0.02	-0.02	0.02	-0.09	0.15

Source: Author's calculations based on data from IMF Database.
Notes: This table summarizes the descriptive statistics for the variables for the control countries of our study. This separate group includes countries that are not subject to the simulation of the adoption of GDP-Linked Bonds, namely, Kenya, Benin, Burkina Faso, Ethiopia, Rwanda and Senegal.

Methodology and Estimation Framework

1. Investigating Public Debt Sustainability: Augmented Dickey-Fuller (ADF) Test

Several studies investigating the sustainability of public finance, through the lenses of the present value budget constraint (PVBC), conducted Dickey-Fuller (DF) tests (Dickey and Fuller, 1979) on historical public debt data, to validate their stationarity. Hamilton and Flavin (1986) pioneered this approach, followed by more recent works (Bravo and Silvestre, 2002). In our analysis, we use an Augmented Dickey-Fuller (ADF) test which estimates the following equation:

$$\Delta d_t = \alpha + \beta_t + \gamma d_{t-1} + \epsilon_t \qquad \textbf{(5.1)}$$

where Δd_t is the first difference of the time series d_t, the debt-to-GDP ratio, α is a constant, β_t represents a time trend, γ is the coefficient of d_{t-1}, the one-year lag of d_t, that we test for unit root, and ϵ_t is the error term.

In the ADF test, the null hypothesis suggests that the coefficient γ is equal to zero, which implies that the series has a unit root and is non-stationary, whereas the alternative hypothesis suggests that coefficient γ is negative, indicating that the series is stationary:

$$H_0\colon \gamma = 0$$
$$H_1\colon \gamma < 0$$

2. Inferring the Causal Impact of the Adoption of GDP-Linked Bonds: A Panel Study Using the Difference-in-Differences (DID) Method

2.1. Testing for Parallel Trends : Wald Test

Before using the DID regression approach , we verify if the parallel pre-treatment trends assumption holds — a critical prerequisite for this methodology. This condition requires that the trends in the debt-to-GDP ratio for Côte d'Ivoire and the control countries are equivalent in the absence of GLBs. We conduct a Wald test (Wald, 1943), a statistical test that essentially aims at confirming whether the coefficients on a set of explanatory parameters in a model are simultaneously equal to zero. In this specific context, this test aims at assessing whether the interaction terms between time and treatment status are jointly equal to zero in the pre-treatment period. To proceed to the test, first, we create interaction terms between the time dummies indicating the pre-treatment period and the treatment indicator variable. Then, we run the following regression model where the change in the debt-to-GDP ratio (Δd_{it}) is the outcome of interest:

$$\Delta d_{it} = \alpha + \beta^{treat} GLBs_i + \sum_{j=1}^{10} \beta_j \left(GLBs_i \times \sum_{t=1998}^{2008} Year_t \right) + \epsilon_{it} \qquad \mathbf{(5.2)}$$

$GLBs_i$ is a dummy variable for the treated country and $Year_t$ is a time dummy for a given year t within the period 1998-2008. In our quasi-experimental study, the pre-treatment period is 2002-2008, however, for this Wald test, we extend the analysis to include the period 1998-2008 in order to add credibility to our findings. The product $GLBs_i \times Year_t$ is the interaction between the treated country and time dummies, capturing the difference in trends, and ϵ_{it} is the error term. After estimating the aforementioned regression, we perform a Wald test to verify if the coefficients ($\beta_1, \dots, \beta_{10}$) of the interaction terms between the time dummies and the treated country are jointly equal to zero. Under the null hypothesis, these coefficients are jointly zero, which implies that the treated and control countries exhibit similar trends in the change in the debt-to-GDP ratio during the pre-treatment period. The alternative hypothesis suggests otherwise.

$$H_0: \sum_{j=1}^{10} \beta_j = 0$$

$$H_1: \sum_{j=1}^{10} \beta_j \neq 0$$

We obtain a high p-value (see Table B2), therefore we cannot reject the null hypothesis that assumes that the pre-treatment trends of the change in the debt-to-GDP ratio in Côte d'Ivoire and the control countries are not significantly different. Obviously, we observe some heterogeneity in debt path across the selected countries (Figure B1), but overall, through this test, we can infer that the parallel trends assumption is fulfilled. This conclusion suggests the reliability of the DID method for our causal inference analysis.

2.2. Difference-in-Differences Regression

Recent studies analyzed the quantitative advantages that GDP-linked bonds bring to the issuer by using a probabilistic approach (Benford *et al.*, 2016) that estimate future debt paths by simulating alternative realisations of GDP, interest rates, the primary balance and the exchange rate, and calculate the resulting path for government debt under conventional and GDP-linked bonds. In our case, the main interest of the analysis is to estimate the causal effect of the transition to GDP-linked bonds on the debt-to-GDP ratio. We deem the Difference-in-Differences (DID) methodology more suitable as it optimally aligns with this purpose by enabling us to isolate the effect of GDP-linked bonds on Côte d'Ivoire's debt dynamics. Given that the parallel trends condition is satisfied, we can conduct a DID regression with fewer reservations pertaining to the reliability of our estimation of the treatment effects. We specify the standard DID regression model that captures this as follow:

$$\Delta d_{it} = \alpha + \beta_1 GLBs_i + \beta_2 Post_t + \beta_{3,DID}(GLBs_i \times Post_t) + \gamma_i + \delta_t + \epsilon_{it} \qquad \mathbf{(5.3)}$$

Where the dependent variable Δd_{it} represents the change in debt-to-GDP ratio for country i in year t and α is a constant. The variable $GLBs_i$ denotes the treatment indicator for Côte d'Ivoire; it is a dummy variable taking the value of one for Côte d'Ivoire and the value of zero for the control countries. $Post_t$ represents the post-treatment period indicator; it is a dummy variable taking the value of one for the years subsequent to 2009 and the value of zero for the period prior to 2009. The variable $GLBs_i \times Post_t$ represents the interaction of the $GLBs_i$ and $Post_t$ dummies. This variable captures the average treatment effect and ϵ_{it} is the error term. The average treatment effect measures the average difference in the debt-to-GDP ratio under the GLBs regime relative to conventional bonds. We include Country-specific (γ_i) and Year-specific (δ_t) Fixed Effects (FEs) to the model to account for unobserved heterogeneity in the group of countries under consideration that can have distorting effects on inference. Specifically, γ_i captures all time-invariant characteristics of country i, and δ_t captures all country-invariant characteristics of year t, such as global shocks. We cluster the standard errors by country to ensure that they correctly account for potential correlation within countries over time, in order to obtain more robust estimates. The estimate $\beta_{3,DID}$ of the interaction term ($GLBs_i \times Post_t$) constitutes the parameter of interest in our analysis. It estimates the causal effect of the transition to GDP-linked government bonds in Côte d'Ivoire on the change in the debt-to-GDP ratio, under the assumption that, without this initiative, the trend exhibited by the change in the debt ratio after 2009 in Côte d'Ivoire would have been similar to the trends seen in the control countries. In our interpretation of our results, we put the emphasis on the magnitude and significance of the coefficient $\beta_{3,DID}$. We anticipate a negative and significant coefficient, implying that the implementation of GDP-linked bonds should significantly reduce the debt ratio and its variability.

2.3. Model Assumptions

In this section, we summarize all the assumptions of our DID model including the parallel trends assumption. They represent foundational principles that ensure the validity and unbiasedness of our estimations and inferences.

Assumption 1. (Parallel Trends)
In the absence of treatment, the difference in the average change in debt-to-GDP ratio between the treated and control groups would have remained constant over time.

$$E\left[\Delta d_{it}^{Treat} \mid Post_t = 0\right] - E\left[\Delta d_{it}^{Cont} \mid Post_t = 0\right] = E\left[\Delta d_{it}^{Treat} \mid Post_t = 1\right] - E\left[\Delta d_{it}^{Cont} \mid Post_t = 1\right] \quad \textbf{(5.A1)}$$

where d_{it}^{Treat} represents the change in the debt-to-GDP ratio for the treated country (Côte d'Ivoire) in year *t.* d_{it}^{Cont} represents the change in the debt-to-GDP ratio for the control countries in year t, and $Post_t$ is the time indicator equal to 1 for the post-treatment period and 0 for the pre-treatment period.

Assumption 2. (Exogeneity of Treatment)
The treatment assignment must be exogenous. In other words, it should be independent of other factors that affect the change in the debt-to-GDP ratio (Δd_{it}).

$$E[\, \epsilon_{it} \mid GLBs_i \,] = 0 \quad \textbf{(5.A2)}$$

This condition states that the expected value of the error term ϵ_i given the treatment $GLBs_i$ is zero. Simply put, the treatment assignment is uncorrelated with unobserved factors in ϵ_i that also affect Δd_{it}. This assumption ensures that the selection bias is minimized, as it posits that the change in the debt-to-GDP ratio of the country that implements GLBs does not systematically differ in unobserved ways from countries that do not implement it, excluding the effect of the treatment itself.

Assumption 3. (Absence of Time-Specific Unobserved Heterogeneity)
The model assumes that any time-specific variation in the change in the debt-to-GDP ratio (Δd_{it}) is either captured by δ_t or is random:

$$E[\,\epsilon_{it} \mid \delta_t\,] = 0 \qquad \textbf{(5.A3)}$$

where δ_t represents time fixed effects that control for unobserved time-varying shocks that affect all countries similarly.

Assumption 4. (Absence of Country-Specific Unobserved Heterogeneity)
The least squares estimate of $\beta_{3,DID}$ will be an unbiased estimate of the average effect of the introduction of GLBs provided that there is no unobserved country-specific heterogeneity:

$$E\left[\,\epsilon_{it} \mid \gamma_i\,\right] = 0 \qquad \textbf{(5.A4)}$$

where γ_i represents country fixed effects that capture unobserved characteristics unique to all countries in the panel. This assumption implies that any unobserved factors specific to each country that could influence the change in the debt-to-GDP ratio (Δd_{it}) are fully captured by γ_i.

2.4. Sensitivity Tests and Robustness Checks

We conduct sensitivity and robustness tests by applying alternative specifications to our basic DID model (*Equation 5.3*) in order to assess by how much the treatment effect changes according to changes in the values of the parameters constituting the GLBs interest rate; namely, the indexation coefficient, the risk premium and the base interest rate. Those tests enable us to further determine the validity and consistency of our results. First, we run regressions adding control variables such as government primary balance and inflation rates to account for unobservables and increase the predictability of the model. Second, we run sensitivity tests based on our assumptions (Kim and Ostry, 2021). We vary the set of control countries in the DID regression. Then, we use alternative indexation coefficients equal to 0.03 and 0.07 to investigate a potential optimal coefficient. Subsequently, we increase the risk premium to 0.04 in order to better consider the preferences of risk-averse investors and assess how it affects the treatment effect. We also test how the change in the debt-to-GDP ratio in the absence of risk premium. Finally, we investigate whether our findings can be extended to

countries with analogous economic profiles to Côte d'Ivoire. To this end, we run a DID regression with Kenya as a treated country and Côte d'Ivoire part of the control group.
To refine the predictive power of our basic model, we include covariates to the basic regression described in *Equation 5.3* :

$$\Delta d_{it} = \alpha + \beta_1 GLBs_i + \beta_2 Post_t + \beta_{3,DID}(GLBs_i \times Post_t) + \beta_4 pb_{it} + \gamma_i + \delta_t + \epsilon_{it} \quad \textbf{(5.4)}$$

$$\Delta d_{it} = \alpha + \beta_1 GLBs_i + \beta_2 Post_t + \beta_{3,DID}(GLBs_i \times Post_t) + \beta_4 pb_{it} + \beta_5 infl_{it} + \gamma_i + \delta_t + \epsilon_{it} \quad \textbf{(5.5)}$$

where pb_{it} and $infl_{it}$ represent the government primary balance expressed as a share of GDP and inflation rate, respectively. These control variables were chosen due to their degree of correlation with the dependent variable.
More importantly, we conduct an additional sensitivity analysis by varying the share of indexed debt stock as follow:

$$\Delta d_{it} \approx [d_{it-1} \times (1 + (i_t^{GLB} + \theta_{GLB})) - pb_{it}] \times \alpha + (1 - \alpha) \times d_{it} \quad \textbf{(5.6)}$$

where : d_{it-1} is the debt-to-GDP ratio of Côte d'Ivoire, lagged by one period. α is the share of GLBs in the public debt stock. The basic model (*Equation 5.3*) assumes a complete reconversion of the debt stock into GDP-indexed debt ($\alpha = 1$), which theoretically enables us to fully grasp effects of GLBs but is not feasible in practice. In contrast, in this extensive model, we consider an Ivoirian economy where 30 percent of the public debt stock is indexed to nominal GDP growth, then, the simulation is repeated for a scenario where this percentage rises to 35 percent. For the sake of clarity, we document the supplementary robustness tests results in the Appendix section (see Appendix D2).

6 Empirical Results

In this section, to begin, we briefly explain the mechanism through which GDP-linked bonds operate, empirically. Subsequently, we present and analyze the main results from our experimental study of the selected emerging African countries, which document the causal effects of introducing GDP-linked bonds. First, we describe our ADF tests results, then we present the estimates of the effect of implementation of GLBs on the differential of the debt-to-GDP ratio. Finally, we analyze some additional results presented in the Appendix and obtained from the alternative versions of our baseline model. We discuss the results in depth in section 7.

All other things being equal, the results from our stress tests (Appendix D1) reveal that debt-to-GDP ratio for Côte d'Ivoire is less vulnerable to negative shocks when public debt is linked to nominal GDP growth. This analysis suggests that GLBs could help alleviate the debt burden by lowering interest rate and mechanically keeping the debt-to-GDP ratio around safer values.

At the core of this thesis are three main questions that we attempt to address through our quasi-experimental study. In the remainder of this section, we structure the presentation of the results in a way that provides clear answers to these questions.

6.1. What implications does a GDP-linked bonds framework have for debt sustainability compared to a conventional debt framework?

In this subsection, we assess the stabilizing effect of GDP-linked debt. Specifically, we investigate whether a full implementation of GDP-linked debt would have resulted in an improved ability to service and manage sovereign debt over time in Côte d'Ivoire for the period under study. Table 2 displays the results from the unit root tests that we performed on the change in the debt-to-GDP ratio. The result from the Augmented Dickey-Fuller (ADF) test provides insights into whether and to which extent the differential of the simulated debt ratio reverts back to the mean in the long run. In simpler terms, the result from this test reveals if the debt ratio is more sustainable under the GDP-linked bonds framework compared to the observed debt ratio. We obtain an ADF statistic of -5.809 within the conventional debt framework, whereas within the GLBs framework, the ADF statistic is -5.829.

TABLE 2 — Public Debt Sustainability Assessment

	ADF Test statistic	*Lag order*	*1% Critical Value*	*5% Critical Value*	*10% Critical Value*	*Conclusion*
$\Delta Debt/GDP$	-5.809***	1	-3.473	-2.880	-2.577	I(0)
$\Delta\ (Debt/GDP)_{GLBs}$	-5.829***	1	-3.473	-2.880	-2.577	I(0)

Source: Author's estimates using data from the IMF, World Bank database.

Notes:

The table displays results from Augmented Dickey-Fuller (ADF) Tests conducted on the differentiated public debt series.
The notation I(0) indicates that the time series is integrated of order zero. In simple terms, it means that it is stationary.
*** indicates rejection of the null hypothesis of unit root at the 1 percent significant level (*** $p < 0.01$).

Both debt ratios are lower than the critical values, hence we reject the null hypothesis of non-stationarity. We observe, however, that the distance between the ADF test statistic and the 1 percent critical value is slightly larger within a GDP-linked bonds framework, which implies that the evidence against the null hypothesis is stronger in the instance of the implementation of GDP-linked bonds. It signals that linking debt to GDP growth could be an approach that enable policymakers to stabilize the debt ratio further, by reducing the volatility of the debt-to-GDP ratio.

6.2. Could African emerging countries initiate a process of contraction in the debt level by adopting GDP-linked bonds?

In the previous subsection, we established that, the implementation of GLBs in 2009 in Côte d'Ivoire could have contributed to keeping the debt-to-GDP ratio sustainable, on average. This raises the natural question of whether debt sustainability is achieved through a reduction in the debt level, and, in that case, how much incremental room would the implementation of GLBs have offered. In this subsection, we complement our findings by investigating suggestive responses to that question within the scope of our quasi-experimental framework. Table 3 displays the estimates from three specifications of Fixed-Effects (FE) Difference-in-Differences (DID) regressions of the change in the debt-to-GDP ratio. Standard errors are clustered by country throughout our analysis. The coefficient of the interaction term $GLBs \times Post$ captures the average impact of the implementation of GLBs after 2008, isolated from the general trends and any initial differences in debt ratio observed between Côte d'Ivoire and the control countries in the pre-implementation period.

TABLE 3 — Average effect of the introduction of GDP-linked bonds on the debt-to-GDP ratio differential

Assessed across covariates scenarios

Dependent variable: $\Delta(Debt/GDP)_{it}$

		Extended models	
	(1)	(2)	(3)
$Constant$	-0.0364***	-0.0421***	-0.0029
	(0.014)	(0.014)	(0.043)
$GLBs$	0.0688***	0.0739***	0.0482***
	(0.014)	(0.016)	(0.023)
$Post$	0.0256	0.0235	0.0046
	(0.023)	(0.024)	(0.022)
$\boldsymbol{GLBs \times Post}$	**-0.0650***	**-0.0648***	**-0.0613***
	(0.020)	(0.022)	(0.020)
$Primary\ Balance$		-0.4357***	-0.4218***
		(0.167)	(0.160)
$Inflation\ rate$			-0.1722
			(0.174)
Time Fixed Effects	YES	YES	YES
Country Fixed Effects	YES	YES	YES
R^2	0.417	0.428	0.437
Adjusted R^2	0.282	0.291	0.295
Sample size	140	140	140

Sources: Author's estimates based on data from IMF and World Bank Database.

Notes:

[1] This table presents the estimates from Equation (**5.3**) (Column 1) and extended models **5.4** and **5.5** (Columns 2 and 3, respectively), which describe the average effect of the implementation of GDP-linked bonds on the debt-to-GDP ratio differential $\Delta(\boldsymbol{Debt/GDP})_{it}$. The estimation is based on the sample consisting of annual observations from 2002 to 2022 for the seven countries under study including Côte d'Ivoire. $\boldsymbol{GLBs}$ is an indicator for Côte d'Ivoire, in which we simulated the implementation of GDP-linked bonds. $\boldsymbol{Post}$ is an indicator for the period after 2008, the year preceding the simulated implementation of GDP-linked bonds in Côte d'Ivoire. The interaction term $\boldsymbol{GLBs \times Post}$ denotes the combined effect of the implementation of GDP-linked bonds after 2008. It represents the explanatory variable of interest in our DID regressions. $\boldsymbol{Primary\ Balance}$ represents the government primary balance as a share of GDP. Finally, $\boldsymbol{Inflation\ rate}$ simply represents the inflation rate variable.

[2] The dependent variable $\Delta(\boldsymbol{Debt/GDP})_{it}$ was adjusted and calculated with the indexation coefficient equal to 0.01 for Côte d'Ivoire exclusively, from 2009 to 2022, to simulate the implementation of GLBs after 2008. The debt-to-GDP ratio is converted and represented as a percentage prior to performing the regression analysis.

[3] Each row displays results from a separate regression. Column 1 shows the coefficients estimates and their standard errors for a basic DID regression of the differential of the debt ratio, including six control countries. Column 2 shows the estimates obtained from an extended version of the regression in Column 1, including $\boldsymbol{Primary\ Balance}$ as a control variable. Column 3 shows the estimates obtained from an extended version of the regression in Column 2, including $\boldsymbol{Inflation\ rate}$ as a control variable. Each regression includes year and country Fixed Effects (FEs).

[4] The standard errors in each regression are robust to cluster correlation by country and are reported in parentheses.

[5] ***, **, and * denote significance at 1 percent, 5 percent and 10 percent, respectively *(*** p < 0.01, ** p < 0.05, * p < 0.10).*

In Columns 1, 2 and 3, the coefficient of the interaction term indicates that the effect of the implementation of GLBs in Côte d'Ivoire during the post-implementation period is associated with a statistically significant decrease in the change in the debt-to-GDP ratio of Côte d'Ivoire compared to the ratio of control countries in the post-implementation period. In other words, across all different specifications, our findings are consistent: the coefficient of the interaction term is negative and significant. Beyond the statistical significance of these results, their economic implications are particularly meaningful: the three models suggest that when debt is indexed to nominal growth rate, debt burden decreases by estimated 6.50 ; 6.48 and 6.13 percentage points, respectively. This statistically significant evidence implies that the transition to GDP-linked debt, presumably intended to decrease changes in the debt-to-GDP ratio, may have the desired effect in the post-implementation period; GLBs could have prevented the debt ratio of Côte d'Ivoire from following erratic paths and provided resilience against macroeconomics shocks.

Adding control variables such as the government primary balance and inflation rate increases the predictability of the model as we can notice by the values of the (Adjusted) R-squared. The statistical significance of the coefficient of interest gradually increases as we increase the number of control variables explaining the model, thereby adding more weight to our conclusion.

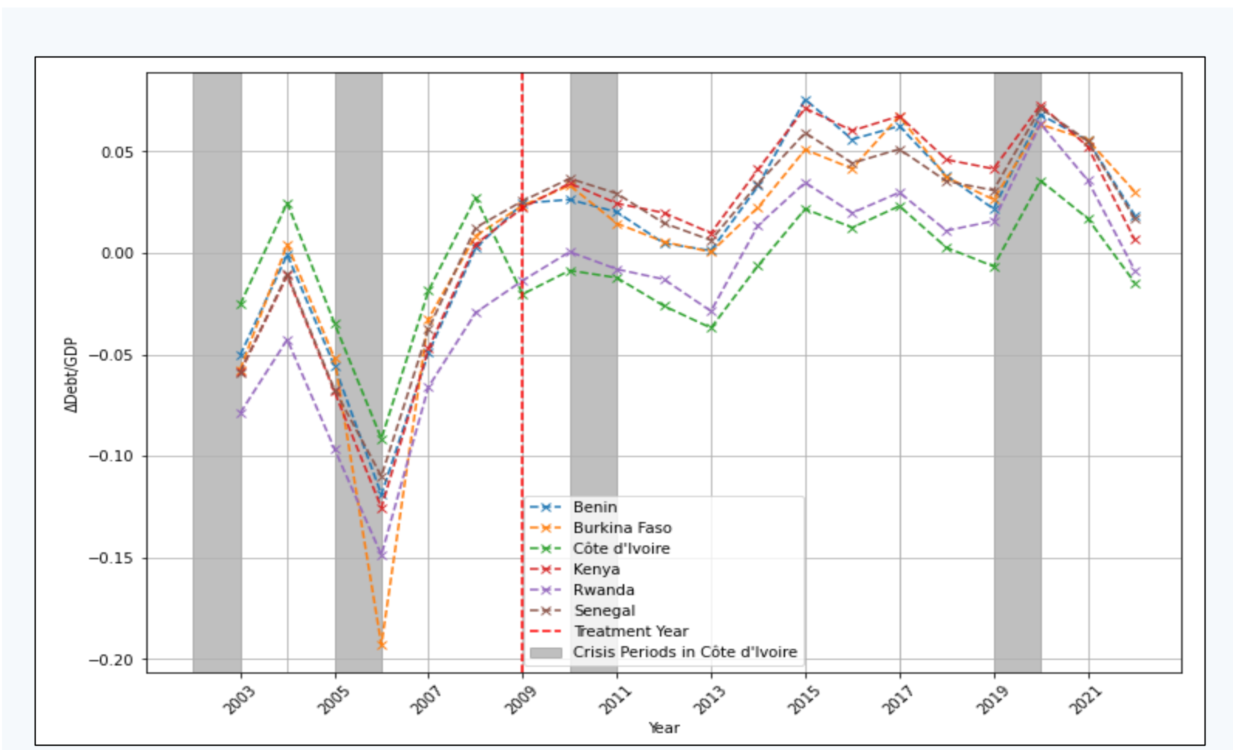

FIGURE 1. DID Analysis: Full-scale implementation of GDP-linked bonds in Côte d'Ivoire in 2009

This graph represents the estimates obtained from the DID model specified in Colum 2 in **Table 3**. The green line represents the estimated change in the Debt-to-GDP ratio of Côte d'Ivoire. The red dashed vertical line indicates the year of treatment (2009) in which we simulated the implementation of GDP-linked bonds in Côte d'Ivoire. The grey shaded areas denote periods of crisis in Côte d'Ivoire.
Sources: Author's estimates based on data from IMF and World Bank Database.

Figure 1 illustrates the predictions from our DID regression for Côte d'Ivoire and only five of the control countries, for clarity purposes. During the pre-implementation period, from 2003 to 2009, we observe that the change of the debt ratio for Côte d'Ivoire was above the differential of the debt ratio of the control countries. On the other hand, after the hypothetical implementation of GLBs, from 2009 onward, a noticeable gap emerges between the change in the debt ratio of Côte d'Ivoire and the change in the ratio of the control countries. Specifically, the predictions show that the change in the debt ratio of Côte d'Ivoire is significantly lower than the control countries after the implementation of GLBs.

6.3. To what extent should traditional debt instruments and GDP-linked bonds be combined to meet the debt reduction goal?

As evidenced in the subsection above, a full-scale implementation of GDP-linked bonds could have sensibly decreased the change in the debt ratio in Côte d'Ivoire. In practice, bonds account for a smaller share of the total public debt stock. In this subsection, to enhance the relevance of our research, we expand on this finding by investigating the degree of combination between traditional instruments and GDP-linked bonds that could have allowed the debt reduction objective to be achieved in Côte d'Ivoire. Table 4 shows the results obtained from running the baseline regression along with two additional regressions, varying the proportion of GLBs issued in the overall public debt stock. For the second specification, where GLBs constitute 35 percent of the debt stock, we find that the change in the debt-to-GDP ratio decreases by 6.01 percentage points in Côte d'Ivoire relative to other countries, on average, with strong statistical significance. In the case where GLBs constitute 30 percent of the debt stock (Column 3), the effect is also significant and negative; the debt-to-GDP ratio decreases by 6 percentage points in Côte d'Ivoire, on average, relative to control countries. This sensitivity analysis demonstrates that the negative effect of the implementation on the change in the debt ratio remain significant when GLBs are adopted at a smaller scale, however, this effect is larger in magnitude when GLBs are adopted at a larger scale.

TABLE 4 — Average Effect of the Introduction of GDP-linked Bonds on the Debt-To-GDP Ratio Differential
Full-scale versus Partial Implementation

Dependent variable: $\Delta(Debt/GDP)_{it}$

	Baseline	*Alternative models*	
	Full-scale Implementation *100%* (1)	Partial Implementation *35%* (2)	Partial Implementation *30%* (3)
Constant	-0.0029	0.0183	0.0173
	(0.043)	(0.033)	(0.033)
GLBs	0.0482***	0.0208	0.0213
	(0.023)	(0.015)	(0.015)
Post	0.0046	0.0163	0.0172
	(0.022)	(0.023)	(0.024)
$\boldsymbol{GLBs \times Post}$	**-0.0613***	**-0.0601***	**-0.0600***
	(0.020)	(0.020)	(0.020)
Primary Balance	-0.4218***	-0.4189***	-0.4187***
	(0.160)	(0.160)	(0.160)
Inflation rate	-0.1722	-0.0921	-0.0859
	(0.174)	(0.154)	(0.154)
Time Fixed Effects	YES	YES	YES
Country Fixed Effects	YES	YES	YES
R^2	0.437	0.455	0.454
Adjusted R^2	0.295	0.317	0.317
Sample size	140	140	140

Sources: Author's estimates based on data from IMF and World Bank Database.
Notes:
[1] This table presents the estimates from Equation (**5.3**) (Colum 1) and Equation (**5.6**) (Columns 2 and 3). The estimation is based on the sample consisting of annual observations from 2002 to 2022 for the seven countries under study including Côte d'Ivoire. The dependent variable $\Delta(\boldsymbol{Debt/GDP})_{it}$ was adjusted and calculated with the indexation coefficient equal to 0.01 for Côte d'Ivoire exclusively, from 2009 to 2022, to simulate the implementation of GLBs after 2008.
[2] Each row displays results from a separate regression. Column 1 shows the coefficients estimates and standard errors from a basic regression of the differential of the debt ratio. Column 2 shows the estimates obtained from the regression model that incorporates a public debt stock consisting of 35 percent of GDP-linked debt and 65 percent of conventional debt. Column 3 shows the estimates obtained from the regression model that incorporates a public debt stock consisting of 30 percent of GDP-linked debt and 70 percent of conventional debt. Each regression includes year and country Fixed Effects (FEs).
[3] The standard errors in each regression are robust to cluster correlation by country and are reported in parentheses.
[4] ***, **, and * denote significance at 1 percent, 5 percent and 10 percent, respectively *(*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$).*

Robustness Tests

To probe the robustness and sensitivity of our results, we allow for alternative specifications of our basic model. Table D2.1 presents the regressions ran with different sets of control countries. In column 1, data suggests that the implementation of GLBs is associated with a 4.69 percent decrease in the debt-to-GDP ratio, statistically significant at a 10 percent level. We increase the number of observations, by adding two control countries to the second model. In column 2, the coefficient of the interaction term indicates that the implementation of GLBs in Côte d'Ivoire after 2008 is associated with an average decrease in the change in the debt-to-GDP ratio of 3.78 percentage points compared to the debt ratios of control countries in the post-implementation period relative to the pre-implementation period. This effect is statistically significant at a 1 percent level. We also yield an estimate of the interaction term that is statistically significant at a 1 percent level for the third specification which includes six control countries as well as Fixed Effects. Consistent with the literature and the theory, higher risk premium leads to diminishing marginal benefits (Table D2.2). Moreover, our findings suggest that the lower the indexation coefficient, the higher the benefits (Table D2.3).

Our findings are robust to different ways of measuring of the effects and to including a different set of control variables. Overall, the various sensitivity tests and robustness checks conducted to strengthen the validity of your findings reinforce the idea that the introduction of GDP-linked bonds could contribute to a decrease in the change in the debt ratio, on average. The observed reduction in the change in the debt-to-GDP ratio by the implementation of GLBs is in line with our main hypothesis of the model.

One of the potential concerns for our analysis is the selection bias; we suspect that the specificities related to the debt trajectory of Côte d'Ivoire at the given period under study might affect our results. Although we attempted to partially solve this issue by adding country and year Fixed Effects to our model, to examine further, outside the scope of this study, whether our estimates are biased because of this concern, we run regression with Kenya as the treated country and Côte d'Ivoire among the control countries (Table D2.4). We obtain a negative and significant coefficient for the alternative specification, suggesting that the implementation of GLBs in 2009 would have decreased the changes in the debt-to-GDP ratio in Kenya by 5.87 percentage points, on average.

7 Discussion

This section presents a discussion of the results from our quasi-experimental study presented in section 6.

We ran stress tests to provide insights on how GLBs alleviate the effects of macroeconomic shocks. A potential limitation of our results is that these observations are based on partial and simplistic projections of the debt-to-GDP ratio and do not account for interconnections across the different factors that influence the debt accumulation dynamic. At the best, our simulations provide a hypothetical picture of the reaction of the debt-to-GDP with the implementation of GLBs. We employed a Fixed Effects regression model to investigate the impact of the implementation of GDP-linked bonds (*Equation 5.3*). The main objective was to corroborate the debt-stabilizing benefits of these instruments argued in the theoretical and empirical studies, with a focus on seven African emerging and developing countries serving as a quasi-experimental setting. Three interesting observations emerge from our analysis. First, through an Augmented Dickey-Fuller test, we found that the debt-to-GDP ratio could have been stabilized further by the implementation of GDP-linked bonds in Côte d'Ivoire, in line with the theory. To date and to the best of our knowledge, there is a lack of academic research addressing the extent to which GDP-linked bonds contributed to debt sustainability by testing the stationarity of the debt-to-GDP ratio. It is important to note, however, that the difference between the ADF statistics obtained was somehow negligible. Second, consistent with previous literature on GLBs (Borensztein and Mauro, 2004), our Difference-in-Differences estimations revealed that GDP-linked had a statistically significant potential to decrease the variations in the debt ratio. In line with Kim and Ostry (2021) who found diminishing fiscal space gains with their model including risk-averse investors, our sensitivity analysis of the risk premium showed that an increased risk premium led to a marginal increase in the change in the debt ratio. The results are also consistent with the findings of Durdu (2007) that GDP-indexed debt expands budgetary flexibility, in addition to the findings of Borensztein *et al.* (2005), indicating that indexing to GDP variables seemingly fosters debt sustainability by stabilizing the debt-to-GDP ratio. Third, our results imply that at a full-scale implementation or a minimum of 30 percent degree of implementation, GDP-linked bonds can reduce the changes in the debt-to-GDP ratio by 6.13 and 6 percentage points, respectively, in Côte d'Ivoire. On the other hand, contrary to our findings, Kim and Ostry (2021) found that the fiscal space benefits from tying debt to GDP were significant only when the proportion of GLBs in the total public debt stock was negligible. The estimated average effect of the introduction of GLBs is consistent with the findings in other papers in the literature, which show that this reform could contribute to generating lower interest payments, hence, shielding the GDP level from a potential decline during recessions (Barr, 2014; Pienkowski, 2017; Igan *et al.*, 2022).

We do not use the same approach, however. Most economists (Borensztein and Mauro, 2004; Chamon and Mauro, 2005; Benford *et al.*, 2016; Kim and Ostry, 2021) used the same approach by simulating and making stochastic projections the path of the debt-to-GDP ratio and comparing it to the path under conventional bonds through Monte Carlo simulations, which present a few limitations, considering their dependence on the assumptions underlying the model and its parameters and the associated need for extensive iterations to achieve a high degree of precision. The divergence in the methodologies employed, and the distinct countries selected for analysis, could potentially explain the few discrepancies between our results.

Taken together, our findings point to the value of GLBs in addressing the public debt burden in an emerging economy in Africa, as demonstrated in our quasi-experimental study on Côte d'Ivoire.

However, it is essential to approach these results with caution, considering potential limitations. Besides the small sample size, the choice of countries, the chosen proxy dependent variable, and the fact that our results are contingent on specific and simplistic assumptions, a few caveats emerge from our study. Specifically, the robustness of our Wald test supporting the presence of parallel trends could be subject to open discussion, especially considering that the changes in public debt path across countries could be relatively heterogeneous as they are shaped by divergent policy frameworks and inherent shocks. To partially handle this concern, beyond validating the parallel trend assumption through the Wald test, we controlled for country-specific and year-specific Fixed Effects.

Acknowledging the limitations of our quasi-experimental study allows us to frame an answer to the concluding question addressed in this thesis within the realistic boundaries of our findings. Specifically, how to ensure the success of GDP-linked bonds for countries comparable to Côte d'Ivoire? Such emerging countries face additional challenges when it comes to the implementation of GDP-linked bonds. As a matter of fact, their debt market is not yet sufficiently developed, and the attractiveness of their debt is still relatively low for the category of investors potentially interested in these types of instruments — pension funds. To ensure a successful implementation, factors contributing to the imbalance between the costs and benefits derived from GLBs should be addressed. The indexation design and the sovereign perceived default risk play their part in the costs. Regarding the length of the indexation, for instance, similar studies (Joy, 2017) showed that a six-month lag guarantees a payment that reflects economic conditions and allows a timely payment for several countries. The perception of the default risk of Côte d'Ivoire is currently low, as reflected by its improved and evolving credit rating since 2014 (see Figure A4) The country has experienced robust growth (Direction Générale du Trésor, 2024) that is also projected in the future (Statista, 2024). Griffith-Jones and Hertova (2013) argue that an optimal context for the issuance of growth-linked debt instruments would be a place and a time where their inherent fundamentals are high and robust enough to boost the confidence of investors. This would guarantee a relatively low novelty premium of the security at issuance. As mentioned by Griffith-Jones and Hertova (2013), governments are less incentivized to issue such bonds during such favorable times of continued growth, perceiving a low probability of crises or recessions. However, it is crucial for them to prioritize long-term objectives and adopt a precautionary approach. Countries similar to Côte d'Ivoire could learn from past failures of GDP-linked applications in Argentina for example, tying debt to GDP level instead of growth levels as proposed in this thesis, led to high and increasing payments. More importantly, the creation of strong domestic financial institutions could play a crucial role in ensuring and monitoring the reliability of GDP growth statistics for this reform to be effective. To expand on our findings and address the limitations of our study, future research could consider addressing the aforementioned limitations of our study.

8 Conclusion

The need for new measures to guarantee the sustainability of public debt is at the center of a heated debate in the growing literature surrounding the subject. In this thesis, we argue that a precautionary approach involving the use of GDP-linked bonds would allow African emerging countries to be better prepared in anticipation of idiosyncratic and exogenous shocks. Our quasi-experimental evidence on the implementation of GDP-linked bonds presented in this paper entails three main contributions.

First, through an Augmented Dickey-Fuller test and our quasi-experimental framework, we proved that the implementation of GDP-linked bonds plays a role in moderately stabilizing the debt-to-GDP ratio. Specifically, data suggests that the debt path of Côte d'Ivoire, for the past two decades, would have been even more sustainable, on average, with the implementation of such instruments, on the assumption that public debt stationarity fulfills all the necessary criteria for sustainability.

Second, using data on seven African countries, we document that changes in the debt ratio decrease by 6.13 percentage points when we proceed to a full-scale implementation of GDP-linked bonds. This negative effect of the implementation of GDP-linked bonds on the changes in the debt-to-GDP ratio is statistically and economically significant. Interestingly, the magnitude of these effects is robust throughout our checks and falls within the range of empirical estimates in the literature.

Third, further analysis shows that when GDP-linked bonds account for a larger proportion of the total debt stock, the changes in the debt ratio are further reduced.
Overall, our findings suggest that GDP-linked bonds might prevent the public debt ratio from growing exponentially.

As the debt ratios of emerging countries continue to increase, this research offers policymakers some potential solutions to manage and keep their public debt ratios at sustainable levels to leave more room for expansion, future needs, and investment opportunities. In our view, international financial institutions (Borensztein and Mauro, 2002) should lead the way in promoting the implementation of the instruments subject to our investigation in this thesis.

The credibility of our findings can, however, obviously be discussed due to the limitations of our data. Even though our proxy — the debt-to-GDP ratio — might appear as a good indicator of debt sustainability, used throughout the literature, it could potentially generate endogeneity issues and ambiguity in the interpretation of the results as it encloses GDP level. While caveats in our quasi-experimental study obviously exist, they do not invalidate our conclusion that GDP-linked bonds have the potential to decrease debt-to-GDP ratio in emerging economies, consistent with the broadly well-founded conclusion drawn from existing empirical studies on advanced economies (Borensztein and Mauro, 2004; Chamon and Mauro, 2005; Barr, 2014;

Benford *et al.*, 2016; Carnot and Sumner, 2017; Pienkowski, 2017; Kim and Ostry, 2021; Igan *et al.*, 2022).

We leave for future research the inclusion of the underlying effects of the additional explanatory variables that we abstracted from in our model to avoid complexity. Our quasi-experimental methodology could be applied to a larger cross-section of countries; particularly emerging volatile countries that have actually undergone such implementation. Our study also gives hope that future research could be conducted with appropriate methods such as two-stage regressions with instrumental variables such as government primary balance — unadjusted for GDP — to address potential simultaneity or reverse causality. Besides, the use of data from the government census at a quarterly scale could bring more precise estimates, provided that they are reliable — as suggested by governance quality indicators. Future research could also consider removing outliers from the data before running regressions to prevent skewed results.

Ultimately, the robustness of our results is highly sensitive to violations of the parallel trends assumption in the absence of the implementation. In the event that this condition proves not to be fulfilled, the Synthetic Control Method (SCM) and Synthetic Difference-in-Differences (SDID) method are better suited to provide more accurate estimates in comparative case studies as they are not reliant on it. To further assess the impact of the implementation of GLBs on public debt dynamics, future research could consider using a SCM (Abadie and Gardeazabal, 2003), which is closely related to DID and widely employed for causal inference. This method allows the creation of a counterfactual by computing a weighted aggregation of the control countries, relying on pre-treatment data exclusively. Within this methodological framework, the assessment of the effect of the implementation of GLBs would be performed by comparing the treated country to its representative synthetic counterpart. The SDID is a relatively more recent alternative approach (Arkhangelsky *et al.*, 2021), a synergy between both SC and DID methods, leveraging the strengths and addressing the weaknesses of each. It allows to generate a synthetic control group with country and time weights to minimize the divergence between the pre-treatment and post-treatment periods. This approach enables the relaxation of the strict parallel trend assumption and the inclusion of the post-treatment trends in the construction of the counterfactual, contrary to the SCM which only accounts for pre-treatment trends. Similarly to the SCM, the assignment of weights makes this methodology more adaptable to address trends' heterogeneity compared to a standard DID method. As a further point, SDID has been found to be an effective alternative approach, potentially outperforming the two methods — SC and DID — it is derived from (Arkhangelsky *et al.*, 2021).

Building upon our study and guided by the areas of improvement that we highlighted, future research would enable a more robust and methodologically rigorous investigation of the impact of the implementation of these instruments in emerging countries in an attempt to decrease the likelihood of future debt crises.

Bibliography

Abadie, A., & Gardeazabal, J. (2003). The economic costs of conflict: A case study of the Basque Country. *American Economic Review, 93*(1), 113–132. https://doi.org/10.1257/000282803321455188

Acalin, J. (2018). Growth-indexed Bonds and Debt Distribution: Theoretical Benefits and Practical Limits. *Peterson Institute for International Economics.* https://ideas.repec.org/p/iie/wpaper/wp18-7.html

African Development Bank Group (2024). PERSPECTIVES ÉCONOMIQUES EN AFRIQUE 2024: Impulser la transformation de l'Afrique par la réforme de l'architecture financière mondiale. 19-93. https://www.afdb.org/sites/default/files/2024/06/06/pea_2024_-_chapitre_1.pdf

African Export-Import Bank.(2024). State of play of debt burden in Africa: Debt dynamics and mounting vulnerability. *Afreximbank.* https://media.afreximbank.com/afrexim/State-of-Play-of-Debt-Burden-in-Africa-2024-Debt-Dynamics-and-Mounting-Vulnerability.pdf

Arellano, C. (2008). Default Risk and Income Fluctuations in Emerging Economies. *American Economic Review*, *98*(3): 690–712. https://10.1257/aer.98.3.690

Arkhangelsky, D., Athey, S., Hirshberg, D. A., Imbens, G. W., & Wager, S. (2021). Synthetic difference in differences. *American Economic Review*, *111*(12), 4088–4118. https://doi.org/10.3386/w25532

Bailey, N. (1983). A safety net for foreign lending. *Business week.* https://www.cia.gov/readingroom/document/cia-rdp85m00363r001302940044-9

Barr, David, & Bush, Oliver, & Pienkowski, Alex (2014). GDP-linked bonds and sovereign default. *Bank of England*. https://www.bankofengland.co.uk/-/media/boe/files/working-paper/2014/gdp-linked-bonds-and-sovereign-default.pdf

Barro, R. J. (1979). On the Determination of the Public Debt. *Journal of Political Economy, 87* (5), 940–71. https://econpapers.repec.org/article/ucpjpolec/v_3a87_3ay_3a1979_3ai_3a5_3ap_3a940-71.htm

Benford, J., Joy, J., & Kruger, M. (2016). Sovereign GDP-linked bonds. *Bank of England*. https://ideas.repec.org/p/boe/finsta/0039.html

Benford, J., Ostry, J., D., & Shiller, R. (Ed(s).) (2018). Sovereign GDP-linked bonds: Rationale and design. *CEPR Press, Paris & London.* https://cepr.org/publications/sovereign-gdp-linked-bonds-rationale-and-design

Blanchard, O. (2019). Public Debt and Low Interest Rates. *American Economic Review, 109* (4), 1197-229. https://www.aeaweb.org/articles?id=10.1257/aer.109.4.1197

Blanchard, O., Dell'Ariccia, G., & Mauro, P. (2013). Rethinking macro policy II: Getting granular. *International Monetary Fund*. https://www.imf.org/external/pubs/ft/sdn/2013/sdn1303.pdf

Blanchard, O. J., Mauro, P., & Acalin, J. (2016). The case for growth-indexed bonds in advanced economies today. *Peterson Institute for International Economics*. https://julienacalin.com/files/pb16-2.pdf

Bohn H., (1998). The Behavior of U.S. Public Debt and Deficits. *Quarterly Journal of Economics*, *113*(3), 949–963. https://doi.org/10.1162/003355398555793

Bohn, H. (2005). The sustainability of fiscal policy in the United States. *CESifo*. https://www.ifo.de/DocDL/cesifo1_wp1446.pdf

Bonfim, D., & Pereira, D. (2018). GDP-linked bonds: design, effects, and way forward. *Banco de Portugal*. https://www.bportugal.pt/sites/default/files/anexos/papers/ree1802_e.pdf

Borensztein, E., Jeanne, O. D., Mauro, P., Zettelmeyer, J., Chamon, M. (2005). Expanding the Set of Instruments: Indexation to Real Variables. https://www.elibrary.imf.org/display/book/9781589063778/ch05.xml

Borensztein, E., & Mauro, P. (2002). Reviving the Case for GDP-Indexed Bonds. *IMF Policy Discussion Papers, 2002*(010). https://doi.org/10.5089/9781451970173.003

Borensztein, E., & Mauro, P. (2004). The Case for GDP-Linked Bonds. *Economic Policy*, *19*(38), 165-216. https://www.jstor.org/stable/pdf/1344718.pdf

Bowman, J., & Naylor, P. (2016). GDP-linked Bonds. *Reserve Bank of Australia Bulletin, September Quarter*, 61-68. https://www.rba.gov.au/publications/bulletin/2016/sep/pdf/rba-bulletin-2016-09-gdp-linked-bonds.pdf

Bravo, A. B. S., & Silvestre, A. L. (2002). Intertemporal Sustainability of Fiscal Policies: Some Tests for European Countries. *European Journal of Political Economy*, *18*(3), 517–528. https://doi.org/10.1016/S0176-2680(02)00103-9

Brooke, M., Mendes, R., Pienkowski, A., & Santor, E. (2013). Sovereign default and state-contingent debt. *Bank of England Financial Stability Paper.* https://www.bankofcanada.ca/wp-content/uploads/2013/11/dp2013-03.pdf

Brooks, S., Lombardi, D., & Suruma, E. (2014). African Perspectives on Sovereign Debt Restructuring. https://www.cigionline.org/static/documents/no43_web.pdf

Cabrillac, B., Gauvin, L., & Gossé, J-B. (2017). GDP-indexed bonds: What are the benefits for issuing countries, investors and international financial stability? *Quarterly Selection of Articles - Bulletin de La Banque de France, 44*, 6–19. https://econpapers.repec.org/article/bfrquarte/2016_3a44_3a01.htm

Carnot, N., & Sumner, P. S. (2017). GDP-linked bonds: Some simulations on EU countries. *Publications Office of the European Union.* https://doi.org/10.2765/866010

Chamon, M. & Mauro, P. (2005). Pricing growth-indexed bonds. *Journal of Banking & Finance, 30*(12), 3349–3366. https://doi.org/10.1016/j.jbankfin.2006.06.007

Costa, A., Chamon, M. D., & Ricci, L. A. (2008). Is There a Novelty Premium on New Financial Instruments? The Argentine Experience with GDP-Indexed Warrants. *IMF.* https://www.imf.org/en/Publications/WP/Issues/2016/12/31/Is-There-a-Novelty-Premium-on-New-Financial-Instruments-The-Argentine-Experience-with-GDP-21851

Daba Finance. (2024, August 2). *WAEMU Q1 GDP growth: A robust start to 2024*. https://dabafinance.com/en/learn/blogs/waemu-q1-gdp-growth-a-robust-start-to-2024

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit Root. *Journal of the American Statistical Association*, *74*(366), 427–431. https://doi.org/10.2307/2286348

Direction Générale du Trésor. (2024, Juillet). Situation économique et financière de l'UEMOA. *MINISTERE DE L'ÉCONOMIE, DES FINANCES ET DE L'INDUSTRIE.* https://www.tresor.economie.gouv.fr/Pays/CI/veille-regionale

Durdu, C. B. (2007). Quantitative Implications of Indexed Bonds in Small Open Economies. *SSRN Electronic Journal.* https://doi.org/10.2139/ssrn.1066787

Easterly, W. R. (2001). Growth Implosions and Debt Explosions: Do Growth Slowdowns Cause Public Debt Crises? *Contributions to Macroeconomics*, *1*(1). https://doi.org/10.2202/1534-6005.1013

Emter, L., & Herzberg, V. (2018). The rationale for GDP-linked bonds for the euro area. 2018(10). https://www.centralbank.ie/docs/default-source/publications/economic-letters/vol-2018-no-10-the-rationale-for-gdp-linked-bonds-for-the-euro-area-(emter-and-herzberg).pdf?sfvrsn=4

Fitch Ratings. (n.d.). *Cote d'Ivoire: Ratings*. Retrieved July 20, 2024, from https://www.fitchratings.com/entity/cote-d-ivoire-94194491

Fitch Ratings. (n.d.). *Kenya: Ratings*. Retrieved July 20, 2024 from https://www.fitchratings.com/entity/kenya-86485911#ratings

Fitch Ratings. (n.d.). *Rating Definitions.* https://www.fitchratings.com/products/rating-definitions#ratings-scales

Froot, Kenneth A., Scharfstein, D. S. & Stein. J. (1989). LDC Debt: Forgiveness, Indexation, and Investment Incentives. *Journal of Finance*, *44*(5), 1335–1350. https://doi.org/10.1111/j.1540-6261.1989.tb02656.x

Griffith-Jones, S., & Hertova, M. (2013). Growth-Linked Bonds. https://www.stephanygj.net/papers/GrowthLinkedBonds2013.pdf

Griffith-Jones, S., & Sharma, S. (2006). GDP-Indexed Bonds: Making It Happen. *United Nations, Department of Economics and Social Affairs*. https://www.un.org/esa/desa/papers/2006/wp21_2006.pdf

Hakura, D., (2020). What Is Debt Sustainability? *FINANCE & DEVELOPMENT*. https://www.imf.org/en/Publications/fandd/issues/2020/09/what-is-debt-sustainability-basics

Hamilton, J. D., & Flavin, M. A. (1986). On the Limitations of Government Borrowing: A Framework for Empirical Testing. *American Economic Review*, *76*(4), 808-819. http://www.jstor.org/stable/1806077

Hatchondo, J. C., & Martinez, L. (2012). On the Benefits of GDP-Indexed Government Debt: Lessons from a Model of Sovereign Defaults. *Economic Quarterly, 98*(2), 139–157. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2191160

Igan, D., Kim, T., & Levy, A. (2022). GDP-linked bonds and the fear of ambiguity. *SUERF – The European Money and Finance Forum*. https://www.suerf.org/wp-content/uploads/2023/12/f_0ace14f7dd3d8e29870664c6fa021440_41065_suerf.pdf

International Monetary Fund (2017). State-Contingent Debt Instruments for Sovereigns. *IMF Policy Paper.* https://www.imf.org/en/Publications/Policy-Papers/Issues/2017/05/19/pp032317state-contingent-debt-instruments-for-sovereigns

International Monetary Fund. (2023). Navigating fiscal challenges in sub-Saharan Africa: Resilient strategies and credible policies. https://www.imf.org/en/Publications/Departmental-Papers-Policy-Papers/Issues/2023/09/15/Navigating-Fiscal-Challenges-in-Sub-Saharan-Africa-Resilient-Strategies-and-Credible-529230

International Monetary Fund (2024). IMF Staff Concludes Visit to Senegal. https://www.imf.org/fr/News/Articles/2024/10/16/pr-24373-senegal-imf-staff-concludes-visit-to-senegalimf

International Monetary Fund (2024). List of LIC DSAs for PRGT-Eligible Countries As of September 30, 2024. https://www.imf.org/external/pubs/ft/dsa/dsalist.pdf

International Monetary Fund. (2024). World Economic Outlook (WEO) database, October 2024. *IMF.* Retrieved October 2024, from https://www.imf.org/en/Publications/WEO/weo-database/2024/October

International Monetary Fund. (n.d.). *General government gross debt (Percent of GDP)* [Data set]. https://www.imf.org/external/datamapper/GGXWDG_NGDP@WEO/BFA/BEN/SEN/RWA/ETH/CIV/KEN

International Monetary Fund. (n.d.). *Government primary balance, percent of GDP* [Data set]. https://www.imf.org/external/datamapper/pb@FPP/BFA/BEN/SEN/RWA/ETH/CIV/KEN

International Monetary Fund. (n.d.). *Interest paid on public debt, percent of GDP* [Data set]. International Monetary Fund. https://www.imf.org/external/datamapper/ie@FPP/BFA/BEN/SEN/RWA/ETH/CIV/KEN

International Monetary Fund. (n.d.). *Real GDP growth (Annual percent change)* [Data set]. https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/BFA/BEN/SEN/RWA/ETH/CIV/KEN

Investing.com. (n.d.). *USD/KES historical data* [Data set]. https://ca.investing.com/currencies/usd-kes-historical-data

Investing.com. (n.d.). *USD/XOF historical data* [Data set]. https://ca.investing.com/currencies/usd-xof-historical-data

Joy, M. (2017), Sovereign GDP-Linked Bonds: Design, Investor Response and Open Issues. *Ad Hoc Working Group on The London Term Sheet Discussion Paper.* https://www.icmagroup.org/assets/documents/Resources/Open-docs/GDP-Linked-%20Bonds-Design-Investor-Response-Open-Issues-(15-March-2017).pdf

Kalamov, Z. Y., & Zimmermann, K. J. (2023). GDP-Linked Bonds and Economic Growth. *Journal of International Money and Finance, 137.* https://doi.org/10.1016/j.jimonfin.2023.102918

Kaminsky, G. L., & Reinhart, C. M. (1999). The Twin Crises: The Causes of Banking and Balance-of-Payments Problems. *American Economic Review*, *89*(3), 473-500. https://doi.org/10.1257/aer.89.3.473

Kamstra, M., & Shiller, R. J. (2009). The Case for Trills: Giving The People and Their Pension Funds a Stake in the Wealth of the Nation. *Cowles Foundation Discussion Paper no. 1717*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1444351

Kemoe, L., Mbohou Mama, M., Mighri, H., & Quayyum, S. (2023, May 15). African currencies are under pressure amid higher-for-longer US interest rates: Weaker currencies make the fight to curb inflation harder given the region's dependence on imports. *IMF Blog*. https://www.imf.org/en/Blogs/Articles/2023/05/15/african-currencies-are-under-pressure-amid-higher-for-longer-us-interest-rates

Kim, J. I., & Ostry, J. D. (2021). Boosting Fiscal Space: The Roles of GDP-Linked Debt and Longer Maturities. *Economic Policy*, *35*(104), 587-634. https://doi.org/10.1093/epolic/eiaa024

Kopf, C. (2017). The case for GDP-linked securities. *DG ECFIN – OECD Workshop*. https://economy-finance.ec.europa.eu/document/download/e209e45c-a597-4c42-8f31-e5024d190424_en?filename=ck_-_brussels_gdp-linked_bonds.pdf&prefLang=ga

Krugman, P. (1988). Financing vs. Forgiving a Debt Overhang. *Journal of Development Economics*, *29*(3), 253–268. https://doi.org/10.1016/0304-3878(88)90044-2

Lukkezen, J., Rojas-Romagosa, H. (2013). Stochastic Debt Sustainability Indicators. Revue de l'OFCE, *Presses de Sciences-Po. 127*(1), 97-121. https://doi.org.10.3917/reof.127.0097

Morgan Stanley. (2012). *Greece: Trading After the PSI*. https://www.researchgate.net/profile/Bernard_Casey/post/Is_the_idea_of_the_GDP-linked_bond_a_real_cure_for_Greece_Or_is_it_rather_an_indecent_proposal/attachment/59d6383dc49f478072ea548a/AS:273696952913921%401442265846605/download/Greek+GDP-linked+bond+in+2012+PSI.pdf&ved=2ahUKEwiFovirpZaKAxWDMVkFHa-SDgQQFnoECBUQAQ&usg=AOvVaw1IW5UO9ujxS21hWlx3VRYi

Mottley, M. A. (2024, June). The IMF must lead on debt sustainability. *International Monetary Fund*. https://www.imf.org/en/Publications/fandd/issues/2024/06/The-IMF-Must-Lead-on-Debt-Sustainability-Mia-Amor-Mottley

Mouabbi, S., Renne, J.-P., & Sahuc, J.-G. (2021). Debt-Stabilizing Properties of GDP-Linked Securities: A Macro-finance Perspective. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3964531

Nicholls, G. P., & Peter, A. (2014). Fiscal Sustainability and Public Debt Limits in the Caribbean: An Illustrative Analysis. In Amo-Yartey, C. & Turner-Jones, T. (Ed(s).), *Caribbean Renewal Tackling Fiscal and Debt Challenges* (pp. 133-157). *IMF*. https://doi.org/10.5089/9781484369142.071

Obstfeld, M., Peri, G. (1998). Regional Non-Adjustment and Fiscal Policy: Lessons for EMU. *Economic Policy, 13*(26), 205-259. https://www.nber.org/system/files/working_papers/w6431/w6431.pdf

Önder, Y. K. (2023). Optimal GDP-indexed bonds. *Review of Economic Dynamics*, *51*, 747-777. https://doi.org/10.1016/j.red.2023.08.002

Papavassiliou, E., Topaloglou, N., & Zenios, S. A. (2024). GDP-Linked Bonds as a New Asset Class. *Quantitative Finance*, 1–19. https://doi.org/10.1080/14697688.2024.2386323

Peter, A. (2014). Fiscal Performance in the Caribbean Before and After the Global Financial Crisis. In Amo-Yartey, C. & Turner-Jones, T. (Ed(s).), *Caribbean Renewal Tackling Fiscal and Debt Challenges* (pp. 25–40). *IMF*. https://doi.org/10.5089/9781484369142.071

Pienkowski, A. (2017). Debt Limits and the Structure of Public Debt." IMF Working Paper, no. 17/117. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2978678

Pina, G. (2022) : State-Contingent Government Debt: a New Database. *Credit and Capital Markets – Kredit und Kapital, 55*(1), 35-66. https://doi.org/10.3790/ccm.55.1.35

Pisani-Ferry, J., Vihriala, E., & Wolff, G. (2013). Options for a Euro-Area Fiscal Capacity. *Bruegel Policy Contribution*. https://www.econstor.eu/bitstream/10419/72119/1/735319456.pdf

Said, S. E., & Dickey, D. A. (1984). Testing for unit roots in autoregressive-moving average models of unknown order. *Biometrika, 71*(3), 599–607. https://doi.org/10.1093/biomet/71.3.599

Shiller, R. (1993), Macro markets: creating institutions for managing society's largest economic risks. *Oxford: Clarendon Press.*

Snow, J. (1849). On the Mode of Communication of Cholera. London: Churchill. http://resource.nlm.nih.gov/0050707

Statista. (2024). Ivory Coast: Growth rate of the real gross domestic product (GDP) from 2019 to 2029 *(compared to the previous year)*. *Statista*. Retrieved October 2024, from https://www.statista.com/statistics/452033/gross-domestic-product-gdp-growth-rate-in-ivory-coast/

Statista. (2024). Ivory Coast: National debt in relation to gross domestic product (GDP) from 2019 to 2029. *Statista.* Retrieved October 2024, from https://www.statista.com/statistics/452051/national-debt-of-ivory-coast-in-relation-to-gross-domestic-product-gdp/

UN Trade and Development. (2024). A world of debt, A growing burden to global prosperity. https://unctad.org/publication/world-of-debt

Wald, A. (1943). Tests of statistical hypotheses concerning several parameters when the number of observations is large. Transactions of the American Mathematical Society, *54*(3), 426–482. https://doi.org/10.1090/S0002-9947-1943-0012401-3

Williamson, J. (2017). Growth-Linked Securities. *Springer Nature*. https://doi.org/10.1007/978-3-319-68333-1

World Bank. (2024). *Cote d'Ivoire Macro Poverty Outlook (MPO)* https://thedocs.worldbank.org/en/doc/bae48ff2fefc5a869546775b3f010735-0500062021/related/mpo-civ.pdf

World Bank. (n.d.). *Inflation, GDP deflator (annual %)* [Data set]. The World Bank. https://data.worldbank.org/indicator/NY.GDP.DEFL.KD.ZG

World Bank Group. (n.d.). *World Development Indicators* https://databank.worldbank.org/source/world-development-indicators/Series/NY.GDP.DEFL.ZS#

Appendix

A. Introduction

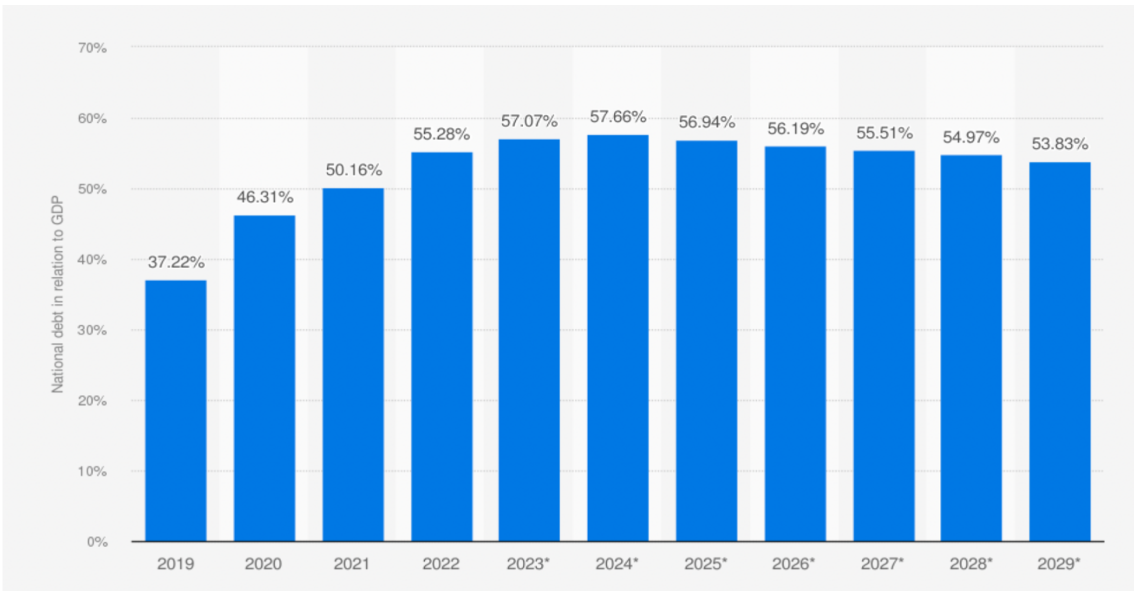

FIGURE A1. Actual and Forecasted National Debt in Côte d'Ivoire as a percentage of Gross Domestic Product (GDP) 2019-2029

The national debt in relation to GDP is forecasted for Côte d'Ivoire from 2023 to 2029. This chart has been retrieved from Statista.

Source: Statista (2024); International Monetary Fund (2024).

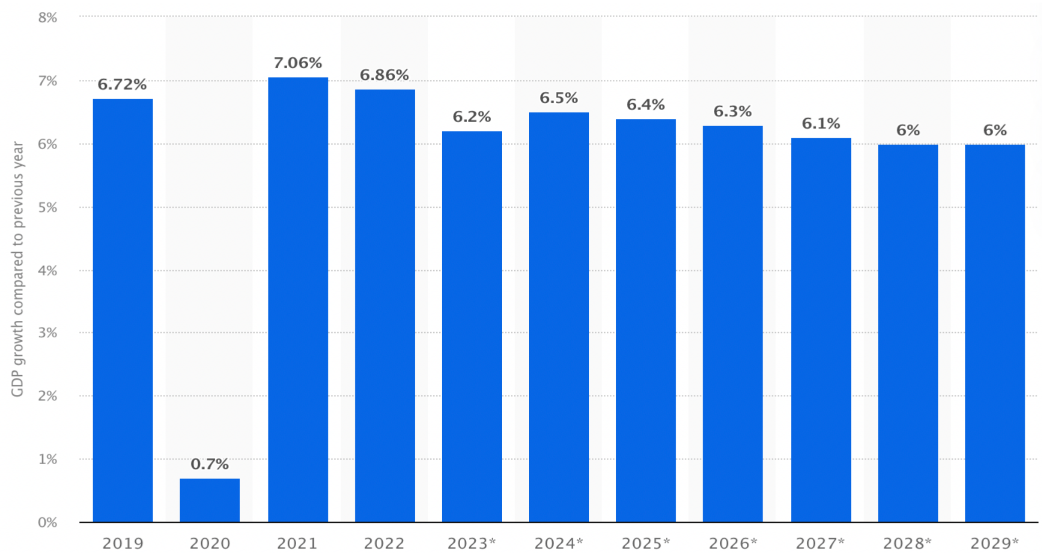

FIGURE A2. Forecast of Growth rate of the real gross domestic product (GDP) in Côte d'Ivoire from 2023 to 2029 *(compared to the previous year)*

The growth rate of the real gross domestic product (GDP) from 2023 to 2029 (compared to the previous year) is forecasted for Côte d'Ivoire from 2023 to 2029.

Source: Statista (2024)

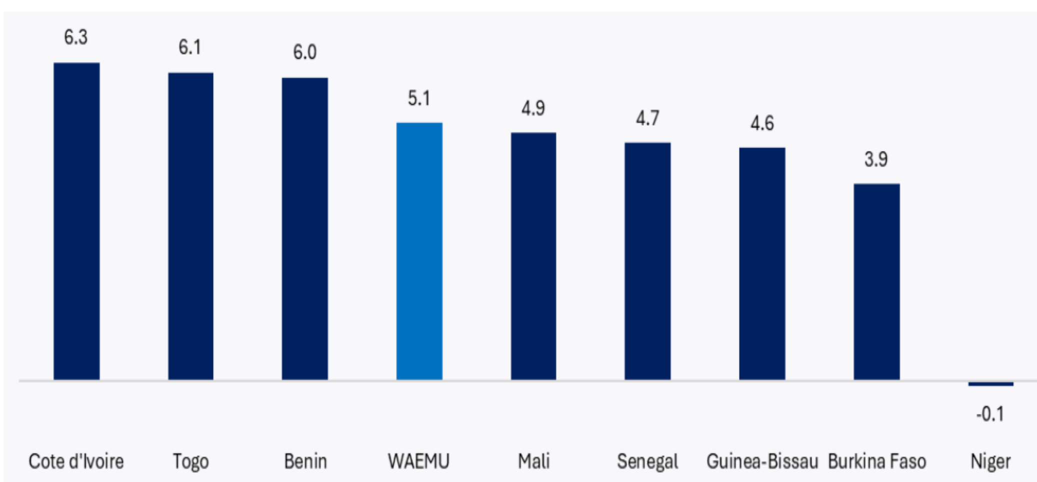

FIGURE A3. Countries in the WAEMU bloc ranked by annual real GDP Growth rate (%)

Gross Domestic Product in the WAEMU zone averaged 5.1% in Q1 2024. The economy of Cote d'Ivoire expanded the most (6.3%), offsetting slower growth in coup-hit peers such as Niger (-0.1%).

Source: BCEAO Quarterly Statistical Bulletin | Chart: Daba Finance (2024).

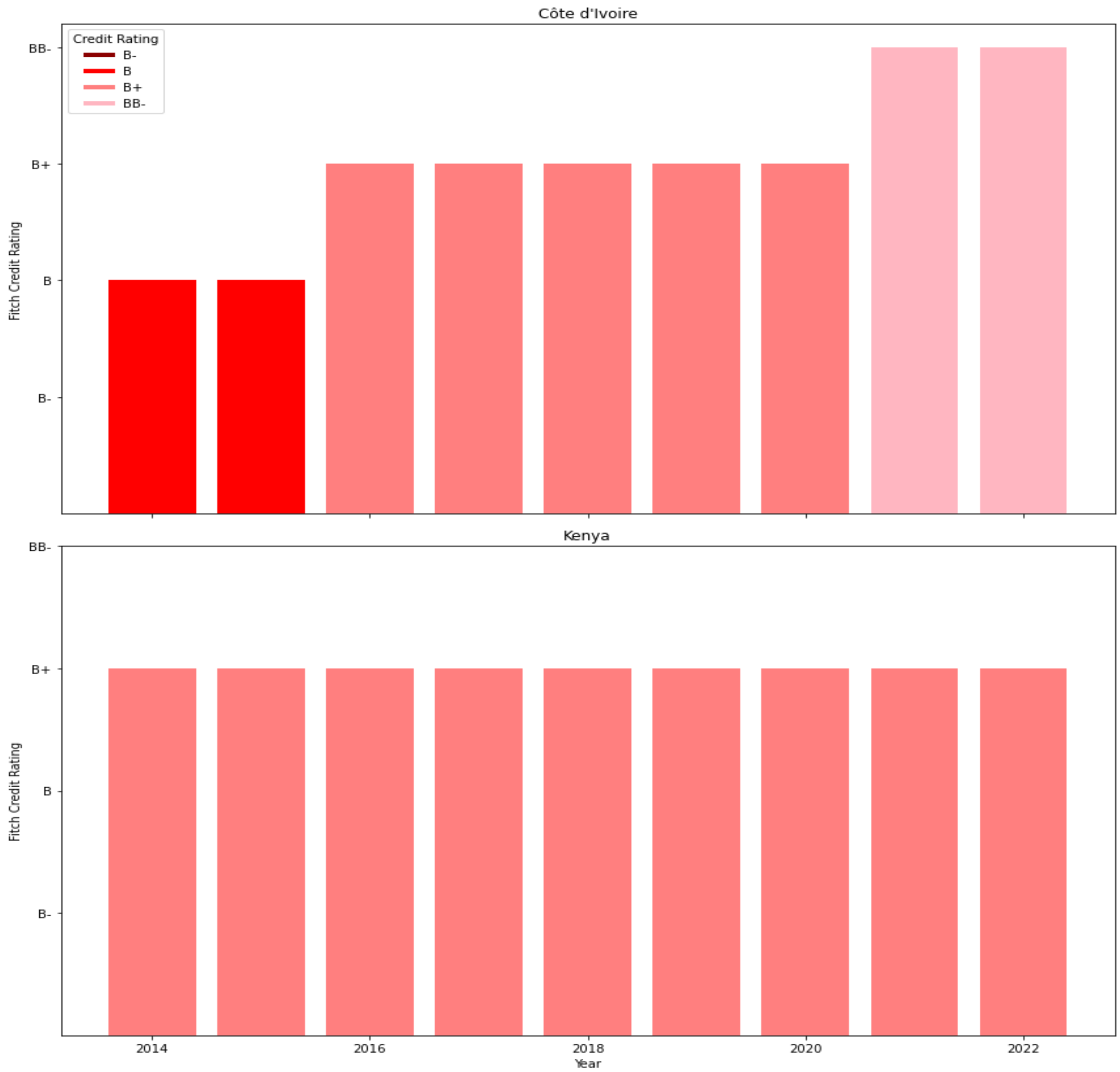

FIGURE A4. Fitch Credit Ratings of Côte d'Ivoire and Kenya 2014–2022

The dark red chart denotes the lowest credit rating[8] (B), whereas the lighter red charts represent comparatively higher ratings (B+, BB-).

Source: Author's estimates based on the ratings of Fitch Ratings.

[8] The **category of "BB"** ratings marks an increased vulnerability to default risk, especially in adverse economic conditions although the sovereign entity remains able to meet its financial commitments. On the other hand, "B" ratings represent a lower rating category and mark the presence of default risk despite the ongoing financial flexibility (Fitch ratings).

B. Literature Review

Lessons from Practical Applications of GDP-Linked Debt Instruments

GDP-linked Warrants in Argentina (2005)

In 2005, Argentina issued GDP-linked warrants valued at 62 billion US dollars within its debt restructuring framework, to replace the USD 82 billion in bonds that the nation defaulted on. The government was intended to process payments under a few conditions. The latter stipulate that real GDP should exceed the base-case GDP, and real annual GDP growth should be above the base-case growth, with a threshold of 4.26 percent in 2005, then 3 percent from 2015 until the expiry date in 2035. Moreover, a cap on the overall payments on the warrants was set at 0.48 per unit of currency. The warrants could terminate earlier if the payment cap was reached before the termination date. The payment structure was specified as follow (Griffith-Jones and Hertova, 2013):

$$Payment\ =\ 0.05 \times (actual\ GDP - base\ case\ GDP) \times\ unit\ of\ currency\ coefficient\ \times Notional\ Amount$$

In Argentina, payments were linked to GDP levels instead of GDP growth. In the subsequent years, the country witnessed an economic growth that led to high payments on GDP-linked warrants. By 2012, these payments represented a large portion of GDP and export revenues. Afterwards, slower economic growth in 2012 provided some relief by reducing payments.

GDP-linked Securities in Greece (2012)

Greece issued a GDP-linked security as part of its debt restructuring a reduction program in 2012. The term of this instrument stipulated that coupons were equal to 1.5 times the excess GDP growth over a target rate of 2.9 percent for 2015, then 2 percent as of 2021*.* The conditions that triggered payment were the following: the nominal GDP should be above or equal to the reference nominal GDP, Real GDP growth should be positive and exceed the predetermined targets. Moreover, investors were entitled to receive annual payments of only up to 1 percent of their notional amount from October 2015 until 2042. Under these conditions, the government was expected to make annual payments according to the formula below (Morgan Stanley, 2012):

$$Payment\ =\ 1.5\ \times\ (real\ GDP\ growth\ -\ Growth\ Target) \times\ Notional\ Amount$$

TABLE C1. Data description and sources

	Units	Frequency	Sources
Interest Paid on Public Debt	Percent of GDP	Annual	International Monetary Fund
General Government Gross debt	Percent of GDP	Annual	International Monetary Fund
Government Primary Balance	Percent of GDP	Annual	International Monetary Fund
Real GDP Growth Rate	Percent (%)	Annual	International Monetary Fund
Inflation (GDP Deflator)	Percent (%)	Annual	World Bank
ΔUSD/KES	…	Monthly	Investing.com
ΔUSD/XOF	…	Monthly	Investing.com

Sources: Author IMF Database; World Bank Database; Investing.com.

TABLE C2 — Correlations between debt components in Côte d'Ivoire

x;y	*Period*	*ρ (x,y)*
Debt/GDP; Growth	2002-2008	-0.54
Debt/GDP; Growth	2002-2022	-0.70
Debt/GDP; Primary balance	2002-2008	0.14
Debt/GDP; Primary balance	2002-2022	0.26

Sources: Author's estimates based on data from IMF Database.
Notes:
[1] *x* and *y* represent the correlated variables
[2] The *debt-to-GDP ratio* used is the raw data from IMF
[3] *2002-2008* represents the pre-treatment period in the framework of our study.
[4] *2002-2022* represents the full sample period of our study.

TABLE C3 — Correlation Matrix

	Debt/GDP	Nominal growth rate	Interest rate	Primary balance	Inflation rate
Debt/GDP	1.000	0.052	-0.023	-0.234	0.079
Nominal growth rate	0.052	1.000	-0.207	0.011	0.920
Interest rate	-0.023	-0.207	1.000	-0.040	-0.143
Primary balance	-0.234	0.011	-0.040	1.000	-0.011
Inflation rate	0.079	0.920	-0.143	-0.011	1.000

1.000

Sources: Author's estimates based on data from IMF Database and World Bank Database.
Notes: This table presents the matrix of correlations between the main variables of the model.

TABLE C4 — Wald Test

F-Statistic	P-value	Degrees of Freedom (Numerator)	Degrees of Freedom (Denominator)
0.6952	0.4058	1	142

Sources: Author's estimates based on data from IMF Database and World Bank Database.

TABLE C5 — Summary of the parameters

Parameters	Description	Baseline Values	Alternative Values
Difference-in-Differences, 2002-2022			
λ	Indexation Coefficient	0.01	0.03 ; 0.07
θ_{GLB}	Risk Premium	0.02	0.04 ; 0
i_t	Base Interest Rate	0.05	
$\overline{g}$	Average Growth Rate	0.0317	
Forecasts, 2022-2032			
λ	Indexation Coefficient	0.5	
θ_{GLB}	Risk Premium	0.02	
i_t	Base Interest Rate	0.05	
$d_{t=2022}$	Debt-to-GDP Ratio ($t = 2022$)	55	
$pb_{t=2022}$	Primary Balance ($t = 2022$)	-4.60	
$\overline{g}$	Average Growth Rate	0.05	

Source: Author's calculations.
Note: This table presents the summary of the parameters of each model. These values are chosen to satisfy the assumptions of the models.

TABLE C6 — Summary of Difference-in-Differences (DID) dummy variables

Variables	Obs.	Min	Max
Côte d'Ivoire			
GLBs	21	1	1
Post	21	0	1
GLBs × Post	21	0	1
Benin, Burkina Faso, Ethiopia, Kenya, Rwanda, Senegal			
GLBs	126	0	0
Post	126	0	1
GLBs × Post	126	0	0

Source: Author's calculations.

Government Debt-to-GDP ratio and Contributing Factors to Debt Accumulation

We derive the government conventional debt-to-GDP ratio as follow (Peter, 2014; Benford *et al.*, 2016; Blanchard *et al.*, 2016):

$$d_{t+1} = d_t + r_t - g_t^r - pb_t + \varepsilon_t$$

$$= d_t + r_t - [g_t^{nom}(1 + \pi_t)] - pb_t + \varepsilon_t$$

where d_{t+1} and d_t represent the general government gross debt-to-GDP ratio in year $t+1$ and t, respectively. r_t denotes the interest payments on outstanding debt in year t and g_t^r represents the real GDP growth. Additionally, pb_t represents the primary balance as a proportion of GDP in period t, and ε_t refers to any other exogenous adjustments and shocks to the debt stock in year t. This term also captures exchange rate shocks. Finally, g_t^{nom} represents the nominal GDP growth and π_t represents the inflation in year t.

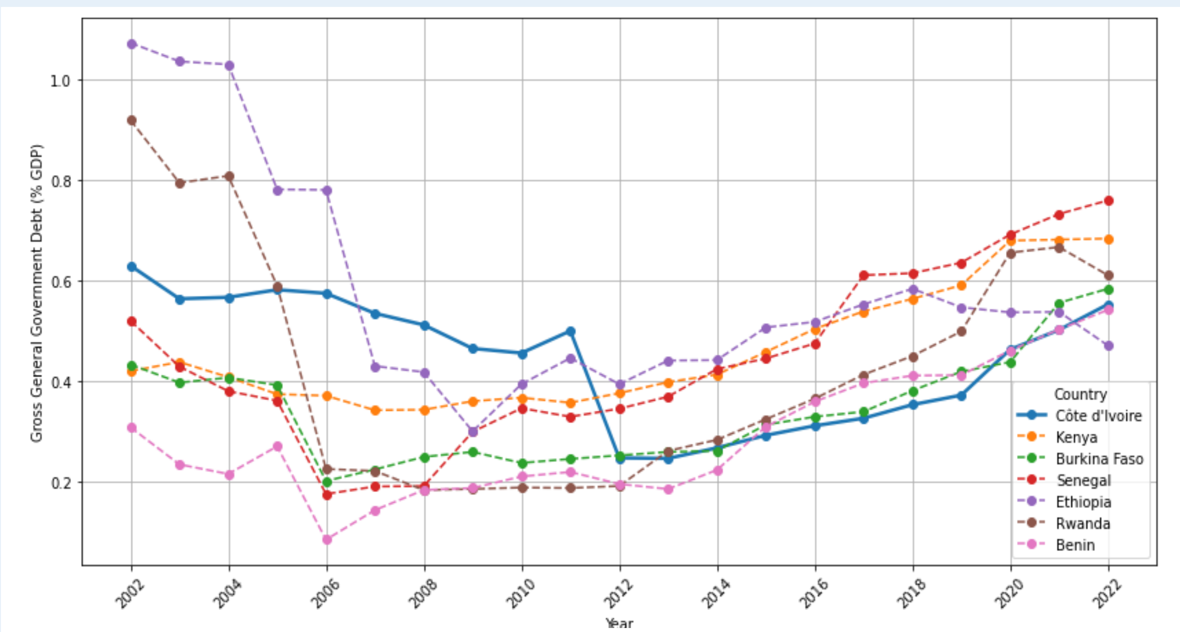

FIGURE C1. Gross General Government Debt, 2002-2022

Sources: Author's estimates based on data from IMF and World Bank Database.

For each country, the gross general government debt is expressed in percentage terms.

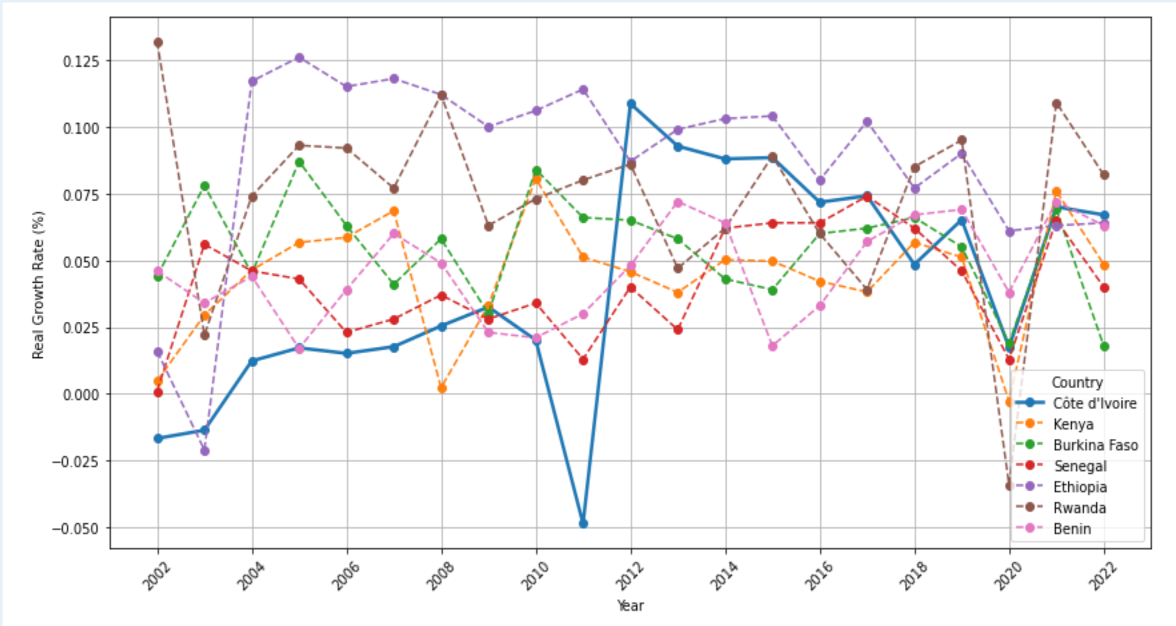

FIGURE C2. Real GDP Growth Rates, 2002-2022

Sources: Author's estimates based on data from IMF and World Bank Database.

The real GDP growth rates are expressed in percentage terms.

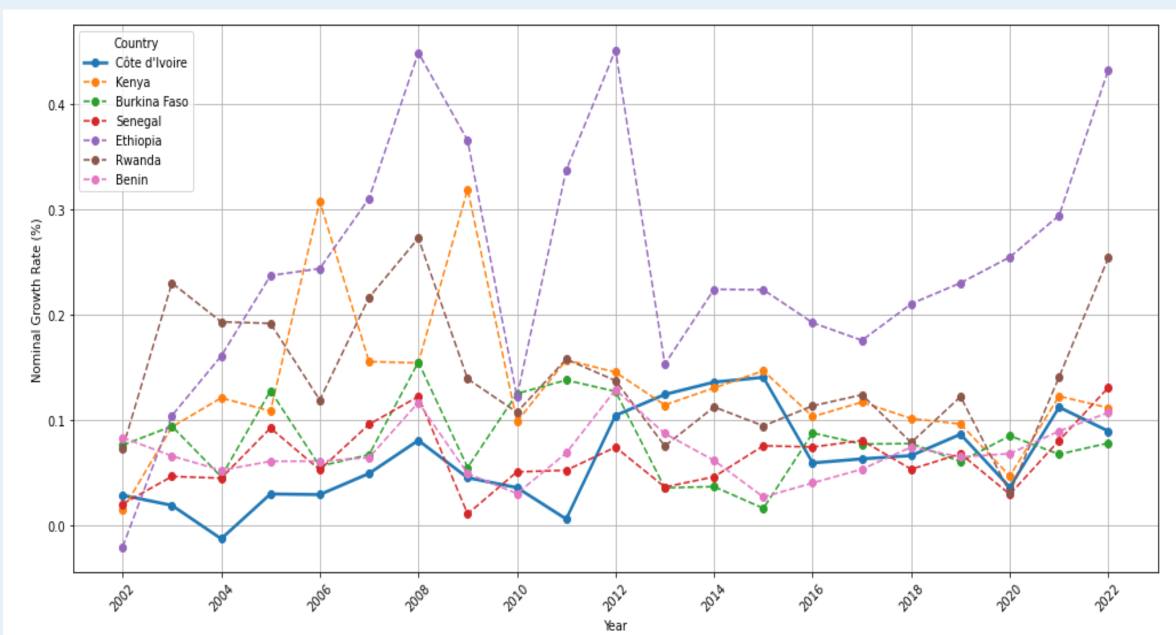

FIGURE C3. Nominal GDP Growth Rates, 2002-2022

Sources: Author's estimates based on data from IMF and World Bank Database.

The nominal GDP growth rates are expressed in percentage terms.

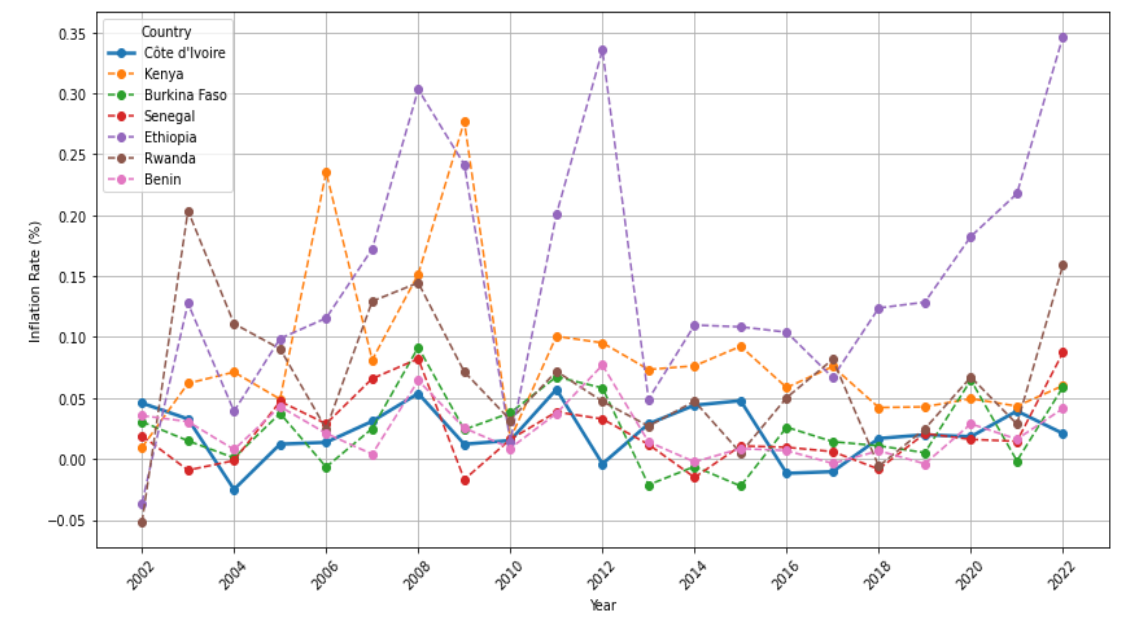

FIGURE C4. Inflation rates, 2002-2022

Sources: Author's estimates based on data from IMF and World Bank Database.

The inflation rates are expressed in percentage terms.

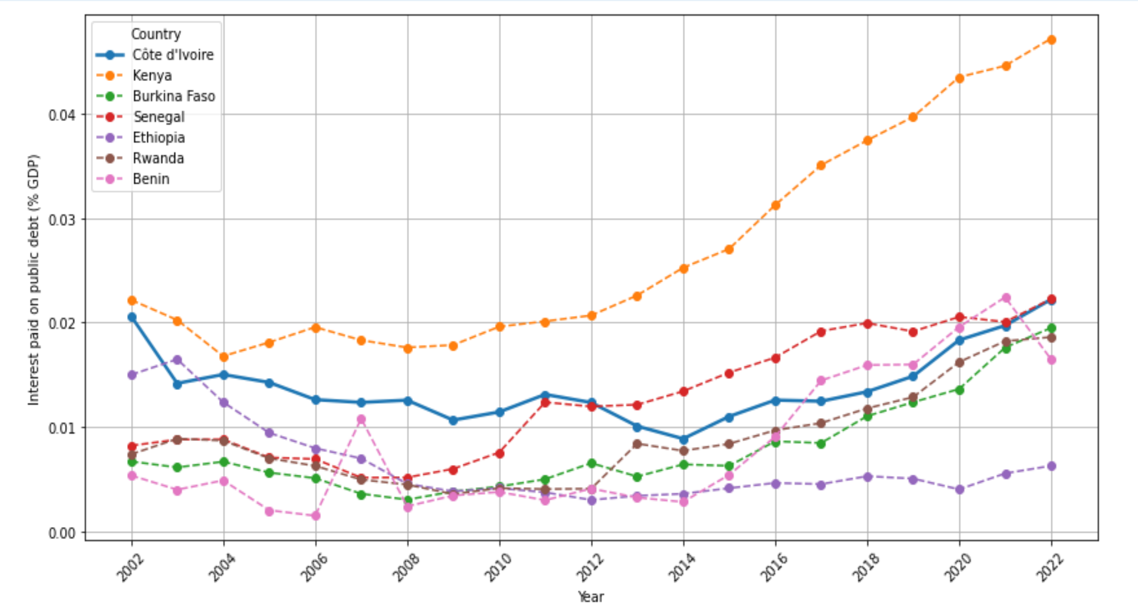

FIGURE C5. Interest Paid on Public Debt, 2002-2022

Sources: Author's estimates based on data from IMF and World Bank Database.

For each country, the interest paid on public debt is expressed in percentage terms.

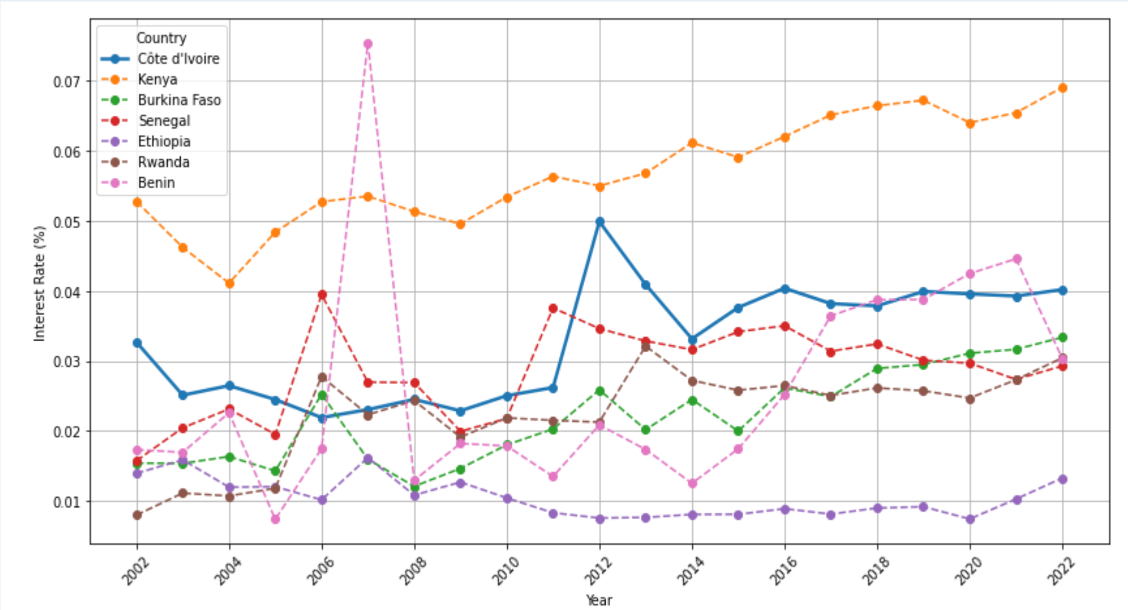

FIGURE C6. Interest Rates, 2002-2022

Sources: Author's estimates based on data from IMF and World Bank Database.
The interest rates are expressed in percentage terms.

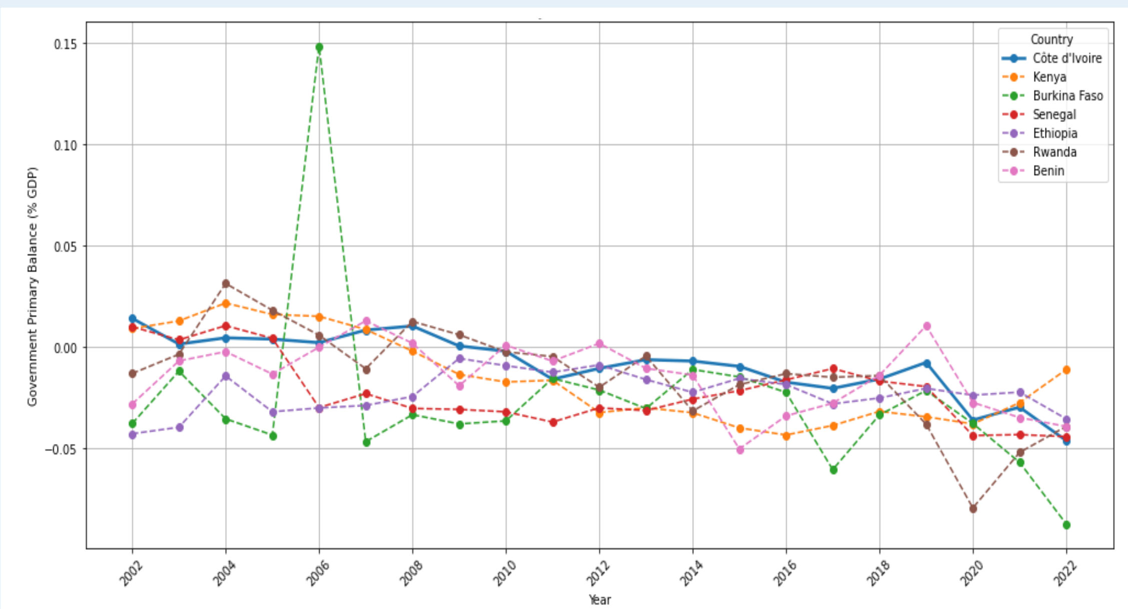

FIGURE C7. Government Primary Balance, 2002-2022

Sources: Author's estimates based on data from IMF and World Bank Database.
For each country, the government primary balance is expressed in percentage terms.

D. Empirical Results

1. Assessing the Performance of GDP-linked Bonds: Scenario Analysis

1.1. Model Specifications

For further exploration, we generate deterministic projections of the debt ratio across different scenarios of GDP growth and decline, with and without the inclusion of GDP-linked bonds in the debt stock, for ten years ahead. We conduct those simulations based on the assumption that GLBs account for 100 percent of the total debt stock. Former scholars (Benford *et al.*, 2016; Acalin, 2018) used Monte Carlo simulations to perform debt ratio projections, however, even though the random shocks incorporated in the model introduces a dimension of realism, there is a risk that the outcome fails to capture rare and extreme events. It might also be overly sensitive to assumptions of the model. In reality, economic shocks do not always follow a joint normal distribution. Stress tests do not rely on assumptions regarding the distribution of the shocks and can therefore minimize bias in the effects of extreme shocks. We use a deterministic approach by simulating different favorable and pessimistic scenarios. In both the expansion and decline contexts of GDP, we calculate the future value of the conventional debt ratio as follow:

$$d_{t,conventional} = \frac{(1\ +\ r\ )^N}{(1\ +\ g)^N} \times d_0$$

where $d_{t,conventional}$ is the conventional debt ratio of conventional, r is the interest rate, g represents the nominal GDP growth (or decline) and remains constant until 2032. N is the number of years forecasted, and d_0 represents the initial debt ratio in 2022. For simplicity, we abstract from the potential effects of the primary balance pb_t.

On the other hand, we calculate the future value of the debt ratio when the public debt stock essentially consists in GLBs as follow:

$$d_{t,GLBs} = \alpha \times \left[\frac{(1\ +\ i_t^{GLBS}\ )^N}{(1\ +\ g)^N} \times d_0\right] + (1-\alpha) \times [\frac{(1\ +\ r\ )^N \times d_0}{(1\ +\ g)^N}]$$

where $i_t^{GLBS} = 1\ +\ i\ +\ \lambda\ \times\ (g\ -\ \overline{g})\ +\ premium)$

and where $d_{t,GLBs}$ is the debt ratio associated with a debt configuration comprising GLBs exclusively. $\overline{g}$ is the average growth rate of Côte d'Ivoire from 2002 to 2022, and i is the benchmark rate approximately equal to the plain vanilla bonds interest rate (*see* Table C5).

1.2. Assumptions

This model assumes no randomness contrary to stochastic projections; it does not account for unpredictable variations or shock. But it rather computes forecasts of the debt to GDP ratio according to the fixed relationships mentioned above and different scenarios of GDP growth and GDP decline.

Due to their inherent interrelation, it is undeniable that the fundamentals of the debt-to-GDP ratio such as the primary balance and the GDP level, are affected by the change in the debt structure, whether through direct or indirect channels. However, it is worth noting that, for the causal effect of GLBs to be conceptually sound and easily estimated, it is essential to assume specific conditions regarding these parameters. Forecasting primary balance presents significant challenges due to changing political decisions, economic uncertainties and external shocks, especially for developing countries. Considering the lack of available forecasts for the countries under consideration, throughout the simulation period, we abstract from the effects of the primary balance, for simplicity. The choice of the interest rate equal to 5 percent is an attempt to quantify the implications of the implementation of GLBs under the most adverse fiscal scenario. For simplicity purposes, in our simulations, we do not take into account the potential variations in the nominal GDP level after the adoption of GLBs and follow the same trajectory to that observed after 2009 in Côte d'Ivoire (Borensztein and Mauro, 2004). Additionally, we do not take into account the changes in the borrowing practices that may occur with the introduction of GDP-linked bonds (Benford *et al.*, 2016). Indeed, the incremental fiscal space resulting from the adoption of GLBs could stimulate the sovereign to expand debt acquisition. In our analysis, to isolate the impact of the instruments and for simplicity purposes, we assume that the Ivoirian government does not change its borrowing patterns.

Furthermore, we assume that the benchmark interest rate used to calculate the interest rate of GLBs is equal to 5 percent, slightly above the peak interest rate of 4 percent recorded by Côte d'Ivoire between 2002 and 2008. Overall, these assumptions are easily justified as they would enable our results to align more closely with potential shocks than a simulation technique, such as Monte Carlo, which assigns random shocks to the variables.

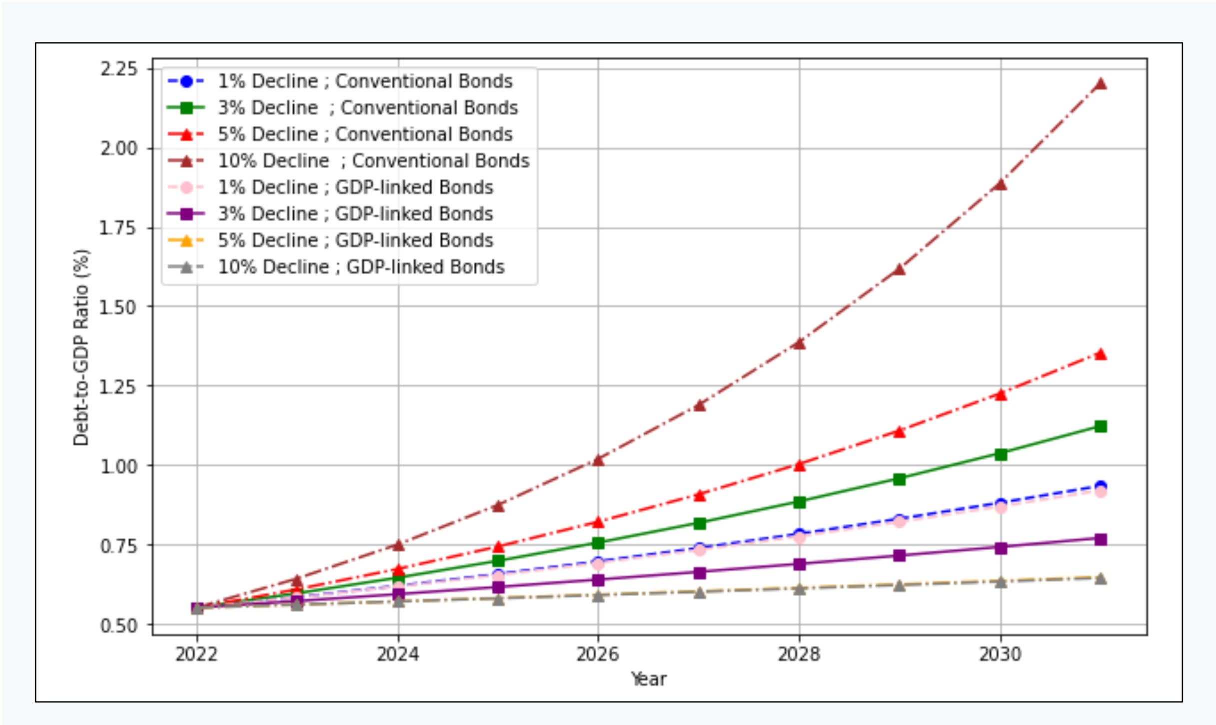

FIGURE D1.1. Adverse Scenario — Ivorian Debt-to-GDP ratio Forecasts 2022-2032

Source: Author's estimates; IMF Database.

Each line represents the debt-to-GDP forecast without or with the adoption of GDP-linked bonds after 2022 for different declining GDP scenarios. In 2022, the debt-to-GDP ratio of Côte d'Ivoire was approximately 55 percent according to the IMF database.

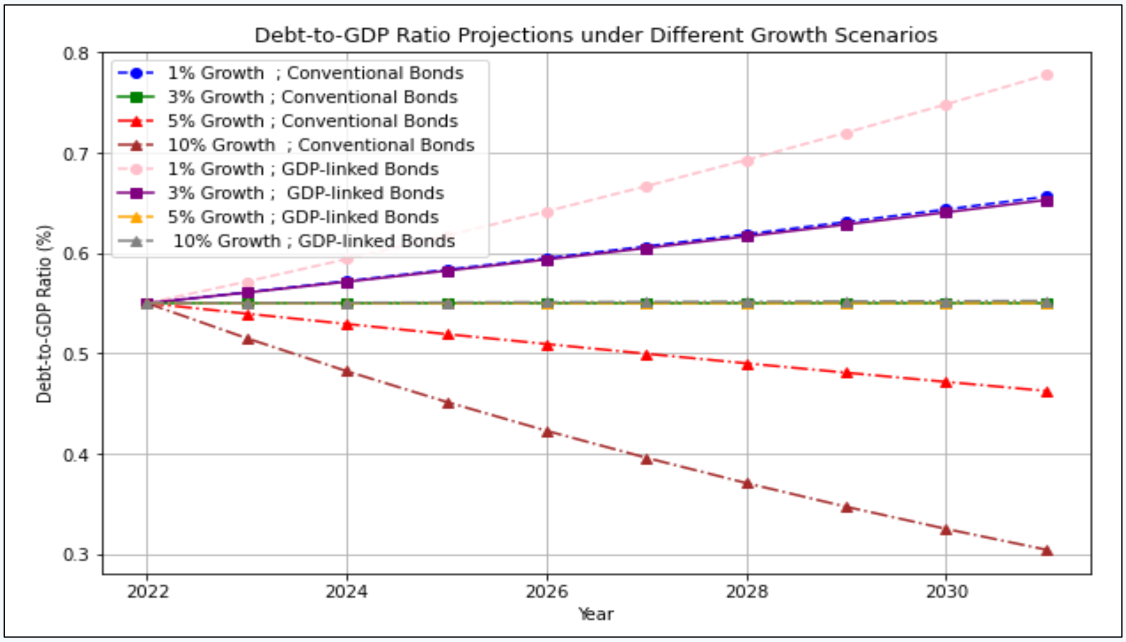

FIGURE D1.2. Growth Scenario — Ivoirian Debt-to-GDP ratio Forecasts 2022-2032

Source: Author's estimates.

Each line represents the debt-to-GDP forecast without or with the adoption of GDP-Linked bonds after 2022 for different GDP growth scenarios. In 2022, the debt-to-GDP ratio of Côte d'Ivoire was approximately 55 percent according to the IMF database.

2. Difference-in-Differences — Robustness Tests

TABLE D2.1 — Robustness to alternative set of control countries

Dependent variable: $\Delta(Debt/GDP)_{it}$

			Baseline
	Two Control Countries (Benin, Senegal) (1)	Four Control Countries (Benin, Burkina Faso, Kenya, Senegal) (2)	Six Control Countries (Benin, Burkina Faso, Ethiopia, Kenya, Rwanda, Senegal) (3)
$Constant$	0.0328	-0.0063	-0.0029
	(0.051)	(0.021)	(0.043)
$GLBs$	0.0169	0.0193***	0.0482***
	(0.021)	(0.008)	(0.023)
$Post$	0.0118	0.0123	0.0046
	(0.076)	(0.029)	(0.022)
$\boldsymbol{GLBs \times Post}$	**-0.0469***	**-0.0378*****	**-0.0613*****
	(0.028)	(0.016)	(0.020)
$Primary\ Balance$	-0.7794***	-0.4557	-0.4218***
	(0.260)	(0.305)	(0.160)
$Inflation\ rate$	-0.5200***	0.0197	-0.1722
	(0.242)	(0.225)	(0.174)
Time Fixed Effects	YES	YES	YES
Country Fixed Effects	YES	YES	YES
R^2	0.649	0.539	0.437
Adjusted R^2	0.409	0.383	0.295
Sample size	60	100	140

Sources: Author's estimates based on data from IMF Database and World Bank Database.

Notes:

[1] This table presents the estimates from Equation (**5.3**), which describes the relative average effect of the implementation of GDP-linked bonds on the debt-to-GDP ratio differential $\Delta(\boldsymbol{Debt/GDP})_{it}$. The estimation is based on the sample consisting of annual observations from 2002 to 2022 for the seven countries under study including Côte d'Ivoire. $\boldsymbol{GLBs}$ is an indicator for Côte d'Ivoire, in which we simulated the implementation of GDP-linked bonds. $\boldsymbol{Post}$ is an indicator for the period after 2008, the year in which the implementation of GDP-linked bonds was simulated. The interaction term $\boldsymbol{GLBs \times Post}$ denotes the combined effect of the implementation of GDP-linked bonds after 2008. It represents the explanatory variable of interest in our DID regressions.

[2] The dependent variable $\Delta(\boldsymbol{Debt/GDP})_{it}$ was adjusted and calculated with the indexation coefficient equal to 0.01 for Côte d'Ivoire exclusively, from 2009 to 2022 ,to simulate the implementation of GLBs after 2008.

[3] Each row displays results from a separate regression. Column 1 shows the coefficients estimates and their standard errors for a regression of the differential of the debt ratio including two control countries Kenya and Benin. Column 2 shows the estimates obtained from the regression that considers a public debt stock divided evenly between GDP-linked debt and conventional debt. Column 3 shows the estimates obtained from the regression model that incorporates a public debt stock consisting of 60 percent of GDP-linked debt and 40 percent of conventional debt. Each regression includes year and country Fixed Effects (FEs).

[4] The standard errors in each regression are robust to cluster correlation by country and are reported in parentheses.

[5] ***, **, and * denote significance at 1 percent, 5 percent and 10 percent, respectively *(*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$).*

TABLE D2.2 — Robustness to alternative risk premium

Dependent variable: $\Delta(Debt/GDP)_{it}$

	Baseline		
	Risk Premium = 0.02 (1)	*Risk Premium = 0.040* (2)	*No Risk Premium* (3)
$Constant$	-0.0029	-0.0022	-0.0035
	(0.043)	(0.043)	(0.043)
$GLBs$	0.0482***	0.0478**	0.0487**
	(0.023)	(0.024)	(0.023)
$Post$	0.0046	0.0041	0.0051
	(0.022)	(0.022)	(0.022)
$\boldsymbol{GLBs \times Post}$	**-0.0613*** **	**-0.0606*** **	**-0.00620*** **
	(0.020)	(0.020)	(0.020)
$Primary\ Balance$	-0.4218***	-0.4209***	-0.4226***
	(0.160)	(0.160)	(0.160)
$Inflation\ rate$	-0.1722	-0.1751	-0.1694
	(0.174)	(0.175)	(0.174)
Time Fixed Effects	YES	YES	YES
Country Fixed Effects	YES	YES	YES
R^2	0.437	0.436	0.439
Adjusted R^2	0.295	0.294	0.297
Sample size	140	140	140

Sources: Author's estimates based on data from IMF and World Bank Database.

Notes:

[1] This table presents the estimates from Equation (**5.3**), which describes the relative average effect of the implementation of GDP-linked bonds on the debt-to-GDP ratio differential $\Delta(\boldsymbol{Debt/GDP})_{it}$. The estimation is based on the sample consisting of annual observations from 2002 to 2022 for the seven countries under study including Côte d'Ivoire.

[2] Each row displays results from a separate regression. Column 1 shows the estimates from the regression model incorporating a risk premium of 200 basis points (bps). Column 2 shows the estimates from the model incorporating a higher risk premium of 400 bps. Column 3 shows the estimates of the model without risk premium. Each regression includes year and country Fixed Effects (FEs).

[3] The standard errors in each regression are robust to cluster correlation by country and are reported in parentheses.

[4] ***, **, and * denote significance at 1 percent, 5 percent and 10 percent, respectively *(*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$).*

TABLE D2.3 — Robustness to alternative indexation coefficient

Dependent variable: $\Delta(Debt/GDP)_{it}$

	Baseline		
	Indexation Coefficient = 0.01 (1)	*Indexation Coefficient = 0.03* (2)	*Indexation Coefficient = 0.07* (3)
$Constant$	-0.0029	-0.0029	-0.0028
	(0.043)	(0.043)	(0.043)
$GLBs$	0.0482***	0.0482***	0.0482***
	(0.023)	(0.024)	(0.024)
$Post$	0.0046	0.0046	0.0045
	(0.022)	(0.022)	(0.022)
$\boldsymbol{GLBs \times Post}$	**-0.0613***	**-0.0612***	**-0.0611***
	(0.020)	(0.020)	(0.020)
$Primary\ Balance$	-0.4218***	-0.4217***	-0.4214***
	(0.160)	(0.160)	(0.160)
$Inflation\ rate$	-0.1722	-0.1724	-0.1727
	(0.174)	(0.174)	(0.175)
Time Fixed Effects	YES	YES	YES
Country Fixed Effects	YES	YES	YES
R^2	0.437	0.437	0.437
Adjusted R^2	0.295	0.295	0.295
Sample size	140	140	140

Sources: Author's estimates based on data from IMF and World Bank Database.

Notes:

[1] This table presents the estimates from Equation (**5.3**), which describes the relative average effect of the implementation of GDP-linked bonds on the debt-to-GDP ratio differential $\boldsymbol{\Delta(Debt/GDP)_{it}}$. The estimation is based on the sample consisting of annual observations from 2002 to 2022 for the seven countries under study including Côte d'Ivoire.

[2] Each row displays results from a separate regression. Column 1 shows the regression estimates, using a positive indexation coefficient of 0.01. Column 2 shows the regression estimates, using a positive indexation coefficient of 0.03. Column 3 shows the regression estimates, using a positive indexation coefficient of 0.07. Each regression includes year and country Fixed Effects (FEs).

[3] The standard errors in each regression are robust to cluster correlation by country and are reported in parentheses.

[4] ***, **, and * denote significance at 1 percent, 5 percent and 10 percent, respectively *(*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$).*

TABLE D2.4 — Robustness to alternative treated country

Dependent variable: $\Delta(Debt/GDP)_{it}$

	Baseline	
	Treated Country: Côte d'Ivoire (1)	*Treated Country: Kenya* (2)
$Constant$	-0.0029	0.0016*
	(0.043)	(0.020)
$GLBs$	0.0482***	0.0625***
	(0.023)	(0.019)
$Post$	0.0046	0.0229
	(0.022)	(0.029)
$\boldsymbol{GLBs \times Post}$	**-0.0613***	**-0.0587**
	(0.020)	(0.022)
$Primary\ Balance$	-0.4218***	-0.5156***
	(0.160)	(0.147)
$Inflation\ rate$	-0.1722**	-0.1322
	(0.174)	(0.104)
Time Fixed Effects	YES	YES
Country Fixed Effects	YES	YES
R^2	0.437	0.449
Adjusted R^2	0.295	0.310
Sample size	140	140

Sources: Author's estimates based on data from IMF and World Bank Database.

Notes:

[1] This table presents the estimates from Equation (**5.3**), which describes the relative average effect of the implementation of GDP-linked bonds on the debt-to-GDP ratio differential $\Delta(\boldsymbol{Debt/GDP})_{it}$. The estimation is based on the sample consisting of annual observations from 2002 to 2022 for the seven countries under study.

[2] In Column 1 (Column 2), the dependent variable $\Delta(\boldsymbol{Debt/GDP})_{it}$ was adjusted and calculated with the indexation coefficient equal to 0.01 for Côte d'Ivoire (Kenya) exclusively, from 2009 to 2022 , to simulate the implementation of GLBs after 2008.

[3] Each row displays results from a separate regression. Column 1 shows the estimates obtained from a DID regression in which Côte d'Ivoire is the treated country. Column 2 shows the estimates obtained from a DID regression in which Kenya is the treated country while Côte d'Ivoire is among the six control countries. Each regression includes year and country Fixed Effects (FEs).

[4] The standard errors in each regression are robust to cluster correlation by country and are reported in parentheses.

[5] ***, **, and * denote significance at 1 percent, 5 percent and 10 percent, respectively *(*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$).*