



Public Debt
Management Network

Risks and Challenges for Public Debt Management: Inflation, Markets and Climate

Proceedings of the 3rd Public Debt
Management Conference,
Washington, D.C., October 3-4, 2024



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REMEMBERING FABIO VITTORINI

To Fabio Vittorini

After a distinguished career in the private sector, from 2017 to 2022 you led the office for international affairs at the Public Debt Directorate, Department of the Treasury, at the Italian Ministry of Economy and Finance, serving as the Head of the PDM Network Secretariat, with dedication, enthusiasm, and competence. Your leadership and passion left an indelible mark on all of us.

You inspired and guided us through your professional achievements, ability to innovate, and wisdom, enabling significant milestones for the PDM Network while fostering a work environment where everyone felt valued and motivated. Even during challenging times, you remained deeply involved and caring, offering invaluable insights and advice. Your encouragement to explore new ideas, such as leveraging the visibility of the PDM Network for various initiatives, and your passion for launching and developing projects like the BTP Green program (the Italian sovereign green bond program now successful and consistently implemented) and studying the role of several economic indicators to enhance Italy's credit rating, thereby improving the attractiveness of the country for foreign investors, were truly inspiring.

You also inspired us through your personal courage and unwavering commitment. Your positivity, resilience, proactive attitude, and profound humanity were recognized and admired by all who worked with you. You taught us that strength and vulnerability can coexist, that one can run without using legs, embrace with a glance, and express everything without saying a word. Your unique humor brought smiles to our faces, such as your recent suggestion about the need to grow extra arms - like the Goddess Kali - to handle the growing activities of the office!

Thank you, Fabio. Your memory will continue to live in the hearts of those who had the privilege of working alongside you. Your legacy of kindness, wisdom, and dedication will continue to inspire us all for years to come.

As we conclude, let us remember one of your favorite movie quotes: "It could be worse, it could be raining." As your beloved wife Daniela and your daughters Chiara and Beatrice testified, you taught us that "if you learn to dance in the rain, the sun will always come out". We want to apply this wisdom to public debt management: if you learn to manage debt during crises, you will be well-prepared to handle it during stable times.

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Closing Remarks *by Jean Pesme*

Please note that this publication includes only the selected papers to which Authors provided their consent.

FOREWORD

Anna Gelpern

*Scott K. Ginsburg Professor of Law and International Finance,
Georgetown University Law Center
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The Third biennial Public Debt Management Conference shows why no academic should ever miss a chance to be among public debt managers, and to learn from them and with them. Debt managers are the premier inter-disciplinary practitioners: to be effective, they must become expert financiers, politicians, and diplomats, conversant in economics, history, political science, law, and increasingly, in climate science. They must be compelling to audiences at home and abroad, in the public and private sectors. Debt managers even have magic powers: they time-travel into the future to procure resources for the rest of the government to serve the public today. I wish they could also tell us what the future holds.

What we do know is that the debt management ecosystem has grown vast and complex in a fragmented world. Conference organizers from the Italian Treasury, the OECD, and the World Bank showed superb judgment in selecting themes and papers that meet today's multifaceted challenges, many of which are included in this volume. Presenters and discussants brought new insights from economic policy, market structure, and instrument design to bear on the resurgent challenge of inflation. They engaged with the challenges of market design and market access using lessons from history, political economy, and contract architecture. And they took on the climate crisis with creative ideas from moral philosophy, history, law, and finance. For a subject that often claims elements of art and science, John Lennon and Leonardo da Vinci properly took center stage in the keynote address. The conference and the volume will continue to be an invaluable resource for crisis prevention, crisis management, and crisis resolution.

Most of all, this gathering reaffirmed the value of community. While public debt management is a time-honored public function, independent professional debt management offices are a relatively new development in much of the world. Bringing together debt managers, policy makers, and experts from every continent and across the national income spectrum regularly in this unique forum is vital to share knowledge, foster best practices, set the research agenda, and promote common values.

Public debt is not an end in itself, but a means to deliver on a shared commitment to the public good. Thanks to the tireless work of its organizers and participants, this Public Debt Management *biennale* models and bolsters this commitment. I am deeply grateful for the privilege of learning from it.

ACKNOWLEDGEMENTS

The Conference Organization Team comprised:

Fatos Koc, OECD
Layla Khalaf, OECD
Lars Jessen, World Bank
Sébastien Boitreaud, World Bank
Matias Ramon Hervera, World Bank
Umkulthum Oumi Himid, World Bank
Davide Iacovoni, Italian Ministry of Economy and Finance
Elisabetta Cervone, Italian Ministry of Economy and Finance
Federica Colombo, Italian Ministry of Economy and Finance

The PDM Network Secretariat extends its gratitude to the members of the papers' selection panel for their invaluable time and expertise. Their dedication and insightful contributions have been instrumental in ensuring the quality and success of our selection process.

For the Italian Treasury:

Leonardo Becchetti, Professor of Political Economy, Faculty of Economics, University of Rome 'Tor Vergata'
Davide Ciferri, Economist and Coordinator of the National Recovery and Resilience Plan (PNRR) Task Force, Ministry of infrastructures and transport, Italy
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Lars Jessen, Lead Debt Specialist, World Bank
David Mihalyi, Senior Economist, World Bank's Global Debt Unit (Prosperity)

Members' affiliations and role descriptions are as of the 2024 Conference date.

Thank You Note:

The PDM Network Secretariat would also like to extend a heartfelt thank you to all participants for their active engagement and valuable contributions. Their participation was essential to the success of the conference, and we deeply appreciate their support and involvement.

INTRODUCTION

The third edition of the biennial Public Debt Management Conference, organized by the Public Debt Management (PDM) Network—a collaborative initiative between the Italian Treasury, the OECD, and the World Bank—was a resounding success. Held at the World Bank headquarters in Washington, DC, on October 3-4, 2024, the conference titled “Risks and Challenges for Public Debt Management: Inflation, Markets, and Climate” centered around these critical themes.

The event saw robust participation, with over 250 attendees joining both in-person and remotely from across the globe. The conference brought together public debt managers, representatives from international institutions, leading academics, and the authors of 23 papers selected from a pool of 64 submissions. This diverse group engaged in rich discussions, underscoring the importance of blending theoretical research with practical insights.

Key figures from the PDM Network’s founding institutions played pivotal roles as moderators and speakers. Notable participants included **Jean Pesme**, Global Director of Finance in the Finance, Competitiveness & Innovation (FCI) Global Practice; **Carmine Di Noia**, Director of the OECD Directorate for Financial and Enterprise Affairs; and **Davide Iacovoni**, Director-General of the Public Debt Department at the Italian Treasury. The keynote speaker was **Ugo Panizza**, Professor of Economics and Pictet Chair in Finance and Development at the Geneva Graduate Institute.

Additionally, the conference was enriched by the participation of two renowned professors, **Anna Gelpern**, Scott K. Ginsburg Professor of Law and International Finance at Georgetown Law and a nonresident senior fellow at the Peter G. Peterson Institute for International Economics, and **Layna Mosley**, Professor in the School of Public and International Affairs (SPIA) and the Department of Politics at Princeton University, and Director of the Princeton Sovereign Finance Lab, who served as discussants, providing valuable insights and fostering engaging debates.

The conference covered a broad spectrum of topics, including traditional public debt management issues and current challenges such as inflation, heightened financial market volatility, and the increasing impact of climate change. The discussions underscored the rising importance of integrating climate considerations into public debt management strategies.

This volume features contributions from both the selected authors and the distinguished speakers.

In the welcoming remarks, **Lars Jessen** greeted attendees at the third Public Debt Management Conference held at the World Bank Headquarters. He highlighted the Network’s activities, including quarterly webinars and the PDM Network website. Jessen noted the initial skepticism about the conference’s success, which has since proven unfounded with high participation and interest. He provided practical information about the conference schedule and amenities before introducing Federico Gil Sander, Practice Manager in the Macroeconomics Trade and Investment Global Practice at the World Bank.

Frederico Gil Sanders, in his opening remarks, warmly welcomed attendees to the third Public Debt Management Conference, the first held outside Europe. He emphasized the gathering’s purpose of bringing together global debt managers and academics to discuss pressing public debt management issues amid unprecedented challenges such as high debt vulnerabilities, climate change, and sluggish growth. Sanders highlighted the high risk of debt distress in many of the world’s poorest countries and the need for strategic macroeconomic policies and robust debt management practices. He also emphasized the impact of climate change on economic management and the importance of integrating climate considerations into fiscal strategies. Additionally, Sanders noted the necessity of economic

growth to maintain debt sustainability and the World Bank's collaboration with the IMF on enhancing fiscal space for resilience. The conference aims to foster innovation and collaboration to shape the future of public debt management.

In his keynote speech, **Ugo Panizza** discussed the critical issues of sovereign debt and climate finance, emphasizing the role of contingent instruments. He highlighted the mismatch between countries causing high emissions and those suffering from climate change impacts. Panizza argued for innovative financial instruments like sustainability-linked bonds and stressed the importance of compulsory net-zero targets to create incentives for reducing emissions. He also discussed the need for public expenditure in climate adaptation and the moral responsibility of high-emission countries to support vulnerable nations. Panizza concluded by acknowledging the challenges in forecasting debt sustainability and the potential of contingent debt instruments to address deep uncertainties in climate finance.

The volume is divided into five sessions.

Session I - Understanding Public Debt Spikes: Implications for Debt Management and Debt Sustainability

David Mihalyi's paper, *Debt Service Spikes and Debt Distress*, examines the effectiveness of public debt management by analyzing the volatility of a country's debt service framework. Using data from 115 countries over a 40-year period, the analysis highlights how improvements in active debt management and debt policies are associated with a reduction in debt service volatility. The document emphasizes that spikes in debt service, especially during adverse economic conditions, might increase the likelihood of debt stress episodes. Mihalyi underscores the importance of active debt management to enhance debt sustainability. Additionally, his study introduces a new measure of external debt service volatility and highlights how effective debt management can reduce the risks of debt stress, particularly during adverse economic conditions.

The paper *The Aggregation Dilemma: How Best to Restructure Sovereign Bonds* by Carlo Galli and Stéphane Guibaud delves into the complexities of restructuring multiple series of sovereign bonds using "enhanced" collective action clauses (CACs). The authors explore how the optimal aggregation procedure and restructuring offer are affected by the heterogeneity of bondholders within and across series, as well as the relative nominal values of the bonds. They analyze the impact of CACs design on bond market equilibrium before restructuring, considering scenarios where bond investor bases are endogenously determined. Galli and Guibaud explain how the choice between single-limb and two-limb aggregation methods is crucial and depends on the specific circumstances of the bond series involved. They suggest that having the flexibility to choose between single-limb and two-limb aggregation methods can benefit debtor countries, as it allows them to adapt their strategy based on the specific context and the behavior of bondholders.

Session II - Market Dynamics and Their Impact on Public Debt Management Performance

The paper *Secondary Market Liquidity: The Role of Repo Market Specialness* by Valentina Catapano, Luciano Greco and Filippo Mormando examines how the "specialness" of a security traded in the repo market affects liquidity in the secondary market, specifically measured by the bid-ask spread. "Specialness" refers to the premium paid to obtain a specific security in the repo market. The authors reverse the usual perspective by investigating whether the specialness priced in the repo market affects the bid-ask spread in the secondary market. They find that higher specialness in the repo market negatively impacts secondary market liquidity, increasing the bid-ask spread. The study uses data from the Italian Treasury's activity in the repo market and MTS Italy's cash and repo segments. The results show that a one basis point increase in repo market specialness is associated with a more than 1.5 basis point increase in the secondary market bid-ask spread. Their findings suggest that increased

specialness worsens liquidity conditions in the secondary market, a conclusion supported by robust statistical analysis. The paper also highlights the Italian Treasury's role in mitigating these liquidity issues by supporting market makers in the repo market.

Philipp Sicking, Achim Kopf, Christoph Peters, Norman Demuth, Felix Klameth, and Tatjana Lemke presented the paper *Average Interest Cost. A novel Cost and Risk Measure and its application in Public Debt Management*. They introduce a new methodology called the "Average Interest Cost" (AIC), which is deemed more fitting for assessing the costs associated with public debt than traditional methods. The AIC metric incorporates historical interest expenses, encompasses the discrepancy between the market value and nominal value of the debt portfolio, and includes the projected future costs for refinancing the entire debt stock over a long-term horizon. This comprehensive metric offers a clear and concise view of the expected average interest payments on public debt in the long run, aiding in more effective debt planning and management. Additionally, the authors illustrate how the AIC can be utilized to compare different issuance strategies and make informed decisions in public debt management.

Session III - Sovereign Debt Management Strategies in the Face of Environmental Challenges and Disaster Risks

Alexander Dryden's paper, *Disasters, Defaults & Debt Restructurings*, explores the impact of natural disasters on sovereign defaults and debt restructuring processes from 1975 to 2024. Key findings include that: 44% of debt restructurings occurred within a year of a major disaster; immediate disasters (e.g., hurricanes, earthquakes) often lead to smaller debt reductions and quicker negotiations; gradual disasters (e.g., droughts) result in larger haircuts and more prolonged discussions. Dryden highlights the importance of incorporating environmental risks into sovereign debt assessments and suggests solutions like disaster-resilient financial instruments (e.g., cat-bonds, disaster clauses) to minimize restructuring needs and manage creditor losses effectively. The paper also details the varying processes and magnitudes of debt restructuring processes both before and after natural disasters occurred.

The paper *Disasters and Exchange Rates* by Yuen C. Lo and Ulrich Volz investigates the impact of disasters on exchange rates, focusing on lesser-developed economies, particularly IDA eligible borrowers. It highlights that these economies suffer the most from capital outflows and exchange rate depreciation following large disasters, leading to higher import costs, inflation, and increased debt service costs, especially for foreign currency-denominated debt. The study emphasizes the growing exchange rate risk for poor countries due to climate change and underscores the need for investment in adaptation, resilience, and hedging exchange rate risk in public debt management. Case studies from the Philippines, São Tomé and Príncipe, Madagascar, and Malawi illustrate significant economic impacts from major disasters. The analysis concludes that disasters can lead to significant exchange rate depreciation, particularly for less developed countries, and stresses the importance of exchange rate matched or hedged borrowing and lending to mitigate financial effects.

Favio Leiva's paper, *Peru's Debt to GDP Ratio, Wars and Earthquakes: 1822-2022*, examines the key factors impacting Peru's public debt over two centuries. Major historical events, such as the independence war and the war against Chile, significantly disrupted economic stability and increased debt levels. The 1980s debt crisis is also identified as another critical period, marked by excessive reliance on foreign loans and weak debt management, exacerbated by external political pressures. Additionally, the *guano-salt-peter-rubber era* is highlighted as a period of unsustainable debt practices. The document underscores the role of internal factors like political instability and corruption, which consistently undermined efforts to manage public debt effectively. Natural disasters are also reported as significant contributors to economic disruptions and increased debt burdens. Overall, Leiva emphasizes the importance of analyzing the historical context to better understand current debt challenges and the need for institutions ready to act during catastrophes and diplomacy to avoid wars.

Session IV - Managing Inflation and Market Risks through Optimal Debt Portfolio Strategies

Antonio Afonso, Jose Alves, Olegs Matvejevs, and Olegs Tkacevs, in their paper *Fiscal Sustainability and the Role of Inflation*, explore the relationship between inflation and fiscal sustainability using a two-step analytical approach. They first estimate a country-specific, time-varying measure of fiscal sustainability through the fiscal reaction function, which captures the response of the primary balance to changes in the public debt ratio. They then analyze how various inflation measures, such as headline, core, energy, and food inflation, affect this fiscal sustainability measure. Their findings indicate that higher inflation rates, particularly core inflation driven by demand factors, positively impact fiscal sustainability by improving the primary balance and reducing the real value of government expenditures. The study shows that fiscal sustainability varies across countries and over time, deteriorates during economic downturns, and tends to improve with higher inflation rates.

Ruurd Brower, Victoria Petrenko and David Vavra, in their paper *Inflation-linked bonds are not a good instrument for financing government debt in emerging and developing economies: a view from risk-return analysis*, explore why inflation-linked bonds (CPIL) are not widely used by governments in developing and emerging market economies, despite their potential benefits. They argue that these bonds hold lower risk-return characteristics compared to other borrowing options like foreign currency or plain local currency bonds. CPIL bonds might not be suitable for economies with strong exchange rate control and weak inflation control, or those with high real exchange rate volatility, due to their higher risk-adjusted borrowing costs. The authors suggest CPIL bonds might be more suitable for economies with good inflation control and lower real exchange rate volatility.

Daniel Carvalho Cunha and Dimitris Drakopoulos are the authors of the paper *Does the creation of a sovereign inflation-linked bond market (information) reduce the domestic financing risk? The interplay between term premium and the demand for government securities*. This study explores the strategic role of inflation-linked bonds (ILBs) in government borrowing. They argue that ILBs can enhance debt maturity profiles and replace foreign currency-linked securities with domestic alternatives, potentially reducing risks tied to short-term borrowing. The authors find that ILBs improve investor information, potentially increasing demand for sovereign debt. Their empirical analysis reveals notable enhancements in risk metrics for emerging market economies. A case study focusing on Brazil shows how ILBs have effectively improved the country's debt profile by extending maturities and minimizing foreign exchange mismatches. The authors conclude that ILBs can be a valuable tool for managing sovereign debt, particularly in environments marked by heightened inflation term premiums.

The paper *The Dynamic Canadian Debt Strategy Model* by Nicolas Audet and Joe Ning presents recent improvements to the Canadian debt strategy model. They developed an innovative analytical model exploiting both a simulation engine and a debt issuance optimization engine. This model allows for dynamic issuance strategies, where issuing decisions depend on the model's state variables. This approach contrasts with traditional fixed or deterministic strategies, showing significant improvements in cost and risk management of public debt. Their dynamic model offers a more realistic and flexible approach, adapting issuance strategies to various economic scenarios and overcoming the limitations of fixed-weight model. Preliminary results indicate that dynamic strategies provide better cost and risk outcomes compared to deterministic strategies.

Session V - Climate Change and Public Debt: Sustainable Strategies and Emerging Markets Insights

The paper *The impact of the creation of Sovereign ESG Reference Yield Curve on Corporate ESG Bonds Issuances from Latin America and the Caribbean*, authored by Daniel Cunha, Giovanna Craveiro, and Marina Rossi, argues that establishing an ESG sovereign yield curve could significantly boost corporate ESG bond issuances in that region, with an estimated 60% increase in volume within three

years. Creating a liquid market for ESG sovereign bonds is crucial for designing a reliable yield curve that serves as a benchmark for investors, reducing uncertainty and improving transparency. The authors identify two main mechanisms through which the ESG sovereign yield curve positively affects the corporate ESG bond market: the “crowd-in” mechanism, and the “novelty/publicity” channel. Empirical data shows that countries with an ESG sovereign yield curve experience faster growth in ESG bond issuances. The paper suggests that governments in Latin America and the Caribbean should implement such yield curves to develop the ESG bond market and attract sustainable investments.

Benche Lukács and András Bebes in their paper *ESG budgeting and the next generation of sustainable bonds* highlight the need for integrating climate and gender mainstreaming into public budgets and proposes a new category of sustainable bonds: *Green Budget Linked Bonds* (GBLBs). Their holistic approach aims to enhance transparency in public resource management, increase accountability, and reduce greenwashing risks, thereby improving the issuer’s ESG rating and potentially leading to more favorable funding conditions. For investors, an ESG-focused accounting environment aligns with social responsibility expectations and improves risk perception associated with sustainability bonds. The integration of ESG budgeting and sustainable bonds issuance creates a symbiotic relationship, enhancing transparency and accountability in public policies. The introduction of GBLBs could simplify reporting processes by directly linking financial instruments to state budgets, offering a more comprehensive view of public spending.

The paper *Mobilizing Private Finance for the Climate Agenda: Introducing Sustainability-Linked Intermediated Debt Instruments (SLIDIs)* by Marcello Estevão, Stephen Stretton and Nils Zimmermann presents SLIDIs as a financial solution to reduce borrowing costs for developing countries while incentivizing progress ESG dimensions. SLIDIs aim to overcome the limitations of existing sustainability-linked bonds (SLBs), which have seen a decline in issuance due to complexity and greenwashing concerns. SLIDIs are designed to attract private sector capital for sustainable development in developing countries. Their technical structure may rely on two frameworks: *Development Bank/Trust Fund Side Payments* and *Trusted Intermediary*. Both models tie financial incentives to the achievement of specific sustainability-related KPIs, with sovereign borrowers receiving financial rebates upon meeting these pre-defined KPIs, promoting progress in ESG dimensions.

Finally, **Jean Pesme**’s closing remarks emphasized the event’s success in merging theoretical research with practical insights. He highlighted the importance of the conference as a platform for academics and practitioners to exchange ideas, noting the need for more private sector involvement in future events. Key topics included the historical analysis of inflation-linked bonds and the integration of climate and ESG considerations into public debt management. Pesme underscored the World Bank’s commitment to supporting developing economies in greening their financial sectors and enhancing financial resilience. He also stressed the significance of developing domestic government bond markets, supported by the *Local Currency Bond Market framework* and the *Joint Capital Market Program*. Pesme concluded by thanking the organizers, participants, and speakers, expressing optimism for continued exploration of these topics in future conferences.

Overall, the conference successfully fostered a valuable exchange of ideas between academia, institutions, and market practitioners, reinforcing the critical role of collaborative efforts in navigating the complex landscape of public debt management.

WELCOMING REMARKS

Lars Jessen

Lead Debt Specialist, The World Bank

On behalf of the organizing committee, it is a great honor to welcome you to World Bank Headquarters for the third public debt management conference organized by the Public Debt Management Network.

The Network is a collaboration between the Italian Treasury, OECD, and the World Bank. What the Network does in addition to organizing this public debt management conference is having quarterly webinars on issues related to debt management and providing information and knowledge through the PDM Network website.

When this type of conference – mixing debt managers and academics – was suggested back in 2018, we from the World Bank were quite skeptical whether it would work. Following two successful conferences in 2019 and 2022, this year we had 65 papers submitted, had to stop the in-person registration at 200 participants, and on top of that we have 240 signed up for online connection. In other words, there seems to be interest.

With that, let me hand over to Frederico Gil Sander, Practice Manager in the Macroeconomics Trade and Investment Global Practice here in the Bank.

OPENING REMARKS

Frederico Gil Sander

Practice Manager, The World Bank

On behalf of the World Bank, I am delighted to extend a warm welcome to each of you attending the third Public Debt Management Conference under the PDM Network, whether you are here or connecting virtually. This is the first PDM conference held outside of Europe, so let me welcome you to the World Bank in Washington, DC. We are thrilled to host you in our headquarters.

This gathering brings together esteemed debt managers and academics from around the globe to delve into the pressing issues surrounding public debt management. We look forward to engaging discussions and a vibrant exchange of ideas and experiences to enrich our collective understanding.

We also convene at a time when debt managers face unprecedented challenges – high debt vulnerabilities, climate change, and sluggish growth.

First, many of the world's poorest countries are facing high debt vulnerabilities. Interest rates remain high, global growth is weak, and multiple global crises make repayment more difficult. As of June of this year, over half (52 percent) of the poorest countries were at high risk or already in debt distress. While this is a reduction from the 58 percent reached in 2021, it remains concerning—and the danger is not limited to low-income countries, with many middle-income countries facing a liquidity crunch.

High debt vulnerabilities underscore the need for strategic macroeconomic policies and robust debt management practices. Since 2020, there have been 18 sovereign defaults in 10 developing countries, greater than the number recorded in the previous two decades.

Still-high interest rates and multiple global crises make repayment more difficult. In some countries, debt service payments are constraining resources for health, education, and other essential public goods.

These large funding needs have coincided with a period of active monetary policy to bring inflation under control. In the US, the Federal Reserve raised the federal funds rate 11 times between March 2022 and July 2023, in the fastest tightening cycle in four decades. The Fed was not alone - over 90% of central banks had raised their policy rates by February 2023.

This year, the fight to reduce inflation has now been largely successful in advanced economies. Three weeks ago the European Central Bank made a second cut to its policy rate this year, as inflation has cooled towards the central bank's 2% target. Days later, the Fed surprised markets with a 50 basis points cut, its first-rate reduction of this new easing cycle.

While these lower global rates will result in more affordable borrowing conditions for developing countries, we recognize that the era of ultra-low rates is unlikely to return. As a result, striking a balance between securing necessary funding and maintaining prudent debt sustainability will remain difficult. Higher global interest rates change investor preferences and can redirect capital away from developing

countries. It is imperative to implement cost-effective funding mechanisms and explore innovative financing options to navigate this landscape successfully.

Second, debt managers face the impact of climate change. Climate change presents an even greater demand on effective economic management. Over the last decade, low-income countries have been hit by nearly eight times as many natural disasters relative to the 1980s. This global shift, already underway, requires us to integrate climate considerations into our fiscal strategies and our financial systems.

Disaster risk finance helps manage the financial losses from natural disasters worsened by climate change, affecting both developing and advanced economies. ESG debt instruments, such as green and sustainability linked bonds, can mobilize private capital for climate action. Understanding these instruments' structure, demand, and pricing is essential to maximize their effectiveness.

Third, we recognize that economic growth is an essential component to free up fiscal space and maintain debt sustainability. Low levels of tax revenue collection can negatively impact economic growth by limiting investment in critical infrastructure and restricting funding of essential public services. The outcome is often greater income inequality and an overreliance on debt. Research has found that raising taxes from 7 to 15 percent of GDP can improve countries future cumulative GDP growth by over 10 percentage points.

The World Bank is responding by working with the IMF on a comprehensive package to enhance fiscal space for resilience. The package rests on three pillars: 1) domestic resource mobilization, facilitated by the WB-IMF Joint Domestic Resource Initiative, and support for structural reforms; 2) external financial support, including from the IFIs; and 3) innovative financing mechanisms, such as guarantees and debt-for-development swaps.^a

In the face of these challenges, there are also opportunities. In the call for papers for this conference, we specifically asked for research on disaster risk, the use of new funding instruments, and managing debt in an inflationary environment. This conference serves as a crucial platform for fostering such innovation and collaboration.

Let us use this opportunity to learn from one another, share our insights, and work together towards effective solutions that will help shape the future of public debt management.

Thank you again for being here, and I look forward to fruitful discussions over the next two days.

^a UN General Assembly (UNGA) talking points 09 20 24.

KEYNOTE SPEECH - SOVEREIGN DEBT AND CLIMATE FINANCE

Ugo Panizza

*Professor of Economics and Pictet Chair in Finance and Development
Geneva Graduate Institute*

Today, I will discuss the link between sovereign debt and climate finance, with a particular focus on the role of contingent debt instruments. My presentation is structured into three parts. First, I will define the problem using one table, three graphs, and one map. Second, I will explore different ways of thinking about the issue. Finally, I will discuss financing strategies, emphasizing three key aspects: innovative financial instruments, mitigation, and adaptation.

Understanding the Carbon Budget

One effective way to approach this issue is by examining the concept of the carbon budget. The carbon budget refers to the amount of carbon dioxide (CO₂) that can still be emitted into the atmosphere before global temperatures exceed critical thresholds.

At the beginning of 2024, scientists estimated that:

- To limit temperature increases to 1.5 degrees Celsius with an 83% probability, the world could emit up to 200 gigatons of CO₂.
- For a 1.7-degree increase, the budget was 450 gigatons.
- For a 2-degree increase, it was 800 gigatons.

Currently, global CO₂ emissions stand at approximately 40 gigatons per year. This means that at the current rate, the 1.5-degree budget will be exhausted in just five years. This stark reality underscores the urgency of achieving net-zero emissions as soon as possible—a formidable challenge.

The Stock Problem of Climate Change

Climate change is fundamentally a stock problem because CO₂ remains in the atmosphere for centuries. The crisis today is the result of accumulated emissions over the past 100 to 200 years. Historically:

- In 1995, advanced economies were responsible for approximately half of all carbon emissions, with the U.S. alone contributing about 25%.
- At that time, developing and emerging economies accounted for less than 40% of total emissions.
- Today, developing economies—particularly China, India, and Russia—are major emitters. China alone emits over 11 gigatons annually, more than one-quarter of global emissions. The U.S. follows at approximately 5 gigatons, with India and the European Union each contributing about 3 gigatons.

Who Emits and Who Suffers?

If we visualize emissions on a map where country size is scaled by emissions, the largest contributors—China, the U.S., Europe, India, and Japan—dominate the image. In contrast, regions like Sub-Saharan Africa and Latin America appear nearly nonexistent. However, if we instead scale the map by climate vulnerability, an entirely different picture emerges:

- North America and Europe shrink significantly due to their lower vulnerability.
- Africa, small island, and part of South Asia expand dramatically as they face the highest risks from climate change. These are also the countries at high risk of debt distress.

Debt Distress and Climate Vulnerability

Ideally, in a world without national borders—echoing John Lennon's vision in his famous song Image—wealthier, high-emission nations would transfer resources to vulnerable nations suffering the consequences. Unfortunately, such transfers are insufficient or nonexistent at the scale needed.

Financing Climate Action: Mitigation vs. Adaptation

Climate finance must address two distinct areas:

1. Mitigation: Efforts to reduce CO₂ emissions, thereby decreasing the likelihood of severe climate change.
2. Adaptation: Investments to cope with existing and inevitable climate impacts.

Mitigation is a global public good—when a country reduces emissions, it benefits everyone. However, there is little financial incentive for nations to invest in mitigation since the benefits extend beyond their borders. For example, a poor nation with oil reserves may face significant economic costs if it chooses not to extract the oil for the sake of climate goals. Without compensation, such actions are unlikely.

Market-Based Solutions: Green and sustainability linked bonds

One financial instrument that has been proposed as a market-driven solution to climate change is green sovereign bonds.

Green sovereign bonds are issued by governments that commit to using the raised funds for environmental initiatives. In theory, investors accept a lower interest rate in exchange for supporting these green projects. However, there are two fundamental problems with this approach.

First, there is no binding commitment that ensures the money is actually spent on environmental projects. Governments may issue these bonds without strict accountability. Second, there is no real evidence that investors are truly willing to accept a lower return purely for the sake of sustainability.

This situation reminds me of an old joke from the Soviet Union: “They pretend to pay us, and we pretend to work.” In this case, the joke could be rephrased: “Countries pretend to invest in green projects, and we pretend to lend to them at lower interest rates.”

A more effective approach is sustainability-linked bonds. Instead of merely promising to allocate funds in a certain way, countries commit to meeting specific environmental targets. If they fail to meet these goals, they are required to pay higher interest rates.

This model is more compelling because it aligns incentives: investors will have a reason to monitor governments, as they benefit financially if the targets are not met. This creates real accountability in a

way that traditional green bonds do not. However, the market remains very small and it is not clear if there is potential for scaling it up substantially

So, going back to John Lennon, you may say that I am not a dreamer. If the success of sustainable finance depends only on the hope that investors will voluntarily accept lower returns, then its impact will be limited. People will always prioritize returns over environmental concerns.

The key is not just relying on goodwill but designing financial instruments that create strong incentives for action. That is how we move beyond dreams and towards real change.

Market-Based Solutions: Compulsory Carbon Offsets

A well-functioning carbon credit market could help address this issue. In such a system:

- Countries with vast forests or untapped fossil fuels could sell carbon credits to high-emitting nations.
- This would enable financial transfers from rich to poor countries, not as aid but as compensation for preserving valuable carbon sinks.

Consider the Amazon rainforest. Research by a group of scientists together with Nobel laureate Lars Hansen and economist José Schenkman suggests that:

- The Amazon stores approximately 120 gigatons of captured carbon.
- Between 1985 and 2021, deforestation grew rapidly the reduction of the rainforest corresponds to an area nearly the size of Texas.
- A compensation mechanism valuing CO₂ at \$15 per ton could provide Brazil with substantial financial incentives to preserve the rainforest. At \$25 per ton, the economic cost of preservation would be fully offset.

Given that carbon in the European Union's trading system is valued nearly \$100 per ton, such an arrangement would be an affordable and effective way to reduce emissions.

Climate Change Adaption: The Role of Debt Restructuring

Many activists advocate for debt relief as a solution for financing climate adaptation. However, this approach is not always the most effective. The Tinbergen Rule in economics suggests that different objectives require different instruments. In other words, debt relief may not be the best tool for financing adaptation.

- If a country has unsustainable debt, restructuring is necessary.
- However, if the goal is to finance adaptation expenditure, direct grants or financial transfers are more effective than debt relief. This is because a country relieved of debt might not necessarily use those funds for climate adaptation.

That said, in politically constrained scenarios, financing adaptation through debt relief might be a second-best option.

The Future of Debt Sustainability Analysis

Going forward, debt sustainability analyses must incorporate climate-related expenditures. If, in a debt restructuring, a country receives a larger haircut in exchange for expanding climate adaptation funding, it is crucial to ensure that the relief funds are genuinely allocated to those activities.

There is a fundamental challenge when it comes to conducting debt sustainability analysis, particularly in cases of debt distress. At its core, debt sustainability analysis requires us to predict a country's future ability to pay. But to do that, we must make assumptions about economic growth, interest rates, and fiscal balances—factors that stretch far into the future and are inherently uncertain.

In fact, my colleague Charles Wyplosz once described debt sustainability assessments as "Mission Impossible." And speaking of that, the IMF—the International Monetary Fund—is often responsible for making these assessments. But maybe, if we think of them as a true mission impossible, we should hire Tom Cruise! After all, in his famous film series, he worked for the IMF—though in that case, it was the Impossible Mission Force.

Jokes aside, how do we improve this situation? One way is by embedding uncertainty directly into the restructured debt. Instead of rigid repayment schedules, restructured debt could incorporate sustainability-linked conditions and be contingent on economic outcomes beyond a country's control. This approach—using contingent debt instruments—allows countries to pay more when they can and less when they cannot. It is an idea that has been around for a long time and has been tested.

However, while these instruments work well in theory, they have struggled in practice. The key issue? Asymmetry. Many of these instruments are designed so that a country must pay more when its situation improves, but they often fail to provide relief when conditions worsen. This imbalance undermines their effectiveness. In a recent policy note for the Finance for Development Lab, I explored the pitfalls of value recovery instruments in sovereign debt restructuring and highlighted this fundamental flaw.

Some argue that because these instruments have not yet worked as intended, we should abandon the idea altogether. But I believe that would be a mistake. Innovation is rarely instantaneous. Think about the airplane: for years, there was a sound theoretical basis for heavier-than-air flying machines, but repeated attempts ended in failure. Then, in 1903, Wilbur and Orville Wright changed everything. Within a decade, airplanes were not just flying but transforming industries and warfare alike.

Debt restructuring innovations should be no different. Just because contingent debt instruments have not worked well yet does not mean they never will. We must refine them, iterate, and improve their structure until they fulfill their intended purpose. We have already explored similar ideas, such as financing mechanisms for pandemic-related expenditures during COVID-19. Why not apply the same creativity to financing climate change adaptation?

The lesson here is clear: we should not discard ideas that are theoretically sound just because they have yet to succeed in practice. Instead, we must keep thinking, innovating, and searching for solutions.

I do believe that, with perseverance, we can build a world where debt restructuring works better, where economic resilience is strengthened, and where countries have a fairer shot at growth and stability.

So maybe, I am a dreamer, after all.

Thank you very much.

SESSION I

Understanding Public Debt Spikes: Implications for Debt Management and Debt Sustainability

Debt Service Spikes and Debt Distress*

David Mihalyi^a

Abstract

Good debt management enables governments to minimize rollover risks and ensure a smooth debt maturity profile. This paper introduces a novel measure of debt management effectiveness as captured by the volatility of a country's debt service patterns. While narrow in its focus, this measure has large coverage of 115 countries and a 40-year period. This paper documents how debt management and debt policy improvements are associated with a reduction in debt service volatility. I also show how spikes in debt service, particularly during bad economic times are associated with higher probabilities of debt distress episodes. Taken together, these findings highlight the importance of active debt management for improving debt sustainability.

Keywords: Sovereign debt, Debt management, Debt policy, Default

JEL Code: F34, H63, G01

* Version as of November 2024.

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1. INTRODUCTION

Public debt management enables governments to meet their financing needs at the lowest possible cost at prudent levels of risk. Mitigating rollover risk arising from large external debt service spikes is a key concern of debt management. Such risks are particularly elevated in developing countries whose ability to raise (hard-currency) debt in any given year may prove challenging depending on market conditions. Large temporary external government funding needs can lead to debt distress with potentially adverse macroeconomic conditions. However, despite its importance, there is little systematic empirical evidence linking debt management to debt sustainability in developing countries. (World Bank, 2022)

Governments differ in their ability to minimize rollover risk arising from debt service spikes depending on the level of capacity, institutional autonomy and technical support they can secure. Debt management offices are the primary institutions tasked with closely monitoring the country's debt portfolio and develop medium-term debt management strategies to minimize rollover risk.¹ They should issue new debts accordingly and use active liability management tools to reduce the size of any expected debt service humps (Jonasson et al., 2019; World Bank, 2020). For example, in 2018 the government of Benin issued a 10-year loan to repurchase debt that was to mature in large volumes over next few years (World Bank, 2022). On the other hand, many other emerging market bond issuers have failed to take advantage of more benign financial conditions to re-profile their debt and now face a wall of debt maturities in 2024-2026 period (Smith, 2021).

There are also structural trade-offs that debt managers face in optimizing their debt portfolio. A larger number of smaller debt instruments can help create a smoother repayment profile, but such smaller instruments may be less liquid. This is particularly challenging for countries with smaller debt volumes. Fixed interest rate instruments are less volatile, but investors may demand additional compensation for the duration risk they take. Project lending (including from bilateral, multilateral and other private creditors) may come with repayment profiles that are aligned to revenue stream that the project is expected to generate. Finally, countries ability to issue longer-term debt critically depend on market conditions and investor's trust in future repayment capacity (Bai et al., 2017; Broner et al., 2013). While these structural factors are important, they should not overshadow the efforts by DMOs in actively managing their debt repayment profile and avoiding debt service spikes.

In order to measure the effectiveness of such efforts across countries and over time, this paper introduces a new measure of external debt service volatility. It is measured across 115 countries for the period 1980-2022. It captures the size of deviations from trend in external public debt service based on data from the World Banks' International Debt Statistics. It enables to measure differences across countries and changes in volatility over time. It also captures spikes in debt service, defined as years in which debt service is well above its trend level.

Debt service volatility is large across emerging market and developing economies. Debt service deviates from their trend value by 1 percent GDP on average. A 50 percent annual jump in nominal debt service due is a 1-in-13-year event for countries in the sample. Large fluctuations are observed across global regions, but are particularly pronounced in small states. Volatility has also declined sharply over time. These findings suggest that debt management offices across the world have become better at dealing with the volatility challenge, but small states have lesser means to do so.

Weaker debt policy and debt management and, more generally, weaker policies and institutions are associated with larger debt service volatility. A one-point improvement in CPIA debt management and policy score (on the six-point scale) is accompanied by a decrease in debt service volatility of

¹ A collection of debt management strategies across developing countries alongside guidance for practitioners is available here.

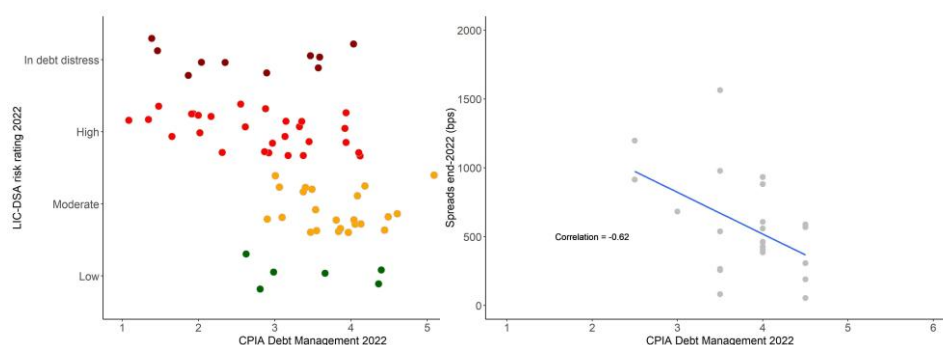
roughly 13 percent. These patterns hold both across countries and within a country over time. The paper shows that among the debt instruments, the volatility of debt service is strongest for bonds and that principal repayments add more to volatility than interest payments.

Finally, I show that spikes in debt service coincide with the onset of debt distress. I augment a classical debt sustainability model (Kraay and Nehru, 2006; IMF-WB, 2018; Kraay et al., 2023) with a decomposition of trend and residual debt service. It shows that the residual debt service is a significant predictor of the debt distress setting in the same year and the year after. I also show that such risks are accentuated when they coincide with the country undergoing harsher economic conditions (as proxied by growth in the region to overcome some key endogeneity concerns). This finding highlights the benefits of smoother debt service in minimizing the risk of debt distress onset. More generally it establishes an empirical link between debt management effectiveness and debt sustainability.

The paper adds to the literature on sovereign debt in two ways. First, it introduces a new (albeit partial) measure of debt management effectiveness which stands out for its large country-year coverage. The most refined existing measure is the Debt Management Performance Assessment (DeMPA) which relies on an extensive questionnaire (Estevao et al., 2021). But since it was launched in 2007, its methodology has been revised twice and so far has been used in less than 200 country-year instances and not all assessments are publicly disclosed. An alternative measure is the CPIA's Debt Management sub-component, which relies on expert judgment, is measured since 2011 and not published (World Bank, 2023)². A third measure is focused on the quality of reporting by debt management offices as tracked on the Debt Reporting Heatmap (Rivetti, 2022). The measure I introduce captures novel aspects tied to the role of the debt management office in minimizing rollover risks.³

It also adds to the growing empirical literature on the macroeconomic impact of debt management. While countries with better debt management performance typically also have lower financing costs and lesser debt sustainability risks (as illustrated in Figure 1),

Figure 1. Debt management vs debt sustainability



Notes: The above graphs show a cross-country correlation between the CPIA debt management subcomponent score (2022) and on the left the rating according to latest 2022 LIC-DSA assessment (for countries with limited market access), and on the right with spreads (for countries with market access).

this does not necessarily imply any causality. A few papers have analyzed the causal chain between debt management and various macroeconomic outcomes, these often focus on the benefits of

² Indicator is only published after aggregating with debt policy sub-component of CPIA and only for IDA-eligible countries.

³ The measures are generally positively correlated across countries in the recent period when such data is available. See Appendix Table 1.

debt transparency (Choi and Hashimoto (2018); Islam and Lederman (2020); Horn et al. (2024)). The closest piece to my research is Pedersoli and Presbitero (2023), which focuses on the impact of debt management on financial development but is limited by relying on CPIA-based measure and a small sample. This piece sheds light on a specific mechanism by which debt management fosters debt sustainability.

The paper is structured as follows. Section 2 discusses the data used and measurement approach, Section 3 discusses the properties of the debt service volatility variable constructed, Section 4 discusses the drivers of debt service volatility and highlights the importance of debt management effectiveness, Section 5 presents evidence linking debt service spikes to debt distress and Section 6 concludes.

2. DATA AND MEASUREMENT APPROACH

In this section I discuss how I construct measures of debt service volatility and debt service spikes, which are at the core of the subsequent analysis.

I use external debt service data from the World Bank's International Debt Statistics (IDS). This is by far the most comprehensive and most disaggregated source of cross-country information on debt service. All countries borrowing from the World Bank have to report their outstanding debt and debt service to this database using standardized templates and based on guidelines which have changed little over time. The debt service figures can be broken down between key creditor categories. A key limitation of the dataset is that it only captures external debt service, not domestic debt service.

I use debt service due, rather than actual debt service paid to avoid any bias from missed payments by countries in difficulties or with poor repayment track records. This debt service due series is estimated the same year by the team maintaining the database, based on information on outstanding debt, terms and repayment profile. The estimated debt service for any given year is published annually.⁴ For robustness, I explore using actual annual external debt service paid plus increase in principal and interest arrears.⁵

The main step is then to decompose the debt service figure for any country/year into a trend and a gap component to capture the volatility of debt service and the timing of debt spikes. The main decomposition method I use relies on the Hamilton filter to decompose trend and residual.⁶ For robustness, I explore using a simple 5-year moving average (current year and 4 years prior) of the debt service to calculate the trend variable and the difference between debt service and trend debt service represents the residual.

For the purpose of scaling the debt service variable, I rely on a 10-year moving average of GDP. Using such a smooth series avoids introducing bias from GDP fluctuations. Scaling to GDP rather than using debt service to exports (which is also an often-quoted measure) allows to lose fewer observation for lack of scaling variable. Additionally, I also present results scaling the residual to the trend value. This measure of 'relative volatility' accounts for differences in debt service levels.

My preferred measure of a debt service spike is the difference between the debt service due in a given year from its trend value (based on Hamilton filter) as a percent of GDP. A positive value

⁴ The dataset of annual debt service due estimates (alongside forecasts for the next five years which we do not use) is not readily published in this form, but could be retrieved from across annual publication vintages as done in Horn et al. (2024).

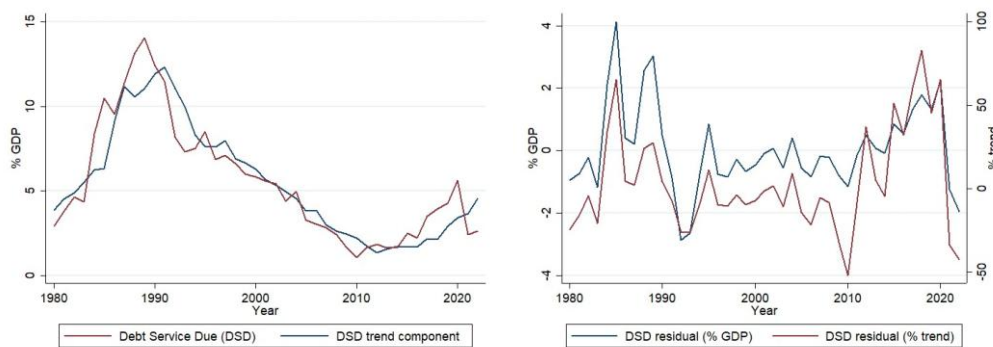
⁵ Results shown in appendix.

⁶ The Hodrick-Prescott (HP) filter is deemed inappropriate given relatively short period and frequency marked with multiple data gaps which results on frequent end-point values, to which the HP filter is highly sensitive (Hamilton, 2018).

represents the spike, a negative is a dip. My preferred measure of debt service volatility (also referred to as debt service smoothness) is their absolute values over the years, the higher the number the more volatile debt service is. Figure 2 provides an illustration of the concept for Ecuador. The left panel shows how the debt service due series is smoothed to create a trend debt service level. The right-hand side shows the residual, that is the gap between debt service due and its trend value measured as percent of (trend) GDP and as percent of trend debt service value.

In order to measure institutional and policy quality, I use the World Bank Country Policy and Institutional Assessment (CPIA) and its most relevant sub-components. The overall score provides a broad and comparable measure across a large range of developing countries since 1977. Since 2004, the measure is decomposed between 16 components (labeled criteria) of which Debt Policy and Debt Management is of particular relevance for this research. This in turn can be decomposed into sub-indicators measuring Debt Management and Debt Policy since 2011 (thus drastically limiting the sample size). The CPIA Debt Management subcomponent measures the effectiveness of debt management functions (including the degree of coordination between debt management and other macroeconomic policies, the effectiveness of the debt management unit, and the existence of a debt management strategy and of a legal framework for borrowing). The Debt Policy sub-component is measuring the extent to which external and domestic debt is contracted with a view to achieving/maintaining debt sustainability.

Figure 2. Debt service decomposition - an illustration



Notes: The above graphs show the decomposition of Ecuador's annual debt service due into trend and residual components. The debt service due is both shown as a share of (10-year moving average) GDP and as a share of the trend of debt service due.

Hence the former sub-component is more directly tied to the ability of governments to conduct good debt management, which is this research's core interest, but is not public and only available since 2011. The latter measure is more likely to reflect debt sustainability concerns associated with debt service spikes, potentially introducing endogeneity when used as a control variable.

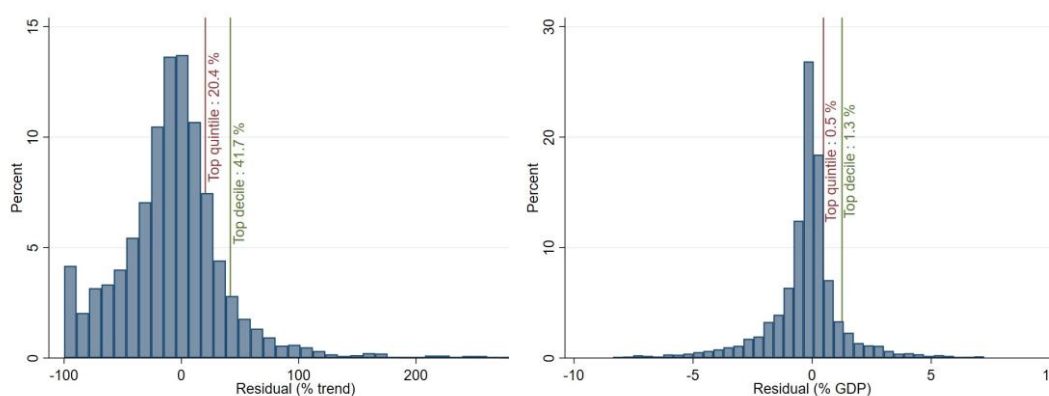
In addition to using debt service and institutional quality data, I rely on the following datasets. Core macroeconomic variables (GDP, export, reserves) used to measure debt sustainability are from the World Development Indicators (WDI). In order to measure debt sustainability challenges, I use a dummy variable which captures the year of the onset of debt distress episodes from Kraay et al. (2023). Regional splits are based on World Bank categorizations. Appendix 2 shows descriptive statistics of the variables used in subsequent analysis.

3. PATTERNS OF DEBT SERVICE VOLATILITY ACROSS DEVELOPING COUNTRIES

In this section I present key characteristics of the measure of debt service volatility and how it varies across the database of 115 countries and 40-year period.

As shown in Table 1, the volatility of the debt service is large. On average countries spend 3 percent of GDP on external debt service annually but with an average distance from trend value of 1 percent GDP. In other words, debt service is equally likely to be 33 percent above or below its trend value than being within that range. The histograms shown in Figure 3 further illustrate the magnitude of volatility. Once every ten-year debt service is 42 percent above its trend value or 1.3 percent GDP above the trend value.

Figure 3. Histogram



Notes: The above graphs show the histogram for the preferred measure of debt service volatility. The left panel scales the variable to the trend value of debt service. The right panel scales it to (10-year moving average) GDP.

Table 1. Summary statistics by group

	N	Debt service volatility (% GDP)	Debt service trend (% GDP)	Debt service residual as share of trend (%)
<i>Full sample</i>	4700	1.07	3.35	32
<i>Regions</i>				
East Asia and Pacific	636	.71	2.08	34
Europe and Central Asia	561	1.08	1.95	55
Latin America & the Caribbean	938	1.01	4.29	24
Middle East and North Africa	444	1.01	4.25	24
South Asia	309	1.27	1.97	64
Sub-Saharan Africa	1812	1.21	3.75	32
<i>Decades</i>				
1980s	970	1.85	4.3	43
1990s	1068	1.57	5	31
2000s	1141	.74	2.83	26
2010–22	1521	.47	1.96	24
<i>Income groups</i>				
Upper-middle income countries and above	1751	1.04	3.09	34
Lower-middle income countries	1900	1.08	3.59	30
Low-income countries	1049	1.1	3.35	33
<i>Small state</i>				
No	3717	.97	3.29	30
Yes	983	1.44	3.55	41

Further statistics that split the sample of 141 emerging market and developing economies across groups and over time are presented in Table 1. It shows that debt service volatility has declined significantly over time: the ratio of residual vs trend debt service has dropped to half from their level in the 1980s. Large fluctuations are observed across all global regions and all income categories. But they are particularly pronounced in countries which are classified as small states.⁷

4. DRIVERS OF DEBT SERVICE VOLATILITY AND THE ROLE OF DEBT MANAGEMENT

This section documents some key drivers of debt management volatility. I decompose volatility drivers by instruments, into principal and interest repayment component. I then discuss the role of exchange rates and of economic cycles. Finally, I analyze the role of policies and institutions generally, as well as narrower measure of debt policy and debt management.

Figure 4 shows the volatility of debt service across instruments. It documents the range of residual to trend debt service ratio. Multilateral and bilateral debts have relatively smooth debt service profiles, as shown by the narrower boxes. On the other hand bonds are the most volatile, with bank loans in between.

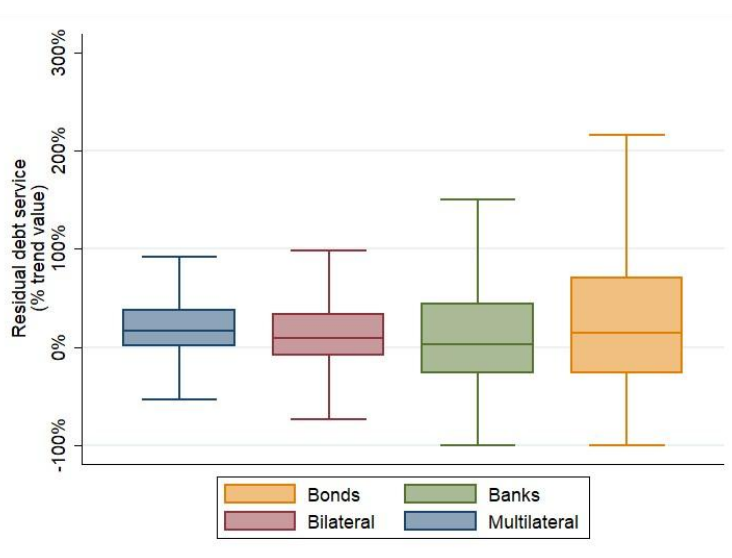
⁷ The World Bank's list of small states used is available here. I kept the list of countries is kept unchanged over time for simplicity.

Figure 5 shows the volatility of the debt service split between amortization/principal repayments and interest payments. Amortization payments due can be highly unequal given long grace periods in loans and large 'bullet' payments in bonds. Interest payments can fluctuate more if countries rely heavily on instruments with variable rates or with 'step-ups' in interest rates. As shown by the wider boxes, principal payments are over twice as large a contributor to overall debt service volatility.

I do not analyze the impact of exchange rate fluctuations on external debt service payment volatility given their expected small impact in the approach I use. This is because the database is measured in USD and much of the external debt portfolio is either in USD or other currencies with strong co-movements.⁸ The impact of exchange rate movements on debt service volatility measured in domestic currency are expected to be large, but should be subject to a separate study with somewhat different methodological approach.

I do not find evidence for any significant cyclical pattern to debt service. As shown in Appendix Figure 1 debt service residuals are near zero on average both in boom times (when the country is growing stronger than its trend performance) and in bad times (when growth is below trend). I then analyze the relationship between debt service volatility and the country's policies and institutions (using the CPIA score) and its sub-component measuring the quality of debt policy and debt management (since 2004). First, the binscatter plot in Figure 6 shows that debt service volatility is lower in countries with stronger institutions.

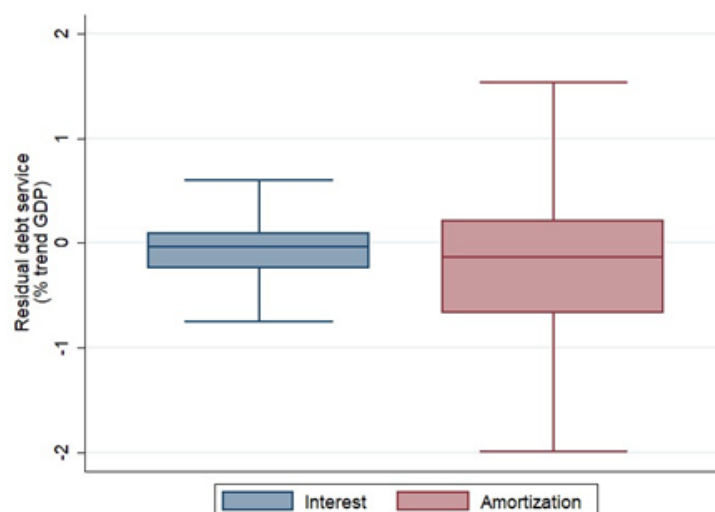
Figure 4. Debt service volatility by instrument



Notes: The above graph shows a box plot of the relative volatility of debt service to various creditor types. The box represents the middle 50 % of observed values. The bottom of the box is the first quartile (25th percentile) and the top of the box is the third quartile (75th percentile). Volatility is measured as the share of residual debt service to trend debt service, where the thinner the range the smoother the debt service. This measure isn't biased by the relative size difference across creditor groups.

⁸ As of 2022, 81 percent of external debts outstanding in the IDS database are in USD. Adding Yen, Euro and SDR takes the ratio 95 percent.

Figure 5. Debt service volatility - Amortization vs interest



Notes: The above graph shows a box plot of the volatility of principal/amortization vs interest payments due. The box represents the middle 50 % of observed values. The bottom of the box is the first quartile (25th percentile) and the top of the box is the third quartile (75th percentile). It is measured as the share of residual debt service to GDP.

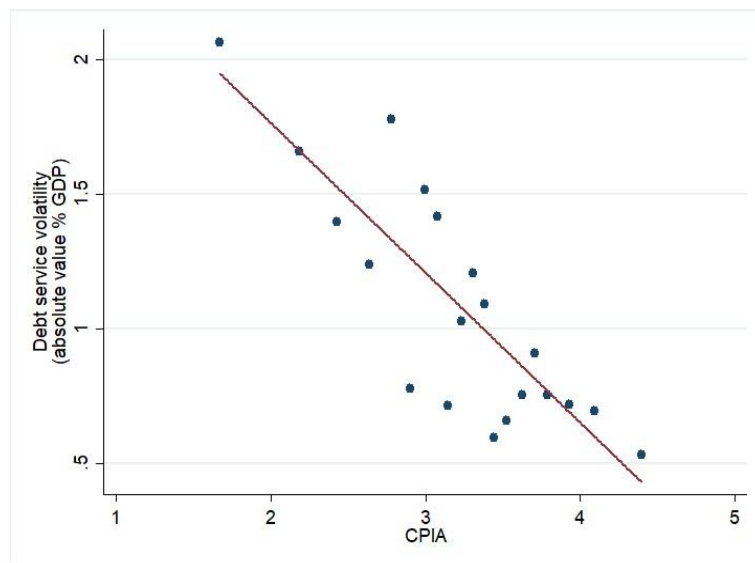
Table 2 provides further evidence from regressions. It shows that countries with weaker institutions and those with weaker debt policy and debt management score in particular have more volatile debt service. These results hold after controlling for time fixed effects which captures the fact that volatility has decreased over time. The regression with both country and year fixed effects highlights that within a country, an improvement in CPIA (or its sub-component) is associated with less volatility in debt service.

The coefficients are sizable. An improvement in debt policy and management score of 1 point on the 6-point scale is associated with a 0.14 percent GDP reduction in debt service volatility. Given that the mean value of the debt service volatility indicator is 1.07, the effect is a 13 percent reduction in volatility at the mean.

Further robustness checks were conducted. In the Appendix Table 4 and 3 I show that the results are similar when using alternative debt service data (debt service paid plus changes in arrears) and when using a 5-year moving average rather than relying on Hamilton filter.

I have identified some key drivers of debt service volatility. Bonds are the instrument, which contribute the most and that principal are a much greater source of volatility than interest payments. I also show that better policies and institutions as well as improvements in debt policy and debt management are strongly associated with smoother debt service.

Figure 6. Debt service volatility and CPIA - Binscatter plot



Notes: The above graphs show the association between countries' debt service volatility (measured as the deviation from trend debt service in absolute value as percentage GDP) and their CPIA score in any given year. Blue dots represent binned averages and the trend line is shown in red.

Table 2. Debt service volatility and policy

Dep. variable: Debt service volatility 1980-2022						
	(1)	(2)	(3)	(4)	(5)	(6)
CPIA	-0.56*** (0.12)	-0.28** (0.12)	-0.20 (0.15)			
CPIA DPM				-0.12*** (0.03)	-0.12*** (0.03)	-0.14*** (0.04)
Observations	4070	4070	4070	1757	1757	1756
R-squared	0.028	0.095	0.249	0.029	0.048	0.346
Year FE		X	X		X	X
Country FE			X			X

Notes: This table shows results from a regression of the absolute size of debt service residuals as percent GDP (debt service volatility) on the lagged CPIA score and the lagged CPIA debt policy and management sub-component (available since 2004). Results are shown with and without fixed effects. Robust standard errors clustered by country shown in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5. FROM DEBT SPIKES TO DEBT DISTRESS

In this section I discuss the link between debt service volatility and debt sustainability. First, I present results from augmenting a standard debt distress prediction model with the timing of debt spikes. Then I show how the impact of debt spikes differs depending on whether they happen in good or bad times.

A probit model is used to examine the predictors of debt distress events, consistent with the literature (IMF-WB, 2018; Kraay and Nehru, 2006; Kraay et al., 2023; Manasse et al., 2003). While a range of predictor variables have been proposed, I follow closely the specification underlying the IMF and the World Bank's debt sustainability framework for low-income countries (IMF-WB, 2018) given its importance for debt policy in developing countries. The dependent variable is the onset of a debt distress event by Kraay et al. (2023) which updates and refines the measure originally used by IMF-WB (2018). Debt distress events are defined as either a default event, the accumulation of sizable arrears or a rapid disbursement under an IMF program.⁹ The explanatory variables include those deemed material for a country's debt-carrying capacity as per IMF-WB (2018): the CPIA, GDP growth, reserve to imports, remittances to GDP and global growth. The main explanatory variable of interest is the debt service to GDP ratio.¹⁰ I show results with additional control variables in the Appendix.

The innovation I introduce compared to earlier models is to separate the debt service ratio into a trend debt service due and residual debt service due component. This allows to capture both whether repayment problems are related to permanently elevated levels of debt service (the trend component) or whether they respond to temporary debt spikes (a large positive residual debt service). One could expect markets to be forward looking and ignore the debt service spikes and rather focus on trend levels, on the other hand if short-term liquidity considerations matter, then spikes should also be significant.

⁹ More specifically: default on private creditors, arrears above 5 percent of external public debt for three consecutive years, IMF disbursements in excess of 30 percent of quota in first six months of a non-concessional IMF program.

¹⁰ As in the previous specification, the debt service is the debt service due rather than the debt service paid. The GDP value is a 10 year moving average to smooth it. I use GDP rather than export or revenue ratios for improved data coverage.

Table 3. Debt service spikes and distress episodes

VARIABLES	Debt distress onset likelihood		
	(1) Same year	(2) Next year	(3) Same and next year
Residual debt service (% GDP)	0.0836*** (0.0269)	0.0838*** (0.0299)	0.100*** (0.0334)
Trend debt service (% GDP)	0.102*** (0.0217)	0.0755*** (0.0221)	0.0936*** (0.0225)
CPIA	-0.435*** (0.0992)	-0.344*** (0.110)	-0.422*** (0.110)
GDP growth (annual %)	-0.0662*** (0.0147)	-0.0279** (0.0117)	-0.0562*** (0.0122)
Remittances (% GDP)	-0.0459*** (0.0120)	-0.0341*** (0.0106)	-0.0437*** (0.0118)
Reserves (% imports)	-0.940*** (0.268)	-1.084*** (0.273)	-1.158*** (0.262)
World GDP growth (annual %)	-0.0764** (0.0342)	-0.0200 (0.0331)	-0.0614** (0.0298)
Observations	1,947	1,939	2,056

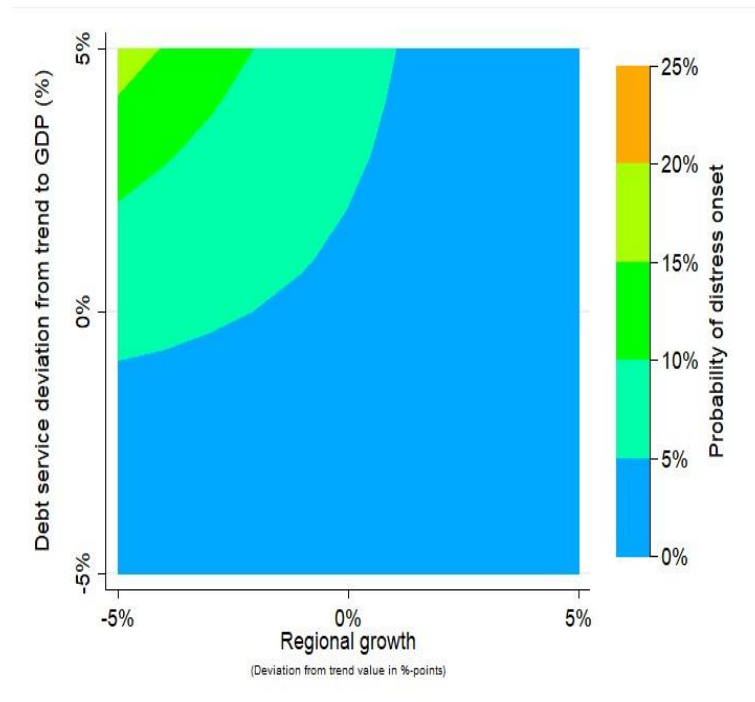
Notes: This table shows probit regression results where the dependent variable is the onset of debt distress from Kraay et al. (2023). Key explanatory variables is the trend and residual debt service due to GDP ratios based on methodology presented above. Control variables follow IMF-WB (2018): CPIA, gdp growth, reserve-to-import ratio, remittance-to-GDP ratio and global growth. Robust standard errors clustered by country shown in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3 shows that both the trend level of debt service and the residual debt service matter. When countries are experiencing debt service spikes they are at higher risk of debt distress onset both that same year and the year after. The two variables have similar sized coefficients suggesting they are of equal importance. The control variables have the expected sign, whereby stronger CPIA, higher country growth, global growth, remittances, and reserves are all negatively associated with debt distress onset. Table 5, Table 6 and Table 7 in the Appendix shows results are similar when using alternative debt service data (debt service paid plus changes in arrears), when using a different decomposition method (5-year moving average) and when adding external debt-to-GDP ratio and the federal funds rates as controls.

Then I turn to analyzing the interaction between debt spikes and the prevailing economic conditions on the probability of debt distress. Because debt spikes may precipitate economic downturns, analyzing growth and debt service simultaneously raises endogeneity concerns. Hence, rather than using the country's own growth, I analyze regional growth (excluding the country's own growth). Regional growth affects the country's own growth, but isn't affected by domestic debt service trends. Hence it allows to capture exogenous variation in economic environment.

I present the combined effects of debt spikes and economic conditions in a contour plot in Figure 7. The coloring highlights the marginal effect of the interaction between regional growth and debt service levels deviate on the likelihood of debt distress. Growth performance is measured by the deviation of regional growth (excluding the country's growth for exogeneity) from its trend values.

Figure 7. Likelihood of debt distress onset



Notes: The above contour plot shows the marginal effects of an interaction term (deviation of debt service and deviation of regional growth from their trend values) of a probit regression where the dependent variable is a dummy capturing debt distress onset events in same year and the year after. Deviation from trend value is measured as the residual from Hamilton filter as a share of GDP. The controls are CPIA score, reserves to imports ratio, annual GDP growth, annual world GDP growth and remittances (in percentages of GDP) following IMF-WB (2018). (Kraay et al., 2023).

The debt service measure is the usual deviation from trend debt service value. The decomposition applies the Hamilton filter. Debt distress is measured as a dummy variable for debt distress onset in the relevant year and the year after.

The contour plot shows that debt distress episodes is much more likely when both debt service is elevated, and regional growth is weak compared to trend value. In the most extreme category alongside both dimensions the probability were over 20 percent. In contrast, during the best of times alongside both axes, the likelihood was below 5 percent. The figure also shows that both axis matter, and that temporarily elevated debt service does not seem to raise distress levels in good times. For robustness, I present results when excluding the additional control variables applied in Appendix Figure 2.

6. CONCLUSION

In this paper I have introduced a new measure of a country's debt management effectiveness based on the volatility of its external debt service. While narrow in scope, it complements existing measures by focusing on mitigating rollover risks, by providing larger country/year coverage and not relying on expert judgments. I have shown key characteristics of this measure, including how it has improved over time but remains a challenge particularly in small states.

I establish a link between debt management and debt sustainability. Improvements in a country's debt policy and debt management scores are followed by decrease in debt service volatility. On the other hand, debt service smoothness matters for debt sustainability, whereby the onset of debt distress

is more likely during debt spikes. This is especially the case when debt spikes occur in economic downturns. While the causal chain between the (unfortunate) timing of debt service spikes and debt distress is plausibly exogenous, the causality between debt management improvements and debt service smoothness is not firmly established. Furthermore, granular work could study the impact of debt management reforms on debt portfolios.

The findings of the paper highlight the benefits of good debt management practices as well as of the use climate resilient debt clauses (CRDCs). Prudent debt management strategies and the use of liability management operations can greatly reduce debt service volatility. 'Debt-pause clauses' offered by an increasing number of official creditors (Mustapha et al., 2023) allow debt service suspension during natural hazards. These tools can help minimize the risk of debt distress resulting from debt spikes in bad times.

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APPENDIX

Table 1. Cross-country correlation across debt management measures in last decade

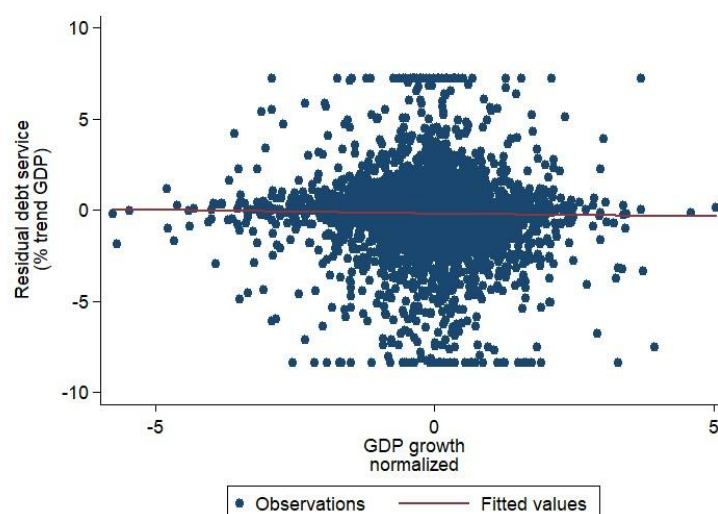
Variables	DeMPA	CPIA Debt Management	Debt Transparency	Debt service smoothness
DeMPA	1.000			
n				
CPIA Debt Management	0.538	1.000		
n	72			
Debt Transparency	0.494	0.481	1.000	
n	59	66		
Debt Service Smoothness	0.105	0.149	-0.194	1.000
n	73	113	66	

Notes: This table shows pairwise correlations across debt management related measures. For DeMPA it captures the share of indicators in which satisfactory performance was achieved across each country's latest reports. CPIA Debt Management is each country's 2011-2022 score averages. Debt Transparency is the average score on the Debt Reporting Heatmap following Rivetti (2022). Debt service smoothness is (for ease of comparison with other metrics) the inverse of the main debt service volatility measure used throughout the paper (residual of Hamilton filter on debt service due as percent GDP) for period 2011-2022.

Table 2. Summary statistics

Variable	Mean	Std. Dev.	N
Debt service due (% GDP)	3.27	8.72	4769
Residual debt service (% GDP)	-0.04	2.41	4700
Debt service residual (% trend)	-53.9	2860.58	4797
Debt service smoothness (% GDP)	1.07	2.15	4700
Trend debt service (% GDP)	3.35	8.29	4700
Foreign exchange reserves (% imports)	3.31	89.62	4314
CPIA	3.19	0.69	4213
CPIA DPM	3.56	0.91	1862
CPIA DM	3.43	0.83	1086
Debt distress onset	0.05	0.21	2461

Figure 1. Debt service volatility over the economic cycle



Notes: The above graph shows a scatter plot of the residual of the debt service variable (measured according to main specification) vs the residual of the cyclical decomposition of the country's growth (using Hamilton filter). Residuals are winsorized at 1 percent for presentation. The trend line shown is not statistically different from zero.

Table 3. Debt service volatility and policy - Alternative debt service data

Dep. variable: Debt service volatility 1980-2022						
	(1)	(2)	(3)	(4)	(5)	(6)
CPIA	-1.13***	-0.89***	-0.64**			
	(0.30)	(0.30)	(0.28)			
CPIA DPM				-0.25***	-0.26***	-0.26**
				(0.09)	(0.09)	(0.10)
Observations	4110	4110	4110	1775	1775	1774
R-squared	0.034	0.052	0.209	0.018	0.034	0.250
Year FE		X	X		X	X
Country FE			X			X

Notes: This table shows results from a regression of the absolute size of debt service residuals as percent GDP (debt service volatility) on the lagged CPIA score and the lagged CPIA debt policy and management sub-component (available since 2004). Rather than using the debt service due series, I use the debt service paid series after subtracting any increase in arrears. Results are shown with and without fixed effects. Robust standard errors clustered by country shown in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4. Debt service volatility and policy - Alternative decomposition

	Dep. variable: Debt service volatility 1980-2022					
	(1)	(2)	(3)	(4)	(5)	(6)
CPIA	-0.40*** (0.10)	-0.20** (0.10)	-0.10 (0.12)			
CPIA DPM				-0.12*** (0.03)	-0.11*** (0.03)	-0.16*** (0.04)
Observations	4082	4082	4082	1763	1763	1762
R-squared	0.028	0.091	0.246	0.039	0.064	0.324
Year FE		X	X		X	X
Country FE			X			X

Notes: This table shows results from a regression of the absolute size of debt service residuals as percent GDP (debt service volatility) on the lagged CPIA score and the lagged CPIA debt policy and management sub-component (available since 2004). Rather than using the Hamilton filter I use a moving average to calculate the trend and residual in debt service due series. Results are shown with and without fixed effects. Robust standard errors clustered by country shown in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5. Debt service volatility - Alternative debt service data

VARIABLES	Debt distress onset likelihood		
	(1) Same year	(2) Next year	(3) Same and next year
Residual debt service (% GDP)	0.0990*** (0.0371)	0.0565*** (0.0219)	0.0911*** (0.0273)
Trend debt service (% GDP)	0.109*** (0.0174)	0.109*** (0.0199)	0.122*** (0.0195)
CPIA	-0.378*** (0.0907)	-0.313*** (0.101)	-0.374*** (0.102)
GDP growth (annual %)	-0.0619*** (0.0142)	-0.0213* (0.0112)	-0.0499*** (0.0114)
Remittances (% GDP)	-0.0426*** (0.0111)	-0.0342*** (0.00988)	-0.0420*** (0.0110)
Reserves (% imports)	-0.972*** (0.270)	-0.976*** (0.253)	-1.102*** (0.256)
World GDP growth (annual %)	-0.0823** (0.0343)	-0.0249 (0.0324)	-0.0673** (0.0297)
Observations	1,956	1,952	2,070

Notes: This table shows probit regression results where the dependent variable is the onset of debt distress from Kraay et al. (2023). Key explanatory variables are the residual debt service variables measured using alternative data of debt service paid plus changes in arrears. Control variables are CPIA, GDP growth, reserve-to-import ratio and the trend debt service to GDP ratio. Robust standard errors clustered by country shown in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6. Debt service volatility - Alternative decomposition

VARIABLES	Debt distress onset likelihood		
	(1) Same year	(2) Next year	(3) Same and next year
Residual debt service (% GDP)	0.0582* (0.0303)	0.0499 (0.0319)	0.0699* (0.0368)
Trend debt service (% GDP)	0.119*** (0.0234)	0.0996*** (0.0237)	0.114*** (0.0257)
CPIA	-0.444*** (0.0988)	-0.345*** (0.109)	-0.424*** (0.110)
GDP growth (annual %)	-0.0652*** (0.0146)	-0.0260** (0.0116)	-0.0540*** (0.0120)
Remittances (% GDP)	-0.0461*** (0.0120)	-0.0343*** (0.0105)	-0.0437*** (0.0118)
Reserves (% imports)	-0.961*** (0.266)	-1.085*** (0.268)	-1.151*** (0.259)
World GDP growth (annual %)	-0.0796** (0.0345)	-0.0235 (0.0336)	-0.0651** (0.0300)
Observations	1,949	1,945	2,062

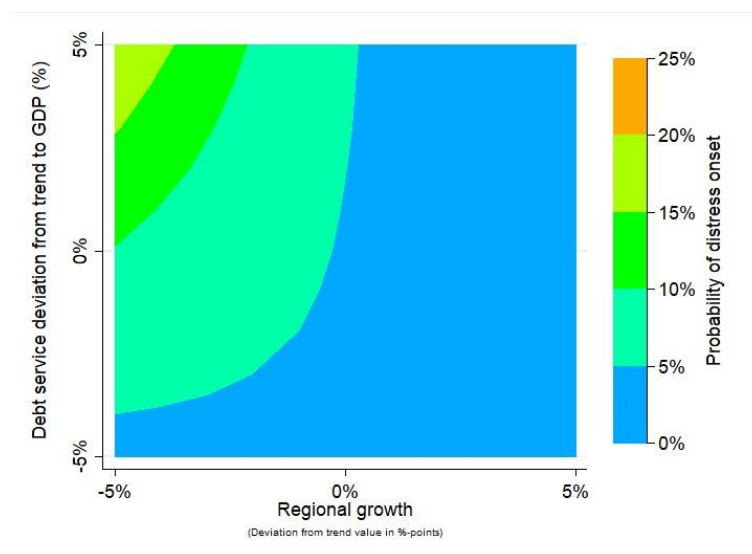
Notes: This table shows probit regression results where the dependent variable is the onset of debt distress from Kraay et al. (2023). Key explanatory variables are the residual debt service variables measured using alternative data of debt service paid plus changes in arrears. Control variables are CPIA, GDP growth, reserve-to-import ratio and the trend debt service to GDP ratio. Robust standard errors clustered by country shown in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 7. Debt service volatility - Additional controls

VARIABLES	Debt distress onset likelihood		
	(1) Same year	(2) Next year	(3) Same and next year
Residual debt service (% GDP)	0.0787*** (0.0266)	0.0801*** (0.0301)	0.0937*** (0.0333)
Trend debt service (% GDP)	0.0877*** (0.0239)	0.0493* (0.0284)	0.0690** (0.0268)
CPIA	-0.365*** (0.0985)	-0.263** (0.104)	-0.332*** (0.105)
GDP growth (annual %)	-0.0650*** (0.0146)	-0.0272** (0.0110)	-0.0553*** (0.0120)
Remittances (% GDP)	-0.0432*** (0.0114)	-0.0301*** (0.00977)	-0.0398*** (0.0111)
Reserves (% imports)	-0.870*** (0.260)	-0.959*** (0.255)	-1.041*** (0.248)
World GDP growth (annual %)	-0.0804** (0.0351)	-0.0274 (0.0332)	-0.0677** (0.0301)
Debt stock / GDP	0.133 (0.192)	0.143 (0.291)	0.174 (0.283)
Fedfunds	2.316 (1.521)	4.109*** (1.595)	3.832** (1.633)
Observations	1,947	1,939	2,056

Notes: This table shows probit regression results where the dependent variable is the onset of debt distress from Kraay et al. (2023). Key explanatory variables are the trend and residual debt service due to GDP ratios based on methodology presented above. Control variables follow IMF-WB (2018): CPIA, GDP growth, reserve-to-import ratio, remittance-to-GDP ratio and global growth with two additions: debt-to-GDP and federal funds rates. Robust standard errors clustered by country shown in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Figure 2. Likelihood of debt distress onset - with control variables



Notes: The above contour plot shows the marginal effects of an interaction term (deviation of debt service and deviation of regional growth from their trend values) of a probit regression where the dependent variable is a dummy capturing debt distress onset events in same year and the year after. Deviation from trend value is measured as the residual from Hamilton filter as a share of GDP. (Kraay et al., 2023)

The Aggregation Dilemma: How Best to Restructure Sovereign Bonds

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November 13, 2024*

Abstract

We consider the problem of a government who seeks to restructure multiple bond series in the presence of last-generation collective action clauses, known as “enhanced” CACs. We characterize how the optimal aggregation procedure and restructuring offer depend on the heterogeneity of bondholders within and across series, and on the relative face values of the bonds. We then analyze how the design of CACs affects the bond market equilibrium prior to restructuring in two extensions where bond investor bases are determined endogenously. In particular, we show that single-limb aggregation can serve as an off-equilibrium threat that deters the potential entry of vulture funds. Our results shed light on the aggregation method employed by Argentina and Ecuador to restructure their international bonds in August 2020, and on the ongoing reform of euro area sovereign CACs.

JEL Codes: F34; F41; H63

Keywords: sovereign debt restructuring, exit consents, creditor coordination, Collective Action Clauses

Introduction

For over two decades, policy efforts aimed at ensuring the timely and orderly resolution of sovereign debt distress have revolved almost entirely around collective action clauses (CACs).¹ These contractual provisions enable the affirmative vote of a qualified majority of bondholders to bind a dissenting minority to the terms of a restructuring proposal—emulating the majority voting provisions of corporate insolvency laws.² CACs have been systematically inserted in the international bonds of major emerging market sovereign issuers since 2003 with a view to alleviate the “holdout” problem in sovereign debt workouts, whereby a minority of creditors can hinder a restructuring and thus increase the cost of debt distress.³ Since 2013, the debt securities of euro area governments also incorporate majority amendment provisions.

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¹In the early 2000s, IMF’s First Deputy Managing Director Anne Krueger envisioned a statutory bankruptcy regime for countries, but the idea of a “sovereign debt restructuring mechanism” failed to gather political support. More recently, the G20 Common Framework introduced in November 2020 focuses on the coordination between bilateral (Paris Club and others) and private creditors for low-income countries.

²For further background information on sovereign CACs, see Buchheit and Gulati (2002), Buchheit et al. (2019), Gelpern et al. (2015), and Weidemaier and Gulati (2013), as well as IMF (2014) and IMF (2020).

³See Eichengreen and Portes (1995) and Group of Ten (1996) for early proposals calling for collective action among creditors in the modification of bond contractual terms.

In practice, the detailed formulation of collective action clauses varies and has evolved over time. In one of their latest and most common incarnations, the so-called “enhanced” CACs provide that when attempting to restructure multiple bond series, the sovereign can choose among three voting procedures (or “modification methods”) to determine which series are restructured according to the terms of the proposal. Specifically:

- i. the *series-by-series* voting procedure operates separately within each series, with a supermajority threshold usually set at 75%;
- ii. the “*two-limb*” method relies both on the voting outcomes within each series and on the aggregate outcome across series—the voting thresholds in this hybrid procedure being typically set at 50% and 66 2/3%, respectively;⁴
- iii. the “*single-limb*” procedure only relies on the aggregate vote across series, with a supermajority threshold of 75% and the additional constraint—known as *uniform applicability* condition—that all bond series receive the same restructuring terms.

The introduction of the single-limb procedure constituted the real innovation in the drafting of enhanced CACs. In view of its highly effective use in the context of the Greek private restructuring of 2012 (Zettelmeyer et al. (2013)), the presumption in policy circles was that this procedure would become the method of choice to conduct distressed bond exchanges.⁵ Yet in the summer of 2020, in the first two instances when last-generation CACs were put to the test, the Argentine and Ecuadorian governments opted in favor of the two-limb procedure, rather than single-limb aggregation.⁶

Motivated by these developments, this paper constitutes a first attempt at providing an economic analysis of enhanced CACs in sovereign debt workouts. To do so, we consider a model with multiple bond series and heterogeneous bondholders, allowing for heterogeneity both within bonds (which in general may arise from differences in discount rates, regulatory constraints, information, or litigation costs) and across bonds (which may differ, e.g., in terms of maturity or coupon rate,⁷ as well as in their bondholder base). Our contribution is twofold: first, we characterize the optimal choice of aggregation procedure by a debtor government in a restructuring; second, we analyze how the design of CACs and the anticipation of their optimal use by the government affects the bond market equilibrium prior to restructuring.

Our analytical framework features several bonds, each held by a continuum of investors. When deciding whether to accept a restructuring offer, bondholders have heterogeneous reservation values. We initially take the distribution of reservation values as given for each bond, assuming that the distributions differ across bonds. Relative to the two-limb procedure, single-limb aggregation comes with a benefit arising from the removal of series-by-series constraints, but also with a cost as it prevents differentiated offers across bonds. In a two-bond case, we characterize the optimal voting procedure and restructuring offers as a function of their determinants: the voting thresholds, the heterogeneity across bonds, and their relative size.

In particular, we show that for realistic threshold values, two-limb aggregation is optimal when the “expensive” bond—i.e., the bond whose holders tend to have higher reservation values, so that attracting a high consent share for this bond is more costly—is relatively large, or when the bonds are not too heterogeneous. In such circumstances, the series-by-series constraints are not binding, and single-limb voting only comes at a cost due to the uniform applicability restriction. Instead, when there is substantial heterogeneity and

⁴See ICMA (2014) for the standard model of enhanced CACs. When two-limb aggregation was first introduced (e.g., Uruguay 2003, Argentina 2005), the voting thresholds were set at 66 2/3% and 85%, respectively.

⁵See the original proposal in IMF (2014) for a rendition of the view commonly held at the time, and Gelpern et al. (2015) and Sobel (2016) for further discussion.

⁶For a detailed account of the 2020 Argentine restructuring, see among others Buchheit and Gulati (2020), Clark and Lyratzakis (2020), de la Cruz and Lagos (2021), and Setser (2020).

⁷These dimensions of heterogeneity are less relevant in circumstances where cross-default clauses are triggered and all bonds series are accelerated upon occurrence of an event of default prior to the restructuring.

the expensive bond is relatively small in the restructuring pool, it can be optimal to resort to the single-limb procedure and make a uniform offer that attracts a low consent rate from this bond. When the expensive bond is very small, the optimal modification method very much depends on how the aggregate voting thresholds compare across procedures: if the single-limb procedure entails a strictly higher (aggregate) threshold, two-limb voting dominates.

In a first extension of our baseline setup, we analyze how the design of CACs and their optimal use by the government can affect the potential entry of vulture funds—who may be able to block a restructuring by acquiring sufficiently large positions. We show that, though it may not be used in equilibrium, the single-limb aggregation procedure can play an important role as an off-equilibrium deterrent to vultures’ holdout attempts.

Taken together, these results shed light on the ongoing reform of euro-area sovereign CACs. By virtue of the Treaty establishing the European Stability Mechanism (ESM), euro-area debt securities issued after January 2013 incorporate two-limb CACs. In November 2021, however, euro-area governments agreed, as part of an amendment of the ESM Treaty, to replace two-limb-only with single-limb-only CACs.⁸ Our analysis suggests that having the option to choose among single-limb and two-limb aggregation would make the debtor country better off: the former discourages the entry of vulture funds, and the latter often turns out to be the optimal restructuring method once the vultures have been kept at bay.

In a second extension, bonds explicitly differ in terms of their maturities and coupon rates, and the bond market is populated by a continuum of investors with heterogeneous discount rates. Investors sort into bonds in an initial trading stage and, in the event of a restructuring, the government optimally chooses the recovery values and modification method. In equilibrium, the anticipation of the government’s restructuring approach affects the outcome of the trading stage, and the government’s approach in the restructuring stage depends on the bond-specific reservation value distributions—which are partly determined by the endogenous sorting of investors in the prior stage. We provide a numerical illustration where long-term bonds are held by more patient investors and also tend to be the more “expensive” ones to restructure. In the context of this example, we revisit the comparative statics with respect to bond heterogeneity and relative sizes, and we discuss the impact of CACs on bond valuations.

Related Literature. This paper contributes to the theoretical economic literature on CACs in sovereign bonds. Previous work—such as [Haldane et al. \(2005\)](#), [Engelen and Lambsdorff \(2009\)](#), [Bi et al. \(2016\)](#), and [Pitchford and Wright \(2012\)](#)—has considered settings with a single bond instrument to study how strategic creditor interactions and restructuring outcomes are affected by the introduction of a supermajority rule in place of a unanimity requirement.⁹ By design, these papers are silent on cross-bond heterogeneity and aggregation. Instead, we adopt a setting with multiple bonds to address questions specifically related to enhanced CACs.¹⁰

On the empirical front, [Fang et al. \(2021\)](#) and [Asonuma et al. \(2023\)](#) provide evidence on bond-level restructuring outcomes, considering samples that comprise bonds without CACs and bonds with old-style series-by-series CACs, as well as Greek local-law bonds which were restructured via single-limb aggregation. Specifically, [Fang et al. \(2021\)](#) analyze the combined impact of CACs and haircuts on participation rates at the bond level, as well as their variation across and within restructuring episodes, while [Asonuma et al. \(2023\)](#) document that bond-level haircuts are negatively related to the maturity of the instrument. These studies do not speak directly to the specific predictions from our analysis but yet constitute an important first step in the empirical analysis of bond and creditor heterogeneity in restructuring episodes.

Our work is also connected to a series of empirical papers investigating how the inclusion of various

⁸The decision will enter into force once the parliaments of all member states have ratified the Amending Agreement. At the time of writing, Italy is the only member state that has not yet ratified the agreement.

⁹Also in a one-bond setting, [Ghosal and Thampanishvong \(2013\)](#) analyses the impact of a decrease in the supermajority threshold on interim and ex ante efficiency in a setup featuring debtor moral hazard and coordination frictions due to incomplete information.

¹⁰Early analyses of CACs in a one-bond setting are still relevant in practice in situations where a single bond is being restructured (as was the case in Ecuador 2012, Belize 2013, and Mozambique 2019) or when the bonds being restructured only feature old-style series-by-series CACs.

versions of CACs affects sovereign bond prices and yields, including early contributions by [Becker et al. \(2003\)](#) and [Eichengreen and Mody \(2004\)](#), and more recent ones by [Carletti et al. \(2016\)](#), [Picarelli et al. \(2019\)](#), [Carletti et al. \(2021\)](#) and [Chung and Papaioannou \(2020\)](#). Theoretical predictions on the pricing of CACs must build on a fine understanding of how CACs are used and actually play out in restructuring times. Our analysis contributes in this direction and can thus inform further empirical investigations.

Outline. The paper proceeds as follows. Section 1 describes the tradeoff that the government faces in choosing its restructuring strategy and formulates general sufficient optimality conditions. Section 2 offers an analytical characterization of the optimal voting procedure and restructuring proposal as a function of the model primitives in the two-bond case. Section 3 provides closed-form results and numerical illustrations in a parametric example. Section 4 analyzes how the design of CACs affects the potential entry of vulture funds. Section 5 embeds the government’s optimization problem in an equilibrium setting where bond-specific reservation value distributions arise endogenously from the sorting of investors into bonds.

1 The Restructuring Problem

This section lays out a general framework to analyze the government’s optimal use of modification provisions in the restructuring of multiple bonds, allowing for creditor heterogeneity both within and across bond series.

Bonds, Restructuring Proposal, and Creditor Heterogeneity. There is a countable set $\mathcal{B}$ of bond series to be restructured, with $|\mathcal{B}| \geq 2$, held by atomistic investors.¹¹ The relative size of bond series i , expressed as a fraction of the face value of the entire restructuring pool, is given by λ_i , with $\sum_{i \in \mathcal{B}} \lambda_i = 1$. A restructuring proposal $\mathbf{w} = \{w_i\}_{i \in \mathcal{B}}$ made by the government consists of series-specific recovery values w_i per unit of face value. Upon receiving an offer from the government, a bondholder accepts if the proposed recovery value w_i is at least as high as her own idiosyncratic reservation value.¹² To capture within-series creditor heterogeneity as well as cross-series heterogeneity arising from differences in creditor base and/or bond characteristics (e.g., payment terms), we assume that the reservation values of holders of bond series i are distributed according to the cumulative distribution function F_i . The share of holders of series i that give their consent to an offer w is thus equal to $F_i(w)$.¹³

Modification Methods under “Enhanced” CACs. The sovereign can choose among the three voting procedures outlined in the introduction to implement a restructuring. We use the subscript 0 to denote the series-by-series procedure, and we use the subscripts 1 and 2 to denote the single-limb and two-limb procedures, respectively. Under series-by-series voting, an entire bond series i is restructured if the share of consent within this series is greater than or equal to a given threshold τ_0 . According to the two-limb procedure, all bond series in the aggregated pool are restructured if the share of consent within each series is greater than or equal to the threshold τ_2^s and the share of consent over the entire pool is no smaller than $\tau_2^a > \tau_2^s$. Finally, under single-limb voting, the uniform applicability condition requires that the same offer be made to all bond series, and CACs are triggered as long as an aggregate threshold τ_1 is reached.¹⁴

¹¹A variety of reasons may lead a government to leave one or more bond series out of the restructuring perimeter. For simplicity, we ignore the endogenous determination of the restructuring pool $\mathcal{B}$.

¹²We take these reservation values as exogenous, abstracting from explicit strategic considerations that may affect the expected value of holding out. There exists little evidence on holdout payoffs, apart from well-publicized cases such as the Argentine settlement following the 2001 default—see [Cruces and Samples \(2016\)](#). [Schumacher et al. \(2021\)](#) provide empirical evidence on the incidence of sovereign debt litigation.

¹³For expositional simplicity, we assume that all investors are atomistic and that the CDFs are continuous. Section 4 analyzes an extension where a vulture fund can take large blocking positions. The deterministic mapping from offers into consent shares is analytically convenient. Appendix ?? considers a more general formulation in which the government’s restructuring proposal affects the *distribution* of consent shares, and shows that the insights on the determinants of the optimal aggregation method are unaffected.

¹⁴The uniform applicability condition is meant to provide a safeguard to ensure inter-creditor equity, by avoiding that holders of large enough bond series effectively dictate terms that are discriminatory against smaller series (see Section B of [IMF \(2014\)](#)).

1.1 Government's Problem

The government seeks to restructure all bonds series $i \in \mathcal{B}$ at minimum cost. The set of constraints that need to be satisfied by the exchange proposal to achieve this objective depends on the elected modification method.¹⁵ With series-by-series voting, the restructuring offer $\mathbf{w} = \{w_i\}_{i \in \mathcal{B}}$ must be such that

$$F_i(w_i) \geq \tau_0 \quad \text{for all } i \in \mathcal{B}.$$

Using the two-limb method over the entire pool, the offer must satisfy the aggregate constraint

$$\sum_{i \in \mathcal{B}} \lambda_i F_i(w_i) \geq \tau_2^a, \quad (1)$$

along with the individual consent requirements

$$F_i(w_i) \geq \tau_2^s \quad \text{for all } i \in \mathcal{B}. \quad (2)$$

Finally, under single-limb aggregation, the “uniform” offer w must be such that

$$\sum_{i \in \mathcal{B}} \lambda_i F_i(w) \geq \tau_1.$$

In choosing a modification method and the offer w_i made to each bond series $i \in \mathcal{B}$, the government wishes to minimize the total payout

$$C = \boldsymbol{\lambda} \cdot \mathbf{w} = \sum_{i \in \mathcal{B}} \lambda_i w_i.$$

We shall proceed under the realistic assumption that¹⁶

$$\frac{1}{2} \leq \tau_2^s < \tau_2^a \leq \tau_1 \leq \tau_0 < 1. \quad (3)$$

Under (3), two-limb aggregation dominates (at least weakly) series-by-series voting. We will thus restrict our attention to the optimal choice of aggregation procedure.

1.2 Optimal Exchange Offers

A preliminary step towards comparing two-limb vs single-limb aggregation consists in characterizing the optimal restructuring proposal under each procedure. The optimal uniform offer u^* under single-limb voting is such that the weighted-average acceptance rate is just equal to the aggregate acceptance threshold τ_1 ,

$$\sum_{i \in \mathcal{B}} \lambda_i F_i(u^*) = \tau_1. \quad (4)$$

Instead, the optimal two-limb offer is solution to the constrained optimization problem:

$$\min_{\{w_i\}} \sum_{i \in \mathcal{B}} \lambda_i w_i$$

subject to

$$\begin{aligned} \sum_{i \in \mathcal{B}} \lambda_i F_i(w_i) &= \tau_2^a, \\ F_i(w_i) &\geq \tau_2^s, \quad i \in \mathcal{B}. \end{aligned}$$

Since $\tau_2^a > \tau_2^s$, the aggregate constraint (1) is binding and holds as an equality. However, it is a priori unclear which, if any, of the individual constraints may be binding.

¹⁵We assume that a unique procedure is applied to the entire pool $\mathcal{B}$. In practice, a government may partition $\mathcal{B}$ and use different modification methods on different subsets of bonds.

¹⁶In the ICMA standard published in 2014-15, the thresholds are $\tau_0 = \tau_1 = 3/4$, $\tau_2^s = 1/2$, and $\tau_2^a = 2/3$. It is worth noting that in the Uruguay-style second-generation CACs (which also appear in the Argentine “Kirchner bonds” issued as part of the 2005 restructuring), thresholds are such that $\tau_2^s < \tau_0 < \tau_2^a$, so that the optimal choice between series-by-series voting and two-limb aggregation is non-trivial.

Auxiliary Problem. It will be useful in our analysis to consider the auxiliary problem

$$\min_{\{w_i\}} \sum_{\mathcal{B}} \lambda_i w_i \quad \text{subject to} \quad \sum_{\mathcal{B}} \lambda_i F_i(w_i) = \tau_2^a. \quad (5)$$

The government's cost-minimization problem under single-limb and two-limb voting can be construed in reference to this problem. Under single-limb voting, the offer needs to satisfy the additional “uniform applicability” restriction, which simplifies the problem into (4). Instead, under two-limb voting, the government needs to take into account the additional series-by-series constraints (2). Whenever the solution to the auxiliary problem satisfies the latter constraints, it therefore coincides with the optimal two-limb offer. The Lagrangian for the auxiliary problem is

$$\mathcal{L} = \sum_{\mathcal{B}} \lambda_i w_i + \xi \left(\tau_2^a - \sum_{\mathcal{B}} \lambda_i F_i(w_i) \right).$$

Assuming differentiability, the corresponding first-order condition is

$$F'_i(w_i) = \xi^{-1}, \quad \text{for all } i \in \mathcal{B}.$$

Intuitively, a marginal increase dw in the offer to series i raises the aggregate approval rate by $\lambda_i F'_i(w_i) dw$ at a cost of $\lambda_i dw$. Interior optimality thus requires that the “bang for the buck” $F'_i(w_i)$ be equalized across all bonds.

1.3 Optimal Voting Procedure: Key Tradeoff

Comparing across procedures, the unique appeal of single-limb voting comes from the fact that it removes the need to satisfy the series-by-series constraints; however, resorting to this method does entail a cost arising from the uniform applicability restriction and the possibly higher aggregate consent requirement (when $\tau_1 > \tau_2^a$). These observations immediately deliver sufficient conditions under which two-limb aggregation is optimal.

Proposition 1. *Two-limb voting is (at least weakly) optimal if one of the following conditions holds:*

- (i) *The optimal single-limb uniform offer, given by the unique solution u^* to (4), is such that $F_i(u^*) \geq \tau_2^s$ for all $i \in \mathcal{B}$;*
- (ii) *The solution $\hat{w}$ to the auxiliary problem (5) is such that $F_i(\hat{w}_i) \geq \tau_2^s$ for all $i \in \mathcal{B}$.*

Furthermore, if condition (ii) holds, the optimal two-limb offer coincides with $\hat{w}$.

Indeed, the unique advantage of single-limb aggregation is worthless if any of the two conditions holds, hence the two-limb procedure dominates in these configurations. Going beyond these general statements requires making further assumptions on the environment—that is, on the number of bonds and their relative sizes λ_i , on the reservation value distributions F_i , and on the various voting thresholds.

2 Two-Bond Case

We now focus on the case where there are only two bond series outstanding, H and L , with relative weights $\lambda_H = \lambda \in (0, 1)$ and $\lambda_L = 1 - \lambda$. We denote by $F_i : \mathbb{R}^+ \rightarrow [0, 1]$ the cumulative distribution function of reservation values for bond $i \in \{H, L\}$, which we assume to be strictly increasing and twice differentiable

on $\mathbb{R}^+$, with $F_i(0) = 0$. We denote by f_i the corresponding density function. We assume that holders of bond H tend to have higher reservation values, so that

$$F_H(w) < F_L(w) \quad \text{for all } w > 0, \quad (6)$$

or equivalently

$$F_L^{-1}(\tau) < F_H^{-1}(\tau) \quad \text{for all } \tau \in (0, 1).$$

This may reflect the fact that bond H has better payment terms or that its holders have better litigation skills. We shall sometimes refer to bond H as the “expensive” bond.

2.1 Single-Limb Aggregation

Under single-limb voting, the government’s exchange offer must satisfy the uniform applicability condition, which requires the offer to be the same across series. As per (4), the cost-minimizing offer u^* is such that the aggregate consent requirement holds as an equality. That is, the optimal uniform offer under the single-limb procedure is given by $u^* = u(\lambda, \tau_1)$, where $u(\lambda, \tau)$ is implicitly defined as the unique solution to the equation

$$\lambda F_H(u) + (1 - \lambda) F_L(u) = \tau. \quad (7)$$

The following observations obtain immediately.

Lemma 1. *The consent shares under the optimal uniform offer are such that*

$$F_H(u^*) < \tau_1 < F_L(u^*). \quad (8)$$

Moreover, u^* is strictly increasing in τ_1 and in the relative size λ of the expensive bond, with

$$\lim_{\lambda \downarrow 0} u^* = F_L^{-1}(\tau_1) \quad \text{and} \quad \lim_{\lambda \uparrow 1} u^* = F_H^{-1}(\tau_1). \quad (9)$$

It will also be useful to establish conditions under which $F_H(u^*) \geq \tau_2^s$, in which case the optimal single-limb offer u^* satisfies both of the series-by-series participation constraints imposed under two-limb voting.

Lemma 2. *If $F_L^{-1}(\tau_1) \geq F_H^{-1}(\tau_2^s)$, the optimal uniform offer u^* is such that $F_H(u^*) \geq \tau_2^s$ for any $\lambda \in (0, 1)$. Otherwise, $F_H(u^*) \geq \tau_2^s$ if $\lambda \geq \lambda_\dagger$, where $\lambda_\dagger$ is such that $u(\lambda_\dagger, \tau_1) = F_H^{-1}(\tau_2^s)$.*

Naturally, the optimal uniform offer $u^* = u(\lambda, \tau_1)$ is more likely to satisfy the individual constraints for high values of τ_1 and low values of τ_2^s . Besides, since the offer u^* induces an average consent share τ_1 , greater homogeneity across bonds makes it more likely that $F_H(u^*)$ is close to τ_1 and thus greater than τ_2^s . Finally, as captured by the second part of the lemma, a higher relative size λ of the expensive bond H makes it more likely that the constraint on this bond be satisfied by increasing the amount of the uniform offer u^* , with the cutoff value $\lambda_\dagger$ increasing in the degree of cross-series heterogeneity.

2.2 Two-Limb Aggregation

Under two-limb aggregation, the optimal offer is solution to

$$\min_{w_H, w_L} \lambda w_H + (1 - \lambda) w_L$$

subject to

$$\lambda F_H(w_H) + (1 - \lambda) F_L(w_L) = \tau_2^a, \quad (10)$$

$$F_i(w_i) \geq \tau_2^s, \quad i = H, L. \quad (11)$$

Let us first focus on the aggregate consent requirement (10) and let $\mathcal{W}$ denote the set of possible offers w_L to the holders of bond L such that this constraint can be met for some value of w_H .¹⁷ Given an offer $w_L \in \mathcal{W}$ to the holders of bond L , the offer w_H that the sovereign needs to make to holders of bond H in order to satisfy the aggregate condition (10) is given by

$$w_H = F_H^{-1} \left(\frac{\tau_2^a - (1 - \lambda)F_L(w_L)}{\lambda} \right) \equiv g(w_L) = g(w_L; \lambda, \tau_2^a). \quad (12)$$

The function g is strictly decreasing in w_L , reflecting the fact that if a more generous offer is made to bond L —thus increasing the consent share for this series—a less appealing offer can be made to the other bond.¹⁸ For future reference, it is worth noting that the following implications derive from the aggregate consent identity (10), establishing intuitive connections between the relative consent shares (or offers) across the two bonds and their absolute levels.

Remark 1. For any pair of offers satisfying the aggregate requirement (10), that is, for any (w_H, w_L) such that $w_L \in \mathcal{W}$ and $w_H = g(w_L)$,

$$F_H(w_H) < F_L(w_L) \quad \Leftrightarrow \quad F_L(w_L) > \tau_2^a \quad \Leftrightarrow \quad F_H(w_H) < \tau_2^a,$$

and

$$w_H > w_L \quad \Leftrightarrow \quad w_L < u(\lambda, \tau_2^a) \quad \Leftrightarrow \quad w_H > u(\lambda, \tau_2^a).$$

Auxiliary Problem. To characterize the optimal offer under two-limb aggregation, we consider the corresponding auxiliary problem

$$\min_{w_H, w_L} \lambda w_H + (1 - \lambda)w_L \quad \text{subject to} \quad \lambda F_H(w_H) + (1 - \lambda)F_L(w_L) = \tau_2^a,$$

and we denote its solution by $\hat{\mathbf{w}} = (\hat{w}_H, \hat{w}_L)$. This problem can be restated more concisely as

$$\min_{w_L \in \mathcal{W}} \lambda g(w_L) + (1 - \lambda)w_L, \quad (13)$$

and one can show that the objective function in (13) is (strictly) convex when

$$\frac{d \log f_L(w_L)}{dw_L} < \frac{d \log f_H[g(w_L)]}{dw_L}. \quad (14)$$

In particular, it is immediate to see that (14) is satisfied if the two densities f_H and f_L are strictly decreasing. Assuming convexity, an interior solution to (13) is pinned down by the first-order condition

$$f_L(w_L) = f_H[g(w_L)]. \quad (15)$$

Optimal Two-Limb Offer. The optimal two-limb offer coincides with the auxiliary solution $\hat{\mathbf{w}} = (\hat{w}_H, \hat{w}_L)$ —such that $\hat{w}_L$ minimizes (13) and $\hat{w}_H = g(\hat{w}_L)$ —as long as the latter satisfies the two individual constraints (11), i.e., when

$$\tau_2^s \leq F_L(\hat{w}_L) \leq \frac{\tau_2^a - \lambda \tau_2^s}{1 - \lambda}. \quad (16)$$

The second inequality in (16) guarantees that $F_H(\hat{w}_H) \geq \tau_2^s$, and is trivially satisfied if $\lambda \geq (1 - \tau_2^a)/(1 - \tau_2^s)$. On the other hand, the inequality $F_L(\hat{w}_L) \geq \tau_2^s$ is necessarily satisfied when λ is sufficiently small. Intuitively, when a bond series is large relative to the total face value of the restructuring pool, the need to reach the high aggregate consent level τ_2^a makes it likely that the series-by-series requirement is met for this bond.

¹⁷When the relative size λ of bond H is sufficiently small, meeting the aggregate consent condition (10) is impossible if w_L is too small (resp., too high), even with an arbitrary large w_H (resp., even when setting $w_H = 0$). See Remark A-1 in the appendix for an explicit definition of $\mathcal{W}(\lambda, \tau_2^a)$.

¹⁸By construction, the unique solution to the fixed-point equation $g(w) = w$ coincides with $u(\lambda, \tau_2^a)$.

Lemma 3. Suppose that the auxiliary problem (13) is strictly convex with an interior solution. The solution $\hat{w}$ to this problem satisfies the series-by-series constraint on bond H when $\lambda \geq (1 - \tau_2^a)/(1 - \tau_2^s)$ or if

$$f_L \left(F_L^{-1} \left(\frac{\tau_2^a - \lambda \tau_2^s}{1 - \lambda} \right) \right) \leq f_H \left(F_H^{-1}(\tau_2^s) \right), \quad (17)$$

and it satisfies the series-by-series constraint on bond L when $\lambda \leq (\tau_2^a - \tau_2^s)/(1 - \tau_2^s)$ or if

$$f_L \left(F_L^{-1}(\tau_2^s) \right) \geq f_H \left(F_H^{-1} \left(\frac{\tau_2^a - (1 - \lambda)\tau_2^s}{\lambda} \right) \right). \quad (18)$$

Conditions (17)-(18) ensure that the first-order optimality condition (15) can be met without violating the individual constraints (11). When instead $\hat{w}_i < F_i^{-1}(\tau_2^s)$, the individual constraint on bond i is binding: the optimal two-limb offer sets $w_i = F_i^{-1}(\tau_2^s)$ and adjusts the recovery value on the other bond downwards to satisfy the aggregate consent condition.¹⁹

2.3 Optimal Restructuring Procedure

Using Proposition 1, we now establish sufficient conditions under which two-limb aggregation is optimal in the two-bond case.

Proposition 2. If either the conditions stated in Lemma 2 or those provided in Lemma 3 hold, two-limb aggregation is optimal.

Indeed, the conditions stated in Lemmas 2 and 3 guarantee that the optimal uniform offer and the auxiliary solution satisfy all series-by-series constraints, respectively—the unique advantage of the single-limb procedure being worthless in either case. In view of our discussion of Lemma 2, two-limb voting is more likely to dominate for high values of τ_1 and low values of τ_2^s , at low levels of heterogeneity across bonds, and for a high relative size λ of the expensive bond. In the next section, we illustrate in a parametric example that the auxiliary solution is also more likely to satisfy the series-by-series constraints for low levels of heterogeneity and high values of λ . To complement Proposition 2, it is worth noting that

$$\tau_1 > \tau_2^a \quad \Rightarrow \quad \lim_{\lambda \downarrow 0} C_1 = F_L^{-1}(\tau_1) > F_L^{-1}(\tau_2^a) = \lim_{\lambda \downarrow 0} C_2, \quad (19)$$

hence when $\tau_1 > \tau_2^a$, two-limb voting also dominates for λ sufficiently small. The last result of this section establishes sufficient conditions under which single-limb voting dominates.

Proposition 3. Suppose that $\tau_1 < F_L(F_H^{-1}(\tau_2^s))$ and the two densities f_H and f_L are strictly decreasing and intersect only once, at a point $\tilde{w} \in (F_L^{-1}(\tau_1), F_H^{-1}(\tau_2^s))$. Then single-limb voting is optimal (i) for λ sufficiently small when $\tau_2^a = \tau_1$, and (ii) in the neighborhood of the point $\tilde{\lambda} > 0$ such that $u(\tilde{\lambda}, \tau_1) = \tilde{w}$ when $\tau_1 - \tau_2^a$ is not too large.

The heterogeneity across bonds must be sufficiently large for the premise of Proposition 3 to be satisfied, as will be illustrated in the next section. Contrasting Part (i) of the proposition with the statement in (19) reveals that, for low values of the relative weight λ , the optimal voting procedure depends crucially (and in an intuitive way) on whether $\tau_1 > \tau_2^a$ or $\tau_1 = \tau_2^a$. The second part of the proposition points to a special parameter configuration in which the uniform applicability restriction comes at little cost while the unique advantage of single-limb voting is valuable—in which case this procedure is clearly optimal.

¹⁹In the parametric example of Section 3, only the individual constraint on bond H can ever be binding.

3 Parametric Example

We now consider a particular incarnation of the two-bond case where reservation values for each bond are exponentially distributed, that is,

$$F_i(w) = 1 - e^{-\frac{w}{\phi_i}}, \quad \text{for } w \geq 0, \quad (20)$$

implying that $F_i^{-1}(\tau) = -\phi_i \log(1 - \tau)$, for all $\tau \in (0, 1)$. As before, we suppose that holders of bond H tend to have higher holdout values. We thus proceed under the assumption that

$$\gamma := \frac{\phi_H}{\phi_L} > 1.$$

3.1 Closed-Form Analytical Results

Under the exponential specification, the auxiliary problem is strictly convex and the consent shares under the auxiliary solution are given by²⁰

$$F_L(\hat{w}_L) = \frac{\lambda(\gamma - 1) + \tau_2^a}{\lambda(\gamma - 1) + 1} > \tau_2^a, \quad (21)$$

and

$$F_H(\hat{w}_H) = \frac{\tau_2^a - (1 - \lambda)F_L(\hat{w}_L)}{\lambda} = \frac{1 + \lambda(\gamma - 1) - \gamma(1 - \tau_2^a)}{1 + \lambda(\gamma - 1)} < \tau_2^a. \quad (22)$$

Hence, only the individual constraint on bond H may ever be binding in the context of this example. The auxiliary consent shares (and the corresponding offers $\hat{w}_L$ and $\hat{w}_H$) are increasing in the relative size λ of the more demanding bond. Moreover, one can check that $F_L(\hat{w}_L)$ is increasing in γ while $F_H(\hat{w}_H)$ is decreasing in γ : the spread in consent shares under the auxiliary solution is increasing in the degree of bond heterogeneity.

Optimal Two-Limb Offer. The optimal offers under two-limb aggregation coincide with the auxiliary solution as long as $F_H(\hat{w}_H) \geq \tau_2^s$. Since $F_H(\hat{w}_H)$ is increasing in λ and decreasing in γ , the inequality is more likely to hold for high values of λ and low values of γ . Indeed, one can show that $F_H(\hat{w}_H) \geq \tau_2^s$

- if $\gamma \leq (1 - \tau_2^s)/(1 - \tau_2^a) \equiv \bar{\gamma}_X$, for all values of λ ;
- if $\lambda \geq (1 - \tau_2^a)/(1 - \tau_2^s) \equiv \underline{\lambda} \in (0, 1)$, for all values of γ ;
- in the remainder of the parameter space for γ sufficiently small or λ sufficiently large.²¹

Conversely, the consent requirement on the expensive bond H is binding when there is sufficient heterogeneity across the two bonds ($\gamma > \bar{\gamma}_X$) and the relative size of bond H is small. Analytical expressions for the optimal two-limb offers in this case are provided in the appendix.

Optimal Voting Procedure. When parameter values are such that $F_H(\hat{w}_H) \geq \tau_2^s$, two-limb aggregation is optimal since the series-by-series constraints have no bite. Yet another sufficient condition for two-limb optimality is that the optimal uniform offer u^* satisfies the series-by-series constraints (i.e., $F_H(u^*) \geq \tau_2^s$), in which case the unique advantage of single-limb aggregation is worthless. In the appendix, we exploit Lemma 2 and show that this condition holds if the heterogeneity parameter γ is below some threshold value $\bar{\gamma}_U$, or alternatively if λ is sufficiently large.²²

²⁰The analytical derivations for the parametric case are provided in Appendix A.3.

²¹An explicit condition of the form $\lambda \geq \ell_X(\gamma)$ for $\gamma > \bar{\gamma}_X$ is provided in the appendix, see Remark A.3.

²²The appendix gives an explicit condition of the form $\lambda \geq \ell_U(\gamma) \in (0, 1)$ for $\gamma > \bar{\gamma}_U$.

Exploiting Proposition 3 allows us to establish instead a sufficient condition for single-limb optimality. One can show that the premise of the proposition is satisfied for sufficiently high values of γ . Then, single-limb voting is optimal for λ sufficiently close to zero when $\tau_1 = \tau_2^a$. If instead $\tau_1 > \tau_2^a$, as long as $\tau_1 - \tau_2^a$ is not too large, single-limb aggregation is optimal when the relative size λ of bond H is close to the value $\tilde{\lambda}$ —given by (A.21) in the appendix—such that the auxiliary solution would require to give the same recovery value to the two bonds, with a consent share for bond H below τ_2^s .

When none of these sufficient conditions holds, one can still compare the restructuring costs across the two aggregation procedures. Under two-limb voting, the participation constraint on bond H must be binding in that case, and the restructuring cost is given by

$$C_2 = \lambda \phi_H \log \left(\frac{1}{\zeta_2^s} \right) + (1 - \lambda) \phi_L \log \left(\frac{1 - \lambda}{\zeta_2^a - \lambda \zeta_2^s} \right),$$

where $\zeta_2^j = 1 - \tau_2^j$ for $j \in \{s, a\}$. Noting that the optimal single-limb offer u^* is such that

$$F(u^*) \equiv \lambda F_H(u^*) + (1 - \lambda) F_L(u^*) = 1 - \lambda e^{-u^*/\phi_H} - (1 - \lambda) e^{-u^*/\phi_L} = \tau_1,$$

one can see that single-limb dominates if and only if $F(C_2) > \tau_1$. We thus obtain a necessary and sufficient condition for single-limb optimality in terms of parameter values, namely:

$$\lambda (\zeta_2^s)^\lambda \left(\frac{\zeta_2^a - \lambda \zeta_2^s}{1 - \lambda} \right)^{\frac{1-\lambda}{\gamma}} + (1 - \lambda) (\zeta_2^s)^{\lambda\gamma} \left(\frac{\zeta_2^a - \lambda \zeta_2^s}{1 - \lambda} \right)^{1-\lambda} < 1 - \tau_1. \quad (23)$$

3.2 Numerical Illustration

For the sake of illustration, we first assume that $\tau_1 = \tau_2^a = 2/3$ and $\tau_2^s = 1/2$, and we set the distributional parameters to $\phi_H = 0.7$ and $\phi_L = 0.2$ (i.e., the average reservation values for the two bonds are 70 and 20 cents on the dollar, respectively). Figure 1 depicts optimal offers (left panel) and consent shares (right panel) under the two aggregation methods as a function of the relative size λ of the expensive bond. Optimal offers and consent shares under two-limb aggregation are represented as blue and red lines for the cheap and expensive bond, respectively, whereas the optimal offer and consent shares under single-limb aggregation are represented by black lines. Consider the two-limb modification method first. When λ is large enough, the auxiliary solution is feasible, both exchange offers are increasing in λ and consent shares are larger than the series-by-series threshold. When instead λ is low, the series-by-series constraint for the expensive bond

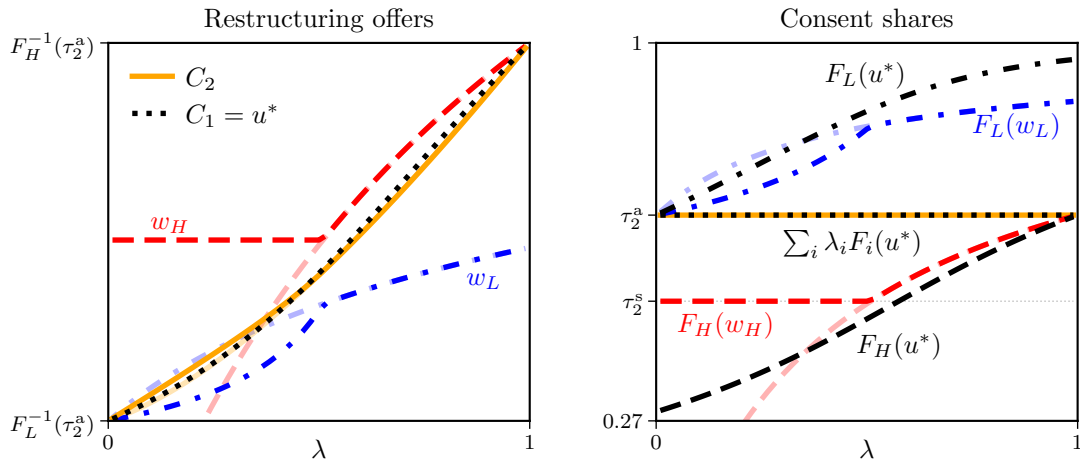


Figure 1: Optimal Restructuring Offers and Consent Shares.

binds: w_H is flat, the consent share for bond H equals τ_2^s , and the government sets $w_L < \hat{w}_L$, just high enough to satisfy the aggregate consent requirement. Under single-limb voting, the optimal uniform offer and the associated consent shares are smoothly increasing functions of λ .

The left panel of Figure 1 also displays the total restructuring cost as a function of λ for each of the two aggregation methods. The single-limb rule is represented by the dotted (black) line, and the two-limb rule by the solid (orange) line. The figure shows that the two-limb method dominates for high values of λ , while the single-limb method dominates when the share of the expensive bond is low, consistent with the rest of our analysis.

Finally, Figure 2 represents regions of the parameter space in which either of the two aggregation methods dominates, when $\tau_1 = \tau_2^a = 2/3$ (left panel) and when the threshold values as set in the standard ICMA CACs, with $\tau_1 = 3/4$ and $\tau_2^a = 2/3$ (right panel). The optimal restructuring method is characterized as a function of the relative size λ of the expensive bond and the degree of heterogeneity between bonds, captured on the y-axis by $\log(\gamma) > 0$. The figure depicts as (colored) dashed or dotted lines various analytical objects introduced above, related to sufficient conditions for two-limb or single-limb optimality. The solid (black) boundary is based instead on the necessary and sufficient condition (23) and illustrates the fact that the single-limb procedure is optimal in circumstances when the heterogeneity across bonds is substantial and the relative size of the expensive bond is not too large. Naturally, the region where single-limb voting dominates shrinks when τ_1 increases. The figure also illustrates the fact that when $\tau_1 > \tau_2^a$, two-limb voting always dominates in the neighborhood of $\lambda = 0$, in line with the general observation formulated in (19).

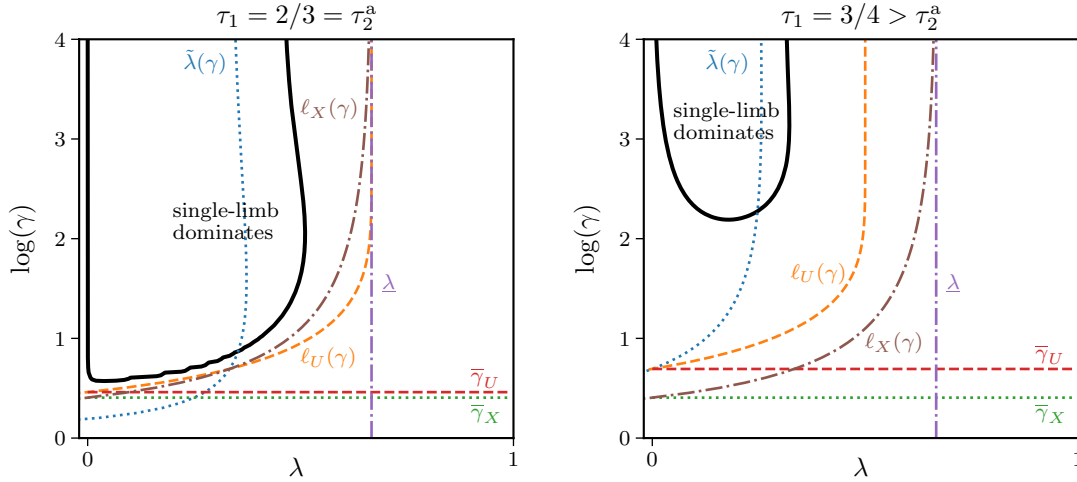


Figure 2: Optimal Voting Rule as a function of Relative Size (λ) and Bond Heterogeneity (γ).

4 CACs and Vultures

This section considers an extension of the two-bond model to analyze how the design of CACs and their optimal use by the government can affect the potential entry of vulture funds who, by taking large positions, may be able to block bond restructurings. We show that, though it may not be used in equilibrium, the single-limb aggregation procedure does play an important role as an off-equilibrium deterrent to vultures' holdout attempts.

4.1 Extended Setup

We consider an extension of the setup of Section 2 in which, prior to the restructuring episode, a vulture fund may potentially acquire bonds H and L from the continua of heterogeneous investors who hold them. We denote by μ_i the share of bond i acquired by the fund, and we denote by q_i the price paid by the fund per unit of face value. We further assume that the fund needs to pay a fixed cost ε_i to enter the market for bond i .

Blocking Positions. When the restructuring comes, holding a sufficiently large position effectively allows the fund to prevent the triggering of CACs. We assume that the fund systematically opposes a restructuring when it is able to do so, and that it derives h_i per unit of face value held from blocking the restructuring of bond i . In particular, single-limb aggregation can be blocked if $\sum_i \lambda_i \mu_i > 1 - \tau_1$, and the fund can block the restructuring²³ of bond i under the two-limb procedure when $\mu_i > 1 - \tau_2^s$.

Bond Market Prices. The price q_i at which the fund may acquire a position in bond i naturally depends on the payoff that atomistic investors expect at the subsequent restructuring stage. If the market understands that the fund will be unable to prevent the restructuring of bond i , the price q_i coincides with the government's optimal restructuring offer w_i . If instead the fund's acquired positions later enable it to block the restructuring of bond i , investors would ultimately be left with their own reservation values for this bond. Hence in that case, each investor is willing to sell ex ante as long as the market price q_i is above her reservation value, implying that the fund can acquire a share μ_i of bond i at a cost of $F_i^{-1}(\mu_i)$ per unit of face value.

Cost of Holdout Strategies. Since $\tau_1 \geq \tau_2^a$, the minimum cost at which the fund can acquire a blocking position in the two bonds under either aggregation method is given by

$$\kappa_2 := \inf_{\{\mu_i\}} \sum_i \mathbf{1}_{\{\mu_i > 0\}} \left(\lambda_i \mu_i F_i^{-1}(\mu_i) + \varepsilon_i \right) \quad \text{s.t.} \quad \sum_i \lambda_i \mu_i > 1 - \tau_1.$$

Likewise, the minimum cost at which the fund may be able to prevent the restructuring of bond i via two-limb aggregation is

$$\kappa_i = \lambda_i (1 - \tau_2^s) F_i^{-1}(1 - \tau_2^s) + \varepsilon_i.$$

To fix ideas, we shall assume without loss of generality that bond L is the cheapest to block, that is $\kappa_L < \kappa_H$.²⁴

Limited Resources. We assume that the fund has limited resources relative to the size of the outstanding bond series, which restricts its potential ambitions as a holdout. Namely, we assume that the fund's resources e are such that

$$\kappa_L < e < \min\{\kappa_H, \kappa_2\}.$$

Hence the only holdout strategy that the fund may contemplate is to acquire a position in bond L that would block the activation of CACs for this bond under two-limb aggregation.

4.2 Equilibrium: Vulture Fund Entry and the Design of CACs

In equilibrium, the outcome of the early stage in which the fund decides on (μ_H, μ_L) needs to be consistent with the outcome of the restructuring stage. To start with, it is straightforward to see that, under the assumptions stated above, the fund would set $\mu_H = 0$, i.e., it would refrain entirely from entering the market for

²³We assume that if CACs are not triggered for bond i , then the bond is left unstructured. That is, CACs thresholds coincide with minimum participation thresholds.

²⁴Under the maintained assumption (6), we know that $F_L^{-1}(1 - \tau_2^s) < F_H^{-1}(1 - \tau_2^s)$. Yet, the minimum blocking costs also depend on the bond sizes (λ_i) and on the entry costs (ε_i) .

bond H . Indeed, since any position that the fund may feasibly acquire in that bond would be non-blocking, the price q_H would be equal to the restructuring payout w_H offered by the government, and the fixed entry cost would thus be enough to keep the fund at bay. By the same logic, one can see that any position $\mu_L > 0$ that is non-blocking is suboptimal. The only remaining question therefore is: would the fund decide to acquire a blocking position in bond L or stay away entirely?

Two-Limb-Only CACs. It is useful to first consider the case where CACs only allow for two-limb aggregation. If the fund contemplates acquiring a blocking position in bond L , the optimal blocking share μ_L^* is given by the solution to the constrained problem

$$B := \sup_{\mu_L > 1-\tau_2^s} \lambda_L \mu_L \left(h_L - F_L^{-1}(\mu_L) \right) - \varepsilon_L \quad \text{s.t.} \quad \lambda_L \mu_L F_L^{-1}(\mu_L) + \varepsilon_L \leq e. \quad (24)$$

As long as $B > 0$, it is optimal for the fund to purchase a share μ_L^* of bond L and then block the restructuring of the bond in order to get the holdout payoff with net benefit B .

Enhanced CACs. Suppose now that the government can choose between the two aggregation methods. How would the government optimally respond if the fund acts aggressively and builds a blocking position in bond L ? Under the two-limb method, bond L would have to be left unstructured. Instead, under the single-limb method (which remains viable since the fund does not have enough resources to block the restructuring of both bonds, by assumption), the government would pick the uniform offer w^* that attracts the required aggregate consent τ_1 . As long as the cost of leaving one bond unstructured is sufficiently high,²⁵ the government would thus optimally respond using single-limb aggregation, thus defeating any attempt to block bond L . Hence, the fund would optimally stay away altogether, and the restructuring approach would be optimally chosen by the government according to the logic outlined in Section 2.

4.3 Take-Away

The analysis of the extended model reveals that although single-limb aggregation may not be used in equilibrium under enhanced CACs, it does serve as an off-equilibrium threat that deters potential holdouts from acquiring a blocking position in a bond. Indeed, in the equilibrium under enhanced CACs described above, the vulture optimally decides to stay at bay. Off equilibrium, the fund considers building a blocking position $\mu_L > 1 - \tau_2^s$ at a cost $q_L = w^*$ per unit of face value, where the market price q_L reflects the (correct) expectation that the government would defeat the holdout attempt using single-limb aggregation with uniform offer w^* —so that the fund would ultimately make a loss due to the fixed entry cost. Hence in the restructuring, the government ends up selecting the aggregation method according to the relative size of the bonds and the cross-bond heterogeneity in the reservation values of non-vulture investors, as illustrated in Section 3. Unless a relatively small bond is held by highly demanding creditors, the government would thus be using two-limb aggregation in equilibrium. However, if the option to use single-limb aggregation were to be removed, the equilibrium outcome would be dramatically different: the vulture fund would optimally decide to acquire a blocking position in one bond, making its restructuring impossible or more costly.

5 Endogenous Sorting

This section provides an explicit treatment of the heterogeneity within and across bonds, going beyond the reduced-form formulation of Section 2. We consider a continuous-time infinite horizon model in which bonds differ in their maturities, and the creditor base of each bond is determined endogenously in equilibrium.

²⁵When unable to restructure a bond via the triggering of CACs, governments typically end up paying large settlement amounts to the holdouts. Such settlement payments are captured by h_i in our setup.

5.1 Stationary Environment

Investor Heterogeneity. The market is populated by a continuum of risk-neutral investors that differ in their discount rates r , distributed according to the cumulative distribution function G on $\mathcal{R} = [r_{\min}, r_{\max}]$.

Bonds. There are two bonds S and L . The face value of bond $i \in \{S, L\}$ decays exponentially at rate δ_i . We shall assume that $\delta_S > \delta_L$, hence bonds S and L can be thought of as short-term and long-term bonds, respectively. The government may default on both bonds, and the arrival time of default is exponentially distributed with parameter η . While there is no default, bond i continuously pays at coupon rate c_i . Upon occurrence of a default, bondholders receive a bond-specific recovery rate w_i , further introduced below. We assume that the government continuously issues new bonds, so that the relative face values of short- and long-term bonds remain constant over time. We denote by $\lambda_S \in (0, 1)$ and $\lambda_L = 1 - \lambda_S$ the relative face values of the two bonds. Moreover, we denote by $\Delta q = q_S - q_L$ the price differential (per unit of face value) between the two bonds.

Restructuring. Upon default, the debtor government offers recovery rates (w_S, w_L) and picks one of the contractually defined modification methods to implement the restructuring. We denote by $h_i(r)$ the reservation value of an investor with discount rate r holding bond i . The exact specification of $h_i(r)$ depends on the details of the microfoundation. In what follows, we shall use the functional form

$$h_i(r) = \frac{c_i}{r + \delta_i + \chi}, \quad \chi \geq 0. \quad (25)$$

Intuitively, the parameter χ captures the extent to which the investor's reservation value is discounted relative to her subjective valuation $c_i/(r + \delta_i)$ of the bond's promised cashflow stream. An investor accepts the government's restructuring offer w_i for bond i if and only if

$$r \geq \frac{c_i}{w_i} - (\delta_i + \chi).$$

Sorting Stage. Prior to the occurrence of a restructuring with expected recovery rate w_i , the valuation of bond i (per unit of face value) by investor r is time-independent, given by

$$Q_i(r, w_i) = \frac{c_i + \eta w_i}{r + \delta_i + \eta}. \quad (26)$$

Given expected recovery rates $\mathbf{w}$, investors choose which bond to hold based on their subjective valuations and the price differential Δq . The subset of investors sorting into bond S is

$$\mathcal{R}_S(\Delta q, \mathbf{w}) = \{r \in \mathcal{R} : Q_S(r, w_S) - Q_L(r, w_L) \geq \Delta q\}, \quad (27)$$

while the subset of investors holding bond L is $\mathcal{R}_L(\Delta q, \mathbf{w}) = \mathcal{R} \setminus \mathcal{R}_S(\Delta q, \mathbf{w})$. We proceed under the additional assumption that all investors hold one unit of either bond.

5.2 Equilibrium Definition

Given a partition $(\mathcal{R}_S, \mathcal{R}_L)$ in the sorting stage, the mass of investors who hold bond i is

$$\mu_i = \int_{\mathcal{R}_i} dG \quad (28)$$

and the endogenous CDF of reservation values for bond i is

$$F_i(w) = \frac{1}{\mu_i} \int_{\mathcal{R}_i} \mathbf{1}_{\{h_i(r) \leq w\}} dG. \quad (29)$$

In the restructuring stage, the government takes these distributions as given when choosing the recovery rates and modification method. We can now define the notion of equilibrium in this two-stage stationary setting.

Definition 1. *Given the distribution G of discount rates on $\mathcal{R}$, bond characteristics (c_S, δ_S) and (c_L, δ_L) , relative face values (λ_S, λ_L) , default arrival rate η , and reservation value discount parameter χ , an equilibrium consists of*

- (i) *a price differential Δq^* and a partition $(\mathcal{R}_S, \mathcal{R}_L)$,*
- (ii) *a modification method and a pair of recovery rates $\mathbf{w}^*$*

such that

1. *the government chooses the modification method and restructuring offers optimally given the implied distributions F_S and F_L given by (29),*
2. *investors optimally choose which bond to hold: $\mathcal{R}_i = \mathcal{R}_i(\Delta q^*, \mathbf{w}^*)$,*
3. *the market clears for each bond, $\mu_i = \lambda_i$.*

5.3 Equilibrium Example

We now illustrate one type of equilibrium that arises in this setting. We assume that G is uniform on $\mathcal{R} = [0, 0.55]$. We set $(\delta_L, \delta_S) = (0.05, 0.25)$ for the face value decay rates, and $\eta = \chi = 0.4$ for the default intensity and the discount spread that affects reservation values in a restructuring. As a baseline, we fix the relative size of the long-term bond at $\lambda_L = 0.37$. We fix the coupon rate of the short-term bond at $c_S = \mathbb{E}(r) + \delta_S$,²⁶ and we set $c_L = \mathbb{E}(r) + \delta_L + \epsilon_L$, where the extra parameter ϵ_L is set at zero by default but later takes value in $[-0.04, 0.04]$ to perform one comparative static exercise. The voting thresholds are set at $\tau_2^S = 1/2$ and $\tau_2^L = \tau_1 = 2/3$, providing for a clean comparison of aggregation methods.

For such parameters, one can construct a threshold-type equilibrium in which

$$\mathcal{R}_L = [r_{\min}, \hat{r}] \quad \text{and} \quad \mathcal{R}_S = [\hat{r}, r_{\max}].$$

In such an equilibrium, short-term bonds are held by the more impatient investors, with discount rates above the threshold level $\hat{r}$. Market clearing requires that

$$\hat{r} = G^{-1}(\lambda_L)$$

and the price differential is pinned down as $\Delta q^* = Q_S(\hat{r}, w_S^*) - Q_L(\hat{r}, w_L^*)$, where w_i^* is the equilibrium offer to bond i . The investors' reservation values for bonds L and S in the restructuring stage fall in the intervals²⁷

$$\mathcal{V}_L = [h_L(\hat{r}), h_L(r_{\min})] \quad \text{and} \quad \mathcal{V}_S = [h_S(r_{\max}), h_S(\hat{r})], \quad (30)$$

²⁶This normalization implies that absent default risk, the average investor would value the bond at par.

²⁷It is worth noting that the lower bound of $\mathcal{V}_L$ and the upper bound of $\mathcal{V}_S$ depend on $\hat{r}$, while the other two bounds are independent of it.

and the reservation value CDFs are of the form

$$F_i(w) = a_i - b_i/w \quad \text{for} \quad w \in \mathcal{V}_i, \quad (31)$$

where the coefficients a_i, b_i are given by

$$\begin{aligned} a_L &:= \frac{\lambda_L r_{\max} + (1 - \lambda_L) r_{\min} + \delta_L + \chi}{\lambda_L (r_{\max} - r_{\min})}, & b_L &:= \frac{c_L}{\lambda_L (r_{\max} - r_{\min})} \\ a_S &:= \frac{r_{\max} + \delta_S + \chi}{\lambda_S (r_{\max} - r_{\min})}, & b_S &:= \frac{c_S}{\lambda_S (r_{\max} - r_{\min})}. \end{aligned} \quad (32)$$

The expressions in (32) illustrate how the relative size λ_i of each bond determines the reservation value distributions through the sorting stage. Thanks to the simple functional form taken by the CDFs, we can solve for the government's optimal restructuring offers under each aggregation method in closed form. The derivations follow the same logic as in Section 2 and are relegated to Appendix A.4.

Figure 3 illustrates the aforementioned equilibrium objects graphically. The left panel plots the bond valuation functions $Q_i(\cdot, w_i^*)$ and the threshold value $\hat{r}$ in the sorting stage. The center panel illustrates the reservation value functions $h_i(\cdot)$, using solid lines in the regions of $\mathcal{R}$ where they are relevant, and dotted lines otherwise. The right panel illustrates the reservation value CDFs, revealing that bond L is the relatively "expensive" one in this example. The consent shares implied by the optimal single-limb and two-limb offers are denoted with diamond and star markers, respectively. In our baseline parametrization, the auxiliary solution is not feasible (the optimal two-limb offer hence inducing a consent share for bond L equal to the series-by-series threshold) and the single-limb method dominates.

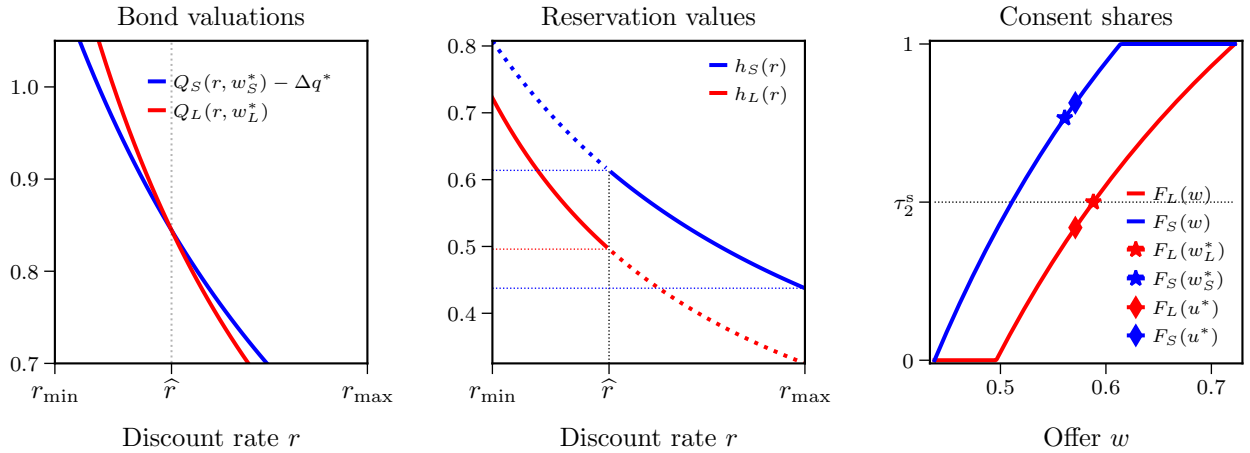


Figure 3: Equilibrium Bond Valuations and Price Differential, Reservation Values, and CDFs.

5.4 Comparative Statics

We now consider how the optimal modification method and restructuring offers depend on the relative face value of the bonds and on the heterogeneity between the reservation value distributions. In Section 3, these two aspects were independently governed by the parameters λ and γ , respectively. Now instead the degree of heterogeneity in the reservation value distributions is endogenous and partly depends on the relative bond size. Yet the insights from Section 3 are useful to interpret the comparative statics obtained in the model with sorting.

Distribution Heterogeneity. We start by considering the effect of a change in the coupon rate of the long-term bond, holding everything else fixed. As can be seen from (31)-(32), an increase in c_L shifts F_L down

and to the right, while leaving F_S unchanged. Hence, relative to the baseline configuration depicted in the right panel of Figure 3, the heterogeneity in equilibrium reservation value distributions increases across the two bonds.

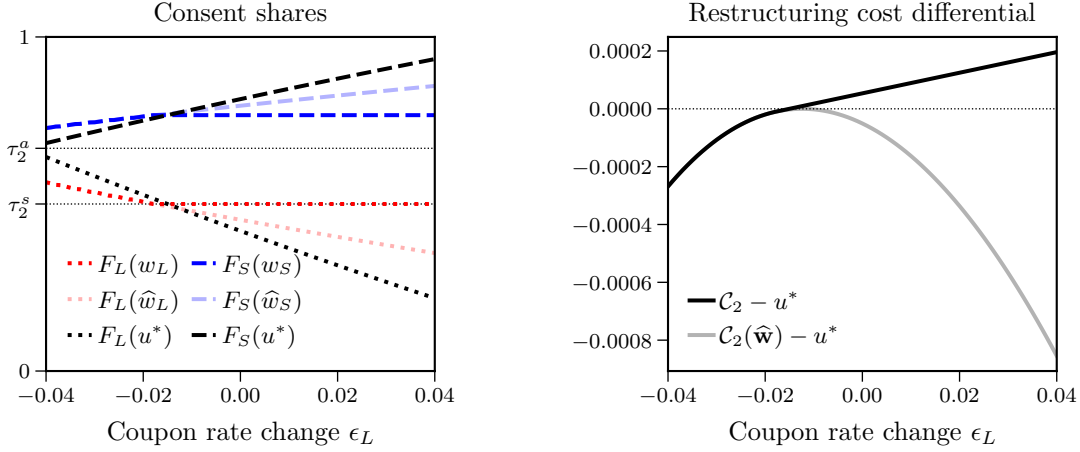


Figure 4: Comparative Static with Respect to Heterogeneity Driven by a Change in c_L .

Figure 4 illustrates the equilibrium restructuring outcomes as a function of the change ϵ_L in the coupon rate c_L . The left panel plots the consent shares implied by the optimal two-limb offers (in dashed blue and dotted red for the short- and long-term bond, respectively) and by the optimal single-limb offer (in black), while the right panel plots the difference between the total restructuring cost of the two-limb and single-limb procedures. The shaded lines in the left panel represent the consent shares induced by the auxiliary solution when it is not feasible: this is a useful reference, because the aggregation method that dominates is typically the one that delivers consent shares that are closest to the auxiliary problem solution. For low values of ϵ_L , the equilibrium reservation value distributions are quite similar,²⁸ and the optimal two-limb solution coincides with that of the auxiliary problem, thus dominating the single-limb solution. For larger values of ϵ_L , the auxiliary solution stops being feasible as the series-by-series constraint for bond L starts binding under two-limb aggregation, and the single-limb method becomes optimal. Hence, as in Sections 2 and 3, single-limb becomes more attractive when the reservation value distributions are (locally) more heterogeneous.

Relative Bond Size: Partial Effect. Next, we consider the effect of a change in the relative size of the long-term bond λ_L . To do so, it is useful to first abstract from any impact of this change on the reservation value distributions, which we shall momentarily keep fixed as in the baseline. Figure 5 provides an illustration. The left panel plots the optimal offers under two-limb and single-limb aggregation, together with the auxiliary offers (shaded). The center panel plots the corresponding consent shares, and the right panel the restructuring cost differential. The dotted vertical lines indicate the value of λ_L used to obtain the baseline reservation value distributions.

The mechanism through which a change in relative bond size affects the restructuring outcome is the same as that described in Section 2: when the share λ_L of the more “expensive” bond increases, all offers increase. The auxiliary offer to bond L is never feasible in this example, because it implies $F_L(\hat{w}_L) < \tau_2^S$; however, as it approaches $F_L^{-1}(\tau_2^S)$, the two-limb method becomes cheaper than single-limb, because the cost of the series-by-series constraints becomes smaller than that of the uniform applicability constraint. Hence, as in Section 2, single-limb tends to be optimal when the expensive bond is relatively small, whereas two-limb is optimal otherwise.

Total Effect of a Change in Relative Size. We can now discuss the full effect of a change in λ_L , which is the sum

²⁸This can be seen from the fact that $F_L(u^*)$ and $F_S(u^*)$ are close to each other.

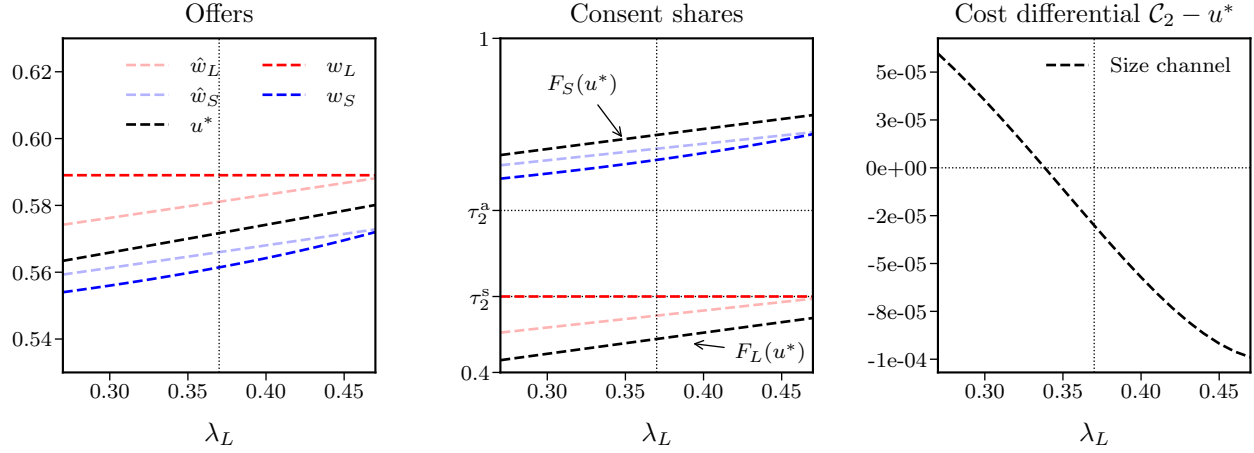


Figure 5: Partial Comparative Static with Respect to λ_L , Holding F_i 's Fixed.

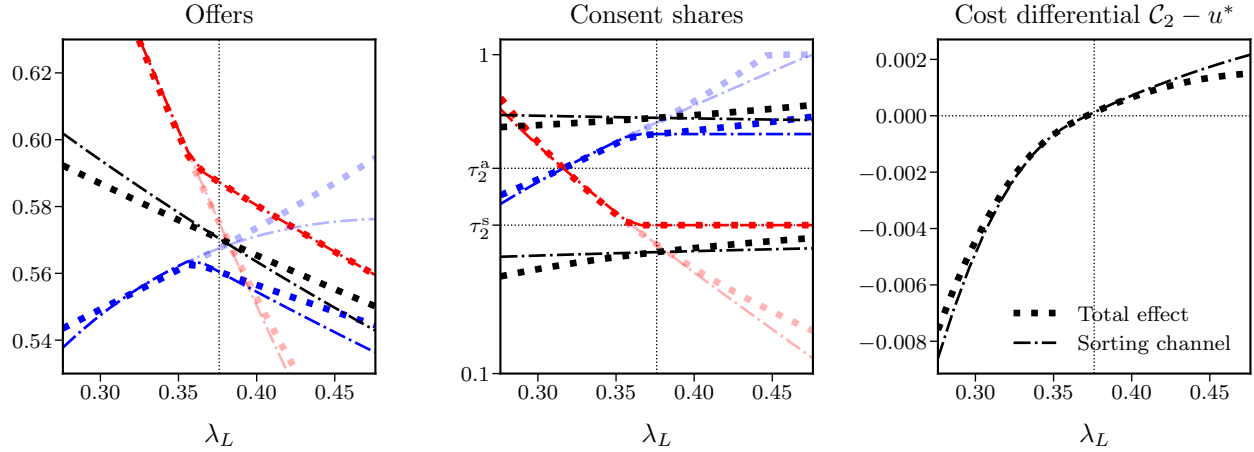


Figure 6: Comparative Static with Respect to λ_L : Sorting Channel and Total Effect.

of the pure size effect as captured in Figure 5, and of the additional effect driven by the change in reservation value distributions arising from the sorting stage. Indeed, as can be seen from (31)-(32), a higher share λ_L of the long-term bond lowers both the upper bound of $\mathcal{V}_S$ and the lower bound of $\mathcal{V}_L$, while it does not affect the other bounds: it follows that F_S becomes steeper, F_L flatter, and both distributions move leftwards.

It is useful to consider the effect driven by this induced change in the equilibrium reservation value distributions, abstracting from the pure size effect. Figure 6 thus depicts with dash-dotted thin lines the partial effect driven by this “sorting channel”, along with the total impact of λ_L on restructuring outcomes depicted with thick dotted lines.²⁹ As λ_L increases, the auxiliary offer increases for bond S and decreases for bond L , since the former now provides a relatively higher “bang for the buck” than the latter due to the steepening (resp. flattening) of F_S (resp. F_L).³⁰ Hence the shaded lines representing $\hat{w}_i$ in the left panel have slopes with opposite signs, and the corresponding consent shares in the center panel ultimately diverge, as in the case of an increase in heterogeneity brought about by an increase in c_L (see Figure 4). For sufficiently high values of λ_L the auxiliary solution violates the series-by-series constraint for bond L , and the single-limb method becomes cheaper as it allows the government to obtain a lower consent share in the expensive bond.

In this example the pure size effect of a change in λ_L is dwarfed by the sorting effect, so the total ef-

²⁹We omit the legends to make the figure less dense; the color coding is as in Figure 5. The consent shares depicted in black correspond to bond L when they are below τ_2^a , and to bond S when they are above.

³⁰See Section 1.2 for further discussion of the determinants of the auxiliary solution.

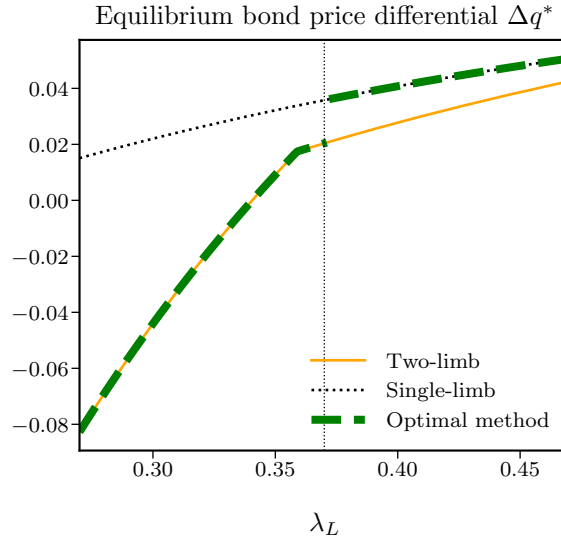


Figure 7: Bond Price Differential as a Function of CACs Specification and Relative Size.

fect closely resembles the latter: a higher share of the long-term bond makes the restructuring cheaper for the sovereign, the reservation value distributions more heterogeneous, and the single-limb method more attractive.

Equilibrium Bond Price Differential. Finally, we discuss the impact of CACs on bond valuations, focusing on the equilibrium price differential (Δq^*) between the short- and the long-term bond.³¹ Figure 7 depicts Δq^* as a function of the relative size λ_L of the long-term bond under either two-limb-only CACs (solid orange), single-limb-only CACs (dotted black), or enhanced CACs (thick dashed green). In this example, Δq^* under single-limb-only is higher than under two-limb-only for any λ_L . Moreover, both price differentials are increasing in λ_L , and the bond price differential under enhanced CACs has a discontinuous jump upwards at the cutoff value of λ_L above which single-limb dominates. More generally, the specification of CACs affects the price differential in the sorting stage through its impact on the level and differential between equilibrium offers in the restructuring stage. Naturally, the design of CACs has a greater price impact when the probability of a restructuring (η) is large.

6 Conclusion

CACs constitute a key pillar of the sovereign debt architecture. This paper analyzes the optimal use of enhanced CACs by a sovereign seeking to restructure multiple bonds at minimal cost. The problem essentially boils down to a comparison between two constrained minimization problems. Our analysis clarifies how the optimal restructuring approach depends on the heterogeneity across bonds and their relative size, as well as on the various voting thresholds. In particular, our analysis reveals that resorting to the single-limb procedure introduced in the last-generation ICMA CACs is optimal only under quite special circumstances, namely, when one bond is held by investors who are particularly reluctant to take a haircut and this bond is relatively small in the restructuring pool. We also show that the distribution of investors within and across bonds depends on the design of CACs and the anticipation of their optimal use. Specifically, single-limb aggregation can be a useful off-equilibrium deterrent in the presence of vulture funds, even though it may not be used in equilibrium.

³¹In our setting, the price level of each bond in the sorting stage is indeterminate.

Although most of our analysis is developed in a two-bond setup, it can easily be extended to N bonds, possibly allowing for interlocking debt stocks featuring different CACs specifications—as was the case in Argentina 2020 with the two subsets of Kirchner and Macri bonds. The optimal use of sub-aggregation could be analyzed in such an extended setting.

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A Technical Appendix

A.1 Proof of Proposition 1

Define the set of offers that satisfy the aggregate constraint

$$\mathcal{A}(\tau) = \left\{ \mathbf{w} : \sum_{i \in \mathcal{B}} \lambda_i F_i(w_i) \geq \tau \right\},$$

the set of offers that satisfy the series-by-series constraints

$$\mathcal{S}(\tau) = \left\{ \mathbf{w} : F_i(w_i) \geq \tau \text{ for all } i \in \mathcal{B} \right\},$$

and the set of offers that satisfy the uniform applicability condition

$$\mathcal{U} = \left\{ \mathbf{w} : w_i = w_j \text{ for all } i, j \in \mathcal{B} \right\}.$$

The restructuring cost associated with the optimal single-limb offer is

$$C_1 \equiv \min_{\mathbf{w} \in \mathcal{A}(\tau_1) \cap \mathcal{U}} \boldsymbol{\lambda} \cdot \mathbf{w} =: \boldsymbol{\lambda} \cdot \mathbf{w}^*, \quad (\text{A.1})$$

while the restructuring cost associated with the optimal two-limb offer is

$$C_2 \equiv \min_{\mathbf{w} \in \mathcal{A}(\tau_2^a) \cap \mathcal{S}(\tau_2^s)} \boldsymbol{\lambda} \cdot \mathbf{w} =: \boldsymbol{\lambda} \cdot \mathbf{w}^{**}, \quad (\text{A.2})$$

and the auxiliary problem can be formulated as

$$\widehat{C} \equiv \min_{\mathbf{w} \in \mathcal{A}(\tau_2^a)} \boldsymbol{\lambda} \cdot \mathbf{w} =: \boldsymbol{\lambda} \cdot \widehat{\mathbf{w}}.$$

Noting that $\mathcal{A}(\tau_1) \subseteq \mathcal{A}(\tau_2^a)$ since $\tau_2^a \leq \tau_1$, condition (i) follows from the fact that

$$\mathbf{w}^* \in \mathcal{S}(\tau_2^s) \Rightarrow C_1 = \min_{\mathbf{w} \in \mathcal{A}(\tau_1) \cap \mathcal{U} \cap \mathcal{S}(\tau_2^s)} \boldsymbol{\lambda} \cdot \mathbf{w} \geq C_2, \quad (\text{A.3})$$

while condition (ii) follows from the observation that

$$\widehat{\mathbf{w}} \in \mathcal{S}(\tau_2^s) \Rightarrow \mathbf{w}^{**} = \widehat{\mathbf{w}} \text{ and } C_2 = \widehat{C} \leq C_1. \quad (\text{A.4})$$

It is immediate to see that (A.3) and (A.4) involve a strict inequality $C_2 < C_1$ if $\mathbf{w}^{**} \notin \mathcal{U}$. ■

A.2 Proofs and Derivations for the Two-Bond Case

Proof of Lemma 1. The properties of $u^* = u(\lambda, \tau_1)$ stated in the lemma follow immediately from the implicit definition (7), using the stochastic ordering assumption (6). ■

Proof of Lemma 2. Using Lemma 1, it is immediate to see that if $F_H^{-1}(\tau_2^s) \leq F_L^{-1}(\tau_1)$, then $u^* \geq F_H^{-1}(\tau_2^s)$ for any value of $\lambda \in (0, 1)$. If instead $F_L^{-1}(\tau_1) < F_H^{-1}(\tau_2^s)$, there exists a unique $\lambda_{\dagger} \in (0, 1)$ such that $u(\lambda_{\dagger}, \tau_1) = F_H^{-1}(\tau_2^s)$, and $u^* = u(\lambda, \tau_1) \geq F_H^{-1}(\tau_2^s)$ for all $\lambda \geq \lambda_{\dagger}$. ■

Remark A-1. When considering two-limb aggregation in the two-bond case, the set $\mathcal{W}$ of possible offers w_L to the holders of bond L such that the aggregate consent requirement (10) can be met for some value of w_H is defined as follows

$$\mathcal{W} = \left\{ \begin{array}{ll} \mathbb{R}^+, & \text{if } \lambda \geq \tau_2^a \\ \left(F_L^{-1} \left(\frac{\tau_2^a - \lambda}{1 - \lambda} \right), \infty \right), & \text{if } 1 - \tau_2^a \leq \lambda < \tau_2^a \\ \left(F_L^{-1} \left(\frac{\tau_2^a - \lambda}{1 - \lambda} \right), F_L^{-1} \left(\frac{\tau_2^a}{1 - \lambda} \right) \right], & \text{if } \lambda < 1 - \tau_2^a \end{array} \right\}. \quad (\text{A.5})$$

Remark A-2. When the auxiliary solution satisfies (15), one can show that

$$\frac{d\widehat{w}_L}{d\lambda} = \left(\frac{f'_L(\widehat{w}_L)}{f'_H(\widehat{w}_H)} + \frac{1 - \lambda}{\lambda} \right)^{-1} \frac{F_L(\widehat{w}_L) - \tau_2^a}{\lambda^2 f_L(\widehat{w}_L)},$$

while

$$\begin{aligned}\frac{d\hat{w}_H}{d\lambda} &= \frac{\partial g(\hat{w}_L; \lambda, \tau_2^a)}{\partial w_L} \frac{d\hat{w}_L}{d\lambda} + \frac{\partial g(\hat{w}_L; \lambda, \tau_2^a)}{\partial \lambda} \\ &= \left(1 + \frac{1 - \lambda}{\lambda} \frac{f'_H(\hat{w}_H)}{f'_L(\hat{w}_L)}\right)^{-1} \frac{F_L(\hat{w}_L) - \tau_2^a}{\lambda^2 f'_L(\hat{w}_L)}.\end{aligned}$$

In particular, in the special case where f_H and f_L are decreasing, one can see that whenever the auxiliary solution is such that $F_L(\hat{w}_L) > \tau_2^a$ (or equivalently, in view of Remark 1, such that the consent share of the cheap bond is higher than for the expensive bond), a marginal increase in the relative size λ of bond H is accompanied by an improvement in the exchange offers made to both bonds.

Proof of Lemma 3. Define $J(w) = \lambda g(w) + (1 - \lambda)w$. Differentiating with respect to w , one can show that the sign of $J'(w)$ coincides with the sign of $f_H[g(w)] - f_L(w)$. The second inequality in (18) is equivalent to the requirement $J'(\underline{w}) < 0$ for $\underline{w} = F_L^{-1}(\tau_2^s)$, while the second inequality in (17) is equivalent to $J'(\bar{w}) > 0$ where $\bar{w}$ is such that $g(\bar{w}) = F_H^{-1}(\tau_2^s)$. ■

Proof of Proposition 2. This is an immediate corollary of Proposition 1: indeed Lemmas 2 and 3 provide conditions such that (i) and (ii) hold, respectively. ■

Proof of Proposition 3. We prove parts (i) and (ii) of the proposition separately.

Part (i). Throughout this part, we denote by $C_1(\lambda)$ and $C_2(\lambda)$ the restructuring cost under single-limb and two-limb voting, and we assume that the aggregate thresholds are identical under the two modification methods, namely, $\tau_1 = \tau_2^a = \tau^a$. It follows immediately that $\lim_{\lambda \downarrow 0} C_1(\lambda) = \lim_{\lambda \downarrow 0} C_2(\lambda) = F_L^{-1}(\tau^a)$. In the remainder of the proof, we focus on the slope of the functions C_1 and C_2 for λ close to zero. Noting that $C_1(\lambda) = u(\lambda, \tau^a)$, we apply the implicit function theorem to obtain

$$\frac{dC_1(\lambda)}{d\lambda} = \frac{\partial u(\lambda, \tau^a)}{\partial \lambda} = \frac{F_L(u^*) - F_H(u^*)}{\lambda f_H(u^*) + (1 - \lambda)f_L(u^*)} > 0.$$

In particular

$$C'_1(0) = \lim_{\lambda \downarrow 0} \frac{dC_1(\lambda)}{d\lambda} = \frac{\tau^a - F_H \circ F_L^{-1}(\tau^a)}{f_L \circ F_L^{-1}(\tau^a)}. \quad (\text{A.6})$$

Next, we analyze the restructuring cost under two-limb voting, $C_2(\lambda)$. First, we establish that under the assumptions of Proposition 3 and for λ small, the individual consent requirement on bond H is binding. To see this, we start from the identity

$$f_L(F_L^{-1}(\tau^a)) - f_H(F_H^{-1}(\tau_2^s)) = \left[f_L(F_L^{-1}(\tau^a)) - f_H(F_L^{-1}(\tau^a)) \right] + \left[f_H(F_L^{-1}(\tau^a)) - f_H(F_H^{-1}(\tau_2^s)) \right].$$

By assumption, $F_L^{-1}(\tau^a) < \tilde{w}$ and $f_L(w) > f_H(w)$ for all $w < \tilde{w}$, implying that the first term is strictly positive. Noting that the second term is also strictly positive under the assumptions of the proposition, we thus conclude that

$$f_L(F_L^{-1}(\tau^a)) > f_H(F_H^{-1}(\tau_2^s)). \quad (\text{A.7})$$

In turn, the inequality (A.7) implies that (17) is violated for λ close to zero. Hence for λ close to zero, the two-limb offer is constrained by the individual consent requirement on bond H . Therefore in this neighborhood

$$C_2(\lambda) = \lambda F_H^{-1}(\tau_2^s) + (1 - \lambda) F_L^{-1} \left(\frac{\tau^a - \lambda \tau_2^s}{1 - \lambda} \right),$$

and

$$\frac{dC_2(\lambda)}{d\lambda} = F_H^{-1}(\tau_2^s) - F_L^{-1}\left(\frac{\tau^a - \lambda\tau_2^s}{1 - \lambda}\right) + \frac{\tau_2^a - \tau_2^s}{1 - \lambda} \left[f_L \circ F_L^{-1}\left(\frac{\tau^a - \lambda\tau_2^s}{1 - \lambda}\right) \right]^{-1}.$$

In particular,

$$C_2'(0) = \lim_{\lambda \downarrow 0} \frac{dC_2(\lambda)}{d\lambda} = F_H^{-1}(\tau_2^s) - F_L^{-1}(\tau^a) + \frac{\tau^a - \tau_2^s}{f_L \circ F_L^{-1}(\tau^a)}. \quad (\text{A.8})$$

Combining (A.6) and (A.8), we obtain that

$$C_1'(0) < C_2'(0) \quad \Leftrightarrow \quad (F_H^{-1}(\tau_2^s) - F_L^{-1}(\tau^a))f_L[F_L^{-1}(\tau^a)] > \tau_2^s - F_H[F_L^{-1}(\tau^a)].$$

To show that this inequality holds, we note that f_H being strictly decreasing implies that F_H is strictly concave, which in turn implies that

$$(F_H^{-1}(\tau_2^s) - F_L^{-1}(\tau^a))f_H[F_L^{-1}(\tau^a)] > F_H[F_H^{-1}(\tau_2^s)] - F_H[F_L^{-1}(\tau^a)] = \tau_2^s - F_H[F_L^{-1}(\tau^a)],$$

and the desired inequality follows from the fact that $f_L(w_L) > f_H(w_L)$ since $w_L < \tilde{w}$. By continuity, we conclude that $C_1 < C_2$ for λ close to 0.

Proof of part (ii). Noting that $F_H^{-1}(\tau_2^s) < F_H^{-1}(\tau_1)$, we know by assumption that the location of the crossing point $\tilde{w}$ is such that $\tilde{w} \in (F_L^{-1}(\tau_1), F_H^{-1}(\tau_1))$. In view of Lemma 1, the intermediate value theorem implies that there exists $\tilde{\lambda} \in (0, 1)$ such that $u(\tilde{\lambda}, \tau_1) = \tilde{w}$. By construction, the single-limb uniform offer u^* is equal to $\tilde{w}$ for $\lambda = \tilde{\lambda}$. Moreover, $\tilde{\lambda}F_H(\tilde{w}) + (1 - \tilde{\lambda})F_L(\tilde{w}) = \tau_1$ is equivalent to $\tilde{w} = g(\tilde{w}; \tilde{\lambda}, \tau_1)$. Therefore we can write

$$f_L(\tilde{w}) = f_H(\tilde{w}) = f_H(g(\tilde{w}; \tilde{\lambda}, \tau_1)). \quad (\text{A.9})$$

Setting $\lambda = \tilde{\lambda}$, we next consider the restructuring cost under two-limb voting for $\tau_2^a = \tau_1$. The assumption that the densities are decreasing guarantees convexity of the corresponding auxiliary problem, and (A.9) implies that the auxiliary solution is given by $\hat{w} = (\tilde{w}, \tilde{w})$. Yet since $F_H(\tilde{w}) < \tau_2^s$ by assumption, the auxiliary solution violates the individual consent requirement on bond H , implying that $C_2 > \tilde{w}$. Therefore, for $\lambda = \tilde{\lambda}$ and $\tau_2^a = \tau_1$, we have $C_1 = \tilde{w} < C_2$ and by continuity, we conclude that the single-limb method is optimal when the parameters (λ, τ_2^a) are close to $(\tilde{\lambda}, \tau_1)$. ■

A.3 Parametric Example: Derivations and Additional Results

With a view towards applying some of the results derived in Section 2, we first note that under the parametric specification (20), the two densities are strictly decreasing, with

$$f_i(w) = \frac{1}{\phi_i} e^{-\frac{w}{\phi_i}}.$$

Moreover, the two densities cross at a single point $\tilde{w}$ given by

$$\tilde{w} = \frac{\gamma \log \gamma}{\gamma - 1} \phi_L. \quad (\text{A.10})$$

Holding ϕ_L fixed, $\tilde{w}$ is increasing in the heterogeneity parameter γ . We also note that

$$F_L^{-1}(\tau_1) < F_H^{-1}(\tau_2^s) \quad \Leftrightarrow \quad \gamma > \frac{\log(1 - \tau_1)}{\log(1 - \tau_2^s)} \equiv \bar{\gamma}_U \quad (> 1). \quad (\text{A.11})$$

Auxiliary Solution. Under the exponential specification, condition (14) for strict convexity of the auxiliary problem is satisfied and the mapping g that captures the aggregate consent requirement becomes

$$g(w_L) = -\phi_H \log \left(\frac{1 - \tau_2^a - (1 - \lambda)e^{-w_L/\phi_L}}{\lambda} \right), \quad w_L \in \mathcal{W}.$$

The first-order condition (15) to the auxiliary problem gives³²

$$\hat{w}_L = \phi_L \log \left(\frac{1 + \lambda(\gamma - 1)}{1 - \tau_2^a} \right), \quad (\text{A.12})$$

and the induced consent share for bond L is given by (21). Since $F_L(\hat{w}_H) > \tau_2^a$, it follows from Remark 1 that $F_H(\hat{w}_H) < \tau_2^a$. Hence, in the context of this parametric example, only the individual constraint on bond H may ever be binding. We compute

$$\hat{w}_H = g(\hat{w}_L) = \phi_H \log \left(\frac{1 + \lambda(\gamma - 1)}{\gamma(1 - \tau_2^a)} \right), \quad (\text{A.13})$$

and the consent share for bond H is given by (22). The auxiliary offers $\hat{w}_L$ and $\hat{w}_H$, and the corresponding consent shares, are increasing in λ —in line with the more general result stated in Remark A-2 in Appendix A.2. Moreover, one can check that $F_L(\hat{w}_L)$ is increasing in γ while $F_H(\hat{w}_H)$ is decreasing in γ —that is, the spread in consent shares under the auxiliary solution is increasing in the degree of bond heterogeneity.

Optimal Two-Limb Offer. The optimal offers under two-limb voting coincide with the auxiliary solution (A.12)–(A.13) as long as $F_H(\hat{w}_H) \geq \tau_2^s$. Using (22), one can see that the latter inequality is equivalent to

$$\frac{1 + \lambda(\gamma - 1)}{\gamma} \geq \frac{1 - \tau_2^a}{1 - \tau_2^s}. \quad (\text{A.14})$$

For given values of the voting thresholds τ_2^a and τ_2^s , one can characterize more explicitly the set of values for λ and γ such that (A.14) holds. Since $F_H(\hat{w}_H)$ is increasing in λ and decreasing in γ , the inequality is more likely to hold for high values of λ and low values of γ . Indeed, it is easy to see that (A.14) holds

- if $\gamma \leq (1 - \tau_2^s)/(1 - \tau_2^a) \equiv \bar{\gamma}_X$, for all values of λ ;
- if $\lambda \geq (1 - \tau_2^a)/(1 - \tau_2^s) \equiv \underline{\lambda} \in (0, 1)$, for all values of γ ;
- in the remainder of the parameter space for γ sufficiently small or λ sufficiently large (see Remark A-3 below for an explicit condition).

Conversely, the consent requirement on the expensive bond H is binding when there is sufficient heterogeneity across the two bonds ($\gamma > \bar{\gamma}_X$) and the relative size of bond H is small. For such parameter values, the optimal two-limb offers are

$$w_H = F_H^{-1}(\tau_2^s) = \phi_H \log \left(\frac{1}{1 - \tau_2^s} \right), \quad (\text{A.15})$$

$$w_L = F_L^{-1} \left(\frac{\tau_2^a - \lambda\tau_2^s}{1 - \lambda} \right) = \phi_L \log \left(\frac{1 - \lambda}{1 - \tau_2^a - \lambda(1 - \tau_2^s)} \right). \quad (\text{A.16})$$

³²The solution to the auxiliary problem is pinned down by this condition as long as the problem's solution is interior. In view of (A.5), one can see that the auxiliary solution is non-interior if and only if $\lambda < 1 - \tau_2^a$ and $\gamma > (1 - \lambda)/(1 - \lambda - \tau_2^a)$, in which case $\hat{w}_L = \sup \mathcal{W}$ and the consent share for bond H is zero, thus violating the individual constraint for this bond. Hence, whenever the optimal two-limb offers coincide with the auxiliary solution, the recovery values on the two bonds are given by (A.12) and (A.13).

Remark A-3. When $\gamma > \bar{\gamma}_X = \underline{\lambda}^{-1}$, the condition on λ such that (A.14) holds is

$$\lambda \geq \frac{\underline{\lambda}\gamma - 1}{\gamma - 1} \equiv \ell_X(\gamma) \in (0, 1), \quad (\text{A.17})$$

where ℓ_X is increasing in γ and converges to $\underline{\lambda}$ in the limit as γ goes to infinity. When $\lambda < \underline{\lambda}$, the condition on γ can be expressed as

$$\gamma \leq \frac{1 - \lambda}{\underline{\lambda} - \lambda}, \quad (\text{A.18})$$

where the right-hand side is increasing in λ , starting at $\bar{\gamma}_X$ for $\lambda = 0$ and going to infinity in the limit as $\lambda \uparrow \underline{\lambda}$.

Optimal Voting Procedure. When parameter values are such that (A.14) holds, two-limb aggregation is optimal since the series-by-series constraints have no bite. Yet another sufficient condition for two-limb optimality is that the optimal uniform offer u^* satisfies the series-by-series constraints, in which case the unique advantage of single-limb aggregation is worthless. Applying Lemma 2 (see also Proposition 2), one can see that $F_H(u^*) \geq \tau_2^s$ if $\gamma \leq \bar{\gamma}_U$, where $\bar{\gamma}_U$ is given by (A.11), or alternatively if

$$\lambda \geq \frac{1 - \tau_1 - (1 - \tau_2^s)^\gamma}{1 - \tau_2^s - (1 - \tau_2^s)^\gamma} \equiv \ell_U(\gamma) \in (0, 1) \quad \text{for } \gamma > \bar{\gamma}_U, \quad (\text{A.19})$$

where one can check that the definition of ℓ_U ensures that $u(\ell_U(\gamma), \tau_1) = F_H^{-1}(\tau_2^s)$. It is worth noting that Condition (A.19) can also be viewed as setting an upper bound on γ that is an increasing function of λ , starting at $\bar{\gamma}_U$ for $\lambda = 0$ and going to infinity as $\lambda \uparrow (1 - \tau_1)/(1 - \tau_2^s)$. One can see that when $\tau_1 = \tau_2^a$, the functions ℓ_U^{-1} and ℓ_X^{-1} both have an asymptote at $\lambda = \underline{\lambda}$, whereas if $\tau_1 > \tau_2^a$ the asymptote for ℓ_U^{-1} is at a value of λ strictly below $\underline{\lambda}$.

In order to exploit Proposition 3 and establish instead a sufficient condition for single-limb optimality, we first need to find restrictions that ensure that $\tilde{w} \in (F_L^{-1}(\tau_1), F_H^{-1}(\tau_2^s))$. It is immediate to see from (A.10) that this amounts to finding $\gamma > \bar{\gamma}_U$ such that

$$-\log(1 - \tau_1) < \frac{\gamma \log \gamma}{\gamma - 1} < -\gamma \log(1 - \tau_2^s), \quad (\text{A.20})$$

and one can show (see Remark A-4 below) that these inequalities are satisfied for high values of γ . For such values of γ , we know from Proposition 3 that single-limb voting is optimal for λ sufficiently close to zero when $\tau_1 = \tau_2^a$, and in the neighborhood of

$$\tilde{\lambda} = \frac{1 - \tau_1 - \gamma^{-\frac{\gamma}{\gamma-1}}}{(\gamma - 1)\gamma^{-\frac{\gamma}{\gamma-1}}}, \quad (\text{A.21})$$

when $\tau_1 - \tau_2^a$ is small, where one can check that the point $\tilde{\lambda} > 0$ is such that $u(\tilde{\lambda}, \tau_1) = \tilde{w}$.

Remark A-4. To see that the inequalities in (A.20) are satisfied for high values of γ , first note that $-\log(1 - \tau) > 0$ is increasing in τ , with $-\log(1 - \tau) > 1$ for $\tau > 1 - e^{-1} \approx 0.63$. Since $\gamma \log \gamma / (\gamma - 1)$ is strictly increasing in γ , with limit 1 as $\gamma \downarrow 1$ and going to infinity as $\gamma \rightarrow \infty$, the first inequality is satisfied for γ sufficiently large. Likewise, since $\log \gamma / (\gamma - 1)$ is strictly decreasing in γ , with limit 1 as $\gamma \downarrow 1$ and going to zero as $\gamma \rightarrow \infty$, the second inequality is also satisfied for γ sufficiently large.

Necessary and Sufficient Condition. When none of the sufficient conditions holds, the participation constraint on bond H must be binding under two-limb voting, in which case the optimal two-limb offers are given by (A.15)-(A.16). The restructuring cost is then given by

$$C_2 = \lambda \phi_H \log \left(\frac{1}{\zeta_2^s} \right) + (1 - \lambda) \phi_L \log \left(\frac{1 - \lambda}{\zeta_2^a - \lambda \zeta_2^s} \right),$$

where $\zeta_2^j = 1 - \tau_2^j$ for $j \in \{s, a\}$. Under single-limb voting, the optimal uniform offer u^* is implicitly defined by

$$F(u^*) \equiv \lambda F_H(u^*) + (1 - \lambda) F_L(u^*) = 1 - \lambda e^{-u^*/\phi_H} - (1 - \lambda) e^{-u^*/\phi_L} = \tau_1,$$

and the total cost for the government is $C_1 = u^* = F^{-1}(\tau_1)$. Therefore, single-limb aggregation is optimal if and only if $F^{-1}(\tau_1) < C_2$, which is equivalent to $F(C_2) > \tau_1$. We thus obtain a necessary and sufficient condition for single-limb optimality in terms of parameter values:

$$\lambda (\zeta_2^s)^\lambda \left(\frac{\zeta_2^a - \lambda \zeta_2^s}{1 - \lambda} \right)^{\frac{1-\lambda}{\gamma}} + (1 - \lambda) (\zeta_2^s)^{\lambda\gamma} \left(\frac{\zeta_2^a - \lambda \zeta_2^s}{1 - \lambda} \right)^{1-\lambda} < 1 - \tau_1. \quad (\text{A.22})$$

Remark A-5. In the limit as $\gamma \rightarrow \infty$, Condition (A.22) boils down to a restriction on λ , namely,

$$\lambda (1 - \tau_2^s)^\lambda < 1 - \tau_1.$$

It is easy to check that the left-hand side is strictly increasing in $\lambda \in (0, 1)$ if $\tau_2^s \leq 1 - e^{-1} \approx 0.63$, in which case there is a unique λ_∞ such that $\lambda (1 - \tau_2^s)^\lambda = 1 - \tau_1$. In the limit as γ goes to infinity, two-limb dominates for λ greater than λ_∞ .

A.4 Derivations for the Model with Sorting

Reservation Value Distributions. Let $R := r_{\max} - r_{\min}$ denote the width of set $\mathcal{R}$. In the equilibrium described in Section 5.3, the reservation value distribution for bond L is

$$\begin{aligned} F_L(w_L) &= \frac{G(\hat{r}) - G(c_L/w_L - (\delta_L + \chi))}{\lambda_L} = \\ &= \frac{\lambda_L R + \delta_L + \chi + r_{\min}}{\lambda_L R} - \frac{c_L}{\lambda_L R} \frac{1}{w_L} = \\ &= a_L - \frac{b_L}{w_L} \quad \text{for } w_L \in \mathcal{V}_L \end{aligned}$$

where $a_L := \frac{1}{\lambda_L R} (\lambda_L R + \delta_L + \chi + r_{\min})$, and $b_L := \frac{c_L}{\lambda_L R}$. The reservation value distribution for bond S is

$$\begin{aligned} F_S(w_S) &= \frac{1 - G(c_S/w_S - (\delta_S + \chi))}{\lambda_S} = \\ &= \frac{R + \delta_S + \chi + r_{\min}}{\lambda_S R} - \frac{c_S}{\lambda_S R} \frac{1}{w_S} = \\ &= a_S - \frac{b_S}{w_S} \quad \text{for } w_S \in \mathcal{V}_S \end{aligned}$$

where $a_S := \frac{1}{\lambda_S R} (R + \delta_S + \chi + r_{\min})$ and $b_S := \frac{c_S}{\lambda_S R}$. For the reservation value CDFs to be well-defined, we need that their support is bounded and given by

$$\mathcal{V}_i = [F_i^{-1}(0), F_i^{-1}(1)] =: [\underline{w}_i, \bar{w}_i] = \left[\frac{b_i}{a_i}, \frac{b_i}{a_i - 1} \right].$$

Auxiliary Problem. The auxiliary problem is given by

$$\min_{w_L \in \mathcal{W} \cap \mathcal{V}_L} \lambda_S g(w_L) + \lambda_L w_L$$

where $g(w_L) = \frac{\lambda_S b_S}{\lambda_S a_S + \lambda_L (a_L - b_L/w_L) - \tau_2^a}$ is as defined in (12), and set $\mathcal{W} := [\underline{w}_L^{\text{aux}}, \bar{w}_L^{\text{aux}}]$ is, as in Section 2, the set of offers to bond L such that the aggregate constraint for the two-limb method can be met for some value of $w_S \in \mathcal{V}_S$. Mathematically

$$w_L \in [\underline{w}_L^{\text{aux}}, \bar{w}_L^{\text{aux}}] := \left[\frac{\lambda_L b_L}{\lambda_S + \lambda_L a_L - \tau_2^a}, \frac{\lambda_L b_L}{\lambda_L a_L - \tau_2^a} \right] \Leftrightarrow w_S^{\text{aux}}(w_L) \in \mathcal{V}_S.$$

Which of the sets $\mathcal{V}_L$ or $\mathcal{W}$ impose tighter bounds depends on parameters, specifically

$$\begin{aligned} \underline{w}_L^{\text{aux}} \geq \underline{w}_L &\Leftrightarrow \lambda_L \geq 1 - \tau_2^a \\ \bar{w}_L^{\text{aux}} \leq \bar{w}_L &\Leftrightarrow \lambda_L \geq \tau_2^a. \end{aligned}$$

When interior, the auxiliary solution is as in (15) and is given by

$$\hat{w}_L = \frac{\lambda_S b_S \sqrt{\frac{b_L}{b_S}} + \lambda_L b_L}{\lambda_S a_S + \lambda_L a_L - \tau_2^a} \quad \text{and} \quad \hat{w}_S = \frac{\lambda_S b_S}{\lambda_S a_S + \lambda_L a_L - \lambda_L \frac{b_L}{\hat{w}_L} - \tau_2^a}.$$

Optimal Two-Limb Offer. The series-by-series constraints are satisfied when

$$w_i \geq F_i^{-1}(\tau_2^s) > \underline{w}_i.$$

We consider configurations where bond L is the expensive one, so its series-by-series constraint may be violated by the auxiliary solution. The optimal two-limb offer is thus given by

$$w_L = \begin{cases} \hat{w}_L & \text{if } \hat{w}_L \in \mathcal{W} \cap \mathcal{V}_L \\ \min\{\mathcal{W} \cap \mathcal{V}_L\} & \text{if } \hat{w}_L < \min\{\mathcal{W} \cap \mathcal{V}_L\} \\ \max\{\mathcal{W} \cap \mathcal{V}_L\} & \text{if } \hat{w}_L > \max\{\mathcal{W} \cap \mathcal{V}_L\}. \end{cases}$$

Single-Limb Offer. The optimal single-limb offer is given by

$$u^* = \begin{cases} \hat{u} & \text{if } \hat{u} \in \mathcal{V}_L \cap \mathcal{V}_S \\ F_i^{-1}\left(\frac{\tau_1 - \lambda_j \phi_j}{\lambda_i}\right) & \text{if } \hat{u} \in \mathcal{V}_i \setminus \mathcal{V}_j, \phi_j \in \{0, 1\}, \text{ for } j \in \{S, L\}. \end{cases}$$

where $\hat{u}$ is defined by equation (7) and is given by

$$\hat{u} := \frac{\lambda_L b_L + \lambda_S b_S}{\lambda_L a_L + \lambda_S a_S - \tau_1}.$$

One can show that $u^* = \hat{u}$ when

$$\lambda_S \in \left[\frac{t_S + \frac{c_S}{c_L} (R \tau_1 - t_L)}{R}, \frac{t_L + \frac{c_L}{c_S} (R \tau_1 - t_S)}{R} \right] \quad (\text{A.23})$$

where $t_i := r_{\max} + \delta_i + \chi$, if parameters are such that the interval exists.

SESSION II

Market Dynamics and Their Impact on Public Debt Management Performance

Secondary Market Liquidity: The Role of Repo Market Specialness

Valentina Catapano^a, Luciano Greco^b, Filippo Mormando^c

Abstract

The repurchase agreements (repo) market plays an essential role to warrant the proper functioning and efficiency of government bond markets. In particular, it is pivotal to ensure the liquidity of the secondary market. Market participants can use the repo market either to borrow liquidity or to borrow a specific bond to accomplish their transactions in the secondary market, thus easing their own inventory costs. While the literature has already explored the impact of a larger bid-ask spread (on the secondary market) on the specialness (on the repo market), we carry out a novel exercise to study the inverse relation, i.e., whether the specialness of a bond is a driver of the bid-ask spread. To conduct the analysis, we rely on a dataset of cash and repo transactions obtained from MTS Italy – the regulated wholesale secondary market for Italian government bonds – which is the first electronic market in Europe. Taking into account the endogeneity that affects the relation between the two variables, we show that a higher level of specialness in the repo market negatively affects secondary market liquidity conditions (i.e., increases the bid-ask spread).

Keywords: Market microstructure, Special collateral, General collateral

JEL Code: E43, G12, G23, C26

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1. INTRODUCTION

The consequences of recent challenges, such as the COVID-19 crisis, environmental challenges and the rise in interest rates driven by tightening monetary policies in response to inflationary pressures, have raised the attention on public debt issuance and management policies. In this context, the liquidity of sovereign bond markets becomes even more crucial. The governments should try to minimize funding costs, subject to maintaining acceptable levels of risk over a medium to long-term horizon, and managing this trade-off is essential especially for countries with a large amount of debt (World Bank and IMF, 2014). In Italy, the size of debt is among the highest in the world in absolute terms, reaching a value of approximately 2,863.4 € billion at the end of 2023, whose 83.1% represented by negotiable bonds of both the central government and local authorities (MEF, 2024). The Italian Treasury's public debt management aims at improving progressively liquidity conditions on the secondary market for government securities.

Market participants and policy makers have always put a lot of attention on market liquidity, defined as the ability to quickly trade large quantities of assets at a low cost and with limited price impact, because it is key for the efficiency of financial markets (Pástor and Stambaugh, 2003). Indeed, if the secondary market for government securities is not sufficiently liquid, primary dealers will request larger premia, hence higher yields, on issued bonds to face such a liquidity risk, leading the Treasury to bear a larger cost of debt. Therefore, the proper functioning of the secondary market for government securities is crucial in a world of growing public debts (OECD, 2023) and larger financial volatility, and this applies especially to Italy because of its huge stock of debt. The Italian Treasury monitors and evaluates the activities of Specialists – dealers specialized in Italian government securities meeting specific requirements – on the secondary market (MTS Italy – the regulated wholesale secondary market for Italian government bonds – is the first electronic market in Europe, launched by the Italian Treasury and Bank of Italy in 1988).

The repurchase agreements (repo) market is an ancillary (though essential) facility aiming at supporting the proper functioning and efficiency of government bond markets. The repo market enhances the liquidity of the secondary market by smoothing liquidity constraints that market makers usually face in transactions. Market participants can use the repo market to borrow liquidity, in which case they use bonds as collateral; or they can borrow a specific bond through the repo market to accomplish their transactions in the secondary market. In turn, the repo market reduces inventory needs that are associated to transactions on the secondary market. Government bonds are used as collateral on the repo market in two types of transactions. A specific bond can be used either as “special collateral”, when the repo contract identifies it as the only possible security to be used as collateral, or as “general collateral”, when the repo contract identifies it among a set of securities that the counterpart can offer as collateral in the repo contract. The “specialness” is defined as the premium of procuring a specific bond in the repo market: the higher the specialness the higher the scarcity of the specific bond in the repo market (Corradin and Maddaloni, 2020).

Quite intuitively, the liquidity conditions of individual securities on the secondary market and the specialness of such securities on the repo market are intertwined. The relation between bid-ask spread (as a measure of market liquidity) on the secondary market and specialness on the repo market claiming the former as driver of the latter is explored in the literature, both theoretically (e.g., Duffie, 1996; Vayanos and Weill, 2008) and empirically (e.g., Corradin and Maddaloni, 2020; Dufour et al., 2020). Though this transmission channel is important, the mentioned empirical analyses may be affected by a reverse causality problem. A first, descriptive contribution of this paper is to show that, indeed, there is bidirectional causality between liquidity on the secondary market and the specialness on the repo

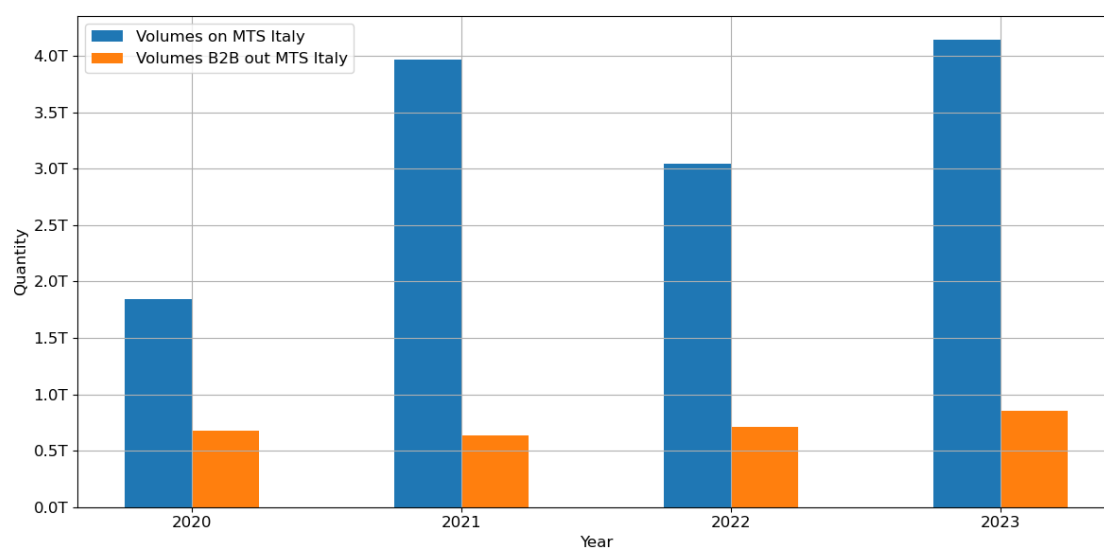
market. Such a consideration brings us to the main contribution of the paper which is to empirically investigate the inverse relation, i.e., how the specialness of a government bond affects its liquidity on the secondary market. The third contribution of the paper is that, from the empirical analysis, we derive policy implications regarding the direct intervention of the Treasury on the repo market. To conduct the analysis, we rely on a dataset of cash and repo transactions obtained from MTS Italy.

The remainder of the paper is organized as follows. Section 2 provides institutional details on cash and repo markets. Section 3 reviews the literature related to the market microstructure, the market liquidity on government bond markets and the specialness on repo markets. Section 4 describes the data and presents some descriptive statistics. Section 5 outlines the empirical model and illustrates the empirical results. Section 6 concludes.

2. CASH AND REPO MARKETS

MTS is one of the largest electronic bond and repo markets in Europe. MTS Italy is the leader inter-dealer platform for the trading of Italian government bonds. Figure 1 illustrates that the trading volumes (in trillions) on MTS Italy are substantial in comparison to the inter-dealer (business-to-business – B2B) volumes traded outside MTS Italy on alternative trading platforms.

Figure 1. Volumes traded on MTS Italy vs. out MTS Italy



Source: Authors' calculations based on data from the Italian Ministry of Economy and Finance.

The secondary market for government securities is where the trading of bonds takes place after their issuance in the primary market. An appropriate microstructure of the secondary market is needed so that it is conducive to market liquidity. Sovereign bond markets are among the most liquid ones, thanks to several factors such as the availability of high-quality voluminous securities with different maturities. Dealers operating in sovereign bond markets are crucial in providing liquidity. The liquidity of Italian sovereign bond market is further enhanced by the integration of multiple linked platforms and services, such as the repo market, which provide additional facilities for managing and trading government debt.

A repo contract involves two financial transactions, occurring at different times. The first one entails the sale of a security – such as an Italian government bond – at its current market value, known as the spot price. In the second transaction, the seller is committed to repurchase the same security at a specified future date and price. The difference between the spot price and the repurchase price effectively determines the repo interest rate, which compensates the lender (i.e., the buyer) of the funds. Thus, a repo contract is sort of a collateralized loan, where the borrower (i.e., the seller) pays a rate for the use of liquidity over the contract term.

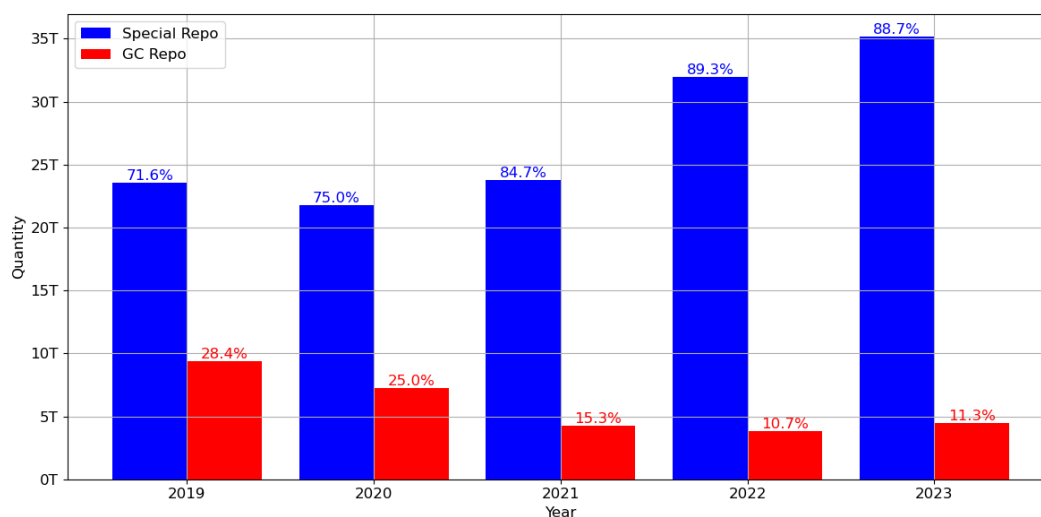
Repos are used by bond market participants either to finance long bond positions by borrowing liquidity or to initiate short bond positions by borrowing the underlying asset (or to cover an outstanding short position). Therefore, transactions in the cash market are often accomplished by market participants through complementary transactions in the repo market.

A repo where the buyer lends liquidity against a generic basket of securities is called “general collateral” (GC) repo, while when the contract requires a specific security to be delivered the transaction is called “special” repo.

In a repo agreement, the party selling the security and obtaining liquidity is entering the repo, while the counterparty that provides the liquidity and takes ownership of the security is entering a reverse repo. This distinction highlights the dual nature of repo transactions as both a funding mechanism and a means of acquiring specific securities. The direction of trading – whether driven by the need for liquidity or the acquisition of a specific bond – affects the dynamics of the repo market.

Figure 2 illustrates that the trading volumes (in trillions) of special repo transactions have increased in recent years. The volume traded in special repo increased consistently, offsetting the slight decline in the volume traded in GC repo.

Figure 2. NRRP resources for firms by mission (values in Eur billion)



Source: Authors' calculations based on MTS Repo data.

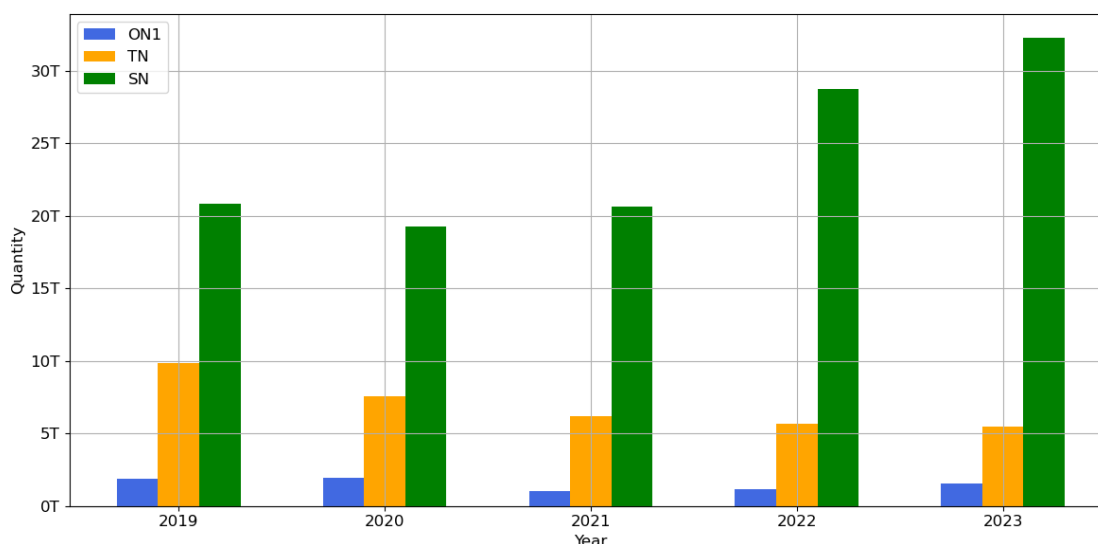
Repo contracts have different maturities. One-day maturity repo contracts are the most common terms and are defined as follows (see Table 1): overnight (ON1), i.e., the repo contract is traded at T, the bond collateral is sold at T and then repurchased at T+1; tomorrow next (TN), i.e., the repo contract is traded at T, the bond collateral is sold at T+1 and then repurchased at T+2; spot next (SN), i.e., the repo contract is traded at T, the bond collateral is sold at T+2 and then repurchased at T+3.

Table 1. Description of repo terms

Repo Term	Repo Settlement Date	Repurchase Date
Overnight (ON1)	T	$T + 1$
Tomorrow Next (TN)	$T + 1$	$T + 2$
Spot Next (SN)	$T + 2$	$T + 3$

Source: our own elaboration.

Figure 3 shows that transactions with SN maturity account for most of the volumes in the repo market.¹ Furthermore, the trading volumes of SN transactions have increased in recent years.

Figure 3. Annual quantity by repo maturity over time

Source: Authors' calculations based on MTS Repo data.

The aim of our work is to explore the mechanisms linking the cash and repo markets² and, in particular, the relation between the scarcity of a specific bond in the repo market and the liquidity of the same bond in the cash market. Indeed, liquidity conditions on the secondary market and specialness on the repo market are intertwined. On the one hand, a more liquid bond with lower bid-ask spread allows dealers to hold the optimal level of inventories and not to have portfolio imbalances. Hence, dealers do not need to rely on the repo market either to finance long positions or to cover short positions on this bond with an effect on the specialness of this bond. On the other hand, a more special bond means that this bond shows some shortage in the repo market; in turn, dealers face some frictions trading such a bond in the secondary market, which arguably leads to worse liquidity conditions (e.g., wider bid-ask spreads).

¹ The most relevant repo maturities are SN and TN, which account for 73.5% and 21%, respectively, of the total volumes in our sample that spans from January 1, 2019 to December 31, 2023. In contrast, ON1 and other repo maturities account for only 4.5% and 0.9% of the total volumes, respectively.

² These two markets feature non-trivial interactions with each other, thus requiring to be considered together by academics and policy makers (Jappelli et al., 2024).

3. LITERATURE REVIEW

The relation between bid-ask spread on the secondary market and specialness on the repo market claiming the former as driver of the latter is explored in the literature, both theoretically (e.g., Duffie, 1996; Vayanos and Weill, 2008) and empirically (e.g., Corradin and Maddaloni, 2020; Dufour et al., 2020). The aim of our contribution is to empirically investigate the inverse relation by carrying out a novel exercise to study whether the repo market specialness is a driver of the secondary market liquidity.

The theoretical foundation of the links between cash and repo markets is provided by the model developed by Duffie (1996). On the basis of the model, all else being equal, a more liquid bond tends to be more special in repo. Indeed, bonds with lower transaction costs are in high demand by short sellers. Duffie shows that collateral bonds' specialness may arise when their owners are prevented from supplying those bonds in repo contracts due to institutional factors or frictional costs of trading.

The theoretical framework of Vayanos and Weill (2008) supports the Duffie (1996)'s prediction that more liquid bonds are likely to have higher specialness. They examine how liquidity and specialness depend on the extent of short-selling activity and on bonds' supplies. Their theory implies that short-selling activity is a driver of both the higher liquidity and the higher specialness of on-the-run bonds. Furthermore, a decline in the supply of a bond decreases liquidity but may increase – due to a scarcity effect in the repo market – or decrease – due to lower short-selling activity on that bond – specialness.

The empirical literature has largely focused on US repo market, while there are few studies on repo specialness in European markets. Among them, Corradin and Maddaloni (2020) analyse the Italian sovereign bond market and argue that the relation between repo specialness and cash liquidity is dependent on the available supply of a security, which is influenced by the European Central Bank (ECB)'s asset purchase programs. This relation needs to be studied within a dynamic framework that accounts for changes in bond supply. Their empirical findings are consistent with the models by Duffie (1996) and Vayanos and Weill (2008).

Dufour et al. (2020) investigate the drivers of repo specialness using data on one-day repo contracts that have Italian government bonds as collateral. The collateral bonds' bid-ask spread represents an important factor in explaining specialness, along with bond volatility, bond supply and the liquidity of repo contracts (e.g., repo market volume). In contrast to Duffie (1996)'s predictions, they provide evidence that more liquid bonds tend to have lower specialness on average, since the bid-ask spread mostly reflects information asymmetry – that drives speculative demand, which in turn increases bond specialness – rather than frictional costs. These findings corroborate the empirical fact that liquidity and specialness do not always move in the same direction. In turn, the relation between cash liquidity and repo specialness is likely to be more complex than suggested by the extant literature, which highlights the need for further research to fully capture the underlying mechanisms.

Huh and Infante (2021) model the role of repo contracts in bond market intermediation. They argue that higher specialness leads to a more illiquid market, because repo specialness represents intermediation costs that dealers must bear and charge to their clients. Their finding regards the correlation between repo specialness and bid-ask spread in the time series (as opposed to cross section), since the model considers a single security. In this regard, frictions in repo market can spillover to the underlying cash market. This proposition is corroborated by the evidence from recent years, which indicates an upward trend in repo specialness while Treasury markets have experienced a deterioration in market liquidity as commented on by market participants. A decrease in securities lenders' willingness to lend is one possible channel consistent with an increase in specialness and a decrease in liquidity. Their model provides a possible theoretical framework for understanding the mechanisms that link the cash and repo markets, which we aim at identifying through empirical analysis.

4. DATASET AND DESCRIPTIVE ANALYSIS

In the following section we describe the data that we use to conduct the analysis and present some descriptive statistics. In our analysis, we integrate three main sources of data to compile an exhaustive dataset: the cash segment of MTS Italy, with information including the ISIN³ of the government bond, the bid price and the ask price at closing time for each trading day; the repo segment of MTS Italy, with information including the ISIN of the underlying government bond used as collateral, the type (GC or special), the maturity (e.g., tomorrow-next and spot-next), the daily average rate and the volume of daily transactions; the Italian Treasury's activity on the repo market starting from 24th of May 2021. Using the bonds' ISIN codes, we match the information among the three sources.

Our sample of cash and repo transactions is daily and covers the period from January 1, 2019 to December 31, 2023. We select all securities for the various Italian government bond segments (BOT, CTZ, BTP, BTP€i, CCTeu).

For each bond and trading day, the quoted bid and ask prices are based on BGN Bloomberg prices at closing time. Secondary market liquidity may be assessed using as indicator the bid-ask spread, i.e., a measure of liquidity ascribable to the tightness of the quoting book, which may calculate the cost to be borne when executing a buy or sell order against the mid-price of the bond:

$$Bid - ask\ spread_{i,t} = \frac{Ask\ price_{i,t} - Bid\ price_{i,t}}{Mid - price_{i,t}} \cdot 100, \quad (1)$$

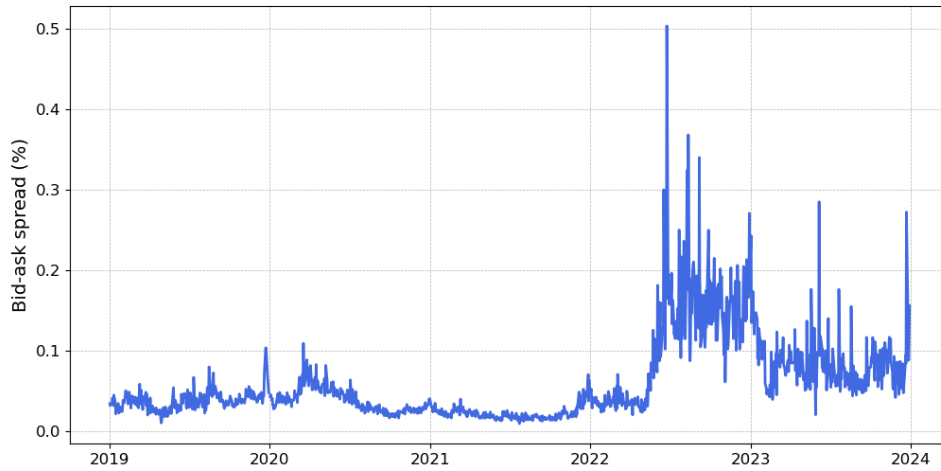
where i is a specific security and t is the day of trading. The lower the bid-ask spread, the greater the liquidity. We compute the daily bid-ask spread (among several liquidity measures) since it is the most widely used indicator of bond market liquidity.

Figure 4 illustrates the time series of the daily bid-ask spread (expressed in percentage) related to the 10-year BTP, considering only the on-the-run bond (i.e., the latest issued bond until a new one is issued and takes the place of the old one). The deterioration in market liquidity observed during the first half of 2020 can be attributed to the outbreak of the Covid-19 pandemic. While liquidity conditions remained relatively stable during the first half of 2021, they began to deteriorate towards the end of the year, in part due to uncertainty triggered by inflation expectations and the subsequent actions taken by the ECB to address inflation.⁴ As a result, the market experienced an increase in volatility and a deterioration in liquidity conditions throughout the first half of 2022, a trend that intensified in the second half of the year. In 2023, liquidity conditions show signs of improvement, diverging from the worsening trend observed since the end of 2021.

³The International Securities Identification Number (ISIN) is a unique twelve-digit code that is assigned to every security issuance in the world.

⁴At the ECB meeting in December 2021, the ECB announced the end of the PEPP Program in March 2022 and the progressive slowdown of the path of APP Program.

Figure 4. 10-year BTP – Bid-ask spread (%) over time



Source: Authors' calculations based on Bloomberg data

Table 2 presents summary statistics of the bid-ask spread (expressed as a percentage) over the whole sample period. The average bid-ask spread is relatively small (0.0736%), but the standard deviation (0.1005%) points to considerable variability in liquidity across different bonds or time periods. The 50th percentile (0.0411%) indicates generally low bid-ask spreads for a significant portion of the data, but there are outliers with significantly wider bid-ask spreads.

Table 2. Summary statistics of bid-ask spread (%)

Mean	0.0736
Standard deviation	0.1005
Minimum	0.0010
25th percentile	0.0187
50th percentile	0.0411
75th percentile	0.0874
Maximum	2.0467
Number of observations	167484
Number of bonds	313

Source: Authors' calculations based on Bloomberg data.

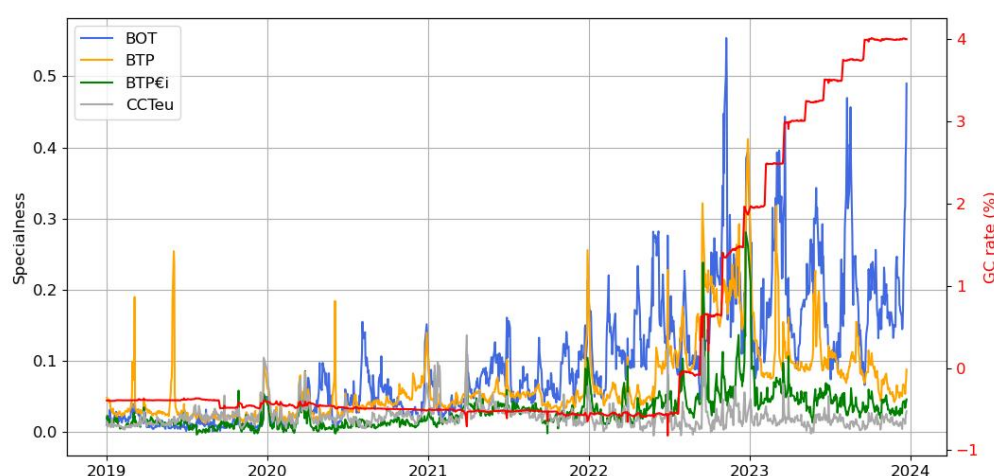
Specialness is the premium of procuring a specific bond in the repo market, resulting from a special repo rate that is lower than the general collateral rate at which a basket of similar bonds trade:

$$Specialness_{i,j,t} = GC\ rate_{j,t} - Special\ rate_{i,j,t}, \quad (2)$$

where i is a specific security, j is the repo maturity and t is the day of trading. It represents the Italian sovereign bond scarcity premium. Higher specialness may signal greater market desirability or relatively scarce supply of the specific bond used as collateral in the repo contract. To construct daily observations, the average rate is weighted by the nominal amount of each repo transaction. For each trading day, we collect the volume-weighted average GC repo rate and subtract the corresponding volume-weighted average special repo rate.

Figure 5 shows the time series of the specialness (expressed in percentage) of Italian government bonds used as collateral in SN repo transactions (after getting rid of outliers⁵), delineating the bonds across the various segments and presenting the GC repo rate in the plot. The repo specialness for Italian government bonds varies over time and across different bond segments. Generally, we would expect non-negative specialness. We observe that often specialness is low. However, there are times when specialness is considerable (exceeding 50 basis points for BOT), due to the fact that the special repo rate is significantly lower (even negative) than the GC rate. The occurrence of high peaks in specialness may be the result of negative special repo rates. Indeed, dealers may be willing to accept such rates in order to gain access to a scarce bond since they are required to cover their short positions. The repo market has experienced an increase in the specialness over time and a rise in the GC rate in response to the ECB interest rate hikes in the 2022-2023 period.

Figure 5. Specialness (%) by bond type over time



Source: Authors' calculations based on MTS Repo data.

The following estimations are carried out on the sample of repo transactions with SN maturity (i.e., repo transactions such that the initial trade of the bond is made on the contract date plus two business days and the bond is then repurchased in the following business day) and TN maturity (i.e., repo transactions such that the initial trade of the bond is made on the next business day and the bond is then repurchased in the following business day). We focus on transactions with a one-day maturity and, among them, we select only SN and TN repo transactions given that the settlement period is two business days in the cash segment of MTS Italy, because our objective is to explore the transmission channels between the cash and repo markets. Therefore, we focus on repo transactions where it is more likely that one of the counterparties may seek to hedge against a position previously acquired in the cash market.

Tables 3 and 4 show the summary statistics and distribution of specialness (expressed in percentage) for both the TN and SN repo contracts over the whole sample period. There are 313 different bonds that are used as collateral. We observe that the mean, median and standard deviation of specialness decrease when moving from TN to SN repos. The specialness for the SN repo maturity is 5.85 basis points on average and shows significant variability across different bonds or time periods (as pointed out by the standard deviation of 11.97 basis points). Moreover, most of the observations

⁵ We remove observations around the end of each year because they exhibit abnormal spikes.

have positive specialness up to 25 basis points (92% and 88.02% for SN and TN repos, respectively). If we consider the proportion of observations with specialness greater than 25 basis points, this is only 3.39% and 3.77% for SN and TN repos, respectively. Observations with negative specialness range from 4.61% for SN repos to 8.21% for TN repos.

Table 3. Summary statistics of specialness (%) by repo maturity

	Spot Next	Tomorrow Next
Mean	0.0585	0.0622
Standard deviation	0.1197	0.1320
Minimum	-0.4948	-1.5417
25th percentile	0.0110	0.0087
50th percentile	0.0310	0.0322
75th percentile	0.0639	0.0711
Maximum	10.6649	11.3430
Number of observations	166935	163670
Number of bonds	313	313

Source: Authors' calculations based on MTS Repo data.

Table 4. Distribution of specialness (%) by repo maturity

Specialness	Spot Next		Tomorrow Next	
	Number	%	Number	%
≤ -0.5	0	0.0%	4	0.0%
$(-0.5, -0.25]$	3	0.0%	11	0.01%
$(-0.25, 0]$	7703	4.61%	13417	8.2%
$(0, 0.25]$	153577	92.0%	144067	88.02%
$(0.25, 0.5]$	4040	2.42%	4298	2.63%
$(0.5, 0.75]$	887	0.53%	984	0.6%
$(0.75, 1]$	376	0.23%	449	0.27%
> 1	349	0.21%	440	0.27%

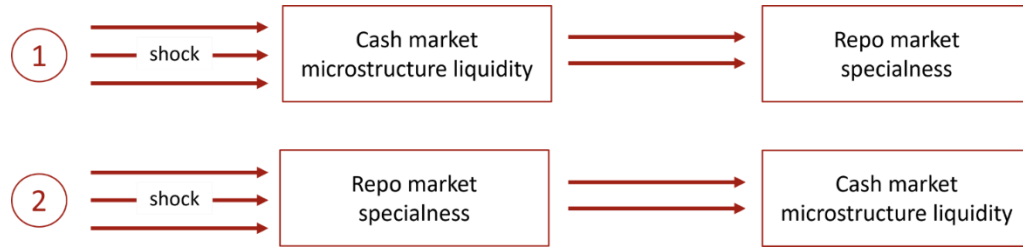
Source: Authors' calculations based on MTS Repo data.

Finally, for each bond we calculate the weekly average of the bid-ask spread and specialness for both SN and TN transactions, thus constructing the basis for the subsequent analyses.

5. EMPIRICAL RESULTS

In Section 4 we have defined the bid-ask spread in the cash market and the specialness in the repo market, and in this section we examine the relation between them. In the event of an exogenous shock to the liquidity conditions in the cash market, we expect that specialness level may undergo a change in the repo market. Conversely, we postulate that the opposite relationship may also be observed: if an exogenous shock occurs that may affect the specialness level in the repo market, then we expect that this will result in a corresponding effect on the liquidity conditions of that bond in the cash market (see Figure 6).

Figure 6. Bidirectional causality between liquidity and specialness



Source: Authors.

In our analysis, we employ the Dumitrescu and Hurlin (2012) test for detecting Granger-causality in panel datasets (Lopez and Weber, 2017), in order to investigate whether the bid-ask spread Granger-causes the specialness (across 313 panels) and vice versa. The test is based on the assumption that the variables are stationary. Consequently, prior to investigating the bidirectional causality relationship between them, we conduct a Fisher-type augmented Dickey-Fuller test to ascertain the presence of unit roots across the panel over the whole sample period (January 1, 2019 to December 31, 2023) (Choi, 2001). We reject the null hypothesis that our main variables are unit root processes (i.e., the series are non-stationary), suggesting that at least one panel is stationary (i.e., the series are not entirely non-stationary).⁶

By performing the Granger-causality test, we test two null hypotheses (H_0) over different sample periods: on the one hand, specialness does not Granger-cause bid-ask spread; on the other hand, bid-ask spread does not Granger-cause specialness. As illustrated in Table 5, we find p-values approximately equal to zero for two standardized statistics ($\bar{Z}$ and $\tilde{Z}$) based on the Wald statistic.⁷ The two different tests ($\bar{Z}$ and $\tilde{Z}$) are used to check the robustness of our results for each null hypothesis. The outcomes of the test strongly reject the null hypothesis that specialness does not Granger-cause bid-ask spread and vice versa in favour of the alternative hypothesis at the conventional significance level of 1% in the majority of cases.⁸ Therefore, Granger-causality between the bid-ask spread and the specialness exists in both directions.

Table 5. Granger non-causality test results

Period	Specialness does not Granger-cause bid-ask spread		Bid-ask spread does not Granger-cause specialness	
	$\bar{Z}$ p-value	$\tilde{Z}$ p-value	$\bar{Z}$ p-value	$\tilde{Z}$ p-value
2019	0.0000	0.0000	0.0377	0.0957
2020	0.0000	0.0002	0.0000	0.0000
2021	0.0000	0.0000	0.0000	0.0000
2022	0.0000	0.0000	0.0000	0.0000
2023	0.0077	0.0293	0.0251	0.0739
05/2019-12/2023	0.0000	0.0000	0.0000	0.0000
05/2021-12/2023	0.0000	0.0000	0.0000	0.0000

Source: Authors' calculations.

⁶ The null hypothesis of non-stationarity is rejected at the 1% significance level across all test statistics (Inverse chi-squared, Inverse normal, Inverse logit, and Modified inverse chi-squared). Establishing whether our data is stationary or non-stationary is critical for the validity of subsequent econometric analyses.

⁷ The Wald test is designed to detect causality at the panel level. The testing procedure of H_0 is finally based on $\bar{Z}$ and $\tilde{Z}$. Specifically, $\bar{Z}$ can be reasonably considered for panel datasets with a large number of securities and weeks, while $\tilde{Z}$ should be favoured for panel datasets with large number of securities but relatively small number of weeks. We select the number of lags to be considered in the testing procedure based on the Bayesian information criterion (BIC).

⁸ We perform the Granger-causality test for SN repo contracts. Our findings hold true even for TN maturity.

This result corroborates our idea that, for a given bond, a bidirectional causality relation exists between liquidity conditions in the secondary cash market and the specialness observed in the repo market. Thus, any estimation of the effect of specialness on liquidity (or the reverse) must address the endogeneity problem that arises by bidirectional causality.

To investigate the causal effect of specialness in the repo market on liquidity conditions in the secondary market, our regression specification is:

$$y_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3t} + v_i + v_{it}, \quad (3)$$

where the dependent variable y_{it} is the bid-ask spread of bond i on week t and the explanatory variable X_{1it} is the specialness⁹ of bond i on week t . X_{2it} is the outstanding amount of bond i issued until week t (which is time-varying and bond-specific and represents the total volume that has been issued until a certain date¹⁰). X_{3t} contains time-varying controls (period-specific components): the VIX as indicator of volatility on global financial markets and the spread between 3-month EURIBOR and 3-month ESTER as a measure of stress on European monetary markets.¹¹ The bond fixed-effects v_i account for all bond-specific characteristics, provided they are invariant over the considered time span.

First, we estimate an Ordinary Least Squares (OLS) panel regression on the basis of the baseline specification (i.e., without the addition of the aforementioned covariates in Equation 3). We estimate the regression model with both bond fixed-effects (FE) and random-effects (RE)¹² for SN repo contracts over the sample period from May 24, 2021 to December 31, 2023 (across 229 panels). The results are reported in Table 6: the estimated coefficient of specialness is positive and statistically significant, and on average a one basis point increase in specialness is associated with a small increase in bid-ask spread (0.1 basis points). Table 6 reports the results with standard errors clustered at the bond level. To determine the most accurate regression model, we perform a cluster-robust Hausman (1978) test over the whole sample period (January 1, 2019 to December 31, 2023), which confirms the need to control for fixed-effects (at the 5% significance level).

⁹ As for now, we select the SN maturity, since transactions with this maturity account for most of the volumes in the repo market.

¹⁰ By controlling for the outstanding amount, we indirectly control for issuance.

¹¹ The data pertaining to the covariates are extracted from Bloomberg.

¹² The estimator we choose to consistently estimate the coefficient of interest depends on the assumption on the relationship between the unobserved fixed effect and the regressors. RE estimator assumes no correlation between the unobserved fixed effect and the regressors, while fixed-effects FE estimator assumes no restrictions on the correlation between the unobserved fixed effect and the regressors. Therefore, the FE estimator is consistent under weaker conditions than the RE estimator, but the RE estimator is more efficient than the FE estimator when both estimators are consistent.

Table 6. OLS panel regression results

Bid-ask spread	(1)	(2)
	Fixed-effects	Random-effects
Specialness	0.110*** (0.00423)	0.110*** (0.00422)
Constant	0.086*** (0.00062)	0.063*** (0.00574)
Observations	18,577	18,577
R-squared	0.036	
Number of id	229	229
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1		

Source: Authors' calculations.

Table 7. OLS panel regression results with clustered standard errors by bonds

Bid-ask spread	(1)	(2)
	Fixed-effects	Random-effects
Specialness	0.110*** (0.0246)	0.110*** (0.0245)
Constant	0.086*** (0.00206)	0.063*** (0.00542)
Observations	18,577	18,577
R-squared	0.036	
Number of id	229	229
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1		

Source: Authors' calculations.

However, to estimate the effect of specialness in the repo market on liquidity conditions in the secondary market we have to address the endogeneity problem that arises by bidirectional causality with an Instrumental Variable (IV) approach. In this regard, we exploit the Italian Treasury's activity on repo as instrument to address the endogeneity problem. Starting from 24th of May 2021, the Italian Treasury launched a new tool for government cash management by carrying out operations on repo market. It represents a good instrument (i.e., there is correlation between the instrument and the specialness) and, given the declared purposes of the Italian Treasury activity on the repo market, it does not directly affect the bid-ask spread on the secondary market (i.e., it is exogenous with respect to secondary market liquidity conditions) fulfilling the exclusion restriction.¹³ By carrying out the Hausman (1978) test, we confirm the need to use the IV method over the OLS method (at the 1% significance level). In our regression model, the Italian Treasury's activity on repo is defined as the outstanding amount of weekly volumes of the operations on the repo market for a specific security.

We estimate the IV panel regression with bond fixed-effects, which ensure that all bond-specific characteristics (invariant over time) are accounted for.¹⁴ The estimation is carried out on the sample of

¹³ See the press release of the Italian Ministry of Economy and Finance about the launch of the Repo activity (MEF, 2021). The activity on the repo market allows the Italian Treasury to borrow and lend liquidity at more convenient rates.

¹⁴ We expect that the bond-specific effects are correlated with the regressors. For example, some bonds may be traded more on special (i.e., with higher specialness) than others, especially if they have been targeted by particular trading strategies.

SN repo transactions because we want to pin down the transmission channels between the repo and the cash market. Table 8 shows the results of our estimates, first for our main variables and then adding the mentioned covariates. We report the estimated coefficients for each specification of our regression.

Table 8. IV panel regression results for SN maturity

Bid-ask spread	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Specialness	1.592*** (0.320)	1.610*** (0.325)	1.716*** (0.331)	1.630*** (0.340)	1.723*** (0.336)	1.706*** (0.331)	1.699*** (0.327)	1.612*** (0.335)
Outstanding		9.17e-09 (3.90e-08)	9.12e-09 (4.14e-08)	6.92e-09 (3.94e-08)	6.71e-09 (4.14e-08)			
VIX			0.00151*** (0.000350)		0.00130*** (0.000422)	0.00132*** (0.000418)	0.00153*** (0.000347)	
Euribor-Ester				0.166* (0.0949)	0.178* (0.0971)	0.176* (0.0963)		0.163* (0.0939)
Constant	-0.0379 (0.0268)	-0.0394 (0.0272)	-0.0790*** (0.0247)	-0.0443 (0.0302)	-0.0787*** (0.0246)	-0.0778*** (0.0243)	-0.0780*** (0.0244)	-0.0428 (0.0298)
Observations	18,577	18,570	18,570	18,570	18,570	18,577	18,577	18,577
Number of id	229	229	229	229	229	229	229	229
F test	24.64	12.21	12.41	103.92	85.48	113.69	18.56	155.71

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

Source: Authors' calculations.

We provide evidence that a higher level of specialness in the repo market negatively affects secondary market liquidity conditions (i.e., increases the bid-ask spread). In all cases, the estimated coefficient of specialness is positive and statistically significant, suggesting a role for specialness as a determinant of bid-ask spread. On average, a one basis point increase in specialness is associated with more than 1.5 basis points increase in bid-ask spread. The intuition is that the scarcity effect in the repo market, which makes a bond more special, leads to worse liquidity conditions for such a bond in the secondary market.

In the case of the baseline specification, the F test for the relevance of the instrument is greater than 20 suggesting that the chosen instrument is a strong one. The results of the first-stage regression (of repo specialness on the instrument) are presented in Table 9.

Table 9. First-stage regression results

Specialness	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Instrument	2.07e-05*** (4.17e-06)	2.05e-05*** (4.15e-06)	2.14e-05*** (4.15e-06)	1.98e-05*** (4.12e-06)	2.12e-05*** (4.12e-06)	2.14e-05*** (4.14e-06)	2.16e-05*** (4.18e-06)	2.00e-05*** (4.14e-06)
Outstanding		-4.82e-09 (2.42e-08)	-5.06e-09 (2.42e-08)	-1.03e-09 (2.41e-08)	-1.26e-09 (2.40e-08)			
VIX			0.000621*** (0.000174)		0.000944*** (0.000173)	0.000941*** (0.000174)	0.000616*** (0.000175)	
Euribor-Ester				-0.268*** (0.0158)	-0.277*** (0.0159)	-0.278*** (0.0160)		-0.269*** (0.0159)
Constant	0.0814*** (0.000990)	0.0815*** (0.00106)	0.0687*** (0.00371)	0.0867*** (0.00109)	0.0675*** (0.00368)	0.0677*** (0.00368)	0.0688*** (0.00371)	0.0868*** (0.00103)
Observations	18,577	18,570	18,570	18,570	18,570	18,577	18,577	18,577
Number of id	229	229	229	229	229	229	229	229
F test	24.64	12.21	12.41	103.92	85.48	113.69	18.56	155.71

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

Source: Authors' calculations.

As a robustness check, we re-estimate our regression model in Equation 3 on the sample of TN repo transactions (see Table 10). We show that our findings hold true even for TN maturity.

Table 10. IV panel regression results for TN maturity

Bid-ask spread	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Specialness	1.591*** (0.337)	1.654*** (0.402)	1.752*** (0.408)	1.675*** (0.418)	1.759*** (0.413)	1.717*** (0.354)	1.709*** (0.349)	1.614*** (0.353)
Outstanding		-1.73e-06 (1.79e-06)	-1.35e-06 (1.94e-06)	-1.63e-06 (1.75e-06)	-1.30e-06 (1.92e-06)			
VIX			0.00161*** (0.000416)		0.00135*** (0.000519)	0.00145*** (0.000425)	0.00169*** (0.000351)	
Euribor-Ester				0.207* (0.122)	0.218* (0.125)	0.206* (0.108)		0.191* (0.105)
Constant	-0.0444 (0.0296)	-0.0226 (0.0193)	-0.0700*** (0.0191)	-0.0302 (0.0225)	-0.0705*** (0.0193)	-0.0889*** (0.0280)	-0.0891*** (0.0281)	-0.0502 (0.0330)
Observations	18,563	18,563	18,563	18,563	18,563	18,563	18,563	18,563
Number of id	229	229	229	229	229	229	229	229
F test	21.90	27.86	23.00	113.30	92.55	110.61	14.85	154.92

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

Source: Authors' calculations.

6. CONCLUSION

This work brings to three main conclusions. First, we find a bidirectional causality between liquidity on the secondary market and specialness on the repo market, which technically implies that any study of the impact of one measure on the other must address endogeneity problems (as we do in our analysis using an instrumental variable approach). This result has several implications for both the academic and the policy debates. Second, we provide sound evidence that a higher level of specialness in the repo market negatively affects secondary market liquidity conditions (i.e., increases the bid-ask spread). It should be noted that the inverse effect of secondary market liquidity conditions on repo specialness is acknowledged, but our objective is to ascertain whether improvements in the functioning of the repo market, specifically in terms of reducing specialness, also lead to improvements in the functioning of the secondary market, and we are able to show that this is indeed the case. Finally, we provide new evidence that the Italian Treasury's activity on the repo market supports market makers by relaxing the frictions determined by the specialness of securities on the repo market and, thus, indirectly improves liquidity conditions on the secondary market.

Ensuring market liquidity in government bond markets may be key to public debt stability. To the best of our knowledge, the effects of repo specialness on liquidity conditions of the Italian government bond market have not been explored. Our analysis may contribute to assess the potential drivers of market liquidity in government bond markets, thus supporting policy makers in public debt management and in the formulation of effective policies to improve the efficiency of both primary and secondary markets. In addition, this work may contribute to a better understanding of the structure and dynamics of public debt markets and of the transmission channels between cash and repo markets.

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Average Interest Cost

A Novel Cost and Risk Measure and its Application in Public Debt Management*

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Abstract

We present the novel cost and risk measure “Average Interest Cost” (AIC) as a highly appropriate cost metric for the purpose of managing public debt. The AIC is the average interest cost over a long-time horizon. It incorporates the historic interest expenses, the difference between market and par value of the portfolio and expected future cost for refinancing for a long-time horizon. We highlight five key requirements for a cost measure in public debt management (i.e. capturing every cashflow, realistic perspective on long-lasting public debt, rising cost with rising interest rates, risk as standard deviation of cost, and longer portfolios implying lower risk). We show that, unlike other used cost measures, the AIC fulfills all of them. Furthermore, the AIC allows intuitive understanding and is easy to use in practice. In addition to the specific parametrization used in the management of the German federal debt portfolio, we present possible modifications for other debt managers. We conclude with fictional analyses based on use cases from the German Finance Agency, including historic performance analyses, deterministic future scenario analyses, and strategical portfolio decision.

Keywords: Public debt management, Government bond market, Interest cost, Market risk, Portfolio decision, Issuance strategy

JEL Code: H63, H68, G11, G12, G17

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1. INTRODUCTION – COST IN PUBLIC DEBT MANAGEMENT

One of the main challenges of public debt management is the choice of a specific portfolio composition. There are numerous demands that typically every considerable debt portfolio has to fulfill like the financing needs, the cash management, the liquidity of the market, regulations and others. These “exogenous” aspects limit the choice of an issuance strategy, yet there remains substantial space for decisions between different strategies that all fulfill these exogenous demands. The decision between these issuance strategies is one of the key tasks of public debt management. It is widely accepted that this decision should be based on minimizing cost while limiting associated risk, see for instance (Lewis & Viñals, 2014), (Jonasson & Papaioannou, A Primer on Managing Sovereign Debt-Portfolio Risks, 2018), (Jonasson, Papaioannou, & Williams, Debt management, 2019) and (Andabaka Badurina & Svaljek, 2012).

The main contribution of this paper is the introduction of a novel cost measure for public debt, the Average Interest Cost, and its corresponding risk measure. This cost measure builds a bridge between the two most common approaches to determining the cost associated with public debt, adapting the advantages of both approaches. The paper provides a detailed derivation of the Average Interest Cost and presents different use cases from the perspective of a debt manager.

In this chapter we outline the challenge of defining a suitable cost measure to fulfill key requirements specific for public debt management. Chapter 2 follows with the motivation and definition of the proposed novel cost measure with a minimum of technicalities. Chapter 3 provides a more in-depth view on the cost and associated risk measure and we show that the proposed cost measure actually fulfills all key requirements introduced in Chapter 1. In Chapter 4 we present some illustrative use cases from a practitioner’s view, followed by concluding remarks in Chapter 5.

1.1. Cost Measures for Management of Public Debt

While it seems clear that cost and risk should be the leading measures for decisions regarding the structure of the debt portfolio, it is not generally defined how to measure cost and risk. Here we focus only on cost due to interest expenses, since they directly impact the budget. For a sizable debt portfolio these cost usually outweigh other cost components, like transaction cost. Additionally, we focus on the associated market risk that needs to be restricted for sustainable debt management. But even with this focus it is not obvious how to define these cost and risk measures.

In the literature there are two different school of thoughts to approach cost for public debt management:

a) Budget Approach

The first, more common approach is mostly used by the practitioners in public debt management organizations. The used cost measures add up the interest expenses and therefore the budgetary burden (see e.g. (European Commission & Eurostat, 2013) for accounting standards) over multiple years. For a historic timespan this cost measure can be calculated straightforward. But it is also possible to determine future interest expenses, by incorporating not only those associated by the current portfolio but also considering those generated by rolling over maturing debt before the end of the specified period. For this cost measure looking into the future it is necessary to define and implement a strategy for the rollover debt and a development of the yields. For more details see (Risbjerg & Holmlund, 2006) for a comprehensive overview to a general framework, or (Bernaschi, et al., 2019), (Yavuz & Gölbaşı, 2019), (Bergström, Holmlund, & Lindberg, 2002), (Bolder & Deeley, 2011), (Larson & Lessard, 2011) and (Bitner, Nowak-Far, & Sierak, 2024).

b) Mark-to-Market Approach

The second approach is a mark-to-market view and is based on the market value of the debt portfolio. The change in market value can be interpreted as cost, similar to the return of an asset portfolio. Due to the close connection to common practices in asset portfolio management, there are suggestions to apply this measure within the domain of public debt management (see e.g. (Hall, Sargent, & others, 1997), (Bernaschi, Missale, Vergni, & others, 2009), (Berndt & Yeltekin, 2015), (Ellison & Scott, 2020)).

Both of these approaches have its advantages and drawbacks as will become clear in the following sections. Additionally, in (Blommestein & Hubig, 2012) it is argued that following these different approaches might lead to different portfolio strategies. A suitable cost and risk measure for public debt management combines all advantages of the above approaches with as few drawbacks as possible.

In this paper we focus on a sustainable long-term perspective on managing public debt. We assume in the following that the issuer has a well-established access to the capital market and that the debt is expected to last much longer than the average maturity of the current debt portfolio. Additionally, we expect that the issued instruments are redeemed at the end of lifetime and are not bought back in a significant amount, analogous to a buy-and-hold-strategy.¹

1.2. Key Requirements for Decision Making in Public Debt Management

In the following we introduce five key requirements of a cost and risk measure that are important for debt management and the strategy choice in particular. We also evaluate whether the two standard approaches mentioned before actually incorporate these requirements.

1.2.1. Capturing Every Cashflow

The requirement of capturing every cashflow regards to the fact that all cashflows of all issued instruments have to be taken into account for the cost measure. Otherwise, it might be possible that unintended window dressing emerges, and a strategy might seem to generate less cost while in reality it only shifts cashflows into the future. Incorporating all cashflows ensures a complete economic view on the debt portfolio.

The mark-to-market approach actually fulfills this requirement by design. All cashflows of the portfolio are discounted to the present value, no matter how far in the future they might be, or whether the cashflows are already fixed or not.

The budget approach, instead, only includes those cashflows that fall within the considered timespan. However, there is still a debt portfolio with outstanding debt at the end of this timespan. Since this portfolio is typically not priced at par at the end of the timespan, a relevant component is not considered in this approach. This effect can be neglected for infinitely long timespans, however e.g. for a future view, most simulations do not consider more than 10 years. In (Dottori & Manna, 2016) the authors examine a model of public debt management and show analytically that the choice of the optimal portfolio highly depends on the considered simulation horizon. This effect is deeply linked to the fact that in the budget approach all portfolio effects after the end of the considered timespan are neglected. This is also already pointed out by (Bernaschi, Missale, Vergni, & others, 2009): “In fact, portfolio strategies cannot be compared in terms of interest costs unless the time horizon extends up to the

¹ Even if not all assumptions hold in a perfect manner, the suggested cost measure might still offer significant insights for the debt manager.

redemption date of the longest maturity bond issued over the simulation period.” These authors instead favor a return-based asset-liability view.

1.2.2. Realistic Perspective on Long-Lasting Public Debt

The requirement of a realistic perspective on long-lasting public debt reflects the general observation that public debt prevails much longer than the average time to maturity of the outstanding debt. Most of the debt portfolio is expected to be rolled over by issuing new bonds after the redemption of the existing ones.

This aspect is incorporated in the budget approach for the considered timespan. In a historic view this is obvious, since the budgeted approach always pertains to the actual debt portfolio. For a future looking view, this requirement is explicitly taken care of by specifying an issuance strategy to accommodate the debt requirements.

The mark-to-market approach, however, does not consider the fact of a long outstanding debt at all. This approach implicitly assumes that a quick redemption of the portfolio is possible. While this is appropriate for many asset managers, it is typically not for public debt management.

1.2.3. Rising Cost with Rising Interest Rates

For public debt it is intuitively obvious that the considered cost of the debt service has to increase, when interest rates rise, and vice versa. Even if the complete debt is financed via fixed bonds, higher interest rates imply higher coupons for the debt refinanced in the future.

This is captured in the budget approach, since rising interest rates results in higher coupons for the newly issued bonds and therefore to a rise of the cost. The mark-to-market approach however shows exactly the opposite behavior. If interest rates rise the present value of the outstanding debt decreases and vice versa². This view might be appropriate if the debt can actually be redeemed at any time. But typically, as already pointed out, public debt has to be refinanced at its maturity and therefore higher cost due to the higher interest rates are almost inevitable.

1.2.4. Risk as Standard Deviation of Cost

As mentioned before, sustainable public debt management should not only focus on cost reduction but also limit or control the risk associated with the debt portfolio. The fluctuation width of the chosen cost measure has to lead to a meaningful measure for market risk. Fluctuations could result from either time series with actual historic movements or from the distribution of different stochastic or deterministic scenarios. The uncertainty could be measured by variance, percentiles or the standard deviation. The close link between cost and risk measure makes it easy to weigh up cost versus risk intuitively and facilitates the comparison of different portfolios in a consistent manner. In the end, even portfolio optimizations based on the portfolio theory by Markowitz (Markowitz, 1952) can be performed. For an appropriate cost measure for public debt management it has to be possible to define a meaningful risk measure in this context. For both approaches described in 1.1 this is straightforward.

1.2.5. Longer Portfolios Imply Lower Risk

Having a sustainable long-time view, it seems clear for public debt management that longer portfolios imply lower risk than a shorter portfolio: A longer portfolio (higher average time to fixing) is less sensitive to movements of the yield curve, since a higher percentage of the future coupons are known and fixed

² We presume positive present value, for more details see chapter 2.

and a smaller percentage has to be re-fixed, or refinanced. Therefore, the cost of a longer portfolio fluctuates less than the cost of a shorter portfolio and in turn implies lower (refinancing) risk.

This behavior is covered by the budget approach by construction. The mark-to-market approach instead shows again the opposite effects. A longer bond has more and later fixed cashflows than a shorter one. The present values of all these cashflows are sensitive to the movement of the yield curve. Therefore, the present value of a longer portfolio fluctuates more with interest rate fluctuations than that of a shorter portfolio and therefore shows larger risk (see also (Hall, Sargent, & others, 1997)).

2. PRESENTING AVERAGE RESENTING SVERAGE INTEREST COST

The Average Interest Cost presented in this chapter combines the best of the two approaches in 1.1 to accommodate all key requirements listed in 1.2 and provides a complete and appropriate cost measure.

Throughout this paper, we use a sign convention with positive debt, positive present value, and positive interest expenses in the case of positive interest rates. However, the arguments presented are invariant under a thorough change of sign convention.

2.1. Defining Average Interest Cost

The main idea of the Average Interest Cost is to add up historic and all expected future interest expenses over a long time and to average the expenses over the considered timespan. This leads to a highly condensed metric that indicates the expected average interest expenses in this time interval.

The historic interest cost can be easily measured following the budget approach, but determining the expected future interest cost is the main challenge. The expected future interest cost can be determined via an additional simulation over a long-time horizon under forward development of yields using the budget approach again. However, inspired by the mark-to-market approach, these future interest cost can be completed by considering the agio of a hypothetical rebuy of the portfolio at the end of this considered period. Since this method requires the specification of a refinancing strategy, the AIC uses an even simpler approach that coincides with that method under the forward development: The expected future interest cost is calculated by a hypothetical rebuy of the debt portfolio at current time t and a refinancing of the debt up to a future time point at current market conditions. In the following this idea will be described in more detail.

The AIC can be split into three parts defined as follows.

- **Historic Interest Expenses:** The historic interest expenses $IE(t_0, t)$ can be seen as the actual accumulated interest expenses from the starting point t_0 to the current point in time t . The accumulation of past interest expenses is necessary for a fair comparison of two different strategies, since two strategies can differ significantly in the distribution of cashflows over time.³ This has to be considered when choosing the starting point t_0 , so that no strategies gain an artificial advantage. This reflects to the requirement of capturing every (relevant) cashflow for the historic interest expenses. Apart from that, t_0 can be chosen pragmatically. It is usually useful to start at a significant point, e.g. a general change in strategy, a new market era or something similar.

³ In a simulation-based view into the future, these historic interest expenses correspond to the accumulated interest expenses in the simulation timespan, as depicted in the use case in 4.2.

- **Market Value Compensation (MVC):** The second part of the AIC, the so-called “Market Value Compensation” (MVC) is defined as

$$MVC(t) = PV(t) - D(t),$$

where $PV(t)$ is the present value and $D(t)$ the debt of the current portfolio at time t . This part can be interpreted as the cost at time t of a hypothetical rebuy of the complete debt portfolio at the current price, combined with the refinancing of the debt at par value. If the debt portfolio already only consists of par bonds regarding the market conditions at time t , the present value is equal to the debt generated by the portfolio and therefore the Market Value Compensation is zero. All deviations of the portfolio from current market conditions are directly reflected in this term.⁴

- **Refinancing Cost:** The third part, the financing cost over the future horizon ΔH , or “Refinancing Cost”

$$RefiCost(t) = D(t) \cdot \Delta H \cdot \bar{z}(t, t + \Delta H),$$

indicates the future interest expenses of the above-mentioned refinancing at par value. It can be interpreted as a hypothetical single bond for the complete debt over a given AIC-Horizon ΔH with the refinancing yield $\bar{z}(t, t + \Delta H)$, for details see 2.3.

The sum of these parts defines the “Total Interest Cost” (TIC)

$$TIC(t) = IE(t_0, t) + PV(t) - D(t) + D(t) \cdot \Delta H \cdot \bar{z}(t, t + \Delta H),$$

and averaging over the considered timespan yields the Average Interest Cost (AIC)

$$AIC(t) = \frac{TIC(t)}{t - t_0 + \Delta H} = \frac{1}{t - t_0 + \Delta H} (IE(t_0, t) + PV(t) - D(t) + D(t) \cdot \Delta H \cdot \bar{z}(t, t + \Delta H)).$$

The Average Interest Cost is therefore the mean annual cost generated by the debt portfolio considering the past period since t_0 and the future period up until $t + \Delta H$.

The inspiration from the two approaches in 1.1 is getting clearer by a detailed look at the AIC. In the Market Value Compensation, the close connection to a mark-to-market approach becomes obvious. The AIC is closely connected to the market value of the current portfolio and the Market Value Compensation moves according to market movements. In contrast to the mark-to-market approach, the hypothetical rebuy is appropriate here, because it coincides with the refinancing. The inclusion of the historic interest expenses and especially the Refinancing Cost in contrast illustrates the close link to the budget approach. However, AIC employs a universal Refinancing Cost, independent of the current portfolio structure with an implied development of yields according to the forward path. This provides a simple comparison of portfolios, while being unaffected regarding shifts of cashflows.

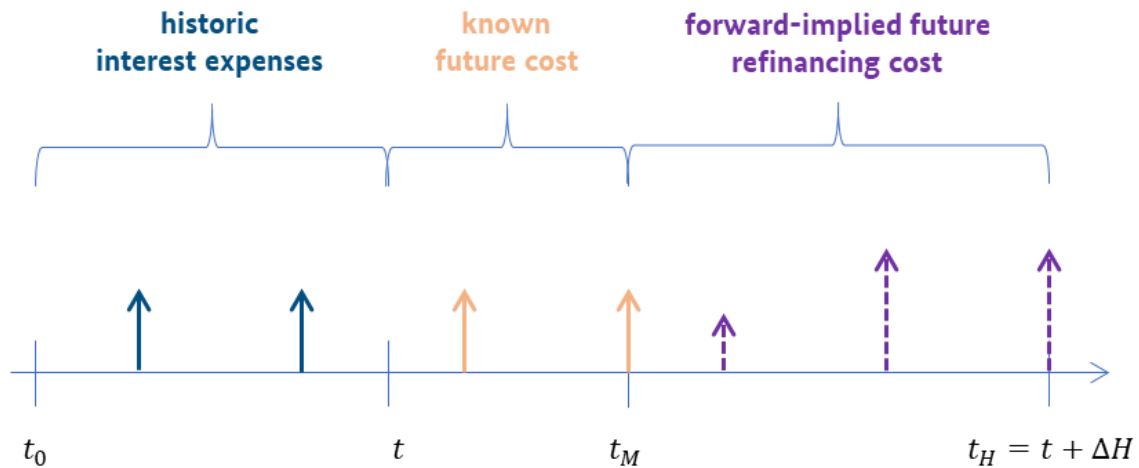
2.2. A Coupon Based View on AIC

There is a second interpretation of the AIC or TIC, respectively. Under some approximations it can be shown that the AIC corresponds to the accumulated interest expenses including the historic interest expenses and also the future interest expenses up to the defined horizon. For illustration purposes consider a single bond. For each bond in the debt portfolio it is possible to determine the expected future interest cost by adding two parts. The first part is the already known future interest cost due to the fixed coupon of this existing bond. The second part, the unknown future interest cost, accounts for refinancing the existing bond after its maturity up to the end of the horizon $t_H = t + \Delta H$, see Figure 1 for a depiction.

⁴ The present value is regarded as a standard measure and is probably already monitored by many debt managers. However, its calculation might be challenging for some instruments, e.g. due to the lack of market liquidity. Addressing this issue in the context of AIC needs further consideration.

The unknown future refinancing cost can be determined by the forward implied interest cost of a bond lasting from maturity of the existing bond to the end of the horizon.

Figure 1. Schematic depiction for a coupon-based view on AIC.



By applying this view to each outstanding bond of the current portfolio, it is ensured that the complete debt is refinanced exactly and only up to the end of the AIC-Horizon⁵. With some approximation (and apart from discounting) the sum of these already known interest cost and the unknown interest cost determined under current market conditions, correspond to the sum of the above defined Market Value Compensation and Refinancing Cost. An approximate derivation can be found in 0.

2.3. The Horizon, The Refinancing Yield and Their Modification

To guarantee that the AIC actually fulfills the key requirements mentioned in 1.2, it is essential to specify the AIC-Horizon ΔH in combination with the refinancing yield $\bar{z}(t, t + \Delta H)$ thoroughly. This becomes clear, by stressing the image of rebuying the debt portfolio and issuing a new single bond at then current market prices to refinance the debt,

The considered horizon ΔH has to be long compared to the average time to maturity of the longest realistic debt portfolio, but does not need to exceed the time to maturity of the longest instrument itself. It has to be longer than the typical average lifetime of a portfolio because otherwise the key requirement of longer portfolios providing lower risk will not hold anymore. For details see chapter 3. On the other hand, if the horizon is too long, the AIC is dominated by the refinancing term, which is the same for all portfolios. This would diminish deviations of the AIC generated by different portfolio strategies. As a rule of thumb, a horizon which is half as long as the longest instrument ensures this property, as it corresponds to a stable strategy issuing each the same amount of only new bonds with this longest possible maturity each year.

It is important to note that the implied refinancing strategy, in our modelling a single bond, is technically a “risk-free” strategy. Since there is no risk-free strategy in the real world of public debt management, the implied refinancing strategy has to be modeled to be not achievable by the debt

⁵ In this view, bonds maturing after the end of the AIC-Horizon have to be bought back at the end of the AIC-Horizon to ensure, that the debt is only financed up to that point. The corresponding agio has to be considered as well for a match with the actual formula of AIC.

managers via realistic issuance strategies. This can lead to different refinancing strategies for different debt managers, depending on the debt portfolio and specific views of the debt manager.

In the management of the federal debt the German Finance Agency uses a time horizon of the AIC of $\Delta H = 15$ years, since the longest issued German bond has a time to maturity of 30 years. We consider this a suitable trade-off between long enough and as short as possible.

The refinancing yield $\bar{z}(t, t + \Delta H)$ is the second important part of the Refinancing Cost in the AIC. This refinancing yield has to have close connections to the current yield curve at time t and has to reflect a suitable yield for the time to maturity of ΔH . The most straightforward approach is the zero yield i.e. $\bar{z}(t, t + \Delta H) = z(t, t + \Delta H)$. However, other definitions and modifications are possible, see 0 for details.

2.4. Incorporating other Instruments

The general idea of the AIC, rebuying the portfolio and refinancing the debt via a “risk-free” strategy, is also compatible with inflation linked bonds, foreign currency bonds or swaps and other derivatives. All properties of these instruments are fully incorporated in the present value and therefore contribute completely and directly to the AIC.

Instruments that generate debt, like inflation linked bonds and foreign currency bonds, also influence the AIC via the considered Refinancing Cost. Swaps and other derivatives, however do not contribute to the debt and therefore have no impact on the refinancing part of the AIC.

Assuming a (sub)portfolio consisting only of swaps, there is no debt and therefore no Refinancing Cost. In this case the AIC matches the total return in close relationship to an asset manager’s view and the mark-to-market approach in 1.1. Here, the lack of Refinancing Cost is appropriate, since such a derivative portfolio could actually be terminated on a short time horizon without implying any significant refinancing needs in contrast to the actual debt portfolio.

3. PROPERTIES OF AVERAGE INTEREST COST AND ITS RISK

Based on the definitions of the AIC in 2.1 we show in this chapter that the AIC actually incorporates all key requirements from 1.2. With the help of some detailed views and definitions it becomes evident that the AIC is an appropriate cost measure for public debt management.

3.1. Incorporating Every Cashflow

From the definition in 2.1, it becomes clear that the AIC or TIC actually captures every cashflow in the sense described in 1.2.1. Using the present value of the complete portfolio for the Market Value Compensation and historic interest expenses, all cashflows of the portfolio are always considered in this approach no matter which timespan is considered. This property is directly inherited from the present value. Additionally, the Refinancing Cost is by design a complete closure of the expected future cost: The refinancing of the debt via a single bond with maturity at $t + \Delta H$ is the same for all portfolios, independent of the specific portfolio structure. Therefore, using the AIC every portfolio is treated equally, and thereby ensuring a fair evaluation at the end of the AIC-Horizon $t + \Delta H$.

3.2. Reflecting a Realistic View on Long-Lasting Public Debt

The key requirement described in 1.2.2 regarding the general observation of long-lasting public debt is ingrained in the definition of the AIC. The Refinancing Cost covers the cost associated with the debt lasting up to the end of the AIC-Horizon $t + \Delta H$. This point in time can differ among debt managers. However, the AIC-Horizon is expected to be significantly longer than the typical average time to maturity of the considered debt portfolio. The Refinancing Cost can also be easily adjusted, e.g. to accommodate an anticipated path of debt reduction or debt increase. Parametrizing the Refinancing Cost in such a way that it reflects a realistic view on the specific debt portfolio is straightforward following the guiding principles presented in 2.3.

3.3. Cost Characteristics: Rising Cost with Rising Interest Rates

The AIC is highly correlated with the movement of interest rates. For a better understanding of this, it is useful to define a new key figure, the $TIC01(t)$, that indicates the change of the Total Interest Cost due to a yield curve shift of 1 bp. It is determined via the derivative of the Total Interest Cost with respect to parallel shifts of the yield curve:

$$\begin{aligned} TIC01(t) &= 10^{-4} \cdot \frac{d}{dz} TIC(t) \\ &= 10^{-4} \cdot \frac{d}{dz} (PV(t) + D(t) \cdot \Delta H \cdot \bar{z}(t, t + \Delta H)) \\ &= PV01(t) + 10^{-4} \cdot D(t) \cdot \Delta H. \end{aligned}$$

The $TIC01(t)$ shows a close relationship with the $PV01(t)$, however it has the opposite sign. From the issuer's perspective the $PV01(t)$ of a debt portfolio is negative and therefore rising interest rates lead to a smaller present value. Due to the second term in the $TIC01(t)$, the sign switches, if ΔH is large enough. The $TIC01$ becomes positive, and therefore the TIC (and with that the AIC) actually increases with rising interest rates.

With a rough approximation of $PV(t) \approx D(t)$ and the definition of the duration as

$$Duration(t) = -\frac{PV01(t)}{PV(t)},$$

the $TIC01$ can become even more intuitive:

$$TIC01(t) \approx 10^{-4} \cdot D(t) \cdot (\Delta H - Duration(t)).$$

The $TIC01$ is positive when the considered AIC-Horizon is longer than the typical duration of the portfolio. The arguments in 2.3 for a suitable length of the horizon are actually based on this view. By choosing a long enough AIC-Horizon, the AIC shows the suitable cost characteristic.

It is also possible to define the AIC01 based on the TIC01

$$AIC01(t) = \frac{TIC01(t)}{t - t_0 + \Delta H}.$$

Due to the averaging over the complete timespan and the corresponding damping effect this key figure has to be used with caution when examining the development over time. For evaluating the development of the portfolio composition over time, the TIC01 provides a more intuitive interpretation.

3.4. AIC-Risk Based on Historic Increments: Risk as Standard Deviation of Cost

The interpretation of the historic AIC-Risk as the fluctuation of the AIC, is straightforward. We define historic increments of the TIC from dates t_1 to t_2 as

$$\delta TIC(t_1, t_2) = TIC(t_2) - TIC(t_1) - \delta D(t_1, t_2) \cdot \Delta H \cdot \bar{z}(t_2, t_2 + \Delta H),$$

which indicates the change in TIC from one timepoint to the next one. The last term is a correction term with

$$\delta D(t_1, t_2) = D(t_2) - D(t_1),$$

that offsets possible fluctuations in the TIC due to changes of the amount of debt. These changes in debt are no source of market risk and should therefore be excluded.

Based on these historic increments, it is possible to use statistical methods to derive all kinds of variance measures. In the German debt management, we use standard deviation on the N daily increments of the last year,

$$TIC_{Risk}(t) = \sqrt{\frac{1}{N-1} \sum_{\tau=t-1\text{year}}^t (\delta TIC(\tau-1\text{day}, \tau) - \overline{\delta TIC}(t))^2},$$

with the corresponding mean increment

$$\overline{\delta TIC}(t) = \frac{1}{N} \sum_{\tau=t-1\text{year}}^t \delta TIC(\tau-1\text{day}, \tau).$$

Other statistical measures and other timespans are of course also possible.

For the calculation of the AIC-Risk, the TIC-Risk has to be normalized by the considered timespan. This can be done in two different ways, depending on preferences. First, normalizing by the same timespan as the AIC itself, using

$$AIC_{Risk}^{long}(t) = \frac{TIC_{Risk}(t)}{t - t_0 + \Delta H}.$$

This incorporates the fact that the AIC will become more and more stable, the further t_0 lies in the past: While only the Market Value Compensation and the Refinancing Cost actually create risk, with a longer history the historic interest expenses start dominating the AIC. Therefore, the $AIC_{Risk}^{long}(t)$ will become lower due to normalization even if neither the portfolio nor the market volatility changes.

The other approach is normalizing only by the future timespan, i.e. the AIC-Horizon ΔH . This slightly decouples the AIC-Risk from the AIC, but has a stronger connection to the current portfolio and its composition. Also, in a time series of the AIC-Risk it is easier to compare the risk at two different timepoints.

In German debt Management the latter perspective is the preferred one and the AIC-Risk is generally given by

$$AIC_{Risk}(t) = \frac{1}{\Delta H} \cdot TIC_{Risk}(t).$$

3.5. Risk Characteristics: Longer Portfolios Imply Less AIC-Risk

The risk characteristics of the AIC can also be examined by using the aforementioned $AIC01(t)$ and $TIC01(t)$. By using the approximation of

$$TIC01(t) \approx 10^{-4} \cdot D(t) \cdot (\Delta H - Duration(t)),$$

it becomes clear that the sensitivity of the TIC decreases when ΔH and the duration get closer. With a suitable choice of ΔH this means: The longer the duration of the portfolio, the less the AIC moves due to movements in the yield curve. This is exactly the intuitive behavior of longer portfolios implying less risk than shorter portfolios. Here also the interpretation of a “risk-free” refinancing strategy becomes clear: When the debt portfolio matches the refinancing strategy, the difference of ΔH and duration becomes zero, and the TIC is independent of shifts in the yield curve and therefore risk-free.⁶

Based on this interpretation, it might also be useful to define the TIC-Duration as

$$Duration_{TIC}(t) = \frac{1}{D(t)} \cdot \frac{d}{dz} TIC(t) = \Delta H - \frac{PV(t)}{D(t)} \cdot Duration(t) \approx \Delta H - Duration(t).$$

This TIC-Duration can be used in a similar way the usual duration is used in asset management.⁷ The larger the TIC-Duration (i.e. a small duration and usually a small average time to maturity), the more sensitive the portfolio is to changes in the yield curve and vice versa.

4. COMPARISON OF FINANCING STRATEGIES WITH AIC IN DIFFERENT USE CASES

Comparing different debt portfolios or strategies is essential for sound decision making in public debt management. In this chapter three analyses based on the Average Interest Cost are presented that are inspired by the use cases of the AIC in the German Finance Agency. Performance Evaluation

4.1. Historic Performance Evaluation

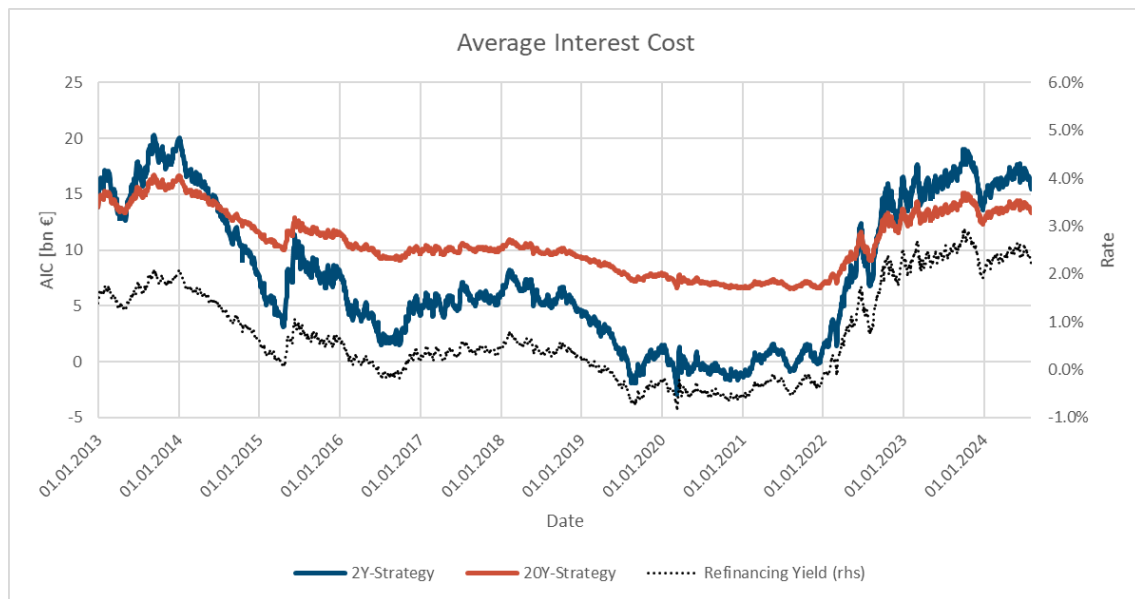
The evaluation of historic performance can provide significant insights into the strategic decisions made in the past and its consequences on the portfolio properties. In Figure 2 you can see the historic development of the AIC with starting date $t_0 = \text{January } 1^{\text{st}} \text{ 2013}$ and an AIC-Horizon of $\Delta H = 15$ years for two different fictional portfolios. The development is based on the historic development of the German yield curve. The two portfolios, both financing a debt of 1 trillion €, are synthetic portfolios only constructed for illustration and are not realistic options. They can be characterized by their issuance strategy of issuing only either 2Y-Bonds or 20Y-Bonds, respectively. A detailed description of the construction of these portfolios including the development of the accumulated interest cost and the present value can be found in 0. The two different issuing strategies, focusing either on short or long instruments, lead to a significant difference between the two strategies in terms of average time to maturity and duration as well. However, due to construction, both strategies start at t_0 with the same PV and the same historic interest expenses and therefore with the same $AIC(t_0)$.

⁶ Here we neglect for simplicity the sensitivities to other movements of the yield curve, but the argument still holds: If the debt portfolio matches the refinancing portfolio exactly, the TIC will not change due to market developments.

⁷ For shortcomings of the standard definition of duration for public debt management, see (Jonasson & Papaioannou, A Primer on Managing Sovereign Debt-Portfolio Risks, 2018).

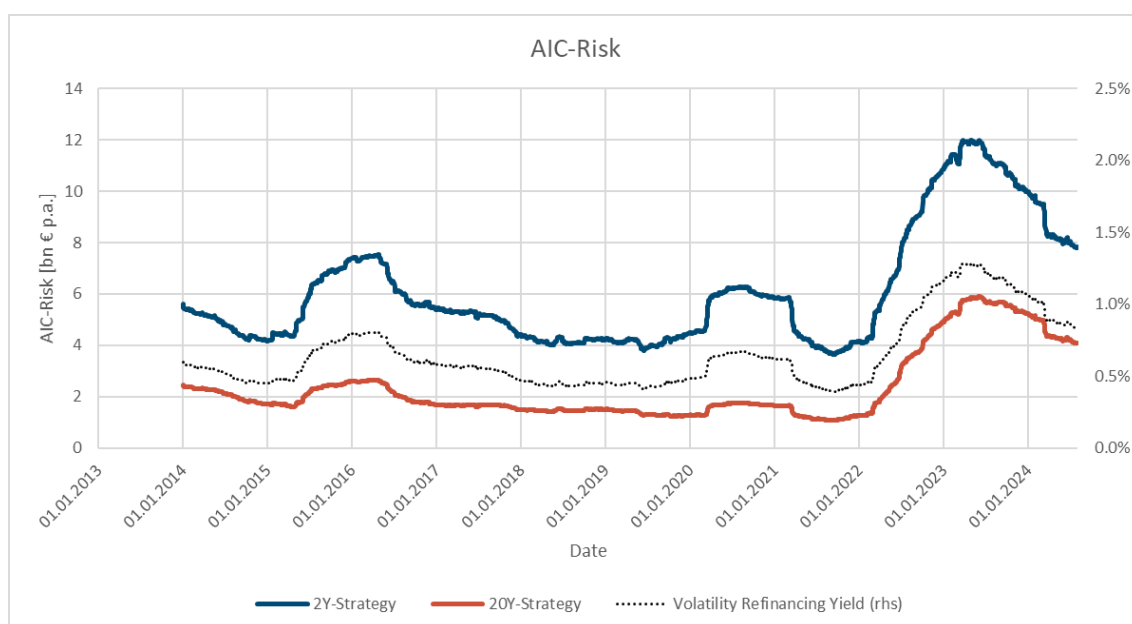
Looking at Figure 2, the high correlation of the AIC and the refinancing yield $\bar{z}(t)$ becomes apparent: A rising interest yield leads to rising AIC, showing one of the key requirements of a cost measure for public debt management. Additionally, it can be seen that the strategy with only 2Y-Bonds implies a shorter portfolio and therefore is more sensitive to the movement of the yield curve. The rising yields in 2012 or 2022 lead to larger increases of the AIC for the 2Y-Strategy than for the 20Y-Strategy. For the decline in interest rates in 2013 to 2020 the shorter strategy provides a larger decline of the AIC than the longer one. This emerges since the 2Y-Strategy has a higher percentage of the debt to be refinanced each year and therefore a stronger connection to the yield movements.

Figure 2. Development of the Average Interest Cost for two different strategies and the refinancing yield $\bar{z}(t)$ based on the yields of German Federal Bonds.



This observation also leads to the key requirement for public debt management regarding appropriate risk behavior. From the development of the AIC we can calculate the associated risk as the standard deviation of the daily TIC increments as described in 3.4, which is shown in Figure 3. The shorter portfolio shows a significant higher AIC-Risk due to the higher sensitivity to yield movements. Additionally, in times of larger volatility of the refinancing yield, the AIC-Risk increases for both strategies.

Figure 3. Development of the AIC-Risk for two different strategies as defined in 3.4 corresponding to the AIC shown in Figure 2 and the volatility of the refinancing yield.



The actual use cases for this historical analysis in the German Finance Agency are twofold. The historical development of the AIC and the AIC-Risk of the German debt portfolio is used for internal and external reporting. Reporting this cost measure provides a more structural view on the expected interest cost in the current market environment. While the actually paid interest expenses are important from a budget point of view, the structural long-term view of the AIC can provide a deeper understanding especially in times with rapidly changing yields, due to its direct response. The second use case for such a historical analysis is a complete and economic fair comparison of the actual portfolio against an alternative benchmark. Strategic decisions based on expectations of the development of the yield curve, say at the beginning of the year, can then be evaluated based on the actual realization of the yield development at the end of the year.

4.2. Future Scenario Analysis

In contrast to the historic evaluation in the previous section, decisions regarding a portfolio composition are made by looking into the future. This core task for public debt management is probably the most important use case for a cost measure in public debt management. Specifying different issuance strategies for the upcoming years and calculating cost and risk under different yield scenarios makes it possible to weigh one strategy against the other and make well-founded decisions. Using AIC for this future strategy evaluation is comparable to the established approach in public debt management already mentioned in the description of the budget approach in 1.1. In fact, the analysis based on AIC matches that approach, with only one major difference: The AIC also include the locked-in portfolio at the end of the simulation horizon and solving therefore the issue of neglecting future cashflows.

For this analysis we want to compare two different strategies and their development over time under different deterministic yield developments. Both strategies start at time t_0 = January 1st 2024 with the same portfolio and always finance a debt of one trillion €. They differ in the future issuance strategy

by using only 2Y-Bonds, or only 20Y-Bonds, respectively, to rollover the debt. Over time this leads to different portfolios which also react differently to the market development. For details see 0.

Figure 4 shows three simple deterministic scenarios for the development of the refinancing yield from January 1st 2024 to January 1st 2034. All scenarios start at a yield of 2.0% and include a linear yield shift over the next 10 years. The first scenario for the refinancing yield is called the “expected path” and reflects the expectation of a fictive debt manager making the decision. This path corresponds to a moderate decline in yields of 100 bp over 10 years. The two other scenarios can be seen as stress scenarios corresponding to a 400 bp shift of the refinancing yield over 10 years upwards or downwards respectively.

Figure 4. Different future deterministic paths of the refinancing yield $\bar{z}(t)$ corresponding to a linear shift over ten years of -100 bp, -400 bp and +400 bp, respectively.

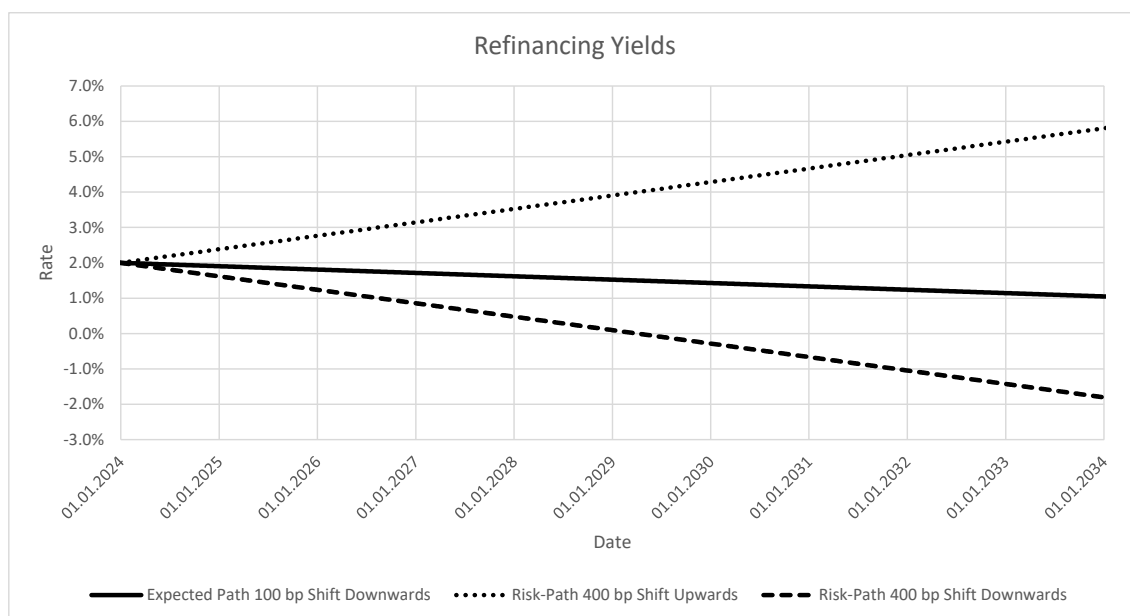


Figure 5. Average Interest Cost for the two different strategies under all three different yield scenarios shown in Figure 4.

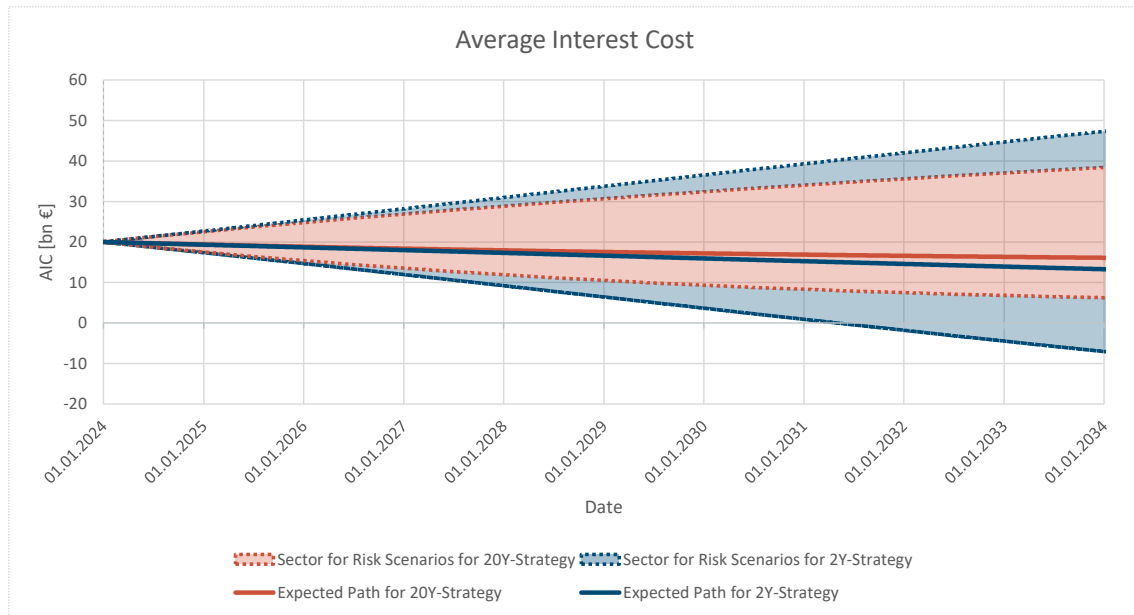


Figure 5 shows the development of the AIC with starting date $t_0 = \text{January 1}^{\text{st}} 2024$ and an AIC-Horizon of $\Delta H = 15$ years for the two different considered strategies under the three selected yield scenarios. We want to emphasize two main observations: The 2Y-Strategy is again more responsive to the yield development. In combination with the small downward shift in the scenario with the expected yield development this results in significantly lower AIC of 13.3 bn € for the 2Y-Strategy than the expected AIC of 16.1 bn € for the 20Y-Strategy.⁸

The second main observation is the significantly larger sector of the AIC for the 2Y-Strategy compared to the 20Y-Strategy. While the yield path with a 400 bp rise is a risk scenario, the AIC in this scenario can be interpreted as a Cost at Risk measure. We interpret the difference between the AIC on the expected path and the AIC on this risk scenario path as the AIC-Risk. With 34.0 bn €, the 2Y-Strategy implies a much larger risk than the 20Y-Strategy with an AIC-Risk of 22.3 bn €. This again shows the expected and desired behavior of shorter portfolios implying higher risk than longer portfolios. In combination these two observations lead to the typical trade-off for debt managers between cost and risk.

This analysis is based on very simple deterministic scenarios for illustration purpose only. However, it can be easily adapted to be based on e.g. sophisticated macro-economically motivated deterministic scenarios or a stochastic interest-rate model. Depending on the view, the AIC-Risk can be derived from the resulting distribution of the AIC under these different paths by using e.g. percentiles or the standard deviation. It is also possible to determine the AIC-Risk on a specific stochastic path due to market movements. Depending on the debt manager's actual point of interest, the AIC can provide a comprehensive measure for investigating future developments of the debt portfolio.

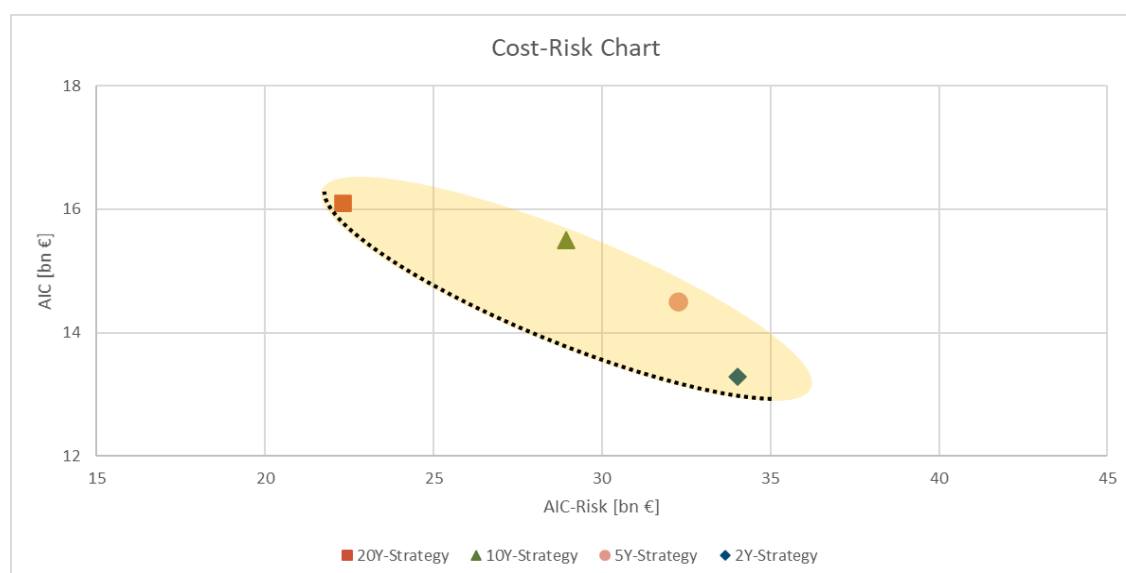
⁸ In this one-factor model, the observation of lower cost for shorter strategies is enforced by the expected decline in yield rate. A more realistic yield model including the typical upwards sloping yield curve usually generates lower cost for shorter strategies even without a dedicated decline in yields.

4.3. Portfolio Optimization and Decision Making

Based on the analysis presented in the previous section it is possible to illustrate a path to decision making in public debt management. With the combination of the AIC and its associated risk, a public debt manager can judge different considerable strategies similar to the standard portfolio selection approach developed by Markowitz (Markowitz, 1952). Figure 6 shows a stylized cost-risk chart with the two specific strategies from the previous section as two examples of possible portfolio strategies. Additionally, we included a comparable 5Y-Strategy and a 10Y-Strategy, respectively, constructed with the same method. However, this stylized chart is not determined by the simple one-factor model used in the previous examples but is based on observations using a more realistic interest rate model. By rendering additional different possible portfolio strategies, calculating their cost and risk and including them in the cost-risk chart, or using optimization methods, it is possible to construct the efficient frontier. This efficient frontier indicates all portfolios that show minimal cost for a given risk, or minimal risk for a given cost. Using a realistic interest rate model with a typical yield curve and realistic scenarios, the longest and the shortest instruments appear to be more efficient than instruments with a medium maturity. Therefore, efficient portfolios regarding AIC and AIC-Risk are dominated by the longest and shortest instruments. A rigorous treatment of the portfolio optimization routine is out of scope of this paper. For a deeper treatment in the context of public debt management see e.g. (Bernaschi, Missale, Vergni, & others, 2009), (Bergström, Holmlund, & Lindberg, 2002), (Bolder & Deeley, 2011), (Yavuz & Gölbaşı, 2019).

In practice, such an efficient frontier indicates the most reasonable portfolio strategies regarding AIC and AIC-Risk. The final decision about one specific strategy on (or near) the efficient frontier is dependent on the risk aversion of the debt manager: How much more AIC-Risk is acceptable for a given reduction of Average Interest Cost? Since the AIC fulfills all key requirements for public debt management, using AIC and AIC-Risk provides a comprehensive and intuitive way for weighing cost against risk.

Figure 6. Stylized cost-risk chart for decision-making with AIC-Risk and AIC for different strategies issuing different instruments. Additionally, the area of all possible strategies and the resulting efficient frontier are indicated.



5. SUMMARY AND OUTLOOK

In this article we discussed key features of a suitable cost and risk measure for public debt management and developed the novel measure Average Interest Cost and its corresponding risk. The Average Interest Cost is based on interest expenses over a long-time span including historic and expected future interest expenses. The expected future interest expenses can be interpreted as the cost associated with a hypothetical buyback of the current debt portfolio and refinancing the complete debt at current market conditions.

We showed that the AIC can accommodate all key requirements for public debt management including capturing every cashflow, a realistic perspective on long-lasting public debt, a high correlation with interest rates, an associated risk measure and lower risk for longer portfolios. With these properties, the Average Interest Cost improves established cost measures in public debt management. We concluded the paper with three analyses inspired by use cases at the German Finance Agency. These analyses include a historic performance analysis that can be used for benchmarking and reporting, a stochastic scenario analysis for evaluating future strategies, and a schematic illustration of a possible portfolio optimization for decision making. The list of possible use cases for AIC can be easily expanded to other issues of interest.

One possible modification to the presented AIC is to normalize the AIC by the present value or the debt of the portfolio and thereby construct the “Normalized Average Interest Cost”. The Normalized Average Interest Cost makes it trivial to compare diverse (sub)portfolios or distinct instrument classes consistently. However, this modification is beyond the scope of this paper and will be explored in a future publication.

The AIC is a highly condensed cost measure, which is useful to compare different portfolios and strategies from a long-term and sustainable perspective. While strategic decisions and high-level discussions can focus on this view, in practice it is still necessary to monitor more imminent aspects, e.g. budget constraints. Additionally, it can still be necessary to calculate the actual interest expenses expected for each year to avoid unbalances from year to year, which is not provided by the AIC.

The AIC-Risk based on a variance measure of the AIC is capturing refinancing risk driven by interest rate risk. While this is a major source of risk, other forms of risk like liquidity, credit, settlement, or operational risk have to be monitored as well and treated separately, see e.g. (Lewis & Viñals, 2014). AIC-Risk is partly including rollover risk since the AIC incorporates the Refinancing Cost, but the concept is based on the ability to rollover the debt, albeit at possibly higher yields. The core of rollover risk, i.e. the inability to rollover the debt, is not encapsulated in the AIC and its risk and has to be monitored differently.

The main contribution of this novel cost measure is the extension of the widespread budgetary approach to cost in public debt management. This extension builds the bridge to a mark-to-market view based on the present value and combines the advantages of both approaches. With the AIC it is possible to generate a meaningful and economic complete metric as a base for different use cases. While the definition of the AIC is adjustable to fit specific needs of a public debt manager, the AIC provides a condensed cost measure that is easy to interpret, simple to calculate and that meets all key requirements for public debt management.

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APPENDIX A - DERIVATION OF COUPON BASED VIEW ON AIC

In a very simplified view the sum of Market Value Compensation and Refinancing Cost corresponds to the already known fixed interest expenses and the expected cost of refinancing each single bond from the time of its maturity up to the end of the AIC-Horizon.

Assuming for simplicity, the debt portfolio consists of only one bond with nominal N , maturing at time t_M and coupon d . For a complete view of the accumulated future interest expenses up to the desired time $t_H = t + \Delta H > t_M$, the maturing bond has to be refinanced. This is done by a par coupon bond issued at time t_M maturing at time t_H , with the par coupon of c . The accumulated future interest expenses asserting a discrete yearly time grid can be expressed as

$$IE(t, t + \Delta H) = N \cdot (t_M - t) \cdot d + N \cdot (t + \Delta H - t_M) \cdot c.$$

Under the assumption of a completely flat yield curve, we can decompose the outstanding bond into a par coupon bond with coupon c , and the off-market part with coupon $(d - c)$:

$$\begin{aligned} IE(t, t + \Delta H) &= N \cdot (t_M - t) \cdot (d - c) + N \cdot (t_M - t) \cdot c + N \cdot (t + \Delta H - t_M) \cdot c \\ &= N \cdot (t_M - t) \cdot (d - c) + N \cdot \Delta H \cdot c. \end{aligned}$$

Note, that the second term is simply the cumulated interest expenses of a bond at current market conditions maturing at t_H , equivalent to the Refinancing Cost in the AIC. The first term, however, can be interpreted as the “undiscounted” Market Value Compensation in the AIC. This becomes clear by using the discount factor $DF(t, t_i)$, discounting from t_i to t , and rewriting the debt corresponding to the nominal of the outstanding bond

$$\begin{aligned} PV(t) - D(t) &= N \cdot \left(\sum_{t_i=t}^{t_M} d \cdot DF(t, t_i) + DF(t, t_M) - \left(\sum_{t_i=t}^{t_M} c \cdot DF(t, t_i) + DF(t, t_M) \right) \right) \\ &= N \cdot \sum_{t_i=t}^{t_M} (d - c) \cdot DF(t, t_i) \approx N \cdot (t_M - t) \cdot (d - c). \end{aligned}$$

Therefore, the sum of the Market Value Compensation and the Refinancing Cost can also be viewed (apart from discounting) as the accumulated future interest cost of the current portfolio and an appropriate refinancing of the maturing bonds up to the end of the horizon $t + \Delta H$.

APPENDIX B - THE REFINANCING YIELD IN DETAIL

In 2.3 it is suggested to use the zero-yield with maturity at the end of the horizon as the refinancing yield, $\bar{z}(t, t + \Delta H) = z(t, t + \Delta H)$.

While this definition is exceptionally easy to calculate and might be sufficient for a lot of use cases, this definition makes the AIC highly correlated with a specific point of the yield curve. Therefore, in the German Finance Agency we use a weighted average over the complete yield curve to also reflect changes of the yield curve structure into the AIC:

$$\bar{z}(t, t + \Delta H) = \frac{1}{2 \cdot \Delta H^2} \cdot \int_{\tau=0}^{2 \cdot \Delta H} \tau \cdot z(t, t + \tau) d\tau.$$

This specific choice also leads to a different interpretation: While this Refinancing Cost can still be seen as the cost of a single bond, just with an average yield, it can also be interpreted as a portfolio consisting of zero-bonds with different times to maturity from 0 to $2\Delta H$. In this interpretation the Refinancing Cost imply a linearly shrinking debt from current time point t until $t + 2\Delta H$.

Both above definitions of the Refinancing Cost assume that the “risk free” portfolio used for refinancing can be built with instruments based only on a single yield curve. This assumption makes the AIC reasonable simple and is appropriate for the German debt portfolio, where the overwhelming part of the portfolio consists of simple nominal bonds. The portfolio consists only to a small percentage of inflation linked bonds and green bonds, and no bonds in foreign currencies are issued.

For other public debt managers, it might be useful to modify the Refinancing Cost so that this part of the AIC is also sensitive to changes in exchange rates or inflation. With the general idea of a “risk-free” refinancing portfolio in mind, the AIC is easily adjustable to the specific need of the debt manager. For instance, the refinancing portfolio can be split into one part refinanced in local currency, and the other part in foreign currency.

APPENDIX C - MODELLING DETAILS

The underlying model for the analyses presented in Chapter 4 is a highly simplified model of public debt management: For the considered timespan a constant debt of one trillion € has to be financed via different fixed bonds with different time to maturity. Each year, some of the outstanding bonds mature and have to be refinanced with a new bond, whose coupons are fixed at the then current rate. For simplicity we assume a flat one factor yield curve that also determines the refinancing yield for the AIC. In the historic analysis this flat yield curve is based on the actual 10-year rate of the German BUND yield curve. We also assume for simplicity that the date of redemption, date of issuance and the coupon payment date all fall on June 30th of the corresponding year.

AC.1 - Historic Analysis

For the historic analysis in 0, we focus on stable portfolios that are generated by a time-stable issuance strategy. Each year the same amount of each instrument is issued to finance the redeeming bonds. Two different strategies are compared here. The so called “2Y-Strategy” only consists of bonds with a maturity of 2 years at time of issuance, the so called “20Y-Strategy” in turn only consists of bonds with a maturity of 20 years at time of issuance. Both strategies are initialized at the December 28th 2012 at then par value. The imposed structure results in the 2Y-Strategy having to refinance 500 bn € each year, while the 20Y-Strategy only refinances 50 bn € each year. It becomes obvious that the 2Y-Strategy has a significantly lower average time to maturity compared to the 20Y-Strategy.

Figure 7 and Figure 8 show the development over time of the Market Value Compensation (i.e. the difference of present value and debt⁹) and the cumulated interest expenses for each of the two strategies. The cumulated interest expenses rise over time, with steps corresponding to the coupon-payments on June 30th each year. Although we assume a flat yield curve for all maturities, the two strategies generate different interest expenses over time. This emerges due to the different amount of refinancing each year and therefore different portions of the portfolio being re-fixed at the then current rate. Note that the cumulated interest expenses for the 2Y-Strategy decrease in 2021 and 2022 because of the negative yields in 2020 and 2021 resulting in negative coupons for the issued bonds in that year. This cannot be observed for the 20Y-Strategy, since the fraction of negative coupons is too small to outweigh the bonds issued before with positive coupons.

The Market Value Compensation moves in opposite direction with the corresponding yield development, and also reacts to the coupon payment dates in opposite direction to the interest expenses. Note that the Market Value Compensation due to the close connection of the PV shows much larger movements for the 20Y-Strategy than for the 2Y-Strategy.

To calculate the AIC shown in Figure 2 in 0, the cumulated interest expenses and the Market Value Compensation have to be added to the Refinancing Cost. This Refinancing Cost is simply the product of the refinancing yield, the debt of 1 trillion and the horizon length of 15 years.

⁹ Since the debt of the portfolio is constant by construction, the Market Value Compensation essentially shows the movement of the *PV*, only shifted by the constant debt.

Figure 7. Development of the cumulated interest expenses and the Market Value Compensation for the 2Y-Strategy, and the refinancing yield.

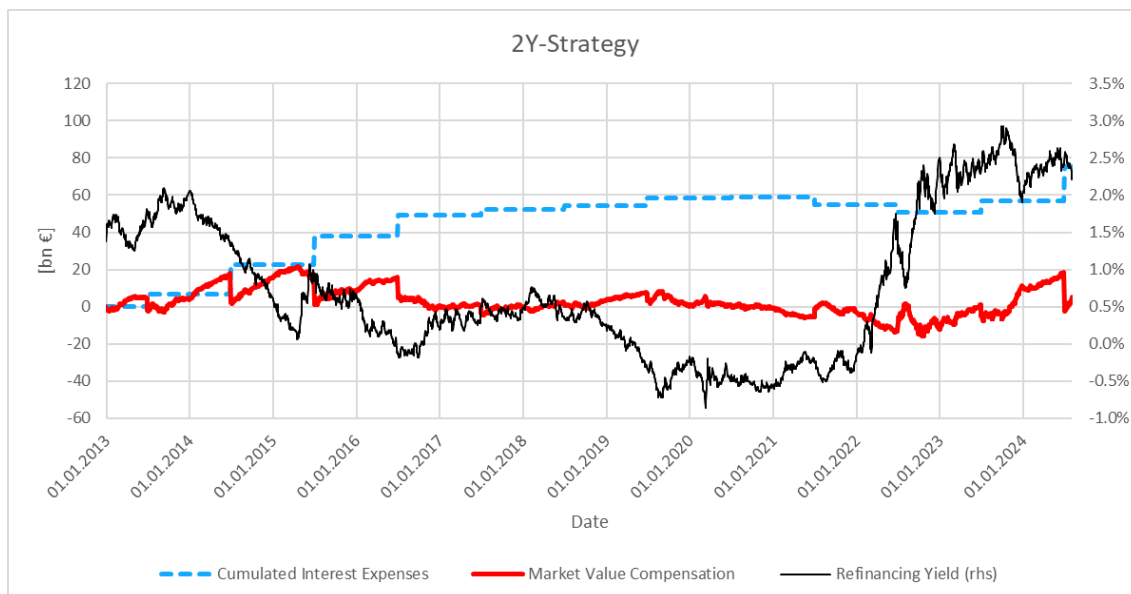


Figure 8. Development of the cumulated interest expenses and the Market Value Compensation for the 20Y-Strategy, and the refinancing yield.



AC.2 - Future Analysis

The general setup for the future analysis in 4.2 is comparable to the method used for the historic analysis, described in 0. Each strategy finances a constant debt of one trillion € by issuing new bonds each year, but using only 2Y-bonds or 20Y-bonds, respectively. However, the starting portfolio on January 1st, 2024, is considered to be the same for both strategies. It consists of 100 billion € par bonds priced at a yield of 2.0% maturing in 2024, 2025, 2026, etc., respectively. Therefore, both strategies have to refinance 100 billion € each year due to the maturing initial portfolio. However, the 2Y-Strategy also has to refinance the nominal corresponding to the maturing newly issued bonds. This is not the case for the 20Y-Strategy, since the simulation horizon ends before the maturity of the first 20Y-bond. The setup with a common initial portfolio implies that both considered strategies diverge from each other relatively slowly.

SESSION III

Sovereign Debt Management Strategies in the Face of Environmental Challenges and Disaster Risks

Disasters, Defaults & Debt Restructurings*

Alexander Dryden

Abstract

This paper examines how disasters influence sovereign defaults and debt restructuring outcomes. From 1975 to 2024, 44 percent of debt restructurings occurred within a year of a major disaster. The type of disaster also influences the loss experienced by private creditors during the debt restructuring experience. 'Immediate' disasters, such as hurricanes and earthquakes, often lead to smaller principal debt reduction ('haircuts') and the restructuring negotiations are typically concluded quickly. In comparison, drought-induced defaults often lead to materially larger haircuts, with creditor discussions often being complex and protracted in nature.

Keywords: Natural disasters, Sovereign default, Debt restructuring, Climate vulnerabilities

JEL Code: F34, G01, H63, Q54

* Version as of November 28, 2024.

1. INTRODUCTION

This paper examines how disasters, such as hurricanes, earthquakes, and droughts, influence the likelihood of sovereign defaults and shape debt restructuring processes. The research focuses on the period from 1975 to 2024, during which 44 percent of debt restructurings occurred within a year of a major environmental hazard. It emphasizes that sudden disasters (like hurricanes) often prompt quicker debt restructuring negotiations with lower “haircuts” (i.e., reductions in the principal amount owed), while droughts lead to prolonged, more complex negotiations and larger creditor losses.

The study is divided into two main parts. The first part investigates how different types of environmental catastrophe precede or contribute to sovereign debt crises. The second part, considers whether disasters influence subsequent debt restructurings, analyzing how these disasters affect the negotiation outcomes and terms of debt restructuring.

2. DISASTERS & SOVEREIGN DEFAULTS

Disasters have increasingly triggered economic instability in vulnerable nations. These events often precede sovereign defaults, especially in countries where climate risks are high, mainly in the Global South. The study draws on various disaster types, differentiating between immediate and gradual-onset events, to understand their distinct impacts on overall sovereign risk.

2.1. Related Literature

The literature connecting disasters to fiscal risk, particularly sovereign default, is limited but growing, as researchers increasingly recognize the severe economic impacts of climate events. Earlier studies focus on the macroeconomic consequences of climate change and its potential to destabilize vulnerable economies. Research has linked climate-related events to economic slowdown, credit downgrades, and increased costs in capital markets, especially for low-income, climate-vulnerable nations. However, few studies specifically link disasters directly to sovereign default events.

Studies like those by Buhr et al. (2018), Kling et al. (2018), Volz et al. (2020) and Klusak et al. (2023) underscore the heightened sovereign risk climate-vulnerable countries face. They argue that by 2030, rising temperatures could negatively impact credit ratings for numerous countries, increasing annual sovereign debt costs by up to \$203 billion. As a result, nations most susceptible to climate shocks are already burdened with higher borrowing rates and increased insurance costs.

Esteves et al. (2021) and Moody's (2020) acknowledge that environmental hazards sometimes trigger sovereign defaults but categorize these events as exogenous shocks without further empirical study. However, Cevik & Jalles (2020) and Klomp (2015) demonstrate that climate vulnerability increases the probability of sovereign defaults, especially in low-income nations, while Mallucci (2022) shows that climate events worsen fiscal vulnerability, often leading to debt restructuring in hurricane-prone Caribbean countries.

The literature also differentiates between high-impact, sudden disasters like hurricanes and gradual-impact events like droughts. High-impact events, like hurricanes, are immediate and destructive, causing extensive physical damage and necessitating rapid fiscal responses. Droughts, however, unfold gradually and often have more profound, long lasting economic repercussions, as described by Damania et al. (2017). Hyland & Russ (2019) refer to droughts as “misery in slow motion,” noting the long-term economic,

social, and agricultural impacts that persist over generations. This distinction becomes crucial in understanding how different disasters influence debt restructuring outcomes.

The study fills a gap by showing that disasters frequently precede sovereign defaults, contributing to the economic instability that triggers such crises. Additionally, it provides insights into how specific types of disasters impact default likelihood and restructuring terms.

2.2. Data Source & Methodology

To analyze the links between climate hazards and sovereign defaults, the study uses two main data sources:

Environmental Hazards

The study relies on the EM-DAT database from the Centre for Research on the Epidemiology of Disasters (CRED), which records over 18,000 large-scale disasters since 1990. Each disaster is classified based on impacts (fatalities, affected population, international aid requests, or emergency declarations). Only "major" disasters are included in the analysis, defined by specific criteria:

- i. The domestic government call for international assistance or declare a state of emergency following the event
- ii. The total damages incurred by the disaster are in excess of 1 percent of GDP
- iii. The impacted population is in excess of 2 percent of the total population

Sovereign Defaults

Sovereign defaults data is sourced from Asonuma & Trebesch (2016), extended to include recent events up to August 2024. A country is considered in default when (a) it misses payments after a grace period, or (b) it publicly announces debt restructuring. This dataset focuses on external debt defaults, excluding domestic debt cases due to limited data.

2.3. Findings

The study finds that in 44 percent of default cases since 1975, a major disaster occurred within the preceding year (see appendix for full list). This correlation underscores the financial vulnerabilities of countries prone to disasters. Hurricanes, floods, and earthquakes feature regularly prior to a sovereign default. However, as table 1 demonstrates, droughts are particularly frequent, causing about 38 percent of disaster-induced defaults between 1975 and 2024. The relationship between disasters and defaults was particularly strong in the 1980s, the pattern lessened in the 1990s and early 2000s, before rising again during the COVID-19 pandemic.

Table 1. Disasters & Sovereign Defaults: By era and disaster type

	Observations	No. of Disasters	% of observations
<i>By era</i>			
1975-2024	204	90	44%
1975-1989	136	61	45%
1990-1999	31	9	29%
2000-2019	25	8	32%
2020-2024	12	12	100%
	Observations	Disasters & Defaults (% of total disasters)	Disasters & Defaults (% of total observations)
<i>By natural disaster type</i>			
Drought	34	38%	17%
Floods	18	20%	9%
COVID-19 Pandemic	11	12%	5%
Earthquakes	10	11%	5%
Storms (Hurricanes, Cyclones)	9	10%	4%
Other (Volcanic Activity, Wildfires)*	8	9%	4%
No Natural Disaster	114	-	56%

Source: Author's Calculation. Default Data: Cruces & Trebesch (2013) 'Sovereign Defaults: The Price of Haircuts' AEJ: Macroeconomics. Disaster Data: World Bank – Natural Hazard Statistics. 'Major' disasters are considered to be disaster events whereby at least one of the following conditions are met: (1) at least 2 percent of the national population are impacted; (2) damage amounts to at least 1 percent of GDP; (3) national or international authorities declare a state of emergency. *Other includes epidemics, infestations, mass movements, volcanic activity, wildfire and extreme temperature changes.

3. DISASTERS & DEBT RESTRUCTURINGS

Part two expands upon the analysis outlined in part one by demonstrating that major disasters not only frequently occur prior to sovereign default announcements but that they also influence the outcomes of subsequent debt restructuring processes. This section outlines the relevant literature in respect to sovereign debt restructurings before discussing the data and methodology used within this study. It then presents a summary of the key findings that showcase that disasters can have a material impact on the debt restructuring process, outcome and the length of discussions with creditors.

3.1. Related Literature

This section considers how environmental catastrophes can influence debt restructuring processes, with particular attention to negotiation duration, the terms of restructuring agreements, and whether these agreements are preemptive or post-default. By examining a range of disaster types, the paper assesses how different disasters impact the approach governments take in renegotiating their debt obligations and the resulting outcomes for creditors and the affected countries.

Research on sovereign debt restructuring generally identifies two primary types: preemptive and post-default restructuring. In a preemptive restructuring, the government proactively negotiates with creditors before any payments are missed, allowing for a smoother process that often results in milder creditor losses. In contrast, post-default restructuring begins only after payments have been missed, a situation that can prolong negotiations and typically leads to higher losses for creditors. Studies by Asonuma and Trebesch (2016), along with guidelines from the IMF, advocate for preemptive

restructuring as a preferable strategy for countries seeking to maintain access to capital markets while minimizing economic disruption. However, the success and feasibility of this approach depend on several factors, including political stability, governance quality, creditor composition, and the legal frameworks governing the restructuring process. These factors shape how negotiations unfold and, ultimately, the terms that both creditors and the debtor country can agree upon.

The paper extends the existing literature by empirically examining how disasters, such as hurricanes, earthquakes, and droughts, influence debt restructuring terms. Anecdotal evidence suggests that “immediate” disasters like hurricanes prompt governments to pursue rapid debt renegotiations to quickly address the fiscal shock, leading to relatively smaller debt reductions and shorter negotiation periods. For example, Grenada’s debt restructuring following Hurricane Ivan in 2004 included an extension of 11.7 years on existing debt maturities, allowing the government some relief without extensive losses for creditors (Asonuma et al., 2017). Similarly, Haiti’s debt restructuring after the devastating 2010 earthquake provided the country with \$1 billion in debt relief, highlighting the influence of sudden, high-impact disasters on the speed and terms of debt agreements (IMF, 2023). In contrast, gradual-onset disasters like droughts tend to lead to more severe restructuring terms. Argentina’s 2020 restructuring, for instance, followed a prolonged drought that caused extensive economic damage, ultimately resulting in a more substantial debt haircut and a lengthier negotiation process (ReliefWeb, 2021; Le Monde, 2023). This distinction between immediate and gradual disasters illustrates how the nature of the disaster itself can shape both the urgency and outcome of sovereign debt restructurings.

3.2. Data Source & Methodology: Sovereign Debt Restructurings

The analysis of debt restructurings in the study employs a range of critical metrics, including debt haircuts, maturity extensions, negotiation duration, and the timing of default announcements, which may occur either on a preemptive or post-default basis. By building upon Cruces & Trebesch’s (2013) haircut dataset, this paper extends the scope of debt restructuring research to include recent cases and provides a more comprehensive understanding of how different types of environmental catastrophe impact restructuring terms and outcomes.

One of the core methodological aspects is the calculation of debt reductions, or “haircuts.” The study utilizes a refined haircut calculation method known as HSZ, which compares the present value of old debt with that of the newly issued debt post-restructuring. Unlike simpler methods, HSZ considers the “exit yield,” or the interest rate at which the newly restructured debt trades immediately after issuance, to account for market perceptions of risk and expected returns. By incorporating this exit yield, the HSZ approach allows for a more accurate, like-for-like comparison between the terms of old and restructured debt.

To analyze maturity extensions, the study follows the approach proposed by Dvorkin et al. (2019), calculating the extension by comparing the maturity terms of the old and new debt while adjusting for the relevant discount rates. This adjustment captures the present value effects of extending debt obligations over a longer period. In cases where data on specific restructurings are unavailable—such as bond buyback events—the analysis omits these observations to maintain accuracy and consistency in the results.

Finally, the study examines the duration of debt restructuring negotiations and the timing of default announcements, classifying them as either preemptive or post-default. To establish these timelines, it draws upon both Asonuma and Trebesch’s foundational data as well as additional sources like government announcements and news reports. Preemptive restructurings, where governments negotiate with creditors before missing payments, generally result in shorter negotiation periods. In

contrast, post-default restructurings, where negotiations begin after payments are missed, typically involve extended discussions with creditors. This nuanced approach to assessing restructuring terms highlights how the timing and nature of default announcements impact the restructuring process, especially in the wake of different types of disasters.

3.3. Key Findings and Stylized Facts

The study presents the following major observations:

Debt Haircuts: Immediate disasters often lead to smaller debt haircuts. For example, floods, earthquakes, and storms yield haircuts averaging 29 percent, compared to 45 percent for drought-induced defaults. This trend reflects governments' tendency to secure quick deals with less creditor loss after sudden disasters, prioritizing speed over extensive debt relief.

Maturity Extensions: Disaster type does not significantly impact the average maturity extension, though drought-related restructurings tend to have longer extensions (averaging 4.8 years). In contrast, hurricanes, floods, and earthquakes see shorter extensions.

Timing of Default Announcements: Governments affected by sudden disasters, such as hurricanes, often approach creditors preemptively, seeking to limit economic fallout. In contrast, drought-induced defaults generally occur post-default, with a significant majority (76 percent) of such cases negotiated after missed payments.

Negotiation Length: Immediate disasters are associated with shorter debt negotiations, averaging 28 months, while drought-induced defaults require prolonged negotiations (nearly 58 months on average). This difference reflects the persistent economic strain of droughts, which complicates fiscal recovery and restructuring talks.

4. CONCLUSION

The findings reveal the importance of considering environmental hazards in sovereign debt assessments, especially as climate change raises the frequency and intensity of such events. Dryden (2025) is investigating this interconnection between disasters and sovereign defaults as well as exploring viable solutions including disaster risk management and transparent creditor communication. Additional areas of investigation could involve considering disaster-resilient financial instruments, such as catastrophe bonds and disaster clauses, to limit restructuring needs and manage creditor losses effectively. Creditors, too, should integrate disaster risks into credit assessments and support flexible restructuring options for disaster-affected nations. As fiscal crises increasingly coincide with climate events, a cooperative approach between nations and creditors is essential for building economic resilience in the face of climate change.

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APPENDIX

Table A. (part 1/2) - Disasters & sovereign defaults: Crisis details (1975-2024)

Country	Sovereign Default Date	Type of Natural Disaster*	% of total population affected	Estimated Damage (% of GDP)	Emergency Crisis Called?	Notes
Türkiye	Dec-76	Earthquake	0.5%	0.25%	Yes	
Türkiye	Dec-76	Earthquake	0.5%	0.25%	Yes	
Uganda	Jun-79	Drought	3.8%	-	Yes	Drought: 1979-1980
Peru	Sep-79	Earthquake	-	-	-	
Jamaica	Mar-80	Floods	9.8%	-	Yes	
Bolivia	Sep-80	Floods	0.3%	-	Yes	
Liberia	Nov-80	Epidemic	0.1%	-	Yes	
Madagascar	May-81	Drought	10.9%	-	No	Drought: 1981
Senegal	May-81	Drought	20.5%	-	Yes	Drought: 1982-1985
Nicaragua	Jun-81	Floods	1.2%	-	Yes	
Tanzania	Jun-81	Drought	100.0%	-	Yes	Drought: 1980-1984
Madagascar	Jun-82	Drought	10.9%	-	No	Drought: 1981
Nicaragua	Jun-82	Storm	1.5%	43.24%	Yes	
Mexico	Aug-82	Volcanic activity	0.1%	0.16%	Yes	
Brazil	Jan-83	Floods	2.3%	0.03%	Yes	
Yugoslavia	Jan-83	Earthquake	-	-	Yes	
Zambia	Jan-83	Drought	100.0%	-	-	Drought: 1983
Nicaragua	Mar-83	Storm	1.5%	43.24%	Yes	
Peru	Mar-83	Mass movement	3.7%	15.40%	Yes	
Congo, Rep.	Jun-83	Drought	100.0%	-	-	Drought: 1983
Côte d'Ivoire	Jun-83	Drought	100.0%	-	-	Drought: 1983
Jamaica	Jun-83	Drought	100.0%	-	-	Drought: 1981-1983
Mozambique	Jun-83	Drought	100.0%	-	No	Drought: 1979-1985
Niger	Jun-83	Drought	52.2%	-	-	Drought: 1980-1985
Yemen	Jun-83	Earthquake	3.9%	95.90%	Yes	
Morocco	Aug-83	Drought	-	-	-	Drought: 1983
Cuba	Sep-83	Storm	1.8%	1.16%	No	
Yugoslavia	Sep-83	Wildfire	-	-	-	
Nigeria	Oct-83	Drought	3.9%	0.15%	No	Drought: 1983-1985
Philippines	Oct-83	Drought	3.2%	-	No	Drought: 1983
Ecuador	Dec-83	Floods	8.0%	4.65%	Yes	
Cuba	Jan-84	Floods	1.6%	0.73%	No	
Brazil	Jun-84	Drought	14.9%	-	Yes	Drought: 1983
The Gambia	Jun-84	Drought	60.6%	-	Yes	Drought: 1980-1985
Niger	Jun-84	Drought	37.0%	-	-	Drought: 1980-1985
São Tomé and Príncipe	Jun-84	Drought	89.0%	-	Yes	Drought: 1983-1985
Peru	Jun-84	Mass movement	50.2%	-	No	Drought: 1980-1985
Ecuador	Aug-84	Floods	2.2%	-	No	
Congo, Dem. Rep. (Zaire)	Sep-84	Drought	1.0%	-	No	Drought: 1984
Costa Rica	Oct-84	Earthquake	0.2%	0.40%	Yes	
Panama	Nov-84	Drought	3.9%	-	No	Drought: 1983
Senegal	Jun-85	Drought	20.5%	-	Yes	Drought: 1982-1985
Argentina	Aug-85	Earthquake	0.1%	-	Yes	
South Africa	Sep-85	Storm	-	0.22%	Yes	
Morocco	Oct-85	Drought	100.0%	-	-	Drought: 1984
Nigeria	Jan-86	Drought	3.9%	0.15%	No	Drought: 1983-1985

Table A. (part 2/2) - Disasters & sovereign defaults: Crisis details (1975-2024)

Table A (Part 2/2) - Natural disasters & sovereign defaults: Crisis details (1975-2024)						
Country	Sovereign Default Date	Type of Natural Disaster*	% of total population affected	Estimated Damage (% of GDP)	Emergency Crisis Called?	Notes
Costa Rica	May-86	Floods	0.0%	-	Yes	
Niger	Jun-86	Drought	37.0%	-	-	Drought: 1980-1985
Jamaica	Sep-86	Floods	1.7%	8.57%	Yes	
Brazil	Sep-86	Drought	-	-	-	Drought: 1985
Philippines	Sep-86	Storm	2.1%	0.50%	No	
Mexico	Sep-86	Earthquake	2.8%	7.00%	Yes	
Chile	Oct-86	Earthquake	11.8%	21.87%	Yes	
Panama	Mar-87	Floods	0.3%	0.02%	Yes	
Panama	Mar-87	Floods	0.3%	0.02%	Yes	
Malawi	Aug-87	Drought	17.2%	-	No	Drought: 1987-1988
Congo, Rep.	Mar-88	Drought	-	-	-	Drought: 1983
Jordan	Feb-89	Infestation	-	-	Yes	
Morocco	Feb-89	Infestation	-	-	Yes	
Gabon	Jun-89	Floods	1.0%	-	Yes	
South Africa	Jun-89	Drought	3.4%	-	Yes	Drought: 1988
Ethiopia	Jun-90	Drought	13.6%	-	Yes	Drought: 1989-1994
Philippines	Jul-90	Storm	1.2%	0.28%	Yes	Series of cyclones in early 1990
Algeria	Oct-90	Earthquake	0.0%	-	Yes	
Albania	Nov-91	Drought	98.0%	-	Yes	Drought: 1989-1991
Kenya	Jan-92	Drought	11.0%	-	Yes	Drought: 1991-1992
Russia	Aug-98	Wildfire	0.1%	0.18%	Yes	
Russia	Nov-98	Wildfire	0.1%	0.18%	Yes	
Pakistan	Jan-99	Floods	0.1%	-	Yes	
Ukraine	May-99	Floods	0.0%	0.01%	Yes	
Moldova	Jun-01	Storm	89.1%	3.63%	Yes	
Dominican, Rep	Apr-04	Floods	0.7%	0.30%	Yes	
Dominican, Rep	Aug-04	Floods	0.7%	0.30%	Yes	
Grenada	Oct-04	Storm	54.8%	229.95%	Yes	
Ecuador	Nov-08	Floods	2.0%	2.20%	Yes	
Mozambique	Jun-15	Floods	0.7%	-	Yes	
Mozambique	Oct-16	Drought	8.3%	-	Yes	Drought: 2016-2017
Belize	Nov-16	Storm	2.8%	-	Yes	
Argentina	Dec-19	Drought	0.1%	-	Yes	Drought: 2019-2021
Ecuador	Mar-20	COVID-19	100.0%	-	Yes	COVID-19 Epidemic
Lebanon	May-20	COVID-19	100.0%	-	Yes	COVID-19 Epidemic
Zambia	May-20	COVID-19	100.0%	-	Yes	COVID-19 Epidemic
Suriname	Jun-20	COVID-19	100.0%	-	Yes	COVID-19 Epidemic
Belize	Sep-21	COVID-19	100.0%	-	Yes	COVID-19 Epidemic
Russia	Mar-22	COVID-19	100.0%	-	Yes	COVID-19 Epidemic
Sri Lanka	Apr-22	COVID-19	100.0%	-	Yes	COVID-19 Epidemic
Belarus	Jul-22	COVID-19	100.0%	-	Yes	COVID-19 Epidemic
Ukraine	Aug-22	COVID-19	100.0%	-	Yes	COVID-19 Epidemic
Ghana	Dec-22	COVID-19	100.0%	-	Yes	COVID-19 Epidemic
Ethiopia	Dec-23	COVID-19	100.0%	-	Yes	COVID-19 Epidemic

Source: Author's Calculation. Default Data: Cruces & Trebesch (2013) 'Sovereign Defaults: The Price of Haircuts' AEJ: Macroeconomics. Disaster Data: World Bank – Natural Hazard Statistics. 'Major' disasters are considered to be disaster events whereby at least one of the following conditions are met: (1) at least 2 percent of the national population are impacted; (2) damage amounts to at least 1 percent of GDP; (3) national or international authorities declare a state of emergency.

Disasters and Exchange Rates ^{*}

Yuen C. Lo ^a and Ulrich Volz ^b

Abstract

This paper investigates the impact of disasters on exchange rates and discusses risks to public debt sustainability and ways of mitigating these. The paper documents heterogeneous effects of disasters across country groups, with lesser developed economies being affected the worst in terms of capital outflows and exchange depreciation. Notably, International Development Association (IDA) eligible borrowers see portfolio and other investment outflows and a decline in their exchange rate after large disasters. A depreciation of the exchange rate implies higher import costs, rising inflation and higher debt service costs in cases where debt is denominated in foreign currency. Since climate change is expected to increase both the frequency and intensity of disasters, our analysis indicates that poor countries are going to face heightened exchange rate risk in the future. This not only heightens the imperative of investing in adaptation and resilience to reduce the vulnerability to disasters. It also reinforces the importance of reducing the dependency on foreign currency financing and the need of hedging exchange rate risk in public debt management.

Keywords: Disasters, Exchange rates, Debt, IDA, Capital flows

JEL Code: F31, F34, H63, Q54

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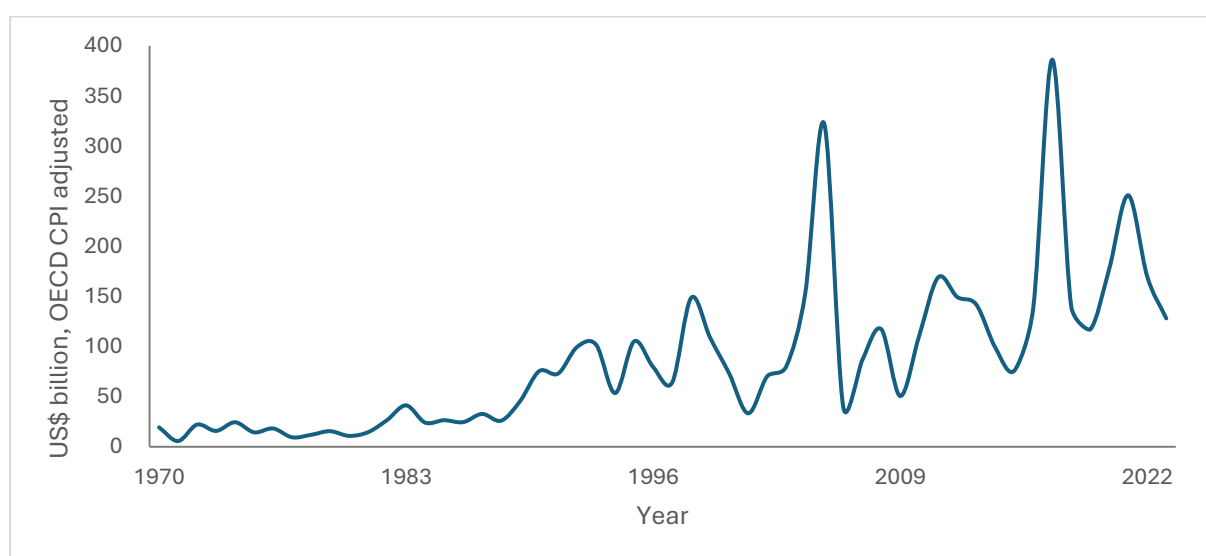
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1. INTRODUCTION

The exchange rate is the single most important price in an open economy, with effects on all other prices. A decline in a country's exchange rate implies higher import costs, inflation, and higher debt service costs in cases where debt is denominated in foreign currency. A weaker exchange rate can benefit exports, but only in countries that have a meaningful export sector. An important question, and one that will be addressed in this paper, is what is the effect of major disasters on exchange rates?

In recent years, anthropogenic climate change has contributed to an increase in both the number and intensity of disasters (IPCC, 2023). As can be seen in Figure 1, global reported disaster damage losses have been rising over time.¹

Figure 1. Global reported annual disaster damages, 1970-2023



Source: Compiled by authors with data from EM-DAT

Physical risks emanating from climate change have become a major driver of sovereign risk (Volz, et al., 2020), increasing the cost of capital of climate-vulnerable countries (Buhr, et al., 2018; Kling, Lo, Murinde, & Volz, 2018; Beirne, Renzhi, & Volz, 2021; Beirne, Renzhi, & Volz, 2021). Besides direct and indirect impacts on fiscal balances, climate disasters can also have profound impacts on exchange rates. Awareness has been growing of the significance of foreign exchange risk in international lending, thanks in part due to the Bridgetown Initiative and the Paris Summit (Persaud, 2023; Élysée Palace, 2023). Despite efforts to reduce vulnerabilities from borrowing in foreign currencies, developing countries are still exposed to foreign exchange risk (Eichengreen, Hausmann, & Panizza, 2023).

Notwithstanding the potentially significant impact that disasters can have on the exchange rate, there has been surprisingly little research on this matter. This paper, along with a sister paper (Lo and Volz (2025)), is seeking to fill the gap and look into the impacts of large disasters on exchange rates. While Lo and Volz (2025) conduct an econometric analysis of the effects of disasters on financial flows, reserves and exchange rates, this paper provides case studies and data analysis of the identified disasters with a specific focus on nominal exchange rates. Building on this, we frame a policy debate and provide a set of policy recommendations.

¹ <https://www.emdat.be/>

The paper is structured as follows. Section 2 briefly reviews four cases of countries that suffered from large disasters, namely the Philippines, São Tomé and Príncipe, Madagascar, and Malawi. Section 3 analyses the impact of disasters on exchange rates in a cross-country analysis. This is followed by a discussion of policy implications in Section 4. Section 5 concludes.

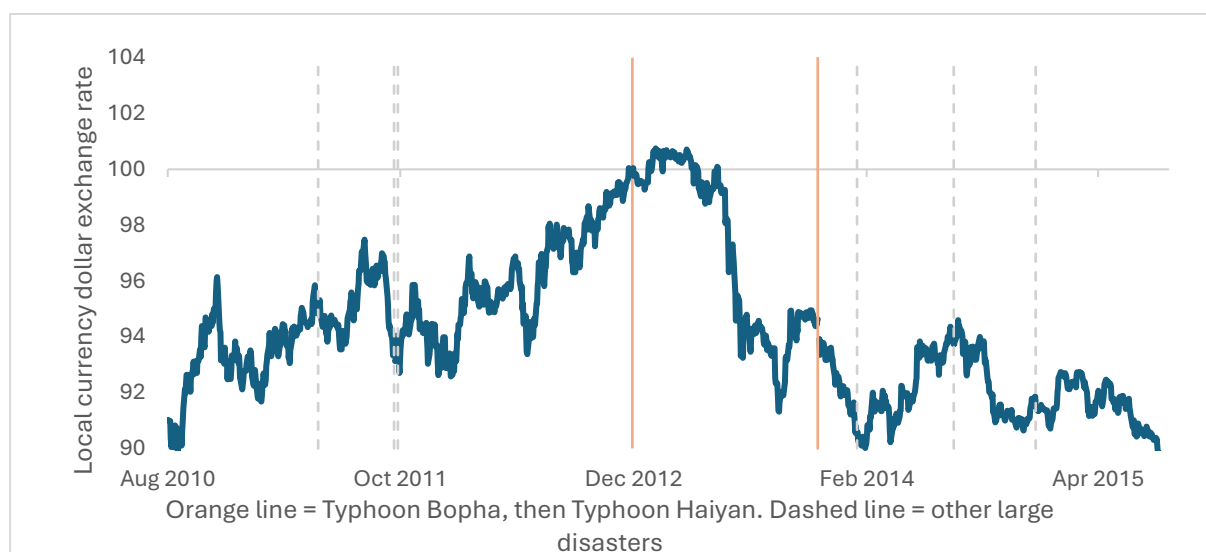
2. COUNTRY CASE STUDIES ON EXCHANGE RATES AND DISASTERS

The exchange rate is arguably the single most important price in an open economy. It is hence a question of critical importance how the exchange rate is affected by large disasters. Major disasters are no rare events, and for many developing countries they happen with alarming regularity. This paper follows a sister paper, Lo and Volz (2025), and defines major disaster quarters as calendar quarters where disaster losses exceed 1% of GDP or numbers affected exceed 1% of population. There are many countries which suffer such major disasters every year. Between 2005 and 2021, this analysis identified 204 major disaster quarters, equivalent to an average of twelve per year.

We begin our analysis with a brief review of four country cases – the Philippines, São Tomé and Príncipe, Madagascar, and Malawi – that suffered from large disasters and subsequently experienced significant movements of their exchange rate.

2.1. Philippines

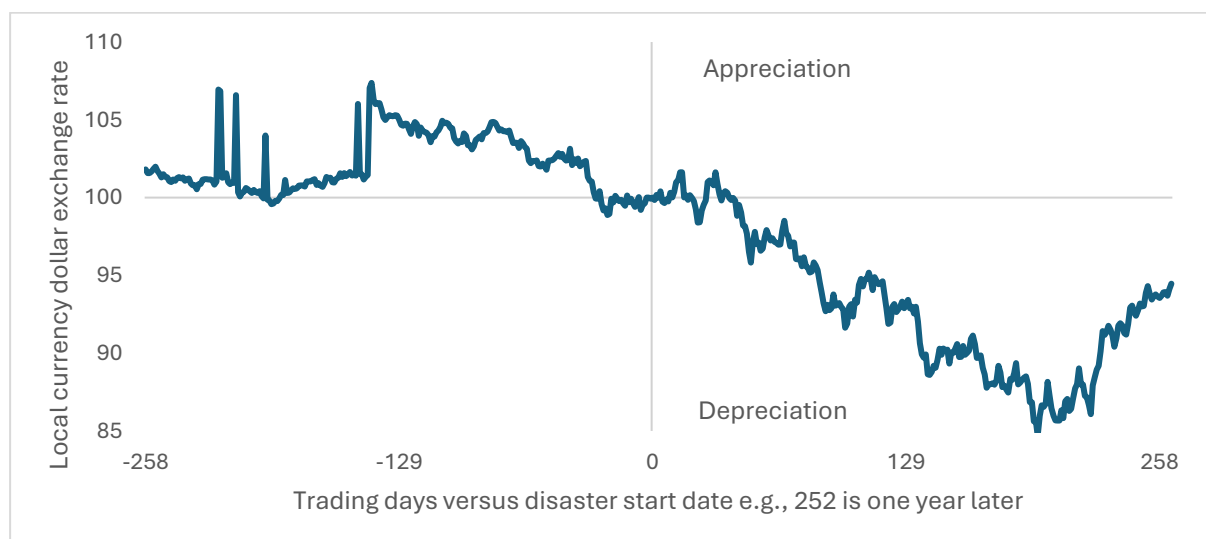
The Philippines, a lower middle-income country, is among the countries that have been suffering regularly from large disasters. In Figure 2, the occurrence of major disaster quarters is marked on the local currency US dollar exchange rate for the Philippines. A total of eight disaster quarters between 2011 and 2015 are identified, two of which, typhoons Bopha and Haiyan, were particularly severe. After four of these major disaster quarters, the Philippines saw initial exchange rate appreciation. We note that the three major disaster quarters of 2011 in the empirical model reflect a seven-month series of tropical storms and floods, including the typhoons Aere, Songda, Nesat, Nalgae and tropical storms Meari, Nock-Ten and Washi. Subsequent to these disasters, the Philippine peso rose 6% before the particular severe Bopha Typhoon. After the latter, the exchange rate appreciated by a percent before falling almost ten percent. The next short lived upward move in the peso was bookended by the third most powerful tropical cyclone ever recorded in the Western Pacific, typhoon Haiyan. The Philippine National Disaster Risk Disaster and Management Center reported wind gusts of 275km/h and 6,300 dead (NDRRMC, 2013). The exchange rate subsequently fell by 4%. Three further calendar quarters in the two years following Haiyan reached the 1% of population affected or 1% of GDP impacted threshold for a major disaster.

Figure 2. Philippines, exchange rate following various disasters, 2010-2015. Normalized to 100 on 4 December 2012

Source: Compiled by authors with data from EM-DAT and Refinitiv

2.2. São Tomé and Príncipe

Figure 3 highlights a major flooding event in São Tomé and Príncipe. Heavy rainfall peaked on 29 December 2021 and led to floods across the country. While the country was still responding to this, two further rounds of flooding occurred in March and May 2022 (IFRC, 2022). The chart shows the 15% nominal depreciation in the currency in 2022.

Figure 3. São Tomé and Príncipe, exchange rate following Dec 2021 floods. Normalized to 100 and day 0

Source: Compiled by authors with data from EM-DAT and Refinitiv

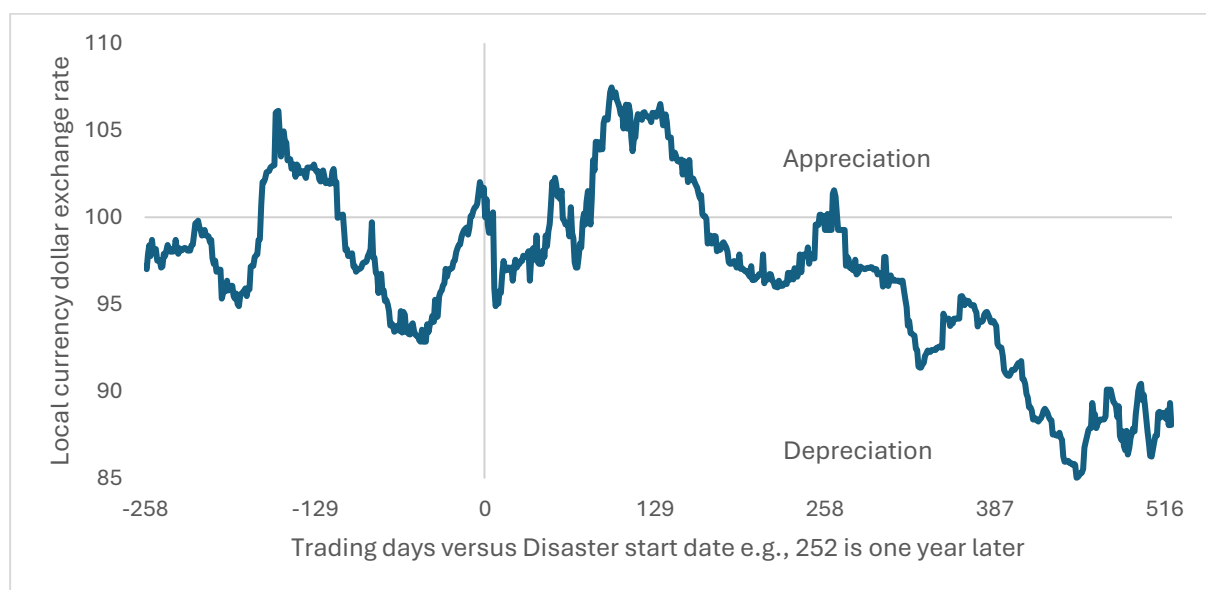
São Tomé is categorised by the World Bank as lower middle income and eligible to borrow from the International Development Association (IDA), the World Bank's concessional lending arm. The World Bank has produced an excellent story map of the flood risks it faces (World Bank, 2023). Its

complex challenges include climate change, the increasing cost of necessities, and limited land that is often rugged. The disaster highlighted came after Covid-19. The World Bank's flood hazard and risk assessments execute combined modelling of simultaneous coastal and rainfall flooding. They estimate average annual losses for the country of 3.06% of GDP in 2020 rising to 4.16% in 2050 and 6.17% in 2080. São Tomé requires large investments in climate adaptation and climate resilience.

2.3. Madagascar

In March 2017, cyclone Enawo made landfall in north-eastern Madagascar with 145mph winds, and then moved southward across central and south parts of the country. Ten days after landfall, the National Office for Risk and Disaster Management (BNGRC) reported 433,000 people affected by the cyclone, including 247,000 displaced and 81 dead (OCHA, 2017). Losses of food and cash crops were widespread, and over 1,300 water wells were flooded and polluted. A key point is that this damage compounded pre-existing problems: agriculture had already been facing water shortages and coincided with a "lean season" where households struggle to meet their needs. Furthermore, a loss of access to clean water generates conditions likely to negatively impact health and the spread of diseases. With respect to the longer term exchange rate trend, the Malagasy ariary depreciated considerably over the years 2014-2015, and then saw a relative period of stability August 2015 to May 2018, which ends approximately a year after cyclone Enawo and is visible in the 15% depreciation shown in Figure 4.

Figure 4. Madagascar, exchange rate Mar 2017 tropical cyclone Enawo. Normalized to 100 and day 0



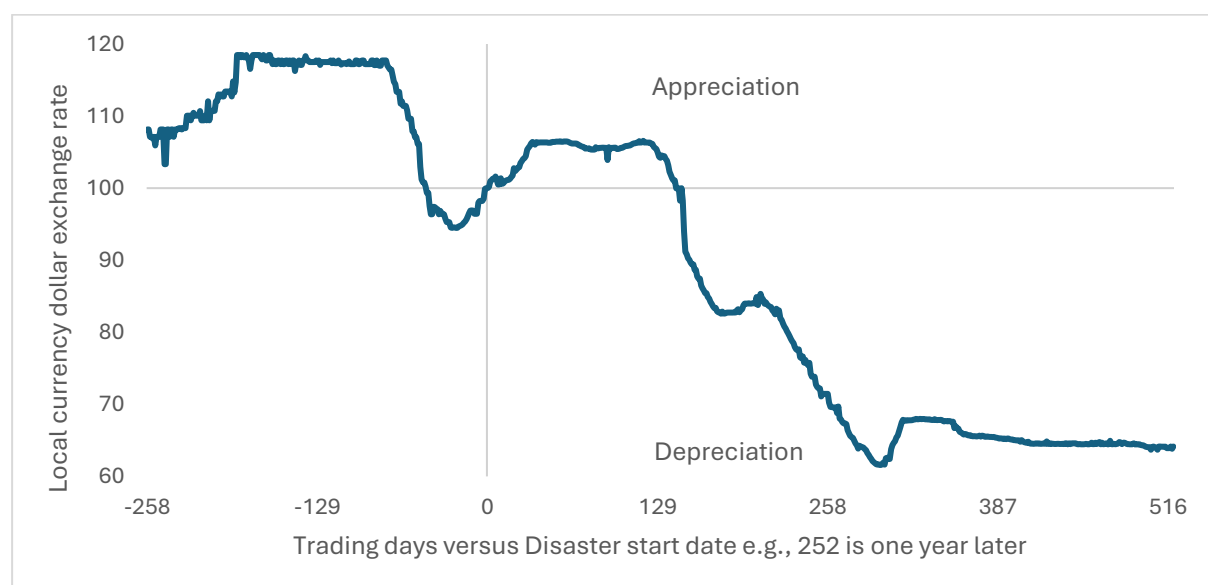
Source: Compiled by authors with data from EM-DAT and Refinitiv

2.4. Malawi

In 2015, Malawi suffered its highest January rainfall, and second highest reported death toll from flooding, in its history. An estimated 1.1 million people were affected, including 230,000 displaced and 106 dead. 500,000 houses, 89,000 hectares of crop land and 3,500 boreholes and shallow wells were destroyed or damaged. The Government of Malawi (2015) estimated the disaster effect across 12 affected sectors to be approximately 5% of GDP. Reconstruction costs were estimated to be significantly

higher. The Reserve Bank of Malawi (2015) noted that these floods, and the drought of the same year, resulted in an estimated 30% decline in the maize harvest, creating a major challenge to monetary policy. Prior to these floods, the Malawian kwacha had been depreciating since 2012, and half a year after suffered a further drop of almost 40% (Figure 5). Subsequent to this, between 2016 and 2020, the kwacha was relatively stable in the absence of further disasters. More recently it is depreciating, potentially influenced by Covid and its after effects.

Figure 5. Malawi, exchange rate Aug 2015 floods. Normalized to 100 and day 0



Source: Compiled by authors with data from EM-DAT and Refinitiv

A central theme that emerges are the multiplicative effects of pre-existing monetary, fiscal and social challenges exacerbated by one or more major disasters. On the monetary side, in 2014 inflation in Malawi averaged 24%, was declining but started to rise again by the second half of 2015. Part of the latter was food inflation related to the floods and drought. The Reserve Bank of Malawi continued its tight monetary policy stance by raising its policy rate by 2% to 27% in November 2015. The Government of Malawi possessed limited fiscal space and depended on domestic borrowing to finance its deficit. On the social side half of Malawian households were living below the poverty line. We not ascribe even the majority of any given depreciation to a specific crisis, but to how disasters compound existing challenges.

Overall, these four country examples illustrate that disasters may in some cases be followed by significant exchange rate depreciation. Nevertheless, it raises a wider question of how strong is the evidence of disaster effects on exchange rates across countries?

3. DISASTERS & DEBT RESTRUCTURINGS

There has been relatively little research into this topic compared to the literature on the effect of disasters on economic growth and inflation (e.g., Noy (2009) and Cavallo et al. (2013)). Additionally, the empirical research published on exchange rates have found in favor of both appreciation and depreciation following a disaster. Strobl and Kablan (2017) focus their analysis of the impacts of tropical cyclones on the exchange rate of small island developing states, and find that under flexible exchange rate regimes

there is a real exchange rate appreciation in the months after the storm. On the other hand, Zhou et al. (2021) examine the impact of COVID-19 on nominal exchange rates, finding significant depreciation effects on exchange rates of emerging markets, but not on those of advanced countries. These somewhat divergent results are to an extent in line with theoretical research on the subject. Farhi and Gabaix (2015) develop a disaster model to explain a variety of phenomena such as how the riskiest currencies have a positive correlation with world stock market returns. Hale's (2022) disaster model builds on this and predicts disasters to cause a real depreciation for risky countries, and a real appreciation for safe countries. These theoretical frameworks put forward predictions that are of particular interest – perhaps less developed countries should see depreciation and more developed countries appreciation?

Lo and Volz (2025) provide empirical evidence consistent with this thesis. They find no statistically significant real effective exchange rate effects for high income countries. For the entire sample of emerging and developing economies (EMDEs), they find evidence in favor of (temporary) appreciation. However, for a subsample of nine IDA eligible borrowers, they find evidence in favor of real effective exchange rate depreciation – a result of statistically significant portfolio and other investment outflows. The analysis by Lo and Volz (2025) – a non-technical summary of which is provided in Box 1 – goes beyond exchange rates to also include portfolio investment flows, other investment flows (e.g., bank loans and deposits) and international reserves. This enables a more holistic view of each country groupings results.

Once financial effects are understood and accepted as second order wider effects targetable by policy makers, Lo and Volz's (2025) results become particularly relevant. For high income countries, the notion that disasters appear to have no wider financial and macroeconomic effects is coherent with a set of countries that have sufficient domestic resources to absorb or address the indirect financial effects of disasters. For EMDEs, that disasters appear to lead to rises in international reserves, and real effective exchange rates, is consistent with a set of countries that, following a disaster, choose to guide future resources into disaster resilience. For IDA eligible borrowers, that disasters appear to drive portfolio and other account outflows, and real effective exchange rate depreciation, is consistent with a set of countries that do not have and do not receive sufficient resources to ameliorate the wider financial effects of disasters

Box 1: Non-technical summary of Lo and Volz (2025)

Empirical results. For the full sample of up to 66 countries, major disaster quarters cause statistically significant portfolio inflows and reserve increases. For the EMDE sample of up to 43 countries, disasters cause statistically significant reserve increases and appreciation of the real effective exchange rate (REER). For the sample of 9-12 IDA eligible countries, disasters cause statistically significant portfolio and other investment outflows, and REER depreciation. Drilling deeper into the IDA eligible results, portfolio investment flows see a statistically significant negative marginal effect from a disaster over three calendar quarters. Other investment flows (including cross-border bank lending) see a statistically significant negative effect in the second quarter after the disaster quarter. This presents us with a loss of short-term private capital coincident with real currency depreciation, yet no statistically significant reserves increase for countries that need it most. This arguably highlights the importance and role of other offsetting flows, for instance through multilateral support.

Definition of major disasters. Data from EM-DAT is used to evaluate disasters on the basis of losses as a percent of GDP and as numbers affected as a percent of population. Major disaster quarters are defined as calendar quarters where disaster losses exceed either 1% of GDP or where numbers affected exceed 1% of population. The included disasters are flood, storm, earthquake and wildfire. Major

disaster quarters are then incorporated as a statistical dummy to test empirically for changes in the variables of interest.

Variables of interest (dependent variables regressed on major disaster quarter dummy and controls). These include portfolio investment flows, other investment flows (e.g., loans and deposits), international reserves and real effective exchange rates. Net portfolio investment, net other investment flows and net foreign direct investment are the three main components of the financial account of the balance of payments, and are therefore important measures of capital flows. For 2021, the International Monetary Fund (IMF) reported global portfolio asset flows of USD 3.4 trillion, other asset flows of USD 2.8 trillion, and FDI asset flows of USD 2.3 trillion.² These figures reflect acquisitions and disposals of assets by non-residents only. Note that the empirical analysis is country specific and therefore net of both residents and non-residents. FDI has not been included in the empirical analysis due to problems with the quarterly data. International reserves and REERs may be impacted in their own right by disasters, as well as acting as mediators between financial flows and wider economic effects.

Controls are lagged first difference in log quarterly local consumer price index, lagged first difference in four quarter rolling log of comparable GDP in US dollars, first difference in log euro US dollar exchange rate (increase is euro appreciation, dollar depreciation), net FDI flows in US dollars, foreign exchange regime (Harms & Knaze, 2021) and an index of financial openness (Chinn & Ito, 2006).

Robustness checks. The core results are shown for each variable of interest split by country groupings. In order to test the validity of the results, multiple robustness checks are carried out. Each statistically significant country group result is tested with alternative lag specifications, and for floating foreign exchange regimes only. At the full sample level, additional robustness checks include alternative disaster thresholds (e.g., 3%, 5%, 10%). The core empirical methodology used is generalized least squares with panel random effects. Testing is carried out to show that this methodology is appropriate. Nevertheless, a further robustness check is carried out with pooled ordinary least squares. Although the robustness checks at times change the statistical significance on some lags of the major disaster dummy, the broad findings appear robust.

To complement the points made above, we present a graphical analysis of the disaster data. On average, countries see nominal exchange rate depreciation following a disaster. Figure 6 charts the average US dollar exchange rate before and after 195 major disaster episodes. This is for all the countries sampled, including high income, EMDEs and IDA eligible borrowers. It excludes countries in currency unions and some disasters where the exchange rate date is truncated by time period. The typical path sees less than half a percent of depreciation in the year prior to the disaster, some appreciation effects in the nine months after, followed by a 4% decline. The temporary appreciation is consistent with Strobl and Kablan (2017), and may be due to the international community's disaster response. The spread of individual exchange rate paths following major disasters are charted in Figure 7. The average blue line in Figure 7 is identical to the line from Figure 6.

The average US dollar exchange rate for 67 major disaster episodes for IDA eligible borrowers is shown in Figure 8. One natural observation from this chart is that there is a clear depreciation trend prior to the disaster. There are three responses to this valid critique. Firstly, the nominal depreciation in the year before is approximately 2.5%. The depreciation in the two years after are 3.5% per year (7% over two years), and would be even higher if measured from the post disaster high. This suggests major disasters may drive an acceleration in exchange rate depreciation. Secondly, the econometric modeling from Lo and Volz's (2025) is on real effective exchange rates, and no trend depreciation is found after adjusting for inflation and trade weights. Thirdly, the existence of trend nominal depreciation effects

² <https://data.imf.org/regular.aspx?key=60961513>

supports the key policy recommendations of this paper – the critical importance of exchange rate matched, or hedged, borrowing and lending.

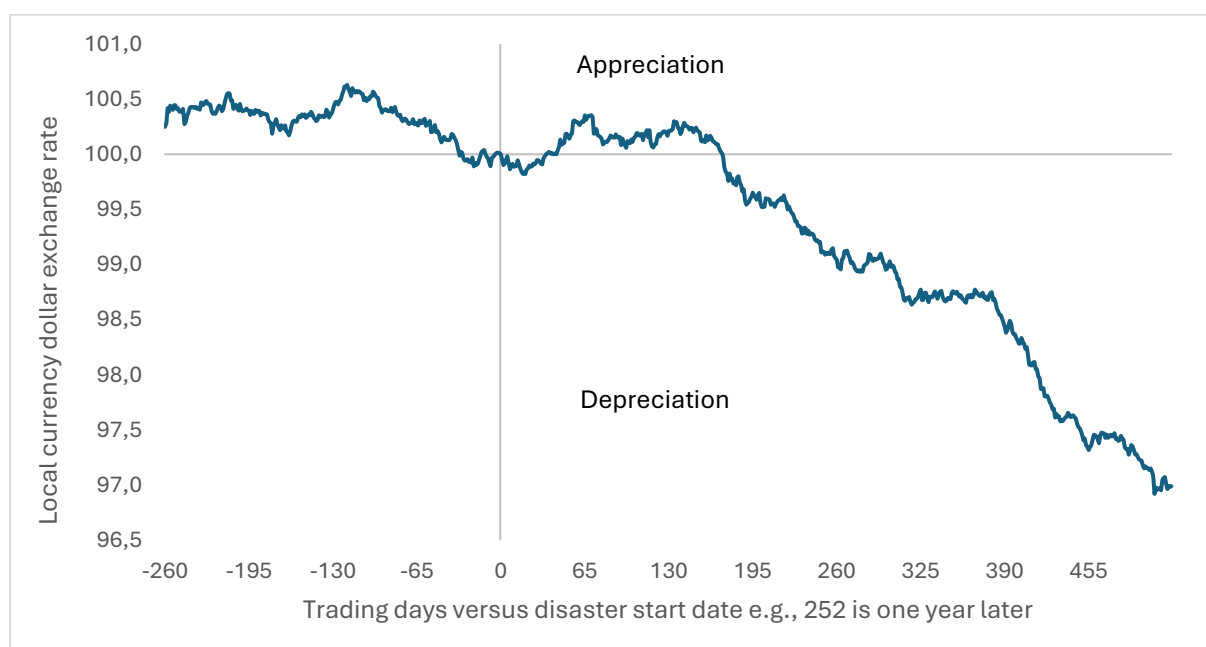
Figure 9 presents the spread of individual exchange rate paths for IDA eligible borrowers. A year after a major disaster, 3 out of 5 disasters have led to a depreciation in the local currency US dollar exchange rate.

The value of a specific exchange rate is a focal dimension of a currency. Another important dimension is the associated volatility. Higher volatility is by definition an increase in uncertainty, and implies additional difficulties in planning, doing business, and higher hedging costs. The average annualized historical exchange rate volatility is charted in Figure 10. An increase in volatility appears the year after a major disaster prior to changes in the average historical exchange rate. The potential implications of this connects to Aghion et al. (2009) who find that increased foreign exchange volatility has negative impacts on productivity growth for less financially developed countries.

In Figure 11 exchange rate volatility is charted for IDA eligible borrowers. At the time of the disaster (day 0), exchange rate volatility is lower (3.9%) than for the full sample (4.77%). After the major disaster, the peak volatility for IDA eligible borrowers is less sustained but with higher peaks than for the full sample.

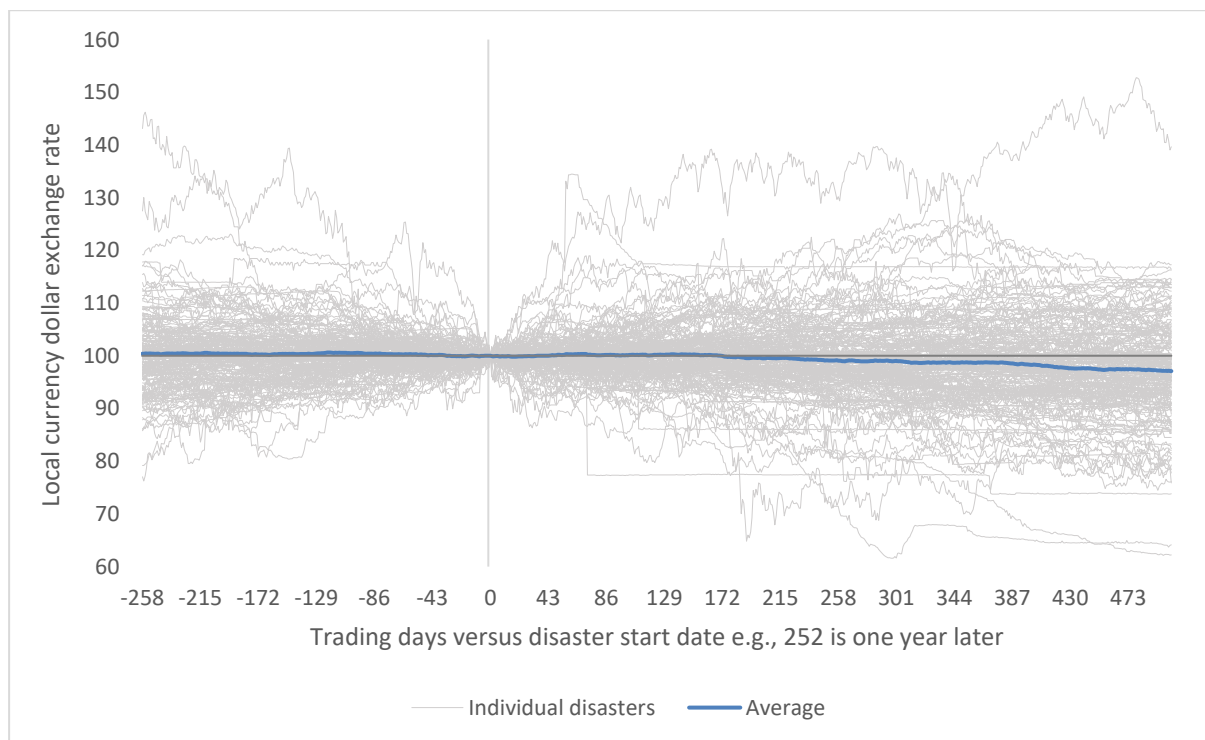
A conclusion of the empirical and graphical analysis includes the following disaster related observations. IDA eligible borrowers appear to face outflows of portfolio and other investment flows, coincident with a depreciation of their real effective exchange rate following major disasters. This finding fits into a wider picture of countries that on average sees their nominal US dollar exchange rate depreciate and FX volatility increase. Together this indicates that separate to the direct impacts, there are wider negative financial effects arising subsequent to disaster events. Arguably, these wider effects ought to be addressed by policymakers and institutions.

Figure 6. Average nominal local currency US dollar exchange rate path for 195 major disasters. Start value normalized to 100 and day 0 at the date of disaster



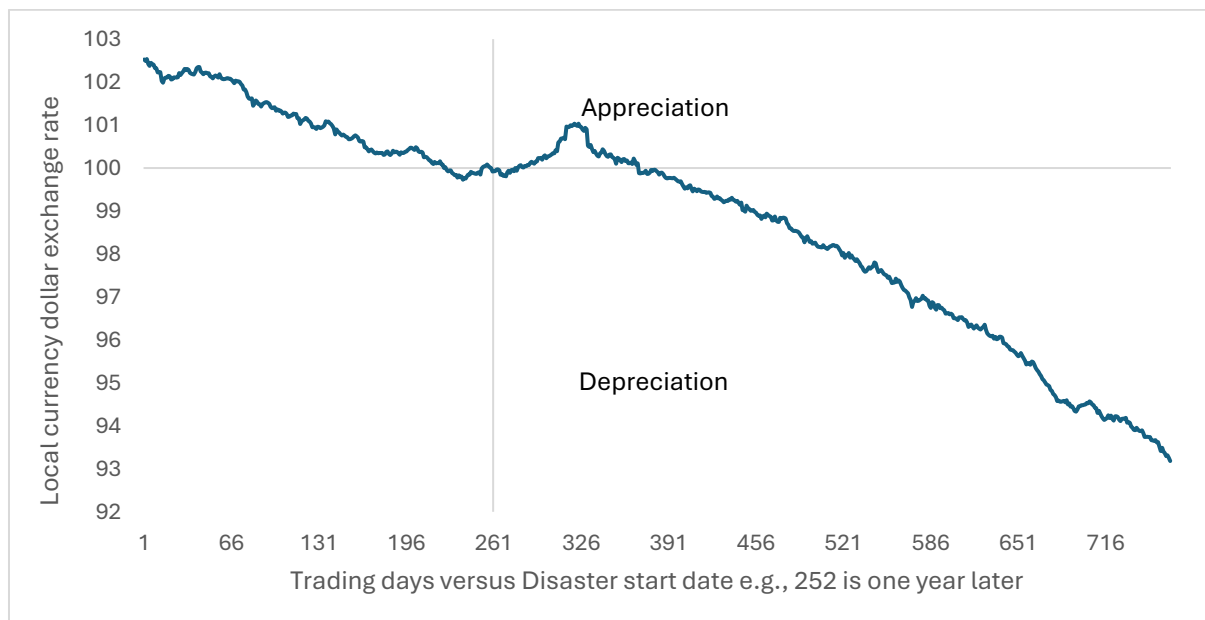
Source: Compiled by authors with data from EM-DAT and Refinitiv

Figure 7. Individual nominal local currency US dollar exchange rate paths for 195 major disasters. Full sample. Start value normalized to 100 and day 0 at the date of disaster



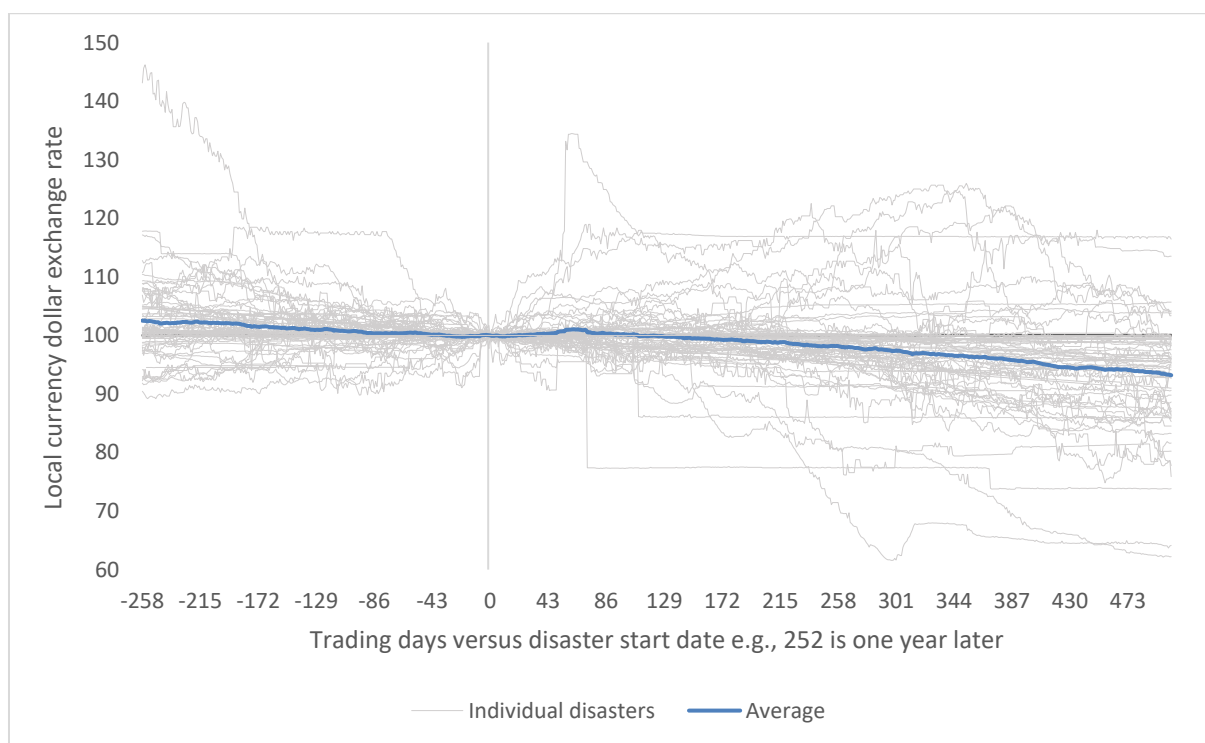
Source: Compiled by authors with data from EM-DAT and Refinitiv

Figure 8. Average nominal local currency US dollar exchange rate path for 67 major disasters. IDA eligible borrowers only. Start value normalized to 100 and day 0 at the date of disaster



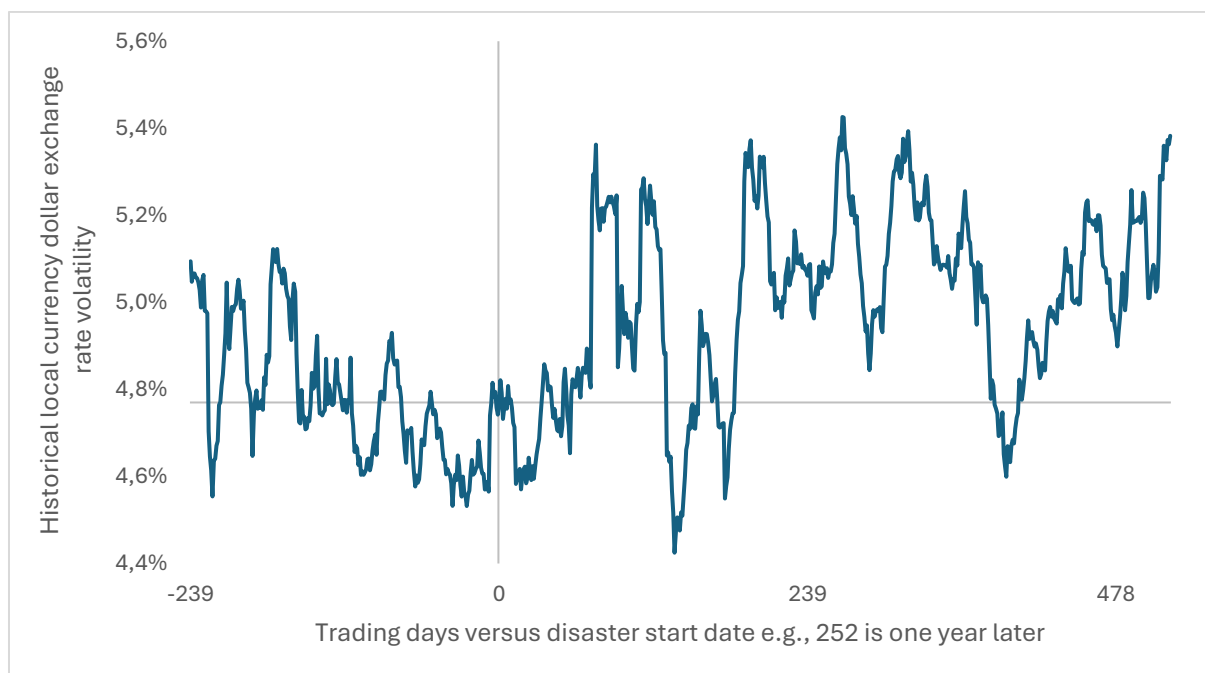
Source: Compiled by authors with data from EM-DAT and Refinitiv

Figure 9. Individual nominal local currency US dollar exchange rate paths for 67 major disasters. IDA eligible borrowers only. Start value normalized to 100 and day 0 at the date of disaster



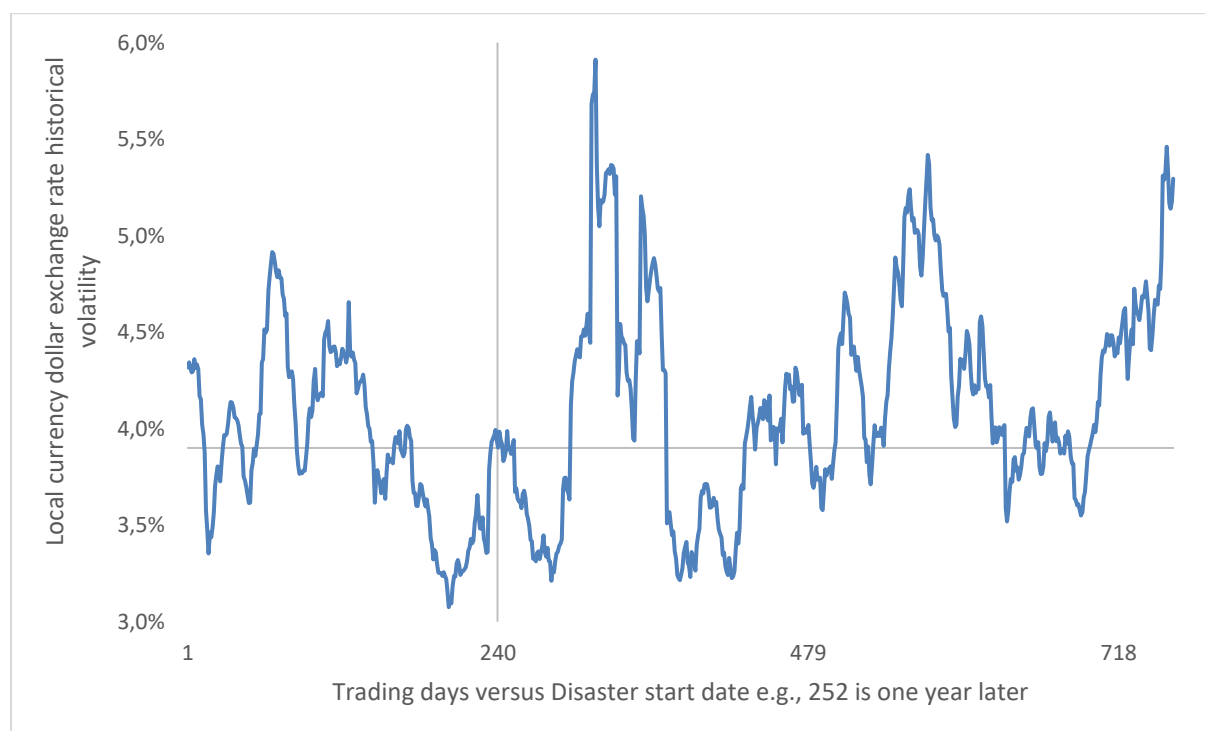
Source: Compiled by authors with data from EM-DAT and Refinitiv

Figure 10. Average historical exchange rate volatility around 195 major disasters. FX volatility calculated as 20-day sample standard deviation, annualised. Average at disaster date of 4.77%



Source: Compiled by authors with data from EM-DAT and Refinitiv

Figure 11. Average historical exchange rate volatility around 67 major disasters. IDA eligible borrowers only. FX volatility calculated as 20-day sample standard deviation, annualised. Average at disaster date of 3.9%



Source: Compiled by authors with data from EM-DAT and Refinitiv

4. POLICY DISCUSSION

While the impact of disasters on capital flows, reserves and exchange rates is not uniform across countries, depending on an economy's specific context and the international support it receives in response to the disaster, our analysis here and the econometric investigation by Lo and Volz (2025) provides clear indications that countries facing disaster risk confront heightened exchange rate risk. In particular, IDA-eligible countries tend to suffer from capital outflows, exchange rate depreciation, and greater exchange rate volatility. Moreover, a majority of EMDEs also suffers from nominal exchange rate depreciation effects and an increase in exchange rate volatility after a disaster. This poses serious challenges for the public sector with respect to public debt and financial risk management. It also raises important questions for development lenders.

Authorities of countries facing elevated exchange rate risk resulting from disasters have several options to mitigate this risk. A first step is to strengthen adaptation and resilience to reduce the impacts of disasters on the economy, the financial system, and public finances (Volz, et al., 2020). But this is of course easier said than done, not least because investment in adaptation will require large amounts of funding. Indeed, those countries that need to invest the most in adaptation to boost resilience against climate shocks are the ones that have the least fiscal space, and they also have to pay a higher cost of capital because of their vulnerability (Buhr, et al., 2018; Kling, Lo, Murinde, & Volz, 2018; Beirne, Renzhi, & Volz, p. 2021a; p. 2021b). Underinvestment in climate resilience is threatening both the economy and public debt sustainability.

Governments of disaster-prone countries must strengthen their disaster risk finance, i.e., develop financial protection strategies and instruments to address the fiscal impacts and economic losses caused by disasters and pre-arrange the release of rapid, predictable funding in the aftermath of a disaster so they can respond swiftly and support recovery and reconstruction. This includes the buildup of domestic disaster reserve funds, participation in sovereign catastrophe risk pools (Ciullo, et al. 2023), and arranging access to contingent credit facilities and parametric disaster insurance.

It is necessary to enhance public debt management to mitigate disaster related risks. One solution that has received a lot of attention recently are debt suspension or disaster risk clauses, which basically allow governments to postpone payments (e.g. Landers and Aboneaaj (2023)). While this can enhance fiscal space in the aftermath of a disaster, it does not address currency risk as such. The public debt service could be even larger at the time of repayment if the local currency devalues. Foreign currency risk emanates from foreign currency-denominated debt and unhedged debt servicing costs (Jonasson, Malik, Chung, & Papaioannou, 2024). To mitigate foreign exchange risk, governments essentially have two options.

Governments can either reduce foreign currency borrowing by strengthening domestic financial resource mobilisation, or they can hedge exchange risk. The former includes efforts to develop local currency bond markets and broaden the domestic investor base (Volz, Lo, & Mishra, 2024). For the time being, most developing countries are still suffering from original sin (Eichengreen, Hausmann, & Panizza, 2023) – the problem that they are unable to borrow in domestic currency, be it from abroad or long term, even domestically (Eichengreen & Hausmann, 1999). Concerted efforts are needed to foster the development of local currency bond markets and overcome original sin. This, however, is nothing that can be achieved in the short run. It is hence important that governments consider options for foreign currency hedging. The challenge here is that for many countries hedging opportunities are either not existing or very expensive.

Especially low and lower middle income countries – the countries that our analysis suggests may face the highest risk of a currency devaluation after a disaster – usually lack sufficiently developed currency risk markets which would allow them or their lenders to hedge currency risks associated with cross border lending. These countries are also most dependent on international development and climate finance, in large part from MDBs. MDBs have already endorsed the demand from the Bridgetown Initiative to include “climate resilient debt clauses” in lending contracts (e.g., World Bank (2024)). Yet, given the currency and associated sovereign debt sustainability risks, MDBs and other international public lenders still need to pay more attention to the currency risk that they pass on to governments. There are three issues that MDBs and other international public lenders could and should do.

First, MDBs and international public lenders should support governments in raising the domestic savings rate and strengthening domestic financial resource mobilization to reduce dependency on borrowing from abroad. To this end, Volz, Lo and Mishra (2024) highlight the potential of MDBs and international development finance institutions (DFIs) to work more closely with national development banks and bolster their capacity to issue local currency debt. They also highlight the opportunities of leveraging digital technologies for broadening the local investor base and developing sustainable investment opportunities for investors.

Second, MDBs and international DFIs should themselves lend more in local currency. They could either do this by raising local currency by issuing local currency bonds – eliminating foreign exchange risk altogether and the same time contributing to the development of local currency bond markets – or they could manage the exchange risk themselves.

Thirdly, if MDBs cannot raise local currency funding and lend in local currencies, they should make use of existing hedging markets or a cooperative hedging platform like TCX to reduce the overall

currency risk exposure of IDA borrowers. This has already been proposed in the Summers/Singh Triple Agenda Report Vol 2 (IEG, 2023). The scaling up of TCX could be an effective short-term measure to facilitate a significant reduction in the currency risk vulnerabilities of IDA lenders and borrowers alike. IDA countries in particular should be made aware of currency risks when borrowing and be offered a choice between traditional (hard currency) borrowing instruments and loans indexed in local currencies. This would effectively work as a form of disaster insurance, working anti-cyclically instead of the existing pro-cyclicality of FX debt. A further elaboration of this would be a systematic voluntary conversion of existing IDA and other concessional debt into local currency-indexed loans. This could go hand-in-hand with capacity building efforts and increase the resilience to shocks. Making climate donor funds available to cover (part) of the higher interest costs should become part of the policy discussions.

5. CONCLUSION AND RECOMMENDATIONS

Direct losses from disasters are rising over time. Climate change is likely to increase the frequency and severity of disasters, continuing this trend. Major disasters are occurring more often in regions where they were previously uncommon. Additionally, a small number of countries face major disasters every year. The size of this category is likely to grow. This may be further exacerbated by non-linear effects – at tipping points the effectiveness of presently adequate infrastructure and barriers goes from reliable to irrelevant.

Most discussions of the frequency and severity of disasters focus on direct impacts and second order economic impacts. Lo and Volz (2025) investigate the second order financial effects of disasters empirically, and provide new color on the impact of disasters on exchange rates. There are clear differences between country categories. High income countries see no detectable disaster impacts on exchange rates. EMDEs enjoy an appreciation, potentially due to the international disaster response. IDA eligible borrowers, however, tend to suffer a depreciation. A corollary of currency depreciation is higher import costs and higher debt service, just as a country is recovering and rebuilding from the physical effects of the disaster.

Building on the econometric results of Lo and Volz (2025), a global sample of 195 disasters reveals that a year after a major disaster three out of five see a depreciation in their nominal exchange rate. After two years the average depreciation is 4%, with many countries far below this average. Exchange rate volatility is markedly higher in the two years following major disasters for the full sample and for IDA eligible borrowers only.

Therefore, this paper puts forward three key recommendations with respect to disasters and exchange rates. The first is for MDBs to support governments in raising the domestic savings rate, potentially by bolstering the capacity of national development banks to issue local currency debt (Volz, Lo, & Mishra, 2024). Secondly, MDBs and DFIs should lend more in local currency, either by issuing local currency bonds or managing the exchange rate risk themselves. Thirdly, if MDBs cannot raise local currency funding and lend in local currencies, they should make use of existing hedging markets or a cooperative hedging platform like TCX to reduce the overall currency risk exposure of IDA borrowers. These three policies are proactive measures that help mitigate the negative impact of disasters on exchange rates for the most vulnerable countries. Failing to address exchange rate risks of poorer countries will result in greater debt sustainability problems as more and larger disasters wreak havoc on economies that are already highly vulnerable.

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Peru's Debt to GDP Ratio, Wars and Earthquakes: 1822-2022*

Favio Leiva^a

Abstract

This essay explores Public Debt in Peru from a historical perspective from Independence until 2022. The main objective is to analyze the relations between natural disasters, human disasters and Public Debt. A wide variety of sources are compiled to generate this long-term estimate of the Debt to GDP ratio. Time series analysis is performed to find correlations between the Debt to GDP ratio, internal wars, external wars and army races. To deal with non-stationarity, the Augment Dickey Fuller tests were performed followed by differences and Fourier transformations. Robust standard errors are applied to deal with heteroskedasticity. Because it's such a long-term analysis, structural breaks are expected, therefore Zivot-Andrews tests and structural break identification strategies are also applied. Wars have a stronger impact on Public Debt Sustainability than earthquakes. Even though results change according to each specification, Internal Wars and Army races seem to impact contemporarily. External wars seem to have an impact 4 years later. The government seems to react slowly to earthquakes no generating the deficit that is totally justified in that situation.

Keywords: Sovereign Debt, National Security and War, Natural Disasters and Their Management, Time-Series Models, Economic History

JEL Code: H63, H56, Q54, C32, N00

*The main source of public debt data is the Thesis "Public Debt in Peru in 1824-2016: Sustainable Development and Sustainable Finance" to obtain my master's degree in international development at the Graduate School of International Development, Nagoya University. It revises the sources and updates the Debt Estimates until 2022, 200 years of Public Debt Data.

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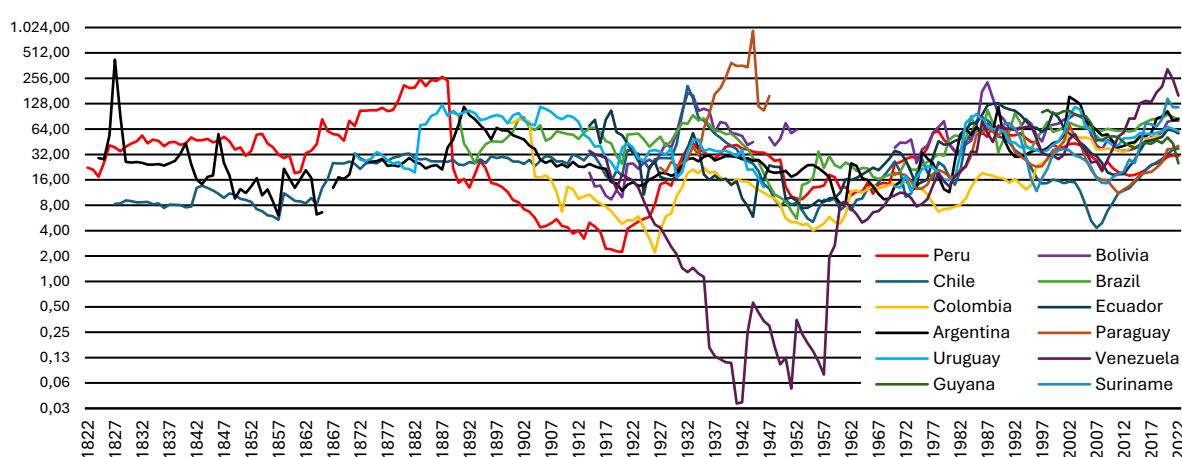
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1. INTRODUCTION

In a broader South American perspective, Public Debt is a key discussion due to shared historical and economic dynamics (Marichal, 1989). In Figure 1, we can see that even though each country has its own specific episodes, there seems to be shared trends, particularly during the 20th century. There are common mechanisms. If the risk-free interest rate increases, everybody gets punished. Another mechanism could come from credit and funds availability. Finally, besides the risk-free mechanism, there could be a South American premium in the approach creditors have towards the region which could be completed with country premiums.

Yet, there is still space for historical research for many countries. Only Chile and Argentina had a long-term history in the classic study by Reinhart and Rogoff's (2010) key study. This working paper tries to provide also a long-term history for Peru. Future research should complete information for Bolivia, Paraguay and Uruguay to have histories of the 20th century. Guyana and Suriname are the countries with least data available. Key to notice is the appearance of natural resources which have different effects in all these countries. Venezuela was the least indebted country around 1942, but now is the most indebted in the group. Research for the 19th century remains a key task for Colombia, Ecuador and Brazil.

Figure 1. Public Debt to GDP ratio evolution in 12 South American Countries: 1822 - 2022



Source: Leiva (2024), IMF (2024) and Reinhart & Rogoff (2011). Note. The information for Perú comes exclusively from Leiva (2024), the other countries were found in Reinhart & Rogoff (2011) and information after then is completed with the World Economic Outlook of 2024. If there was information in both sources, the maximum estimate was chosen.

Public Debt has always been a central topic in economic and historical discussions in Peru. Economists interested in it vary from the Dependence Theory School and Heterodox Economy to the Neoclassical and Public Choice ones. In contrast, many books have been written about it by Historians with other perspectives and tools. The so-called lost decade in Peru and Latin America directly relates to this. Still, differences must be considered between the lost decades in each country of Latin America because even though they share some features (external-supply related), they also have different historical paths (internal-demand related). We should also add the importance that Seminario (2015) put on the topic of Catastrophes on GDP growth. He argued that the Independence War, the War with Chile, and the 1980s Debt Crisis significantly impacted Peru's growth. Had Peru not had those catastrophic events, it would have been like the United Kingdom. However, we should be careful with this kind of conclusion because we could argue that the UK had its catastrophes, such as WWII.

Collecting data during the 19th century was challenging because not even the Government knew exactly how much it owed or to whom, particularly regarding the Internal Debt. This would become even more difficult during war times, whether these were civil or with other countries because the military would offer to pay back when they won during civil wars or just because everything becomes chaotic during them.

There were internal and external possible causes of the loss of the decade of the 1980s. Some possible internal causes were 1) an excessive dependency on debt (particularly foreign debt) due to excessive investments (many of which were not productive but destructive, such as weapons and ammunition in the previous decade) and public consumption (mainly salaries) and 2) lousy management of debt service from a diplomatic perspective. (Montoya, 1994; Ugarteche, 1991, 1998) and 3) arms race-related debt demand (Ferrero Costa & Obando Arbuli, 1992). Some possible external causes were 1) excessive bank lending due to excess savings in developed countries. (Devlin, 1989), 2) political interests from foreign countries in expanding their influence in Latin America (Ugarteche, 2019) and 3) excess of weapons supply after World War II (Ferrero Costa & Obando Arbuli, 1992).

However, this lost decade is nothing compared to the Lost Decades in the 19th century. The guano-salt-peter-rubber era was, by far, the worst for Public Finance Sustainability. Indeed, as Revilla (1993) points out, in the UK, people did not know what to do with the money, and even *The Economist* advised people to invest in Peru until, of course, Peru could not pay anymore. There were external (supply motives) and internal (demand motives) for that specific crisis. And this should make us think about the concept of hegemony. Hegemony is not driven necessarily by the will of the Government but by the rules of Political Economy in the classical sense. And, as the Greeks would say, Hegemony has the seed of its destruction inside of it if the Hegemonic Power does not act with caution. Other different approaches would consider that war is not only in the hands of the Government or the market but that the People's Sentiment and the ability of the Military play a crucial role in the war outcome (Summers, 1983).

Many studies have paid attention to debt related to guano and other commodities, railroads, and military efforts in the 19th century (Revilla, 1993; Vizcarra, 2009) And even some, like Revilla (1993), try to model the gap between the risk-free interest rate and the actual interest rate of Peruvian debt. Research on Public Debt in the long term was usually from a historical perspective, such as the ones of Quiroz (1993) for the period 1850-1950 for Peru and Marichal (1989) Latin America's time span is from 1820 to 1930. This article covers the most extended period of Peru's Public Debt, which is itself a contribution.

Many articles have been written on the issue of three specific wars or conflicts in Peru: Independence, the Pacific War, and the Terrorism Epoch. In the case of Independence, some documents reflect on the economic impact of it in Peru, whether it made her poor (de Haro, 2021) and the consequences of it in Latin America (Prados de la Escosura, 2005). In the case of the Pacific War, some explore the fiscal impact of it and how it was seen in the London bond market (Sicotte et al., 2009, 2010), others explore the impact of that war on frontiers between countries (Soto Lara et al., 2022; Stefoni et al., 2022). Regarding the conflicts between the Republic of Peru and internal subversive groups, which we call the Terrorism Epoch to make the difference with other internal armed disputes (particularly those during the 19th century in which they were majoritarian), most publications are related to the human rights research (Koc-Menard, 2014; Laplante & Theidon, 2009) or to describe the process dynamics (Arbulú, 1993; Fielding & Shortland, 2012; Taylor, 1998). However, the impact on Public Debt is not a general discussion. All these reflections on war are important (whether the conflict is internal or external), but still, more discussion is required.

Besides these, other papers on the Republican Consolidation and Civil Wars have been written (Perea, 2009; Pinto Vallejos, 2016) with the explicit role of the Army building politics and the idea of Peruvian Society (Silva, 2018). Other important groups of papers have been written on the issue of the Peru-Bolivia Confederation around 1835-1839 (Del Pozo, 2018; Figueroa & Del Pozo, 2018; Ruiz, 2020; Serrano del Pozo, 2023) and on the Chincha island “guano” fertilizer-related conflict in which foreign powers had diverse interests (Sheldon-Duplaix, 2017) to guarantee food security and access to fertilizers.

Civil wars' impact on Peruvian identity is less significant than in other countries, which requires a proper study (Méndez G. & Granados Moya, 2012). Still, we should point out that they may be an actual and troublesome source of debt since each time there is a power shift, the expenses by the rebel group that got into power sum up to the expenses the group in power had before either in the form of pensions or in the form of recognition of prior costs. If accountancy is not held correctly, it's not necessary to have a particularly corrupt situation, as other studies pointed out before, to have high debts because evaluating how much the State owes to those groups is complicated. Corruption does exist, taking advantage of the war's disgrace and profiting from the suffering of others (Quiroz, 2013). We should also point out that army races play a role in Public Debt even though war does not come explicitly into reality (Ferrero Costa & Obando Arbuli, 1992).

This article continues with the efforts of Gamboa and Leiva (2013) and Leiva (2019) to compile data on Public Debt and add other variables related to War and Natural Disasters (starting with Earthquakes). The objectives are the following:

- 1) Generate the largest estimates regarding Public Debt and Public Debt to GDP ratio for Peru, which in this case is from 1822 to 2022,
- 2) Analyze the relationship between Wars and Earthquakes on the debt-to-GDP ratio in Peru and other variables.

To fulfill its objectives, this article has the following structure: Section 1 provides the introduction; in Section 2, we discuss the sources and our nominal estimates in USD of the External and Internal Debt which together account for the total Debt. After this, using the latest estimates of Seminario et al. (2020), we estimate long-term Debt to GDP ratios; in section 3, we provide the empirical strategy considering time series analysis; in section 4 we show the results; in section 5 we summarize the main conclusions and recommendations; finally, section 6 lists the References.

2. DATA

In this article, we use a wide variety of sources to estimate public finance-related variables such as foreign debt, internal debt, contingent liabilities, and current assets. Up until today, all the Annals of the Treasury of Peru were revised for this document. Data from the 20th Century could improve in quality even more if we process the tables in the Statistical Abstracts of Peru, which we now have digitalized in PDFs. Additional discussion is also provided on key regressors such as catastrophes later. Finally, a discussion on corruption, stability, growth, inflation, depreciation, and interest rates is provided.

Table 1. Peru's Monetary Units' equivalence

From/To	Peso (Feble)	Sol (oro/plata)	Libra Peruana	Inti	Nuevo Sol
Peso (Feble)	x 1	÷ 1.25	÷ 12.5	÷ 1,250	÷ 1,250 MM
Sol (oro/plata)	x 1.25	x 1	÷ 10	÷ 1,000	÷ 1,000 MM
Libra Peruana	x 12.5	x 10	x 1	÷ 100	÷ 100 MM
Inti	x 1,250	x 1,000	x 100	x 1	÷ 1 MM
Nuevo Sol	x 1,250 MM	x 1,000 MM	x 100 MM	x 1 MM	x 1

Source: Own preparation based on BCRP (2023b); Decreto-Ley N° 7126 de La Junta Nacional de Gobierno. Estableciendo Como Unidad Monetaria de La República El Sol de Oro Sin Acuñar (1931) ; Ley de 14 de Diciembre de 1901. Estableciendo Disposiciones Aplicables a La Unidad Monetaria de La República (1901) y Ley de 14 de Febrero de 1863. Amonedación Conforme al Sistema Métrico Decimal (1863). MM=million

We use a wide variety of Exchange Rates. Pound Sterling to Dollar, which is expressed in Dollars per Pound Sterling, comes from Officer (2023) and currencies from Argentina, France, Switzerland, and Germany from Officer (2018) where data is expressed in each currency unit per Dollar. Researchers should be careful when using this source because the data from the Pound Sterling is not expressed as someone would expect. The exchange rate between the dollar and the sol was built over Seminario (2015) in tables VI-51 on pages 840-842, which has information on exchange rates from 1824 to 1896, where the exchange rate between 1821 and 1823 is assumed to be the same as the one in 1824, and VII-90, which has data available from 1896 to 2012. The rest of the timespan, 2013-2022, can be found in BCRP (2023) in which we considered the average bid-ask exchange rates yearly.

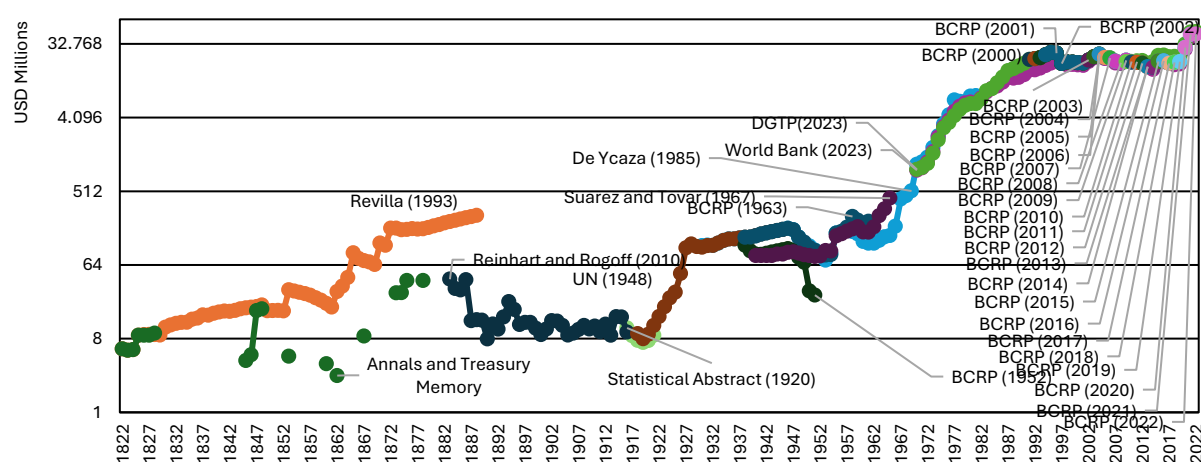
The first difficulty is linking Peru's different currencies throughout its history. When it began its Republic History, it used the currency Peso, which had a fraction of the amount divided into eights. Then, we had to deal with the Bolivian Peso Feble issue. Later, Sol was born. Then we got the Peruvian Pound (Libra Peruana) and returned to the Sol. After that, the Sol would become the Inti; then the Inti would transform into the Nuevo Sol, and finally, the Nuevo Sol would be relabeled Sol. That is why we provide a conversion table for all these currencies in Table 1.

2.1. Foreign Debt

Regarding Foreign Debt, this essay continues with the efforts of Leiva (2019), who worked with a timespan that began in 1824 and ended in 2016. In Table 2 we can see all sources with information regarding total foreign public debt identified. There are 68 references. These sources allow us to avoid interpolations for foreign debt, which is an improvement compared with Leiva (2019), where there were some interpolations. Figure 2 portrays the available information in USD millions and the vertical axis is in logarithms. It shows that after 1952 there is not a wide discrepancy between all the available sources. From 1916 to 1952, the sources don't coincide always, but the differences are minor. The debt estimated using Reinhart and Rogoff's (2010) data is problematic because in that time, particularly from 1890 to 1900, the Ministers of the Treasury argued that Peru did not have Foreign Debt, so it should have been zero. However, Reinhart and Rogoff (2010) show that Peru was paying somehow its debt, so it should have been more than zero.

The same happens with the data that the Annals provide. The Annals record debts to many countries such as Venezuela, Ecuador, Chile, USA, and others in the 19th century. However, if we compare the total amounts that are in the Annals, they are by far less than the debt that Revilla (1993), who also cites Wynne (1951) and McQueen (1926) as his sources. He argues that Peru issued Debt with UK private agents to pay the foreign debt to other countries. Therefore, even after revising the Annals and the Memories of some Treasury Ministers, Revilla (1993) remains the primary data source for the 19th Century Public Debt. We should also say that the data sources are inconsistent, even from the same institution. This may be because some reports were made in a specific month and others at the end of the year or maybe just because the Peruvian Government did not know how much it owed, especially during the 19th Century. If we think about it, if that is the case, in a pessimistic scenario, the most significant estimate would be the one at the end of the year. Therefore, what we do is to get the maximum estimate of debt. In this document, we repeat the same exercise.

Figure 2. Data availability on Foreign Public Debt 1822-2022 (USD Millions)



Source: Own preparation. See Table 2 for more details

Table 2. Data sources for Peru's Foreign Public Debt

Source	Years	Currency Denomination
Annals of the Public Treasury of Peru. (Dancuart, 1903a, 1903b, 1903c, 1904, 1905b, 1905a, 1906b, 1907, 1908; Rodríguez, 1919)	Volume and years in parenthesis, page is next to the hyphen: I (1822-222, 1825-222, 1828-226); III (1845-49); IV(1846-42, 1847-43, 1848-43); V (1853-20); VI (1860-57); VII (1862-161); VIII (1867-138); IX(1873-44); X (1874-95,1875-96,1878-96); XX(1890-93)	
Treasury Memory by Almenara (1901)	Internal debt only exists due to negotiations with foreign creditors. Therefore, foreign debt was 0 in 1889-1900 (page 54).	
Revilla (1993)	1830-1888	Pound Sterling. Debt to the UK.
United Nations (1948)	1918-1945	Pound Sterling, US. Dollar and French Franc
BCRP (1962)	1938-1961	Pound Sterling, US. Dollars, Swiss Franc, Argentinean Peso, and German Mark.
Peru's Statistical Abstract (Ministerio de Fomento, 1922)	1916-1921	They separate debt into internal debt and other kinds of debt. This essay assumes that the rest is Foreign Debt, but this could not be the case. This could be revised.
DGTP (2023)	1970-2022	Total estimates and disaggregation for Latin America, Socialist countries and others.
World Bank (2023)	1970-2021	This reference improves Leiva (2019) because it does not focus on the currency of debt but on the country, institution, or instrument holder.
De Ycaza Clerc (1985)	1930-1981	Consolidated (no disaggregation).
BCRP (1952)	1938-1950	Consolidated (no disaggregation)
Memories of the Central Bank 1966-1969 (BCRP, 1966, 1967, 1968, 1969)	Consolidated (no disaggregation). Information for the years 1940-1966 comes from the memory of 1966. Memories of 1967, 1968, and 1969 provide information on the same years.	
Memories of the Central Bank 2000-2022 (BCRP, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022)	Consolidated in groups: International Organizations, Paris Club, Bondholders, Suppliers, International Banks, Latin America, and Communist Countries →2000 (1991-2000), 2001 (1992-2001), 2002 (1993-2002), 2003 (1994-2003), 2004 (2002-2004), 2005 (2003-2005), 2006 (2004-2006), 2007 (2005-2007), 2008 (2006-2008), 2009 (2007-2009), 2010 (2007-2010), 2011 (2009-2011), 2012 (2010-2012), 2013 (2011-2013), 2014 (2012-2014), 2015 (2013-2015), 2016 (2014-2016), 2017 (2015-2017), 2018 (2016-2018), 2019 (2017-2019), 2020 (2018-2020), 2021(2019-2021), 2022 (2020-2022).	
Reinhart & Rogoff (2011)	These authors have estimates of the foreign debt to Exports ratio from 1883 to 1916. We multiply those ratios by Seminario et al.'s (2020) exports estimate.	
In the following list we put the data availability in parenthesis next to each volume year:		
League of Nations (1930, 1932, 1933, 1935, 1937, 1938, 1939, 1940)	<i>International Statistical Yearbook 1929</i> : 1930 (1926-1928), <i>Statistical Yearbook of the League of Nations</i> : 1932 (1927-1929), 1933 (1929-1931), 1935 (1932-1934), 1937 (1933-1936), 1938 (1935-1937), 1939 (1936-1938), 1940 (1936-1939)	
Epstein (1928, 1930, 1932, 1934, 1935, 1936, 1937, 1939) and Keltie & Epstein, (1920, 1921, 1922, 1924, 1925, 1926)	<i>The Stateman's Yearbook</i> . 1920 (1918), 1921 (1920), 1922 (1921), 1924 (1923), 1925 (1924), 1926 (1925), 1928 (1926), 1930 (1929), 1932 (1930), 1934 (1931,1932), 1935(1933), 1936 (1935), 1937 (1936), 1939 (1937).	

2.2. Internal Debt

Before 1916, we had a more difficult task regarding internal debt because we didn't have data for many years. The primary source is the Annals of Public Finance. Sometimes, particularly at the beginning of the Republic, we only have some estimates of specific debts and sometimes estimates of total Public Internal Debt. Therefore, after the discussion on interpolation, we divide the section into two subsections. Subsection 2.2.1 discusses the sources of Internal Debt for 1916-2022, and Subsection 2.2.2 discusses the sources for 1821-1916.

Table 3. Data sources for Peru's Internal Public Debt: 1916-2022

Source	Years	Currency Denomination of Foreign Public Debt
Peru's Statistical Abstract (Ministerio de Fomento, 1922)	1916-1921	Here, they separate debt into internal debt and other kinds of debt. The present working paper assumes that the rest is foreign debt, but this could not be the case. Therefore, this source could be revised.
United Nations (1948)	1918-1945	Consolidated and disaggregated by funded and floating debt.
Memories of the Central Bank (BCRP, 1963)	1938-1961	Total estimates disaggregated by consolidated internal, floating, and short-term and administrative debt.
DGTP (2023)	1990-2022	Total Estimates and disaggregation in Social Security credits, bonds, and bonds.
Guardia (2007)	1994-1998	Consolidated (no disaggregation).
De Ycaza Clerc (1985)	1930-1981	Consolidated (no disaggregation). Based on reports by the General Comptroller of the Republic.
Contaduría Pública de la Nación (1992, 1993)	1992-1993	Consolidated (no disaggregation)
In the following list of the years of these periodical publications, we put the data availability in parenthesis:		
League of Nations (1930, 1932, 1933, 1935, 1937, 1938, 1939, 1940)	League of Nations. Consolidated and disaggregated by funded and floating debt. 1930 (1926-1928), 1932 (1927-1929), 1933 (1929-1931), 1935 (1932-1934), 1937 (1933-1935), 1938 (1935-1937), 1939 (1936-1938), 1940 (1936-1939)	
Memories of the Central Bank 2004-2022 (BCRP, 2004-2022)	Disaggregated in the short term and long term: 2004 (2002-2004), 2005 (2003-2005), 2006 (2004-2006), 2007 (2005-2007), 2008 (2006-2008), 2009 (2007-2009), 2010 (2007-2010), 2011 (2009-2011), 2012 (2010-2012), 2013 (2011-2013), 2014 (2012-2014), 2015 (2013-2015), 2016 (2014-2016), 2017(2015-2017), 2018(2016-2018), 2019(2017-2019), 2020(2018-2020), 2021(2019-2021), 2022(2020-2022)	
Instituto Cuánto (1992, 1993)	It was consolidated with no disaggregation between 1982 and 1990.	

Splines are interpolations that consider all the information contained in the available data. In contrast to regressions that estimate a line between the original dots, splines pass through the original dots. This means that splines evaluated in the year where there is data show the actual data and only interpolate where there is no data. Only in the domain, without information regarding the function range, do they show their estimates. Splines do not estimate one unique equation for all the data but different equations between two dots for which data is available. We use the tool provided by SRS1 Software, LLC (2018) which is a freely available add-in for Excel to interpolate using nonmonotonic splines. There are other possibilities of cubic interpolation and even multivariate cubic splines (Press et al., 2007) that could be explored in future studies. Some researchers also try Random Forest Methods, which could be more helpful.

Table 3 provides information for 1916-2022. It is important to note that there is no need to interpolate anything for this part. This is an improvement compared to Leiva (2019), who did not have data for 1916 or 1917. Data from Statistical Abstracts are also available in PDF versions, and foreign debt data is available there. We will mine those data sources in a future project.

The timespan 1821-1916 requires its own treatment because it is mainly based on the data available from the Annals of Public Finance, where, for the first years of the Republic, there are no consolidated estimates of Internal Public Debt. We will write down in paragraphs all the information we have identified if necessary because the 19th Century Internal puzzle is very complicated. Indeed, this puzzle is so complex that it is the primary source of corruption but also the main source of conflicts and political instability, as can be seen in the study on corruption by Quiroz (Quiroz, 2013).

The first Debt we can identify is the one of 30,000 pesos of General San Martin, which was covered totally (Dancuart, 1905a, p. 223). We assume this is in 1821 and that it was paid in total in 1823. Then, in November 1823, a new Debt emerged with the Lima Chamber of Commerce, which would be 200,000 pesos, which would cost the end 300,000 pesos when the State paid back (Dancuart, 1905a, p. 223). Later, a new Debt would be recognized with particulars that had economic relations with the Vice Royalty of Peru. This Debt was estimated at 12,246,812 pesos and two and $\frac{1}{2}$ reales and was not paid totally until 1865. We assume that this amount was the recognized Debt and that it was paid yearly until 1865 when it was totally paid (therefore, we have estimates of minimum debt from 1825 to 1865). However, because we don't want to make unnecessary assumptions when there is no data available, in this case, we don't provide estimates of Internal Public Debt from 1821 to 1825. Finally, up to 1826, the State had recognized owing money to internal creditors, suppliers, unpaid salaries, and others up to 7,069,000 pesos, of which it had paid 1,809,000 pesos. Therefore, the State owed to these people 5,260,000 pesos in 1826 (Dancuart, 1905a, p. 226).

It was not until 1830 that we can find a table with consolidated debt in the Annals as in Dancuart (1906a, p: 42). However, as Dancuart (1906a, p: 40) explains, this did not include the debt related to the Vice Royalty of Peru during the Spanish regime we mentioned before, nor the debt associated with Tagle and Unanue which would require another legislation themselves. We distribute this information from 3,008,385 and 4/8 yearly from 1827 to 1830 and the same with the amortization but from 1828 to 1830. The 2,332,012.06 that were issued until 1930 were distributed from 1821 to 1930. Then we have an estimate of total Internal Debt in 1845 of 6 million pesos (Dancuart, 1903a). It's important to note that between 1830 and 1845, we have a gap that could be filled with our projection of the Spanish Debt. However, it's obvious that those 6 million estimated contain more kinds of debt than it, even though our projection and their projection are very close (6,272,757.53 pesos is what we estimate for that year).

For 1846, we have the information in Volume IV, page 46 (Dancuart, 1903b) giving 6,846,344.5 pesos. It is vital to notice that President Castilla stated that Internal Debt with a Decree on December 28th, 1848, that there was a limit to which no other debt would be recognized. Those with that specific kind of debt that was out of the country would only have 18 months to exchange the debt for money. Therefore, after this consolidation of internal debt, in 1849, internal public debt would be 3,472,284.375 pesos (Volume IV, page 48 of the Annals of Public Finance (Dancuart, 1903b). But then, from 1850 to 1854, according to Dancuart (1903c) in Volume V, Peru lived an illusion. All the order that was achieved during the previous regime got into chaos again. The guano era was, by far, the most problematic of the Public Finance in Peru. In Volume V, page 20 of the Annals of Public Finance we can see that in 1853, Internal Public Debt was 23,211,400 pesos.

Table 4. Data sources for Peru's Internal Public Debt: 1821-1915

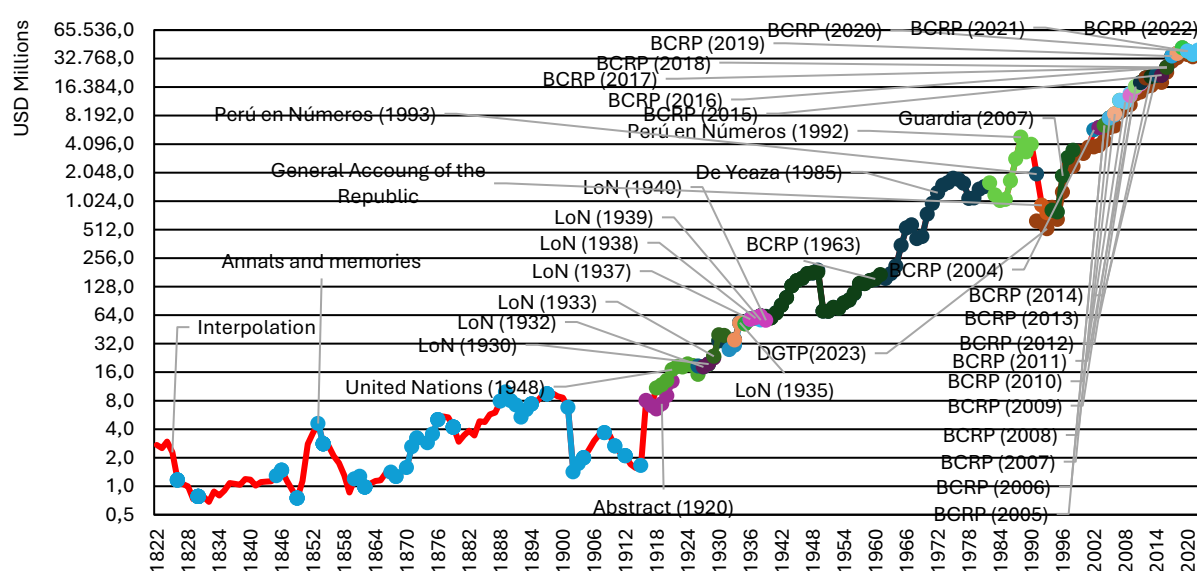
Year	Source	Page	Amount	Currency
Annals of the Public Treasury of Peru (Volumes and references)				
1826	I (Dancuart, 1905a)	226	5,260,000	Pesos
1830	II (Dancuart, 1906a)	42	3,524,558	
1845	III (Dancuart, 1903a)	50	6,000,000	
1846	IV (Dancuart, 1903b)	46	6,846,344.5	
1849		48	3,472,284	
1853	V (Dancuart, 1903c)	20	23,211,400	
1854		20	14,140,400	
1860	VI (Dancuart, 1904)	65	7,324,479	
1861		243	7,789,654	
1862	VII (Dancuart, 1905b)	162	6,015,100	
1867		105	8,645,511	
1868		106	6,210,634	
1870	VIII (Dancuart, 1906b)	59	7,716,536	Soles
1871	IX (Dancuart, 1907)	48	12,814,048	
1872		44	15,831,314	
1874	X (Dancuart, 1908)	95	14,108,609	
1875		96	17,465,025	
1876	XII (Rodríguez, 1913)	68A	24,723,582	
1879	XX (Rodríguez, 1919)	6	20,633,950	
1888		7	38,798,190	
1890	XXII (Rodríguez, 1924)	11	39,387,500	
1891		13	35,365,545	
1889		71A	48,599,924	
1892	XXIV (Rodríguez, 1926)	45	26,282,553	
1893		47	31,572,500	
1894		52	36,232,600	
Memories of the Ministers of Finance				
1897	Memory 1897 (Rey, 1897)	23	47,591,761	Soles
1901	Memory 1900 (Belaúnde, 1900)	55	3,257,747	Peruvian pound
1902	Memory 1902 (Ward, 1902)	27	683,455	
1903	Memory 1903 (Sarria, 1903)	27	842,495	
1904	Memory 1904 (Reinoso, 1904)	53	965,885	
1908	Memory 1908 (Schreiber, 1908)	62	1,760,620	
1910	Memory 1910 (Schreiber, 1910)	69	1,287,330	
1912	Memory 1912 (Plácido Jiménez, 1912)	19	1,012,855	
1915	Laws, Decrees, and Governmental Resolutions (Ministerio de Hacienda, 1929)	76	702,648	

Source: Own preparation. All sources are inside the table

After seeing this massive amount of debt, the government transformed part of it into foreign debt through the Urribarren and Montané negotiations. Therefore, we have another estimate for Internal Debt in 1854: 23,211,400-9,071,000, which is 14,140,400 pesos. In 1860, some of the debt was either converted into external debt or paid and a stock of 7,324,479.44 pesos was the result (See Volume VI, page 65 of the Annals of Public Finance (Dancuart, 1904)).

In the 1861-1862 budget, we have information about the Internal Public Debt in 1861 (Dancuart, 1904, p. 243-244). In 1861, consolidation debt was 7,123,461.688 pesos, but then 600,000 pesos were amortized, the debt to pay for the freedom of slaves (manumission) was 414,000 pesos then, the census was 464,024.375 pesos, the one to Capellanías was 351,509.625 pesos. Making the summation and resting the amortization, we get 7,789,654.19 pesos as an estimate for 1861. See p. 243-244 in Dancuart (1904) for more details. In 1862, Minister Pedro Galvez, in his Memory of the Congress, said the debt was 6,015,100 pesos (Dancuart, 1905b, p. 161).

Figure 3. Data availability on Internal Public Debt 1822-2022 (USD Millions)



Source: Own preparation.

Note: All references are inside the figure signaling where they are used. Interpolation in red.

2.3. Catastrophes

Catastrophes are adverse shocks. In general, there are catastrophes whose origin is natural and others whose origin is human. In this essay, we explore the case of earthquakes as an example from a natural disaster and wars as an example of human origin disaster.

2.3.1. Earthquakes

Regarding the earthquake data, the information is not uniform, and after the International Geophysical Year (1956) the number of observations has increased dramatically (Ferro, 1978) And yet curation is required. It is important to notice that data after 2000 is even more regular, which could make the entire dataset not comparable (Instituto Geofísico del Perú (IGP), 2024). Now, the Geophysical Institute of Peru (IGP) provides access to two datasets: the historical before 1960 and the instrumental after 1959. Because seismology is a science that requires time and effort, this essay builds upon the efforts of

different scientists compiled by the IGP. Therefore, the number of earthquakes cannot be used as an indicator.

Figure 4. Dummy for a big earthquake



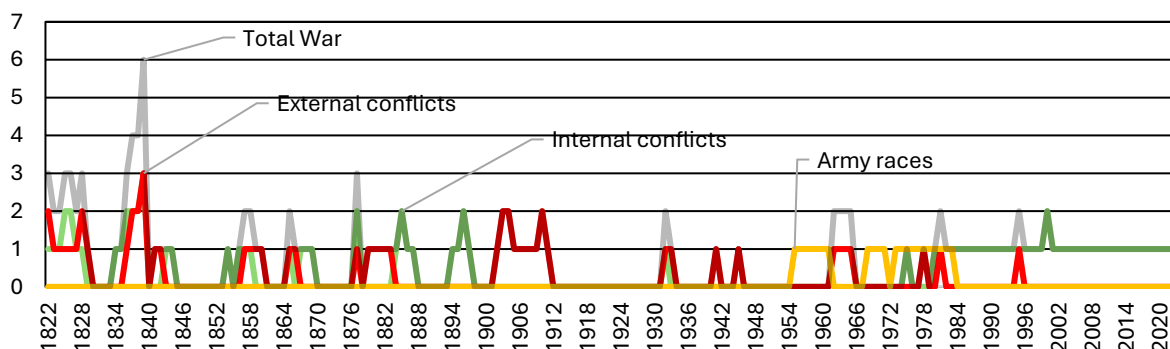
Source: Own preparation based on IGP (2024)

We cannot use the magnitude simply because the magnitudes in which the earthquakes are measured change over time. If we count the number of earthquakes recorded in the IGP dataset, we will find that before 1921, there were only one or two and only three in 1913. However, it was after 1900 that more observations became available. The maximum in each kind of measurement in each year was found. After this, from 1901 onwards, only the P75 higher earthquakes remain. This is transformed into a dummy variable, which can be seen in Figure 4.

2.3.2. Wars

The list of wars is still a work in progress. Yet, in this working paper, information is not only reduced to the wars that came into reality, but we also include armaments races since they increase debt levels due to many reasons: 1) purchases of guns are usually made on credit, 2) it's a stable equilibrium in which all buyers try to buy the highest amount of guns and ammo available 3) once the war explodes, fixed demand for ammo is determined by the number of guns and how much of it was already used. In Figure 5 we can see the number of wars or arms races from 1822 until these days.

Figure 5. Internal, External, Arms Races and Total War

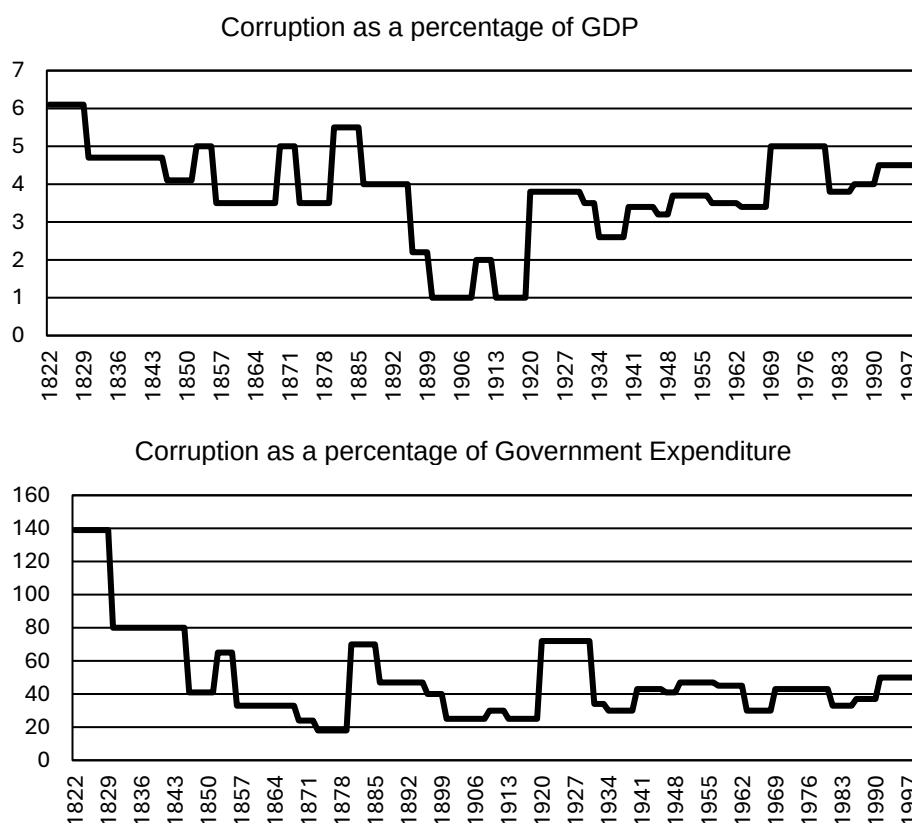


Source: Own preparation. See the GitHub repository documentation for details

2.4. Incorporating Every Cashflow

Estimates of corruption are available in the famous study by Alfonso Quiroz (Quiroz, 2013, pp. 551–553) in table A.7. In this essay, the years have been fixed so that the beginning and end of the government estimates match without gaps. In particular, the author does not provide information on the Peru-Bolivia Confederation when Santa Cruz was in power. We work assuming that it is the same as Gamarra and La Fuente's regime estimates. The main problem is that there is only data until 2000. Future essays can complete the information until the current year. As can be seen in Figure 6, the ranking shifts depend on the denominator. The most corrupt years would change if we used the GDP or the total expenses. In any case, the most corrupt years happened at the beginning of Independence. In the first scenario, the pre-war with Chile era was the second most corrupt time, followed by the Revolutionary Government of the Armed Forces in the 1970's. In the second case, it would be the 11 years of government of Leguía around the 1920's followed by the Pacific War.

Figure 6. Relative cost of corruption (1822-2000)



Source: Own preparation based on Quiroz (2013)

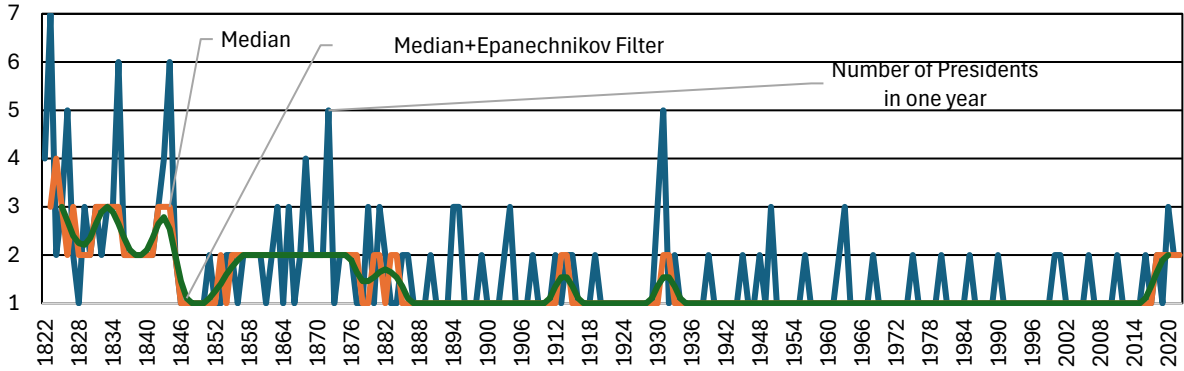
2.5. Political instability

The number of presidents comes directly from the information compiled by the Library of the Congress of the Republic of Peru (Biblioteca del Congreso de la República, 2023). In this approach, we only consider the shifts in government. If a President was reelected or only changed the status of their presidency but remained in charge, we assumed that the government remained equal. This allows us

to identify that Leguía (11 years), Fujimori (10 years), Odría (8 years) (not considering the interruption with Zenón Noriega), Velasco and Mariano Ignacio Prado (both with 7 years) were the presidents that ruled the most continuously. In the context of Public Debt, our working hypothesis is that political instability in the form of government shifts may correlate with Public Debt due to the classic motives explained by the Public Choice Theory (Buchanan, 1988; Puviani, 1903). The analysis can be improved in the future.

In Figure 7, we see the political shifts. There are three kinds of states. In state one, one President governs; in state 2, there is a change in which there would be 2 Presidents in those specific years. We could expect instability because there have been many military regimes, but that was not the case. If we apply a median with a 5-year window and over it, we use an Epanechnikov kernel. If that can be seen, it is because those years were volatile. This happens primarily right after the Independence and before the war with Chile. Other eras of high instability were during the Billinghurst Regime and the clash between the Congress and Executive, right after the coup d'état from Sánchez Cerro and, finally, during the latest political crisis that started during the government of Pedro Pablo Kuczynski and lasted until these days.

Figure 7. Data availability on Foreign Public Debt 1822-2022 (USD Millions)



Source: Own preparation based on the list by the Congress of the Republic of Peru

2.6. Cost Characteristics: Rising Cost with Rising Interest Rates

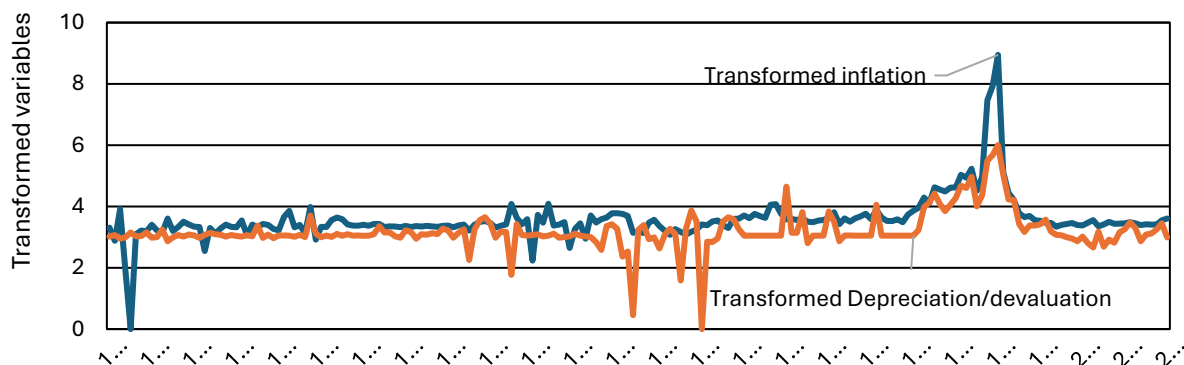
The primary sources for GDP growth, inflation and depreciation/devaluation are the important studies in which Professor Seminario was involved (Seminario, 2015; Seminario et al., 2020) with the data reported by the Central Bank until today (BCRP, 2023b). Interest rate is understood as a long-term interest rate and is the minimum between USA and UK expressed as consistent by Officer (2024). This procedure will guarantee we extract a proxy for the risk-free nominal interest rate. Inflation and depreciation were transformed with the following formulas:

$$Inflation_{transformed,t} = \ln(Inflation_t - \min(Inflation) + 1) \dots (1)$$

$$Depreciation_{transformed,t} = \ln(Depreciation_t - \min(Depreciation) + 1) \dots (2)$$

With this, we can represent in the same figure each of these variables and appreciate fluctuations (Figure 8). Interest rate in Peru should be higher than this due to the risk premium.

Figure 8. Transformed inflation and depreciation/devaluation



Source: Own preparation based on Seminario (2015) and BCRP (2024)

3. METHODOLOGY AND EMPIRICAL STRATEGY

To understand the relation between natural disasters, human disasters and Public Debt, we can start with a basic budget function in terms of percentage of GDP (Blanchard, 1990):

$$b_t = -s_t + \left(\frac{1 + i_t}{1 + \gamma_t} \right) b_{t-1} \dots (3)$$

Where:

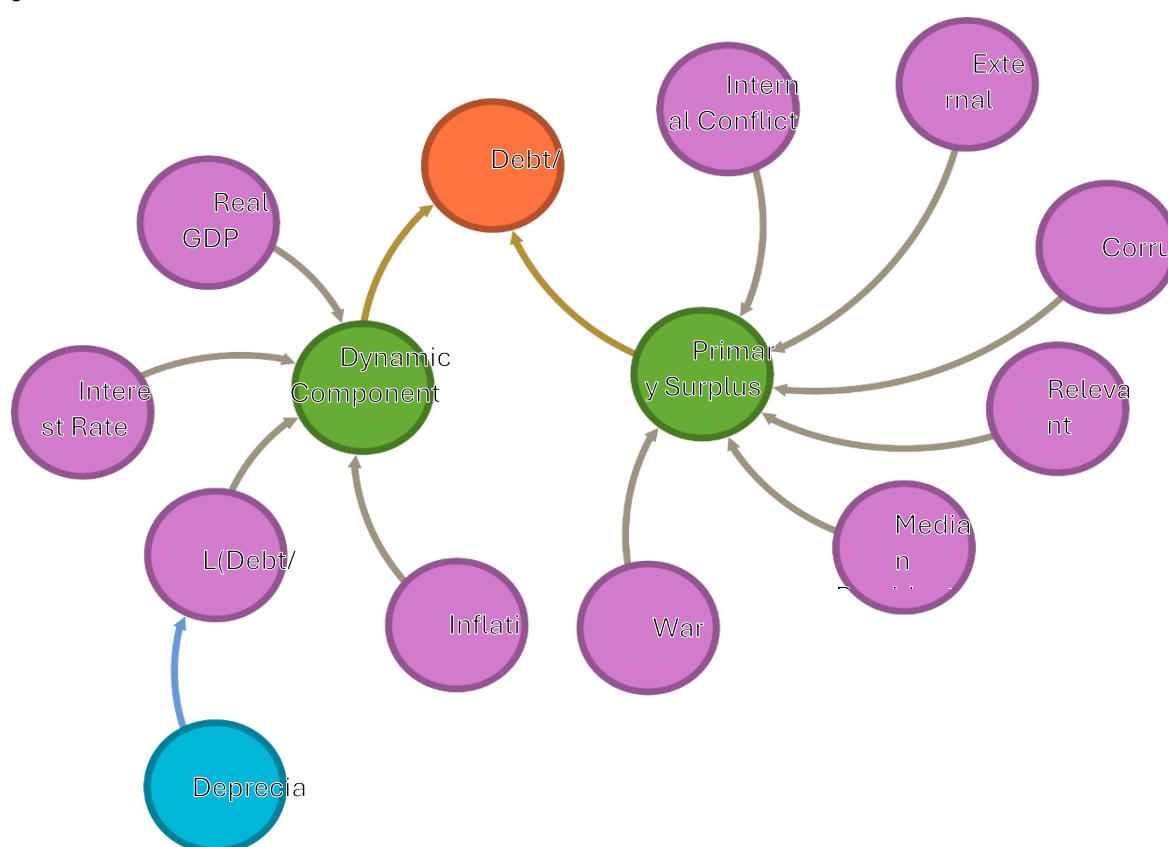
b_t is the stock of Total Public Debt, s_t is the primary surplus in year t , i_t is the nominal interest rate in year t and γ_t is the nominal growth rate of GDP.

Now, let us discuss the Primary Surplus s . This is the theoretical link between Debt and Natural Disasters, Corruption, Instability, and War. We can define it as:

In general, we would expect s_t to decrease with the occurrence of a disaster, however the relation may not be necessarily immediate. There could be lags or even contrary effects in the short run: maybe expenditure is reduced because the government is not able to spend as planned or just could be the case that the government is slow to react to the disaster.

Based on the previous discussion, we can build a theoretical Directed Acyclic Graph (DAG) which will be the base of our regressions in Figure 9. We still have a missing variable which is the Primary Surplus. However, we argue that, from an exploratory perspective, we can assume the Debt to GDP ratio is dependent on a reduced form on the purple and blue variables. To control for the Lag of Debt as a Percentage of GDP, we use Fourier Transformations. The hypothesis of this paper is that Internal Conflict, External Conflict and Earthquakes have a positive impact on the Debt to GDP ratio.

Figure 9. Public Debt to GDP DAG



4. DIAGNOSIS AND RESULTS

This section shows the diagnosis, statistics, and regression results. All of the estimates on which this section is based can be found in the following computational notebook: Earthquakes, wars and Debt: a computational notebook by Favio Leiva.

4.1. Diagnosis and Results

Before performing any econometric analysis, we must find out if the assumptions of the OLS hold or not. In Table 5. Almost all the variables except for the Dummy created for earthquakes have heteroscedasticity problems, and 3 of them have stationarity issues: Gross Debt, Corruption and Internal Conflict. Of these three, Gross Debt, which is Gross Debt as percentage of GDP, is our key dependent variable.

To address the issue of heteroscedasticity, robust standard errors are used. To tackle non-stationarity, two steps are followed. First, after taking the logarithm of the Debt-to-GDP ratio, Fourier transformations are applied to filter out the effects of cyclical events occurring every 100, 50, 25, 12, 6, and 3 years. Additionally, the approach of differencing the data is employed. This strategy generates seven dependent variables related to the Debt-to-GDP ratio, all of which are confirmed to be stationary according to the Augmented Dickey-Fuller (ADF) test. The issue of structural change is also examined in the computational notebook. Using the Zivot-Andrews test, only the variable derived from differencing

is free of structural breaks. For simplicity, a single structural break is identified in each estimate, although the computational notebook allows for the identification of multiple breaks using the package ruptures in python (Truong et al., 2020). Similar results are found there when using the Partial Autocorrelation Function which shows that the issue of autocorrelation is only fixed when taking differences.

Table 5. Descriptive statistics of the variables used

Label	N	μ	σ	min	25%	50%	75%	max	ADF	ARCH
Year	201	1922	58.17	1822	1872	1922	1972	2022	n.a.	n.a.
Gross Debta	201	41.915	47.07	2.24	14.73	31.91	45.96	266.70	N.S.	Het.
Corruptiona	179	3.78	1.23	1	3.45	3.8	4.7	6.1	N.S.	Het.
Internal Conflict	201	0.46	0.61	0	0	0	1	3	N.S.	Het.
War Race	201	0.11	0.31	0	0	0	0	1	N.S.	Het.
Corruptionb	179	48.97	26.14	18	33	43	57.5	139	Stat.	Het.
Median Presidents	200	1.37	0.61	1	1	1	2	4	Stat.	Het.
External Conflict	201	0.28	0.55	0	0	0	0	3	Stat.	Het.
Total Wars	201	0.74	0.91	0	0	1	1	6	Stat.	Het.
Wars + Army Races	201	0.85	0.91	0	0	1	1	6	Stat.	Het.
Relevant Earthquake	201	0.22	0.41	0	0	0	0	1	Stat.	Hom.
GDP Growth	201	2.98	7.73	-44.33	-0.80	4.27	7.21	25.84	Stat.	Het.
Inflationc	201	3.58	0.75	0	3.34	3.45	3.63	8.95	Stat.	Het.
Depreciationc	201	3.20	0.60	0	3.02	3.07	3.26	6.00	Stat.	Het.
Interest rate	201	4.06	2.14	0.82	2.85	3.15	4.37	13.200	Stat.	Het.

Note: The last two columns have information on ADF Test and ARCH test. Stat.=Stationary, N.S.=Non-Stationary, Het.=Heteroscedastic, Hom.=Homoscedastic. a. As percentage of GDP. b. As percentage of budget. c. Transformed using equation 1.

The structural changes are identified by setting Dynamic Programming with a normal cost function (Lavielle, 1999; Lavielle & Teyssière, 2006). When we take differences, no algorithm identifies structural change anymore. Finally, we analyze the correlation of each dependent variable with 10 lags of the variables of interest, one at a time. All these regressions are expressed in Table 6.

Regarding earthquakes, we find a significant positive effect at a 10% significance level ($\alpha = 0.1$) using the second lag when accounting for the effects of events recurring every six years. This does not necessarily imply that earthquakes have no impact on public debt. Two possibilities could explain this finding: (1) the effects of earthquakes might dissipate within months or quarters, as observed during the COVID-19 pandemic, or (2) the government's response may be delayed, taking up to two years to see a relation with the budget allocated to addressing emergencies, resulting in less pronounced effects. For events recurring every 50 years or more, earthquakes exhibit a positive correlation with the debt-to-GDP ratio nine and ten years later, significant at the 5% level ($\alpha = 0.05$).

Regarding the "wars and races" variable, we observe a significant positive effect at $\alpha = 0.1$ with the 8th lag when accounting for the effects of events recurring every 12 years. Conversely, a significant negative effect is identified when using differences and the 9th lag at the same significance level. Wars alone are significant only when using differences with a 9th lag. Due to the inconsistency of these results, we will exclude this variable from our final regressions.

Focusing on internal wars, they show significant effects at $\alpha = 0.1$ both contemporaneously and with a one-year lag after controlling for events recurring every 100 years. Additionally, internal wars remain significant at $\alpha = 0.1$ for lags 5, 8, and 9 after controlling for events recurring every 12 years. These results suggest that internal wars strongly influence public debt in both the short and long term.

Table 6. Significant coefficients in lag models by different cleaning approaches

Regressors	Debt to GDP ratio in logarithms					
	(1)	(2)	(3)	(4)	(5)	(6)
Earthquake						
L2						0.0311*
L9			0.1277**			
L10			0.1321**			
Wars/Army races						
L8					0.0195*	
L9	-0.0214*					
Wars						
L9	-0.0295**					
Internal wars						
L0		0.1447*				
L1		0.1470*				
L5					-0.0479*	
L8					0.0380*	
L9					0.0534**	
External wars						
L1				-0.0518*	-0.0350*	
L4	0.0575**		0.1188***	0.0577*		
L5			0.1528***	0.1030***	0.0628**	
L6			0.1210***	0.0849**		
L7			0.0805*			
L9	-0.0856**	-0.1579*			-0.0545*	
L10		-0.1994**	-0.0982*	-0.0721*	-0.0683**	
Army races						
L0		-0.3536***				
L1		-0.3278***				
L2		-0.2745**				
L3		-0.2611**				
L4		-0.2632**				
L5		-0.2690**				
L6		-0.2370*				

Note: Each coefficient comes from a regression. In total 420 regressions were estimated. Of this, only 36 hold significant coefficients. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Each of the models includes a constant. (1) Differences, (2) 100+ clean, (3) 50+ clean, (4) 25+ clean, (5) 12+ clean, (6) 6+ clean

Regarding external wars, we find a significant positive relationship with public debt at $\alpha = 0.05$ when using differences, specifically with a 4th lag. External wars remain significant and positive in models controlling for events recurring every 50 years, particularly for lags 4, 5, 6, and 7. Finally, army races are significant across lags 0 to 6. However, the sign of the effect is contrary to expectations, which may be attributable to confounding factors not included in the model such as the interest rate or an increase of the guns supply in the world.

4.2. Results

A series of regressions were performed and the ones in Table 7 show the expected signs and are significant. The strategy used was to choose the first lag in which the key variables have a significant effect in the previous section except for External Wars. The same was with the controls.

Table 7. Chosen regressions

	Gross Debt as Percentage of GDP in Logs					
	Filtered 50+			Filtered 25+		
	(1)	(2)	(3)	(4)	(5)	(6)
Earthquake L2	-0.024 (0.051)	-0.057 (0.052)	-0.082 (0.060)	0.003 (0.041)	-0.015 (0.043)	-0.031 (0.047)
Internal wars	0.020 (0.047)	0.024 (0.046)	0.031 (0.053)	0.060 (0.038)	0.084** (0.039)	0.062 (0.047)
External wars L4	0.135*** (0.044)	0.133*** (0.046)	0.147*** (0.050)	0.075* (0.039)	0.079** (0.040)	0.060 (0.043)
Army races	0.074 (0.076)	0.160** (0.075)	0.195** (0.084)	0.064 (0.066)	0.180*** (0.063)	0.178*** (0.062)
Inflation L1		-0.013 (0.031)	-0.012 (0.031)		0.024 (0.026)	0.038 (0.026)
Depreciation		-0.009 (0.060)	0.003 (0.065)		0.020 (0.045)	0.023 (0.046)
Risk free interest rate		-0.039*** (0.013)	-0.041** (0.020)		-0.037*** (0.012)	-0.040*** (0.013)
Real GDP growth		-0.006 (0.004)	-0.006 (0.004)		-0.003 (0.003)	-0.003 (0.003)
Corruption as percentage of budge in logs			-0.012 (0.056)			0.106** (0.050)
Median presidents			-0.035 (0.056)			0.046 (0.085)
Observations	197	197	175	197	197	175
R2	0.052	0.102	0.104	0.034	0.070	0.088
Adjusted R2	0.027	0.059	0.043	0.009	0.025	0.027
AIC	140.47	137.81	143.77	72.89	73.52	81.50
Residual Std. Error	0.340 (df=191)	0.335 (df=187)	0.353 (df=163)	0.287 (df=191)	0.284 (df=187)	0.295 (df=163)
F Statistic	2.165* (df=5; 191)	4.143*** (df=9; 187)	2.833*** (df=11; 163)	0.919 (df=5; 191)	1.847* (df=9; 187)	2.166** (df=11; 163)

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Each of the models includes a constant and a dummy to control one structural change. Standard Errors in Parenthesis

The table is divided into two parts. The first part runs regressions of the Debt to GDP as percentage of GDP in cleaned of the effects of events that happen each 50 years or more. The other part cleans for events that happen each 25 years or more. In no regression the earthquake variable is significative. This supports the idea that there is no reaction of the government on time to the emergency nor does it have a significant coefficient related to debt, which is a proxy of the budget.

As for wars, in model 5 all regressors have the expected sign. Wars in general seem more robust to explain debt than earthquakes. It's important to notice that after adding additional controls, army races become significative. Even though we added corruption as a control, including that regressor reduces the number of observations because there is only data until the year 2000. Army races and external wars seem robust to adding additional controls. In any case, internal conflicts, external wars and army races seem more important than our proxy of earthquakes to explain Public Debt. An additional comment comes with the issue that external wars have a positive effect in Public Finance 4 years later, while army races and internal wars seem more contemporary.

The risk-free interest rate reduces debt after cleaning for 50+ and 25+ regularity events. We used a proxy in this essay based on the interest rate the UK and the USA seem to offer and yet it is significant. In these chosen models, inflation is not relevant. Corruption is significant in the last regression. Future studies could compile information on the interest rate in Peru.

The issues of endogeneity, reverse causality and non-stationarity have been dealt here through the utilization of Fourier Series decomposition. On the other hand, if we pay attention to the Adjusted R2 and Akaike Information Criteria, the best model is model 2 for the first group of regressions. On

the other hand, model 4 is the best for the second group of regressions according to the AIC, while the adjusted R2 expresses model 6 is the best. It's important to notice that the low values of R2 are expected because of cleaning the effects of time and the strong autoregressive components related to this from the formation of Debt as a stock.

The regressions include a dummy to control structural change in 1955 for the first group of regressions and another for 1894 for the second group of regressions. Additional structural changes are identified in the computational notebook. Corruption may also play a role in explaining high levels of debt. However, we don't go in depth on that discussion in this essay.

5. CONCLUSIONS AND RECOMMENDATIONS

In this document, the historical development of Public Debt, in many of its forms has been explored since Independence until 2022. This document makes public the longest estimates of Debt to GDP ratio for Peru and shows preliminary results on the relationship between Debt, Wars and Earthquakes. The moments of social crisis, including civil wars, external wars and natural disasters seem to have a correlation with Public Debt unsustainability. Even though, earthquakes don't seem to be so important and it takes time for the government to make a significative reaction to it. Exploring conflict, war and disasters is key to understanding Public Debt Sustainability. This is a first exercise of exploring disasters. Future studies could explore the role of El Niño phenomenon on Public Debt.

When not controlling for endogeneity, among all conflicts, internal conflicts had the highest correlation with the Debt to GDP ratio, therefore, compromising Sustainability. However, after cleaning the effects of time and taking the proper lags of the regressors, external wars become the most important, but with a lag of 4 years. Army races and Internal wars show a contemporary relation. Future studies could explore how to deal with the issue of identification the optimum lags. This essay shows that the coefficients are highly sensitive to econometric specifications. Using DAGs instead of equation is more useful to work in this scheme since we don't know, a priori, which is the lag that should be included in the regressions.

Beyond regressions, focusing on describing the results of the compilation, the worst moments for Public Debt in Peru were right after Independence in which Peru did not have a Public Budget and did not even know how much it owed to almost nobody. This was more serious for the case of internal debt for which many books have been written about. The appearance of guano and Public Finance irresponsibility seems to represent the worst impact in Public Finance. The idea that continuous deficit is sustainable in the long run existed in Peru even before Keynesian policy. This is what Basadre called Illusory Prosperity.

The variables studied in this essay have certain problems that shall be addressed to avoid bias in the estimators. The issue of endogeneity in time series analysis is well known. Public Debt as percentage of GDP is nonstationary. This is mainly because there have been waves of unsustainability which were related to irresponsibility in Public Finances and because there are subjacent processes that impact the long-term generating long-term debt cycles. Recently Public Debt does not show explosive patterns. It is important to point out that Debt does not occur in abstract but in the real world where there is corruption, war and disasters. Even though this essay was not focused on the issue of corruption nor stability, these variables seem important to understand why Peru may have had higher debts in the past. Also considering additional classic controls such as interest rate, growth rate, depreciation/devaluation rate and inflation are key. However, there is still space to complete the time series on corruption that ends in 2000.

From the perspective of policy recommendation, the necessity of having institutions ready to act during catastrophic events and to reduce the time policy responds to those crises is key. It's also important to point out that diplomacy has also value since, despite its costs, it could avoid wars if countries understand each other and work together to reach a sustainable peace where security is not compromised. Coordinated disarmament or coordinated purchases of weapons could guarantee a strategic equilibrium in which countries can protect themselves and avoid army races. On the future, even joint disarmament could be a diplomacy objective. But just as Peru shall have positive relations with her neighbors, Peru shall have a positive relation with itself. Dialogue and mutual understanding should be promoted among all Peruvians, respecting their cultures and identities and doing the best efforts to avoid war.

Corruption should be fought everywhere and whenever possible because it has a negative effect in Public Finances and, through that, in the wellbeing of all Peruvians. Corruption seems like a robust regressor. Therefore, fighting corruption should be a common day activity if reaching Public Debt Sustainability is our objective. Transparency with conflicts of interests, honesty and diligence are key requirements of it. Future studies could go in depth in war related variables such as deaths, expenditures and others. Other kinds of disasters, such as El Niño phenomenon could be incorporated in the future. Of course, adding classical regressors such as internal and external actual interest rates (instead of our proxy), taxation, public investment and others remain research opportunities for the future. Economic growth remains a key explanatory variable for the Debt to GDP ratio.

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SESSION IV

Managing Inflation and Market Risks Through Optimal Debt Portfolio Strategies

Fiscal Sustainability and the Role of Inflation *

Antonio Afonso^a, Jose Alves^b, Olegs Matvejevs^c, Olegs Tkacevs^d

Abstract

We examine the relationship between inflation and fiscal sustainability with a two-step approach. In the first step, we estimate to estimate a country-specific time-varying measure of fiscal sustainability using the fiscal reaction function. This function captures the response of the primary balance to changes in the public debt ratio. In the second step, we examine how various measures of inflation such as headline inflation, core inflation, energy inflation, and food inflation affect the estimate of fiscal sustainability found previously. Our findings indicate that higher inflation rates contribute positively to the measure of fiscal sustainability, specifically through core inflation causing an improvement in fiscal sustainability, while the effect of energy inflation is conversely found to be negligible or even negative. These results imply that the initial burst of inflation caused by the energy price shock in 2021 probably did not help improve fiscal sustainability, whereas the subsequent high core inflation had a positive effect.

Keywords: Fiscal sustainability, Fiscal reaction function, Time-varying coefficients, Euro area, Inflation, Core inflation, Panel data

JEL Code: C23, E31, E62, H50, H62

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1. INTRODUCTION

Whether fiscal policy is sustainable in the long run is a fundamental question in macroeconomic analysis. A country is typically deemed to be fiscally sustainable when government revenues closely align with government expenditures and when the fiscal authorities manage to achieve a primary balance that essentially stabilises the debt-to-GDP ratio. The issue of fiscal sustainability is particularly relevant right now, as the average level of public debt in advanced OECD economies has increased from 37% in 1980 to 76% in 2021, with a significant rise of some 10 percentage points occurring during the Covid-19 crisis. On top of this, inflation has surged in the euro area since mid-2021 to levels reminiscent of the 1970s and the early 1980s, after a decade when it was below the target of 2%. This raises the question of whether higher inflation alleviates or aggravates the challenges associated with fiscal sustainability, but how inflation and its various components affect the indicators of debt sustainability remains insufficiently explored. This paper attempts to find an answer to the question by examining this relationship.

There is no universally accepted measure of fiscal sustainability. This study, like many other papers, uses the framework of Bohn (1998), which describes fiscal sustainability as the positive response of the primary balance in year t to the public debt-to-GDP ratio accumulated by the end of year $t-1$. There are two ways in which inflation may influence this fiscal response. One is that the expectation of higher inflation in year t increases expected nominal GDP, lowering the level of the public debt-to-GDP ratio expected by the end of year t . Fiscal authorities that expect the debt ratio to decline may in response increase expenditures and reduce tax rates, ultimately weakening the response from the primary balance in year t to the accumulated public debt. The other way inflation may exert an influence is that the fiscal authorities may view higher inflation as giving them an opportunity to strengthen the fiscal policy stance. They may do this by refraining from adjusting certain expenditures in line with the inflation rate, thereby reducing the value of the expenditure in real terms. In the first scenario, the response of the primary balance to the accumulated level of public debt would be expected to worsen, whereas in the second case, that measure of fiscal sustainability should improve.

The analysis in this paper is conducted using a sample of industrialised countries from the OECD and, separately, a more homogenous group of the euro area countries between 1981 and 2021. The study follows Afonso and Jalles (2017a), Afonso and Jalles (2017b) and Afonso and Coelho (2022) in employing the two-step approach. The first step is that the fiscal reaction function with time-varying coefficients is estimated for each country in the sample following the approach of Schlicht (2021a). The measure of fiscal sustainability that we use is the fiscal response coefficient that relates the primary balance to the lagged debt-to-GDP ratio in the fiscal reaction function. The second step is to analyse how important alternative measures of inflation such as the headline inflation rate, core inflation, energy inflation, and food inflation are for the fiscal response coefficient that was estimated previously. We do this by applying panel regression techniques and estimating the coefficients using the WLS.

The findings of this paper suggest that i) the measure of fiscal sustainability varies across countries and over time, ii) fiscal sustainability deteriorates during economic downturns, iii) higher rates of inflation help raise the level of fiscal sustainability, and iv) core inflation has the largest positive influence on fiscal sustainability. The latter suggests that the positive effect of inflation on fiscal sustainability is probably driven by demand factors.

The remainder of the paper is structured as follows. Section 2 presents a brief literature review. Section 3 explains the empirical strategy and data. Section 4 reports and discusses the empirical results and Section 5 concludes.

2. REVIEW OF LITERATURE

2.1. Backward-looking fiscal sustainability tests

There are two types of fiscal sustainability test, as there are backward-looking and forward-looking tests. Backward-looking tests determine whether policies for public debt and the primary balance have historically been consistent with meeting the intertemporal budget constraint (IBC). Forward-looking tests use forecasts for whether the current and future stances of fiscal policy are compatible with the IBC. Each type of test has its shortcomings. The backward-looking analysis does not allow that future fiscal policy may not be the same as the policy observed in the past, while the forward-looking analysis ignores the past and implies that any future behaviour may be consistent with the IBC if the public commitment to it is deemed credible (see Debrun et al. (2019) for a discussion on this).

The academic literature has primarily focused on backward-looking analysis, while also acknowledging its limitations. Earlier backward-looking tests of fiscal sustainability evolved around examinations of the stationarity of public debt and the budget balance Hamilton and Flavin (1986). Trehan and Walsh (1988) showed that even if both series appear non-stationary, fiscal solvency is satisfied as long as both series are cointegrated, meaning that larger debt is systematically associated with higher primary balances. Various papers such as Hakkio and Rush (1991), Haug (1995) and Quintos (1995) for the United States, Olekalns (2000) for Australia, Hatemi-J (2002) for Sweden, and Afonso and Jalles (2014) for 19 countries have conducted analysis of cointegration between budget revenues and expenditures. Afonso and Jalles (2014) take a longer-term perspective and cover the period 1880–2009. More recent literature has also used panel data techniques to explore panel cointegration relationships (Afonso and Rault (2010), Magazzino et al. (2019)).

Another strand of the literature uses the fiscal reaction function framework proposed by Bohn (1998) to assess the sustainability of fiscal policy. Bohn (1998) demonstrates that the intertemporal budget constraint may be satisfied with neither cointegration nor stationarity of the variables explaining the debt trajectory, and suggests that testing should span a relatively long time period if meaningful conclusions are to be drawn. He finds that the primary balance gives a positive marginal response to changes in public debt in the US. Mendoza and Ostry (2008) use a similar testing procedure and show that the fiscal response varies across countries. They specifically find that the fiscal response is stronger in emerging markets than in industrial ones, indicating that countries with emerging markets tend to converge to lower levels of mean public debt.

Afonso et al. (2021) use a sample of 28 European Union countries and a timespan from 1995 to 2021 and confirm the existence of the Ricardian fiscal regime, which became more prominent after the global financial crisis. In this fiscal regime, improvements in the primary government balance lead to greater reductions in the public debt-to-GDP ratio when there is a positive differential between the long-term real interest rate and the rate of economic growth, but this effect disappears when the differential is negative. Several papers that employ the framework of Bohn (1998) (e.g. Checherita-Westphal and Žďárek (2017), Ostry et al. (2010), Ghosh et al. (2013), or Tran (2018)) conclude that the ability to increase the primary balance in response to rising debt levels cannot last indefinitely. There is a debt limit beyond which there arises fiscal fatigue, which is the inability of the fiscal authorities to keep the primary balance at the necessary level.

Primary balances are influenced by various factors that warrant attention. One crucial factor is the difference between the cost to the government of long-term borrowing (r) and the rate of economic growth (g). Blanchard et al. (2021) explore the relevance of the differential between interest rates and growth within the framework of fiscal reaction functions. Afonso et al. (2021) similarly emphasise the significance of that differential, and their study reveals that a positive differential following improvements in the primary balance leads to a greater reduction in the debt- to-GDP ratio across a sample of 28 EU countries from 1995Q1 to 2021Q2. Tkačevs and Vilerts (2019) identify that the cost of government borrowing has a positive impact on primary balances. The fiscal policy response to the business cycle also plays a significant role in determining fiscal sustainability, and Aldama and Creel (2019) observe an asymmetric pattern whereby fiscal policy tends to be pro-cyclical during economic downturns but exhibits insensitivity during periods of growth in the economy.

2.2. Time-varying fiscal sustainability

The response of the primary balance to changes in the accumulated level of public debt may vary over time under the influence of shifts in the policies of the fiscal authorities. The factors affecting this variation are assessed by Mauro et al. (2015) using an estimation of the non-linear fiscal reaction function that incorporates interactions between the lagged debt ratio, real interest rates, surprises in real GDP growth, and various political variables. Their study notably does not provide an analysis of the inflation effect. Numerous papers, including Afonso and Jalles (2017a), Afonso and Jalles (2017b), Afonso and Coelho (2022), Saadaoui et al. (2022) and Afonso et al. (2023), estimate time- varying coefficients for fiscal sustainability for a range of countries using either the cointegration approach or Bohn's framework. These works examine the evolving nature of fiscal sustainability over time. The Schlicht (2003) estimation procedure is commonly used in these studies to estimate the time-varying coefficients for the fiscal response because it has several advantages over other methods, which are detailed in the next section.

Afonso and Jalles (2017a) focus their analysis on 11 euro area countries between 1999 and 2013, concluding that fiscal policy has been sustainable in Belgium, France, Germany, and the Netherlands. For their investigation they construct time-varying coefficients to examine how the primary government balance responds to the public debt-to-GDP ratio. They find that the global financial crisis had a negative impact on fiscal sustainability, while expenditure-based fiscal rules had a positive effect on it. Afonso and Jalles (2017b) estimate time-varying coefficients for 13 advanced economies, and their findings suggest that the degree of fiscal sustainability increases with the share of foreign currency debt, the share of longer-term debt, the share of debt held by the central bank, and the share of marketable debt. Afonso and Coelho (2022) provide evidence that economic growth and the presence of fiscal rules positively steer measures of fiscal sustainability, but trade openness, sovereign ratings, and the government effectiveness index have a negative effect on fiscal sustainability. In contrast to previous studies, Afonso et al. (2023) take an expanding window approach to estimate time-varying fiscal sustainability for 22 developed OECD countries. They employ panel data and quantile regression techniques to analyse the heterogeneity in how fiscal sustainability coefficients respond to a set of explanatory variables. However, none of these studies thoroughly examine how inflation and its components impact measures of fiscal sustainability.

2.3. Role of inflation

Examining the relationship between inflation and fiscal aggregates reveals several significant effects that inflation has. The well-known Olivera-Tanzi effect posits that high inflation can erode the real value of tax revenues when there is a delay in the collection of taxes (Olivera (1967); Tanzi (1977)). Another effect is that inflation may reduce real expenditure since expenditure is typically planned in nominal terms (Patinkin (1993); Cardoso (1998)).

A recent paper by Staehr et al. (2023) confirms the positive relationship between inflation and the primary balance and finds that the effect arises from both the revenue and expenditure sides. High inflation boosts indirect tax revenues from consumption taxes and VAT as prices rise, while also causing the real value of many government transfers to fall because they are defined in nominal terms. Moreover, wages in the public sector are generally not indexed in most countries, and so although there might be social pressure to maintain the real value of government benefits and wages, that value is usually only partially restored and after some delay. Garcia-Macia (2023) finds that inflation spikes also result in a persistent reduction in debt-to-GDP ratios that is driven both by improvements in the primary balance and by the impact of changes in nominal GDP.

Finally, there is also the Fiscal Theory of the Price Level (FTPL), which argues that inflation might be a consequence of active fiscal policies. In this telling, the government budget constraint plays a key role in determining the price level. Several studies have addressed this topic, notably Sargent and Wallace (1981), Leeper (1991), Sims (1994), Woodford (1995), and Cochrane (2001), and they propose a reverse link between fiscal sustainability or unsustainability and inflation. The study by Afonso and Jalles (2020) for instance observes a significant positive correlation between changes in the fiscal policy stance through year-on-year adjustments in the cyclically adjusted primary balance and inflation volatility, across a panel of 54 countries from 1980 to 2013. Contrary to this, Cevik and Miryugin (2023) report from a panel of 139 countries spanning from 1970 to 2021 that both headline and core inflation increase in response to expansionary fiscal policies.

As the review of the literature clearly shows, the impact of inflation on the indicators of debt sustainability has not yet been conclusively described. This paper aims to close this gap in the literature.

3. METHODOLOGY AND DATA

3.1. Backward-looking fiscal sustainability tests

As explained above, there is no universally acceptable backward-looking measure of fiscal sustainability. Arguably the most parsimonious measure of fiscal sustainability is Bohn's fiscal response coefficient (see Bohn (1998), Bohn (2007)). Bohn (1998) suggested a model-based sustainability framework, in which for a given country, its primary balance is linked to the lagged value of public debt-to-GDP ratio:

$$PB_t = \alpha_t + \beta D_{t-1} + \varepsilon_t \quad (1)$$

According to Bohn (1998), a positive response of primary balance to an increase in government debt in the previous period ($\beta > 0$) is sufficient to satisfy the IBC¹. Besides signalling the compatibility of fiscal policy with the IBC, the magnitude of the fiscal response coefficient is important as it enters the requirement for public debt dynamics to be stable. Thus, public debt is mean reverting if $\beta > \gamma$, where $\gamma = r - g$, r is interest rate and g is GDP growth rate (see Debrun et al. (2019) for details on public debt sustainability arithmetic). If this condition is fulfilled, then public debt converges to level d^* defined as $d^* = -k_*$. Higher values of β imply a bigger fiscal response to public debt and lead in the longer run to a lower debt-to-GDP ratio.

3.2 Response of the primary balance to public debt

In the first step, we estimate the fiscal reaction function for each country in our sample. To account for the cyclical component of the primary balance, we also add the output gap as an explanatory factor:

$$PB_t = \alpha_t + \beta D_{t-1} + \gamma \hat{Y}_{t-1} + \varepsilon_t \quad (2)$$

where PB_t is the primary balance-to-GDP ratio in year t , D_{t-1} is the public debt-to-GDP ratio lagged by one year, $\hat{Y}_{t-1}$ is the output gap lagged by one year and ε_t is a standard i.i.d. disturbance term in year t . The fiscal response coefficient β is thus estimated for each country and each year.

If estimated using OLS, this regression yields a single, time-invariant fiscal response coefficient. We are rather interested in a fiscal sustainability measure that is country-specific, but also changes over time. For this purpose, we estimate β as a time-varying coefficient using the Schlicht (2021a) method, which relies on the assumption that β changes “slowly and unsystematically over time”:

$$\beta_t = \beta_{t-1} + v_t, \quad (3)$$

where $v_t \sim N(0; \tau^2)$.

According to Schlicht (2021a) and Schlicht (2021b), equations 2 and 3 should be estimated jointly. This approach is a generalization of the standard linear model where the independent variables can (slowly) change over time (as opposed to remaining constant, as assumed in the linear model). As it is assumed that the fiscal response coefficient follows the random walk process, the expected value of this coefficient in time t is equal to its value in time $t - 1$. The change of the coefficients is denoted by v_t , which is assumed to be normally distributed with zero mean and variance τ^2 . The variances τ^2 are computed using a method of moments estimator, which coincides with the maximum-likelihood estimator for large samples, although it is statistically more efficient and numerically more transparent and straightforward to interpret in small samples. Thus, the standard regression model is a special case when τ^2 tends to zero, which in turn translates into $\beta_t = \beta_{t-1}$. By departing from this assumption and allowing τ^2 to be small but different from zero, we allow the coefficients to move slowly through time, departing from the previous year's coefficients but reflecting changes or departures from the stance that occurred in that year.

Schlicht's (2021a,b) approach has several advantages over other methods such as the rolling or expanding window estimation in estimating the time-varying fiscal reaction coefficient. One is that it allows all the observations in the sample to be used. Individual country regressions estimated over rolling or

¹ The problem with Bohn (1998) test of fiscal sustainability is that it does not rule out rising public debt ratios for a long period of time which by itself can trigger investors' concerns

expanding windows of predetermined length² provide a much shorter series for the fiscal reaction coefficient. A second advantage is that changes in the magnitude of the time-varying coefficients estimated for a given year come from innovations in the same year rather than from shocks that occur in other years. A third point is that it reflects how changes in policy are slow and depend on the immediate past.

3.3. Relationship between inflation and fiscal sustainability measure

In the second step, we use the time- and country-specific fiscal response coefficient β_{it} obtained previously as the dependent variable and regress it on a measure of inflation π_{it} . We also include the difference between the ten-year sovereign bond yield and the growth rate of the economy $(r-g)_{it}$ as a control factor, and the country fixed effects γ_i to account for time-invariant, country-specific, unobservable effects:

$$\beta_{it} = \theta_0 + \theta_1 \pi_{it} + \theta_2 (r - g)_{it} + \gamma_i + u_{it} \quad (4)$$

where u_{it} is the error term, θ_1 is the coefficient that captures the effect of inflation on fiscal responsiveness. If $\theta_1 > 0$, inflation improves the reaction of the primary balance to government debt. Since inflation is included as the main variable, we use the real GDP growth rate to calculate $r - g$. The dependent variable is the coefficient estimated previously, i.e. this is a measure and not a precise data point. Therefore, it is important to account for the fact that this measure is estimated more precisely for some observations than for others. In view of this, we use the weighted least squares (WLS), where each observation in the second step is weighted by the inverse of the standard error of the fiscal response coefficient obtained in the first step.

Fiscal response coefficients can differ from one country to another for a number of reasons, such as political and social pressures, country-specific laws and fiscal rules, election cycles, and so forth. Therefore we treat each country separately in the first step, and we do not exploit the panel nature of the data. Moreover, we do not use any control variables other than the output gap in that regression, since we are interested in a parsimonious and unconditional measure of fiscal sustainability. We do the opposite in the second step, because we aim to study how inflation impacts fiscal sustainability in developed OECD countries in general and in groups of countries such as the euro area, its core and its periphery in particular.

We use the headline CPI inflation rate as the key explanatory variable in the baseline estimation. To look more deeply into the source of the impact that inflation has on fiscal responsiveness, we also check whether the effect varies for different inflation components and run several more regressions that replace headline inflation with core inflation, energy inflation, and food inflation.

3.4. Data

This study uses the annual panel dataset of 35 current member countries of the Organization for Economic Cooperation and Development (OECD). Three countries, namely Costa Rica, Columbia and Estonia, are excluded because data are unavailable for certain series, as there are no data available on the ten-year sovereign bond yield for Estonia for instance. Our estimations are conducted both for the entire sample and

² Mauro et al. (2015) suggest that the shortest time span should be at least 25 years if meaning full estimates of the fiscal response coefficient are to be obtained. Afonso et al. (2023) use an expanding window that starts with 20 years.

for a more homogeneous subgroup of countries within the euro area. The estimations cover the period from 1980 to 2021, but the starting year for each country depends on the availability of data, as indicated in Table A.1 in the Appendix. The data used in our analysis are sourced from the databases of the OECD and the International Monetary Fund (IMF). Table

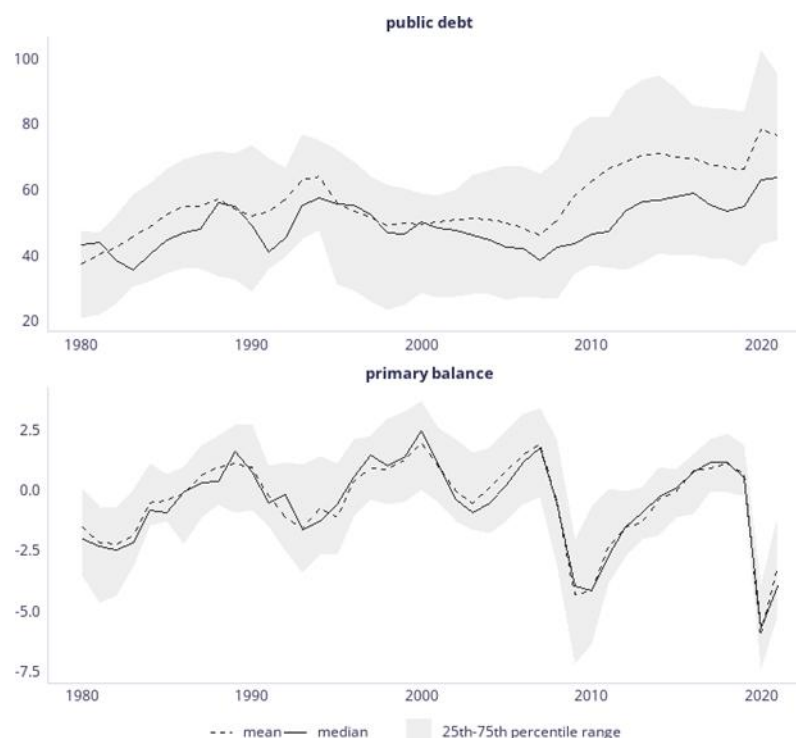
A.2 in Appendix A presents the variables employed in our analysis along with their sources, while Table A.3 presents the corresponding descriptive statistics.

Across the entire sample of OECD countries, the average primary balance stands at -0.37% of GDP, with the public debt-to-GDP ratio averaging 59.2%. The average value for the output gap is negative at -0.5% of potential GDP. The mean inflation rate is heavily influenced by outliers³, while the median value hovers around 3%. Core inflation remains below this value, but energy inflation exceeds it. Norway, which is a commodity-producing country, has the highest values for the primary balance, while Japan, Italy and Belgium have high debt-to-GDP ratios. The highest mean inflation rates have historically been seen in Turkey and several Central and Eastern European countries such as Hungary and Slovakia.

Figure 1 depicts the primary balance and the debt-to-GDP ratio for the full sample of countries. It presents the simple averages and medians for these variables for each year in the sample, with the shaded areas representing the range between the 25th and 75th percentiles. Sharp declines in primary balances are observed during periods of crisis, including the recession in the 1990s, the dot-com crisis in the early 2000s,

the Great Recession from 2008 to 2011, and the Covid-19 crisis from 2020 to 2021. Although the primary balances managed to recover following these events, it took several years for the fiscal stance to be restored after the Great Recession. Consequently, the trajectory of the public debt-to-GDP ratio was gradually rising during the second decade of the 2000s.

³ Those outliers are not part of the estimation sample (see Table A.4)

Figure 1. Primary balance and public debt in OECD countries, 1980-2021

Source: IMF, OECD

4. RESULTS

4.1. Estimates of fiscal responsiveness

As outlined in the Methodology section, we use the method of Schlicht (2003, 2021a,b) to gauge the time-varying coefficients that link the primary balance to the lagged public debt-to-GDP ratio for each OECD country. There is a clear and direct interpretation of these coefficients, as a coefficient value of 0.05 for instance implies that an increase of 10 percentage points in the public debt ratio corresponds to an improvement in the next year of 0.5 percentage point in the primary balance expressed as a ratio to the country's GDP, assuming that the output gap remains constant.

Figure 2 displays the evolution of the median value of the estimated mean of the fiscal response coefficient, alongside its interquartile range, for the set of OECD countries.⁴

⁴The interquartile range should not be confused with the confidence band around the mean value of the coefficient. This is the interquartile range of the mean coefficients for all countries in every year. The coefficient for each individual country may be statistically significant or insignificant in any given year irrespective of whether the range of the estimated means of the coefficient across countries includes zero.

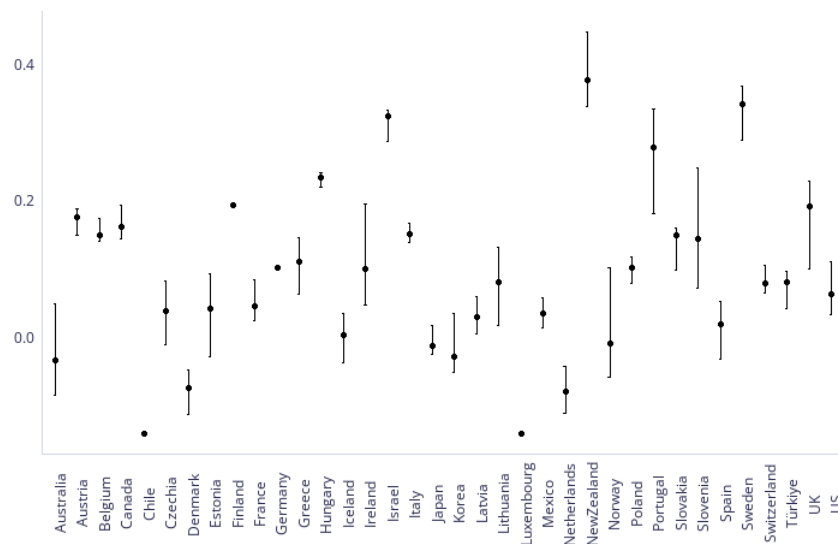
Figure 2. Developments of the fiscal response coefficient, 1980-2021



Source: Authors' estimation

The median value increases gradually, starting at 0.05 in 1980, reaching 0.1 around 2007, dipping just below zero in 2009, and subsequently stabilising at approximately 0.04 during the latter half of the 2010s, after which it notably falls substantially below zero in 2020. This pattern is observed in numerous individual countries as well.

Figure 3. Fiscal response coefficient by country



Source: Authors' estimation

Figure 3 illustrates the fiscal response coefficients for individual OECD countries. Each point denotes the average value throughout the period when data are available, and the whiskers surrounding each point indicate the entire range encompassed by this coefficient. Whether the range includes or excludes zero says nothing about the statistical significance of the coefficient. Table C1 in the Appendix shows for each decade of the time sample the share of countries where the coefficient is above zero and statistically significant, meaning the countries that were following a sustainable fiscal policy in that decade. There is considerable variation across countries in the cross-time median and the range of values of the fiscal response coefficient. New Zealand, Sweden, Israel, Portugal, Hungary, and Finland have the highest median values for the fiscal response coefficient among the countries examined, while Chile, Finland, Germany, and Luxembourg have a very narrow range for the coefficient estimate.

4.2. Impact of inflation on fiscal responsiveness

We next use the fiscal response coefficient estimated previously as the dependent variable, and regress it on HICP inflation while controlling for the differential labelled $r-g$ between the interest rate from the ten-year sovereign bond yield and output growth. Following the approach described in Section 3, we first test whether the fiscal response coefficient is cointegrated with each measure of inflation. Most test results signal that there is cointegration (see Table B.1 in the Appendix), hence the regression is well-specified in levels.

The estimation results for HICP headline inflation are presented in Table 1. The columns in the table correspond to the different specifications of the regression, including one with $r-g$ as a control and one without it. The first two columns display the results estimated for the entire OECD sample, while the last two columns focus on the estimation results for the euro area countries. It is important to note that all the panel regressions use country-fixed effects but do not incorporate time-fixed effects.

The findings for the impact of inflation indicate that fiscal policy makers tend to tighten the fiscal stance more forcefully as inflation increases in response to a given rise in public debt. This outcome is aligned with those found by the earlier studies conducted by Afonso and Jalles (2017b) and Afonso and Coelho (2022)), which considered headline inflation as a control variable. That inflation has a positive impact may suggest that the fiscal authorities are using inflation strategically as a tool to tighten the fiscal stance, perhaps by not fully adjusting expenditure.

Table 1. The effect of headline inflation on fiscal responsiveness

Variable	(1)	(2)	(3)	(4)
HICP inflation	0.0026** (0.0012)	0.0067*** (0.0019)	0.0063*** (0.0014)	0.0094*** (0.0024)
R-G		-0.0025*** (0.0006)		-0.0025*** (0.0009)
Constant	0.0741*** (0.0036)	0.0731*** (0.0043)	0.0734*** (0.0042)	0.0749*** (0.0053)
Country group	OECD	OECD	EA	EA
Observations	1,085	1,006	523	484
R-squared	0.026	0.066	0.142	0.181
# of countries	36	35	17	16

Notes: The dependent variable is the response of the primary government balance to a unit change in public debt lagged by one period, where both variables are a percentage of GDP. The sample consists of annual panel data for the OECD countries (columns 1-2) and the euro area countries (column 3-4) over the time period 1980-2021. The estimation is performed using WLS (weighted least square). Country fixed effect is included. *, **, and *** denote significance at the level of 0.1, 0.05, and 0.01 respectively

For the sample of OECD countries, an increase of one percentage point in the inflation rate is associated with an increase in the fiscal response coefficient of 0.0026 if the control variable is not considered, and of 0.0067 if the negative impact of $r-g$ is taken into consideration; the difference arises because inflation and the interest rate-growth differential are positively correlated. This indicates that the primary balance improves by an additional 0.007 percentage point on average with each additional percentage point of inflation. For a country with a fiscal response coefficient of, say, 0.05, which corresponds to the median of the OECD sample, this represents a substantial 14% increase in fiscal responsiveness when inflation rises by one percentage point. The magnitude of this effect is somewhat larger for the sample of euro area countries, where each additional percentage point of inflation leads to an increase of 0.0063-0.0094 in the fiscal response coefficient depending on whether the impact of $r-g$ is accounted for.

We next investigate whether the extent of fiscal policy tightening varies for different types of inflation. Core inflation is often regarded as a measure of demand-driven inflation, while food and energy inflation are understood to indicate cost-push inflation. Unfortunately, the OECD database does not offer a breakdown of food inflation into its components of processed food, which is driven by both demand and supply, and unprocessed food, which is mostly supply-driven. We consequently use energy inflation as the most appropriate proxy for cost-push inflation, but we also provide separate results from food inflation.

Table 2. The effect of core inflation on fiscal responsiveness

Variable	(1)	(2)	(3)	(4)
HICP core inflation	0.0035*** (0.0011)	0.0079*** (0.0020)	0.0059*** (0.0013)	0.0102*** (0.0025)
R-G		-0.0029*** (0.0007)		-0.0032*** (0.0010)
Constant	0.0731*** (0.0031)	0.0721*** (0.0042)	0.0817*** (0.0038)	0.0835*** (0.0047)
Country group	OECD	OECD	EA	EA
Observations	1,067	1,006	516	481
R-squared	0.041	0.084	0.139	0.222
# of countries	36	35	17	16

Notes: The dependent variable is the response of the primary government balance to a unit change in public debt lagged by one period, where both variables are a percentage of GDP. The sample consists of annual panel data for the OECD countries (columns 1-2) and the euro area countries (column 3-4) over the time period 1980-2021. The estimation is performed using WLS (weighted least square). Country fixed effect is included. *, **, and *** denote significance at the level of 0.1, 0.05, and 0.01 respectively

Tables 2 to 4 present the estimation results from Equation 4 for three different inflation measures: core inflation, energy inflation, and food inflation. Core inflation emerges as the primary driver behind the increase in the fiscal response coefficient, as an increase of one percentage point in the core inflation rate is associated with growth in the fiscal response coefficient of 0.0082 in the OECD sample, or 0.0097 in the euro area, which slightly exceeds the point estimate for the headline inflation coefficient.

Table 3. The effect of energy inflation on fiscal responsiveness

Variable	(1)	(2)	(3)	(4)
HICP energy inflation	0.0007*** (0.0002)	0.0006** (0.0002)	0.0006* (0.0003)	0.0004 (0.0002)
R-G		-0.0011 (0.0007)		-0.0009 (0.0009)
Constant	0.0805*** (0.0008)	0.0837*** (0.0022)	0.0972*** (0.0013)	0.101*** (0.0032)
Country group	OECD	OECD	EA	EA
Observations	1,071	1,006	520	481
R-squared	0.009	0.011	0.009	0.011
# of countries	36	35	17	16

Notes: The dependent variable is the response of the primary government balance to a unit change in public debt lagged by one period, where both variables are a percentage of GDP. The sample consists of annual panel data for the OECD countries (columns 1-2) and the euro area countries (column 3-4) over the time period 1980-2021. The estimation is performed using WLS (weighted least square). Country fixed effect is included. *, **, and *** denote significance at the level of 0.1, 0.05, and 0.01 respectively

In contrast, energy inflation appears to have a negligible effect and is found to be insignificant in the euro area. The effect of food inflation lies somewhere in between.

Table 4. The effect of food inflation on fiscal responsiveness

Variable	(1)	(2)	(3)	(4)
HICP food inflation	0.0019* (0.0010)	0.0035*** (0.0012)	0.0046*** (0.0010)	0.0059*** (0.0019)
R-G		-0.0016** (0.0007)		-0.0016** (0.0007)
Constant	0.0764*** (0.0030)	0.0777*** (0.0033)	0.0864*** (0.0027)	0.0889*** (0.0040)
Country group	OECD	OECD	EA	EA
Observations	1,068	996	510	471
R-squared	0.016	0.034	0.097	0.114
# of countries	36	35	17	16

Notes: The dependent variable is the response of the primary government balance to a unit change in public debt lagged by one period, where both variables are a percentage of GDP. The sample consists of annual panel data for the OECD countries (columns 1-2) and the euro area countries (column 3-4) over the time period 1980-2021. The estimation is performed using WLS (weighted least square). Country fixed effect is included. *, **, and *** denote significance at the level of 0.1, 0.05, and 0.01 respectively

The finding that core inflation has a stronger effect and energy inflation⁵ has limited significance probably arises because higher cost-push inflation leads to considerable political and social pressure to offset rising living costs, and this then compels the fiscal authorities to take the necessary measures to compensate.

It is likely that the impact of inflation is not linear and may depend on the inflation rate itself, meaning the inflation effect is non-linear. To investigate this hypothesis, we conduct additional analysis and present the estimation results in Table 5.

Our first observation is that the effect of inflation diminishes as inflation itself increases. In other words, inflation cannot continually improve the fiscal response, as there is a threshold beyond which real expenditure cannot decrease further, and real revenue cannot rise any higher, because adjustments are needed to nominal revenue and expenditures to ensure the public sector keeps functioning properly and to preserve a certain pattern of income distribution within society.

We next examine the differential impact of inflation on fiscal sustainability for the core and periphery countries of the euro area. The euro area periphery for this purpose is taken as Portugal, Italy, Ireland, Greece and Spain.⁶ To perform this analysis we introduce an interaction term to account for periphery countries within the euro area. The findings reported in Table 6 reveal that the effect observed in the core countries of the euro area is slightly smaller than that of the overall euro area, and there is a marginal loss of significance. However, fiscal sustainability displays a significantly stronger response to higher inflation in the periphery countries than it does in the core countries. It is essential to emphasise here that inflation having a relatively more substantial impact on the fiscal response coefficient in the periphery should not automatically be interpreted as indicating that fiscal policy there is more sustainable. Drawing from Mendoza and Ostry (2008), these results may suggest that fiscal behaviour in these countries comes with greater risk

⁵ We also tested whether the difference between the effects of these two inflation components is statistically significant. We included both inflation measures in single regressions (1) to (6) and conducted a t-test of the H0 that the two estimated coefficients are equal. The test results allow us to reject H0 for all six regressions.

⁶ See Afonso et al. (2014) for the split between core and periphery euro area countries.

in budget revenues and more volatility in expenditures. Consequently, a more robust response from the primary balance is required to an increase of similar magnitude in public debt, and inflation may simply serve as a tool for achieving this objective.

Table 5. The effect of headline inflation with a quadratic term on fiscal responsiveness

Variable	(1)	(2)	(3)	(4)
HICP inflation	0.00472** (0.0019)	0.0132*** (0.0027)	0.0142*** (0.0039)	0.0166*** (0.0045)
HICP inflation squared	0.000 (0.000)	-0.0006*** (0.0002)	-0.0006** (0.0002)	-0.0007** (0.0003)
R-G		-0.0023*** (0.0006)		-0.0022** (0.0008)
Constant	0.0699*** (0.0047)	0.0646*** (0.0051)	0.0612*** (0.0076)	0.0647*** (0.0075)
Country group	OECD	OECD	EA	EA
Observations	1,085	1,006	523	484
R-squared	0.037	0.089	0.192	0.212
# of countries	36	35	17	16

Notes: The dependent variable is the response of the primary government balance to a unit change in public debt lagged by one period, where both variables are a percentage of GDP. The sample consists of annual panel data for the OECD countries (columns 1-2) and the euro area countries (column 3-4) over the time period 1980-2021. The estimation is performed using WLS (weighted least square). Country fixed effect is included. *, **, and *** denote significance at the level of 0.1, 0.05, and 0.01 respectively.

Table 6. The effect of headline inflation on fiscal responsiveness in the euro area's core and periphery countries

Variable	(1)	(2)
HICP inflation	0.0048 (0.0030)	0.0056* (0.0030)
HICP inflation # EA Periphery dummy	0.0022 (0.0035)	0.0082* (0.0039)
R-G		-0.0025** (0.0009)
Constant	0.0747*** (0.0054)	0.0765*** (0.0053)
Country group	EA	EA
Observations	523	484
R-squared	0.146	0.222
# of countries	17	16

Notes: The dependent variable is the response of the primary government balance to a unit change in public debt lagged by one period, where both variables are a percentage of GDP. The sample consists of annual panel data for the euro area countries over the time period 1980-2021. The periphery is Portugal, Italy, Ireland, Greece and Spain. The estimation is performed using WLS (weighted least square). Country fixed effect is included. *, **, and *** denote significance at the level of 0.1, 0.05, and 0.01 respectively.

4.3. Robustness

This section reports the results of the robustness analysis. It initially focuses on the importance of the time period chosen, as the estimation results may be influenced by two significant events during this period, the Great Recession in 2008-2011 and the Covid-19 crisis in 2020-2021. To ensure that our results are not driven by those events we exclude these years and re-estimate the regressions. We then focus on the period of euro adoption for the euro area, and we re-estimate the regressions for the time between 2000 and 2021.

Table 7. The reduced effect of headline inflation on fiscal responsiveness in 2008-2011 and 2020-2021

Variable	(1)	(2)	(3)	(4)
HICP inflation	0.0016 (0.0017)	0.0065*** (0.0016)	0.0045*** (0.0011)	0.0076*** (0.0022)
R-G		-0.0030*** (0.000824)		-0.0024** (0.0009)
Constant	0.0847*** (0.0034)	0.0824*** (0.0039)	0.0874*** (0.0035)	0.0875*** (0.0046)
Country group	OECD	OECD	EA	EA
Observations	905	831	438	404
R-squared	0.015	0.063	0.118	0.146
# of countries	36	35	17	16

Notes: The dependent variable is the response of the primary government balance to a unit change in public debt lagged by one period, where both variables are a percentage of GDP. The sample consists of annual panel data for the OECD countries (columns 1-2) and the euro area countries (column 3-4) over the time period 1980-2021. The estimation is performed using WLS (weighted least square). Country fixed effect is included. *, **, and *** denote significance at the level of 0.1, 0.05, and 0.01 respectively

The estimation results when the two recessions are excluded from the sample are reported in Table 7. The impact of inflation on the measure of fiscal sustainability remains comparable to that in the baseline shown in Table 1. Focusing on the shorter sample for the euro area does not markedly affect this result, as the inflation coefficient loses some of its significance, but its magnitude increases a little (see Table 8).

Table 8. The effect of headline inflation on fiscal responsiveness estimated for the euro area countries in 2000-2021

Variable	(1)	(2)
HICP inflation	0.0109** (0.0043)	0.0108** (0.0050)
R-G		-0.0025*** (0.0008)
Constant	0.0559*** (0.0081)	0.0627*** (0.0085)
Country group	EA	EA
Observations	371	346
R-squared	0.116	0.170
# of countries	17	16

Notes: The dependent variable is the response of the primary government balance to a unit change in public debt lagged by one period, where both variables are a percentage of GDP. The sample consists of annual panel data for the euro area countries over the time period 2000-2021. The estimation is performed using WLS (weighted least square). Country fixed effect is included. *, **, and *** denote significance at the level of 0.1, 0.05, and 0.01 respectively.

To scrutinise further the robustness of our results for the specification of the fiscal reaction function used in the initial step, we estimate the fiscal reaction function while excluding the output gap from the set of control variables, which gives an alternative series for the fiscal response coefficient. After this we re-estimate the second-step regressions. The findings, detailed in Table 9, confirm that inflation has a positive and statistically significant impact, though the magnitude of the effect is somewhat reduced.

Table 9. The effect of headline inflation on fiscal responsiveness defined without the output gap

Variable	(1)	(2)	(3)	(4)
HICP inflation	0.0022** (0.0011)	0.0048*** (0.0017)	0.0035** (0.0016)	0.0058** (0.0023)
R-G		-0.0034*** (0.0008)		-0.0038*** (0.0011)
Constant	0.0430*** (0.0039)	0.0450*** (0.0047)	0.0532*** (0.0049)	0.0561*** (0.0063)
Country group	OECD	OECD	EA	EA
Observations	1,085	1,006	520	481
R-squared	0.017	0.066	0.042	0.141
# of countries	36	35	17	16

Notes: The dependent variable is the response of the primary government balance to a unit change in public debt lagged by one period, where both variables are a percentage of GDP. The sample consists of annual panel data for the OECD countries (columns 1-2) and the euro area countries (column 3-4) over the time period 1980-2021. The estimation is performed using WLS (weighted least square). Country fixed effect is included. *, **, and *** denote significance at the level of 0.1, 0.05, and 0.01 respectively.

Table 10: The effect of headline inflation on fiscal responsiveness with r-g calculated using the nominal GDP growth rate

Variable	(1)	(2)	(3)	(4)
HICP inflation	0.0026** (0.0012)	0.0045** (0.00172)	0.0057*** (0.0014)	0.0062*** (0.0021)
R-G		-0.0068*** (0.0007)		-0.0026** (0.0009)
Constant	0.0741*** (0.0036)	0.0723*** (0.0043)	0.0828*** (0.0042)	0.0846*** (0.0052)
Country group	OECD	OECD	EA	EA
Observations	1,085	1,006	520	481
R-squared	0.026	0.078	0.124	0.176
# of countries	36	35	17	16

Notes: The dependent variable is the response of the primary government balance to a unit change in public debt lagged by one period, where both variables are a percentage of GDP. The sample consists of annual panel data for the OECD countries (columns 1-2) and the euro area countries (column 3-4) over the time period 1980-2021. The estimation is performed using WLS (weighted least square). Country fixed effect is included. *, **, and *** denote significance at the level of 0.1, 0.05, and 0.01 respectively.

Additionally, we explore whether the results remain consistent when the r-g variable is calculated as the difference between the nominal interest rate from the ten-year sovereign bond yield and the nominal rate of GDP growth. Once again, the estimated impact of inflation is negative and statistically significant, as presented in Table 10, though it is slightly smaller in magnitude. Finally, we calculate r-g using an average,

or effective, interest rate⁷ instead of the sovereign bond yield. The estimated coefficients are very similar to those obtained above.⁸

5. CONCLUSIONS

This study adopts a two-step approach to investigate the relevance of inflation for fiscal sustainability. We first estimate a time-varying fiscal response coefficient, which serves as a measure of fiscal sustainability, and we establish the relationship between the primary balance and the lagged public debt-to-GDP ratio in the fiscal reaction function. We then analyse how various inflation measures impact the fiscal response coefficients derived previously, considering headline inflation, core inflation, energy inflation, and food inflation.

We establish in the first step that there is significant volatility in the measure of fiscal sustainability across countries and over different time periods, and it has a tendency to deteriorate during economic downturns. These dynamics are expected, as they correspond to a countercyclical fiscal policy whereby governments support businesses and households with more spending in an economic slowdown, even though the higher debt-to-GDP ratio then requires improvements in the primary balance.

The key finding of this study is that higher inflation rates have a positive impact on the measure of fiscal sustainability. The results show that the primary balance improves on average when the public debt is larger, and this relationship strengthens when inflation is rising. The magnitude of the improvement in fiscal sustainability in response to inflation depends on the type of inflation considered, as the largest positive effect is observed for core inflation, which is mostly demand-driven, while energy inflation tends to have an insignificant effect. Moreover, we find that fiscal sustainability exhibits a significantly stronger response to higher inflation in the euro area periphery countries than it does in the core countries. The impact of inflation on the measure of fiscal sustainability remains consistent with the baseline findings even after numerous robustness checks, for which we exclude the Great Recession of 2008-2011 and the Covid-19 crisis of 2020-2021 as two major events that might have influenced the estimation results, redefine fiscal sustainability by disregarding the output gap in the first step, and use different definitions of $r-g$.

This study is the first to analyse thoroughly the positive impact that inflation has on fiscal sustainability. Understanding this relationship is more important today as two factors are currently coinciding, since the level of public debt is historically high in many countries around the world, and inflation is also high. The findings imply that the ongoing burst of higher inflation might help ameliorate fiscal sustainability problems. This is likely to be the case because high inflation makes it easier for governments to readjust the real value of certain revenue and expenditure items by deciding whether and by how much to readjust their value in nominal terms. At the same time, the results indicate that the effects vary over various inflation measures and with the underlying source of the inflation shock, since only demand-driven inflation seems to improve fiscal sustainability, whereas inflation caused by an energy price shock is not associated with improved fiscal responsiveness.

⁷ As a ratio of government budget interest payments in year t and the public debt stock in year $t - 1$.

⁸ The estimation results are not reported for the sake of brevity and are available upon request.

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APPENDICES

A.Data

Table A.1. Data samples

Country	Time sample	Country	Time sample
Australia	1991-2021	Latvia	2001-2021
Austria	1989-2021	Lithuania	2004-2021
Belgium	1981-2021	Luxembourg	1996-2021
Canada	1981-2021	Mexico	2001-2021
Chile	2004-2021	Netherlands	1996-2021
Czechia	2000-2021	New Zealand	1996-2021
Denmark	1993-2021	Norway	1981-2021
Finland	1981-2021	Poland	2000-2021
France	1981-2021	Portugal	1991-2021
Germany	1992-2021	Slovakia	1996-2021
Greece	1996-2021	Slovenia	2002-2017
Hungary	1999-2021	Spain	1981-2021
Iceland	1992-2021	Sweden	1994-2021
Ireland	1996-2021	Switzerland	1991-2021
Israel	2000-2021	Türkiye	2005-2021
Italy	1989-2021	United Kingdom	1981-2021
Japan	1981-2021	United States	2002-2021
Korea	1996-2021		

Table A.2. List of variables used in the study, their definition and source

Variable	Data source	Definition
Primary balance	OECD	General government net borrowing, excluding interest payable, % of GDP
Output gap	OECD	Gap between actual and potential GDP, % of potential GDP
Public debt	OECD	General government consolidated gross debt, % of GDP
CPI inflation	OECD	Annual average rate of change in CPI, %
CPI core inflation	OECD	Annual average rate of change in CPI (all items non-food non-energy), %
CPI energy inflation	OECD	Annual average rate of change in CPI (energy), %
CPI food inflation	OECD	Annual average rate of change in CPI (food and non-alcoholic beverages), %
Interest rate	OECD	Nominal long-term interest rate (10-year sovereign bond yield), %
GDP growth	OECD	Change in GDP at constant prices, %
Current account balance	OECD	Current account balance, % of GDP

Table A.3. Descriptive statistics – whole sample

Variable	Mean	Median	Standard Deviation	Min	Max
Primary balance	-0.371	-0.243	3.597	-29.896	15.826
Output gap	-0.5	-0.346	3.103	-17.07	17.145
Public debt	59.186	50.902	38.7	3.765	259.433
CPI inflation	11.41	2.925	58.912	-4.478	1281.444
CPI core inflation	5.787	2.4	17.31	-4.304	371.939
CPI energy inflation	7.176	4.491	19.942	-23.027	376.594
CPI food inflation	7.118	2.807	27.622	-13.846	773.987
Interest rate	6.03	5.042	4.447	-0.524	29.742
GDP growth	2.751	2.781	3.275	-14.839	25.383
Current account balance	-0.977	-0.729	11.785	-172.09	78.82

Table A.4. Descriptive statistics – estimation sample

Variable	Mean	Median	Standard Deviation	Min	Max
Primary balance	-0.391	-0.346	3.732	-29.896	15.826
Output gap	-0.582	-0.396	2.993	-17.07	17.145
Public debt	63.971	55.993	39.111	3.902	259.433
CPI inflation	2.584	2.14	2.381	-4.478	15.402
CPI core inflation	2.459	1.921	2.345	-4.304	14.748
CPI energy inflation	3.756	3.548	7.069	-20.27	44.519
CPI food inflation	2.525	2.047	3.011	-7.914	18.263
Interest rate	5.017	4.553	3.613	-0.524	22.498
GDP growth	2.294	2.405	3.026	-14.839	25.383
Current account balance	-0.597	0.082	13.479	-172.09	78.82

B. Cointegration

Table B.1. Cointegration between fiscal responsiveness and inflation

Test \ Inflation	Headline	Core	Energy	Food
Westerlund				
1. All panels	-3.7712 (0.0001)	-4.3020 (0.0000)	-3.0428 (0.0012)	-3.5699 (0.0002)
2. Some panels	-4.1790 (0.0000)	-4.0284 (0.0000)	-2.0800 (0.0188)	-2.7405 (0.0031)
Pedroni				
1. Modified Phillips-Perron t	-0.6394 (0.2613)	-0.7244 (0.2344)	0.2564 (0.3988)	-0.2019 (0.4200)
2. Phillips-Perron t	1.7511 (0.0400)	1.7457 (0.0404)	2.7307 (0.0032)	1.9064 (0.0283)
3. Adjusted Phillips-Perron t	2.7847 (0.0027)	2.7527 (0.0030)	3.7425 (0.0001)	2.0374 (0.0208)
Kao				
1. Modified Dickey-Fuller t	0.8966 (0.1850)	0.5976 (0.2750)	-1.6198 (0.0526)	2.2383 (0.0126)
2. Dickey-Fuller t	0.7313 (0.2323)	0.4938 (0.3093)	-1.0176 (0.1544)	2.1543 (0.0156)
3. Augmented Dickey-Fuller t	-1.8472 (0.0324)	-2.0107 (0.0222)	-3.6420 (0.0001)	-0.0254 (0.4899)
4. Unadjusted modified Dickey-Fuller t	-2.4982 (0.0062)	-2.5244 (0.0058)	-1.8976 (0.0289)	-2.5076 (0.0061)
5. Unadjusted Dickey-Fuller t	-1.7146 (0.0432)	-1.6867 (0.0458)	-1.1794 (0.1191)	-1.7382 (0.0411)

Notes: Results of cointegration tests between dependent variable β_{it} and independent variable π_{it} in Equation 5. For the inflation measure, the headline, core, energy and food inflation rates are used in turn. Westerlund Test 1. H_0 : No cointegration. H_a : Some panels are cointegrated. Westerlund Test 2. H_0 : No cointegration. H_a : All panels are cointegrated. Pedroni. H_0 : No cointegration. H_a : All panels are cointegrated. Kao. H_0 : No cointegration. H_a : All panels are cointegrated.

C. Fiscal responsiveness

Table C.1. The share of countries with a responsive fiscal policy

Decade	OECD	Euro Area
1980s	37.5%	40.9%
1990s	42.2%	55.0%
2000s	38.6%	42.0%
2010s	34.4%	39.4%
2020-2021	18.1%	23.5%

Notes: The percentage shows the average share of countries in each decade that conduct a sustainable fiscal policy that is sufficiently responsive to the debt-to-GDP ratio, where the β_t coefficient in Equation 2 is statistically significantly above zero at the 95% confidence level.

Inflation-Linked Bonds are not a Good Instrument for Financing Government Debt in Emerging and Developing Economies: A View from Risk-Return Analysis

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Abstract

We investigate why inflation-linked (CPIL) instruments are not used much by governments of developing and emerging market economies despite many potential benefits of such instruments for lenders, borrowers as well as financial stability of the borrowing economies. We show theoretically and empirically that the limited utilization of CPIL instruments may owe to inferior risk-return characteristics of these instruments compared to other alternatives, e.g. in foreign currency (FCY) or in plain local currency (LCY). We find that CPIL instruments bring higher risk-adjusted borrowing costs than these alternative forms of borrowing, which may contribute to their lower use. Furthermore, we show that investors are more likely to be interested in CPIL instruments than borrowers, *ceteris paribus*. We show that CPIL instruments are not suitable for economies with strong control over the exchange rate and weak control of inflation. Neither are they suitable for countries with large volatility in the real exchange rate and terms-of-trade.

Keywords: Inflation-linked bonds, Emerging market economies, Sovereign debt, Risk-return analysis

JEL Codes: E44

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1. INTRODUCTION

There seem substantial benefits to investors, borrowers as well as local regulators from considering CPI-linked (CPIL) financing. For many developing and emerging market economies CPIL instruments may be a cheaper form of local currency (LCY) financing than fixed-rate LCY or foreign currency (FCY) instruments. For investors with a hard-currency balance sheet, CPIL instruments can offset the exchange risk involved in LCY lending with an inflation risk, thus providing for lower market risk premiums and more affordable and plentiful LCY financing. For borrowers, the interest risk in CPIL products may often be lower than in FCY financing (when expressed in an LCY equivalent) and can be hedged naturally through a link between the borrower's LCY revenues and inflation. For country authorities, CPIL financing is free from systemic financial stability risks involved in FCY borrowing, stimulates financial sector development and incentivizes a welfare-improving low inflation environment (Panizza and Taddei, 2020, Abbas and Rogoff, 2019).

Yet, despite all these benefits, CPIL financing is not used often. According to publicly available data on government debt, there have been only 346 issues of CPIL bonds in the past 15 years by 16 countries out of a total of 69 developing and emerging market economies in our sample.^{1 2}

This contrasts with 13710 issues of FCY and LCY bonds issued by the same countries over the same period in total. Even the countries that have issued some CPIL have also issued FCY and plain LCY instruments during the same period.

In this paper, we investigate why the CPIL instruments are used so scarcely in financing the investments in developing and emerging market economies. We use a simple risk-return preference framework for analyzing the trade-offs facing the lender and borrower when considering CPIL instruments relative to the more conventional FCY or plain LCY instruments. We focus on the market risk the borrowers and lenders take in these instruments and develop theoretical conditions under which CPIL loans can bring a cheaper source of LCY financing for developing economies than FCY and plain LCY instruments.

We show that in certain cases CPIL instruments can offset the exchange risk otherwise involved in LCY lending with an inflation risk, thus providing for lower market risk premiums and more affordable LCY financing. Specifically, we show that the benefits of CPIL for the borrower are most likely to arise in the environment with positive and high correlation between exchange rate depreciation and inflation, but low volatility in the real exchange rate. As a consequence, CPIL financing should work best in the economies with high business cycle volatility in inflation and exchange rate, but not necessarily commodity rich, because it provides protection against business cycle volatility, but not against shocks to terms-of-trade, real exchange rate and other fundamentals.

Perhaps surprisingly, we also find the economies with good inflation control are better suited for CPIL instruments than those with a high degree of exchange rate control, *ceteris paribus*. There is little reason to invest through CPIL instruments in credibly pegged currencies, because inflation is an unnecessary source of additional risk. LCY or FCY instruments provide safer alternatives.

However, our analysis also demonstrates that the CPIL borrowing will unlikely bring the same reward for the market risk borrowers take as the plain LCY or FCY alternatives. This is because such an adequate reward would require perfect correlation between inflation and nominal depreciation, which is a practical impossibility. We show that the risk-adjusted costs of CPIL instruments will always be

¹ There have probably been more CPIL loan instruments provided to the private sector in the EMEs over-the-counter. However, such data are not publicly available.

² We exclude developed economies from this version of the analysis.

higher than those of conventional FCY and LCY alternatives. As a result, the borrower has, other things being equal, always a greater incentive to borrow in LCY or FCY than through a CPIL instrument.

Furthermore, we find that the CPIL borrower can never be compensated for the market risk as well as the CPIL investor, putting a wedge between the incentives of both parties to engage in CPIL financing and making CPIL more attractive for the investor than the borrower.

We back these theoretical findings with empirical analysis of ex post macroeconomic data. Overall, we find robust support to our assertion that the risk-return characteristics given by the macroeconomic environment are an important factor in determining the attractiveness of CPIL financing. Most CPIL-issuing economies have met the inflation-exchange rate correlation condition. Only one out of 16 CPIL-issuing economies in our sample has not satisfied these conditions at all. Moreover, the group of CPIL bond issuing countries could have achieved much lower risk-adjusted costs of CPIL borrowing relative to FCY or LCY than the rest of the sample. Nevertheless, we also show that these risk-adjusted costs of CPIL borrowing would still have been higher than those of FCY borrowing or the risk-adjusted return achieved by the potential foreign investor.

Our research yields several important policy implications. One is that CPIL financing is unlikely to be a preferred way of borrowing in developing and emerging market economies irrespective of the ex-ante market risk expectations. This would require either a risk neutral borrower or some channel through which CPIL instruments would reduce some other than market risks facing the investor (e.g. the credit risk) and thus lead to an overall cheaper source of financing. Furthermore, CPIL instruments are not suitable for economies with strong control over the exchange rate and weak control of inflation. Neither are they suitable for countries with large volatility in the real exchange rate and terms-of-trade.

Several caveats are in place. Our analysis ignores any other possible motivations for issuing CPIL bonds than risk-return analysis. The practice is, of course, more colorful. Political considerations, debt management strategies of the governments/issuers and the investors' appetite for the credit, market or country risk in a particular period have a large influence on the type of instrument issued. Furthermore, we take into account only the market risk, ignoring other types of risks and premiums that may affect the choice of the instrument issued, e.g. the credit risk of the government, the liquidity risk or the convertibility/transfer risk.³ On top of it, the interest rate risk is imperfectly measured using some short-term market benchmarks which may nonetheless not reflect well the marginal cost of LCY funding in the interbank market. Finally, our empirical analysis uses ex-post sample data and realized excess returns which may not reflect well the ex-ante expectations the investors had.

We intend to extend the present analysis in several directions. First, we are planning to expand the analysis to more countries, including from developed economies. Second, we would also like to consider and compare actual prices of LCY, FCY and CPIL instruments issued by governments in the past. This should give more insight into the actual Sharpe ratios that investors and borrowers have realized through these vehicles. Third, we would like to consider different maturities of the debt and analyze how the CPIL attractiveness may vary across different tenors. Fourth, we would like to extend the search for CPIL instruments through additional data sources.

³ Some of these risks and the related risk premiums may correlate with the market risks considered in our analysis. For instance, the default risk may correlate with the exchange rate risk for countries with a large share of FCY debt.

2. LITERATURE REVIEW

Much of the theoretical research on CPIL instruments focuses on using CPIL in constructing an optimal portfolio. Theoretical analyses demonstrate that inflation-linked bonds should be included in an optimal portfolio, even when considering the presence of indexation lags. For instance, Li (2019) calculates the price of inflation-indexed bonds when payments are tied to a lagged price index, and determines the optimal bond portfolio considering both inflation and indexation lags. The research reveals a positive impact of indexation lags, typically viewed as a form of market friction, on the bond portfolio.

The empirical research on CPIL instruments assesses whether inflation-linked bonds outperform traditional bonds. The overarching conclusion is affirmative, but the studies generally do not consider whether the CPIL instruments present an adequate return relative to the market risks for the borrower and investor, and do not study the macroeconomic characteristics of the borrowing economy as a factor in determining the attractiveness of CPIL instruments.

For instance, Chopra, Mehta and Srivastava (2021) study inflation-linked bonds as a separate asset class and conclude that CPIL bonds offer advantageous excess returns compared to nominal bonds across different inflation scenarios. The inclusion of CPIL bonds in a portfolio enhances mean-variance efficiency, suggesting that these bonds can serve as both a hedge and a means to improve strategic asset allocation within a portfolio.

Furthermore, although there are findings available for developing markets, the majority of the empirical literature centers on developed markets. One of the exceptions is de Jong and Swinkels (2022) who focus on an American investor contemplating an allocation to emerging-market inflation-linked bonds instead of US bonds to obtain greater inflation compensation. The findings indicate that such an allocation would have been beneficial over the past decade, even when considering latent risks like country defaults. Like us, they compute excess returns from investing into emerging market CPIL bonds using historical data, but they do not explicitly express the results in terms of risk-return characteristics that would compare CPIL instruments with other alternatives, e.g. FCY or plain LCY bonds. Unlike us, they ignore the risk-return perspective of the borrower.

Another branch of the empirical research employs the so-called “hypothetical indexed bonds approach”. For instance, Auckenthaler, Kupfer, and Sendlhofer, R. (2015) employ a VAR model incorporating 3-month nominal T-bill rates and inflation rates to predict quarterly real interest rates. Using these predictions, they calculate hypothetical long-term yields for CPIL bonds and compare them to actual bond yields. The researchers then study how monetary policy and liquidity affect the CPIL bond yield curve in developed countries, but do not compare CPIL, FCY and plain LCY instruments.

3. THEORETICAL ANALYSIS

We consider the risk-return preferences of a foreign investor to a developing or emerging market economy and a (sovereign) borrower from such an economy. We assume the investor is risk-averse and postulate that the preferences can be expressed using a specific value of the Sharpe ratio (SR), i.e. a ratio of an expected excess return over a risk-free return and the standard deviation of that excess return.

Furthermore, we assume that the only risk faced by the lender and the borrower involved in any forms of the investment is the market risk of interest and exchange rate movements in the borrowing economy. The lender’s balance sheet is in FCY, while the borrower’s is in LCY. Neither is naturally

hedged against the market risk involved in the lending instrument between the two and we do not consider the liability side of the lender nor the asset side of the borrower.⁴

Overall, we consider three ways of lending to the borrower: in FCY, in LCY, and in CPIL. The respective risk-return characteristics of the three instruments for the investor are in each case as follows (see Math Appendix, Foreign Investor Characteristics):⁵

Table 1. Risk-return characteristics of the different instruments for the investor

Investor:	FCY	LCY	CPIL
Lending interest rate	$i_{t,h}^*$	$i_{t,h}^{LCY}$	$i_{t,h}^{LCY,CPIL}$
Excess return	$ER_{t,h}^{Inv,FCY} = 0$	$ER_{t,h}^{Inv,LCY} = E\Delta_h S_t + \lambda_t - \Delta_h S_t$	$ER_{t,h}^{Inv,LCY,CPIL} = \pi_t + \omega_t - \Delta_h S_t - i_{t,h}^*$
Expected Excess Return	$EER_{t,h}^{Inv,FCY} = 0$	$EER_{t,h}^{Inv,LCY} = \lambda_t$	$EER_{t,h}^{Inv,LCY,CPIL} = E\pi_t + \omega_t - E\Delta_h S_t - i_{t,h}^*$
Standard error of the Excess return	$\sigma(ER_{t,h}^{Inv,FCY}) = 0$	$\sigma(ER_{t,h}^{Inv,LCY}) = \sigma^{\Delta_h S}$	$\sigma(ER_{t,h}^{Inv,LCY,CPIL}) = \sqrt{(\sigma^\pi)^2 + (\sigma^{\Delta_h S})^2 - 2\rho\sigma^\pi\sigma^{\Delta_h S}}$
Sharpe Ratio	NA	$SR^{Inv,LCY} = \frac{\lambda_t}{\sigma^{\Delta_h S}}$	$SR^{Inv,LCY,CPIL} = \frac{E\pi_t + \omega_t - E\Delta_h S_t - i_{t,h}^*}{\sqrt{(\sigma^\pi)^2 + (\sigma^{\Delta_h S})^2 - 2\rho\sigma^\pi\sigma^{\Delta_h S}}}$

Source: Authors' calculations

The investor's risk-free investment is an investment in FCY, because that way the investor does not face any market risk. By contrast, both the LCY and CPIL investments carry market risk for the investor: the LCY through exchange rate movements (Gadanecz et al., 2014, Leung and Wan, 2019), and CPIL through both the exchange rate and inflation movements.

Because of the risk involved, the investor must be compensated by higher expected excess returns when investing in CPIL or LCY instruments in order to be indifferent among the three forms of investing. We postulate that the expected excess return in either CPIL or LCY investment must be such, so as to lead to a Sharpe ratio equal to a specific positive value of $\overline{SR} > 0$.⁶

Altogether, this implies the following conditions for the lending rates in each three instruments:

Table 2. Lending rates

	FCY	LCY	CPIL
Lending interest rate	$i_{t,h}^*$	$i_{t,h}^{LCY} = E\Delta_h S_t + i_{t,h}^* + \lambda$	$i_{t,h}^{LCY,CPIL} = \pi_t + \omega$

Source: Authors' calculations

⁴ This assumption is especially important for the position of the borrower who is by definition naturally hedged against the inflation risk, as the tax revenues are collected in local currency. Furthermore, one could naturally suppose that a developing country borrower will have much of the revenues denominated in FCY too. We deliberately abstract from these considerations, because they would automatically render CPIL instruments free of any market risk for the borrower, making them very attractive. Yet, this runs against the empirical observation that CPIL instruments are not much used. Instead, we picture a debt management office of the borrower choosing the borrowing instruments on their own merits, without considering the capacity to repay them.

⁵ All interest rates and rates of change are expressed as annualized rates accruing over the same period with simple compounding using log-approximations. In the main text we suppress the time subscripts and other variable notation where unambiguous to ease the exposition. The mathematical appendix provides full notational detail on the variables and equations used. The appendix is accessible here.

⁶ For the purpose of this analysis, we ignore other sources of the investor's profit than the reward for risk.

where $\omega \geq 0$ and $\lambda \geq 0$ are constant risk premiums required by the investor when investing in the CPIL or LCY instrument respectively such that the Sharpe ratio is in each case equal to $\overline{SR}$.⁷ If the investor is risk neutral, then $\omega = \lambda = 0$. For instance, the LCY market premium λ is determined so that

$$SR^{Inv,LCY} = \frac{\lambda}{\sigma^{\Delta_h S}} = \overline{SR} \Rightarrow \lambda = \overline{SR} \sigma^{\Delta_h S}.$$

The CPIL market premium ω is determined analogously from:

$$SR^{Inv,LCY,CPIL} = \frac{E\pi_t + \omega_t - E\Delta_h S_t - i_{t,h}^*}{\sqrt{(\sigma^\pi)^2 + (\sigma^{\Delta_h S})^2 - 2\rho\sigma^\pi\sigma^{\Delta_h S}}} = \overline{SR}$$

We now consider the point of view of a (sovereign) borrower from a developing or emerging market economy. For such a borrower, the market-risk-free form of borrowing is in LCY. FCY borrowing carries an exchange rate risk and CPIL carries both the exchange rate and inflation risks. We therefore define the expected excess return (and Sharpe ratio) for the borrower as the difference between the risk-free rate of i^{LCY} and the respective expected interest cost in each form of investment. In other words, the expected costs of borrowing in CPIL or FCY must be lower than the risk-free rate of i^{LCY} so that a risk-averse borrower considers them.

The risk-return characteristics of the three types of borrowings are in Table 3 (see Math Appendix, Domestic Borrower Characteristics).

Table 3. Risk-return characteristics of the different instruments for the borrower⁸

Borrower:	FCY	LCY	CPIL
Borrowing interest rate	$i_{t,h}^*$	$i_{t,h}^{LCY}$	$i_{t,h}^{LCY,CPIL}$
Excess return	$ER_{t,h}^{Bor,FCY} = i_{t,h}^{LCY} - i_{t,h}^* - \Delta_h S_t$ $= E\Delta_h S_t + \lambda_t - \Delta_h S_t$	$ER_{t,h}^{Bor,LCY} = 0$	$ER_{t,h}^{Bor,CPIL} = i_{t,h}^{LCY} - i_{t,h}^{LCY,CPIL}$ $= E\Delta_h S_t + i_{t,h}^* + \lambda_t - \pi_t - \omega_t$
Expected Excess Return	$EER_{t,h}^{Bor,FCY} = \lambda_t$	$EER_{t,h}^{Bor,LCY} = 0$	$EER_{t,h}^{Bor,CPIL} = E\Delta_h S_t + i_{t,h}^* + \lambda_t - E\pi_t - \omega_t$
Standard error of the Excess return	$\sigma(ER_{t,h}^{Bor,FCY}) = \sigma^{\Delta_h S}$	$\sigma(ER_{t,h}^{Bor,LCY}) = 0$	$\sigma(ER_{t,h}^{Bor,CPIL}) = \sigma^\pi$
Sharpe Ratio	$SR^{Bor,FCY} = \frac{\lambda_t}{\sigma^{\Delta_h S}}$	NA	$SR^{Bor,CPIL} = \frac{E\Delta_h S_t + i_{t,h}^* + \lambda_t - \pi_t - \omega_t}{\sigma^\pi}$

Source: Authors' calculations

3.1. Risk-neutral borrower

First, we consider the case of a risk-neutral borrower. The risk-neutral borrower will choose the instrument with the lowest expected borrowing costs. In order for the CPIL to be a preferred alternative to an LCY borrowing, it must be that the CPIL is cheaper in expectations, i.e., that the excess return for the borrower is positive:

$$EER_{t,h}^{Bor,CPIL} > 0$$

⁷ For the ease of exposition, we define risk premiums as additive, which is in line with common investment practice. Similar results could be obtained for multiplicative risk premiums.

⁸ For full exposition of the calculations see the Math appendix.

We show in the Math Appendix (Propositions 1 and 2) that if the excess return for the CPIL borrower is positive, then it is also higher than the expected return from FCY borrowing, i.e. borrowing in CPIL is cheaper relative to both LCY and FCY alternatives:

$$EER_{t,h}^{Bor,CPIL} > 0 \Rightarrow EER_{t,h}^{Bor,CPIL} > EER_{t,h}^{Bor,FCY}$$

Elaborating on the $EER_{t,h}^{Bor,CPIL} > 0$ condition further we see:

$$i_{t,h}^{LCY,CPIL} < i_{t,h}^{LCY}$$

$$E\pi_t + \omega_t < E\Delta_h S_t + i_{t,h}^* + \lambda_t$$

$$E\pi_t + \omega_t - E\Delta_h S_t - i_{t,h}^* < \lambda_t$$

This is equivalent to $EER_{t,h}^{Inv,LCY,CPIL} < EER_{t,h}^{Inv,LCY}$. In other words, CPIL will be a cheaper source of borrowing if and only if it earns a lower expected return for the investor than a plain LCY instrument.

This may seem a paradox, but it makes sense, if the volatility of the investor's returns from a CPIL instrument is lower than that from a plain LCY instrument, because the investor can then charge a lower risk premium on the CPIL instrument than the LCY instrument. Indeed, assuming a generally real-averse investor with a positive SR, the Proposition 3 in the Math Appendix shows that

$$EER_{t,h}^{Inv,LCY} > EER_{t,h}^{Inv,LCY,CPIL}$$

$$(\sigma^{\Delta_h S})^2 > (\sigma^\pi)^2 + (\sigma^{\Delta_h S})^2 - 2\rho\sigma^\pi\sigma^{\Delta_h S}$$

$$\rho > \frac{1}{2} \frac{\sigma^\pi}{\sigma^{\Delta_h S}} > 0 \quad (1)$$

In other words, for the CPIL to be the preferred form of borrowing for the risk neutral borrower, the correlation between inflation and exchange rate depreciation must be positive and sufficiently high so as to offset the effect of exchange rate and inflation volatility on the CPIL returns for the investor. If the correlation is negative, then the real exchange rate is so volatile that there is no such offset: the CPIL returns of the investor are more volatile than the sum of inflation and depreciation volatility.

This makes intuitive sense. Because the investor requires compensation for the market risk, investors can charge lower market risk premiums for CPIL than on otherwise equivalent LCY instruments, if the returns from the former are expected to be less volatile (uncertain) than the latter. The excess return under the CPIL instrument is subject to both inflation and exchange rate risks, whereas the excess return on an LCY instrument is subject to the exchange rate risk only. But the overall risk in the CPIL returns can still be smaller than the exchange rate risk involved in plain LCY investing, if the movements in inflation correlate well with those of nominal depreciation, thus offsetting the impact of the exchange rate movements on the investor's CPIL returns. This creates conditions for charging lower market premiums and making CPIL instruments cheaper in expectations for borrowers than plain LCY instruments.

Condition (1) has an important interpretation for the macroeconomic situation and monetary policy of the borrowing economy. Note that the condition is equivalent to (Math Appendix, Proposition 3):

$$(\sigma^{\Delta_h S})^2 > (\sigma^{\Delta Z})^2 \equiv (\sigma^\pi)^2 + (\sigma^{\Delta_h S})^2 - 2\rho\sigma^\pi\sigma^{\Delta_h S}$$

where ΔZ refers to real exchange rate depreciation. In other words, real depreciation variance is equivalent to the variance of the lender's return on a CPIL instrument (see Table 1). The condition says that the variance of nominal depreciation must be higher than that of real depreciation, which also implies

positive correlation between inflation and nominal depreciation. Economies exhibit positive correlation between inflation and nominal depreciation if and only if the variance of real depreciation is smaller than the sum of inflation and nominal depreciation variances (see Math Appendix, Correlation Analysis).

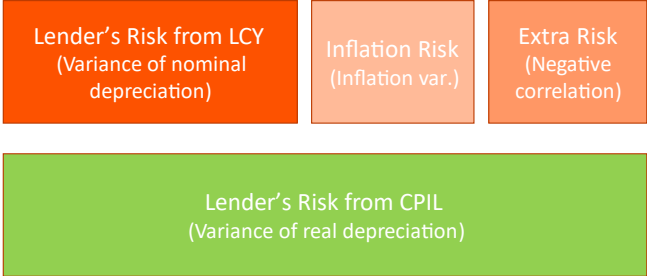
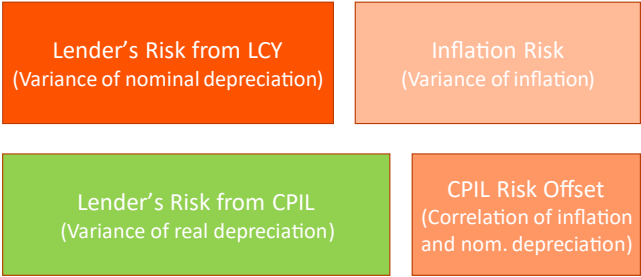
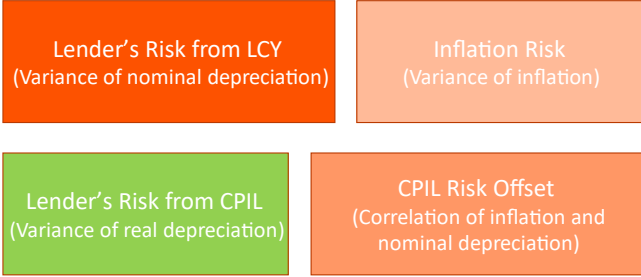
We can therefore categorize the macroeconomic conditions of an economy for our purposes by the relative size of real depreciation variance. Exhibit 1 below distinguishes among three important cases. In Case 1, real depreciation variance is larger than the sum of inflation and nominal depreciation variances. This can occur only if nominal exchange rate depreciation and inflation are negatively correlated. Such a situation may arise in economies exposed to frequent and significant shocks to terms-of-trade or other productivity levers, such as in economies rich or poor in natural resources. Such economies do not satisfy Condition (1).

In Case 2, real depreciation variance no longer dominates the sum of inflation and nominal depreciation variances, because inflation and nominal depreciation are positively correlated. The positive correlation is a sign of typical business cycle shocks, including fiscal and monetary policy shocks, to which inflation and depreciation tend to react together (with some lags). The positive correlation reduces the size of the real depreciation variance, but not enough – the real depreciation variance is still higher than the nominal depreciation variance. Such economies do not satisfy Condition (1) either.

Finally, in Case 3, the correlation between inflation and nominal depreciation is so strongly positive that the variance of real depreciation is smaller than the variance of nominal depreciation. Such economies are primarily exposed to business cycle and policy shocks; frequent shocks to productivity or terms of trade do not take place. Only such economies satisfy Condition (1).

In summary, Condition (1) implies that CPIL instruments should be more affordable (and therefore more in demand) in economies with high business cycle volatility characterized by co-movements of inflation and nominal depreciation, but not in economies in which shocks to the real exchange rate or terms-of-trade are prominent. Such shocks are often characterized by negative correlation between depreciation and inflation and are likely to be important in economies either very rich or poor in natural resources.

Exhibit 1. Classification of macroeconomic conditions suitable for CPIL instruments

<i>Case 1: Unsuitable for CPIL borrowers</i> <i>Variance of lenders' returns from CPIL instruments is higher than the sum of variances of nominal depreciation and inflation, if and only if correlation between inflation and ex rate depreciation is negative. Such a situation may arise, for instance, if the economy faces mostly terms-of-trade and other real exchange rate shocks.</i>	
<i>Case 2: Unsuitable for CPIL borrowers</i> <i>Variance of lenders' returns from CPIL instruments is higher than variance of returns from LCY lending. Correlation between inflation and ex rate depreciation is not sufficient to offset the effect of inflation volatility on lenders' returns from CPIL instrument.</i>	
<i>Case 3: Suitable for CPIL borrowers</i> <i>Variance of lenders' returns from CPIL instruments is lower than variance of returns from LCY lending. Inflation and exchange rate depreciation are highly correlated, as business cycle, fiscal and monetary policy shocks are prevalent.</i>	

Source: Authors

Perhaps surprisingly, Condition 1 also implies that economies with good inflation control (σ^π small) will be better candidates for CPIL instruments than those with a high degree of exchange rate control ($\sigma^{\Delta S}$ small), ceteris paribus. This too has an intuitive interpretation: there is little reason to invest through CPIL instruments in credibly pegged currencies, because inflation is an unnecessary source of additional risk. LCY or FCY instruments provide safer alternatives and can therefore be priced more favorably from the perspective of the borrower.

By contrast, good inflation control means that CPIL instruments do not need a high-risk margin for the inflation risk. This could perhaps partly explain why CPIL instruments are issued by developed economies, e.g., the US and UK, with good inflation control. Moreover, developed economies are less likely to be subject to real exchange rate and terms-of-trade shocks than to business cycle shocks.

3.2. Risk-averse borrower

Let's now consider a risk-averse borrower. Such a borrower will weigh the expected costs from CPIL and FCY borrowings against the risk associated with these instruments. Such an investor will prefer CPIL bonds if the respective SR (risk-adjusted costs) is greater (are lower) than the SR (risk-adjusted costs) of the FCY borrowing.

In particular, note from Table 1 and Table 3 that the SR of the borrower in the case of FCY borrowing is the same as the SR of the investor in the case of LCY borrowing. In other words, LCY and FCY forms of investments represent two polar cases of who carries the exchange rate risk and the related compensation. In LCY investment, the exchange rate risk is borne by the investor and the borrower must therefore pay a risk premium to the investor which makes the LCY borrowing myopically (in a risk-neutral setting) more expensive than FCY borrowing. By contrast, in FCY investment, the exchange rate risk is borne by the borrower, which makes the borrowing rates myopically cheaper than LCY rates. This way the borrower in FCY indirectly receives the risk premium that would have gone to the investor in LCY borrowing. In relation to risk, however, both forms of investments are equivalent for both the investor and the borrower.

We have reached an important conclusion: the risk-adjusted costs for the FCY borrower and the risk adjusted return for the investor in plain LCY or CPIL are equal:

$$SR^{Bor,FCY} = SR^{Inv,CPIL} = SR^{Inv,LCY} = \overline{SR}$$

What remains to be determined is the relation of the risk adjusted cost (SR) of the borrower in the case of CPIL borrowing. First, the Math Appendix (Corollary 1 and Proposition 4)⁹ shows that

- (i) Higher correlation between depreciation and inflation increases the borrower's risk-adjusted excess return from a CPIL bond (reduces the risk adjusted costs).
- (ii) $SR^{Bor,CPIL} = \overline{SR}$ iff inflation and FX depreciation are perfectly correlated ($\rho = 1$).

As the latter condition is a practical impossibility, the relation between $SR^{Bor,CPIL}$ and $\overline{SR}$ is determined by the ratio between standard deviations of exchange rate depreciation and inflation $k = \frac{\sigma^{\Delta S}}{\sigma^{\pi}}$. The Math Appendix (Propositions 5 and 6) shows that

- (iii) $\frac{SR^{Bor,CPIL}}{\overline{SR}}$ increases with k
- (iv) $SR^{Bor,CPIL} \leq \overline{SR}$ for all values of k and ρ .

These conclusions confirm the intuition gained when studying the risk-neutral borrower: countries with a high degree of exchange rate management and/or countries with a high incidence of real exchange rate shocks (low correlation between inflation and exchange rate) are not set to benefit from CPIL instruments. Plain FCY and LCY instruments are likely to have a better risk-return profile for the borrower.

⁹ For full exposition of the calculations see the Math appendix.

On the other hand, for the borrowers to benefit from CPIL instruments, not only must the exchange rate be very flexible, but also their control over inflation must be relatively good and the prevailing nature of macroeconomic shocks be such that inflation and depreciation are highly correlated.

Such conditions making CPIL a preferred borrowing instrument may not be met by every emerging market or developing economy. Some of them engage in heavy exchange rate management (e.g., to keep monetary control or to prevent the LCY value of FCY debt from spiraling out of control) and their inflation control is poor. At the same time, some of these countries are either commodity rich or, by contrast, dependent on commodity imports, making terms-of-trade and real exchange rate an important source of macroeconomic volatility so that correlation between inflation and depreciation is low.

The most important conclusion, however, is that the risk-return characteristics of CPIL instruments can never be better for the borrower than those of an FCY instrument. The SR of the borrower borrowing through CPIL will always be weakly lower than the SR the borrower can obtain from an FCY borrowing. In other words, the risk adjusted costs of borrowing in CPIL will always be higher than the risk-adjusted costs of borrowing in FCY (Math Appendix, Corollary 2):

$$SR^{Bor,CPIL} \leq SR^{Bor,FCY} = SR^{Inv,CPIL} = SR^{Inv,LCY} = \overline{SR}$$

Furthermore, the SR of the borrower in CPIL will also be lower than the SR of the investor in CPIL. The CPIL borrower can never be compensated for the risk as well as the CPIL investor. This puts a wedge between the incentives of the investor and borrower to engage in CPIL instruments – the investor is likely to prefer CPIL instruments more than the borrower.

3.3. Summary of predictions

Our key theoretical predictions regarding the conditions for the issuance of CPIL instruments can be summarized as follows:

Prediction 1: Countries issuing CPIL satisfy condition (1), i.e., correlation between nominal depreciation and inflation is positive, while volatility of nominal depreciation is low relative to that of inflation, so that the variance of real depreciation is smaller than that of the nominal depreciation;

Prediction 2: Countries with lower risk-adjusted costs of CPIL borrowing (higher CPIL SRs) relative to FCY or LCY borrowing are more likely to issue CPIL bonds than otherwise;

Prediction 3: The risk-adjusted costs of CPIL borrowing will always be higher than those of conventional FCY alternatives;

Prediction 4: Risk-averse borrowers will never find the CPIL instruments as attractive as risk-averse foreign investors.

4. EMPIRICAL ANALYSIS

We now examine the empirical relevance of our key theoretical findings on a set of 69 emerging market and developing economies over the period from 2000 to 2024. A full list of the countries, along with the data sources, can be found in the data appendix¹⁰. The exact estimation range for each country varies and depends on the availability of reliable and comparable economic data for the exchange rate, inflation

¹⁰ Data appendix available here.

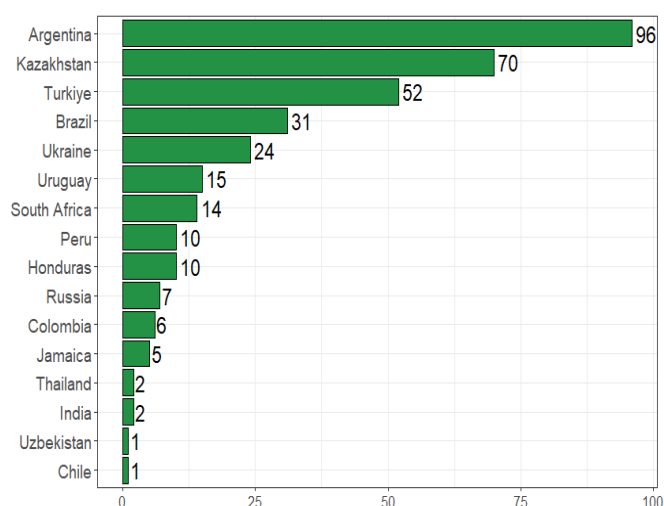
and the interest rate. For the CPIL issuing countries those time ranges include the periods during which they issued those securities.¹¹

In our analysis we take that ex-post historical macroeconomic data represent true ex-ante expectations of investors and borrowers about these variables during the particular estimation periods. This is, of course, a huge simplification, but a good starting point for the analysis.¹² We use these macroeconomic characteristics to compute ex-post returns and Sharpe ratios of various instruments that could have been hypothetically expected by the lenders and borrowers during the relevant periods under perfect foresight. In so doing we abstract from any transaction costs as well as other premiums that foreign lenders might have reasonably expected to receive as compensation for other than market risks, e.g., liquidity premiums, convertibility and transfer premiums etc.

In computing standard errors and excess returns from macroeconomic data we use three different horizons of 1-month, 12-month, and 36-month respectively to test the robustness of our results.

Out of the 69 emerging and developing countries under consideration we have identified that in only 16 of them the governments have issued some form of a CPIL instrument (bond). The total number of CPIL issues is thus 346. The leading issuers have been Argentina, Kazakhstan and Turkey (Figure 1).

Figure 1. Number of bonds issued by the countries in 2015-2024



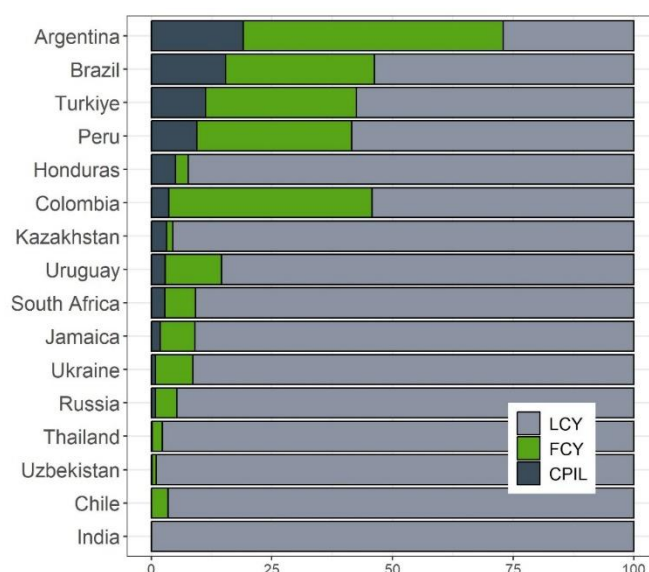
Source: Cbonds database

This stands in contrast with the issuance of other forms of government debt – issued in or indexed to FCY and plain LCY debt – which have been far more frequent (Figure 2). In terms of proportions, Argentina stands out as the most active user of CPI-linked bonds, with approximately one third of its issued bonds being CPI-linked.

¹¹ Variations of the estimation period around the period during which the countries had the CPIL bonds outstanding did not produce qualitatively different results. As some countries (e.g. Uzbekistan) experienced enormous depreciation spells during these periods, we have also tested the robustness of the results to removing such outlier spells from the sample.

¹² Further work in this respect is underway.

Figure 2. Structure of bond issuance by instrument



Source: Cbonds database

Prediction 1: Countries issuing CPIL satisfy condition (1), i.e. correlation between nominal depreciation and inflation is positive, while volatility of nominal depreciation is low relative to that of inflation, so that the variance of real depreciation is smaller than that of the nominal depreciation.

Figure 3 depicts the correlation coefficient between inflation and nominal depreciation over the horizon of 12. The chart for the 1-month and 36-month horizons can be found in the appendix.

We observe that 41 out of 69 countries have the correlation positive on all three horizons. For many countries, at least one of the correlation coefficients is quite high, close to unity.

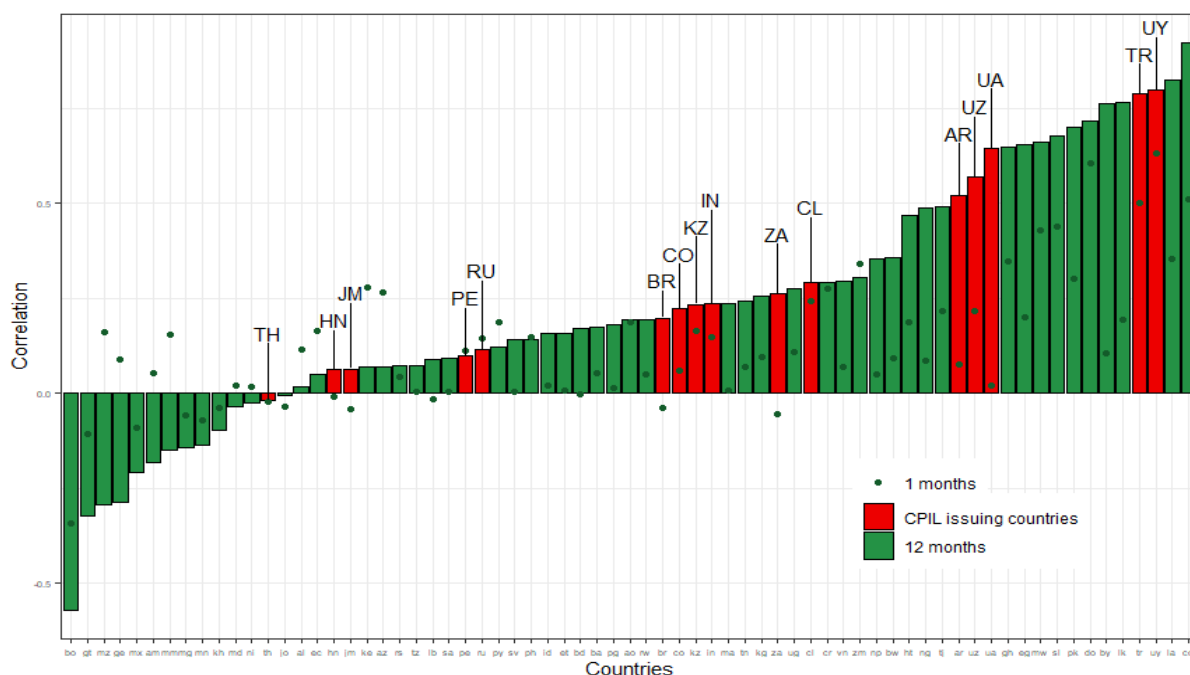
Higher correlation makes CPIL more attractive for the borrower, as the movements in inflation tend to compensate exchange rate changes, thus commanding lower risk premiums from investors. Indeed, we find that, with the exception of Thailand, all CPIL issuing countries have had the correlation positive on at least one of the horizons and ten of them had it positive on all three horizons. For 36-month correlations, Turkey, Uruguay and Ukraine have correlations around 0.8; others have it below 0.5.¹³

By contrast, 7 countries had the correlation negative on all three horizons and 21 countries had the correlation negative on at least one of the horizons. As such, these countries do not satisfy Condition (1) on the respective horizons, belonging to Case 1 from the previous section. Negative correlation is a symptom of real exchange rate shocks and makes CPIL less attractive for the borrower. Borrowers from such economies are not likely to profit from CPIL borrowing relative to FCY or plain LCY borrowing. Only one CPIL issuing country in our sample (Thailand) had negative correlation between inflation and exchange rate depreciation on all three horizons, i.e., no volatility offset between inflation and exchange rate depreciation.¹⁴

¹³ The 36-month correlations are in general higher than the 1-month correlations, as expected given the time lags involved in the exchange rate pass-through to inflation (and vice versa). The median correlation is 0.09 for the 1-month period, increasing to 0.2 for the 36-month period. Out of the CPIL issuing countries, only Kazakhstan and Russia demonstrate higher correlation on the 1-month than on the 36-month horizon.

¹⁴ 6 CPIL issuing countries had the correlation negative on at least one of the horizons.

Figure 3. Correlation coefficients between inflation and changes in the nominal exchange rate

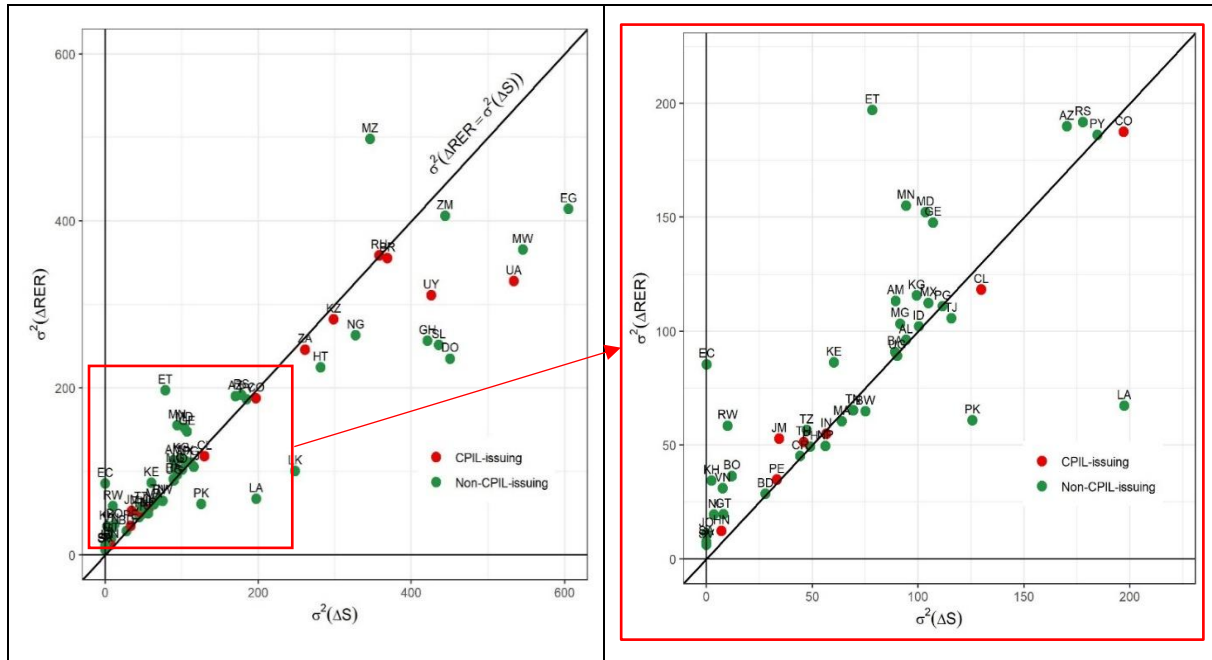


Source: Authors' calculations

As we assert in the previous section, positive correlation between inflation and exchange rate depreciation is only a necessary, but not a sufficient condition for a CPIL instrument to be attractive for the risk-neutral borrower. The correlation must be high enough to ensure that the variance of real depreciation is lower than the variance of nominal depreciation. Only then will the expected costs for the CPIL borrower be lower than those involved in the plain LCY borrowing.

Putting it all together, Figure 4 displays which countries in our sample satisfy condition (1) using the comparison of standard errors between nominal and real depreciation (graphically it corresponds to the area below the 45-degree line) on the 12-month horizon. We see that only about half of our sample (31 countries) has met the condition for this horizon.¹⁵ If we compare this list with the list of countries that have issued at least one CPIL instrument during this period (they are highlighted in red in the chart), we see that, with the exception of four (Jamaica, Honduras, Thailand and Peru), all the CPIL issuing economies have satisfied condition (1) and therefore had a positive excess return (and SR) from issuing CPIL bonds on the 12-month horizon.

¹⁵ 32 countries on 1-month and 28 countries on 36-month horizons respectively.

Figure 4. Sample standard errors of real and nominal exchange rate for 12-month horizon¹⁶

Source: Authors' calculations

At the same time, it is interesting to note, that 24 economies in our sample have the correlation between inflation and exchange rate positive on the 12-month horizon, but did not satisfy condition (1).¹⁷ Those belong to Case 2 from the previous section: inflation and depreciation movements partially compensated one another, but not sufficiently to make CPIL borrowing cheaper than the plain LCY alternative. Honduras, Jamaica, Russia and Peru are among those countries – the countries that issued CPIL bonds and had the correlation positive on the 12-month horizon, but did not satisfy condition (1).

Overall, Table 4 shows the split of the countries by the cases identified in Exhibit 1 when Condition 1 is evaluated on the three horizons. We see that the number of countries satisfying Condition 1 is relatively uniform (more than 40% of the sample) across the horizons.

¹⁶ Myanmar, Angola, Turkey and Belarus not shown in the chart due to the large historical exchange rate volatility.

¹⁷ 23 countries on 1 month, and 20 on 36 month.

Table 4. Split of the countries by the cases identified in Exhibit 1

			Case 1: Unsuitable for CPIL borrowers (Condition 1 not satisfied)	Case 2: Unsuitable for CPIL borrowers (Condition 1 not satisfied)	Case 3: Suitable for CPIL borrowers (Condition 1 satisfied)
Horizon			<i>Variance of lenders' returns from CPIL instruments is higher than the sum of variances of nominal depreciation and inflation, if correlation between inflation and ex rate depreciation is negative. Such a situation may arise, for instance, if the economy faces mostly terms-of-trade and other real exchange rate shocks.</i>	<i>Variance of lenders' returns from CPIL instruments is higher than variance of returns from LCY lending. Correlation between inflation and ex rate depreciation is not sufficient to offset the effect of inflation volatility on lenders' returns from CPIL instrument.</i>	<i>Variance of lenders' returns from CPIL instruments is lower than variance of returns from LCY lending. Inflation and exchange rate depreciation are highly correlated, as business cycle, fiscal and monetary policy shocks are prevalent.</i>
1 month	# of countries % of countries	69 <i>100%</i>	14 <i>20%</i>	23 <i>33%</i>	32 <i>46%</i>
12 months	# of countries % of countries	69 <i>100%</i>	14 <i>20%</i>	24 <i>35%</i>	31 <i>45%</i>
36 months	# of countries % of countries	69 <i>100%</i>	21 <i>30%</i>	20 <i>29%</i>	28 <i>41%</i>

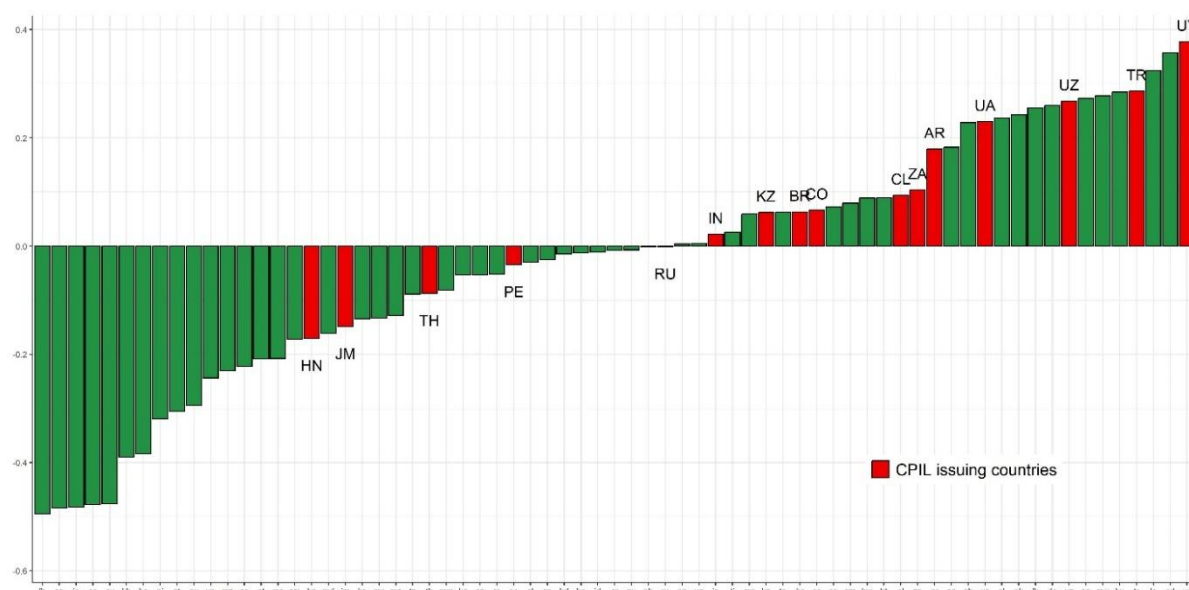
Source: Authors' calculations

Prediction 2: Countries with lower risk-adjusted costs of CPIL borrowing (higher CPIL SRs) relative to FCY or LCY borrowing are more likely to issue CPIL bonds than otherwise.

In checking for the effect of risk tolerance on the CPIL issuance we use the excess returns and the corresponding standard errors in computing ex-post Sharpe ratios for all three forms of investment.¹⁸ First, we compute the borrower's ex-post excess returns for a given investor's SR for three different horizons: one month, one year, and three years. The results for all countries are shown in the appendix. To arrive at the borrower's SR, we then combine these excess returns with the ex-post standard errors of these instruments computed from macroeconomic indicators on the relevant horizons. For illustration, the results for the investor's SR of 0.5 and 12M horizon are displayed in Figure 5.

¹⁸ It is useful to bear in mind that these are hypothetical SRs computed using historical macroeconomic data and not (i) actual SRs achieved on specific investments over the period, (ii) SRs that would have been expected to be achieved by investors when making the investment decisions during this period.

Figure 5. Calculated borrower's Sharpe ratio corresponding to investor's Sharpe ratio = 0.5 (12-month horizon)



Source: Authors' calculations

We see in Figure 5 that, with the exception of the 4 countries above (Jamaica, Honduras, Peru, and Thailand), all CPIL issuing countries had a positive ex-post SR, implying that their risk-unadjusted costs from borrowing in CPIL relative to borrowing in LCY would have been lower. We also see that the CPIL issuing countries would have benefitted from the CPIL borrowing more than the rest of the sample and the difference is statistically significant.¹⁹ We therefore see some evidence that CPIL borrowing is more likely to occur in countries with higher CPIL Sharpe ratios.

To see how these high SRs from CPIL borrowing compare with the SRs of the FCY alternative, we then compute a ratio between this SR of the CPIL borrower and the SR of the borrower in FCY.²⁰ In Figure 6, we order the countries by the size of this ratio and find that most CPIL issuing economies have this ratio relatively high, significantly higher than the rest of the sample (Figure 6).²¹ Similar charts for the 1M and 36M horizons are in the appendix²². We therefore have some evidence that the countries with lower risk-adjusted costs of CPIL borrowing (higher CPIL SRs) relative to the FCY borrowing are more likely to issue CPIL bonds than otherwise. In other words, the Sharpe ratio optic may indeed matter for the incidence of CPIL borrowing.

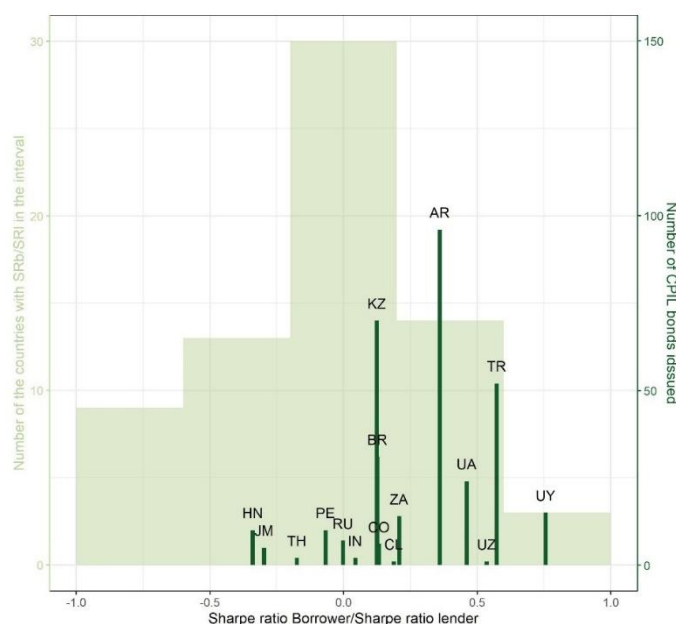
¹⁹ The sample average SR for the countries that did not issue CPIL is negative, -0.06, while the average for CPIL-issuing countries equals 0.08, and increases to 0.15 when removing four countries with negative SRs.

²⁰ Note that the SR of the borrower in FCY is the same as that of the investor in CPIL or LCY by construction.

²¹ The sample average SR for the countries that did not issue linkers is negative, -0.12, while the average for CPIL-issuing countries equals 0.16, and increases to 0.29 when removing four countries with negative SR.

²² Appendix accessible here.

Figure 6. Histogram of relative ex-post SRs between the borrower and lender on the 12-month horizon



Source: Authors' calculations

Prediction 3: The risk-adjusted costs of CPIL instruments will always be higher than those of conventional FCY alternatives.

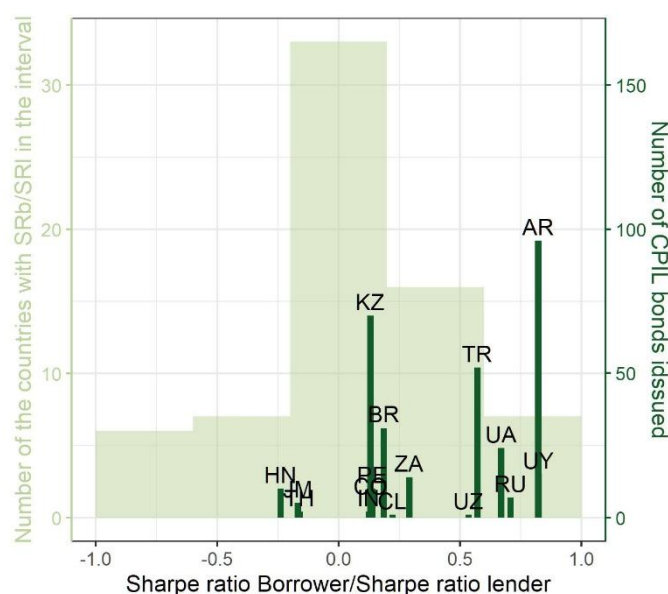
We saw in Figure 5. and Figure 6. evidence that the Sharpe ratio optic matters for the CPIL issuance: the countries with higher CPIL SRs are more likely to issue CPIL bonds than otherwise. However, this does not mean that the CPIL option is cheaper than the FCY option after adjusting for risks.

In fact, we see in Figure 6. that, as expected, the ratios of the SRs of a CPIL borrower and FCY borrower were in all cases lower than one for all countries (not only those issuing CPIL) for the 12M horizon. Figure 7. completes this information by showing a histogram of the maximum values of these ratios across all three horizons. Again, the same pattern emerges. This means that the risk-adjusted costs of the CPIL borrowing were on average larger than those of FCY borrowing.

Finding 4: Risk-averse borrowers will never find the CPIL instruments as attractive as risk-averse foreign investors.

At the same time, Figure 6. and Figure 7 imply that the SR of the CPIL borrower has always been lower than the SR of the CPIL investor, creating a risk-return wedge between the two. This demonstrates in practice our theoretical assertion that the CPIL borrower can never be compensated for the risk as well as the CPIL investor.

Figure 7. Histogram of maximum relative ex-post SRs between the borrower and lender across the 1M, 12M and 36M horizons



Source: Authors' calculations

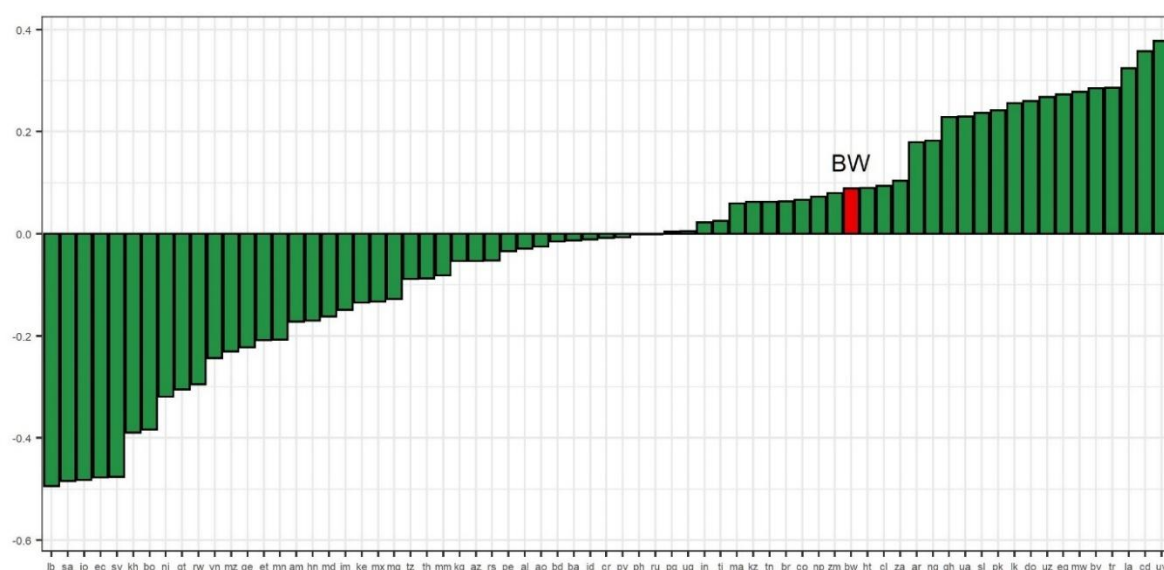
5. COUNTRY APPLICATION

This section presents a practical application of our approach in identifying good cases for CPIL bonds in practice. As announced in the 2024/2025 Budget Speech, the Botswana Government continues to run budget deficits while pursuing the reform agenda outlined in the Transitional National Development Plan. In this context, domestic borrowing will include the issuance of new instruments, such as inflation-linked bonds and green bonds, among others, contributing to the development of the capital market.

Botswana is a country that runs a crawling peg infused with elements of inflation targeting. Inflation has been under good control for decades. According to our methodology, Botswana is among the countries that stand to benefit from issuing CPIL bonds. Depending on the horizon, Condition 1 is satisfied, or at least there is a positive correlation between inflation and exchange rates, placing the country in either Case 1 or Case 2 of Exhibit 1.

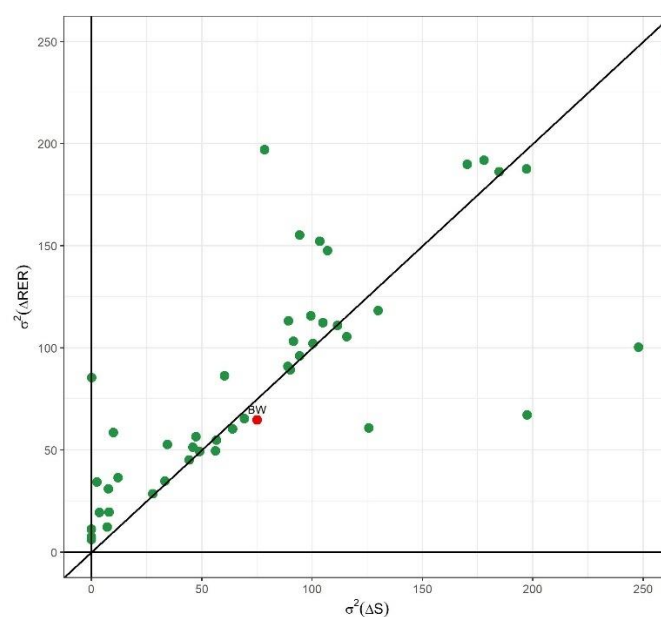
Historically, the excess return for lender and borrowers in Botswana has been quite high compared to other countries in our sample. These values are similar to those in Brazil, which was the fourth-largest CPI-linked bond issuer in our sample.

Figure 8. Borrower's Sharpe ratio corresponding to investor's Sharpe ratio = 0.5 (12-month horizon) - Botswana's relative position is highlighted



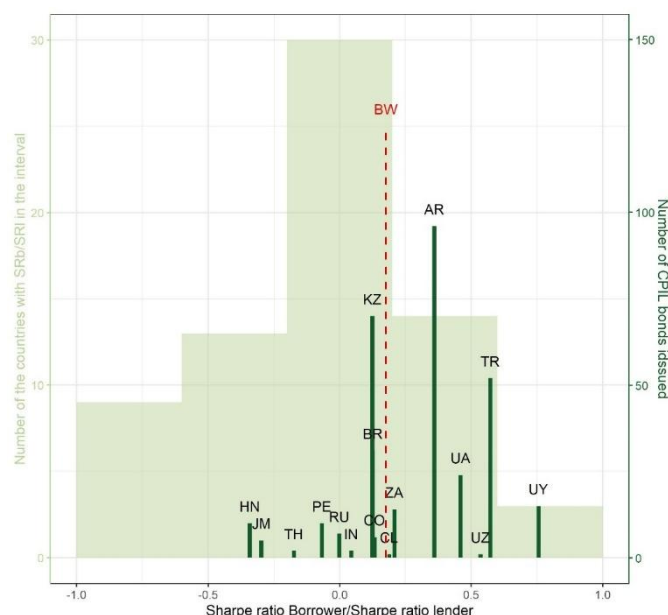
Source: Authors' calculations

Figure 9. Sample standard errors of real and nominal exchange rate for 12-month horizon - Botswana's relative position is highlighted



Source: Authors' calculations

Figure 10. Histogram of relative ex-post SRs between the borrower and lender on the 12-month horizon - Botswana's potential position is highlighted



Source: Authors' calculations

The introduction of CPI-linked bonds could therefore provide Botswana with a significant opportunity to manage its public debt efficiently. By aligning bond returns with inflation rates, these bonds can help attract investors seeking protection against inflation, ultimately supporting Botswana's broader economic objectives. Given the positive historical correlations and returns, Botswana's move towards CPI-linked bonds would not be much costlier than plain FCY borrowing, while at the same time it could serve as a strategic tool for enhancing fiscal resilience and market confidence.

6. CONCLUSIONS

Our research shows that the limited utilization of CPI-linked (CPIL) financing instruments in developing and emerging market economies may owe to inferior risk-return characteristics of these instruments compared to other financing alternatives, e.g., in FCY or plain LCY.

Limiting ourselves to the implications of the market risk only, we consider the risk-return perspective of a foreign investor as well as a domestic (sovereign) borrower. We show that the interest rates on LCY and CPIL instruments can be set so that the investor is indifferent between investing in LCY, CPIL or FCY. By contrast, the borrower will always tend to prefer FCY or plain LCY borrowing to CPIL instruments, because the latter has higher risk-adjusted costs.

Only a risk-neutral borrower may find CPIL instruments more attractive than FCY and plain LCY instruments, because the expected, risk-unadjusted, borrowing costs can under certain conditions be lower. These conditions require that the correlation between inflation and nominal depreciation is positive and high enough. The positive correlation offsets the impact depreciation volatility has on CPIL returns for the investor, resulting in lower market risk premiums required by the investor and therefore also lower borrowing costs than the plain LCY or FCY instruments.

This condition implies that the economies most likely to benefit from CPIL financing are those with (i) high nominal depreciation volatility relative to inflation volatility, and (ii) low real depreciation volatility. This is because CPIL instruments provide a hedge against business cycle volatility characterized by co-movements of inflation and depreciation, but not against shocks to the real exchange rate or terms-of-trade. Perhaps surprisingly, economies with good inflation control are better suited for CPIL instruments compared to those with high exchange rate control, *ceteris paribus*.

Considering a risk averse borrower brings more complex considerations. We show theoretically that the attractiveness of CPIL borrowing depends on its risk-adjusted costs and find empirically that countries with lower risk-adjusted costs of CPIL borrowing (higher CPIL SRs) relative to FCY or LCY borrowing have been more likely to issue CPIL bonds than otherwise.

Nevertheless, we also show that the risk-adjusted costs of CPIL instruments will always be higher than those of conventional FCY and LCY alternatives, thus making the CPIL instruments in general a less preferred way of borrowing. Furthermore, we find that the CPIL borrower can never be compensated for the market risk as well as the CPIL investor, putting a wedge between the incentives of both parties to engage in CPIL financing by making CPIL more attractive for the investor than the borrower.

Overall, we find robust empirical support for our assertion that the risk-return characteristics given by the macroeconomic environment are an important factor in determining the attractiveness of CPIL financing. Most CPIL-issuing economies have met the inflation-exchange rate correlation condition. Only one out of 16 CPIL-issuing economies in our sample did not satisfy these conditions at all. Moreover, the group of CPIL bond issuing countries was likely to achieve lower risk-adjusted costs of CPIL borrowing relative to FCY or LCY than the rest of the sample on average. Nevertheless, we also show that these risk-adjusted costs of CPIL borrowing would still have been higher than those of FCY borrowing or the risk-adjusted return achieved by the potential foreign investor.

Our research yields several important policy implications. One is that CPIL financing is unlikely to be a preferred way of borrowing in developing and emerging market economies irrespective of the ex-ante market risk expectations. This would require either a risk neutral-borrower or some channel through which CPIL instruments would reduce some other than market risk facing the investor (e.g., the credit risk) and thus lead to an overall cheaper source of financing. Furthermore, CPIL instruments are not suitable for economies with strong control over the exchange rate and weak control of inflation. Finally, they are not suitable for countries with large volatility in the real exchange rate and terms-of-trade.

More work is needed. We are planning to expand the analysis to more countries, including from developed economies. We would also like to consider and compare actual prices of LCY, FCY and CPIL instruments issued by governments in the past. This should give more insight into the actual Sharpe ratios that investors and borrowers have realized through these vehicles. We should also consider different maturities of the debt and analyze how the CPIL attractiveness may vary across different tenors. It will also be worthwhile to extend the search for CPIL instruments through other data sources, potentially including private sector borrowers.

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MATH Appendix

https://ftp1.ogresearch.com/publications/CPIIL_research_paper_final_full_version_with_appendix.pdf#page=24

CORRELATION Appendix

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Does the creation of a sovereign inflation-linked bond market
(information) reduce the domestic financing risk? The
interplay between term premium and the demand for
government securities

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PRELIMINARY DRAFT

Abstract

We show that the demand for public bonds will be higher if agents expect that the term premium will contract over time and/or the variation of the term premium is low. Using a difference-in-differences approach, we estimate the impact of the creation of a sovereign Inflation-Linked Bond (ILB) market finding that the opening leads to a significant improvement across different risk metrics for Emerging Market Economies (EMEs). As expected, in an environment where the inflation term premium increases, the demand for ILB is higher than for nominal bonds. As discussed in a case study, countries have successfully used ILBs to improve the composition of their debt structure.

JEL: H63, E43, R50

Keywords: Term premium, sovereign debt

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1 Introduction

The role that inflation linked bonds (ILB) play in government borrowing has been a topic of discussion in several countries in recent years. Most prominently Canada and Germany have decided to cease further issuance, while other Advanced Economies (AEs) are also actively reviewing the role of ILBs going forward (E.g. Sweden). Besides the specific cost-benefit considerations that guide the decisions of debt management offices we argue that ILBs can expand the information set for investors which can create a positive impact in the overall demand of sovereign debt.

The main contributions of this paper is the provision of novel theoretical and empirical analysis on the complementary interplay between a ILBs and a conventional bonds. We address key questions for sovereign debt: i) how the demand for sovereign debt is impacted by the term premium?, ii) how the demand for sovereign debt is impacted by the ILB market, and iii) what is the impact of the opening of ILB market on various risk metrics?

To answer the first question we build a simple model to map how the share allocated in government bonds of an investor is impacted by the term premium. To respond to the second question, we apply the fisher decomposition on the optimal allocation derived from our structural model. Finally, we address the final empirical question using a difference-in-differences approach and a case study.

A key assumption in our modelling effort is that the fundamentals of government yields bonds are derived from the expectations of macroeconomics variables of a given economy. In particular, they are expressed by the expectation on the future short term policy rate and inflation. These fundamentals can then be estimated by a macro-model, surveys of forecasters, or models designed to extract fundamentals from yield curves. Regarding the latter, Cohen et al (2018) argue that the most popular term premium models produce different estimates for the level of term premium, but broadly agree on the trends and dynamics. Therefore, the log difference-stationary environment in the price informativeness framework of D’ávila and Parlato (2018) suits well the purpose of this paper given that the choice of the method of estimation of fundamentals does not impact our exercise. In the spirit of the price informativeness framework, we demonstrate that we can interpret the term premium as a metric of how much an external observer **cannot** learn about fundamentals from prices.

On the role of ILB for sovereigns, Velandia-Rubiano et al. (2022) present mixed evidence on the cost-effectiveness of ILBs. On one hand, it can be used to improving the risk profile of the public debt composition by lengthening debt maturity and replacing FX-linked and FX-denominated securities. On the other hand, introducing ILBs may reduce government securities’ trading and liquidity by fragmenting an already small market. In the empirical section we focus specifically on the opening of ILB market and we find that that the opening leads to a significant improvement across different metrics for EMEs, but it is not significant for AEs.

The paper is structured as follows. Section 2 details our identification strategy to bridge price informativeness from linear regressions to our extension of D’ávila and Parlato (2018) model. Section 3 introduces a fully microfounded model, allowing us to recover model primitives. Section 4 depicts our empirical exercises on the estimation of the impact of the creation of ILB market on risk metrics, section 5 unpacks a case study for Brazil and section 6 concludes.

2 Identifying Government Bonds Price Informativeness

In this section, we introduce the main identification results in the context of a dynamic model with a single government bond yield of a given maturity whose payoff process is stationary. We show how to identify and estimate price informativeness from an asset pricing equation and a stochastic process for government yield payoffs. In line with D’ávila and Parlato (2018), we derive the main results in the body of the paper in a log difference-stationary environment.

Model

Time is discrete, with periods denoted by $t = 0, 1, 2, \dots, \infty$. There is a continuum of investors, indexed by $i \in I$, who trade a risky nominal government bond in fixed supply each period at a (log) price p^t . The payoff of the nominal yield in period $t+1$, x^{t+1} , - as well as the payoff of the real interest rate component, x_t^r , and the inflation priced in government bonds, x_t^π are given by the following stationary AR(1) process:

$$\Delta x_{t+1}^r = \mu_{\Delta x^r} + \rho^r \Delta x_t^r + u_t^r \quad (1)$$

$$\Delta x_{t+1}^\pi = \mu_{\Delta x^\pi} + \rho^\pi \Delta x_t^\pi + u_t^\pi \quad (2)$$

$$\Delta x_{t+1} = \mu_{\Delta x^r} + \mu_{\Delta x^\pi} + \rho^r \Delta x_t^r + \rho^\pi \Delta x_t^\pi + u_t^r + u_t^\pi \quad (3)$$

$$u_t = u_t^r + u_t^\pi \quad (4)$$

Where $\mu_{\Delta x^r}$ and $\mu_{\Delta x^\pi}$ are scalars, ρ^r and $\rho^\pi < 1$, and where the innovations to the payoff, u_t have mean zero, finite variance denoted by $Var(u_t) = Var(u_t^r) + 2Cov(u_t^r, u_t^\pi) + Var(u_t^\pi) = \sigma_u^2 = \tau_u^{-1}$.

It is important to note that u_t are identically and independently distributed over time. The payoff setup is built in such way that the innovation to the $t + 1$ payoff difference, u_t , is indexed by t — instead of $t + 1$ — to indicate that investors can potentially learn about the realization of u_t at date t .

We assume that the equilibrium nominal (log) yield difference, Δp_t , the real (log) yield difference, Δp_t^r , and the inflation log difference, Δp_t^π , are given by

$$\Delta p_t = \phi + \phi_0 \Delta x_t^r + \phi_1 \Delta x_t^\pi + \phi_2 \Delta x_{t+1} + \phi_n \Delta n_t \quad (5)$$

$$\Delta p_t^r = \xi + \xi_0 \Delta x_t^r + \xi_2 \Delta x_{t+1}^r + \xi_n \Delta n_t^r \quad (6)$$

$$\Delta p_t^\pi = \iota + \iota_0 \Delta x_t^\pi + \iota_1 \Delta x_{t+1}^\pi + \iota_n \Delta n_t^\pi \quad (7)$$

$$\Delta n_t^r = \mu + \epsilon_t^{\Delta n^r} \quad (8)$$

$$\Delta n_t^\pi = \mu_{\Delta n^\pi} + \epsilon_t^{\Delta n^\pi} \quad (9)$$

$$\Delta n_t = n_t^r + n_t^\pi = \mu_{\Delta n} + \epsilon_t^{\Delta n} \quad (10)$$

where $\iota, \iota_0, \iota_1, \iota_n, \xi, \xi_0, \xi_2, \xi_n, \phi, \phi_0, \phi_1$, and ϕ_n are parameters and where $\Delta n_t, \Delta n_t^r$ and Δn_t^π represents the change in the aggregate component of investors' trading motives on nominal and real yields and inflation that are orthogonal to the yield payoff. Our timing assumes that date t variables, in particular Δx_t and u_t , are realized before the price p_t is determined. Moreover, we assume that u_t and Δn_t are independent.

3 Structural Model

Environment We consider a tractable overlapping generations model. Time is discrete, with dates denoted by $t = 0, 1, 2, \dots, \infty$. The economy is populated by a continuum of investors, indexed by $i \in I$, who live for two dates. Each investor I is born with wealth w_0 and has well-behaved expected utility preferences over his terminal wealth w_1^i , with flow utility given by $U_i(w_1^i)$, where $U_i'(\cdot) > 0$ and $U_i''(\cdot) < 0$. We assume that the distribution of initial wealth is bounded and i.i.d. across time and investor types.

There are two types of assets in the economy: a short-term risk-free asset in perfectly elastic supply, with gross return $R^f > 1$, and a risky government bond asset with a given maturity m in fixed supply Q . The government bond price valued by fundamentals P^X depend on the fundamental yield Y^X , which denotes the expected average short-term policy rate from date $t + m$ according to fundamentals with the (log) payoff is $x_t = \ln(Y_t^X)$. The government bond price traded is denoted by P with an underlying yield Y and (log) yield $p_t = \ln(Y_t)$. The law of motion of the fundamentals x_t, x_t^r , and x_t^π are given by

$$\Delta x_{t+1}^r = \mu_{\Delta x^r} + u_t^r \quad (11)$$

$$\Delta x_{t+1}^\pi = \mu_{\Delta x^\pi} + u_t^\pi \quad (12)$$

$$\Delta x_{t+1} = \mu_{\Delta x^r} + \mu_{\Delta x^\pi} + u_t \quad (13)$$

where $u^t = u^t + u^*$, $\Delta x^{t+1} = x^{t+1} - x^t$, $\Delta x^{\pi t+1} = x^{\pi t+1} - x^{\pi t}$, $\mu_{\Delta x^r}$ and $\mu_{\Delta x^\pi}$ are a scalars, $x_0^r = 0$, and $x_0^\pi = 0$. The realized payoff x^r and x^π are common knowledge to all investors before the yield p_t is determined. The realized payoff at date $t + 1$, x_{t+1} , is only revealed to investors at date $t + 1$.

It is important to highlight that equation (12) is a special case of equation (5) when $\rho^r = 0$ and $\rho^\pi = 0$.

We assume that investors receive private signals about the innovation to the risky asset payoff. Formally, each investor receives a signal about the payoff innovation u_t given by

$$s_t^i = u_t + \epsilon_{st}^i$$

with

$$\epsilon_{st}^i \sim N(0, \tau_s^{-1})$$

where $\epsilon_{st}^i \perp \epsilon_{st}^j$ for all $i \neq j$ and $u_t \perp \epsilon_{st}^i$ for all t and for all i .

We also assume that investors have additional private trading motives coming from random heterogeneous priors that are random in the aggregate. Formally, each investor i born at date t has a prior over the innovations to the payoff difference u_t given by

$$u_t \sim i, tN(\bar{n}_t^i, \tau_u^{-1})$$

where

$$\bar{n}_t^i = n_t + \epsilon_{nt}^i$$

with

$$\epsilon_{nt}^i \sim N(0, \tau_n^{-1})$$

and

$$\Delta n_t = \mu_{\Delta n^r}^r + \mu_{\Delta n^\pi}^\pi + \epsilon_t^{\Delta n^r} + \epsilon_t^{\Delta n^\pi} = \mu_{\Delta n} + \epsilon_t^{\Delta n}$$

with

$$\epsilon_t^{\Delta n} \sim i, tN(0, \tau_n^{-1})$$

where $n_0 = 0$, $\mu_{\Delta n}$ is a scalar, and $\epsilon_t^{\Delta n} \perp \epsilon_t^{\bar{n}_t^i}$ for all i and for all t . One can read the variable n_t as the aggregate sentiment in the economy. n_t is not observed and acts as a source of aggregate noise, preventing the yield from being fully revealing. In addition, we assume that $u_{t+s} \sim i, tN(0, \tau_u^{-1})$ for all $s > 0$.

Each investor i born at date t optimally chooses a portfolio share in the risky asset, denoted by θ_t^i , to solve

$$\max_{\theta_t^i} E_t^i[U_i(w_1^i)] \tag{14}$$

subject to a wealth accumulation constrain

$$w^1_i = (R^f + \theta^i_t \frac{\frac{r_{t+1}}{P^X_{t+1}}}{\frac{P_t}{P^X_t}}) w^0_i = (R^f + \theta^i_t (\frac{r_{t+1}}{r_t} \frac{P^X_t}{P^X_{t+1}})) w^0_i \quad (15)$$

where the information set of an investor i in period t is given by

$$I^t_i = \{s^t_i, n^t_i, \{X^s\}_{s \leq t}, \{P_s\}_{s \leq t}\}$$

An investor i faces a trade-off between allocating its resources at the short-term policy rate, R^f , or at a government bond with a maturity m , whose return is determined by the term premium over investor i expectation on future short-term policy rate according to fundamentals which denotes an extra return (a risk premium) that investors demand to compensate them for the risk associated with a non-short term bond.

The economic return of a government bond The wealth accumulation constrain given by equation (15) entails the profitability of government bond is depicted by $\frac{PV_{t+1}}{PV_t}$ where $PV_{t+1} = \frac{r_{t+1}}{P^X_{t+1}}$ and $PV_t = \frac{r_t}{P^X_t}$ are the price-to-value ratio of periods $t + 1$ and t respectively. Intuitively, an overvaluation in period $t + 1$ (higher PV_{t+1}) in relation to fundamentals increases the bond return all else equal. Conversely, an undervaluation in period t (lower PV_t) implies a greater profitability. A key implication of this setup is that investors are seeking arbitrage opportunities derived from the spread between market prices and fundamentals of a bond with maturity m taking into account the opportunity cost given by risk-free rate.

Definition. (Equilibrium) A stationary rational expectations equilibrium in linear strategies is a set of portfolio shares θ^i_t for each investor i at date t and a price function P_t such that: i) θ^i_t maximizes the investor i 's expected utility given his information set and ii) the price function P is such that the market for the risky asset clears at each date t , that is, $\theta^i_t w^i_0 di = Q_t$

Even though for this type of models it is not possible to characterize in closed-form the portfolio problem solved by investors and the equilibrium price, D'Avila and Parlato (2018) showed that it is possible to find a closed-form solution to the model in approximate form.

The optimally condition of an investor who maximizes Equation (14) subject to the wealth accumulation constraint in Equation (15) is given by

$$E[U'(w^1_i)(\frac{\frac{r_{t+1}}{P^X_{t+1}}}{\frac{P_t}{P^X_t}}) | I^t_i] = 0 \quad (16)$$

Similar to D'Avila and Parlato (2018), we approximate the first-order condition expressed in equation (16) in five steps. First, we use a first-order Taylor expansion of an investor's future marginal

utility $U'(w^1)$ around the current date wealth level w^0 . As a result, we approximate $U'(w^1)$ as follow

$$U'(w^1) \approx U'(w^0) + U''(w^0)\Delta w^1 \quad (17)$$

which permit us to write equation (16) as

$$U'(w^0)E\left[\frac{\frac{r_{t+1}}{P_{t+1}^X}}{\frac{P_t}{P_t^X}}\right] + U''(w^0)w^0E\left[\left((R^f - 1) + \theta^t\left(\frac{P_{t+1}}{P_t^X}\right)\right)\left(\frac{\frac{P_{t+1}}{P_{t+1}^X}}{\frac{P_t}{P_t^X}}\right)\right] \approx 0$$

Second, we impose that terms that involve the product of two or more net interest rates are negligible. In continuous time, these terms would be of order $(dt)^2$, implying that

$$((R^f - 1)E\left[\frac{\frac{r_{t+1}}{P_{t+1}^X}}{\frac{P_t}{P_t^X}}\right]) \approx 0$$

and

$$(E\left[\frac{\frac{r_{t+1}}{P_{t+1}^X}}{\frac{P_t}{P_t^X}}\right])^2 \approx 0$$

which allow us to recovery equation (16) as follow

$$U'(w^0)E\left[\frac{\frac{r_{t+1}}{P_{t+1}^X}}{\frac{P_t}{P_t^X}}\right] + U''(w^0)w^0\theta^tVAR\left[\frac{\frac{P_{t+1}}{P_{t+1}^X}}{\frac{P_t}{P_t^X}}\right] \approx 0$$

Thus, we can write an investor's risky portfolio share θ_t^i as

$$\theta_t^i \approx \frac{1}{\gamma^i} \frac{E\left[\frac{\frac{r_{t+1}}{P_{t+1}^X}}{\frac{P_t}{P_t^X}}\right]}{VAR\left[\frac{\frac{P_{t+1}}{P_{t+1}^X}}{\frac{P_t}{P_t^X}}\right]} \quad (18)$$

where $\gamma^i \equiv -\frac{w_0^i U''(w_0^i)}{U'(w_0^i)}$ indicates the coefficient of relative risk aversion. These coefficients are time invariant since we have assumed that the distribution of investor types is time invariant and the wealth distribution across time and investor type is i.i.d.

Third, we write the bond prices P_{t+1} , P_t , P_{t+1}^X and P_t^X as a perpetuity as follow

$$\frac{\frac{r_{t+1}}{P_{t+1}^X}}{\frac{P_t}{P_t^X}} = \frac{Y_{t+1}^X}{Y_{t+1}} \frac{Y_t}{Y_t^X}$$

Fourth, we take a log-linear approximation of the yields around the predetermined term premium variation. Formally, we find that

$$\ln\left(\frac{Y_{t+1}^X}{Y_{t+1}} \frac{Y_t}{Y_t^X}\right) = \Delta x_{t+1} - \Delta p_{t+1}$$

Fifth, we interpret $\Delta p_{t+1} - \Delta x_{t+1}$ as the change in the term premium. Accordingly, relative term premium definition, τ_{t+1}^E , gauges this differential in narrower sense as the residual uncertainty about fundamentals innovations after observing prices. Nonetheless, we use the stylized fact highlighted by Cohen et al (2018) of the similarity of term premium trends to do the following approximation $\Delta p_{t+1} - \Delta x_{t+1} \approx \Delta \tau_{t+1}^E$. Hence, we can express an investor's risky portfolio share, θ_t^i , as follow

$$\theta_t^i \approx \frac{1}{\gamma^i} \frac{E[\Delta x_{t+1} - \Delta p_{t+1}]}{VAR[\Delta x_{t+1} - \Delta p_{t+1}]} \approx \frac{1}{\gamma^i} \frac{E[-\Delta \tau_{t+1}^E]}{VAR[-\Delta \tau_{t+1}^E]} \quad (19)$$

Forming expectations In order to characterize the equilibrium it is necessary to characterize investors' expectations. We conjecture and subsequently verify that $E[\Delta x_{t+1} - \Delta p_{t+1}]$ is linear in s_t^i , $\bar{n}_t^i, x_t^r$, and x_t^π and $VAR[\Delta x_{t+1} - \Delta p_{t+1}]$ is constant. Assuming this conjecture, θ_t^i is linear function of s_t^i , $\bar{n}_t^i, x_t^r$, and x_t^π that can be written as follow

$$\theta_t^i \approx \alpha^i s_t^i + \alpha^{x^r} x_t^r + \alpha^{x^\pi} x_t^\pi + \alpha^n n_t^i - \alpha^p p_t + \psi^i \quad (20)$$

These coefficients are time invariant given that we have assumed that the distribution of investor types is time invariant and the wealth distribution across time and investor type is i.i.d.. This expression and the market clearing conditions $\theta_t^i w_0^i di = Q$ yield that

$$p_t = \frac{\bar{\alpha}_s}{\bar{\alpha}_p} u_t + \frac{\bar{\alpha}_{x^\pi}}{\bar{\alpha}_p} x_t^\pi + \frac{\bar{\alpha}_{x^r}}{\bar{\alpha}_p} x_t^r + \frac{\bar{\alpha}_n}{\bar{\alpha}_p} n_t + \frac{\bar{\psi}}{\bar{\alpha}_p} \quad (21)$$

where $\bar{\alpha}^h \equiv \int \alpha^h w_0^i di$ for $h = \{x^r, x^\pi, n, p\}$ and $\bar{\psi} = \int \psi^i w_0^i di - Q$. As in D'Avila and Parlatore (2018) and Vives (2008), we make use of the Strong Law of Large Numbers, since the sequence of independent random variables $\{\alpha^h w_0^i \frac{1}{N} \sum_{i=1}^N \alpha^h w_0^i \frac{1}{N} \sum_{i=1}^N \bar{n}_t^i\}$ has uniformly bounded variance and mean zero, allowing us to rewritten equation (21) as follow

$$p^t = \frac{\overline{\alpha_s}}{\overline{\alpha_p}} u_t + \left(\frac{\overline{\alpha_{x^\pi}}}{\overline{\alpha_p}} - \frac{\overline{\alpha_s}}{\overline{\alpha_p}} \right) x_t^\pi + \left(\frac{\overline{\alpha_{x^r}}}{\overline{\alpha_p}} - \frac{\overline{\alpha_s}}{\overline{\alpha_p}} \right) x_t^r + \frac{\overline{\alpha_s}}{\overline{\alpha_p}} x_{t+1} + \frac{\overline{\alpha_n}}{\overline{\alpha_p}} n_t + \frac{\overline{\psi}}{\overline{\alpha_p}} - \frac{\overline{\alpha_s}}{\overline{\alpha_p}} \mu_{\Delta x} \quad (22)$$

In this model, investors extract information from government bonds yields. The information incorporated in the yield for an investor in the model is

$$\hat{\nu} = \frac{\overline{\alpha_p}}{\overline{\alpha_s}} \left(p_t - \left(\frac{\overline{\alpha_{x^\pi}}}{\overline{\alpha_p}} x_t^\pi + \frac{\overline{\alpha_{x^r}}}{\overline{\alpha_p}} x_t^r + \frac{\overline{\alpha_n}}{\overline{\alpha_p}} \mu_{\Delta x} + \frac{\overline{\psi}}{\overline{\alpha_p}} \right) \right) \quad (23)$$

which has a precision $\tau^{\hat{\nu}} \equiv VAR[\hat{\nu} | u^t, \{x^s\}_{s \leq t}, p_{t-1}]^{-1} = \left(\frac{\overline{\alpha_s}}{\overline{\alpha_n}} \right)^2 \tau_{\Delta n}$. It is important to highlight that we express by ν the unbiased signal of u_t incorporated in the change in log yields Δp_t and by $\hat{\nu}$ the unbiased signal about u_t contained in the log yield p_t . Considering the investor's information set, $VAR[n^t | u^t, \{x^s\}_{s \leq t}, p_{t-1}] = VAR[\Delta n^t | u^t, \{x^s\}_{s \leq t}, p_{t-1}]$. Therefore, we have that

$$E^i[u^t] = E[u^t | I^t] = \frac{\tau_s s_t^i + \tau_u n_t^i + \tau_{\hat{\nu}} \hat{\nu}}{\tau_s + \tau_u + \tau_{\hat{\nu}}}$$

$$E[u^t | I^t] = \frac{\tau_s s_t^i + \tau_u n_t^i + \tau_{\hat{\nu}} \left(\frac{\overline{\alpha_p}}{\overline{\alpha_s}} \left(p_t - \left(\frac{\overline{\alpha_{x^\pi}}}{\overline{\alpha_p}} x_t^\pi + \frac{\overline{\alpha_{x^r}}}{\overline{\alpha_p}} x_t^r + \frac{\overline{\alpha_n}}{\overline{\alpha_p}} \mu_{\Delta x} + \frac{\overline{\psi}}{\overline{\alpha_p}} \right) \right) \right)}{\tau_s + \tau_u + \tau_{\hat{\nu}}}$$

$$VAR[u^t | I^t] = (\tau^s + \tau^u + \tau_{\hat{\nu}})^{-1}$$

These expressions means that our conjecture about θ_i is satisfied. To see this, it is key to note that

$$E[\Delta x_{t+1} - \Delta p_{t+1}] = \mu_{\Delta x} - \frac{\overline{\alpha_{x^r}}}{\overline{\alpha_p}} \mu_{x^r} - \frac{\overline{\alpha_{x^\pi}}}{\overline{\alpha_p}} \mu_{x^\pi} - \frac{\overline{\alpha_s}}{\overline{\alpha_p}} \mu_{\Delta x} + \left(1 + \frac{\overline{\alpha_s}}{\overline{\alpha_p}} - \frac{\overline{\alpha_{x^r}}}{\overline{\alpha_p}} w_{x^r} - \frac{\overline{\alpha_{x^\pi}}}{\overline{\alpha_p}} w_{x^\pi} \right) E[u_t]$$

where we considered that $w_{x^r} = \frac{E[u_t^r]}{E[u_t]}$, $w_{x^\pi} = \frac{E[u_t^\pi]}{E[u_t]}$ are scalars. We used that $E[u_{t+1}] = 0$, and $E[\epsilon_{t+1}^{\Delta p}] = 0$. In addition, we have that

$$VAR[\Delta x_{t+1} - \Delta p_{t+1}] = \left(1 + \frac{\overline{\alpha_s}}{\overline{\alpha_p}} - \frac{\overline{\alpha_{x^r}}}{\overline{\alpha_p}} w_{x^r} - \frac{\overline{\alpha_{x^\pi}}}{\overline{\alpha_p}} w_{x^\pi} \right)^2 VAR[u_t]$$

$$= \left(1 + \frac{\overline{\alpha_s}}{\overline{\alpha_p}} - \frac{\overline{\alpha_{x^r}}}{\overline{\alpha_p}} w_{tx^r} - \frac{\overline{\alpha_{x^\pi}}}{\overline{\alpha_p}} w_{tx^\pi} \right)^2 (\tau_s + \tau_u + \tau_{\hat{\nu}})^{-1}$$

Using these expressions in the first-order condition and matching coefficients gives

$$\begin{aligned}
\alpha_{x^r}^i &= \frac{1}{\gamma^i \left(1 + \frac{\overline{\alpha_s}}{\alpha_p} - \frac{\overline{\alpha_{x^r}}}{\alpha_p} w_{x^r} - \frac{\overline{\alpha_{x^\pi}}}{\alpha_p} w_{x^\pi}\right)} \\
\alpha_{x^\pi}^i &= \frac{1}{\gamma^i \left(1 + \frac{\overline{\alpha_s}}{\alpha_p} - \frac{\overline{\alpha_{x^r}}}{\alpha_p} w_{x^r} - \frac{\overline{\alpha_{x^\pi}}}{\alpha_p} w_{x^\pi}\right)} \\
\alpha_s^i &= \frac{1}{\gamma^i \left(1 + \frac{\overline{\alpha_s}}{\alpha_p} - \frac{\overline{\alpha_{x^r}}}{\alpha_p} w_{x^r} - \frac{\overline{\alpha_{x^\pi}}}{\alpha_p} w_{x^\pi}\right)} \\
\alpha_n^i &= \frac{1}{\gamma^i \left(1 + \frac{\overline{\alpha_s}}{\alpha_p} - \frac{\overline{\alpha_{x^r}}}{\alpha_p} w_{x^r} - \frac{\overline{\alpha_{x^\pi}}}{\alpha_p} w_{x^\pi}\right)} \\
\alpha_p^i &= \frac{1}{\gamma^i \left(1 + \frac{\overline{\alpha_s}}{\alpha_p} - \frac{\overline{\alpha_{x^r}}}{\alpha_p} w_{x^r} - \frac{\overline{\alpha_{x^\pi}}}{\alpha_p} w_{x^\pi}\right)} \\
\psi^i &= \frac{1}{\gamma^i} \frac{\mu \Delta x - \frac{\overline{\alpha_{x^r}}}{\alpha_p} \mu_{x^r} - \frac{\overline{\alpha_{x^\pi}}}{\alpha_p} \mu_{x^\pi} - \frac{\overline{\alpha_s}}{\alpha_p} \mu \Delta x + \left(1 + \frac{\overline{\alpha_s}}{\alpha_p} - \frac{\overline{\alpha_{x^r}}}{\alpha_p} w_{x^r} - \frac{\overline{\alpha_{x^\pi}}}{\alpha_p} w_{x^\pi}\right) - \tau_{\tilde{\nu}} \left(\frac{\overline{\alpha_n}}{\alpha_p} + \psi\right)}{\left(1 + \frac{\overline{\alpha_s}}{\alpha_p} - \frac{\overline{\alpha_{x^r}}}{\alpha_p} w_{x^r} - \frac{\overline{\alpha_{x^\pi}}}{\alpha_p} w_{x^\pi}\right)^2}
\end{aligned}$$

Lemma 1 The change in yields described in Equation (5) in the identification framework in Section 2 can be calculated endogenously as an approximation of the equilibrium price process in the model described in this section, i.e., the equilibrium price process is given by

$$\Delta_p^t \approx \phi + \phi^0 \Delta x_t^r + \phi^1 \Delta x_t^\pi + \phi^2 \Delta x_{t+1} + \phi_n \Delta n_t$$

where the coefficients $\phi = 0$, $\phi_0 = \left(\frac{\overline{\alpha_{x^r}}}{\alpha_p} - \frac{\overline{\alpha_s}}{\alpha_p}\right)$, $\phi_1 = \left(\frac{\overline{\alpha_{x^\pi}}}{\alpha_p} - \frac{\overline{\alpha_s}}{\alpha_p}\right)$, $\phi_2 = \frac{\overline{\alpha_s}}{\alpha_p}$, and $\phi_n = \frac{\overline{\alpha_n}}{\alpha_p}$.

Lemma 1 Taking the differences of equation (21) in $t + 1$ and t implies the following

$$\Delta p^t = \left(\frac{\overline{\alpha_{x^\pi}}}{\alpha_p} - \frac{\overline{\alpha_s}}{\alpha_p}\right) \Delta x_t^\pi + \left(\frac{\overline{\alpha_{x^r}}}{\alpha_p} - \frac{\overline{\alpha_s}}{\alpha_p}\right) \Delta x_t^r + \frac{\overline{\alpha_s}}{\alpha_p} \Delta x_{t+1} + \frac{\overline{\alpha_n}}{\alpha_p} \Delta n_t$$

Then, the matching process to map the coefficients comes directly from the comparison with equation (5).

3.1 Investors' optimal allocation in sovereign bonds

In this section, we argue that an adequately deep ILB market unveils information on real interest rates, break-even inflation and relevant risk premium. This information can shed a light on why nominal yields are where they are which can boost the demand for conventional nominal bonds and lower nominal yields.

By construction ILBs provide an assessment of market expectations of real interest rates and inflation breakevens also known as inflation compensation. Like traditional nominal interest rate decomposition in term premium models, the real interest rates can be decomposed to a real term premium and a real short-term rate expectation. The difference between the nominal and real interest rate, allows to do the equivalent calculation for the breakeven rate to inflation risk premium and expected inflation (see Figure 1).

Nominal bond investors demand a positive inflation risk premium to protect against inflation. A positive inflation risk premium implies that the breakeven rate will be higher than the cashflows of an ILB based on expected inflation. As a result, the higher the inflation risk premium the lower the ex-ante borrowing costs for an ILB issuer compared to nominal issuance.

On the flipside, ILBs tend to be less liquid than nominal bonds and investors demand a liquidity premium. This premium reflects investors' concerns about their ability to resell their ILB holdings in a less liquid secondary market compared to nominal bonds and especially fixed rate bonds. Consequently, this premium would increase ex-ante borrowing costs relative to nominal issuance by driving up the real yield and reducing the breakeven rate.

The relative size of these two premiums is difficult to determine ex ante. As Veladia-Rubiano et al (2019) note nominal bonds may be more attractive in countries with small, shallow and potentially fragmented bond markets where the liquidity premium becomes a dominant factor. In contrast for countries with high and volatile inflation, the inflation risk premium might be a more important factor than liquidity.

Figure 1: Yield Curve and Term Premium Decomposition

Real yield	+	Breakeven rate		Nominal Yield
=		=		=
E[real policy rate rate]	+	E[inflation target]	=	E[policy rate]
+		+		+
Real term premium	+	Inflation risk premium	=	Nominal Term premium
+		-		
Liquidity premium		Liquidity premium		

Departing from equation (19), we can express the share of an investor's, i , portfolio allocated in

risky nominal sovereign fixed-rate bond, $\theta_t^{i,nominal}$, as follow

$$\theta_t^{i,nominal} \approx \underbrace{\frac{1}{\gamma^i} \frac{E[-\Delta\tau_{\nu t+1}^{E,nominal}]}{VAR[-\Delta\tau_{\nu t+1}^{E,nominal}]}}_{\text{demand for fixed rate bonds}} \approx \underbrace{\theta_t^{i,real} \omega_{real} + \theta_t^{i,inflation} \omega_{inflation}}_{\text{Fisher decomposition}} \quad (24)$$

where we define $\theta_t^{i,real}$, $\theta_t^{i,inflation}$, ω_{real} , $\omega_{inflation}$ as follow

$$\theta_t^{i,real} \approx \frac{1}{\gamma^i} \frac{E[-\Delta\tau_{\nu t+1}^{E,real}]}{VAR[-\Delta\tau_{\nu t+1}^{E,real}]} \quad (25)$$

$$\theta_t^{i,inflation} \approx \frac{1}{\gamma^i} \frac{E[-\Delta\tau_{\nu t+1}^{E,inflation}]}{VAR[-\Delta\tau_{\nu t+1}^{E,inflation}]} \quad (26)$$

$$\omega_{real} = \frac{VAR[-\Delta\tau_{\nu t+1}^{E,real}]}{VAR[-\Delta\tau_{\nu t+1}^{E,nominal}]} \quad (27)$$

$$\omega_{inflation} = \frac{VAR[-\Delta\tau_{\nu t+1}^{E,inflation}]}{VAR[-\Delta\tau_{\nu t+1}^{E,nominal}]} \quad (28)$$

From equation (24), one can see that the demand for fixed-rate bonds, $\theta_t^{i,nominal}$, is positively related with the demand for ILB, $\theta_t^{i,real}$, and break-even inflation, $\theta_t^{i,inflation}$. As such, demand for nominal bonds will be higher if investors expect declining inflation risk premium in the ILB market and/or inflation volatility is expected to be low. A potential driver for such a scenario could be due to investor perceptions that the central bank will be less lenient in fighting inflation going forward. In this case, the demand for ILBs would be negatively impacted while the allocation on fixed rate bonds would increase other things equal.

We can also rewrite equation (24) to express the demand for ILBs, $\theta_t^{i,real}$, as follow

$$\theta_t^{i,real} \approx \theta_t^{i,nominal} \omega_{real}^{-1} - \theta_t^{i,inflation} \frac{\omega_{inflation}}{\omega_{real}} \quad (29)$$

Intuitively, equation (29) shows that the demand for ILBs is negatively related to the demand for break-even inflation. As such, in an environment where upside risks to inflation and/or inflation variability increase, the demand for ILBs would be positively impacted while the allocation on fixed rate bonds would be reduced other things equal.

Its worth noting that the above section doesn't capture the signalling effect of the amount of ILBs supplied by the government. If a government opts to maintain or increase its share of ILBs, it may help to signal to the markets that it has less to benefit from higher inflation going forward. This can increase the credibility of the inflation targeting regime and reduce the inflation risk premium which has an indirect positive effect on the overall cost of government borrowing.

4 Empirical analysis

In this section, we make use of the insights of the structural model detailed in Section 3 to construct and analyze a shock triggered by the opening of ILB sovereign market.

4.1 The opening of an ILB market

Data To track the opening of a sovereign ILB market we relied on the dataset of General Government Debt composition by instrument (fixed-rate, floaters, ILBs, and FX) provided by Banking of International Settings (BIS), covering 30 countries on yearly basis from 1995 to 2021. We set a cut-off for ILB of 5 percent¹ of total stock of the General Government debt to define the opening of a sovereign ILB market. As the bulk of the opening happened in late nineties and early 2000, we do not have data on local bond secondary market for several countries. As a result, we used alternatives term premium measures such as the sovereign credit rating (average of Fitch, Moodys, and SP rating) and the 5Y CDS depicted by the work of Kose et al. (2022) that built a broad cross-country database of 30 fiscal space metrics over the period of 1990-2021. Furthermore, we use this database to map the developments of local sovereign market underpinned by the creation of ILBs structure focusing on changes of General Government debt in foreign currency and debt average maturity.

¹We also run robustness tests using different cut-offs of 3, 2, and 1 percent that are broadly in line with the results shown in Figures 3, 4 and 5.

Table 1: Summary Statistics of EMs treated units

Statistic	N	Mean	St. Dev.	Min	Median	Max
ILB as a share of GGGD	8	24.86	25.28	1.41	21.76	78.91
Year of ILB market opening	8	2003	7	1995	2003	2015
Average of credit agencies sovereign rating (1-21 scale)	8	11.71	3.06	5.82	11.97	15.77
CDS5Y (bps)	8	594	1,106	80	205	3,314
GGGD in foreign currency (percent of total)	5	25.60	14.02	5.18	29.43	42.47
Sovereign debt average maturity (years)	8	12.47	3.49	6.19	12.71	16.74
GGGD (share of GDP)	8	47.45	18.60	16.32	46.32	71.45
Primary balance (share of GDP)	8	0.14	0.84	-1.32	0.53	1.04

Note: The unit of analysis is EMs sovereigns, which are classified using IMF's Fiscal Monitor taxonomy, aggregated in a yearly basis. Data on ILB as a share of GGGD (average centered at the country level) and year of ILB market opening come from the BIS spanning from 1995 to 2021. The remainder of the variables comes from averages centered at the country level using the database built by Kose et al. (2022) over the period of 1990-2021.

Table 2: Summary Statistics of EMs never-treated units

Statistic	N	Mean	St. Dev.	Min	Median	Max
Average of credit agencies sovereign rating (1-21 scale)	46	9.63	2.81	5.44	8.87	15.84
CDS5Y (bps)	17	306	285	118	223	1,176
GGGD in foreign currency (percent of total)	16	41	25.00	0.00	43	77
Sovereign debt average maturity (years)	33	8.95	4.26	3.21	7.24	19.50
GGGD (share of GDP)	51	48.37	23.88	13.49	41.21	118.34
Primary balance (share of GDP)	50	-0.28	2.33	-6.09	-0.53	7.21

Note: The unit of analysis is EMs sovereigns, which are classified using IMF's Fiscal Monitor taxonomy, aggregated in a yearly basis. The variables comes from averages centered at the country level using the database built by Kose et al. (2022) over the period of 1990-2021.

Empirical strategy of the event-study We follow the approach of Callaway and Sant'Anna (2021) as traditional Two-Way Fixed Effects (TWFE) event-study may be significantly biased. There is a growing literature on the casual interpretations of TWFE regressions² pointing out that TWFE linear regression should not be used to highlight treatment effect dynamics. Callaway and Sant'Anna (2021) does not rely on restricting treatment effect heterogeneity assuming only the no-anticipation condition and the existence of parallel trend based on a never-treated and/or not-yet-treated group.

Results The creation of a sovereign Inflation-Linked Bond (ILB) market leads to a significant improvement across different metrics for EMs, but it is not significant for AEs. We find that EMs use ILB market both to migrate from external to local debt and to expand its debt maturity. On the mechanisms, in an environment of deteriorated expectations on the inflation term premium, the demand for ILB is higher than for conventional nominal bonds. As such, ILBs are well-positioned

²For a detailed discussion see Athey and Imbens (2018; Borusyak and Jaravel (2017); Callaway and Sant'Anna (2021); de Chaisemartin and D'Haultfoeuille (2020); Goodman-Bacon (2018); Sun and Abraham (2021)

to unlock the migration both from local FX-linked and short fixed-rate debt. Stylized facts shown by Velandia-Rubiano et al. (2022) point out that ILBs were indeed used as a tool to induce an improvement of debt profile by some EMs, such as Brazil, Chile, and Israel.

Analytically, recovering our simple theoretical model, equation (29) details that the demand for ILBs is negatively related to the demand for break-even inflation. As a result, an environment of deteriorating inflation expectations (an increase of the inflation term premium) has different effects on ILBs and conventional bonds. The demand for ILBs would be positively impacted while the allocation on conventional bonds would be reduced other things equal. Considering that the FX pass-through is effectively operating, ILBs could also be a substitute asset to local FX-linked debt. Nevertheless, in line with Velandia-Rubiano et al. (2022), the use of ILBs as a tool to trigger an improvement in the debt profile is contingent on existence of some local buyers, meaning that the typical marginal buyers of ILBs are residents, rather than non-residents. On the flip side a predominately domestic buy-and-hold ownership (e.g. by pension funds) can increase the liquidity premium of ILBs.

Figure 2 details the response of a rating scale (average of Fitch, Moodys', and SP) where 1 represents a technical default and 21 indicates a AAA rating. The vertical lines indicate a 95 confidence interval. It is important to highlight that credit ratings metrics are slowly moving variables, responding, thus, with lag in comparison with regular market variables. From a quantitative standpoint, the methodology of these agencies is sensible to the debt profile (FX and rollover risk), which is, in turn, positively impacted by ILBs assuming as a starting point a riskier debt composition. In line with intuition, the benefits from the FX and rollover risk reduction underpinned by the opening of the ILB market take some time to factor in as the peak-response happens 10 years after the creation, roughly implying a 20 percent increase in credit ratings for both comparison groups (never-treated and not-yet-treated).

Figure 3 shows the impact on 5y CDS, which can be interpreted as the price of an insurance against a sovereign default in external debt. Similarly to Figure 2, considering the never-treated units as the comparison group, we see that the peak-response occurs about 10 years after the opening leading to 50 percent contraction of 5Y CDS. Furthermore, Figure 4 shows that EMs use ILB market both to migrate from external to local debt and to expand its debt maturity, reducing the rollover risk and, thus, the term premium.³

³A scenario not captured in this study is the impact of a high share of ILBs in credit risk metrics depending on the type of an inflation shock. For example, an unexpected increase in inflation e.g. due to higher energy shocks can be particularly costly for an energy importing economy given that the debt servicing costs of ILBs will increase due to higher realized inflation. At the same time, tax revenues will likely not increase by the same amount to compensate this cost. As a result, an issuer that has opted to increase ILB issuance at the expense of fixed rate issuance, could experience a deterioration in the demand of both nominal and ILB bonds due to the adverse impact of ILBs on overall debt servicing.

Figure 2: Average effect on sovereign credit rating (percentage change) by the length of exposure since the opening of the ILB market for EMs

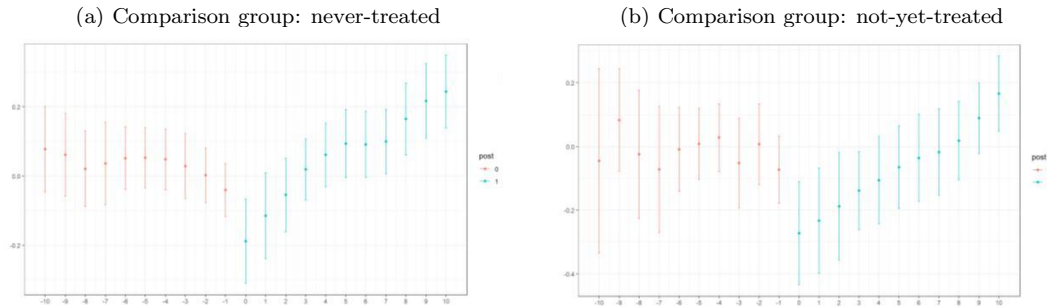


Figure 3: Average effect on 5Y CDS (percentage change) by the length of exposure since the opening of the ILB market for EMs

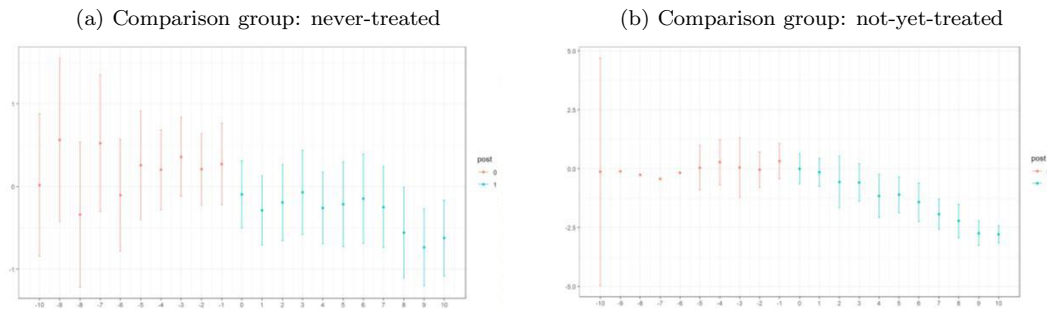
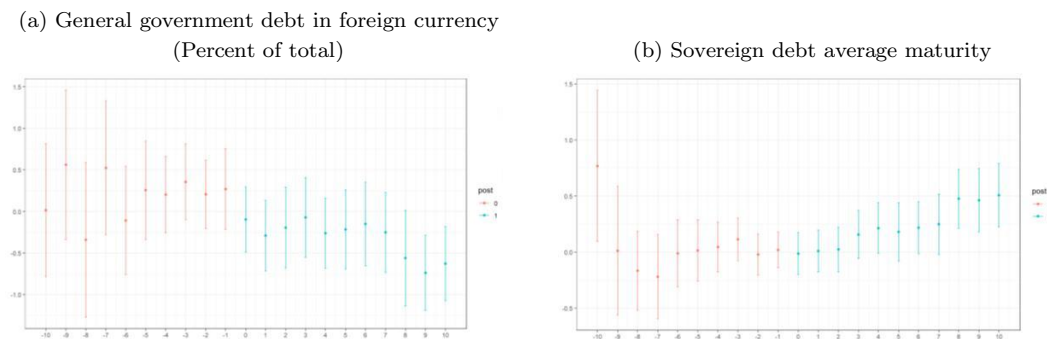


Figure 4: Average effect (percentage change) by the length of exposure since the opening of the ILB market for EMs (Comparison group: never-treated)

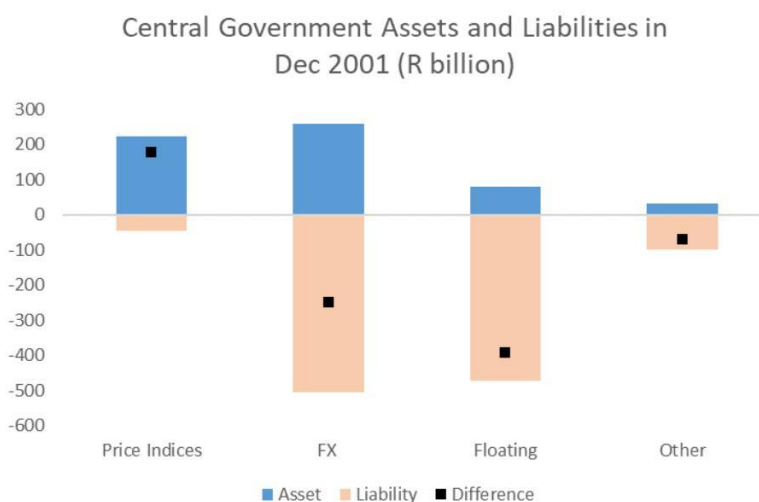


5 Case Study: Brazil

The Brazilian treasury announced its plans to issue its current ILB benchmark (NTN-B) in 2002. The NTN-B is linked to the Extended National Consumer Price Index which is the reference for Brazil's inflation-targeting framework established in 1999. Prior to 2002, there have been multiple ILBs issued that were linked to other price indices such as the General Index of Market Prices (IGP-M) and the National Consumer Price Index (INPC). Despite the introduction of NTN-Bs the treasury continued issuing NTN-Cs (linked to IGP-M) up until 2006.

The introduction of NTN-Bs was part of a new asset and liability management strategy launched in 2002. This ALM strategy (Brazilian National Treasury, 2002) considered the imbalance between the central government assets and liabilities as well as the expected cash flows. In terms of net assets, the treasury at the time had large claims originating from the refinancing of state debt in the 1990s that were linked to inflation. In terms of net liabilities, the biggest mismatch were due to the outstanding debt linked to the U.S. dollar and to floating interest rates. The treasury also took into account the mismatches in terms of future cash flows. Namely tax revenues were "denominated in domestic currency" and demonstrated "high correlation with nominal GDP, which in turn follows prices indices", while a large amount of expenditures at the time was used to service US Dollar denominated debt.

Figure 5: Asset and Liability Management



In the context of reducing these mismatches, Brazil begun replacing floating-rate and FX debt for longer term fixed-rate securities and NTN-Bs. Starting from an ILB share of under 6 percent in 2001, the issuance strategy proceeded gradually for over a decade, supported

by measures to expand their investor base (See below) and taking into account market absorption constraints in the short run . The treasury’s communication strategy was enhanced in 2010 with the introduction of ”optimal” long term debt composition limits that were later converted to intervals in 2011 (see figure 7). The ILB share reached the ”optimal levels in in 2012-13 and has hovered around 30 percent since then.

Figure 6: Brazilian Debt Composition Developments

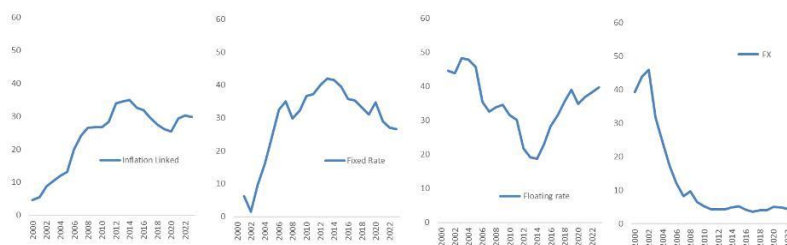
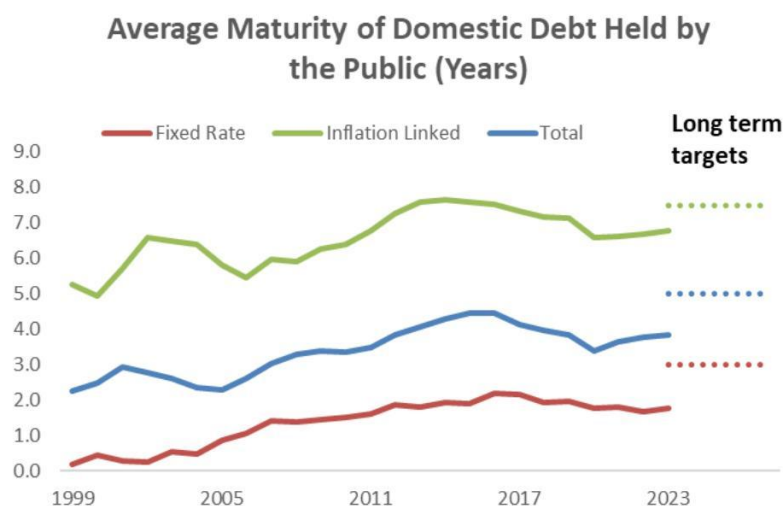


Figure 7: A Benchmark for the long-term Debt Composition

Brazil's Optimal Debt Composition Over the Long - Term						
	2002: ALM strategy	2010: Limits introduced	2011 to 2012	2013 to 2016	2017 to 2023	2024
Fixed rate	Increase	70 to 80	40 to 50	45 +/- 2	40 +/- 2	35 +/- 2
Inflation Linked	Increase		30 to 35	35 +/- 2	35 +/- 2	35 +/- 2
Floating Rate	Reduce	20	10 to 20	15 +/- 2	20 +/- 2	23 +/- 2
FX	Reduce	10	5 to 10	5 +/- 2	5 +/- 2	7 +/- 2

ILB debt has had the largest contribution in terms of lengthening domestic federal debt. With an average maturity close to 7 years and the ILB weight in debt composition increasing from under 6 percent in 2000 to over 30 percent in recent years, the issuance of NTN-Bs has contributed the most in lengthening the average maturity of debt. In contrast even though the weight of fixed rate debt has also increase during the same period its average maturity has remained low, close to half the average maturity of the overall debt held by the public.

Figure 8: Average Maturity and Long-term Targets



The increased supply of ILBs coincided with measures that increased the domestic investor base for longer term debt. Along with the launch of NTN-Bs, over the years the government^[footnote] took several measures with the intention of reducing the indexation of the domestic fund industry to short term rates, due to the high inflation rates in previous years. These include the extension of the minimum average remaining term for private pension funds and the introduction of tax incentives that support the lengthening of portfolios. Additionally as discussed in Veladia et al (2023), between 2002 and 2010 several regulations supported the increase of pension fund assets, which ended up the main investor in ILBs given the nature of their liabilities. As a result, pension funds have held on average 40 percent of the ILB market over the last decade followed by mutual funds at around 20 percent. Between 2006 and 2014 the ILB market also benefited from a series of measures to attract foreign participation (e.g. elimination of withholding tax, simplification of FX controls) in the domestic bond market. The share of non-resident investors in the ILB market reached a high of 10 percent in 2014 but their share declined rapidly after Brazil lost its investment rating by SP and Fitch in 2015 and by Moody's in 2016. Finally, a large increase in ILB issuance occurred in 2012, as the government adjusted the portfolio of extra-market funds by redeeming floating rate debt in exchange of fixed rate and NTN-Bs. Due to new regulations the extramarket funds adopted broader benchmarks that capture the total the federal public bond portfolio including the NTN-Bs. This benchmark switch was supported by an active communication strategy by the treasury that made the use of the new indices more common among the domestic fund industry⁴.

⁴The treasury also took several other measures that helped increase the attractiveness and liquidity of NTN-Bs

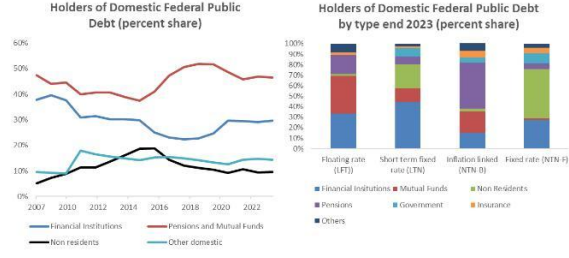


Figure 9: Public Debt Holders

Ex-ante issuance of NTN-Bs clearly benefits the treasury but ex-post results are more mixed. Breakevens across the NTN-B curve are well above forecasts of both markets and the government as well as the BCB's target. This allows the treasury to issue NTN-Bs at a lower ex-ante cost than nominal securities assuming that inflation forecasts are going to be realized. In practice, especially during periods of unexpected high inflation (e.g. in 2014-2015 and post COVID), the ex-post cost has been higher than nominal bonds, but on average over a longer time span the cost has been similar. more ex-post analysis to be included in future versions **All in all, Brazil's experience with ILBs has been successful, leading to a notable increase the maturity of debt and a significant reduction in FX mismatches as well as a a reduction in the overall indexation of the economy to short term interest rates.** Even though the Brazilian treasury at times had to switch issuance towards shorter debt due to changing market conditions it has managed to maintained its share of ILB debt close to its targets, largely due to presence of stable domestic investor base.

6 Conclusion

The main contributions of this paper is the provision of a novel theoretical and empirical analysis on the complementary interplay between a sovereign ILB market. We develop an empirical micro-funded method to extract the term premium and the underling demand for government securities. To the best of our knowledge, this is the first study that estimates the impact of the opening of an ILB sovereign market on risk metrics.

In light of the theoretical insights stemming from price informativeness framework, we conciliate this puzzle by empirically segregating the outcomes of the creation of ILB per se and the dynamics of conventional bonds. On the opening of ILB market, we discovery that the opening leads to a significant improvement across different risk metrics for EMs, but it is not significant for AEs.

that are not covered in this section. These included a careful re-organization and simplification of maturities, auction dates and bond cash flows. The presence of a deep interest rate derivatives market, with liquid future contracts at matching dates with government bonds also helped NTN-B demand by providing effective hedging instruments



Figure 10: Inflation expectations and Breakeven Inflation

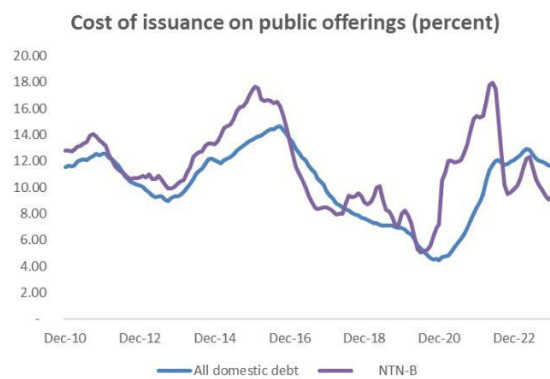


Figure 11: Ex-post Cost

Brazil is a notable example where ILBs were used as an effective way to improve the risk profile of the debt portfolio.

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A Government bonds Price Informativeness Appendix

From the perspective of understanding the informativeness of government yields about future payoffs, the key variable of interest is the unbiased signal of the innovation to future payoffs, u_t , incorporated in the price. This endogenous signal, which we denote by ν_t , is given by

$$\nu_t \equiv \frac{\Delta p^t - (\phi + \phi^2 \mu^{\Delta x^r} + \phi_2 \mu^{\Delta x^\pi} + (\phi_0 + \phi_2 \rho^r) x_t^r + (\phi_1 + \phi_2 \rho^\pi) x_t^\pi + \phi_2 Z_n)}{\phi_2} \quad (30)$$

where $Z_n = \mu_{\Delta n^r} + \mu_{\Delta n^\pi} + \epsilon_t^{\Delta n^r} + \epsilon_t^{\Delta n^\pi}$

Given equation (30), we can write the endogenous unbiased signal about u_t as

$$\nu_t = u_t + \frac{\phi_n}{\phi_2} (\Delta n^r - \mu^{\Delta n^r}) + \frac{\phi_n}{\phi_2} (\Delta n^\pi - \mu^{\Delta n^\pi}) \quad (31)$$

One can easily see that the signal, ν^t is unbiased because $E[\nu^t | u^t, \Delta x^r, \Delta x^\pi] = u^t$.

Following D’ávila and Parlatore (2018) steps’, we define two key measures of government yields informativeness: absolute and relative price informativeness. These are the crucial metrics for an external observer who learns about the future payoff from the government yields. Additionally, we define a key metric for government bonds: the relative term premium.

Definition. (Government bonds yield informativeness)

a) Absolute price informativeness, denoted by $\tau_\nu \in [0, \infty)$ is the precision of the unbiased signal about the innovation to the asset payoff contained in the asset price. Given Equation (5), it is formally given by

$$\tau^\nu \equiv (Var[\nu^t \mid x^{t+1}, \Delta x_t^r, \Delta x_t^\pi])^{-1} = \left(\frac{\phi_2}{\phi_n}\right)^2 \tau_{\Delta n} \quad (32)$$

where $\tau_{\Delta n} = (Var[\Delta n_t])^{-1} = (Var[\Delta n_t^f] + 2Cov[\Delta n_t^r, \Delta n_t^f] + Var[\Delta n_t^\pi])^{-1}$

b) Relative price informativeness, denoted by $\nu^R \in [0, 1]$, is the ratio between absolute price informativeness and the sum of absolute price informativeness and the precision of the innovation to the yield payoff. Given Equation (5), it is formally given by

$$\tau_\nu^R \equiv \frac{\tau_\nu}{\tau_\nu + \tau_u} \quad (33)$$

where $\tau_u = (Var[u_t])^{-1} = (Var(u_t^r) + 2Cov(u_t^r, u_t^\pi) + Var(u_t^\pi))^{-1}$

c) Relative term premium, denoted by $\nu^E \in [0, 1]$, is the ratio between the precision of the innovation to the yield payoff and the sum of absolute price informativeness and the precision of the innovation to the yield payoff. Given Equation (5), it is formally given by

$$\tau_\nu^E \equiv \frac{\tau_u}{\tau_\nu + \tau_u} \quad (34)$$

The definition of absolute price informativeness is derived from Blackwell(1953) criterion to rank experiments/signals, which is deeply used in literature on information and learning in financial markets, see, e.g., Vives (2008) and Veldkamp (2011).

Absolute price informativeness reveals, for given realizations of the future and current fundamentals, x_{t+1} , Δx_t^r , and Δx_t^π , indicates whether the signal incorporated in the yield is close to the fundamental taking into account the volatility expressed by $\tau_{\Delta n}$. On one hand, absolute price informativeness has a negative relation with the dispersion of the noise, τ_n , and the trading needs given by ϕ_n . On the other hand, τ_ν is positively related with private signals given by ϕ_2 . As a result, absolute price informativeness captures how much information about the fundamental can be gained by an uninformed external observer by exclusively observing the yield. When absolute price informativeness is high, an external observer receives a very precise signal about the fundamental by observing the nominal yield Δp_t . On the contrary, when price informativeness is low, Δp_t chiefly represents noise rather than fundamentals.

Relative price informativeness adjusts absolute price informativeness for the precision of the innovation to the fundamental through τ_u . As D'Avila and Parlato (2018) pointed out, this measure

expresses how much can be learned by observing the price relative to the volatility of the fundamental. Relative price informativeness measures, for an external observer, how much can be learned from the price relative to the total amount that can be learned. In the body of the paper, we focus on the identification of relative metrics of price informativeness rather than absolute ones because it is easily interpreted and comparable across bonds of different countries and maturities.

Relative term premium is, by construction, the complement of relative price informativeness, providing, thus, a metric about how much an external observer can not learn from the price relative to the total amount that can be learned. Thus, relative term premium can be interpreted as the residual uncertainty about payoff innovations after observing prices. On the one hand, relative term premium definition is similar to the term premium definition highlighted in the literature -such as in Kim and Orphanides (2007) and Cohen et al (2018)- because it gauges a risk compensation for the variance of the expected future short-term policy rate. On the other hand, relative term premium is different from the standard term premium metrics as $\nu^E \in [0, 1]$, and the regular term premium returns a fraction of gross yields.

Price Informativeness: Identification

Proposition 1. (Identifying price informativeness) Let $\beta, \beta_0, \beta_1, \beta_2$ denote the coefficients of the following regression of log-price differences on realized and future log-payoff differences:

$$\Delta p_t = \beta + \beta_0 \Delta x_t^r + \beta_1 \Delta x_t^\pi + \beta_2 \Delta x_{t+1} + e_t \quad (R1)$$

where $\Delta p_t = p_t - p_{t-1}$ denotes the date t change in log-yields, $\Delta x_t^r = x_t^r - x_{t-1}^r$, $\Delta x_t^\pi = x_t^\pi - x_{t-1}^\pi$, and $\Delta x_{t+1} = x_{t+1} - x_t$ respectively represent the date t and $t+1$ log-payoff differences of real yields, inflation, and nominal yields, and where $R_{\Delta x \Delta x'}^2$ denotes the Rsquared of Regression R1. Let ζ, ζ_0, ζ_1 indicate the coefficients of the following regression of log-yield differences on realized log-payoff differences:

$$\Delta p_t = \zeta + \zeta_0 \Delta x_t^r + \zeta_1 \Delta x_t^\pi + e_t^\zeta \quad (R2)$$

where $R_{\Delta x}^2$ is the R-squared of Regression R2. Then, relative price informativeness, τ_ν^R , defined in Equation (34), can be recovered as

$$\tau_\nu^R = \frac{R_{\Delta x \Delta x'}^2 - R_{\Delta x}^2}{1 - R_{\Delta x}^2} \quad (35)$$

The proof of Proposition 1 relies on identifying the right combination of parameters in the econometric specification defined by Regressions R1 and R2 that maps into the definition of relative price informativeness, τ_ν^R .

(Identifying price informativeness). The R-squareds of both regressions can be expressed as follows

$$R^2_{\Delta x \Delta x'} = 1 - \frac{Var(e_t)}{Var(\Delta p_t)}$$

$$R^2_{\Delta x'} = \frac{Var(\zeta_0 \Delta x_t^r + \zeta_1 \Delta x_t^\pi)}{Var(\Delta p_t)}$$

After substituting Equation (5) in Equation (30), we find that

$$\Delta p_t = \phi + \phi_2 \mu_{\Delta x^r} + \phi_2 \mu_{\Delta x^\pi} + \phi_n \mu_{\Delta n^r} + \phi_n \mu_{\Delta n^\pi} + (\phi_0 + \rho_0 \phi_1) \Delta x_t^r + (\phi_0 + \rho_0 \phi_1) \Delta x_t^\pi + \phi_2 u_t + \phi_n (\epsilon_t^{\Delta n^r} + \epsilon_t^{\Delta n^\pi}) \quad (36)$$

From the comparison of regression R2 with the structural Equation (35), one can see that $\psi = \phi + \phi_2 \mu_{\Delta x^r} + \phi_2 \mu_{\Delta x^\pi} + \phi_n \mu_{\Delta n^r} + \phi_n \mu_{\Delta n^\pi}$, $\psi_0 = \phi_0 + \rho_0 \phi_1$, $\psi_1 = \phi_0 + \rho_0 \phi_1$ and $\epsilon_t = \phi_2 u_t + \phi_n (\epsilon_t^{\Delta n^r} + \epsilon_t^{\Delta n^\pi})$. By comparing Regression R1 with the structural Equation (5), it follows that $\beta = \phi$, $\beta_0 = \phi_0$, $\beta_1 = \phi_1$, $\beta_2 = \phi_2$, and $e_t = \phi_n \Delta n_t$.

From Equation (35), the following variance decomposition must hold

$$Var[\Delta p] = Var[\zeta_0 \Delta x_t^r + \zeta_1 \Delta x_t^\pi] + Var[\phi_2 u_t + \phi_n (\epsilon_t^{\Delta n^r} + \epsilon_t^{\Delta n^\pi})]$$

$$= Var[\zeta_0 \Delta x_t^r + \zeta_1 \Delta x_t^\pi] + \phi_2^2 Var[u_t] + Var[e_t]$$

which can be rearranged to express $\frac{\tau_\nu}{\tau_u}$ as follows

$$1 = \frac{Var[\zeta_0 \Delta x_t^r + \zeta_1 \Delta x_t^\pi]}{Var[\Delta p]} + \frac{Var[e_t]}{Var[\Delta p]} \left(\frac{\phi_2^2}{Var[e_t]} Var[u_t] + 1 \right)$$

$$1 = R^2_{\Delta x \Delta x'} + (1 - R^2_{\Delta x \Delta x'}) \left(\frac{\tau_\nu}{\tau_u} + 1 \right) \implies \frac{\tau_\nu}{\tau_u} = \frac{R^2_{\Delta x \Delta x'} - R^2_{\Delta x \Delta x'}}{1 - R^2_{\Delta x \Delta x'}}$$

As a result, relative price informativeness can be written as

$$\tau_\nu^R = \frac{\tau_\nu}{\tau_\nu + \tau_u} = \frac{1}{1 + \frac{1}{\frac{\tau_\nu}{\tau_u}}} = \frac{R^2_{\Delta x \Delta x'} - R^2_{\Delta x \Delta x'}}{1 - R^2_{\Delta x \Delta x'}}$$

Numerically, a relative price informativeness of, for instance, 0.6, means that the initial uncertainty of an external observer about the innovation to the future payoff is reduced by 60 percent after learning from the price — this reading follows from the fact that $(\tau_\nu + \tau_u)^{-1} = \frac{1}{\tau_u} \frac{R}{1 - R}$.

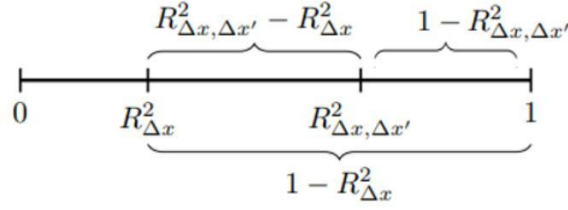


Figure 12: Explaining relative price informativeness

Geometrically, Figure 1 provides another angle to interpret Equation (33). The denominator $1 - R^2_{\Delta x'}$ can be interpreted as the residual uncertainty about future payoffs after conditioning on the realized date t yield payoff. In turn, the numerator, $R^2_{\Delta x, \Delta x'}$, can be understood as the percentage reduction in uncertainty about future payoffs after observing the asset price at date t in addition to the realized payoff.

Proposition 2. (Relative term premium). Relative term premium τ_ν^E , defined in Equation (34), can be recovered as

$$\tau_\nu^E = \frac{1 - R^2_{\Delta x, \Delta x'}}{1 - R^2_{\Delta x'}} \quad (37)$$

(Relative term premium). By definition the relative term premium is the complement of relative price informativeness. Therefore, the proof of proposition 2 is straightforward as $R^2_{\Delta x, \Delta x'} + 1 - R^2_{\Delta x, \Delta x'} = 1 - R^2_{\Delta x'}$.

Proposition 3. (Identifying absolute price informativeness) Let $\beta_0, \beta_1, \beta_2$ denote the coefficients of the following regression of nominal log-price differences on realized and future log-payoff differences described by (R1). Let $\beta_1', \beta_0', \beta_1''$ represent the coefficients of the following regression of real log-price differences on realized and future log-payoff differences described by (R1'). Finally, let $\beta_1'', \beta_0'', \beta_1'''$ denote the coefficients of the following regression of inflation log-price differences on realized and future log-payoff differences described by (R1''). Then, we can recover absolute price informativeness of a nominal government yield, τ_ν , real interest rates, τ_ν^r , and inflation, τ_ν^π , as follows

$$\Delta p_t^r = \beta_1' + \beta_0' \Delta x_t^r + \beta_2' \Delta x_{t+1}^r + e_t^r \quad (R1')$$

$$\Delta p_t^\pi = \beta_1'' + \beta_0'' \Delta x_t^\pi + \beta_2'' \Delta x_{t+1}^\pi + e_t^\pi \quad (R1'')$$

$$\tau_\nu = \frac{\beta_2^2}{\sigma_e^2} = \frac{\phi^2}{\phi_n^2 \tau_{\Delta_n}^1} = \left(\frac{\phi}{\phi_n} \right)^2 \tau_{\Delta_n}^1 \quad (38)$$

$$\tau_{\nu_r} = \frac{\beta_{2r}^2}{\sigma_{e^r}^2} = \frac{\xi_2^2}{\xi_{n^r}^2 \tau_{\Delta_n^r}} = \left(\frac{\xi_2}{\xi_r}\right)^2 \tau_{\Delta_n^r} \quad (39)$$

$$\tau_{\nu_\pi} = \frac{\beta_{2\pi}^2}{\sigma_{e^\pi}^2} = \frac{\iota_2^2}{\iota_{n^\pi}^2 \tau_{\Delta_n^\pi}} = \left(\frac{\iota_2}{\iota_\pi}\right)^2 \tau_{\Delta_n^\pi} \quad (40)$$

(Identifying absolute price informativeness). The proof of proposition 3 comes directly from the comparison of Regression R1 with the structural Equation (5), which implies that $\beta = \phi$, $\beta_0 = \phi_0$, $\beta_1 = \phi_1$, $\beta_2 = \phi_2$, and $e_t = \phi_n \epsilon_t^{\Delta_{nt}}$ and, thus, $\sigma_e^2 = Var[e_t] = \phi_n^2 Var[\epsilon_t^{\Delta_{nt}}] = \phi_n^2 \tau_{\Delta_n}^{-1}$.

The comparison of Regression R1' with the Equation (6) yields that $\beta' = \xi$, $\beta_0' = \xi^0$, $\beta_1' = \xi^1$, and $e_t' = \xi_{n^r} \epsilon_t^{\Delta_{nt}^r}$ and, thus, $\sigma_{e^r}^2 = Var[e_t'] = \xi_{n^r}^2 Var[\epsilon_t^{\Delta_{nt}^r}] = \xi_{n^r}^2 \tau_{\Delta_n^r}^{-1}$. Lastly, the matching of Regression R1'' with the Equation (7) implies that $\beta'' = \iota$, $\beta_0'' = \iota_0$, $\beta_1'' = \iota_1$, and $e_t = \iota_{n^\pi} \epsilon_t^{\Delta_{n^\pi t}}$ and, as a result, $\sigma_{e^\pi}^2 = Var[e_t^\pi] = \iota_{n^\pi}^2 Var[\epsilon_t^{\Delta_{n^\pi t}}] = \iota_{n^\pi}^2 \tau_{\Delta_n^\pi}^{-1}$.

The Dynamic Canadian Debt Strategy Model^{*}

Nicolas Audet^a, Joe Ning^b

Abstract

We present recent improvements to the Canadian Debt Strategy Model. This model is intended to assist debt portfolio managers in choosing an optimal debt issuance strategy. The model consists of two parts: a simulation engine and a debt issuance optimization engine. The main innovation brought by this model is the introduction of dynamic issuance strategies, where issuances decisions are contingent on the realization of the model's state variables. We show that these strategies, when compared to more traditional fixed or deterministic issuance strategies, can bring considerable improvements to the costs and risks that are available to debt portfolio managers.

Keywords: Sovereign Debt Management; Portfolio Choice; Financial Forecasting and Simulation; Optimization Techniques; Dynamic Analysis.

JEL Code: H63; H68; G11; G17; C61

^{*} The views presented in this article are the views of the authors and do not necessarily represent the views of the Bank of Canada.

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1. INTRODUCTION

Debt managers face the task of structuring issuances in a way that minimizes debt costs subject to limitations on risk, while considering external objectives such as preserving the liquidity of secondary markets and maintaining predictable issuance plans. Moreover, recent economic and political events have created an economic environment that is singularly different from that of the last few decades, most notably from its high inflation and interest rates. Debt managers must therefore find how they should alter and adapt their issuance strategy.

In this paper, we show how incorporating a dynamic issuance strategy in the Canadian Debt-Strategy Model allows debt managers to adapt their issuances to a variety of economic environments, including high inflation and high interest rates. A dynamic debt issuance strategy model is a simulation-based model, in which, debt issuances are a function of the macroeconomic and financial conditions prevailing on each simulated path and point in time. This contrasts with the more classical approach where issuances weights are deterministic. See for example an earlier version of the Canadian Debt Strategy Model (Bolder & Deeley, 2011), as well as (Bergstrom, Anders, & Sara, 2002), or (Pick & Anthony, 2006).

Models with fixed or deterministic issuance weights suffer several drawbacks. For example, those models can only be used to set long-term target issuance weights and provide little guidance on how issuances should be decided in the short term. Using such a model for deciding on current issuances leads to a time-inconsistency between the issuance decisions that will be taken on the subsequent years. The mapping between issuance strategies and the cost & risk space that the model should provide only makes sense if the debt manager commits to the multi-year strategy proposed by the model. With fixed weights, this would mean that, at all time steps, the debt manager should issue with the same fixed weights until the model horizon, which is not what debt managers do. In practice, debt managers do adjust issuances to take advantage of current and expected future economic conditions. This inconsistency is precisely what breaks the mapping between issuance strategies and the cost / risk that the strategies entail.

The discussion above highlights that debt strategy modeling is not only about replicating the dynamics of the economic environment but also the decisions of the debt managers, which points to making issuance decisions contingent on economic conditions. Not only will the model be more realistic, but it will also stand a better chance of not suffering from the time inconsistency problem mentioned above. Moreover, such models can provide information on the short-term issuance strategy as well as insights on how the debt manager should react to a changing environment.

Our paper therefore aims at addressing that shortcoming. It follows from (Belton, et al., 2018), in the sense that it allows issuances to depend on the economic, financial, or fiscal environment. It differs from it by the functional forms mapping state variables to issuances: Belton uses a framework where issuances deviate from a “base” allocation using linear combination of issuance kernels, which are intended to induce a bias towards either short, middle or long-term debt issuances. In our paper, we use a more generic functional form of type “softmax” which is often used as the activation function of a neural network to normalize the output. We believe that our specification is more flexible and avoids issues related to negative issuances¹, which are a possibility with Belton’s model.

¹ Negative issuances do occur in reality as debt buy-back. However, these operations are generally either for cash management purpose or for improving secondary market liquidity. They therefore fall outside the scope of this paper.

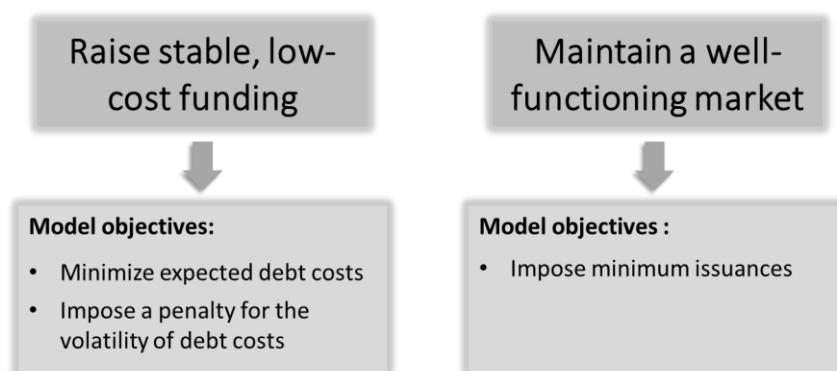
The remainder of this article is structured as follows. Section 2 provides an overview of the workflow of the debt optimization problem. Section 3 contains an in-depth description of the components of the model used in this article. Section 4.10 presents preliminary results of a debt optimization which includes conditioning issuances on various levels of inflation. Section 5 discusses the results and future planned analysis based on this framework.

2. OVERVIEW OF THE ISSUANCE STRATEGY OPTIMIZATION PROBLEM

2.1. Translating policy objectives into model objectives

Canadian debt managers aim to achieve two primary objectives: the first is to provide the government with stable low cost of funding, while the second one is to maintain a well-functioning market for government securities. From the point of view of the debt strategy modeler these policy objectives must be translated into the model's objective function.

Figure 1: Policy and model objectives



The first objective will be understood as choosing the issuance strategy in a way that minimizes the expected debt costs², subject to maintaining the volatility of costs below a certain threshold. Spanning a range of values for the threshold for the cost volatility generates the efficient frontier, which maps the minimum expected cost for a range of risk levels. This part of the issuance strategy optimization is perfectly analogous to the common mean-variance portfolio selection, as in (Markowitz, 1952).

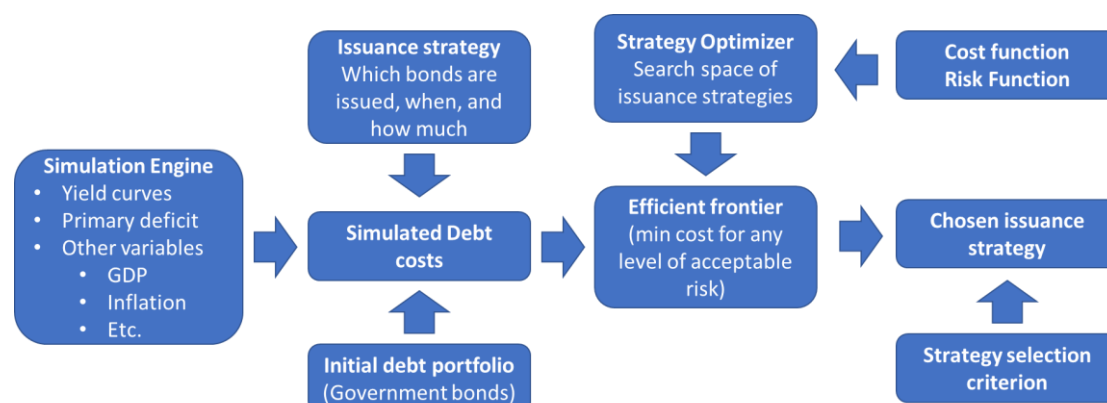
The second objective aims at preserving a well-functioning market for government securities. This objective can be understood as promoting the external effects from having high levels of liquidity on the secondary markets. In terms of the issuance strategy optimization, this objective is implemented as a constraint on minimum levels of issuances, for each bond type. The determination of these levels is outside the scope of this paper. We will therefore treat the minimum issuance constraints as given.

2.2. Overview of the strategy optimization process

This section provides an overview of the workflow used for the optimization of the issuance strategy. The process is illustrated in Figure 2.

² Debt costs are understood as the amounts paid as coupon on bonds.

Figure 2: Issuance strategy optimization workflow.



The first component in the optimization of the issuance strategy is the simulation engine. It is charged with the simulation of the financial, fiscal, and macroeconomic environment. The fiscal variables consist of the nominal and / or real term structure of interest rates at which government bonds are issued. The fiscal environment is intended to describe the evolution of the government's funding needs, which often take the form of the primary government deficit. Macroeconomic variables complete the description of the environment³.

The second element is the definition of the issuance strategy. In a simpler model, the strategy would be defined as a set of weights (one per term issued) and issuances in each sector would equal to total funding requirements times the weight associated to that sector. A slightly more sophisticated model would associate weights with a deterministic function of time. In this paper, issuance weights are associated to a function of both time and the state variables generated by the simulation engine.

The next element will be the calculation of the simulated debt costs associate with a particular issuance strategy. This calculation simply relies on an accounting-style description of the portfolio dynamics.

The following item is the definition of a cost and risk function. These will typically be defined over the debt costs, but can also include other variables, such as the government primary deficit⁴, GPD or CPI⁵, debt stock, etc. The cost function will typically be a measure of central tendency such as the expected total debt cost, while the risk function is typically a measure of dispersion such as the variance of the cost or a tail risk measure.

The next step is to pass the objective function to a numerical optimizer, which find issuance strategies that minimize the cost measure subject to an upper bound on the risk function. Spanning different values for the risk function generates the efficient frontier, from which debt managers can pick a debt issuance strategy. The selection of a specific point on the efficient frontier depends on the aversion to risk of the debt managers, and therefore fall outside the scope of this paper.

³ Note that our framework implies that the simulation engine produces data that is independent of the issuance strategy. This means that we exclude the possibility that the issuance strategy can influence, for example, the dynamics of macroeconomic variables. This is a simplification that is made to ease the numerical burden associated with optimization of the debt issuance strategy. Estimating the cost and risk associated with any given strategy would otherwise require re-running the simulation engine.

⁴ This can be included to rewrite the optimization in terms of the total deficit, which is the sum of the primary deficit (generated by the simulation engine) and the debt costs.

⁵ This could be used to deflate the debt costs using the GPD or CPI growth.

3. MODEL COMPONENTS

This section provides a detailed description of the model components discussed in section 2. Many of the components described should be thought of as examples of valid implementations for this framework⁶.

We will use the following notational conventions throughout the rest of this document.

- Time: $t \in (1 \dots T)$.
 - A variable indexed by t is $\mathcal{F}_t$ -measurable.
 - Today is $t = 0$. First simulated date is $t = 1$.
 - In general, the simulation horizon will be relatively long (for example: $T = 60$, or 15 years)
 - Bond maturity: $m \in (1 \dots M)$
 - A bond issued at t with maturity m matures at $t + m$.
 - Time and maturities are measured (and indexed) in quarters.
 - Bond year fraction: $\theta = 0.25$
 - Simulated path: $p \in (1 \dots P)$
 - State variable index⁷: $n \in (1 \dots N)$
- The order of the indices is always (t, m, p) or (t, n, p) .

3.1. The Simulation Engine

3.1.1. General requirements

The simulation engine is intended to produce:

Bond yields: $y_{p,m,t}$ observed at time t for a bond reaching maturity at time $t + m$. The coupon paid by this bond will be $\theta y_{p,m,t}$ for each unit of the bond issued, which are to be paid at times $t + 1, \dots, t + m$. The principal will be repaid at time $t + m$.

Note that we assume that all bonds pay a coupon, which is not the case for bills (for $m \in \{1, 2, 4\}$). This approximation is done for simplicity.

Primary deficit: $D_{p,t}$ which represents the government's funding needs, excluding debt costs and rollover of bonds that have reached their maturity.

The simulation engine can also generate other variables, such as inflation, output, or other macroeconomic variables. These variables can be added if they are part of the calculation of the objective function, the strategy selection criteria or if they improve the properties of the simulated distribution of yields or the primary deficit (such as adding to the predictive power).

3.1.2 Our simulation engine

The debt issuance strategy optimization in this paper is based on a Vector Autoregression, similar to (Diebold & Li, 2006) augmented with fiscal (primary deficit) and macroeconomic variables (inflation and output).

⁶ Note that both for simplicity and because real-return bonds are not issued by the Canadian government anymore, we will assume throughout that only nominal bonds are issued by the government. Adding RRB should not be particularly complex, although care must be taken to include in the debt costs the effect of the indexation of the principal amount to the price index. See (Bolder & Deeley, 2011) for discussion on how this can be done.

⁷ These variables form a basis for the dynamic issuance strategy, which will be described in section 3.2.3.

Let x_t represent the model state variables, which are⁸:

- L_t : yield curve level factor from the Nelson-Siegel decomposition.
- S_t : yield curve slope factor from the Nelson-Siegel decomposition.
- C_t : yield curve curvature factor from the Nelson-Siegel decomposition.
- $D_t = \log(1 + PD_t/GDP_t)$ where PD_t is the quarterly primary deficit.
- $G_t = \Delta \log(GDP_t)$
- $\pi_t = \Delta \log(CPI_t)$

The data is taken from the following data sources and transformations:

- Inflation: core CPI, seasonally adjusted (v41690924 in Statistics Canada's catalogue). The data is first subsampled to quarterly frequency. Inflation is then computed as the first difference of the log-CPI.
- GDP: nominal GDP, seasonally adjusted (v62305784 in Statistics Canada's catalogue). Note that the "quarterly" GDP is annualized and requires multiplying the data by a 0.25. The growth of GDP is the first difference of the log of the quarterly GDP.
- Deficit: primary deficit (excluding debt costs), which is built from the difference between:
 - Fiscal balance: net lending or net borrowing (v62425704 in Statistics Canada's catalogue). Note that the "quarterly" fiscal balance is again obtained by multiplying the data by 0.25.
 - Debt costs: interest on debt (v62425704 in Statistics Canada's catalogue). Again, the data needs to be multiplied by 0.25 to get quarterly costs.

Both series are for the Federal government and are seasonally adjusted. The primary deficit is computed as (-Fiscal Balance) minus Debt Costs.

- Yields: GoC zero-rates published by the Bank of Canada (Yield curves for zero-coupon bonds - Bank of Canada).
 - The tenors published rates at tenors (3M, 6M, 12M, 2Y, 5Y, 10Y, 30Y) are extracted from the published data.
 - The Nelson-Siegel factors (LEVEL, SLOPE, CURVATURE) are extracted from the selected rates.

The simulation engine is based on a VAR specification:

$$x_t = c + \sum_{l=1}^L \phi_l x_{t-l} + C \varepsilon_t \quad (1)$$

Here: x_t is stationary, $\varepsilon_t \sim iid N(0, I_K)$ and $\Omega = CC'$ is the covariance matrix of the VAR innovation. In general, CC' is the Cholesky decomposition of Ω , with C being a lower-triangular with real and positive diagonal entries. In general, in this document we will set $L = 1$.

The model parameters of the model can be estimated via OLS.

3.1.3. Simulation output conditioning

In general, the output of the simulation engine will not match expectations one could obtain expert forecasters. Also, debt managers will often want to align the simulation output with those forecasts or with various other scenarios. The main challenge with this requirement is to "discipline" the simulation output in a way that is meaningful from a probabilistic point of view.

⁸ The transformation used for D_t is intended to ensure its stationarity and improve its similarity to a gaussian distribution.

A description of such a method can be found in Appendix 1. The forecast data for the various model state variables can be obtained as follows.

- Rates: forecast data can be obtained on the Department of Finance's website.
- Deficit: forecasts for the Primary Deficit over GDP can be obtained from the budget available on the Departments of Finance's website (see for example the 2023 budget, table A1.5).
- Inflation and GDP growth: these can be obtained from the Department of Finance's website.

3.2. Portfolio dynamics, issuance strategy, and debt costs calculation

The debt portfolio dynamics are defined from the following variables:

- $G_{p,m,t}$: the issued amounts at time t of bonds reaching maturity at time $t + m$. These bonds are assumed to be issued at par and pay a coupon rate $y_{p,m,t}$ until maturity.
- $C_{p,t}$: the total debt costs, which are the coupons paid at time t .
- $R_{p,t}$: the total redemption amounts, which are the payments on bonds that have reached maturity.

Issuances are the choice variable for our optimization problem. In general, $G_{p,m,t}$ can take any positive value⁹, provided that those values respect the budget constraint. Also, the issuance amounts can only be a function of variables that are known to the debt manager, standing on path p at time t . Finally, $G_{p,m,t}$ must respect other constraints, such as those related to minimum issuances.

The redemption amounts and debt costs are calculated as:

$$R_{p,t} = \sum_{m=1}^M G_{p,m,t-m} \quad (2)$$

$$C_{p,t} = \theta \sum_{m=1}^M \sum_{i=1}^m y_{p,m,t-i} G_{p,m,t-i} \quad (3)$$

Issuances must be chosen in a way that respects the budget constraint, which specifies that the amounts raised through issuance must cover the primary deficit, bond redemptions and debt costs:

$$\sum_{m=1}^M G_{p,m,t} = D_{p,t} + R_{p,t} + C_{p,t} \quad (4)$$

Equations (2), (3) and (4) describe the portfolio dynamics. Note that equations (2) and (3) refer to past issuances and coupon rates (with time indices $t \leq 0$), which are already known, and are therefore defined by the composition of the initial debt stock, while equation (4) connects past and current issuance amounts.

⁹ We ignore the possibility of bond buybacks.

3.2.1. Static issuance strategy

The simplest way to parametrize the issuance strategy is to assume that each sector forms a fix percentage of the total amount issued.

$$G_{p,m,t} = w_m \sum_{l=1}^M G_{p,l,t} = w_m (D_{p,t} + R_{p,t} + C_{p,t}) \quad (5)$$

This strategy is the simplest, but obviously it has the drawback of being independent of the model state variables, and it also implies a discontinuity with the issuances at time $t = 0$.

3.2.2. Deterministic issuance strategy

A simple way to improve on the discontinuity of the previous the issuance strategy is to assume that the proportion of issuances for each sector is given by a deterministic function of time.

$$G_{p,m,t} = \left((1 - \phi(t))w_{m,0} + \phi(t)w_{m,\infty} \right) (D_{p,t} + R_{p,t} + C_{p,t}) \quad (6)$$

Here $D_{p,t} + R_{p,t} + C_{p,t}$ is the total issuances, via the budget constraint (4).

Therefore, we have $w_{m,t} = \frac{G_{p,m,t}}{\sum_{l=1}^M G_{p,l,t}} = \left((1 - \phi(t))w_{m,0} + \phi(t)w_{m,\infty} \right)$

Therefore, the term $w_{m,t}$ corresponds to the percentage, or weight, of the issuances in bonds with term m . They are not indexed with the path and are therefore deterministic.

The term $w_{m,0}$ is the initial issuance weights at time $t = 0$, and corresponds to

$$w_{m,0} = \frac{G_{p,m,0}}{\sum_{l=1}^M G_{p,l,0}}$$

The function $\phi(t)$ is defined such that $\phi(0) = 0$, $\phi(\infty) \rightarrow 1$ and $\phi(x) > 0$. It is therefore used as an interpolation coefficient between current issuances $w_{m,0}$ and long-term issuances $w_{m,\infty}$. Introducing this interpolation guarantees that issuance weights will not deviate too quickly from current issuance weights to ensure the consistency of government's issuance strategy near the initial time.

The parameters $w_{m,\infty}$ represent the long-term issuance weights. They are the choice variable for the portfolio manager. As will be described in the next sections, the values for $w_{m,\infty}$ can be found via the optimization of the cost and risk trade-off, as defined by the specific objective function guiding the portfolio manager.

Finally, note that the parameters $w_{m,\infty}$ are assumed to be zero for maturities that are not issued by the government.

3.2.3. Dynamic issuance strategy

The dynamic issuance strategy parametrization is a generalization of the deterministic issuance strategy. It allows issuance weight to be a function of the state variables of the model. Issuances are defined similarly as before, with the exception that weights can now vary across paths:

$$G_{p,m,t} = \left((1 - \phi(t))w_{m,0} + \phi(t)w_{p,m,t} \right) (D_{p,t} + R_{p,t} + C_{p,t}) \quad (7)$$

With the dynamic issuance strategy, the issuance weights are defined as a function of the state variables. Let $(V_{p,n,t})_{n=1}^N$ be a set of N state variables generated by the model. We will call the set of those variables the “issuance basis”. These can be any transformation of any variable that is observable at time t or earlier, along path p . These can include for example simulated variables such as those in x_t , variables that are part of the portfolio dynamics such as past issuances, debt stock composition, etc. Lagged values can also be included, as well as well as deterministic function of time, and combinations of all of these. By convention, we assume that a constant is included $V_{p,1,t} = 1$

We have chosen a linear-logistic functional form for this mapping:

$$w_{p,m,t} = \frac{\exp(\sum_n V_{p,n,t} \beta_{n,m})}{\sum_m \exp(\sum_n V_{p,n,t} \beta_{n,m})} \quad (8)$$

The set of parameters $\beta_{n,m}$ for the set of choice variables for the debt portfolio manager. By choosing different values for the β s, the debt manager will be allowed to vary the composition of issuances according to the state of the financial, fiscal, or macroeconomic environment, or as a function of the current composition of the debt stock. For example, the portfolio manager can adjust the issuances of short versus long bonds depending on the steepness of the yield curve, expectations of increasing or decreasing short-term rate, etc.

It should be noted that when constants are included as part of the issuance function one can show that the deterministic issuance strategy can be written as a restricted form of the dynamic issuance strategy.

Again, $w_{p,m,t}$ is assumed to be zero for maturities outside of those issued by the GoC.

3.3. Cost and risk functions

In the two following subsections, we present examples of possible cost and risk functions, the first one being in terms of nominal costs, and the second one in terms of real costs.

Note that those costs and risk functions are function of the simulated debt costs $C_{p,t}$, which are implicitly function of the parameters of the issuance strategy. To make the notation more concise, we have removed that dependence from the notation.

3.3.1. Nominal costs and risks

Here the cost is simply defined as the average debt cost, over all paths and timesteps, without discounting.

$$Cost^{Nominal}(\theta) = \frac{1}{TP} \sum_{t,p} C_{p,t} \quad (9)$$

The risk function most commonly used by the Government of Canada is the Conditional Cost Volatility (CCV). It is meant to represent the volatility of the conditional surprise in debt costs. It is defined

by the variance of the residual of a regression of $C_{p,t}$ on $C_{p,t-1}$ and a constant. Technically this can be written as:

$$Risk^{Nominal}(\theta) = \min_{a,b} \frac{1}{(T-1)P} \sum_{t,p} \left(C_{p,t} - (a - b C_{p,t-1}) \right)^2 \quad (10)$$

The estimators for (a, b) can obviously be obtained via OLS.

3.3.2. Real costs and risks

Here the cost $C_{p,t}$ is simply replaced by its real counterpart.

$$Cost^{Real}(\theta) = \frac{1}{TP} \sum_{t,p} C_{p,t} \frac{CPI_0}{CPI_t} \quad (11)$$

$$Risk^{Real}(\theta) = \min_{a,b} \frac{1}{(T-1)P} \sum_{t,p} \left(C_{p,t} \frac{CPI_0}{CPI_t} - \left(a - b C_{p,t-1} \frac{CPI_0}{CPI_{t-1}} \right) \right)^2 \quad (12)$$

3.4. Issuance strategy optimization

The issuance strategy optimization is assumed to be of the mean-variance type, where expected costs are minimized over the choice variables of the issuance strategy subject to a given risk measure being lower than some maximum threshold. The set of all optimum expected cost for any level of maximum threshold risk form the efficient frontier.

Note that the costs are risk functions that we give below are example of functions that are commonly used for issuance optimization by the GoC. Other specifications could also be considered.

The choice variables of the strategy are denoted ρ , which are:

- $w_{m,\infty}$ when the deterministic issuance strategies are considered, and
- $\beta_{n,m}$ with dynamic strategies.

The debt manager optimization problem can be written as:

$$\rho^*(R) = \underset{\rho}{\operatorname{argmin}} Cost(\rho) \text{ s.t. } Risk(\rho) \leq R \quad (13)$$

The efficient frontier is simply the parametric curve $(Cost(\rho^*(R)), Risk(\rho^*(R)))$ with R spanning a broad set of possible levels of risk.

3.5. Choosing the issuance basis for dynamic strategies

The choice of issuance basis affects the performance of dynamic strategies. In theory, all variables forming a Markovian process should be part of the issuance strategy. In our case, it can be shown that this would be the last L values of the state variables from the Simulation Engine, plus all the future cashflows from the already-issued debt. In practice this set of variables is too large to allow for the numerical optimization to take place in a reasonable time.

We have therefore chosen to use a small number of variables produced by the simulation engine. In order to remain parsimonious in the specification of the model and in order to improve the tractability of the issuance function, we normally try several combinations of those variables, and for each of those combinations we compute the efficient frontier. We keep adding new variables until the efficient frontier is no longer improved by the addition of new variables.

4. PRELIMINARY RESULTS

This section presents some preliminary results obtained from the issuance strategy optimization procedure presented above. More analysis of our methodology should be conducted in the near future.

We use the following setup for this test:

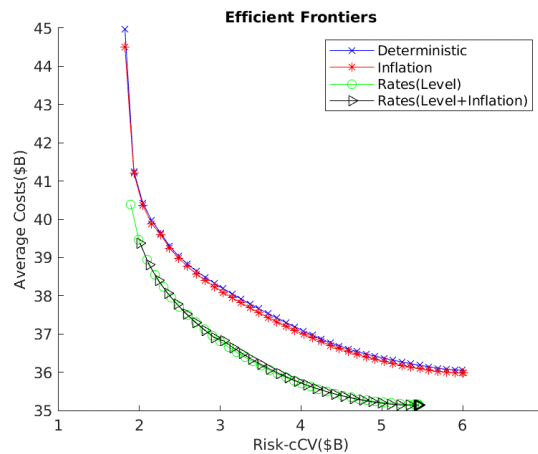
- The simulation engine is estimated over data from Q1 1996 to Q1 2023. The private sector forecasts used for conditioning the simulation output is from Q1 2023.
- The initial debt portfolio is the actual Canadian domestic debt portfolio from Q1 2023. Note that it does include real-return bonds, which are not part of this issuance strategy optimization analysis but are nevertheless included with their CPI-adjusted costs properly taken into account, as in (Bolder & Deeley, 2011).
- The simulation engine generates 4000 paths and uses a 15-year horizon.
- The costs are risks measures include a CPI adjustment, as described in section 3.3.2.
- The issuance basis variables that we will be testing are “level” and “inflation”¹⁰. All issuance strategies that we use are described in sections 3.2.2 and 3.2.3, with the “deterministic” strategy having only a constant as its issuance basis variable. The possible combinations are therefore deterministic, inflation, level, and both level and inflation.

4.1. Comparing efficient frontiers

The first step in analysing the impact of the choice of issuance basis variables is to compute the associated efficient frontiers. These can be found on Figure 3.

¹⁰ Several other variables were also tested. It appears that in all test level is the variable that carries the most importance in terms of its capacity to improve the efficient frontier. Inflation also has some importance, albeit to a much lesser extent than level.

Figure 3: Efficient Frontiers for a deterministic strategy as well as dynamic issuance strategy using inflation, level, and both inflation and level. Amounts are in annual billion dollars.



Since the various combinations of issuance basis form a set of embedded models, we find that adding variables to the set of issuance basis variables reduces the expected costs for all levels of risks. For example, the deterministic issuance strategy appears to be dominated by the dynamic issuance strategy based on inflation.

However, our analysis shows that the largest gain one can make when moving towards a dynamic issuance strategy is when using the level as issuance basis variable. The difference in expected costs is around one and two billion dollars, annually, over the range of possible risk levels.

Further adding inflation to levels yields a small amount of improvement in terms of costs, for all risks levels. This means that the information from inflation that is relevant to the debt manager seems to be contained in the level of rates. Note that this is the case even though we are using a CPI-adjusted measure of debt costs.

This difference between the static and dynamic issuance strategies does not imply that moving from a model with static issuances to a model with dynamic issuances will produce savings of one to two billion dollars annually. The reason for this is that debt managers, when using a static model, do not behave in a way that is consistent with the model. In practice, debt managers behave more as if they were using a dynamic strategy, albeit not one that is guided by a mathematical model such as ours.

However, the difference between the expected costs of the two types of strategies does indicate that debt managers relying on a static issuances model significantly over-estimate the costs that they should expect to face. Moving to a dynamic issuances model is more likely to yield a truer picture of the expected costs and risks faced by portfolio managers.

4.2 Analysing dynamic issuance strategies

Dynamic issuance strategies are more complex to visualize than static ones, which are essentially just a single weight for each issued sector. A dynamic issuance strategy can be represented in two ways. First, one can graph the impact on issuances of changing the values of the variables entering the issuance basis. This is what we will refer to as a “cross section view” of the issuance strategy. Second, one can project expected issuance weights against time, which is what we will refer to as the “time series view” of the issuance strategy.

4.2.1. Cross-section view of the issuance strategies

Note that the issuance strategies vary along the efficient frontier. In the following figures, we will display the issuance strategies for bonds and bills, while varying inflation or rates, for either low, mid or high levels of risks.

Figure 4: Percentage of bills and long bonds (10Y + 30Y) issuance against inflation (low, mid, and high rates refer to level being in the 15%-25%, 45%-55% and 75%-85% percentile of its distribution)

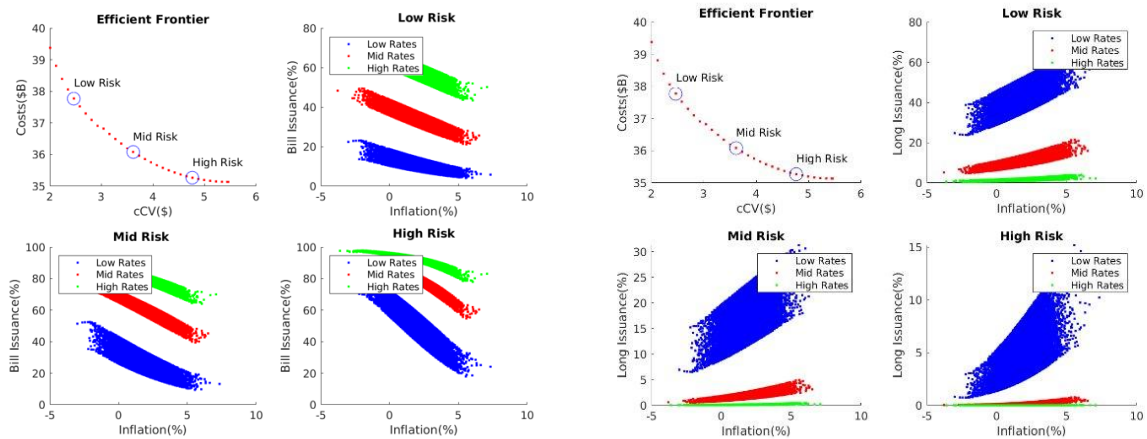
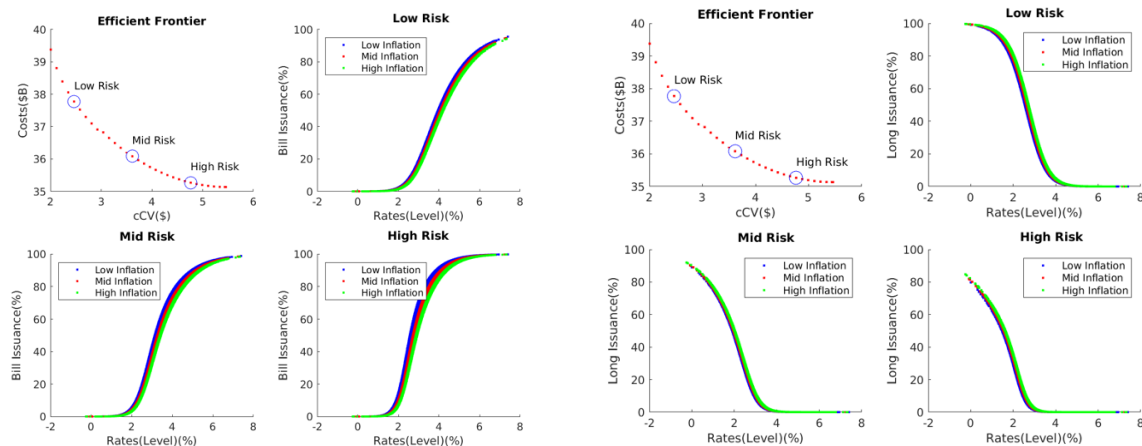


Figure 5: Percentage of bills and long bonds (10Y + 30Y) issuance against rates (level) (low, mid, and high inflation refer to inflation being in the 15%-25%, 45%-55% and 75%-85% percentile of its distribution)



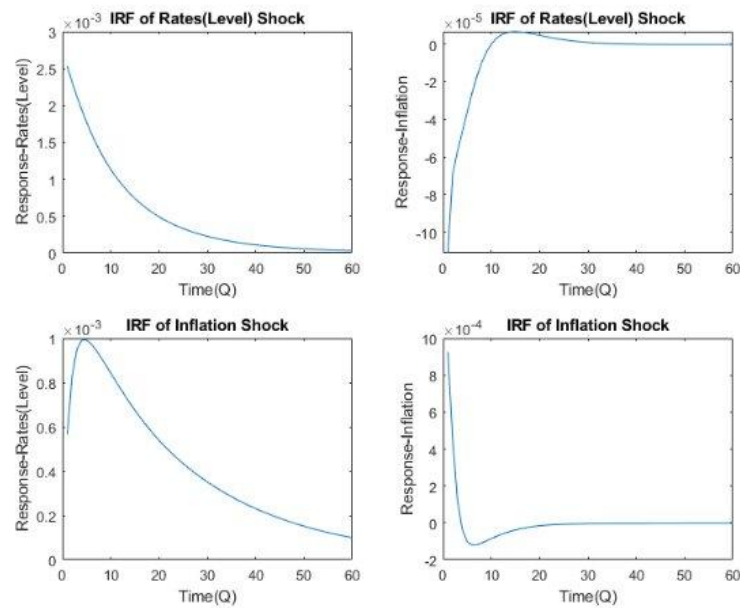
Several observations can be made from these cross-sections of the issuance strategy. First, moving from low to high levels of risk imply an increase in the percentage of bills issued and a decrease of the percentage of long bonds. This appears to be true for all values of level or of inflation. This is as expected, as short-term instruments generally pay a lower rate than long-term ones because of the generally upward-sloping yield curve but carry more risk from the frequent rollovers and the higher volatility of short-term rates.

Another observation that can be made is that issuances are driven to a larger extent by level rather than by inflation. This can be seen both in the larger range of issuances weights obtained when rates vary, as well as the tightness of the lines mapping rates to issuances.

The slope of the relationship between issuance variables is also interesting. Higher rates generally imply increasing the weight of bills and reducing the weight of bonds. Inflation acts in the opposite way: higher inflation implies less bills and more bonds.

The first fact can be understood by realizing that our simulation engine assumes that the level factor is stationary. A high level for rates today implies lower rates in the future, from mean-reversion. This means that one can take advantage of decreasing rates by not locking-up the funding into long-term bonds, and instead issuing bills.¹¹ The shape of the relation between inflation and issuances is opposite because high inflation today correlates with higher rates in the future. This can be seen in the impulse-response functions of our simulation engine, in Figure 6 below.

Figure 6: Impulse-response functions for inflation and level.

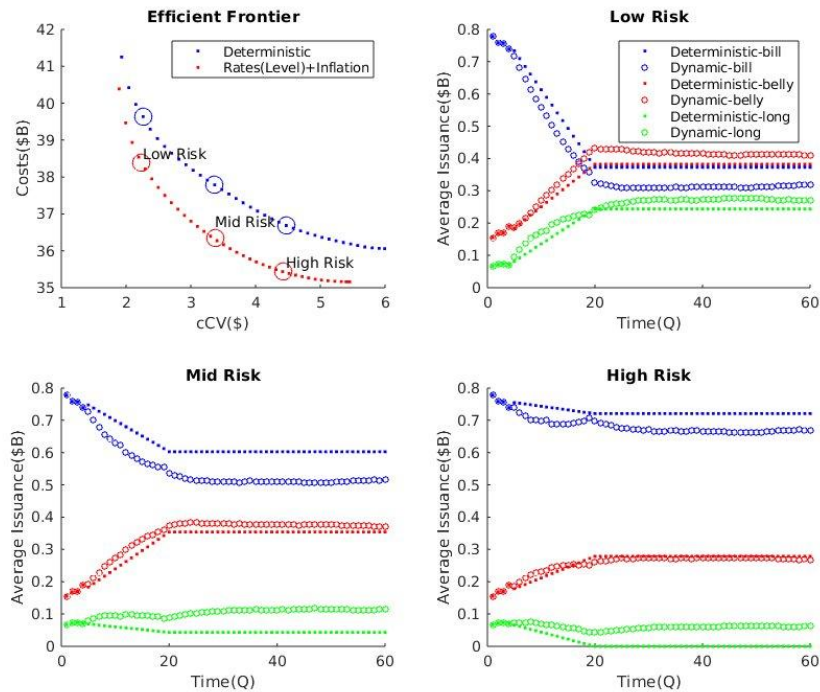


4.2.2. Times series view of the issuance strategies

Chart shows expected issuances versus time, for both the deterministic strategy and the dynamic strategy with level and inflation. The low, mid and high-risk strategies of the deterministic and dynamic strategies are for the same level risk.

¹¹ Tests done with another version of the simulation engine where level is modeled as an I(1) process shows that in that setup level is much less useful as part of the issuance basis variables, and slope becomes much more important.

Figure 7: Expected issuance weights vs. time.



This graph shows that the issuances from the deterministic strategy and expected issuances from the dynamic strategy differ even when comparing strategies with a similar level of risk. This shows that deterministic strategies cannot entirely be thought of as a first-order approximation of dynamic strategies.

5. CONCLUSIONS

We propose a new model to allow the debt portfolio manager to dynamically adjust their issuance strategy according to the fast-changing macro-economic environments. The optimal dynamic reaction function between issuance strategy and its issuance basis provides insightful guidance for the decision-making process of debt issuance. We find that the level of interest rates is by far the most relevant driver for optimal issuance strategies.

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APPENDIX 1 SIMULATION CONDITIONING

This section broadly follows on (Jarociński, 2010), with the addition of a method for applying “soft conditioning”. Starting from a VAR(L) model:

$$y_t = c + \sum_{l=1}^L \Phi_l y_{t-l} + C \varepsilon_t \quad (14)$$

Here: y_t has size N and is stationary, $\varepsilon_t \sim iid N(0, I_K)$ and $\Omega = CC'$ is the covariance matrix of the VAR innovation. In general, CC' is the Cholesky decomposition of Ω , with C being a lower-triangular with real and positive diagonal entries.

Centering the model and rewriting it in terms of $z_t = y_t - \mu$, with $\mu = E[y_t] = (I_K - \sum_l \Phi_l)^{-1}c$, we have:

$$z_t = \sum_{l=1}^L \Phi_l z_{t-l} + C \varepsilon_t \quad (15)$$

We can write the companion-form of the VAR model as:

$$\tilde{z}_t = F \tilde{z}_{t-1} + G \tilde{\varepsilon}_t \quad (16)$$

Where $\tilde{z}_t = (z_t' \dots z_{t-L+1}')'$, $F = \begin{pmatrix} \Phi_1 & \dots & \Phi_L \\ I_{(L-1)N} & & 0_{(L-1)N,N} \end{pmatrix}$, $G = \begin{pmatrix} C & 0_{N,(L-1)N} \\ 0_{(L-1)N,N} & 0_{N,N} \end{pmatrix}$ and $\tilde{\varepsilon}_t = (\varepsilon_t' \ 0_{N,(L-1)N})'$.

A1.1. Conditioning

Assume that we know the parameters of the VAR. We want to simulate its state variables over $[1 \dots T]$, conditional on some starting point z_0 . First, write the VAR in “impulse response” for z_t :

$$z_t = F_{(1:N,:)}^t \tilde{z}_0 + C \varepsilon_t + \Psi_1 C \varepsilon_{t-1} + \dots + \Psi_{t-1} C \varepsilon_1 \quad (17)$$

Here we have $\Psi_i = F_{(1:N,1:N)}^i$ which is the $N \times N$ left-upper block of F raised to its i^{th} power, while $F_{(1:N,:)}^t$ is the first N rows of F^t .

The previous equation shows that all z_t are linear functions of $(\varepsilon_1 \dots \varepsilon_t)$ and are therefore jointly gaussian. We can write all (future) timesteps (and variables) as

$$\begin{pmatrix} z_1 \\ \dots \\ z_T \end{pmatrix} = \begin{pmatrix} F_{(1:N,:)}^1 \\ \dots \\ F_{(1:N,:)}^T \end{pmatrix} \tilde{z}_0 + \begin{pmatrix} C & 0 & 0 \\ \vdots & \ddots & \vdots \\ \Psi_{T-1} C & \dots & \Psi_1 C & \dots & C \end{pmatrix} \begin{pmatrix} \varepsilon_1 \\ \dots \\ \varepsilon_T \end{pmatrix} \quad (18)$$

Or in short form:

$$z = H \tilde{z}_0 + R \varepsilon \quad (19)$$

We want to simulate P paths for z :

$$z^{(p)} = H\tilde{z}_0 + R\varepsilon^{(p)} \quad (20)$$

We need to choose the correct distribution for $\varepsilon^{(p)}$ which is conditional on

$$Az^{(p)} = b^{(p)} \quad (21)$$

Where A is a $q \times TK$ array, $b^{(p)}$ is a $q \times 1$ random vector drawn from some random distribution. Using (20) the condition in equation (21) can be written as $AR\varepsilon^{(p)} = b^{(p)} - AH\tilde{z}_0$ or $\tilde{R}\varepsilon^{(p)} = r^{(p)}$, where $\tilde{R} = AR$ and $r^{(p)} = b^{(p)} - AH\tilde{z}_0$. Given that the joint distribution of $\varepsilon^{(p)}$ and $\tilde{R}\varepsilon^{(p)}$ is:

$$\begin{pmatrix} \varepsilon^{(p)} \\ \tilde{R}\varepsilon^{(p)} \end{pmatrix} \sim N \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} I & \tilde{R}' \\ \tilde{R} & \tilde{R}\tilde{R}' \end{pmatrix} \right) \quad (22)$$

We therefore have:

$$(\varepsilon^{(p)} | \tilde{R}\varepsilon^{(p)} = r^{(p)}) \sim N \left(\tilde{R}'(\tilde{R}\tilde{R}')^{-1}r^{(p)}, I - \tilde{R}'(\tilde{R}\tilde{R}')^{-1}\tilde{R} \right) \quad (23)$$

We can therefore simulate with equation (20) while imposing (21) by drawing from the conditional distribution for $\varepsilon^{(p)}$ from (23).

A1.2. Numerical Considerations

It is numerically more efficient to simulate $\varepsilon^{(p)}$ by first applying the singular value decomposition¹² to $\tilde{R} = U(D \ 0_{q \times (T-q)})(V_1 \ V_2)'$ where D is a $q \times q$ diagonal array of singular values of $\tilde{R}$, $U'U = UU' = I_{q \times q}$, $(V_1 V_2)'(V_1 V_2) = (V_1 V_2)(V_1 V_2)' = I_{NT \times NT}$, where V_1 is the first q right singular vectors, and V_2 is the $(NT - q)$ orthogonal vectors. One can show that we can generate the conditional distribution of $(\varepsilon^{(p)} | \tilde{R}\varepsilon^{(p)} = r^{(p)})$ by setting:

$$(\varepsilon^{(p)} | \tilde{R}\varepsilon^{(p)} = r^{(p)}) = V_1 D^{-1} U' r + V_2 \eta \quad (24)$$

A1.3. Soft Conditioning

If only the expected value of $b^{(p)}$ is known, i.e. $E[b^{(p)}] = \mu_b$ (for example: when imposing that the expected rates, GDP growth, inflation, etc., as simulated by the conditioned model must match an exogenously provided expected value, such as one coming from a survey), one can impose that the covariance structure from the conditioned model is the same as the covariance structure of the conditional model.

¹² See for example (Press, Teukolsky, Vetterling, & Flannery, 1992).

In the unconditioned model:

$$Cov(b^{(p)}) = Cov(Az^{(p)}) = Cov(A(H\tilde{z}_s + R\varepsilon)) = ARR'A' = \tilde{R}\tilde{R}' \quad (25)$$

One can therefore draw $b^{(p)} \sim N(\mu_b, \tilde{R}\tilde{R}')$.

Note that by preserving the estimated covariance structure of $b^{(p)} = Az^{(p)}$ we are also preserving the covariance structure of $z^{(p)}$:

$$\begin{aligned} Cov(z^{(p)}) &= E[Cov(z^{(p)}|Az^{(p)} = b^{(p)})] + Cov[E(z^{(p)}|Az^{(p)} = b^{(p)})] \\ &= (RR' - R\tilde{R}'(\tilde{R}\tilde{R}')^{-1}\tilde{R}R') + R\tilde{R}'(\tilde{R}\tilde{R}')^{-1}\tilde{R}\tilde{R}'(\tilde{R}\tilde{R}')^{-1}\tilde{R}R' \\ &= RR' \end{aligned} \quad (26)$$

In simple terms, this means that assuming that $Cov(b^{(p)}) = \tilde{R}\tilde{R}'$ will preserve the covariance structure of $z^{(p)}$, which means that the co-movements of the modeled variables are not affected by this assumption.

For example: assume that in the sample data we observe that high inflation is positively correlated with higher rates. If we impose the view that inflation should be higher in the conditioned model than in the unconditional model, then we should also find that rates will be higher in the conditioned model than in the unconditional model. In other words, views on one variable will affect other variables in a way that is consistent with the data.

APPENDIX 2 HISTORICAL ISSUANCE STRATEGY ESTIMATION

A2.1. Summary

In this section we estimate from historical data the issuance strategy used by the Government of Canada. We then compare this empirical issuance strategy to the optimal strategies described in the main section of this document.

A2.2. Empirical estimation of the issuance strategy

We base our estimation of the Government of Canada's issuance strategy on issuance data between Q1 1999 and Q4 2023¹³. From this data we can compute the empirical issuance weights¹⁴. Let $w_{i,t}$ be the empirical issuance weight for sector i at time t . We can recover the empirical issuance strategy by solving the least-squares estimation problem:

$$\hat{\beta} = \min_{\beta} \sum_{t,i} \left(\frac{\exp(\sum_n \beta_{i,n} V_{n,t})}{\sum_j \exp(\sum_n \beta_{j,n} V_{n,t})} - w_{i,t} \right)^2$$

The variables $V_{n,t}$ are issuance basis variables, such as those that are generated by our simulation engine. In our case we use various combinations of the variables listed in section 3.1.2: level, slope and curvature of the yield curve, primary deficit, GDP growth and inflation. In all cases a constant is always included in the regression.

A2.3. Testing the specifications of the empirical issuance strategy

We can test for the significance of these variables using a chi-square test, where the null hypothesis is the deterministic model where only a constant is used as basis variable. The significance of the test against various combinations of issuance basis variables are given in Table 1.

¹³ Note that for years where there were quarters without any issuances for a specific term, we replaced the data for quarters with no issuance by the quarterly average for that year.

¹⁴ Weights are for issuances in excess of minimum issuances.

Table 1: Testing of the deterministic issuance strategy against dynamic alternatives

H0 (Deterministic)	H1 (Dynamic)	P- value	Rejected (5%)
Const	Const, Level	0.0%	Yes
Const	Const, Slope	26.4%	No
Const	Const, Inflation	7.1%	No
Const	Const, GDP	34.9%	No
Const	Const, Total Deficits	22.9%	No
Const	Const, Level, Slope	0.0%	Yes
Const	Const, Level, Inflation	0.0%	Yes
Const	Const, Level, GDP	0.1%	Yes
Const	Const, Level, Slope, Inflation	0.0%	Yes
Const	Const, Level, Inflation, GDP	0.0%	Yes
Const	Const, Level, Slope, Inflation, GDP	0.0%	Yes

####	0.0%
####	26.4%
####	7.1%
####	34.9%
####	22.9%
####	0.0%
####	0.0%
####	0.1%
####	0.0%
####	0.0%
####	0.0%

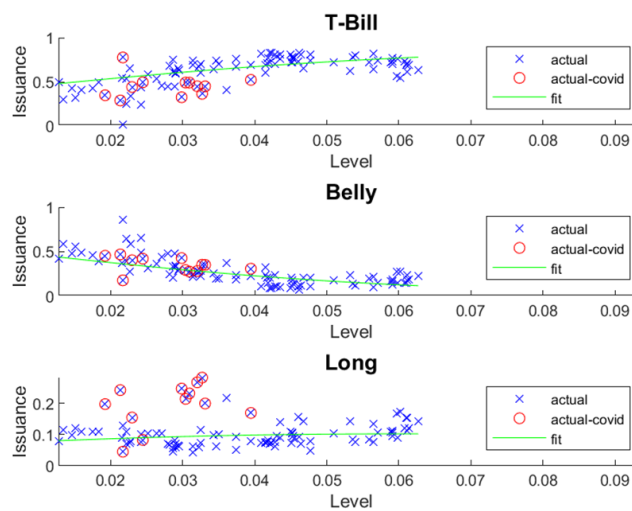
The tests indicate that the deterministic model is rejected against several alternative formulations. These have in common that “Level” is included as part of the variables forming the basis for the issuance

strategy. This result is interesting since it is in agreement with the findings from the debt strategy optimization.

A2.4. The empirical issuance strategy

The relation between issuances and the level of interest rates is illustrated in Figure 8.

Figure 8: Empirical issuance strategy as a function of the interest rates level. Issuances during the Covid period are highlighted with a red circle. T-Bills are instruments 1Y and shorter, Belly is 2Y and 5Y, while Long is 10Y and 30Y.



The empirical issuance strategy shows a picture which is generally consistent with the one found in the main part of this document. Issuances of bills tend to increase with higher rates, and issuances of mid-rates (2y-5y) tend to decrease with higher rates. The issuance of long bonds is not very affected by changes of the level of rates.

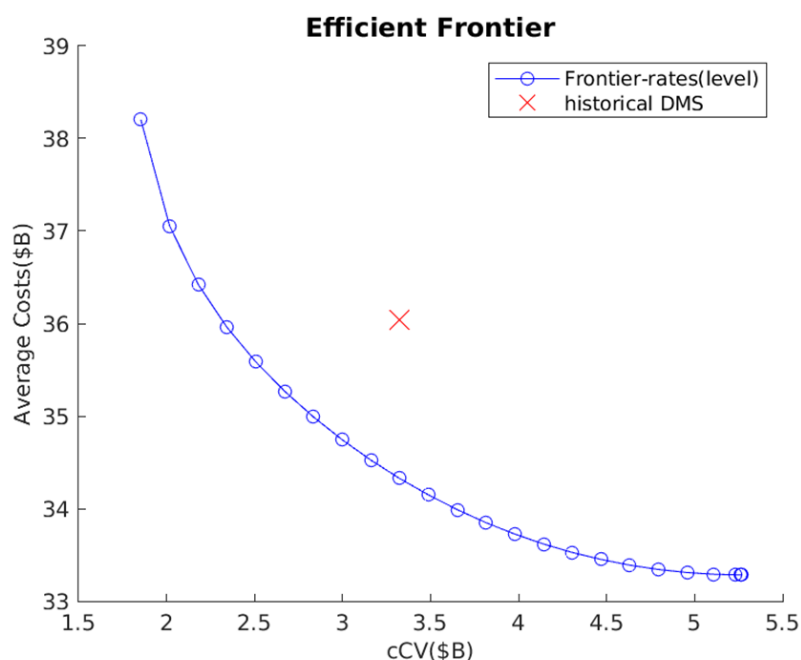
Although these findings are somewhat different from what is described in the main part of this document (where the issuance of long bonds tend to decrease with higher rates) the global effect is similar since in both cases higher rates are associated with a reduction in the ATM of issuances. It is possible that the issuances of long bonds are effectively bound by minimum issuance requirements stemming from the well-functioning market objective pursued by the Government of Canada.

Note that the outliers on the long-bond panel are associated to the Covid period (2020Q1 to 2022Q4), for which issuances of long bonds were historically high given the then prevailing low rates. These points are in effect in even better accordance with the strategy found in the main part of this document, since they associate low rates with larger issuances of long bonds.

A2.5. Efficiency of the empirical issuance strategy

The empirically estimated efficient frontier can finally be compared to the efficient frontier obtained by optimizing the issuance strategy. This comparison is found in Figure 9, where we assume that the issuance strategy for the Government is the one that was estimated empirically.

Figure 9: Empirically estimated vs optimized issuance strategies. The historical issuance strategy is conditional on the level of interest rates.



A2.6. Discussion

Our findings indicate that debt issuance decisions made by the Government of Canada are correlated with the historical economic and financial data. This suggests that the behaviour of the debt manager is better described within our dynamic issuance model than with a deterministic model.

Also, the level of interest rates seems to have the best explanatory power over issuances decisions. This is in agreement with the results from the issuance strategy optimization done in the main part of this document. This observation furthers the point that a dynamic model for the issuance decisions is a more accurate approximation of the of debt manager's actions.

Moreover, the fact that the level of interest rates is identified by both the empirical estimation and the issuance strategy optimization constitute a general validation of the various components of the dynamic issuance model¹⁵, such as the simulation model and the choice of objective function.

Finally, the empirically estimated debt issuance strategy employed the Government of Canada does not seem to lie on the efficient frontier identified by our model. Given that the Government of Canada seems to already be using a dynamic strategy based on level of interest rates, a dynamic model such as the one presented in the main section of this document is likely to provide the Government with the insights that will help it refine its current strategy.

¹⁵ Further investigation of the model indicates that the relevance of the level of interest rates depends on the fact that the simulation model assumes that interest rates are stationary. Alternative specifications of the simulation model will make other issuance basis variables stand out. For example, assuming that the level of rates is stationary in difference will make the slope of the yield curve a more relevant factor for issuance decisions.

SESSION V

Climate Change and Public Debt: Sustainable Strategies and Emerging Markets Insights

The Impact of the Creation of a Sovereign ESG Reference Yield Curve on Corporate ESG Bond Issuances from Latin America and Caribbean

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Abstract

We explore a granular data base from the Inter-American Development Bank (IDB) Green Bond Transparency platform covering 430 corporate and sovereign ESG bonds' issuance in the Latin America & the Caribbean region (LAC) outstanding in international markets to investigate how the creation of a sovereign ESG reference yield curve can boost the private ESG bond market. Using a difference-in-differences approach, we empirically estimate the creation of a sovereign ESG reference curve roughly leads to a 60 percent increase in the volume of corporate bond issuances and 25 percent increase in the number of ESG corporate bond issuances in the external markets after three years. On the mechanisms, we argue that the sovereign ESG reference yield curve works as a benchmark for private sector ESG bond issuers by providing a standard against which the performance of ESG bonds can be measured.

Keywords: ESG, Thematic bond, Green, social, sustainability, sustainability-linked bond, Debt capital markets, Sovereign debt, LAC, Corporate sector, International markets.

JEL Code: H63, E43, R50

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1. INTRODUCTION

The main contribution of this paper is the analysis of the impact of the creation of a sovereign Environmental, Social and Governance (“ESG” or “thematic”) reference yield curve by Latin America and the Caribbean (LAC) countries in international debt capital markets. To the best of our knowledge, this is the first study that empirically estimates the knock-on effect of the inauguration of a sovereign ESG market on corporate thematic bond issuance.

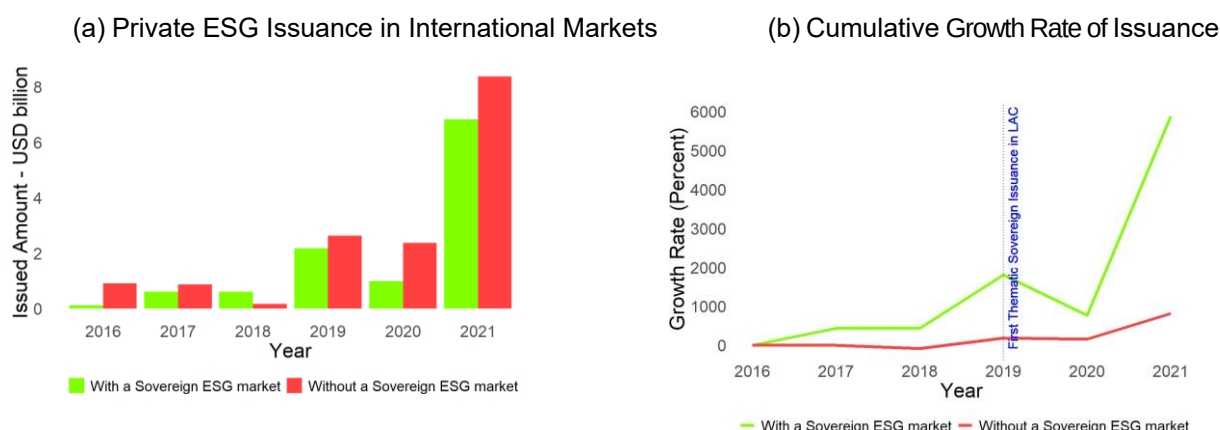
For the purposes of this paper, thematic bonds include labelled green, social, sustainability and sustainability-linked bonds. (Hussain, 2022) highlights that ESG bonds are also known as thematic bonds and are fixed income instruments issued to raise financing for projects and activities related to a specific theme, such as climate change, education, housing, ocean and marine conservation, and the Sustainable Development Goals (SDG).

The yield curve of conventional sovereign bonds carries information about key macroeconomic variables while the ESG sovereign yield additionally unveils information on ESG topics. On one hand, sovereign bonds are debt securities issued by national governments to finance government needs. Differently from corporate bonds, the fundamental of government yields bonds are purely derived from the macroeconomics fundamentals of a given economy. They are expressed by the expectation on the future short term policy rate, inflation, and real interest rates. On the other hand, the sovereign thematic yield curve, on top of unveiling information on macroeconomic variables, under-pins ESG policies at the national level. More importantly, with the increase of sovereign issuers in the thematic bond market, public debt has also become a source of information about country-level commitment with environment, social, and sustainable development topics.

Emerging markets still represent a small fraction of the ESG bond market — 15 percent of the total amount issued (based on data from Bloomberg (2022)) — but volume issued is growing. Global issuance of green bonds began with multilateral development banks raising money for climate change-related projects in 2007/2008. Since then, the market has been growing every year. According to Climate Bonds Initiative, the volume of thematic bonds issuance rose by USD 730.5 bn in 2020 to USD 1.1 tn in 2021, more than 46 %. Looking at LAC, the first issuers accessed the market in 2014 and green bond issuances in the region more than doubled in less than two years, from USD 13.6 billion in September 2019 to USD 30.2 billion at the end of June 2021. Of the cumulative issuance so far, Brazil continues to dominate, despite a reduced share of 34% compared to 41% in 2019. Chile ranks second with 31%, followed by Mexico with 13%. In terms of issuers, non-financial corporate (39%) and sovereigns (25%) maintain the top spots among issuer types in cumulative terms, thanks to large issuance from Brazil and Chile.

Is the creation of a sovereign ESG reference yield curve a paradigm shift for private ESG issuance? Looking into the recent developments of the thematic debt market in LAC, Figure 1 shows that the amount of ESG bonds issued by the private sector in international markets has grown more rapidly when the issuer has a sovereign bond as a “thematic benchmark” since private firms use the sovereign ESG yield curve as a reference to tap the markets. Accordingly, since 2016 the group of countries that issued a sovereign thematic bond (treated countries) showed an annual average growth rate of issuance around 98%, meanwhile the group of countries without the presence of the thematic benchmark (never-treated countries) printed an average growth rate of 45 %. But what would have happened if Debt Management Offices (DMO)’s of these countries had issued sovereign thematic bonds?

Figure 1 Recent Developments in LAC Private ESG Issuance in International Markets



Source: IDB Green Bond Transparency platform

The literature on the factors that drive the issuance of thematic bonds by the corporate sector is timid, but it is growing rapidly. (Prasad, et al. 2022) argue that multilateral banks, national development banks, and public private partnerships play an important role on boosting ESG corporate bond issuances. (Ferreira and Suntheim 2021) highlight that the setting of a proper transparency and accountability of climate data is a key ingredient to back the market. (Goel, Natalucci and Gautam 2022), in turn, point out that EMs' policy makers should focus on improving ESG data quality and fostering green projects. Nevertheless, not much has been debated about the role played by sovereign debt in mobilizing private sector capital into ESG investing.

Our hypothesis is that the first issuance of a thematic sovereign bond is a paradigm shift for the private ESG capital markets due to the creation of a sovereign ESG reference yield curve. The introduction of a liquid sovereign ESG market has spillover effects on the ESG private capital market because it gives rise to a sovereign ESG reference yield curve that reduces information frictions in the pricing of ESG debt in private capital markets. We make the case that the creation of a sovereign ESG yield curve is a crucial building block to further foster the development of an ESG debt market. On the crucial role played by public debt, (Martinez, et al. 2022) argue that sovereign debt is very different from debt issued by private sector players as the former is both safer and more liquid. Using the Brazilian external debt market as an example, we show that sovereign debt is indeed different from corporate debt with a lower underlying rollover risk and yield, resulting in positive externalities on the private market. Moreover, we argue that sovereign ESG debt is an important booster to private ESG debt for EMs with market access¹. More precisely, we conjecture the existence of two main mechanisms that channels the knock-on effect of the creation of a sovereign ESG reference yield curve: i) crowd-in and ii) novelty/advertisement channels.

First, using a conventional sovereign yield curve as a benchmark has an underlying larger and noisier cost on average than employing a thematic sovereign curve as there is limited market price information on sovereign ESG metrics/performance. As a result, the price effect derived from the inauguration of the sovereign ESG debt would induce private players to tap the market as well.

Second, the issuance of a sovereign thematic bond may lead financial and non-financial corporates to step-in the market right after the sovereign issuer. Intuitively, private sector issuers are likely to follow the sovereign as its issuance is a sign of possible good window of opportunity. Furthermore, by issuing

¹ If sovereign issuance is sufficiently large, some cannibalization issues may kick in between the two markets. However, this is not likely to be the case in early/middle stages of development.

bonds around the time of the sovereign placement, private players ensure their cost will price in the latest sovereign figures.

Research questions. We address key questions for ESG debt market players: i) what is the impact of the sovereign knock-on effect on the issued volume of private sector issuances? and ii) what is the impact of the sovereign knock-on effect on the number of ESG debt deals? To answer both questions, we apply a difference-in-differences approach comparing the outcome of LAC issuers with opened and closed sovereign ESG markets.

Contribution to the literature. Our paper is close in spirit to the work of (Dittmar and Yuan 2008) insofar as we aim to investigate the positive externalities to corporates derived from the creation of a sovereign reference yield curve. However, instead of focusing on conventional (brown) bonds and price effects on corporate bonds underpinned by the sovereign issuance, we narrow down our analyses to estimate the impact of the creation of a sovereign ESG reference to private players focusing on the impact on corporate issuance volume rather than price effects. (Murillo and Vasa 2023) examine the behavior of green bonds to negative exogenous shocks. The authors analyze the COVID-19 selloff finding that green bonds yields reacted less to the shock, aligning with investors' preference for long-term holdings. Our study, in turn, focus on one specific positive exogenous shock to corporate ESG funding: the creation of a sovereign ESG reference yield curve.

Main findings. We argue that sovereign ESG bonds would serve as benchmarks for private sector ESG bond issuers by providing a reference for ESG bonds. Accordingly, we empirically estimate the impact of the creation of a sovereign external ESG debt market finding that it roughly leads to a 60 percent increase in issuance volumes and 25 percent expansion in the number of private external ESG issuances after three years.

The paper is structured as follows. Section 2 unpacks insights of the key role played by the sovereign derived from the Brazilian external debt experience on the transmission channels of the sovereign knock-on effect. Section 3 introduces our data base and depicts our empirical exercises, while section 4 presents our final remarks.

2. THE ROLE OF THE SOVEREIGN REFERENCE YIELD CURVE: THE BRAZILIAN EXPERIENCE

The experience of Brazilian external sovereign issuance provides a useful set of insights with regards to the importance of sovereign bonds as a benchmark for the private sector. More specifically, given that the domestic market represents the Brazilian federal government main source of fund, the external debt profile is since 2006 characterized by a qualitative approach (Silva, de Carvalho and de Medeiros 2010), which seeks to establish a liquid and efficient sovereign yield curve in international markets as a reference for corporates².

The role of the sovereign reference yield curve in fostering corporate issuance. While the private sector does not rely on the public sector to access the markets, having shown the capacity to produce its own references of size and liquidity, the government bond market represents a benchmark yield curve, serving as an instrument for the development of bond markets in broader terms³. (Sarr and Lybek 2002) state that the *“secondary market for government securities is generally perceived as being the*

² For a detailed discussion see the 2022 Annual Borrowing Plan of the Brazilian Treasury: <https://www.tesourotransparente.gov.br/publicacoes/annual-borrowing-plan-abp-ingles/2022/114>

³ For a comprehensive debate see (Silva, de Carvalho and de Medeiros 2010) and (Mohanty 2002).

most liquid of the various bond markets. Government securities often play a special role as collateral and benchmarks for pricing of other securities”.

A well-developed sovereign yield curve improves liquidity and cost conditions for the corporate market. We recall the pricing rationale for a fixed income security is based on curves that represent a risk-free rate, usually government securities, on top of which we add an extra cost that accounts for liquidity premium, credit risk premium and other factors. In this sense, there are indications on the financial literature repository and amongst market participants that an active sovereign issuer makes the market more complete and helps to promote price discovery and transparency that ultimately leads to reduced borrowing costs and lower bid/ask spreads.

Positive externalities to private players of developing a sovereign reference yield curve with sufficiently large issuance with diversified investor base. Firstly, as highlighted by (Silva, de Carvalho and de Medeiros 2010), sovereign issuance tends to increase market size, which in turn is important to support liquidity and market depth. In addition, government bonds are also key to attract a diversified base of investors. According to (IMF and World Bank 2001), a heterogeneous investor base for fixed-income securities is important for ensuring resilient secondary markets and stable demand under a wide range of market conditions. Indeed, measures to expand and diversify its investors’ base have been one of the Brazilian Treasury guidelines, given its important role in improving liquidity not only because of the size effect, but also because different risk profiles help to dissipate market shocks and tends to mitigate funding-related risks⁴.

How the Brazilian sovereign yield curve works as a key reference for corporate helping to increase the efficiency of the market. As pointed out in a most recent report of the Trade Association for the Emerging Markets⁵, Brazil’s sovereign and corporate securities are one of the most liquid among emerging economies⁶. In this context, Figure 2 (a) shows that, on average, Brazilian government securities in international markets have greater maturity in comparison with private players, representing a curve reference that potentially paves the way for Brazilian companies to extend duration⁷. This data comprises a wide range of corporate issuers focusing on relatively new bonds that were originally issued in the past 13 years⁸. Moreover, our data base includes bonds that are bullet. The original currency is United States Dollars, and the date of reference is September 30, 2022. In Figure 2 (b), we show that the average yield per tenor is higher for the corporate sector in comparison to the sovereign yield curve. This indicates that government bonds look to represent a floor for private securities, since the former usually account for country specific risks whereas the latter also reflect company related risks, on top of other factors. This difference seems to be higher for short- and medium-term bonds in comparison to long-term bonds⁹, which could be associated to the fact that corporate borrowers that are able to offer longer maturities usually exhibit better fundamentals and credit rating.

The Brazilian experience seems to be in line with the literature that indicates that the benchmark status of sovereign securities is essential not only for developing a robust corporate bond market for emerging economies, but also for developed countries where corporate bonds are often accompanied

⁴ See (IMF and World Bank 2001) and (Mohanty 2002) for details.

⁵ <https://www.emta.org/media/pnjhu05r/press-release-2q22.pdf>

⁶ The EMTA Debt Trading Volume Survey compiles information from industry participants on sovereign and corporate Eurobonds, loans, local currency and USD-denominated local instruments, and debt options and warrants. Surveys include trading volume data indexed by issuing country and instrument type, an analysis of market trends and historical information on volume breakdowns (<https://www.emta.org/activities-and-services/volume-surveys/>).

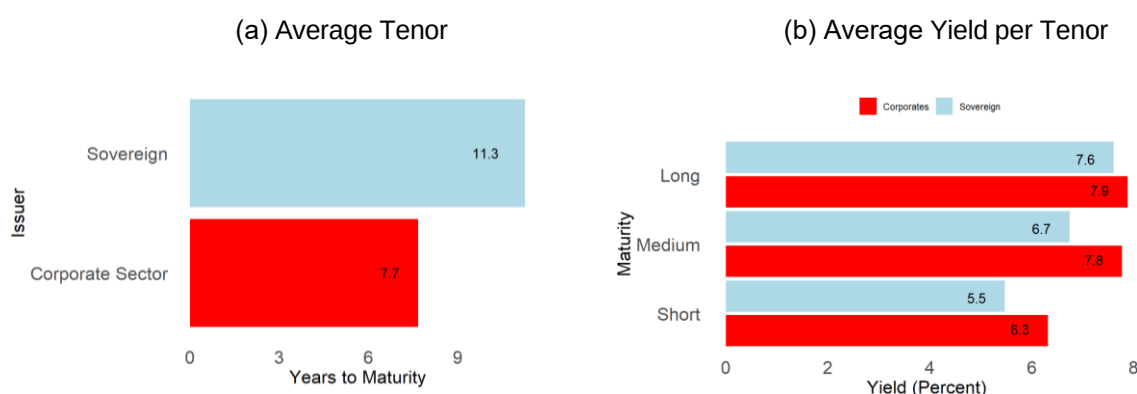
⁷ According to the OCDE glossary, duration is “the weighted average term to maturity of a debt instrument”.

⁸ We acknowledge that we have removed century bonds from our sample primarily because this type of maturity is usually accessed under specific market conditions and objectives.

⁹ To the purpose of this study, we consider: (a) short-term bonds as those with up to around 5 years to maturity; (b) medium-term bonds show between 6 and 10 years to maturity; and finally (c) long-term bonds as those with as much as 30 years to maturity.

by active government bond issuance and trading (Dittmar and Yuan 2008). When looking at the universe of green bonds more specifically, or ESG more broadly¹⁰, sovereign issuances would be expected to also help determine to what extent investors attribute any value to the green label in the case of Brazil.

Figure 2 The Brazilian Sovereign and Private External Debt Market



Source: Bloomberg

The transmission channels of the knock-on effect on private issuance derived from the creation of a sovereign reference yield curve. We use the insights unfolded at the provision of a reference by Brazilian conventional (brown) external debt experience to conjecture two channels for the knock-on effect of sovereign ESG issuance: i) crowd-in and ii) advertisement channels. The first channel depicts the cost and uncertainty reduction caused by the creation of the sovereign ESG reference curve, while the second channel narrows down the analysis to the timing of the private sector issuances as corporates tend to issue thematic bonds once sovereign issuers tap into the ESG bond market. Both channels are closely related. For instance, the setting of a price reference by the sovereign pricing in a green premium or “greenium” is likely to trigger a following behavior of private firms in which the sovereign is the first mover.

3. EMPIRICAL ANALYSIS

Identification. We use an event study approach to test our hypothesis that the first issuance of a thematic sovereign bond is a paradigm shift for the private ESG capital markets due to the creation of a sovereign ESG reference yield curve. In a nutshell, the first sovereign ESG issuance, an exogenous shock for private issuance, is a tipping point for corporate as before the event they cannot directly use the sovereign yield curve as a reference and after the issuance they can do so. Moreover, we can also compare the performance of private issuance between treated countries, the ones with a sovereign ESG reference yield curve, and never treated countries, the others that do cannot directly use the sovereign ESG yield curve as a reference.

3.1. Database

Data. To track the existence of a sovereign ESG market, we rely on the data base of sovereign and non-financial corporate ESG issuances provided by the Green Bond Transparency Platform, an initiative developed by the Inter-American-Development Bank (IDB) to promote transparency in the green bond

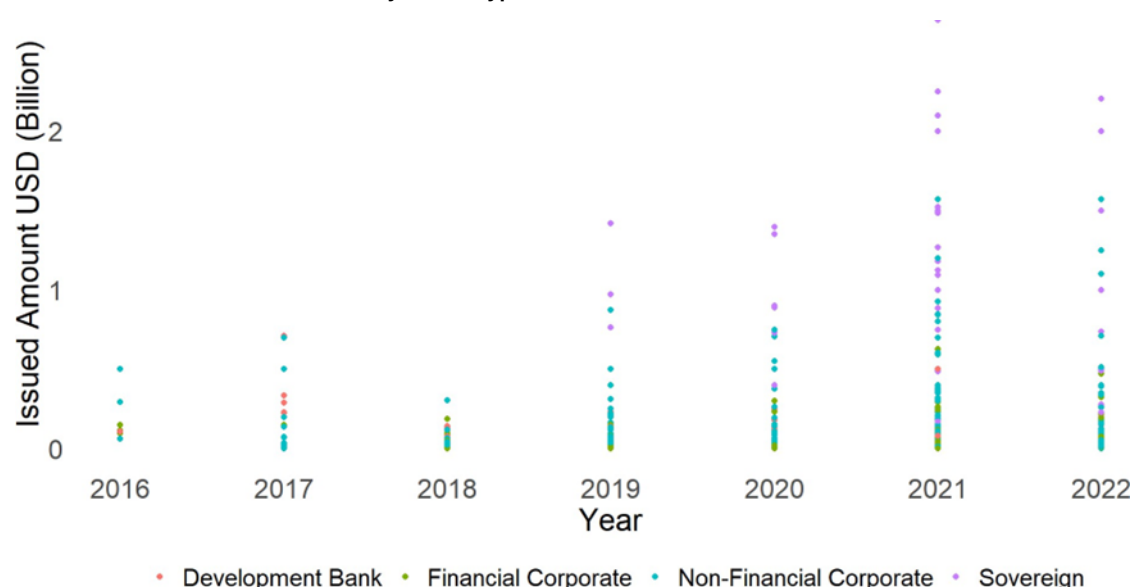
¹⁰ More information about this growing market in the Climate Bonds Initiative report www.climatebonds.net/files/reports/cbipricing1202103b.pdf.

market in Latin America and the Caribbean (LAC)¹¹, covering around 430 issuances of 14 countries from 2015 to 2022.

We recovery from IDB's dataset issued volume, and number of deals of non-financial corporate ESG issuances before and after treatment, that is, before the issuance of a sovereign ESG bond. For the purposes of this paper, we consider ESG bond all the labelled green, social or sustainability bonds, i.e., all the bonds that have been granted through an external review¹². A labelled ESG bond is considered at a lower risk of "greenwashing"¹³, since it has been through an external review that testify that the proceeds are fully allocated to projects with sustainable benefits.

Profile of Private ESG issuance in Latin America. Figure 3 details how the individual issued volume and number of deals have evolved since 2016. As expected, financial corporate, non-financial corporate, and domestic development banks were the first participants of the market as they typically have fewer constraints than sovereigns. Interestingly, from 2019 onward, both the issued volume and the number of deals has increased after the inauguration of the Latin American sovereign ESG debt market by Chile in 2019.

Figure 3 LAC Thematic Bonds Issuances by Issuer Type



The distribution of Private and Sovereign ESG issuance. Figure 4 depicts the evolution of distribution of private (a) and sovereign (b) issuance over time. After Chile's inauguration in 2019, Mexico, Guatemala, and Ecuador issued sovereign thematic bonds in 2020, whereas Peru and Colombia in 2021. Lastly, Uruguay issued its first thematic bond in 2022. From 2016 to 2022, the average ticket of private placement was USD 0.14 billion, while the mean sovereign issuance was around USD 1 billion. After the first issuance of a sovereign thematic bond in 2019, the distribution of

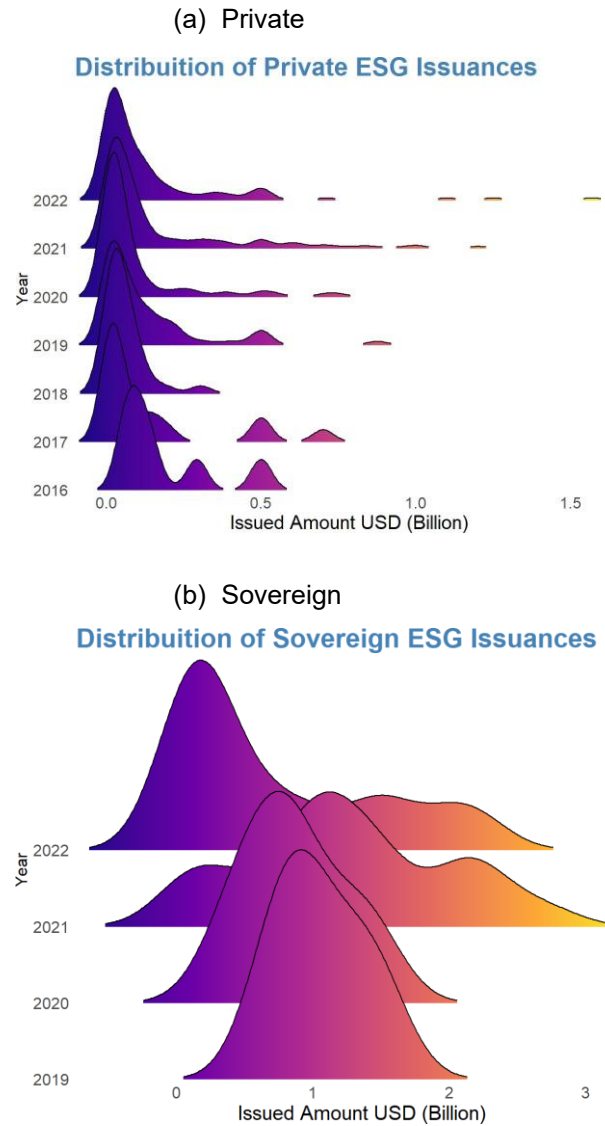
¹¹ <https://www.greenbondtransparency.com/support/about-us/>

¹² According to the Green Bond Platform, an external reviewer is an independent entity that carries out any type of external review pre- or post-issuance. External reviews comprise second party opinions (SPOs), certifications under the Climate Bond Standard, ratings, assurance statements, and impact verification.

¹³ The term "greenwashing" refers to the practice of making exaggerated claim on the environmental benefits in the attempt to gain market share <https://www.scielo.br/j/rmj/a/j8KWHs8k4XfndmpPCcG9f6f/?lang=en>.

private issuance has become even more right tailed, signaling that the transmission channels detailed in section 2 are more effective for non-small private issuance.

Figure 4 Distribution of Private and Sovereign ESG Issuances in Latin America



3.2. Empirical Strategy

Empirical strategy of the event-study. We follow the Difference-in-Difference (DiD) approach of (Callaway and Sant'Anna 2021) as traditional Two-Way Fixed Effects (TWFE) event-study may be significantly biased¹⁴. There is a growing literature on the casual interpretations of TWFE regressions pointing out that TWFE linear regression should not be used to highlight treatment effect dynamics. (Callaway and Sant'Anna 2021) approach does not rely on restricting treatment effect heterogeneity

¹⁴ (Callaway and Sant'Anna 2021) and (Sun and Abraham 2021) show that when the treatment is not triggered at the same time across different cohorts, as it is in our study, then TWFE is biased. Nonetheless, at section 3.4 we run robustness tests using the TWFE method.

assuming only the no-anticipation condition and the existence of parallel trend based on a never-treated group.

As we are interested in percent rather than absolute changes, we work with logarithm form of our left-hand side variables (issued volume and number of closed deals). Considering that these variables may be equal to zero for a given year, we use country-level logistic transformation of standardized issued volume and number of closed deals to run our estimations¹⁵

Specification. As shown by table 1 and 2, we work with a full sample covering both domestic and external issuances and a restricted sample showing only external issuance, which is our preferred specification. The restricted sample covers roughly 45 percent of the issued volume of the full sample and around 18 percent of the number of closed deals. The dominance of domestic market in a comparison with external issuance in terms of number of deals is mainly explained by two factors. First, the domestic market is affected by national financial regulation that aims to boost the ESG market, while its effect on external market is somewhat limited as they are not easily applied to different jurisdictions. Second, the size of issued amount could be a binding constraint in the external market, limiting, thus, the funding of small amounts.

We aggregate individual private issuance in an annual basis by countries dividing them into two groups: i) treatment (countries that issued a sovereign ESG bond) and ii) never-treated (countries that do have a sovereign thematic benchmark). We set the pre and post treatment periods as follows: $post_{npost}^j = t_{npost}^j - 1$, where t_{npost}^j is the number of years after the first sovereign issuance set by $npost$ in a country j . Accordingly, $t_1^j = 1$ implies that $post_1^j = 0$. Similarly, the pre-treatment periods are given by $pre_{npre}^j = t_{npre}^j - 1$, where t_{npre}^j entails the number of years before the first sovereign placement.

This approach protects our analyses from potential concerns about market players anticipating the sovereign thematic issuance. The date of the first issuance is well-defined, but the first formal signal from the sovereign to markets on its intentions to issue a thematic bond happens before the issuance by the publishing of thematic bond framework. The thematic framework sets up the rules for future issuance and, therefore, is a needed condition to create the sovereign thematic market. As the time between the publishing of the framework and the issuance can take up to 10 months in our sample, we define pre_{npre}^j and $post_{npost}^j$ assuming that the publishing of the framework happens up to one year before the issuance. Importantly, we run robustness placebo tests reassuring the respect of DID's no anticipation assumption.

Contingent on Stable Unit Treatment Value Assumption (SUTVA), our DiD specification assumes that a private ESG issuance of country m does not affect decision of firm in a country j , implying that we are ruling out market segmentation effects. Moreover, our baseline specification does control for covariate-specific trends steaming from country sovereign rate scale and the size of private ESG market before the treatment factor in.

Controls and robustness tests. We use the sovereign credit rating (average of Fitch, Moodys, and S&P ratings) where 1 represents a technical default and 21 indicates an AAA rating built by (Kose, et al. 2022) to control for pre-trends related to country-level economic and credit features. We also control for the heterogeneity of the size of private thematic debt before the treatment (creation of the sovereign ESG market) using the median issued ticked before the treatment. Finally, we run robustness tests finding that even after removing controls the economic and statistical significance of the sovereign knock-on effect is still preserved.

¹⁵ For a detailed discussion see (D'ávila and Parlato 2018).

Table 1 Summary Statistics of Private ESG Issuances before the Treatment (Full Sample)

Statistic	N	Mean	St. Dev.	Median
Never Treated units Issued Amount - USD billion	7	0.07	0.18	0.00
Treated units Issued Amount - USD billion	7	0.9	0.09	0.12
Never Treated units Number of Deals	7	0.94	2.09	0.10
Treated units Number of Deals	7	1.09	0.76	1.50
Never Treated units Sovereign Rate Scale	7	8.87	2.73	9.00
Treated units Sovereign Rate Scale	7	12.35	3.46	12.67

Note: The unit of analysis is Latin American economies aggregated in a yearly basis. The variables come from averages centered at the country level using the database built by the IDB Green Bond Transparency platform over the period of 2016-2022. The sovereign credit rating (average of Fitch, Moodys, and S&P ratings) where 1 represents a technical default and 21 indicates an AAA rating built by (Kose, et al. 2022).

Table 2 Summary Statistics of Private ESG Issuances before the Treatment (External)

Statistic	N	Mean	St. Dev.	Median
Never Treated units Issued Amount - USD billion	7	0.07	0.18	0.00
Treated units Issued Amount - USD billion	7	0.10	0.09	0.12
Never Treated units Number of Deals	7	0.94	2.09	0.10
Treated units Number of Deals	7	1.08	0.76	1.50
Never Treated units Sovereign Rate Scale	7	8.87	2.73	9.00
Treated units Sovereign Rate Scale	7	12.35	3.46	12.67

Note: The unit of analysis is Latin American economies aggregated in a yearly basis. The variables come from averages centered at the country level using the database built by the IDB Green Bond Transparency platform over the period of 2016-2022. The sovereign credit rating (average of Fitch, Moodys, and S&P ratings) where 1 represents a technical default and 21 indicates an AAA rating built by (Kose, et al. 2022).

3.3. Discussion

The creation of a sovereign ESG reference yield curve leads to a significant statistical and economic improvement of issued amount of private ESG debt as well as its number of closed deals. The estimated effect is highly significant for external funding, but it is not significant for domestic issuance. This finding is consistent with main takeaways of the Brazilian external debt experience detailed and the key mechanisms highlighted in section 2.

Section 2 shows that Brazilian sovereign external issuance causes a positive externality on the external private market. In addition, section 2 unpacks how the crowding-in and advertisement channels unlocks the sovereign ESG knock-on effect mainly due to the greater impact at the margin of sovereign external issuance vis-à-vis a domestic funding transaction.

Figure 5 details the response (percent change) of the average issued amount of private ESG debt (a) for treated countries after the treatment kicks-in and the number of thematic debt deals closed in the

post treatment period. The vertical lines indicate a 95-confidence interval. The benefits from the issued volume and closed deals improvement underpinned by the opening of the ESG market take three years to factor in, implying a 50 percent jump in terms of issued volume and 25 percent increase looking at the number of closed deals. The peak-response happens 4 years after the creation, meaning an even larger expansion of the issued volume (100 percent) and number of closed deals (60 percent).

Replicating the same exercise to our restricted sample (external issuance), Figure 6 indicated that the magnitude of the outcomes shown by Figure 5 is amplified in line with rational of the transmission channels of the knock-on effect detailed in section 2. The impact on issued volume also takes three years to kick-in, but with a larger impact entailing an increase of around 60 percent. The impact on the number of closed deals, in turn, takes two years to kick-in instead of three years (Figure 5) implying a 25 percent increase. The peak-response also occur 4 years after the creation, but the magnitude of the effect is larger in comparison with Figure 5 showing a jump of the issued volume (175 percent) and number of closed deals (60 percent). Importantly, Figure 6 also provides evidence that pre-trends is respected. By restricting our sample to domestic private issuance, however, we have not found any significance evidence of changes in the issued volume and number of closed deals as only Colombia has exclusively focused on the sovereign domestic ESG market since 2021.

Looking at the estimation of Figure 5 (full sample) from another angle, Figure 7 displays the same information shown by Figure 5 but breaking down the event-study charts by the four treatment cohorts. The first cohort, group 2018, represents Chile with its underlying sovereign issuance in 2019. The second cohort, group 2019, is the representative group of the countries that issued a sovereign in 2020 (Mexico, Ecuador, Guatemala). The third cohort, group 2020, aggregates the countries that posted a sovereign thematic issuance in 2021 (Colombia and Peru). Finally, the fourth cohort, group 2021, unfolds the knock-on effect for Uruguay's 2022 inaugural thematic issuance via a SLB.

Considering the issued volume and number of deals, the estimated effect of the first, second, and third cohorts (group 2018, 2019, 2020) are economically and statistically significant, while the outcome of the fourth cohort (group 2021) is not significant. The estimated effect of the fourth cohort is explained by the knock-on effect of Uruguay's SLB issuance which chiefly unlocked external private placements, rather than domestic ones.

Still analyzing the impact of the creation of a Sovereign ESG market by cohorts, Figure 8 details the estimated results for the restricted sample (external issuance). Interestingly, by removing the domestic issuance, the outcome of the fourth cohort (group 2021) has become more economic and statistical meaningful, providing further evidence that the inauguration of sovereign external ESG issuance is a paradigm shift for the international private ESG debt market.

Figure 5 Baseline Average Effect (Full Sample) by Length of Exposure since the Opening of the ESG Sovereign Market

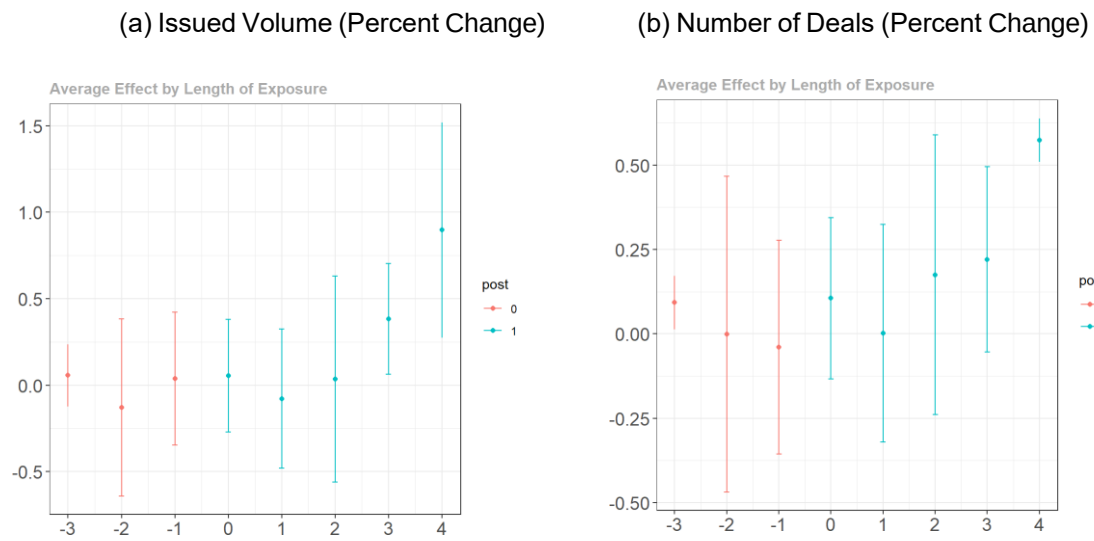


Figure 6 Baseline Average Effect (External Issuance) by the Length of Exposure since the Opening of the ESG Sovereign Market

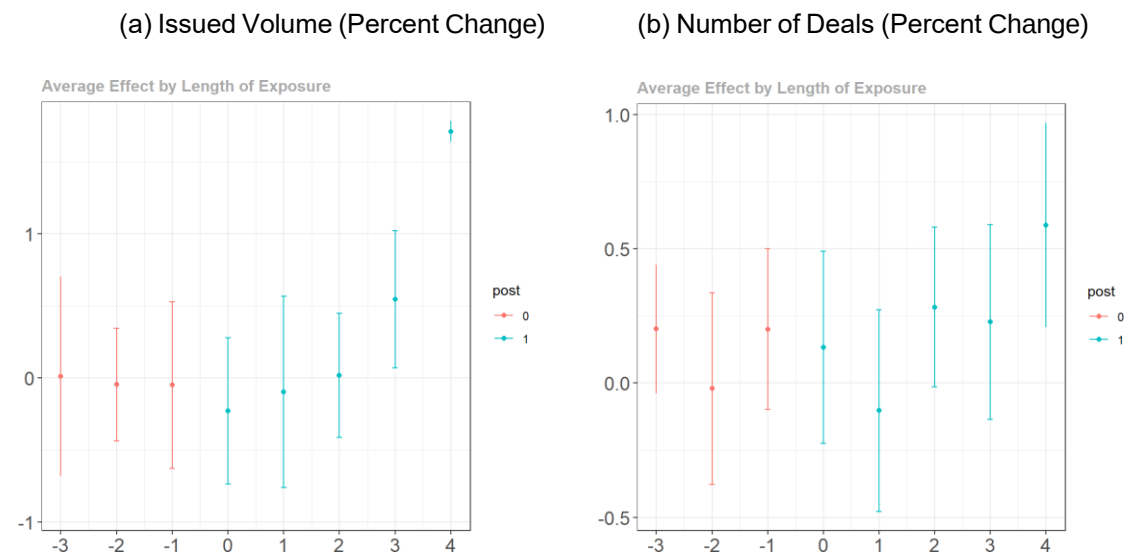


Figure 7 Baseline Average Effect (Full Sample) by Cohorts

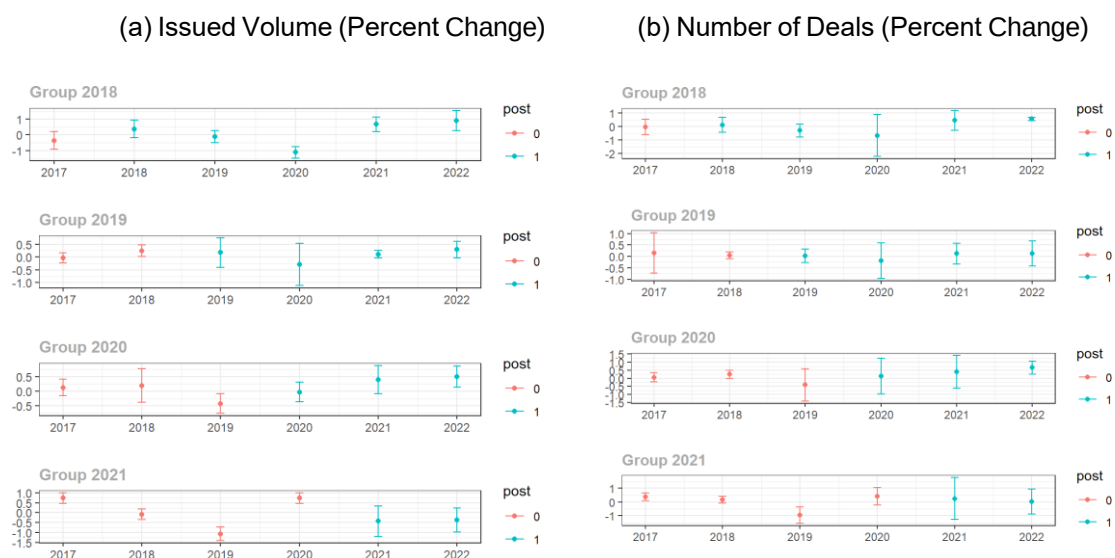
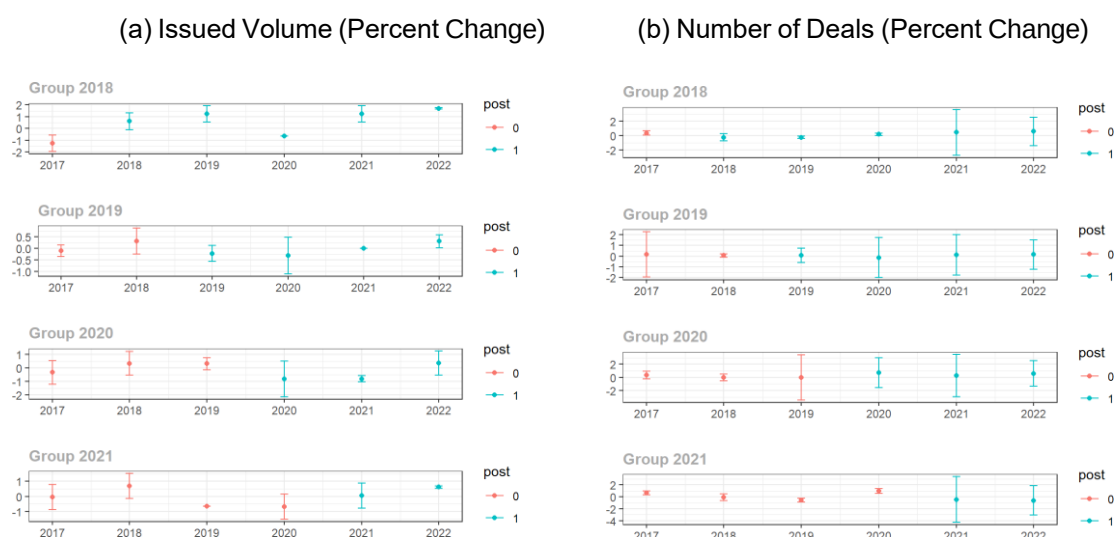


Figure 8 Baseline Average Effect (External Issuance) by Cohorts



3.4. Robustness

Alternative estimation. As highlighted in section 3.2, DiD literature has been evolving at fast pace mapping a potential bias in the use of TWFE for event-study estimation in the presence of treatment effect heterogeneity. (Callaway and Sant'Anna 2021) approach does not rely on restricting treatment effect heterogeneity assuming only the no-anticipation condition and the existence of parallel trend based on a never-treated group comparison. Additionally, our baseline specification does control for covariate-specific trends steaming from country income group, sovereign rate scale, and the size of private ESG market before the treatment factor in.

We run an alternative specification with unconditional parallel trends (removing the controls of the baseline specification) through three different estimation methods i) (Callaway and Sant'Anna 2021), ii) TWFE, and iii) (Sun and Abraham 2021), which also addresses the heterogeneity in time treatment issue. Figures 9 and 10 depict the impact on issued volume and number of deals for the full and restricted sample respectively, showing that even in the alternative specifications parallel trend condition still holds, and the estimated effect is significant.

Placebo test. To make the case that our results are not driven by the setting of the pre/post period and treatment group composition, we re-estimate our baseline specification considering three scenarios: i) setting a fake treatment time 2 periods before the baseline, ii) setting a fake treatment time 1 period before the baseline, and iii) setting a fake treatment group using never-treated countries. The goal of these placebo exercises is to test the falsifiability of our premises, meaning that a fake input leads to an outcome statistically equal to zero. Figures 11 and 12 indeed show the estimated effects become insignificant.

Figure 9 Issued Volume Robustness Test Average Effect (Full Sample) by the Length of Exposure since the Opening of the ESG Sovereign Market

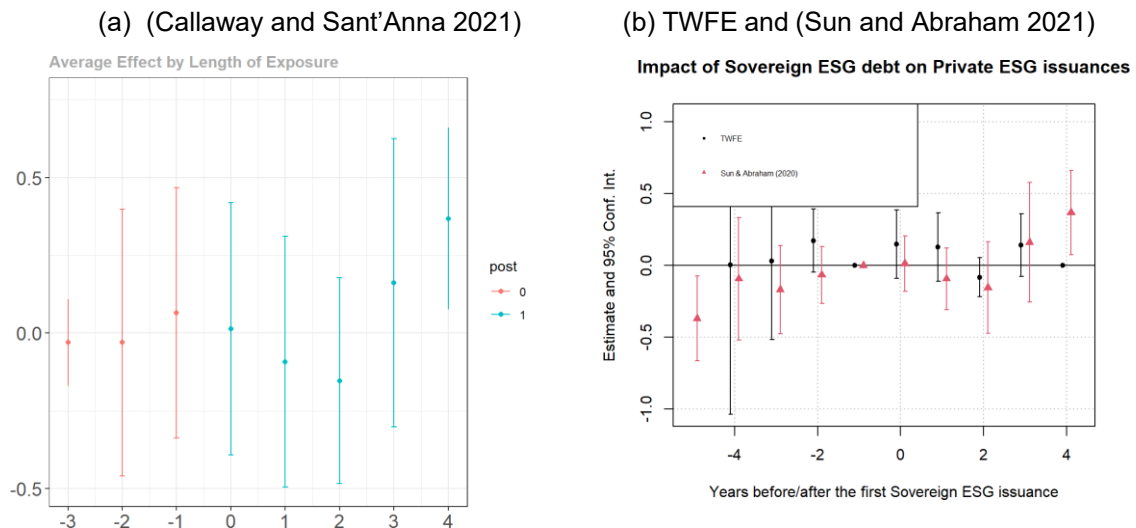


Figure 10 Issued Volume Robustness Test Average Effect (External Issuance) by the Length of Exposure since the Opening of the ESG Sovereign Market

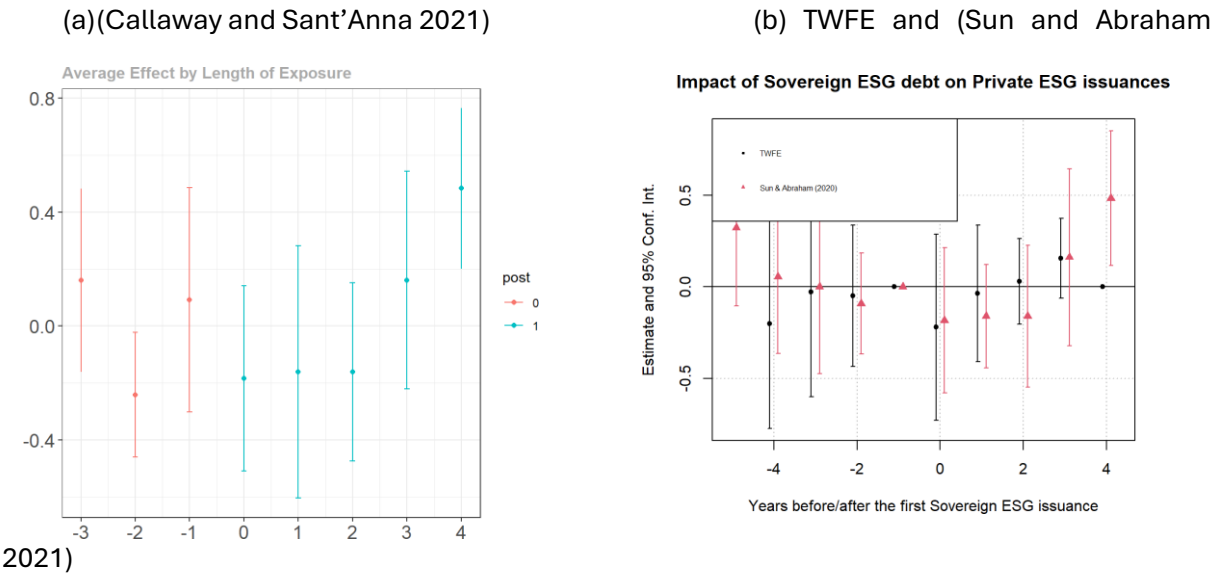


Figure 11 Issued Volume (Full Sample) Robustness Placebo Test

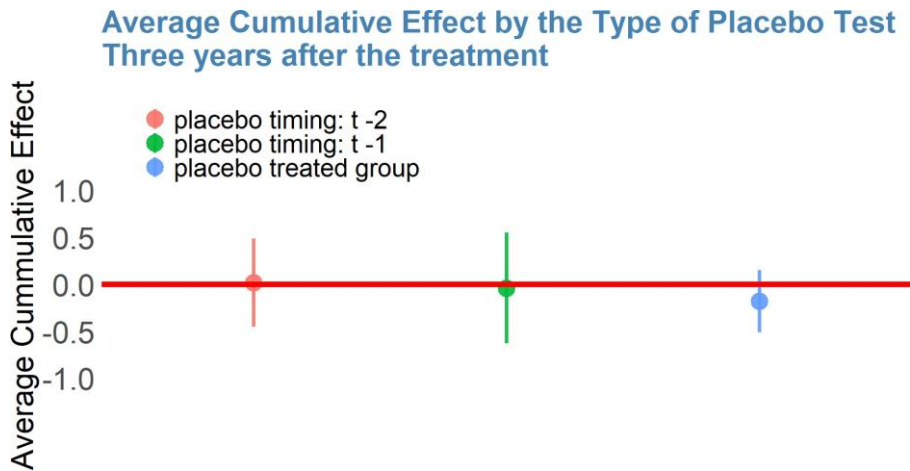
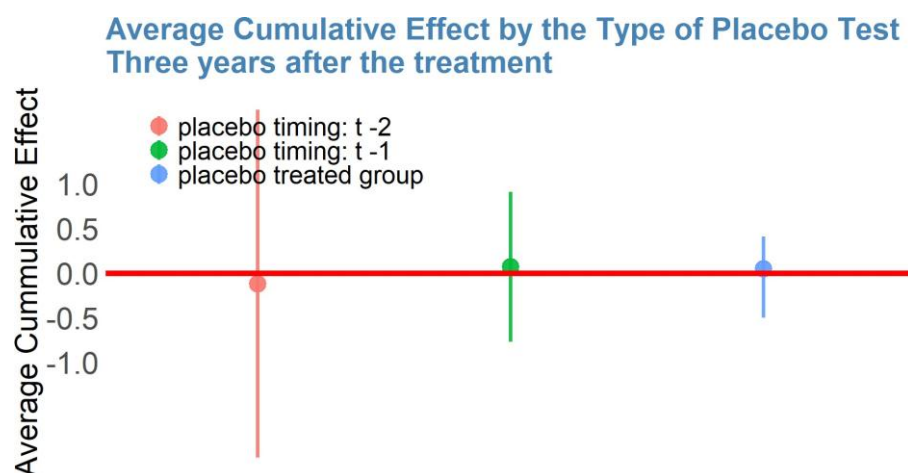


Figure 12 Issued Volume (External Issuance) Robustness Placebo Test



4. CONCLUSIONS

We provide an estimate of the knock-on effect of the creation of a sovereign ESG reference yield curve on corporate ESG bonds from LAC issuers. To the best of our knowledge, ours is among the first studies to focus on the key role played by sovereign debt on fostering the development of private thematic debt market.

Using a difference-in-differences approach, we empirically estimate the impact of the creation of a sovereign external ESG debt market finding that the opening roughly leads to a 60 percent increase in issuance volumes and 25 percent expansion in number of private external ESG issuance after three years. On the mechanisms, we argue that the opening of a sovereign ESG market provides a reference enhancing the price discovery process of private issuance. Our estimation method considers in spirit of time and country fixed effects, implying that the creation of a sovereign thematic bond in Brazil could provoke a substantial impact on thematic bonds issued by Brazilian private players.

We contribute to the development of the literature by being, perhaps, the first empirical study to focus on the estimation of the impact of the creation of a sovereign ESG reference to private players. Looking ahead to further work, while our study contributes to the assessment of size of the knock-on effect in LAC, more analysis is needed to understand the heterogeneity of the knock-on effect in non-LAC EMs. Moreover, the analysis of the knock-on effect at the domestic level is also welcome as several EMs started to issue thematic bond at their local market.

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ESG Budgeting and the Next Generation of Sustainable Bonds *

Bence Lukács ^a and András Bebes ^b

Abstract

This paper provides a comprehensive overview of ESG budgeting (including green, gender and SDG budgeting) and the issuance of sustainable bonds (green, social, sustainability, sustainability-linked and transition) by European Union sovereigns. The synergies between budgetary systems and sustainable bonds are explored with suggestions regarding the further development of the market. Climate and gender mainstreaming, ESG budgeting and the sustainable bond market with its regulatory environment is described from the perspective of sovereigns. Two thirds of EU sovereigns issued sustainable bonds while approximately only one third implemented some kind of ESG budgeting. Sovereigns using ESG budgeting tend to connect eligible expenditures to their state budget in their sustainable bond disclosures. Evidence suggests that ESG budgeting boosts the alignment with the European green bond standard (EUGBS), the EU Taxonomy and fosters the issuance of sustainable bonds. In this paper, the next generation of sustainable bonds are introduced, highlighting the so-called green budget-linked bonds (GBLBs), which merge the allocation and impact report of the sustainable bonds with the state budget. With the issuance of GBLBs, a separate bond allocation and impact report is no longer necessary as budgetary lines in the state budget are properly scrutinized and assessed. Investors would be able to observe how the issuer is progressing to net-zero. GBLBs have the potential to lower investment risk for investors and the cost of funding for issuer.

Keywords: Budget Systems, Sustainable bonds, Sustainable Development.

JEL Code: F64, Q01, Q56, J16, H61, H72

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1. INTRODUCTION

The world is facing challenges, including climate change and gender inequality (UN, 2024a). Various initiatives have been launched over the past years to address them, including the Paris Agreement, Agenda 2030 or the European Green Deal.

In 2015, countries adopted the Paris Agreement, taking responsibility in limiting global average temperature to well below 2°C above pre-industrial level. Countries agreed in attempting to limit the increase of global temperature to 1.5°C (UN, 2024b). Under article seven of the Paris Agreement, countries declared that they need to reduce vulnerability, strengthen resilience to climate change and adoption, taking into account a gender-responsive approach (UNFCCC, 2015).

In the same year, countries approved Agenda 2030. The action programme identifies 17 Sustainable Development Goals and 169 targets with several indicators under economic, social and ecological dimensions. The goals are structured around five pillars: People, Planet, Prosperity, Peace and Partnerships (UN, 2024c).

In 2021, the European Union (EU) adopted the European Green Deal. With the objectives set in the Green Deal, the EU aims to become the first climate-neutral region by 2050 and targets at least 55% lower net greenhouse gas emission by 2030 compared to 1990 (European Commission, 2024a).

In order to comply with the provisions set in these documents, countries need to integrate green and gender considerations into their national policy (climate and gender mainstreaming), develop new financial, budgeting tools (green, gender or sustainable development goal – SDG – budgeting) and mobilise an enormous amount of resources (e.g. by issuing sustainable /green, social, sustainability, sustainability-linked, transition/ bonds).

2. METHODOLOGY AND OVERVIEW

This study is an evaluation of publicly available data, e.g. international guidelines, working papers, regulations, budgetary and bond frameworks and reports, budget tools, documents published by EU sovereigns, the EU, the Organisation for Economic Co-operation and Development (OECD) and the United Nations (UN).

We analyzed the budgetary practices of EU sovereigns, including the assessment of state budgets, budget annexes, spending reviews, cross-cutting reports, special parts of budgets and guidelines for budgeting methodologies. Surveys on green and gender budgeting published by the European Union (Pouwels, 2023; European Commission, 2023) were taken as a reference. Additionally, we examined the publicly available sustainable bond disclosures of the sovereigns (under sustainable bonds, we refer to green/social/sustainability/sustainability-linked/transition bond while under sustainable bond disclosures, we refer to the framework and allocation/impact report of the sustainable bonds) taking into account the ICMA's Sustainable Bond Market Data (ICMA, 2024a).

We identified EU sovereigns applying ESG budgeting (under ESG budgeting we refer to green/gender/SDG budgeting) and setting up a sustainable bond framework or issuing such bonds based on the assessed documents. Sustainable bond guidelines and practices used by the EU countries for the issuance of sustainable bonds were also examined. We scrutinized how ESG budgeting enhances alignment with widely accepted guidelines and fosters the issuance of sustainable bonds. Finally, based on the analyzed ESG budgetary practices and sustainable bond issuances in the EU, we

introduce the possible future of sustainable bond market with the emergence of the next generation sustainable bonds, the green budget-linked bonds – GBLBs.

The study has some limitations. First, in a few cases, it was difficult or not possible to find the relevant budgetary documents of the sovereigns. Second, budgets were published in the official language of each country (except France, which provides an English version of its state budget). To comprehend the documents published by these countries, we used online AI translator.

2.1. Climate and gender mainstreaming

Climate and gender mainstreaming takes into account climate and gender considerations during the processes of decision making, development of programmes, policies, mission statements and strategies. Climate and gender mainstreaming can also consider reshaping the development, the design, the implementation, the evaluation and the monitoring phases of programmes and actions according to climate or gender objectives (Lam et al., 2024). Climate and gender mainstreaming can be fostered by implementing budgetary systems based on climate and gender perspectives (green and gender budgeting) or financing with debt instruments (e.g. sustainable bonds).

The European Union is advocating climate and gender mainstreaming at EU level with several tools (Table 1).

Table 1: Climate and gender mainstreaming at EU level (examples)

Tools	Climate mainstreaming	Gender mainstreaming
Budgetary system	Green budgeting	Gender budgeting
Financial instruments	NextGenerationEU green bonds	¹
Programmes, actions	LIFE, Just Transition Mechanism, Common Agricultural Policy 2023-2027	InvestEU, Horizon Europe, requiring entities to have a gender equality plan for eligible for funding
Strategies	Biodiversity Strategy for 2030, Environment action programme to 2030	Gender Equality Strategy 2020-2025
Legislation	EU Taxonomy Regulation	Directive on Gender Balance
Institutions	European Environmental Agency	European Institute for Gender Equality
Monitoring, evaluation	EU Climate Progress report	EU Annual report on gender equality
Awareness raising	EU Climate Change Adaptation Conference	EndGenderStereotypes campaign

Source: European Commission (2024b, 2024c, 2024d, 2024e)

¹ So far, the EU has only issued green (NextGenerationEU green bonds) and social bond (EU SURE social bonds), but none of these bonds have financed objectives specifically related to gender equality.

2.2. ESG budgeting

Most budget lines have an evident or potential impact on sustainability including climate, environment, society and gender equality (Frey – Köhnen, 2012), thus increasing spending related to these specific objectives in the budget is necessary for sovereigns to reach sustainable goals. To do so, countries might need to develop new budgetary systems or restructure their current budget in order to better outline their financing. There are several possibilities for sovereigns to transform their budgetary systems including the use of performance-based budget and budgeting from green, gender or SDG perspectives.

Performance-based budgeting aims to provide information on the results of the spending (including output, outcome or impact) and the objectives of the budgetary items. Therefore, additional transparency, accountability and contextual information of budgetary lines are provided which can be an important input for a more effective decision-making (Decuyper - Institute For The Equality of Women and Men, 2010; Tryggvadottir - Bambalaite, 2023; Pojar, 2023). The importance of climate and gender mainstreaming is growing, while more and more sovereigns are implementing performance-based budgeting on green or gender perspectives or taking into account the SDGs.

Green budgeting means using the tools of budgetary policy to help achieve climate and environmental goals (Sakrak et al., 2022). Gender budgeting integrates a clear gender perspective within the budgetary process, through the use of special measures and analytical tools, with an aim to promote gender-related policies (OECD, 2023). Green and gender budgeting are implicit elements of SDG budgeting as several sustainable development goals target green (e.g. SDG7: Affordable and clean energy, SDG13: Climate Action) and gender (e.g. SDG5: Gender Equality) objectives (Sakrak et al., 2022).

Providing an enabling environment is fundamental for the implementation of ESG budgeting. The EU, the OECD and the UN all created their own guidance in order to promote and foster ESG budgeting across the globe. These include the Green Budgeting Reference Framework, the Green and Brown budgetary items list, the OECD Best Practices for Gender Budgeting, the Toolkit for Mainstreaming and Implementing Gender Equality 2023, the Budgeting for the SDGs: A Modular Handbook (European Commission, 2024f; Poghosyan et al., 2022; OECD, 2023). Additionally, governments providing templates to the ministries for budgeting, setting up dedicated committees for managing the process of budgeting (e.g. Green Budgeting Steering Committee), conducting trainings for capacity building also supports the implementation of such budgeting.

Tools of ESG budgeting include tagging the budgetary lines, conducting cost benefit, impact, risk analyses or ex-ante and ex-post assessments on budgetary lines, reporting from climate, gender or SDG perspectives in spending reviews and publishing cross-cutting reports² or annexes of the budget (Pojar, 2023; Ministerio de Hacienda, 2024a).

At EU level, action is taken to promote climate and gender mainstreaming through the EU's budgeting processes and its funding. The EU introduced a tracking system requiring the countries receiving specific EU funds (e.g. ESF+/ERDF/ Cohesion Fund/ JTF) to indicate a gender equality dimension (gender targeting / gender mainstreaming / gender neutral) in their funding plan (EU, 2021a). Additionally, in the Gender Report 2024, the EU presents how its funding programmes (e.g. Horizon Europe) are related to gender equality based on a scoring system³ (European Commission, 2024c). The

² Cross-cutting budget reports highlight the linkage and contribution of spending programmes to certain areas or objectives of public interest, which usually involve several budget policies.

³ Score 2: improves gender equality with a principal objective, score 1: promotes gender equality but it is not the objective, score 0*: potentially contributes to gender equality, score 0: do not have any significant impact on gender equality.

Commission has also developed the “EU Climate markers”⁴ – based on the internationally recognised “Rio-markers” – which are used for climate tracking under the Recovery and Resilience Facility (EU, 2021b; European Commission, 2022).

2.3. The sustainable bond market

In order to finance the sustainability related budgetary lines, many sovereigns decided to raise capital by issuing sustainable bonds (*Table 2*).

Table 2: Summary of the sustainable bond instruments based on their objectives and types

Objectives	Type of bond		
	<i>Restricted UoP</i>	<i>General purpose</i>	<i>Restricted UoP or general purpose</i>
Environmental	Green		Transition
Social	Social		
Environmental or social	Sustainability	Sustainability-linked	

Source: ICMA (2023a)

Restricted Use of Proceeds (UoP) bonds including green, social, sustainability bonds aim to finance certain projects, while general purpose bonds with key performance indicators (KPIs) and sustainable performance targets (SPTs) at the issuer level are sustainability-linked bonds financing sustainability/ESG objectives and targets. Transition bonds might be issued as a restricted UoP or general purpose bond. Specific type of bonds may include blue or gender bonds, the former is a sub-type of green while the latter is a sub-type of social bond. Some sovereigns also issue sustainable development goals bonds (SDG bonds), which is a sub-type of sustainability bond (ICMA, 2024a).

Green bonds finance different green projects that contribute to several environmental objectives including biodiversity, pollution prevention and control, renewable energy, clean transport, climate change or climate change mitigation (ICMA, 2022). The objective of blue bond is to finance projects that contribute explicitly to marine and coastal conservation, protect the marine ecosystem or the establishment of sustainable fishery etc. (CFA Institute, 2023).

Social bonds finance social projects including areas like affordable housing, infrastructure, access to essential services, targeting a certain population (women, disabled, homeless or unemployed people) (ICMA, 2023b). The proceeds of gender bonds are exclusively channelled to programmes or activities promoting women's empowerment or gender equality targeting female entrepreneurs, employees in organisations, or consumers (ADB, 2024). In 2024, Iceland was the first country to issue a gender bond.

Sustainability bonds finance projects that combine both green and social elements (ICMA, 2021).

SDG bonds foster the progress towards achieving the SDGs (Gouvernement de la République du Bénin, 2022)

Sustainability-linked bonds support the achievement of KPIs and SPTs, which can be linked to both social and environmental objectives (ICMA, 2024b).

⁴ The methodology assigns three different coefficients (0%, 40% or 100%) based on a list of possible activities on their contribution to climate change and environmental objectives.

Climate transition or transition bonds focus explicitly on activities and sectors where currently no technologically and economically feasible low-carbon alternatives are available thus cannot fit into the criteria of green financial instruments.

Over the past years, several voluntary guidelines and standards were published in order to improve the transparency of the market, to strengthen investor confidence and to promote the issuance of sustainable bonds. These include the ICMA (International Capital Market Association) Principles⁵, the Climate Bond Standard by Climate Bonds Initiative (CBI), the European green bond standard (EUGBS) and the Basic Guidelines on Climate Transition Finance by the Japanese Ministry of Trade, Economy and Industry (METI). By now, the principles published by ICMA have become the most commonly used for sustainable bond issuances. By September 2024, 97% of the entire sustainable bond market was aligned with ICMA Principles according to ICMA's sustainable bond database (ICMA, 2024a). In case of Europe, the use of EUGBS might become a general requirement in the future.

The European green bond standard regulation finalised in 2023 aims to further improve the European sustainable bond market. The standard requires 85% of the proceeds of the bonds to be allocated to EU Taxonomy-aligned⁶ activities. Issuers using the standard must indicate the planned allocation structure and the estimated impact of the bonds before the issuance (pre-issuance) using the EUGBS factsheet. Regarding post-issuance requirements, for every 12-month period until the date of full allocation of the bond, the issuer must report the allocation. In addition, the issuer must produce an impact report after the full allocation of the proceeds (or at least once during the lifetime of the bond) using the templates provided in the regulation. The EUGBS factsheet and the allocation report must be supervised by an external reviewer, while validation of the impact report is only recommended (EU, 2023).

On the sustainable bond market, the importance of taxonomies is also growing, as taxonomies continue to improve the transparency by defining specific criteria (e.g. emission thresholds) for economic activities that are aligned with net-zero trajectory (European Commission, 2024g). Several regions have created their own taxonomies in order to direct investments towards the transition, e.g. EU Taxonomy, ASEAN Taxonomy, Singapore-Asia Taxonomy, Mexican Sustainable Taxonomy, Climate Bonds Initiative Taxonomy, China's Green Bond Endorsed Projects Catalogue, ASFI Taxonomy project⁷ (ICMA, 2024c).

3. RESEARCH AND DISCUSSION

As the bond market evolves, regulations tighten and investor demand increases. Investors are now not only interested in the use of proceeds of the bonds they are buying, but increasingly expect sovereigns to provide credibility and transparency by presenting their comprehensive ESG profiles, including strategies, programmes and financial background.

Issuers must adapt to the changing market and need to comply with best market practices, taking into account the developing guidelines, standards and regulations like the EU Taxonomy and the EUGBS. They are also expected to provide the adequate transparency for investors through investor engagement.

⁵ Green Bond Principles, Social Bond Principles, Sustainability Bond Guidelines, Sustainability-linked Bond principles, and Climate Transition Handbook.

⁶ It means the compliance of the financed activity with the set of criteria defined in the delegated acts of the Taxonomy.

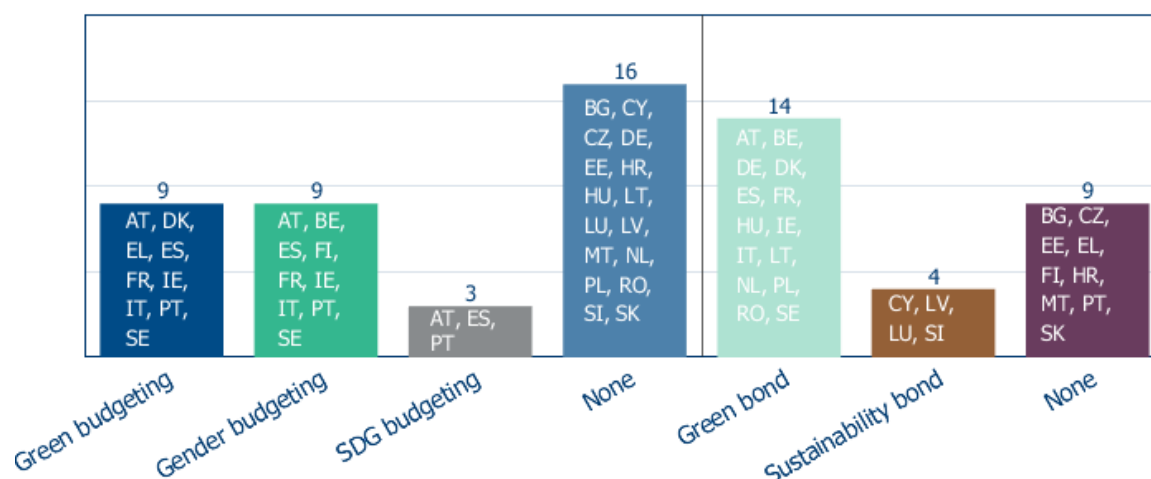
⁷ In Australia, the taxonomy is in the state of proposal.

ESG budgeting has the potential to ensure the sufficient transparency for investors, boost investors' confidence, while also supports the issuance of sustainable bonds with the simpler identification of eligible expenditures. ESG budgeting and sustainable bond issuance have the same objectives (e.g. better identification of the budgetary items based on different perspectives, financing sustainable goals and enhanced transparency of budget spending), and thus combining them and exploiting the potential synergies can be beneficial for both the issuer and the investors.

3.1. ESG budgeting, sustainable bond issuances and disclosures of EU sovereigns

Based on the analysis of EU sovereigns' budgetary systems, approximately one third of EU countries have implemented ESG budgeting. Nine sovereigns use some form of green budgeting, nine apply gender budgeting, while only three sovereign introduced SDG budgeting or are currently at the early stages of its application (*Figure 1*). Some countries (AT, ES, PT, FR, IE, IT, SE) use multiple types of ESG budgeting.

Figure 1: EU sovereigns using ESG budgeting and EU countries setting up sustainable bond framework or issuing sustainable bonds



Source: EU sovereigns' budgetary and sustainable bond disclosures (2024)

Approximately two thirds of the EU sovereigns have set up a sustainable bond framework or issued at least one sustainable bond (*Figure 1*). Fourteen countries created green bond frameworks and by now, only Romania has yet to publish an allocation or impact report on its green bond issuance⁸. Four sovereigns have set up a sustainability bond framework, out of which Slovenia, Latvia and Luxemburg already issued allocation and impact reports⁹. No social, sustainability-linked, SDG, gender or blue bond was issued by EU sovereigns, although Slovenia has indicated gender equality goal in its sustainability bond documentation.

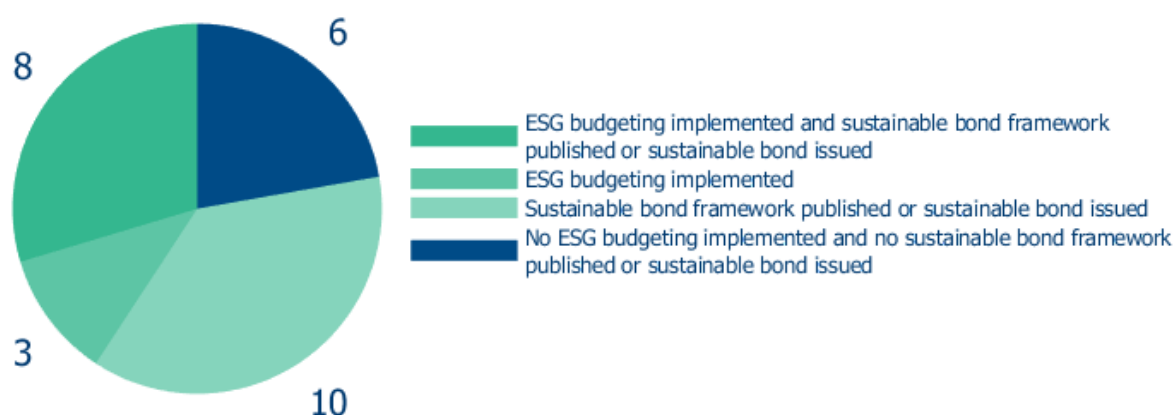
Sustainable bonds (re)finance eligible budgetary lines. One would expect that countries issuing sustainable bonds have also implemented ESG budgeting to take advantage of the synergies between the two. However, only eight (AT, BE, DK, ES, FR, IE, IT, SE) out of the eighteen EU sovereigns setting

⁸ The country issued its first green bond in 2024, and thus the first report is expected to be published in 2025.

⁹ Cyprus issued its inaugural sustainability bond in 2023, thus report on its allocation and impact is expected to be published in 2024.

up green or sustainability bond framework or issuing green or sustainability bonds have implemented some form of green, gender or SDG budgeting (*Figure 2*).

Figure 2: EU sovereigns using ESG budgeting and EU countries publishing sustainable bond frameworks or issuing sustainable bonds



Source: EU sovereigns' budgetary and sustainable bond disclosures (2024)

A sustainable bond issuer sovereign can have many reasons to not implement ESG budgeting. Transforming budgetary systems often requires more resources than issuing bonds and the issuance of sustainable bonds does not require changing the budgetary system. Sustainable bond issuances can be part of long-term sustainable finance strategies, however they do not require long-term commitments as strong as the transformation of a central budget. Some sovereigns might not even see the benefit of the implementation of ESG budgeting. Further analysis of the motives for not adopting ESG budgeting is a subject for future research.

3.2. Connecting sustainable bond disclosures to the state budget

Several EU sovereigns connect eligible expenditures to the state budget by using links, hyperlinks and detailed budget descriptions in their sustainable bond disclosures (*Table 3*).

Table 3: Tools used by EU sovereigns to connect eligible expenditures in their sustainable bond disclosures to their state budgets

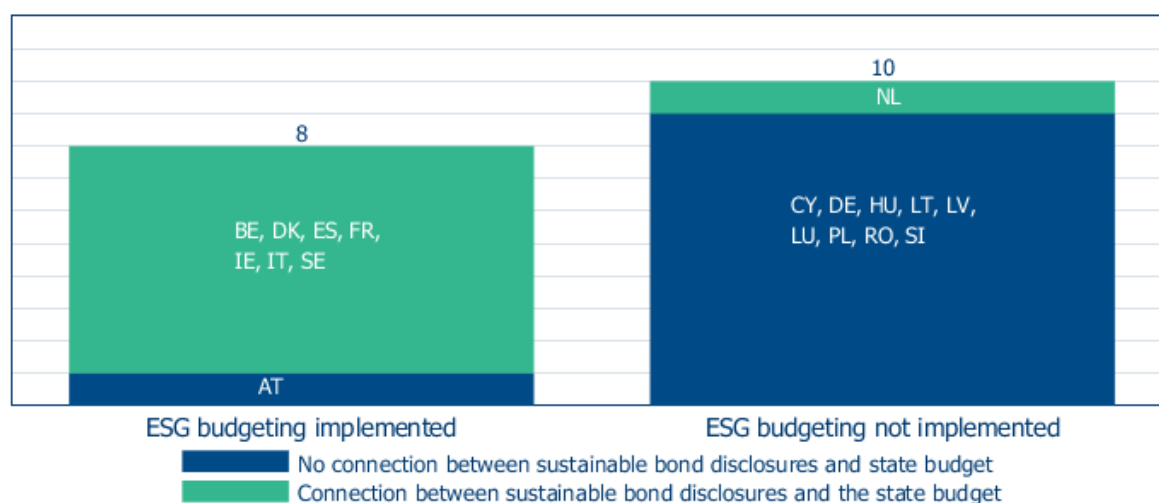
Observed practices	Countries	Use in practice (example)
<i>Hyperlink, links</i> In the sustainable bond disclosure, the country uses hyperlinks and links to redirect the reader to the whole or relevant parts of the state budget financed by the sustainable bond.	BE, DK, NL	In the Kingdom of Denmark Green Bond Framework, under Appendix 1, the country details the eligible expenditures with their appropriation account and hyperlinks. Clicking on the appropriation account, the hyperlink redirects the reader to the online version of the state budget, to the eligible expenditures indicated in the framework (Ministry of Finance, 2021). The Green Bond Allocation Report of Denmark also details the appropriation account under each eligible expenditure and provides references to the state budget (Ministry of Finance, 2023).
<i>Budget descriptions</i> In the sustainable bond disclosure, the country describes the location (in the state budget) of the budgetary item financed by the sustainable bond with detailing its budgetary chapter, budgetary code, appropriation account or number.	ES, FR, IE, IT, SE	In Sweden's green bond investor report 2021, under „Appendix 2: Appropriations in the central government budget” - except for the expenditure „Maintenance of state transport infrastructure, Railways” - the country leaves notes under each eligible expenditure indicating the location of the expenditure in the state budget. For example, under „marina and aquatic environment expenditure”, the report notes that the financed item can be found in Government Bill 2020/21:1 Expenditure area 20, p 101. (Riksgälden Swedish National Debt Office, 2021).

Source: EU sovereigns' budgetary documents and sustainable bond disclosures (2024)

A direct connection between the sustainable bond disclosures and the state budget can be observed in case of eight countries out of the eighteen countries setting up a sustainable bond framework or reporting on the allocation or impact of their sustainable bonds. Out of these eight countries, seven have implemented green, gender or SDG budgeting (BE, DK, ES, FR, IE, IT, SE) (*Figure 3*). Out of the ten countries with no apparent direct connection¹⁰, only one country (AT) is applying ESG budgeting.

¹⁰ For example, no links of the state budget were provided in the sustainable bond disclosures or the presented information was only showcasing the name of the financed budgetary programme without further detailing the code or number of the budget. In these cases, identification of the budgetary items financed by the sustainable bonds was not possible in the state budget due to the lack of details.

Figure 3: Breakdown of EU countries connecting eligible expenditures in their sustainable bond disclosures to their state budgets



Source: EU sovereigns' budgetary documents and sustainable bond disclosures (2024)

Investors buying sovereign sustainable bonds expect sovereigns to present the financing background of their transition to net-zero. Sovereigns with ESG budgeting provide better identification of the budgetary items financed by sustainable bonds by creating a direct link between the sustainable bond disclosures and their state budget. This practice allows investors to easily find these countries' state budget, identify the spending on transition and scrutinise the background of the budgetary items they finance. The greater transparency and additional data can strengthen investor demand for sovereigns' debt instruments; however, the effect of connecting sustainable bond disclosures with state budget can only be confirmed by a comprehensive investor survey.

3.3. ESG budgeting fostering the issuance of sustainable bonds

Sovereigns in the EU applying green, gender or SDG budgeting use several budgetary practices including ex-ante and ex-post analyses, budget tagging (e.g. based on the EU Taxonomy objectives or SDGs), monitoring the impact of budgetary lines by connecting indicators, climate/gender/social related goals or dimensions to the budget, and publishing the budget in an interactive form. Several sovereigns also explain the content of the budgetary lines and the tasks and the goals of the ministries responsible for the execution of the budgetary lines. Other countries provide forecasts for the future allocation and impact of their budget (*Table 4*). In most cases, countries report on the budgetary lines in state budget annexes or in separate documents (e.g. spending review, cross-cutting report).

Table 4: High-level summary of ESG budgeting practices used by the EU sovereigns

Budgeting practice	Use in practice (examples)	Country
Tagging	In the green budget, budget tagging is based on a six-level scorecard system ¹¹ (Bundesministerium Finanzen, 2024a).	AT
	Tagging is based on a scoring system ¹² and on the contribution to 6 environmental objectives inspired by the EU Taxonomy (Ministère de l'Économie, 2024).	FR
Long-term planning, ex-ante or ex-post analyses	The strategy report 2024 to 2027 published in one document with the budget report 2024 provides budget forecast until 2027, indicating the future expenditures on climate and environment (Bundesministerium Finanzen, 2023).	AT
	Under expenditure area 20 “Climate, environment and nature”, the budget bill for 2024 submitted to the government contains ex-ante assessment of proposals ¹³ with a climate effect for future years (Regeringskansliet, 2024).	SE
Additional budgetary information (indicators, goals, tasks etc.)	In the Federal Budget 2024, under area called Climate and Energy, goals are connected to each budget programme including descriptions of their measurements, milestones and several indicators (Bundesministerium Finanzen, 2024b).	AT
	Under the budget chapter called „annual programme plans”, each programme is described in detail with related performance indicators, detailing the expected results, outcomes and actions (Υπουργείο Εθνικής Οικονομίας και Οικονομικών, 2024).	EL
	The green budget report contains several environmental performance data linked to each budgetary mission with objectives, indicators and sub-indicators. France uses some of these indicators in its sustainable bond disclosures ¹⁴ (Agence France Trésor, 2023; Ministère de l'Économie, 2024).	FR
	In the Revised Estimates Volume for the Public Services (REV), output and outcome indicators are connected to the budgetary programmes for presenting their achieved impact and target outturn. The country uses the same indicators both in the impact report of the green bond and in the REV (Irish Government, 2024a and 2024b; Rialtas Na Héireann, 2022).	IE
	The REV contains equality budgeting under each relevant programme, providing disaggregated data on areas like income, health, education	IE

¹¹ Productive (score -2: counter-productivity; score-1: counter-productivity as a side-effect), negative expenditures (score+1: productivity as a side effect; score+2: intended productivity on the environment), budget with no impact (score 0), budget with unclear impact (score 99) and untagged expenditures. Score 1 and Score 2 budgetary lines are considered to be financed by green bonds.

¹² Favourable (score 3, score 2 and score 1), neutral (score 0), unfavourable (score -1) or untagged expenditures

¹³ „+”: is judged to increase emission, „(+)”: judged to worsen the transition, „0”: considered neutral to the environment, „-”: will reduce emission; „(-)”: judged to improve the transition.

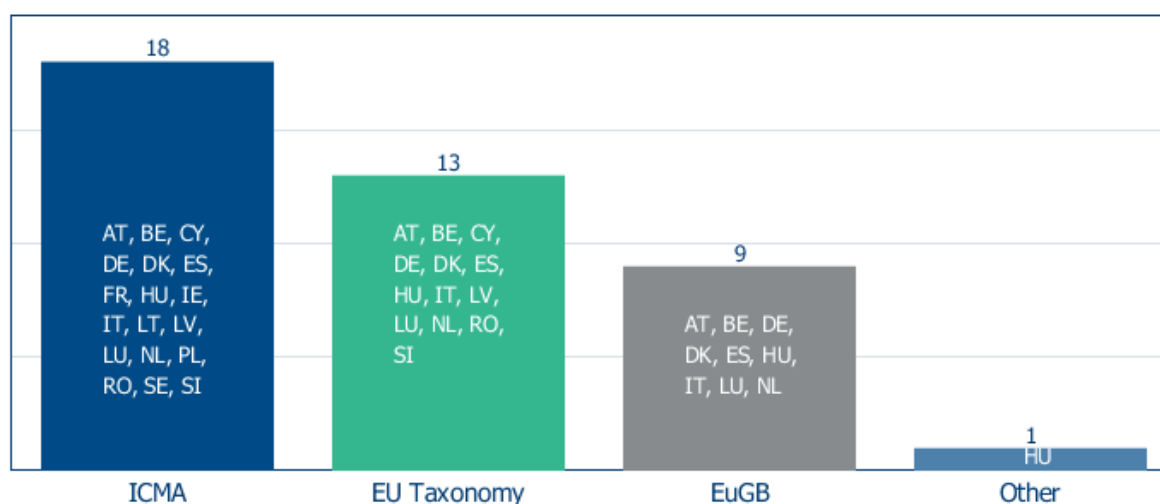
¹⁴ For example the indicator “Share of public forests under management” in France’s green budget under Programme 149 is used in the country’s green bond allocation and impact report with slightly different name „Percentage of forest areas in public ownership (%)”.

Multiple dimensions	and showcasing how the outcomes of these areas differ across gender, age, ethnicity etc. (Irish Government, 2024a and 2024b).	
	In the state budget proposal, information is provided under each main appropriation regarding how gender equality ¹⁵ and sustainable development is taken into account. The proposal also presents several social impact goals ¹⁶ (Valtiovarainministeriö, 2024).	FI
Interactive budget	Green budget data and interactive content is available in an online tool, Datavision (Ministère de l'Économie, 2024).	FR
	PowerBI based online green budget is available (Ministerio de Hacienda, 2024b, Bundesministerium Finanzen, 2024c)	ES, AT

Source: EU sovereigns' budgetary documents and sustainable bond disclosures (2024)

All EU sovereigns issuing sustainable bonds use the ICMA Principles and the majority of them strives to implement the EU Taxonomy regulation and the EUGBS on a best effort base¹⁶ (Figure 4), potentially due to the strict requirement of these regulations.

Figure 4: Principles, guidelines, regulations used by the EU countries for sustainable bond issuance



Source: EU sovereigns' sustainable bond disclosures (2024) Note: Other guidelines include the Japanese Ministry of Environment Green Bond Guidelines (2022 edition) and the China Green Bond Principles (2022 edition)

The use of EUGBS is currently voluntary in the EU but as sustainable market gains momentum and investor demand for sustainable bonds increases, using the EUGBS for EU sovereigns can be obligatory or inevitable in the future.

Different budgetary practices observed in EU countries can contribute to a better alignment with the pre- and post-issuance requirements of the EUGBS (Table 5), as well as ICMA's Principles and foster the issuance of sustainable bonds.

¹⁵ Gender indicators include e.g. the ratio of graduation and unemployed job seekers based on their gender while social impact goals include for example employment rate, and development of traffic safety.

¹⁶ Sovereigns use the following terms in their sustainable bond disclosures when explaining the way they implement the EUGBS and Taxonomy: "compliance with important elements", "align with key elements", "to the extent possible", "where relevant and feasible", "on a best effort basis".

Table 5: ESG budgeting practices used by EU sovereigns fostering alignment with regulations, standards and principles

Requirements	Budgetary practices	Alignment of the budgetary practices with the requirements of the guidelines and principles
Pre-issuance <i>ICMA</i> (e.g. use of proceeds, process for project evaluation and selection) <i>EUGBS</i> (e.g. 85% of proceeds aligned with EU Taxonomy, EUGBS factsheet)	Additional budgetary information	Eligible expenditures are easier to identify if the content of each budgetary programme is explained in the state budget.
	Tagging	Tagging based on e. g. EU taxonomy objectives provides a general overview on the eligible expenditure pool and helps in planning the issuance volumes since the EUGBS requires 85% of the (re)financed activities to be aligned with the EU Taxonomy.
	Long-term budgetary forecast	Prognosis of future allocation and long-term impact of budgetary lines supports the financing of future expenditures with sustainable bonds. Estimated long-term impact and planned allocation are both important information for investors during their investment decision making process.
	Indicators	Indicators already connected to the budgetary programmes in the state budget helps in filling out the EUGBS pre-issuance factsheet which requires the issuer to estimate the impact of the bond before the issuance.
Post-issuance <i>EUGB and ICMA</i> (e.g. Allocation and impact reporting)	Additional budgetary information	Information presented in the state budget under the budgetary programmes (e.g. detailed description, tasks and measures) can be used in the allocation and impact report of the sustainable bonds.
	Indicators	Detailed data on impact is available as ministries are already tracking and monitoring these information for the state budget. Impact indicators can be used in sustainable bond disclosures making reporting less complex, resource-intensive and time-consuming.
	Dimensions	Equality, social or gender dimension of programmes complement the information on how the issuer aims to reduce social risks. In addition, it strengthens alignment with the Minimum Social Safeguards criteria of the EU Taxonomy.
	Interactive budget	It provides higher transparency, visualisation for impact and allocation reporting, making the interpretation of the content of the report easier and more reader-friendly.

Source: EU sovereigns' budgetary documents and sustainable bond disclosures (2024)

4. THE NEXT GENERATION OF SUSTAINABLE BONDS – GREEN BUDGET-LINKED BOND

As sustainable bond market and ESG budgeting is evolving, a next generation of sustainable bonds e.g. the so-called green budget-linked bonds (GBLBs)¹⁷ can be expected to emerge, where the allocation and impact reporting of the bond is in line with the already approved and assessed budget lines.

- Budgetary items financed by GBLBs should be distinguished from other budgetary lines (e.g. by using visualisations and markings in the budgetary chapters).
- The financing intensity of the budgetary lines should be indicated.
- Budget lines financed by GBLBs should be further broken down into sub-programmes and projects to showcase which part of the programme is financed.
- The budget type (e.g. operating or capital expenditure) should be clearly outlined.
- Additional information (including goals and indicators, already achieved results and estimated target values) should be connected to the budget lines financed by GBLBs for the purposes of impact reporting.
- General information about the ministry responsible for the execution of the financed budgetary lines should be provided including information like the overall tasks and operation of the ministry.¹⁸
- Other dimensions, e.g. gender, equality or sustainable development should be implemented to indicate how the budgetary item aligns with other sustainability targets.
- Budgetary lines financed by GBLBs should be summarised in the annex of the budget with their budgetary codes and related indicators, summarizing the most important allocation and impact data.
- As some countries already provide a state budget forecast for future years regarding the allocation and impact, estimated information on the future allocation and impact of the budget items financed by GBLBs could also be indicated in the budget.

The above information would provide an overall picture describing the financing background of the programmes and their comprehensive impact, thus better disclosure on the proceeds of the bonds.

In order to issue GBLBs, sovereigns need to transform their budgetary system. Financing or refinancing budgetary lines with GBLBs increases transparency and simplicity on the sustainable bond market. As the budgetary items (re)financed by GBLBs are properly assessed and reported in the state budget, publishing separate allocation and impact reports could become unnecessary. Additionally, budgetary lines financed by GBLBs and audited within the central budget could lead to simplification on the sustainable bond market¹⁹.

The clear benefit of GBLBs for investors is increased transparency and easier access and understanding of use of proceeds. Higher level of data, transparency and clarity provided on budgetary lines (e.g. their impact, content, goals, different dimensions, projection of future impact and allocation) can serve as a base for better ESG country assessment and mitigation of potential ESG risks. Thus, GBLBs can reduce the possibility of greenwashing, foster the positive perception of sovereigns and

¹⁷ Any sustainable bond (e.g. green, social, gender, SDG, transition) could be directly linked to the budget items. In this paper we only focus on green budget-linked bonds as an example for simplicity.

¹⁸ Thus, investors would get an insight into the general operation of the government departments and understand how sustainability is supported.

¹⁹ This practice would also align with the EUGBS, as the regulation entitles state auditors to review the allocation of the bond proceeds.

attract a higher investor demand. GBLBs have the potential for a tangible greenium on the sustainable bond market.

Investors buying GBLBs could benefit from a better risk-adjusted return over the long-term, while issuers would be able to finance their transition with lower funding costs.

5. CONCLUSION

The EU and its member states are taking action in mitigating global issues through fostering climate and gender mainstreaming, which might include the transformation of state budget to ESG budgeting (green, gender and SDG budgeting) and raising capital to finance budgetary lines through the issuance of sustainable bonds (green, social, sustainability, sustainability-linked and transition bonds). ESG budgeting and sustainable bonds have the same objectives (e.g. better identification of the budgetary items based on different perspectives, financing sustainable goals and enhanced transparency of budget spending), and thus combining them and exploiting the potential synergies can be beneficial for both the issuer and the investors.

Approximately one third of the EU sovereigns have implemented performance-based budgeting from the perspectives of climate, gender or SDG, while approximately two thirds of the EU sovereigns have set up a green or sustainability bond framework or issued at least one green or sustainability bond. A sustainable bond issuer sovereign can have many reasons not to implement ESG budgeting including the lack of sufficient resources, the complexity and clear benefit of its implementation, the long-term engagement it requires.

On the sustainable bond market, investors expect issuers to report on the use of the proceeds of the bonds and are also increasingly interested in the overall financing background of the country. Connecting the sustainable bond disclosures with state budgets can provide investors with comprehensive budgetary information. Several EU countries connect eligible expenditures to the state budget by using links, hyperlinks and detailed budget descriptions in their sustainable bond disclosures. Sovereigns with ESG budgeting provide better identification of budgetary items financed by sustainable bonds as they link sustainable bond disclosures with their state budget. This practice provides a greater transparency on the sovereign's transition and can potentially elevate investor demand for sovereigns' debt instruments.

EU sovereigns use ICMA Principles as a base for their sustainable bond issuances and at the same time apply the EU Taxonomy and EUGBS on best effort basis. Sovereigns issuing sustainable bonds need to comply with the expectations of the investors and with the requirements of the sustainable bond guidelines, regulations and principles. ESG budgeting practices including budget tagging based on EU Taxonomy, monitoring of budgetary items with indicators, planning the future budget allocation and impact, integrating gender, social and sustainable development dimension in the budget, all contribute to the alignment with best market practices on the sustainable bond market, fostering the issuance of sustainable bonds. These practices support the identification of eligible budgetary items for (re)financing. Reporting on the allocation and impact becomes less complex, because adequate information of the budgetary programs is provided in the state budget, and can be used in sustainable bond reports.

As ESG budgeting and sustainable bonds both complement and strengthen each other in terms of providing additional data and transparency on the budget spending, with the further development of ESG budgeting and sustainable bond market, the next generation of sustainable bond instruments can be expected to emerge, e.g. the green budget-linked bonds – GBLBs. The issuance of GBLBs would

be in line with the already approved state budget and separate allocation and impact reports could become unnecessary. Sovereigns would have to transform their budgetary system in order to issue GBLBs as it would require the use of visualizations in the state budget and a detailed breakdown of the budgetary lines (e.g. describing their objectives, goals, context, and the monitoring of indicators connected to the budget). However, a clear benefit of GBLBs for issuers would be the simplification and improvement of sustainable bond disclosures. GBLBs would enable assessing the overall budget spending on transition. Due to the higher level of transparency, GBLBs could offer risk mitigation for investors, potentially leading to increased demand and perhaps to a tangible greenium on the sustainable bond market. This would also allow issuers to raise capital at a lower cost for their transition.

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Mobilizing Private Finance for the Climate Agenda: Introducing Sustainability-Linked Intermediated Debt Instruments (SLIDIs) *

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Abstract

We propose a scalable solution to the twin challenges of reducing developing countries' cost of borrowing whilst incentivizing their governments to achieve progress in agreed environmental, social, and governance (ESG) dimensions. We propose a set of 'sustainability-linked intermediated debt instruments' (SLIDIs; informally 'KPI-linked lending') designed to address the limitations of existing sustainability-linked bonds (SLBs), which have seen a decline in annual issuance since peaking in 2021.

We describe two approaches to construct SLIDIs. The first approach entails a sovereign bond that includes results-based payments from the World Bank or another fund to the issuing government, contingent upon the achievement of specific outcomes, or key performance indicators (KPIs). In the alternative recommended approach, an intermediary sustainable lending fund, supported by a voluntary coalition of advanced economies, issues bonds at a fixed coupon rate. Due to the de-risking nature of these bonds, they are offered at lower coupon rates. The money raised is then on-lent to developing-country sovereigns at a higher interest rate, via SLLs. If after several years, the developing country borrower has met specific ESG goals, as measured via KPIs specified in their SLL terms, then a significant portion of the interest that has been paid by the borrower since the beginning of the loan term is refunded to the borrower.

Developing countries' efforts to meet the KPIs can be assisted by development agencies, which also monitor and verify performance. Development agencies and/or developed country partners can also offer guarantee products that would reduce country-issuer risk, and thus the coupon payments needed to attract private investors. The net effect is to incentivize and reward developing countries for progress on agreed ESG goals

* Please note: these remarks are made in a personal capacity and do not represent the views of any institutions the authors are affiliated to.

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ABBREVIATIONS

AFD: French Agency for Development

AfDB: African Development Bank

ESG: Environmental, Social and Governance

GHG: Greenhouse Gas

GiZ: German Corporation for International Cooperation

IDB: Inter-American Development Bank

KPIs: Key Performance Indicators

MLDB: Multilateral Development Bank

MLFIs: Multilateral Financial Institutions

NZE: Net Zero Emissions

OECD: Organization for Economic Co-operation and Development

SDGs: Sustainable Development Goals

SLBs: Sustainability-Linked Bonds

SLIDIs: Sustainability-Linked Intermediated Debt Instruments

SLLs: Sustainability-Linked Loans

SPV: Special-Purpose Vehicle

WB: World Bank

SUMMARY OF INSTRUMENT

This paper introduces innovative financial mechanisms designed to attract private sector capital to developing countries for sustainable development purposes, including (but not limited to) the climate adaptation, biodiversity conservation, and clean infrastructure development agendas. By involving trusted intermediaries in the process of arranging, de-risking, issuing, and monitoring sustainability-linked debt, our proposed system of ‘sustainability-linked intermediated debt instruments’ addresses critical shortcomings of existing SLBs by offering more effective structures for incentivizing sustainable policies and mobilizing investments, particularly in developing countries where climate finance is most urgently needed.

The IEA (2023) estimates that closing the clean infrastructure investment gap in developing countries, essential for reaching global NZE by mid-century, will require \$2 trillion annually. Globally, total investments will need to reach approximately \$5 trillion per year starting in 2030. Due to currency risk and other country risks, institutional investors are often unwilling to invest in developing countries, or demand punitively high interest rates to do so.

Like SLBs, SLIDIs provide reduced interest rates or interest payment rebates to governments (or other borrowing entities) that achieve targets defined by agreed sustainability-linked KPIs. However, unlike SLBs, our proposed SLIDI system would raise money by issuing bonds with fixed coupon payments to investors (e.g., industrialized-world pension funds or other institutional investors), avoiding the rate-of-return uncertainty posed by existing SLBs. A rebate would be paid to borrowers that achieve KPI targets – but that rebate would not be paid by bond investors. Guarantee products (including co-lending of the private sector and the development partner) would further decrease country risk and the cost of borrowing by developing countries.

Within that frame, we outline two alternative implementation models for sustainable development financing featuring KPI-linked variable interest rates. In the first model, developing country sovereigns directly issue fixed-coupon KPI-linked bonds at normal market rates; institutional investors that buy these are not exposed to any step-ups or step-downs. Interest payment rebates are paid out when the KPI-linked bond matures if the KPIs have been met, but the rebates aren’t paid by bondholders.

The rebate payments are made by a third party. This could be the WB Results-Based-Payment, or a donor-country-supported trust fund managed by a development bank to reward developing-country bond issuers who have performed well according to agreed KPIs. The involvement of official development partners in the operation can create a ‘halo effect,’ decreasing the coupon payments required by the private sector. Different degrees of official development partner involvement in the operation would alter the extent of this effect.

To achieve sufficiently strong incentives for good KPI performance and a high volume of SLIDI lending, the aggregate financial subsidies offered by the trust fund (and hence the donations collected from developed-country sovereign donors) would need to be very substantial, e.g., at least tens of billions of dollars per year if the overall portfolio is to reach \$2 trillion per year. A possible original source of money for these rebates could be levies on bulk fossil fuel sales in participating wealthy donor countries. In this model, it could be helpful if a trust fund managed by the WB or another MLFI makes a practice of buying a small fraction, e.g., 1%, of each such bond issuance, provided the bond issuance has been accompanied and endorsed by trusted development-agency partners, to signal to issuing sovereigns that these bonds are to be considered as senior debt and to reassure bond markets, thus producing a strong ‘halo effect’.

The other SLIDI implementation model proposes a donor-country-derisked ‘trusted intermediary’ (which could also potentially be managed by the WB or another development bank) to raise money from institutional investors at low interest rates by issuing fixed-coupon climate bonds. The bonds issued by the trusted intermediary fund are de-risked via co-guarantees from a coalition of willing developed-country sovereigns. The intermediary fund subsequently on-lends the money it has raised to public or private borrowers in developing countries at somewhat higher interest rates. This on-lending takes the form of SLLs whose nominal rate is fixed over the loan term. Trusted development-agency partners, e.g., Germany’s GiZ or France’s AFD, will monitor progress, provide ongoing technical advice, and evaluate whether borrowers meet or exceed specified KPIs. If the assessment performed at the bond maturity date (or, for long-duration bonds, at predefined milestone years over the course of the bond’s term) shows KPIs have been met, the borrower is rewarded by a partial refund of interest previously paid.

The trusted-intermediary-fund model enables a significant spread between the fund’s cost of money and the interest rates on loans charged by that fund to developing-country borrowers. With this approach, the intermediary fund should be financially self-sustaining. Developed-country sovereigns would co-guarantee the fund’s bond issuances and thus be at risk of absorbing losses, but thanks to the spread, barring miscalculations or global crises, the portfolio of loans made by the fund should turn a modest profit. The fund would essentially be a specialized development bank. The fund’s ability to issue bonds with low coupon rates (because the bonds are co-guaranteed by wealthy developed-country sovereigns) should enable a lower overall cost of finance through this approach compared to a model in which bonds are issued directly by developing-country sovereigns.

This paper shows how sustainability-linked intermediated debt instruments can align the interests of sovereigns, private investors, and development partners toward an acceleration of the global transition to a NZE economy and improved performance on biodiversity conservation, as well as other sustainable development indicators identified in the UN SDGs. We note some of the challenges hindering private sector investment in sustainable development initiatives in developing countries, such as the ‘tragedy of the commons,’ geopolitical conflicts, and high interest rates driven by perceived country risk. We discuss the prospective roles of development agency partners like Germany’s GiZ or France’s AFD in making the SLIDI system work in practical terms – by structuring climate and clean development financing via sustainability-linked intermediated debt instruments; monitoring and evaluating client country KPIs; and assisting developing-country partners with the technical steps necessary for success in meeting agreed KPIs. KPI-linked lending via SLIDIs is presented as a potentially scalable and practical solution for bridging the enormous investment gap in global climate mitigation and adaptation finance, especially in developing countries.

1. INTRODUCTION

The transition to a global NZE economy by 2050 requires substantial investment, particularly in developing countries, where the capital required for decarbonization is very large and access to affordable finance is limited. Achieving this transition is both a technical and financial challenge, with the need for approximately \$5 trillion a year in global investment by 2030, of which \$2 trillion in developing countries alone (IEA, 2023; IMF, 2023), a fivefold increase compared to 2020. This requires policy action at a national level, including

policies that enable and provide investable projects at scale. Present financing mechanisms do not sufficiently encourage such policy actions.

Current financing mechanisms are inadequate, relying heavily on multilateral development bank (MDB) finance but failing to provide sufficient incentives for countries to implement necessary policy changes. A WB analysis (World Bank, 2023) projects that growth in public investment will be limited, and that the private sector will need to supply about 80 percent of the required climate-related investment in emerging market and developing economies; this share rises to 90 percent when China is excluded. However, private investors that control most of the available investible funds, such as pension funds or private equity funds in developed countries, are generally disinclined to invest in developing countries, due to perceived country risks and foreign exchange risks (Chowdhury & Tadjoeeddin, 2022).

The gap between the level of financing needed and what is available underscores the urgency for innovative financial instruments that can mobilize private sector capital at scale and support green development policies. Meanwhile, hundreds of billions of dollars in direct financial subsidies for fossil fuels and harmful agricultural practices and trillions in implicit subsidies (amounts calculated when the harm done is accounted for) continue to exacerbate the problem (World Bank, June 2023).

The existing flow of private and public climate finance from developed to developing countries is insufficient in scale and efficacy in incentivizing provision of global public goods. Despite international commitments such as the \$100 billion annual pledge (an amount far below what is needed in aggregate) made in Copenhagen in 2009 at UNFCCC's 15th Conference of the Parties (CoP15) and reaffirmed in Paris in 2015 at CoP21, the actual flow of climate-related funds from developed into developing countries, tracked by the OECD, has been far lower (an estimated \$34 bn in 2022) (OECD, 2024a).

There is a pressing need for financial instruments that can bridge this gap, mobilize additional resources, and incentivize and enable the implementation of effective climate policies. Developing countries are often the most vulnerable to climate change but least able to finance the necessary infrastructure transitions. (Bhattacharya et al., 2023.)

In recent years, since the late 2010s, SLBs have emerged as a new instrument intended to help close the climate and clean development financing gap (Giráldez and Fontana, 2022). SLBs differ from other green, social, and sustainability (GSS) bonds in that most GSS bonds are use-of-proceeds (UoP) debt instruments that are tied to specific projects. In contrast, SLBs specify sustainability-related targets and key performance indicators (KPIs) for the issuing entity (corporation or sovereign) without reference to a specific project, so they are not considered to be use-of-proceeds instruments (OECD, 2024b). To date, only a handful of SLBs have been issued by sovereigns; most issuances have been by industrialized-world corporations, though interest is growing in the potential for sovereign sustainability-linked bond issuances (Maplecroft, 2024).

This paper is concerned with sustainability-linked finance for developing-country sovereigns. However, the same instruments we describe here (SLIDIs) could be adapted for bonds issued by sub-national governments such as municipalities or individual provinces or states within federations, or in modified form, also by state-owned or private corporations in developing countries.

After early excitement, interest in SLBs has been waning over the past three years. After a peak in issuance volumes in 2021, the global market for SLBs (most of them issued by corporations) shrank for two consecutive years, 2022 and 2023, and again during the first half of 2024 (Ahren, 2024). SLBs have

struggled to gain traction due to their complexity, concerns around potential greenwashing, and the unattractive nature of unpredictable variable coupon payments (Lefournier, 2023). It appears that both issuers and investors are increasingly assessing that the current generation of SLBs is not fit-for-purpose.

The sustainability-linked intermediated debt instruments (SLIDIs) we present here comprise a suite of financial instruments specifically designed to attract private institutional investors to the sustainable development agenda in emerging and developing economies. Unlike existing SLBs, which link interest rates paid to bondholders to the issuer's achievement of sustainability targets by means of variable coupon payments ('step-ups' or 'step-downs') depending on whether or not target KPIs were met, SLIDI-type SLIDIs as we define them in this paper offer fixed-coupon returns to investors, removing a key uncertainty factor in rate-of-return, making the bonds less complex and more attractive to investors.

This paper introduces a modified form of sustainability-linked debt instrument whose coupon does not vary from the perspective of the bond investor, regardless of whether the issuer meets target KPIs or not. However, from the perspective of the borrower, the loan rate *does* vary depending on the borrower's performance in terms of meeting sustainability-linked KPI targets. This asymmetry is enabled by intermediary institutions: trusted and well-resourced third parties that offer technical assistance and financial rewards for meeting the KPI targets.

Before explaining in detail the workings of our proposed intermediated sustainability-linked debt instruments, we briefly provide an overview of the key challenges to attracting private capital to the climate challenge, the current menu of sustainability-linked financial instruments, and the issues with those instruments.

2. KEY CHALLENGES IN INTERNATIONAL FINANCE FOR THE CLIMATE AGENDA

2.1. The 'Tragedy of the Commons'

One key challenge in attracting private sector capital to climate initiatives is the "tragedy of the commons" dilemma, where private agents fail to internalize the broader impact of their investment decisions on common goods – e.g., global climate outcomes. This tragedy can be seen to exist on two levels: private sector agents have little or no incentive to internalize the climate externality, and countries' governments have insufficient incentive to set the right incentives for private sector agents.

Sustainability-linked finance instruments could help address the Tragedy of the Commons. SLBs and improvements on them, such as the SLIDIs described in this paper, have promise because they can act at the international level to incentivize governments to do what is in the interest of conserving or delivering global public goods.

2.2. Fiduciary Responsibility and the 'Tragedy of the Horizons'

Another challenge is short-termism in financial markets, sometimes known as the 'Tragedy of the Horizons'. Fiduciary responsibilities to shareholders compel money managers to prioritize short-term asset profitability over long-term environmental, social, and governance benefits.

The result is a persistent underinvestment in climate-related projects, as their immediate financial returns are often perceived as likely to be lower compared to other investment opportunities. This misalignment between individual and collective interests is a major barrier to mobilizing private finance for the climate agenda. Overcoming the misalignment requires financial instruments that align investor incentives with broader environmental and climate goals.

2.3. High Debt Levels and Low Fiscal Space in Developing Countries

High debt levels and limited fiscal space in developing countries present additional challenges to investing in climate-related initiatives. Developing countries face a dual burden: the need to service existing debt while also financing the costly transition to a low-carbon economy. That transition will reduce the long-run operating costs of the energy system by shifting to renewable energy and so eliminating fuel costs. But this requires major front-loaded capital investment (McKinsey Global Institute, 2022). This situation limits developing countries' ability to leverage traditional debt instruments. International financial institutions have a major role to play in overcoming these problems (McGeady & Baskaran, CSIS, 2023).

2.4. Geopolitical Conflicts and Competitive Dynamics

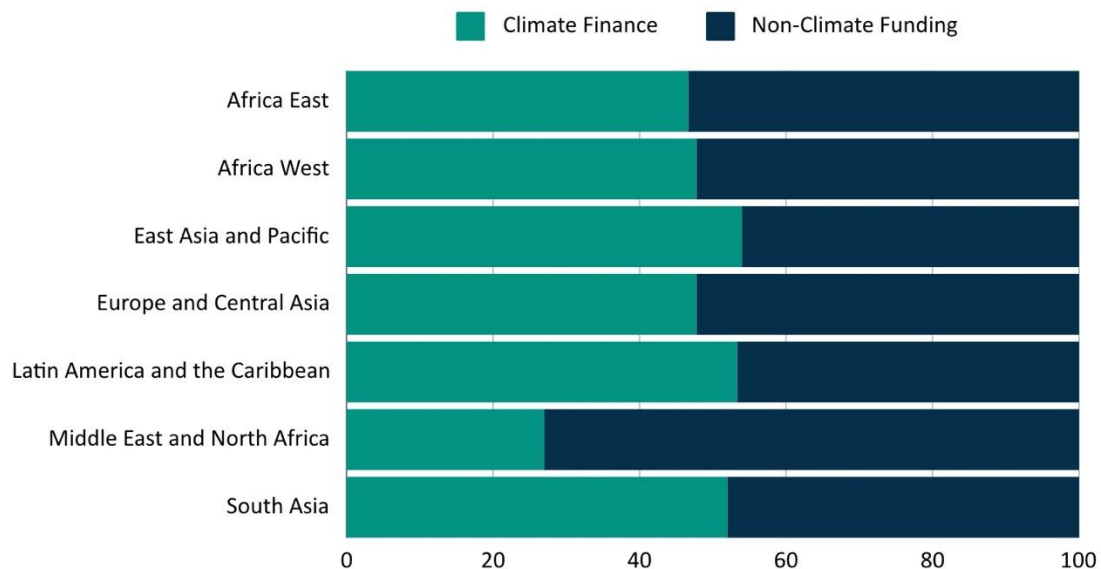
Geopolitical conflicts and competitive dynamics among governments further complicate the mobilization of private sector capital for climate finance (Hurrell, 2024). These tensions result in a reluctance to commit to global climate goals, particularly where political instability or international rivalry undermines cooperative efforts. In developing countries, where the cost of capital is already high due to forex and other country risks, geopolitical factors can exacerbate the challenges of financing climate-related infrastructure projects. The lack of coordination and trust between nations also hinders the flow of private capital into climate finance, making it more difficult to achieve the scale of investment needed for meaningful climate action. See Diwan et al. (2024) for a recent proposed deal that acknowledges the collective action problem of new lenders bailing out old ones and links a plausible solution to meaningful climate action.

2.5. The Necessity of Additional and Improved Climate Finance

Given the scale of the climate challenge, additional financing beyond standard development needs will be essential. Climate mitigation and adaptation efforts require a scale of financial resources that current financial instruments and mechanisms cannot fully provide (McGeady & Baskaran, CSIS, 2023; McKinsey, 2023). Although the majority of funding must come from the private sector, achieving this requires effective mobilization and appropriate incentives from institutions like MDBs and MLFIs.

The World Bank is well positioned to reassure investors and unlock private capital for climate finance due to its preferred creditor status. Having steadily increased over the past five years, the World Bank aims to raise its climate funding to 45% of total lending in the upcoming financial year (FY25). However, the current climate finance architecture often discourages effective climate policy. Therefore, innovative mechanisms are needed, alongside additional financing, that address the significant fiscal responsibilities faced by developing countries while ensuring robust climate action.

Figure 1: World bank regional lending FY24.



Source: World Bank (2024).

3. CURRENT SUSTAINABILITY-RELEVANT FINANCIAL INSTRUMENTS AND THEIR LIMITATIONS

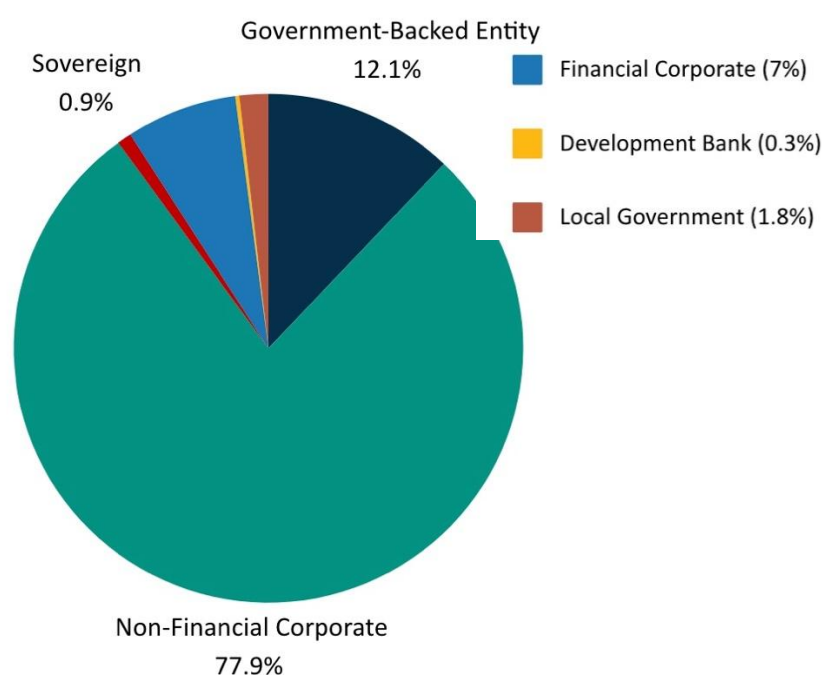
Several financial instruments are currently used to mobilize capital for climate finance, each with strengths and limitations.

Green bonds are defined as Use of Proceeds bonds that raise money for specific ‘green’ projects (‘green’ according to a taxonomy such as the EU’s Taxonomy for Sustainable Activities). Examples include renewable energy installations, energy efficiency upgrades, ‘green’ steelmaking projects, or ecotourism developments. Green bonds have succeeded in raising money for many projects. (Climate Bonds Initiative maintains a database of green bonds and projects linked to them.) However, green bonds lack the scope to address broader national- or regional-scale sustainability goals (Bouzidi and Papaioannou, 2021), and they face the problem of investor reluctance to accept country risks in developing-country contexts.

Green bonds cannot, by themselves, ensure a country’s transition to sustainability. A bond’s meeting the criteria of a ‘green’ taxonomy does not guarantee that a country’s overall investment volume in ‘green’ infrastructure is sufficient, nor does issuance of green bonds ensure ‘green’ sustainable development policies are in place, nor that desired outcomes (such as forest protection and biodiversity conservation) result at a national or regional scale.

Sovereign sustainability-linked bonds could, in principle, incentivize a country's national transition to sustainable development. In contrast to green bonds, sovereign SLBs are not project-specific; they can specify national-scale outcomes as their target KPIs, driven by changes at the overall national policy level. Horrocks *et al.* (OECD, 2024b) explored ways of applying SLBs to developing-world sovereign debt (as distinct from the more common use case of industrialized-world corporate debt) in their paper "Sustainability-linked bonds: How to make them work for developing countries, and how donors can help". To date, sovereign SLB issuances have been minimal, accounting for only 0.9% of the total issued (see Figure 1). Sovereign SLB transactions have included Uruguay's Sovereign Sustainability-Linked Bond (Uruguay, 2022), issued with Inter-American Development Bank support.

Figure 2.: Issuers of SLBs.



Source: Climate Bonds Initiative (2024)

Sustainability-linked bonds, SLBs, have significant potential, but in their current form, they face several challenges that limit their effectiveness as a tool for mobilizing private capital at the scale required for global sustainability transitions. SLBs link coupon payments to the achievement of sustainability-related KPIs, with mechanisms such as step-downs for meeting targets and step-ups for missing them. The complexity of these instruments, particularly the variable coupon structures, has been a deterrent for investors, who often prefer more straightforward financial products (Kölbel and Lambillon, 2022; Lefournier, 2023). Issuers may be compelled to accept higher coupons at issuance, while many investors might be unwilling or unable to accommodate a step-down due to their fiduciary duties. Additionally, the Climate Bonds Initiative (2024) emphasizes that the financial mechanisms should be substantial; as a result, the current average step-up of 25 basis points may be inadequate to incentivize meaningful progress.

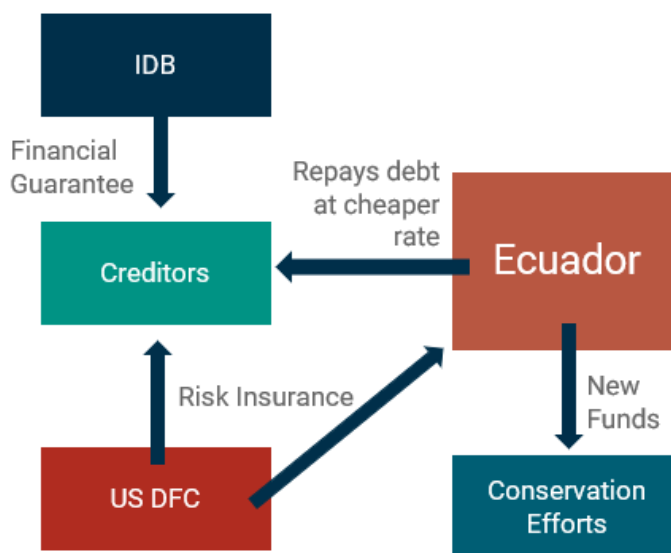
Moreover, the risk of greenwashing—where issuers set easily achievable or vague KPIs—undermines the credibility of SLBs and diminishes their appeal to investors concerned about the genuine impact of their investments. The current SLB market is heavily populated with low-quality deals that fall short on ambition and credibility, hindering scalability (Climate Bonds Initiative, 2024).

Similarly, SLLs tie lending terms to the achievement of specific KPIs, providing more favorable conditions as sustainability goals are met. For example, a World Bank loan issued to Uruguay in 2023 included step-down sustainability-linked provisions, highlighting the potential of this approach (World Bank, 2023). While SLLs show promise, they remain in the early stages of development and require further refinement for widespread adoption (Silva, 2021). Additionally, they may carry a higher risk of greenwashing than SLBs due to inadequate disclosures and weak target credibility (Climate Bonds Initiative, 2024). The challenge is to improve, adapt, and scale this model across a broader range of countries and projects, as proposed in this paper.

Debt-for-X Swaps involve exchanging debt for commitments to some specific outcome(s) 'X', e.g., nature conservation or energy efficiency improvements, providing a direct link between debt relief and environmental outcomes. While offering a diverse array of use cases and having been effective in some cases (Cassimon & Essers, 2013), such swaps tend to be limited in scope and scale, making them insufficient to address the broader financing needs for global climate action. They are also typically complex to negotiate and implement, limiting their applicability.

One recent example of a Debt-for-Nature swap involving guarantees is the 2023 transaction in Ecuador. The transaction included an \$85million IDB guarantee and \$656 million DFC political risk insurance and was estimated to generate savings of \$323 million to finance conservation activities in the Galapagos islands. It is notable for the use of guarantees, which can be a very cost-effective method to generate interest savings.

Figure 3.: Debt-for-nature swap in Ecuador



4. SLIDIS: CONCEPT AND IMPLEMENTATION

4.1. Concept

SLIDIs offer a novel approach by providing fixed coupon payments to investors, separating private sector returns from sovereign incentives. The SLIDI structure, explained in detail below, de-links bond buyer returns from sustainability outcomes, instead tying development partner co-lending to KPI achievement. By aligning the interests of sovereigns, private investors, and development partners, SLIDIs create a more predictable and stable return for investors, while ensuring that the financing is directed toward meaningful climate outcomes. This model addresses the shortcomings of existing SLBs by offering a simpler and more transparent mechanism for linking financial returns to sustainability achievements.

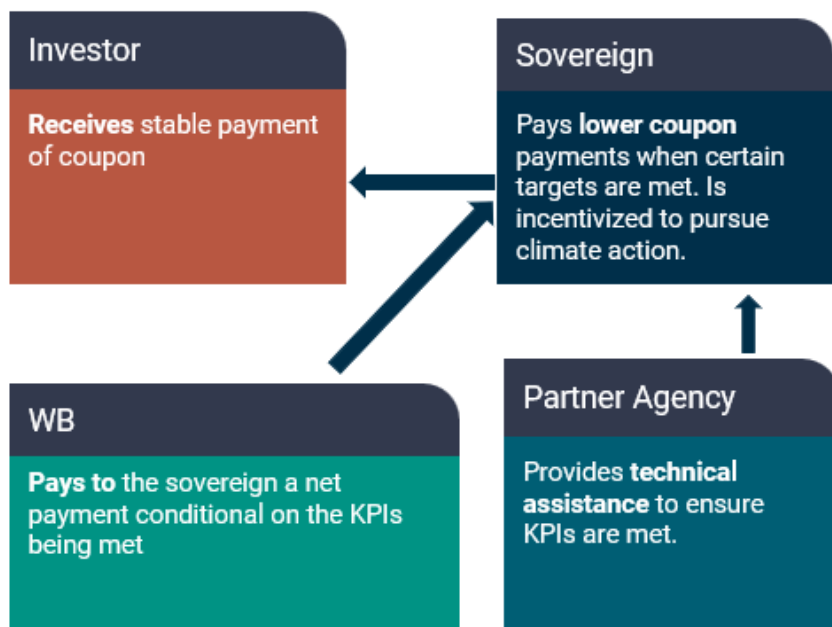
SLIDIs also could reduce the cost of capital. The high cost of capital in developing countries is a major barrier to scaling up financing of renewable energy and other climate-related infrastructure projects. This challenge is driven by the perceived risks associated with investing in these regions. SLIDIs address this issue by incorporating de-risking mechanisms, such as financial guarantees and collateralization, that lower the overall cost of capital for these projects. By leveraging the credibility of multilateral development banks (MDBs) and other development partners, SLIDIs can reduce the risk premium associated with sustainable infrastructure investments in developing countries, making them more attractive to private investors. This cost efficiency is critical for enabling the large-scale deployment of renewable energy and other climate-related projects in developing countries.

In the next sections, we outline two main implementation models for SLIDIs: side payments and trusted intermediaries.

4.2. Option 1: Development Bank/Trust Fund Side Payments

One proposed model for implementing SLIDIs involves side payments managed by the WB or other MLFIs. Under this model, a special-purpose fund disburses subsidies to sovereigns upon their achieving KPI targets previously specified in approved sustainability-linked bonds which those sovereigns have issued directly to financial markets. This reduces the issuing sovereigns' financial burden and incentivizes and rewards progress on agreed sustainability priorities, e.g., climate action. These subsidies could be funded by a trust fund managed by the WB or another MLFI, with funds contributed by highly developed countries or carbon markets. Bond payments could be tied to both KPI achievement and contingent on a high level of private sector participation in bond purchases. This approach provides a direct financial incentive for governments to meet their climate targets, whilst ensuring that investors receive a stable return. Bond buyers are not exposed to any 'step-up' or 'step-down' in the coupon rate; their coupon rate is fixed.

Figure 4: Side payment options for SLIDIs

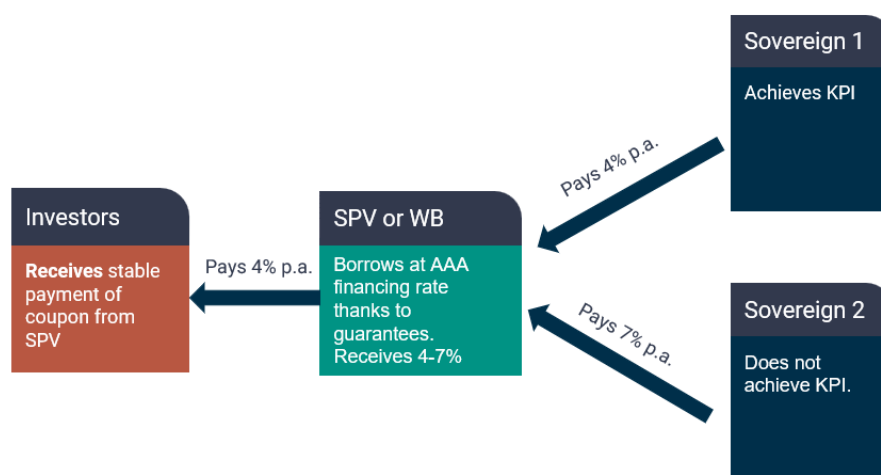


4.3. Option 2: Trusted Intermediary

Another implementation model involves using a trusted intermediary institution to raise money in bond markets through fixed-coupon de-risked sustainable development bonds and then on-lend it to developing-country sovereigns via SLLs. The intermediary also manages disbursements of rewards to sovereign borrowers, contingent on verified achievement of target KPIs specified in those SLLs. This model enhances

investor confidence by maintaining a low-risk rating and a fixed coupon rate for the bonds, broadening the appeal of SLIDIs to a wider range of private investors. By acting as a neutral third party, the intermediary institution ('SPV or WB', in Figure 3 below) ensures transparency and accountability in the issuance and management of the bonds and the measuring, reporting, and verification (MRV) of the performance of developing-country sovereigns in meeting sustainability-linked target KPIs. The intermediary institution would likely partner with leading international development agencies like Germany's GiZ or France's AFD for purposes of MRV of target KPIs, and for technical assistance to developing countries in meeting KPIs.

Figure 5.: Trusted intermediary option for SLIDIs (Example)



A donor-country-derisked 'trusted intermediary,' such as a special purpose vehicle managed by the WB or another MLDB, can raise money from institutional investors at low interest rates by issuing fixed-coupon sustainable development bonds or climate bonds backed (guaranteed and de-risked) by a coalition of willing highly developed country sovereigns.

The intermediary fund subsequently on-lends the money it has raised to public or private borrowers in developing countries at somewhat higher interest rates. This on-lending takes the form of SLLs whose nominal rate is fixed over the loan term. Trusted development-agency partners, e.g., Germany's GiZ or France's AFD, monitor progress, provide ongoing technical advice, and evaluate whether borrowers meet or exceed specified KPIs. If the assessment performed at the bond maturity date (or, for long-duration bonds, at predefined milestone years over the course of the bond's term) shows KPIs have been met, the borrower is rewarded by a partial refund of interest previously paid.

The trusted-intermediary-fund model enables a significant spread between the fund's cost of money and the interest rates on loans charged by that fund to developing-country borrowers. With this approach, the intermediary fund should be financially self-sustaining. Developed-country sovereigns would co-guarantee the fund's bond issuances and thus be at risk of absorbing losses, but thanks to the spread, barring miscalculations or global crises, the portfolio of loans made by the intermediary fund should turn a modest profit. The intermediary fund would operate as a specialized development bank. By issuing bonds with low coupon rates—thanks to co-guarantees from wealthy developed-country sovereigns—it could offer

developing-country sovereigns a lower overall cost of financing compared to a model where these countries issue bonds independently.

Lending intermediaries such as regional development banks already reduce credit risk and help developing countries overcome debt sustainability constraints by providing an additional layer of risk management. Such intermediaries can facilitate the flow of funds and ensure that sustainability-linked bonds and loans are structured in a way that maximizes their impact (Bouzidi and Papaioannou, 2021). The involvement of lending intermediaries likewise enhances the scalability of SLIDIs, making them a viable option for a broad range of countries and projects.

4.4. Advantages of SLIDIs

SLIDIs offer a pathway to mobilize additional resources by aligning the interests of developing-country governments with the achievement of specific climate and sustainable development goals. This alignment is achieved by tying financial rewards to the successful implementation of target KPIs, thereby creating a clear incentive for both public and private sector participation in specified sustainable development and climate-related investments. By bridging the gap between needed and available resources, SLIDIs can play a critical role in advancing global climate goals.

The introduction of climate-KPI-linked SLIDIs, which offer fixed returns and are backed by robust de-risking mechanisms, provides a potential solution to the challenge of attracting private capital for climate finance in developing countries while managing country risk. By reducing perceived financial risk and offering predictable returns, climate-related SLIDIs backed by highly developed sovereigns can help alleviate the financial constraints faced by developing countries, including in relation to the development of non-fossil energy infrastructure.

5. RISK MANAGEMENT

5.1. Managing Bond Payment Default Risks

Each implementation model must account for the risk of default, assessing whether the structure reduces the likelihood of default and how investors can be protected. SLIDIs, by design, incorporate de-risking mechanisms that align the interests of all stakeholders, thereby minimizing the risk of default on bonds and providing incentives for meeting agreed sustainability-linked target KPIs. These de-risking mechanisms, i.e., financial guarantees and collateralization, provide a safety net for investors and enhance the credibility of SLIDIs, making them a viable option for mobilizing private capital in developing countries. The next section explores an additional de-risking mechanism: participation of institutions like the WB or other development banks which have preferred creditor status in buying approved bonds issued under a SLIDI program.

5.2. Purchasing Bonds

A risk of harm to the relationship between an official development partner and a borrowing developing-country sovereign, consequent to defaults on approved SLIDI bonds, can serve as a further de-risking mechanism and make such SLBs more attractive to private sector investors. For example, the WB or another development partner with preferred creditor status could purchase a small portion of an approved sustainability-linked sovereign bond issuance, effectively positioning the bond issuance as super-senior debt. This approach could tie defaults on *any* bond in the sovereign's approved SLIDI program SLB issuance, including bonds sold to private sector investors, to defaults against the participating official development partner. In case of defaults on payments on such bonds, the borrowing country would forego MLDB funding for other projects, MLDB technical assistance, and other forms of support provided by the development partner. The bond amounts bought by the participating MLDB can be very small, in essence 'symbolic,' and, thus, would not represent a real threat to its balance sheet and credit rating, even as the arrangement would be seen as presenting a credible threat of serious consequences to the borrowing country in case it defaults on the bond. This should be seen as a strong de-risking measure or implicit credit guarantee by private investors.

In this model, a preferred creditor such as the WB purchases a small proportion of the SLIDI program approved sustainability-linked bonds issued by a developing-country sovereign, creating a 'halo' effect that discourages sovereign default on these bonds. The involvement of the WB or some other multilateral development bank provides a strong signal to the market, enhancing the credibility of the bonds and making them more attractive to private investors. This approach also allows the development bank and affiliated development agencies to directly influence the achievement of KPIs by providing technical assistance and monitoring support.

6. SETTING AND MONITORING KPIs

6.1. Types of KPIs

Policy Reform KPIs: Examples include introduction of carbon pricing, feebates, or renewable energy auctions. These KPIs are designed to incentivize policy changes that broadly impact climate outcomes. Policy reform KPIs are particularly effective in creating systemic changes that drive long-term sustainability.

Clean Energy Infrastructure KPIs: KPIs related to the rollout of renewable energy and other clean infrastructure projects. These KPIs focus on tangible projects that contribute directly to reducing carbon emissions. Clean energy infrastructure KPIs are critical for meeting immediate climate targets and creating a foundation for sustainable development. While green energy bonds generally relate to specific projects, a sustainability-linked bond KPI would relate to a national goal, e.g., it might specify a progressively larger target percentage of renewable energy in the issuing country's total electricity supply.

Forest Cover KPIs: KPIs related to forest cover or policies to reduce deforestation. These KPIs are critical for protecting natural carbon sinks and maintaining biodiversity. Forest cover KPIs are essential for preserving ecosystems and preventing the release of stored carbon.

6.2. Baseline and Accounting

KPIs typically require a baseline, but this comes with the risk of perverse incentives (establishment of deliberately weak baselines). Establishing norms for credible baselines is essential to avoid ad hoc baselining, which can distort the effectiveness of sustainability-linked bonds (Kölbel and Lambillon, 2022).

A standardized approach to baselining ensures that KPIs are set in a way that accurately reflects the environmental impact of the projects funded. By avoiding the pitfalls of ad hoc baselining, SLIDIs can provide a more accurate and reliable measure of their environmental impact. Climate-related KPIs can be assessed using GHG accounting to measure the benefits of the projects.

6.3. Capacity Assessment

An assessment of the issuer's capacity to deliver on climate targets is also crucial (Bouzidi and Papaioannou, 2021). This involves evaluating the technical and financial capabilities of the issuer to ensure that they can meet the KPIs and deliver on the bond's promises. Capacity assessment is a critical step in the structuring of SLIDIs, as it ensures that the issuer has the necessary resources and expertise to achieve the desired outcomes – or that development agency partners are recruited to help the issuer achieve realistically set targets.

Careful negotiation with stakeholders is required to align KPIs with the issuer's climate goals and development partners' expectations. This collaborative approach ensures that all parties are committed to achieving the bond's specified objectives. Stakeholder negotiations are needed ensure that the KPIs are realistic, achievable, and aligned with broader climate and public policy goals. By bringing all stakeholders to the table, SLIDIs can create a sense of shared responsibility and commitment to achieving the bond's objectives.

Additional considerations include regulating target KPIs to prevent greenwashing, establishing institutions for monitoring, and setting private sector participation thresholds for purchases of new bond issuances. These measures ensure the integrity of the bonds and protect against potential abuses (Giráldez and Fontana, 2022). By establishing clear rules and guidelines, SLIDIs can maintain their credibility and effectiveness in mobilizing private capital for climate finance.

7. THE ROLE OF INTERNATIONAL INSTRUMENTS

7.1. The Role of the World Bank

The WB collaborates with impact investors to create KPIs in key areas such as natural forest protection, carbon pricing, and renewable energy targets. Such collaborations can ensure that KPIs are aligned with global climate goals and that the bonds have a significant impact. If the WB were to get involved in structuring SLIDIs, this would provide credibility and assurance to investors, making prospective WB-linked SLIDIs a more attractive investment option than bonds that lack WB involvement. Involvement of regional development banks, e.g., IDB or AfDB, could have similar benefits.

The WB could prioritize developing KPI norms in each region. This approach can ensure that the bonds are tailored to the specific needs of each region, making them more effective in achieving their objectives (Bouzidi and Papaioannou, 2021). Norm development is critical for creating a consistent and reliable framework for SLIDIs, ensuring that they can be scaled up and applied across different contexts.

7.2. The Role of Development Partners

Development partners such as development banks and development agencies are crucial in designing KPIs that are specific, measurable, achievable, relevant, and time-bound (SMART). Their role includes aligning KPIs with sovereigns' climate goals and providing the necessary technical assistance to ensure that these goals are met (Giráldez and Fontana, 2022). The effectiveness of SLIDIs will depend largely on the quality and relevance of the KPIs set by development partners, making their involvement essential to the success of these instruments.

Development partners play a key role in monitoring KPI achievement, ensuring accountability, and preventing greenwashing. Regular evaluations and transparent reporting are essential to maintain investor confidence and ensure that sustainability-linked bonds and loans achieve their intended environmental and social outcomes (Kölbel and Lambillon, 2022).

8. CONCLUSIONS

A coherent suite of sustainability-linked intermediated debt instruments, including fixed-coupon climate bonds to raise money for on-lending via sustainability-linked loans, with partial interest rate refunds paid out to developing-country borrowers on achievement of sustainability-linked KPIs with the support of trusted development agencies, could offer a promising solution to mobilizing private sector capital for the climate agenda. By incorporating clear KPIs, robust de-risking mechanisms, and fixed coupon payments, climate KPI-linked bonds and associated sustainability-linked loans may present a more effective means of mobilizing private capital for environmentally responsible projects in developing countries than current-generation sustainability-linked loans.

SLIDIs could reduce the cost of capital for sustainable development in developing countries while providing a stable, predictable, de-risked return structure for institutional investors. By aligning sovereign incentives, private investor interests, and development partner goals, SLIDIs could play a pivotal role in closing the enormous climate finance gap in developing regions.

9. RECOMMENDATIONS FOR FUTURE RESEARCH

Further research should focus on refining the technical details of SLIDIs, exploring additional implementation models, and assessing the long-term impacts of KPI-linked financing on global climate goals. It should include:

- Developing sophisticated risk management frameworks for SLIDIs.
- Exploring hybrid models that combine SLIDIs with other financial instruments.

- Evaluating the likely impact of SLIDIs on the cost of capital in developing countries.
- Evaluating the potential for SLIDIs to drive policy reform and systemic change.
- Exploring the role of technology in monitoring and verifying KPI achievements.
- Assessing the scalability of SLIDIs in different regional and economic contexts, identifying factors that influence their success.

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CLOSING REMARKS

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Dear colleagues,

The past two days have been fascinating and exciting as we heard from the best specialists, academics and practitioners, about the current debates and questions on public debt management. It is a fascinating topic at the core of the World Bank's mission to end extreme poverty and boost shared prosperity on a livable planet. It contributes to sovereign debt sustainability, supports sound fiscal policy, helps develop domestic capital markets and climate finance, amongst many dimensions.

While traveling on mission, I joined several sessions and my colleagues have told me how rich and exciting the presentations and discussions were during the past two days.

Value added of the Conference

I'm really impressed by what was achieved in creating a regular forum to discuss the latest topics on public debt development from both theoretical and operational angles. A key value added of the PDM conference for me is its ability to combine the results of very thorough research, backed by quantitative analysis, with hands on experience of practitioners. When you look at the authors of the papers presented, universities still represent the majority [48%]. While the presentation of practitioners from Ministries of Finance and Central Banks was somewhat lower compared to the previous conference (28% to 13%), their valuable insights were an essential component of the conference. I also hope we'll see more contributions from private sector experts in the future as they are important stakeholders in public debt management and government securities markets.

This exchange between academics and practitioners is also a testimony of the success of the PDM network led by the Italian Treasury that allows the public debt management community to stay up-to-date and debate ideas.

I hope that the practitioners benefited from better understanding of rationale for their action and can expand their toolkit to address problems, new or old. Equally I hope that the academics and researchers benefited from the reality check to confirm their assumptions and open new paths for their work.

How the Conference contributes to FCI agenda

Turning to the issues covered over the past two days, it is interesting to see how new topics are emerging or gaining visibility while traditional questions remain relevant. We had to speak about inflation in the current interest rate context, but it was so interesting to listen to analytical work leveraging 50 years or more of history of inflation-linked bonds and looping in the angles of monetary policy, fiscal sustainability, and bond market development. Another topic is climate: the ESG dimension is continuing to gain traction since the first event in 2019, which is not a surprise.

What I noticed is how it is not about adding new instruments such as green bonds or Sustainability-linked loans anymore, but the climate agenda is now permeating almost all dimensions of the discussion on public debt management, which is reflected in the agenda of this year.

Strengthening the financial sector's role in climate and sustainable finance is a priority in my department in the World Bank. As mentioned during the conference, addressing the externalities associated with climate change is crucial. We are committed to supporting developing economies in their efforts to green financial sector and being the catalyst for green economy, such as carbon market development. We are committed to supporting developing countries in their efforts to enhance their financial resilience, including from pre-and post-natural disaster financing and insurance. This goes hand in hand with ESG or green budgeting.

In addition, sound and deep domestic government bond market is an important topic in the discussion of public debt management. It is a key pillar that contributes to the development of domestic capital markets in general – corporate bonds, equity, derivatives – and improve the long-term financing of the economy, in particular for emerging and medium-income countries.

As global director for the Finance, Competitiveness and Innovation Global Practice, this question is dear to me. With the International Monetary Fund, we have been involved in diagnostics and reforms for many years and more recently synthesized our approach into a Local Currency Bond Market (LCBM) framework which aims at covering all the dimensions of sound government securities market.

We are also engaged with the International Finance Corporation, our sister institution, in a joint program to develop capital markets in a select but growing number of countries, through technical assistance and innovative transactions. It is called Joint Capital Market Program (JCAP) and covers many instruments and markets. In every country JCAP includes substantial technical assistance on government securities markets, because they contribute to pricing risk of government securities appropriately, expanding the domestic investor base, setting the stage for private sector issuances, to mention only a few of their benefits.

To complement this work, analytical research would be extremely useful to focus the support to government bond market development on the most effective mechanisms, to identify and quantify related risks, to assess its impact. I encourage all of you to explore and study these topics and hope that we could discuss them in detail in the next PDM conference.

Thanks

To conclude, let me thank the organizers from the three institutions – the Italian Treasury, the OECD and the World Bank. It was the first time we hosted the PDM conference, and we benefited immensely from the experience of the other two institutions.

This is an honor but also represent a lot of work for colleagues from the two units, Economic Policy and Finance, Competitiveness and Innovation global practices, in particular Oumi Himid who managed most of the logistics.

I would like to thank the moderators, the discussants, the presenters and their co-authors, the speakers, as well as those who connected virtually, and all the participants. I would also like to thank Professor Ugo Panizza for his insightful keynote speech on the link between public debt and climate change.

Thanks to all of you and see you all for the next PDM conference!