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Yacouba COULIBALY

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**Natural Resources, Fiscal Policy and Financing for
Development in Developing Countries**

Ressources naturelles, politique budgétaire et financement du développement dans les pays en développement

THÈSE dirigée par :

M. MINEA Alexandru

Professeur, Université Clermont Auvergne

M. VILLIEU Patrick

Professeur, Université d'Orléans

RAPPORTEURS :

M. DUFRENOT Gilles

Professeur, Université d'Aix-Marseille

Mme. COUHARDE Cecile

Professeur, Université Paris Nanterre

JURY :

M. COMBES Jean-Louis

Professeur, Université Clermont Auvergne,
Président du jury

M. MINEA Alexandru

Professeur, Université Clermont Auvergne

M. VILLIEU Patrick

Professeur, Université d'Orléans

M. DUFRENOT Gilles

Professeur, Université d'Aix-Marseille

Mme. COUHARDE Cecile

Professeur, Université Paris Nanterre

M. KILOLO Jean-Marc

Economist, United Nations-ECA

M. KINDA Tidiane

Senior Resident Representative, IMF

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*A ma mère feu KONE Korotoumou...
j'espère que de là-haut tu es fière de ton
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Abstract

Financing sustainable development requires substantial budgetary resources, which are often insufficient relative to existing needs. Estimates indicate that trillions of dollars are needed annually to finance the Sustainable Development Goals (SDGs), yet mobilizing these resources remains a major challenge in developing countries. Moreover, the investments required to combat poverty, reduce socio-economic inequalities, create employment, address climate change, and protect biodiversity remain largely inadequate. Despite the magnitude of the financial resources needed to achieve the SDGs, there is a significant gap between the funds currently available and the amounts required to meet these objectives. Given the current context of developing countries—characterized by limited domestic resource mobilization, the persistent volatility of official development assistance and migrant remittances, climate vulnerability, as well as ongoing socio-economic crises and geopolitical tensions—it has become increasingly urgent to adopt new sustainable financing strategies capable of addressing the growing needs of their populations. Consequently, over the past few years, various proposals have emerged to help governments mobilize additional financial resources and accelerate the financing of sustainable development.

Among these proposals, two financing instruments have gained significant attention in recent years: the natural resources–external debt nexus, particularly resource-backed loans, and debt relief initiatives, especially debt-for-nature swaps. While the former is rooted in the concept of weak sustainability, which assumes that natural capital and manufactured capital are substitutable, the latter is more closely aligned with the principle of strong sustainability, whereby natural capital and manufactured capital are considered complementary. These financing instruments can have important economic implications. Therefore, the main objective of this dissertation is to examine how these two financing mechanisms contribute to sustainable development in developing countries. To achieve this objective, the dissertation is organized into two interconnected parts, each assessing the effectiveness of these financing instruments in promoting sustainable development.

The first part of this thesis is subdivided into three chapters. Chapter 1 analyzes the societal profitability of resource-backed loans. Numerous studies have evaluated the socioeconomic risk-benefit of conventional loans (non-collateral loans). Unfortunately, little is known about

resource-backed loans. This chapter contributes to the literature by analyzing the causal effect of resource-backed loans on the ecological efficiency of human development in 45 African countries over the period 1990-2019. The ecological efficiency of human development is an index of development adjusted for the ecological footprint proposed by Hickel (2020). This index best reflects and is suitable for our study because it takes into account the creation of wealth by nations and incorporates an ecological dimension. Theoretically, the effect of resource-backed loans on the ecological efficiency of human development is ambiguous. On the one hand, resource-backed loans, by increasing public investment, create certain benefits such as facilitating trade through road infrastructure, boosting GDP per capita, improving human capital and reducing inequalities, which are key pillars of the Sustainable Development Goals. On the other hand, resource-backed loans can accelerate the development of natural resources through the intensification of mining activities by extractive industries, suggesting a negative effect of resource-backed loans on ecological efficiency. To settle this debate, we adopt an impact analysis strategy, in particular entropy balancing developed by Hainmueller (2012). The results—robust in various tests—show that resource-backed loan is associated with an increase in the ecological efficiency of human development. Subsequent heterogeneity tests show that cocoa and tobacco-backed loans reduce the ecological efficiency of human development, while oil and mineral-backed loans have a positive impact on the ecological efficiency of human development. In addition, we perform a debt threshold effect analysis and show that resource-backed loans are immaterial in the presence of high debt. Another result found in this study shows that guaranteed loans seem to go against ecological and planetary limits since they increase CO₂ emissions and greenhouse gases. To explain the positive effect of resource-backed loans on the ecological efficiency of human development, we conduct a transmission channel test. The results show that the gross national product per capita, the level of education and the number of years of schooling are potential channels through which loans guaranteed by natural resources affect the ecological efficiency of human development. Finally, further analysis suggests that joining the Extractive Industries Transparency Initiative is beneficial in amplifying the positive effect of loans on environmental efficiency. Chapter 2 analyzes the impact of resource-backed loans on deforestation in developing countries. Deforestation in developing countries has seen contrasting trends in recent years. Despite international commitments to halt this phenomenon, the loss of primary tropical forests increased by 4% in 2022 compared

to 2021, with 6.6 million hectares destroyed, including 4.1 million hectares of primary forests. The literature has identified many causes of deforestation: agricultural expansion, mining, fires and climate change, population growth and urbanization, etc. However, no study points to loans guaranteed by natural resources. This is surprising because the way resource-backed loans can affect forest cover is different from that of non-resource-backed loans. In fact, in resource-backed loans, there is a formal agreement obliging the debtor country to exploit the natural resources to ensure the repayment of the loan. This can put implicit pressure on borrowing countries to overexploit natural resources—an activity associated with a high risk of forest loss. In addition, resource-backed loans can contribute to increased permitting of extractive industries, intensifying mining, which destroys forest cover. The approaching repayment deadline and the debt burden may push the country to accelerate the pace of natural resource exploitation, which can rapidly increase the rate of deforestation. Based on this observation, we test the following two hypotheses: *i*-resource-backed loans increase deforestation by maximizing natural resource rents and resource depletion; *ii*-resource-backed loans accelerate deforestation by exacerbating debt sustainability and affecting the quality of institutions. Using the propensity score matching method on a sample of 64 developing countries over the period 2004-2018, our results show that resource-backed loans significantly increase deforestation. This increase in deforestation appears to be driven by loans secured by minerals, tobacco and cocoa. In addition, the results show that the size of loans on forest cover depends on the forest canopy, structural and institutional factors. Finally, the analysis of the channels indicates that the positive effect is channeled through the depletion of natural resources, the level of public debt, the procyclicality of the debt, consumer spending and particularly Chinese FDI. Finally, Chapter 3 analyzes the effect of resource-backed loans on fiscal discipline. Fiscal discipline is a central concept in public economics and public finance, which refers to a government's ability to manage its finances responsibly, avoiding excessive deficits and uncontrolled debt. Classical and neoclassical economists, basing their arguments on the crowding-out effect and Ricardian neutrality, consider that the state must maintain a balanced budget to avoid negative effects on the economy. In contrast, Keynes rejected the idea of a rigid budget balance. According to him, public deficits are necessary in times of recession to revive demand and stimulate growth. Some modern theories take an intermediate position, notably through the budgetary "golden rule", which suggests that: *i*-the state can go into debt, but only to finance

productive investments (infrastructure, education, etc.), which generate long-term economic benefits; *ii*-current expenditure must be covered by tax revenues, in order to avoid excessive indebtedness for operating expenditure. Building on this work on resource-rich countries, for example, Stiglitz (2005) shows that natural resource endowment is considered to be one of the sources of the procyclical nature of public debt. The idea is that natural resource endowments affect the cyclicity of public debt because of the collateral aspect of natural resources (Budina et al., 2007). Along with resource-backed loans, if countries take on debt and make productive investment, this can help broaden the tax base and increase the mobilization of tax revenues, which can be used to finance other spending. However, if countries take on too much debt and without a return on investment, this could lead to procyclicality in fiscal policy. The observation at this level is that among the fourteen countries that have subscribed to this type of loan, ten have experienced a situation of debt distress (Mihalyi et al., 2020). Faced with this finding, we analyze the effect of resource-backed loans on the cyclicity of fiscal policy in 127 developing countries over the period 1990-2020. Our motivation stems from the collateral nature of resource-backed loans, which have been identified as a source of procyclicality. We follow Guerguil et al. (2017) and Aghion et al. (2007) in calculating the cyclicity coefficients of fiscal policy using a nonparametric regression method: Gaussian-weighted local ordinary least squares (LGWOLS). Using the entropy balancing method, we show that resource-backed loans trigger the procyclicality of fiscal policy. However, the results indicate that this procyclical effect is non-linear and would become countercyclical when public investment is in the range of 15% to 35% of GDP.

The first part of this thesis shows that poor management of sovereign debt and natural resources can represent a major problem of sustainable development. Indeed, we argue that unsustainable debt puts strong pressure on natural resources, increases socioeconomic inequalities, reduces efforts to mobilize tax revenue, and reduces the government's ability to cope with climate shocks. Therefore, the second part of this thesis analyzes a debt relief program, particularly debt-for-nature swaps that could help countries implement sound fiscal policy and promote sustainable development. Debt-for-nature swaps raise two debates in the literature. The first is based on the ability of debt-for-nature swaps to create fiscal space for recipient countries, while the second debate focuses on the effectiveness of swaps in promoting environmental sustainability. We contribute to this literature in two ways. First, in the

Chapter 4, we analyze the effect of debt-for-nature swaps on fiscal policy volatility. The objective of this chapter is to settle the theoretical debate according to which debt-for-nature swaps would cause two contradictory effects: *i*-a healthier fiscal policy effect that translates into a reduction of public debt and their reallocation in climate actions (optimistic vision); *ii*-a fiscal debauchery effect characterized by an increase in discretionary spending following the reduction in the debt burden "*pessimistic view*". Contrary to this literature, some authors believe that debt-for-nature swaps have no effect on fiscal policy because of the debt cancellation, which is considered to be small "*a more pessimistic view*". We test these three hypotheses using a large sample of 134 developing countries over the period 1990-2020 and based on the propensity score matching method. Our robust results obtained after several tests show that debt-for-nature swaps reduce the volatility of fiscal policy, thus supporting the "*optimistic view*" of this program on the macroeconomic level. While we do not reject the idea of a potential discretionary spending that could arise as a result of a fiscal windfall, we argue that this can be avoided by adopting more fiscal rules, particularly the balanced budget rules and the debt rules. In fact, fiscal rules are recognized for their important role in boosting fiscal capacity, by limiting fiscal risk by reducing the volatility of fiscal resources in developing countries. Further analyses of heterogeneity show that only bilateral debt-for-nature swaps have a statistically significant negative effect on fiscal policy volatility. Finally, our results indicate that a particular focus must be placed on the quality of institutions to expect more positive effects from swaps. Chapter 5 analyses the effectiveness of debt-for-nature swaps in promoting sustainable development. In this chapter, we investigate whether debt-for-nature swaps can help developing countries improve their human development index and environmental quality. Two contradictory effects are observed in the literature. On the one hand, by transforming part of the debt into investments for the conservation and sustainable management of natural resources, these agreements can improve the living conditions of local populations. On the other hand, debt reduction often remains modest relative to the country's total debt, meaning that economic gains may be limited. Moreover, if the funded programmes are not well targeted, they can mainly benefit ecotourism companies or large NGOs, to the detriment of local populations. The idea is that the projects financed can concern the protection of areas that would be intended for agriculture. This will reduce the agricultural productivity of farmers, who are highly dependent on agricultural incomes, reduce their well-being, and thus increase

their vulnerability. The literature, until now, has remained silent on the link between debt-for-nature swaps and the ecological efficiency of human development. To our knowledge, we are the first to test this link. By adopting an impact analysis strategy, including entropy balancing to control the selection bias in the policy of adopting debt-for-nature swaps, our results show that debt-for-nature swaps increase the ecological efficiency of human development in developing countries. This result remains robust to a series of specification tests. To explain this result, we highlight different transmission channels. The results show that resource depletion, CO₂ emissions, public investments (% of GDP), economic growth, and well-being are the potential channels through which debt-for-nature swaps positively affect ecological efficiency. Moreover, an additional result shows that if the treated countries had not benefited from the debt-for-nature swaps, their ecological efficiency of human development index would have decreased by 11%, whereas if the non-treated countries had benefited from the debt-for-nature swaps, their index would have increased by about 2%. The analysis also reveals a non-linear relationship between the size of debt-for-nature swaps and the sustainable development index, with an optimal threshold estimated at 42% of the public debt level, beyond which diminishing returns are observed. Finally, by combining environmental conservation and improved living conditions, our results confirm that these debt relief mechanisms can be a powerful tool for fairer and more sustainable development. Therefore, we call on all stakeholders, namely policymakers, NGOs, national and international institutions, civil society, etc., to work towards the extension of debt-for-nature swaps by relaxing eligibility conditions, for example.

Summary in French

Le financement du développement durable nécessite des ressources budgétaires importantes, qui sont souvent insuffisantes par rapport aux besoins. Les estimations indiquent que des milliers de milliards de dollars sont nécessaires chaque année pour financer les objectifs de développement durable (ODD), mais la mobilisation de ces ressources reste un défi majeur dans les pays en développement. De plus, les investissements nécessaires pour lutter contre la pauvreté, les inégalités socio-économiques, la création d'emploi, le changement climatique et la protection de la biodiversité sont encore largement insuffisants. Malgré l'ampleur des besoins financiers pour réaliser les ODD, il existe un fossé important entre les fonds disponibles et les montants nécessaires pour atteindre ces objectifs. Au regard du contexte actuel des pays en développement marqué par une faible mobilisation des ressources internes, la volatilité persistante de l'aide publique au développement et des transferts de fonds des migrants, la vulnérabilité climatique combinés avec les crises socio-économiques et les tensions géopolitiques, il paraît plus urgent d'adopter de nouvelles stratégies de financement durable afin de répondre aux besoins grandissants de la population dans ces pays. C'est ainsi qu'au cours des dernières années, des propositions diverses ont été mises sur le devant de la scène pour aider les Etats à obtenir des fonds et accélérer le financement du développement durable.

Parmi ces propositions, deux instruments de financement, devenues populaires ces dernières années, ont fait leur apparition: l'interaction ressources naturelles—dette extérieure spécialement les prêts garantis par les ressources naturelles et le programme d'allègement de dette particulièrement les échanges dette-nature (debt-for-nature swaps). Si le premier se focalise sur les visions de la soutenabilité faible (le capital naturel et le capital manufacturé sont interchangeableables), le deuxième quant à lui, milite plutôt en faveur de la soutenabilité forte (le capital naturel et le capital manufacturé sont complémentaires). Ces instruments de financement peuvent avoir des répercussions importantes sur l'économie. Par conséquent, l'objectif principal de cette thèse est de savoir comment ces deux sources de financement favorisent le développement durable dans les pays en développement. Pour y parvenir, nous structurons la thèse en deux grandes parties interconnectées dans lesquelles nous analysons l'efficacité de ces deux instruments de financement à promouvoir le développement durable.

La première partie de cette thèse est subdivisée en trois chapitres. Le Chapitre 1 analyse la

profitabilité sociétale des prêts adossés aux ressources naturelles. De nombreuses études ont évalué les risques-avantages socio-économiques des prêts classiques (prêts non collatéraux). Malheureusement, on sait peu de chose sur les prêts adossés aux ressources naturelles. Ce chapitre contribue à la littérature en analysant l'effet causal des prêts adossés aux ressources naturelles sur l'efficacité écologique du développement humain dans 45 pays Africains sur la période 1990-2019. L'efficacité écologique du développement humain est un indice du développement corrigé de l'empreinte écologique proposé par Hickel (2020). Cet indice reflète le mieux et est adapté à notre étude car il prend en compte la création de la richesse par les nations et intègre une dimension écologique. Théoriquement, l'effet des prêts garantis par des ressources naturelles sur l'efficacité écologique du développement humain est ambigu. D'une part, les prêts garantis par des ressources, en augmentant l'investissement public, créent certains avantages tels que la facilitation du commerce par le biais de l'infrastructure routière, la stimulation du PIB par tête, amélioration du capital humain et la réduction des inégalités, qui sont des piliers essentiels des objectifs de développement durable. D'autre part, les prêts garantis par les ressources peuvent accélérer l'équipement des ressources naturelles via l'intensification des activités minières par les industries extractives, suggérant un effet négatif des prêts garantis par les ressources naturelles sur l'efficacité écologique. Pour trancher ce débat, nous adoptons une stratégie d'analyse d'impact, notamment l'entropie balancing développé par Hainmueller (2012). Les résultats — robustes à divers tests — montrent que les prêts garantis par les ressources naturelles sont associés à une augmentation de l'efficacité écologique du développement humain. Les tests d'hétérogénéité effectués par la suite montrent que les prêts adossés au cacao et au tabac réduisent l'efficacité écologique de développement humain tandis que les prêts adossés au pétrole et minéraux ont un impact positif sur l'efficacité écologique du développement humain. En outre, nous effectuons une analyse d'effet seuil de la dette et montrons que les prêts adossés aux ressources naturelles sont non significatifs en présence d'une forte dette. Un autre résultat trouvé dans cette étude montre que les prêts garantis semblent aller à l'encontre des limites écologiques et planétaires puisqu'ils augmentent les émissions de CO₂ et les gaz à effet de serre. Pour expliquer l'effet positif des prêts garantis par les ressources naturelles sur l'efficacité écologique du développement humain, nous effectuons un test de canaux de transmission. Les résultats montrent que le produit national brut par tête, le niveau d'éducation et le nombre d'années de scolarisa-

tion prévues sont des potentiels canaux par lesquels les prêts garantis par les ressources naturelles affectent l'efficacité écologique de développement humain. Enfin, des analyses supplémentaires suggèrent que l'adhésion à l'initiative pour la transparence dans les industries extractives est bénéfique pour amplifier l'effet positif des prêts sur l'efficacité écologique. Le Chapitre 2 analyse l'impact des prêts garantis par des ressources naturelles sur la déforestation dans les pays en développement. La déforestation dans les pays en développement a connu des tendances contrastées ces dernières années. Malgré des engagements internationaux visant à enrayer ce phénomène, la perte de forêts tropicales primaires a augmenté de 4% en 2022 par rapport à 2021, avec 6,6 millions d'hectares détruits, dont 4,1 millions d'hectares de forêts primaires. La littérature a identifié de nombreuses causes de la déforestation : expansion agricole, exploitation minière, incendies et changements climatiques, croissance démographique et urbanisation, etc. Cependant, aucune étude ne pointe les prêts garantis par les ressources naturelles. Ceci est surprenant car la façon dont les prêts adossés aux ressources naturelles peuvent affecter le couvert forestier est différente de celle des prêts non adossés aux ressources naturelles. En fait, dans les prêts garantis par les ressources naturelles, il existe un accord formel obligeant le pays débiteur à exploiter les ressources naturelles pour assurer le remboursement du prêt. Ce qui peut exercer une pression implicite sur les pays emprunteurs à surexploiter les ressources naturelles — activité liée à un grand risque de perte forestière. De plus, les prêts adossés peuvent contribuer à l'augmentation de l'octroi de permis d'exploitation aux industries extractives, intensifiant l'exploitation minière, ce qui détruit le couvert forestier. Le rapo de l'échéance de remboursement et le fardeau de la dette peuvent pousser le pays à accélérer le rythme d'exploitation des ressources naturelles, ce qui peut accroître rapidement le taux de déforestation. Fort de ce constat, nous testons deux hypothèses suivantes : *i-les prêts adossés à des ressources naturelles augmentent la déforestation par la maximisation des rentes des ressources naturelles et l'épuisement des ressources; ii-les prêts adossés à des ressources naturelles accélèrent la déforestation en exacerbant la viabilité de la dette et en affectant la qualité des institutions* . En utilisant la méthode d'appariement de score de propension sur un échantillon de 64 pays en développement sur la période 2004-2018, nos résultats montrent que les prêts garantis par les ressources naturelles augmentent significativement la déforestation. Cette augmentation de la déforestation semble être provoquée par les prêts garantis par les minéraux, le tabac et le cacao. De plus, les résultats montrent que l'ampleur

des prêts sur le couvert forestier dépend du canopée forestière, des facteurs structurels et institutionnels. Enfin, l'analyse des canaux indique que l'effet positif transite par l'épuisement des ressources naturelles, le niveau de la dette publique, la procyclicité de la dette, les dépenses de consommation et les IDE particulièrement chinois. Enfin, le Chapitre 3 analyse l'effet des prêts adossés aux ressources naturelles sur la discipline budgétaire. La discipline budgétaire est un concept central en économie publique et en finance publique, qui désigne la capacité d'un gouvernement à gérer ses finances de manière responsable, en évitant des déficits excessifs et une dette incontrôlée. Les économistes classiques et néoclassiques, en fondant leurs arguments sur l'effet d'éviction et la neutralité ricardienne, considèrent que l'État doit maintenir un budget équilibré pour éviter des effets négatifs sur l'économie. À l'opposé, Keynes rejette l'idée d'un équilibre budgétaire rigide. Selon lui, les déficits publics sont nécessaires en période de récession pour relancer la demande et stimuler la croissance. Certaines théories modernes adoptent une position intermédiaire, notamment à travers la "règle d'or" budgétaire, qui suggère que: *i*-l'État peut s'endetter, mais uniquement pour financer des investissements productifs (infrastructures, éducation, etc.), qui génèrent des bénéfices économiques à long terme; *ii*-les dépenses courantes doivent être couvertes par des recettes fiscales, afin d'éviter un endettement excessif pour des dépenses de fonctionnement. Dans le prolongement de ces travaux sur le cas des pays riches en ressources naturelles, par exemple, Stiglitz (2005) montre que la dotation en ressources naturelles est considérée comme l'une des sources du caractère procyclique de la dette publique. L'idée est que les dotations en ressources naturelles affectent la cyclicité de la dette publique en raison de l'aspect collatéral des ressources naturelles (Budin et al., 2007). Parallèlement aux prêts garantis par les ressources naturelles, si les pays s'endettent et réalisent un investissement productif, cela peut contribuer à l'élargissement de la base fiscale et accroître la mobilisation des recettes fiscales, lesquelles serviront à financer d'autres dépenses. Cependant, si les pays s'endettent trop et sans retour sur investissement, cela pourrait entraîner une procyclicité de la politique budgétaire. Le constat à ce niveau est que parmi les quatorze pays qui ont souscrit à ce type de prêt, dix ont connu une situation de surendettement (Mihalyi et al., 2020). Face à ce constat, nous analysons l'effet des prêts garantis par les ressources naturelles sur la cyclicité de la politique budgétaire dans 127 pays en développement sur la période 1990-2020. Notre motivation découle du caractère collatéral des prêts adossés aux ressources naturelles qui identifié comme source procyclicité. Nous suivons

Guerguil et al. (2017) et Aghion et al. (2007) en calculant les coefficients de cyclicité de la politique budgétaire à l'aide d'une méthode de régression non paramétrique : les moindres carrés ordinaires locaux pondérés par la gaussienne (LGWOLS). En utilisant la méthode d'entropie balancing, nous montrons que les prêts adossés aux ressources naturelles déclenchent la procyclicité de la politique budgétaire. Cependant, les résultats indiquent que cet effet procyclique est non-linéaire et deviendrait contracyclique lorsque les investissements publics réalisés se situent dans la fourchette de 15% à 35% du PIB.

La première partie de cette thèse montre qu'une mauvaise gestion de la dette souveraine et des ressources naturelles peut représenter un problème majeur de développement durable. En effet, nous soutenons qu'une dette insoutenable exerce une forte pression sur les ressources naturelles, augmente les inégalités socio-économiques, réduit les efforts de mobilisation de recette fiscale et la capacité du gouvernement à faire face aux chocs climatiques. Par conséquent, la deuxième partie de cette thèse analyse un programme d'allègement de la dette, particulièrement les debt-for-nature swaps qui pourrait aider les pays à mettre en place une politique budgétaire saine et promouvoir le développement durable. Les debt-for-nature swaps soulèvent deux débats dans la littérature. La première repose sur la capacité des debt-for-nature swaps à créer un espace budgétaire pour les pays bénéficiaires tandis, que le second débat se concentre sur l'efficacité des swaps à promouvoir la durabilité environnementale. Nous contribuons à cette littérature de deux manières. Premièrement, dans le Chapitre 4, nous analysons l'effet des debt-for-nature swaps sur la volatilité de la politique budgétaire. L'objectif de ce chapitre est de trancher le débat théorique selon lequel les debt-for-nature swaps provoqueraient deux effets contradictoires : *i*-un effet de politique budgétaire plus saine qui se traduit par une réduction de la dette publique et leur réallocation dans les actions climatiques "*vision optimiste*"; *ii*-un effet de débauche budgétaire caractérisé par une hausse des dépenses discrétionnaires suite à la diminution du fardeau de la dette "*vision pessimiste*". Contrairement à cette littérature, certains auteurs estiment que les debt-for-nature swaps n'ont pas d'effet sur la politique budgétaire en raison de la dette annulée, jugée de petite taille "*vision plus pessimiste*". Nous testons ces trois hypothèses en utilisant un large échantillon de 134 pays en développement sur la période 1990-2020 et en se basant sur la méthode d'appariement de score de propension. Nos résultats robustes obtenus après plusieurs tests montrent que les debt-for-nature swaps réduisent la volatilité de la politique budgétaire soutenant ainsi la

"*vision optimiste*" de ce programme sur le plan macroéconomique. Si nous ne rejetons pas l'idée d'une éventuelle dépense discrétionnaire qui pourrait survenir suite à une manne de manœuvre budgétaire, nous soutenons que cela peut être évité en adoptant des règles budgétaires plus, particulièrement les règles sur l'équilibre budgétaire et celles sur l'endettement. En fait, les règles budgétaires sont reconnues pour leur rôle important dans la stimulation de la capacité budgétaire, en limitant le risque budgétaire en réduisant la volatilité des ressources budgétaires dans les pays en développement. Des analyses supplémentaires sur l'hétérogénéité montrent que seuls les debt-for-nature swaps bilatéraux ont un effet négatif statistiquement significatif sur la volatilité de la politique budgétaire. Enfin, nos résultats indiquent qu'un accent particulier doit être mis sur la qualité des institutions pour escompter davantage d'effet positif des swaps. Le Chapitre 5 analyse l'efficacité des debt-for-nature swaps à promouvoir le développement durable. Dans ce chapitre, nous cherchons à savoir si les debt-for-nature swaps peuvent aider les pays en développement à améliorer leur indice de développement humain et la qualité environnementale. Deux effets contradictoires sont observés dans la littérature. D'une part, en transformant une partie de la dette en investissements pour la conservation et la gestion durable des ressources naturelles, ces accords peuvent améliorer les conditions de vie des populations locales. D'autre part, la réduction de la dette reste souvent modeste par rapport à l'endettement total du pays, ce qui signifie que les gains économiques peuvent être limités. De plus, si les programmes financés ne sont pas bien ciblés, ils peuvent profiter principalement aux entreprises de l'écotourisme ou aux grandes ONG, au détriment des populations locales. L'idée est que les projets financés peuvent concerner la protection des zones qui seraient destinée à l'agriculture. Ce qui va réduire la productivité agricole des agriculteurs, qui sont fortement dépendant des revenus agricoles, diminuer leur bien-être, et par cette occasion augmenter leur vulnérabilité. La littérature, jusqu'à présent est restée silencieuse sur le lien entre les debt-for-nature swaps et l'efficacité écologique du développement humain. À notre connaissance, nous sommes les premiers à tester ce lien. En adoptant une stratégie d'analyse d'impact, notamment l'entropy balancing pour contrôler le biais de sélection dans la politique d'adoption des debt-for-nature swaps, nos résultats montrent que les debt-for-nature swaps augmentent l'efficacité écologique du développement humain dans les pays en développement. Ce résultat reste robuste à une série de test de spécification. Pour expliquer ce résultat, nous mettons en évidence différents canaux de transmission. Les résultats

montrent que l'épuisement des ressources, les émissions de CO₂, les investissements (% du PIB), la croissance économique, et le bien-être constituent les potentiels canaux par lesquels les debt-for-nature swaps affectent positivement l'efficacité écologique. De plus, un résultat supplémentaire montre que si les pays traités n'avaient pas bénéficié des debt-for-nature swaps, leur indice d'efficacité écologique du développement humain aurait diminué de 11%, alors que si les pays non traités avaient bénéficié des debt-for-nature swaps, leur indice aurait augmenté d'environ 2%. Enfin, en combinant conservation environnementale et amélioration des conditions de vie, nos résultats confirment que ces mécanismes d'allègement de la dette peuvent être un outil puissant pour un développement plus juste et durable. Par conséquent, nous appelons toutes les parties prenantes, à savoir les décideurs politiques, les ONG, les institutions nationales et internationales, la société civile, etc., à œuvrer pour l'extension des debt-for-nature swaps en assouplissant les conditions d'éligibilité, par exemple.

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GENERAL INTRODUCTION

“Funding gaps for SDG investments in developing countries are increasing, and debt burdens are becoming unbearable for many countries of the Global South;” “debts are unsustainable if the only way to pay for them is to compromise sustainable development.”

– Ms. Rebeca Grynspar (2023)

The Covid-19 pandemic and the resulting economic and social crisis have undermined the progress made in the fight against poverty. Developing countries are still struggling to redress their development trajectory towards sustainable and sustained development. These crises, combined with existing challenges such as unemployment, food insecurity, inequality, low productivity, high exposure to debt crises, and natural disasters, have devastated the economies of developing countries. Fiscal pressures linked to economic recessions, conjugated with difficulties in accessing financial markets, compounded by over-indebtedness, series of sovereign debt defaults, and sovereign debt restructuring, continue to slow down the effective and exclusive financing of sustainable development in developing countries. To meet these challenges and promote sustainable development, the interplay between natural resources and sound fiscal policy, more specifically, sovereign debt, can be used as a powerful instrument to regulate economic activity and finance sustainable development. As a result, the debate surrounding responsible management of natural resource revenues and sovereign debt sustainability in developing countries by all stakeholders, including practitioners, policymakers, academics, international institutions, NGOs, etc., needs to be significantly deepened.

The endowment of natural resources as an engine of economic development for the countries that possess them has been the subject of much debate in the economic literature but so far remains a moot point. Some authors have established that natural resource endowments are important determinants of economic development (Henderson et al., 2018; Nordhaus et al., 2006; Sachs and Warner, 1995). These authors base their arguments on the fact that the exploitation of natural resources generates substantial revenues and foreign currency and contributes to job creation, which in turn stimulates economic growth, development, and poverty reduction. Some authors have successfully established the link between natural resources, re-

newable energy production, and economic growth. For instance, Khan et al. (2022) evaluated the link between natural resource rents and economic growth in the G7 economies. Applying the MMQR approach as the main method over the period 1990-2020, the authors reach the conclusion that natural resources are both a curse and an advantage at different income levels. The results for renewable energies are negative, while the capital acculturation is positive. For Ploeg (2011), natural resources boost public and private investment, which in turn facilitates industrial development, the creation of markets, and a good investment environment. Kwakwa et al. (2022) examined the influence of natural resources on economic growth in Tunisia. The findings emphasized that natural resources have a positive impact on the sectoral growth of the economy. The same results were found by Adabor et al. (2022) who studied the link between resource rents and economic performance in Ghana. The main results revealed that a 1% increase in oil rent generates a 0.84% increase in Ghana's long-term economic growth. In an innovative study, a bidirectional causal association was observed between resource rents and economic growth by Ben-Salha et al. (2021) and Hamdi and Sbia (2013). In another innovative study, Xie et al. (2022) inspected the positive and substantial impact of natural rents on economic performance with a unidirectional causal relationship in all periods (long, short and medium).

Furthermore, many countries such as Great Britain, Germany, Australia, Canada, and the United States have succeeded in transforming the exploitation of natural resources into economic growth and development (see Acemoglu, 2008; Halland et al., 2015). More recently, developing countries such as Botswana, Chile, Malaysia, and South Africa have seen their income levels increase due to the extraction of natural resources (Halland et al., 2016). According to Akinlo (2012), oil and natural resources indirectly promote growth through foreign direct investment and portfolio investment. In addition to this literature, other studies questioning the resource curse are reemerging with empirical evidence on natural resources as a means of economic growth and prosperity (see, for instance, North and Thomas, 1973; Brunnschweiler, 2008; Brunnschweiler and Bulte, 2008; Alexeev and Conrad, 2011). There are reports in the literature that, prior to the 20th century, natural resources, generally raw materials, played a central role in world trade and economic growth. Countries such as Australia, the United States and Canada benefited greatly from the export of raw materials in their early economic development. Other more recent ones are Ecuador, which saw a significant increase in in-

come following its resource boom, and Norway, which has used its natural wealth to ensure continued economic prosperity for future generations (Auty, 2002; North and Thomas, 1973; Papyrakis, 2017).

From the literature we have just discussed, it is clear that the management of a nation's natural resources can foster national development if carried out wisely. In fact, efficient utilization of natural resources increases sustainable economic growth (Li et al., 2023), and also provides support in real economic sectors, generates employment, and reduces poverty (Khan et al., 2023). Unfortunately, this is not the case for all resource-rich countries, and the apparent mismanagement of these resources, low growth rates, social tensions, and civil strife in resource-rich countries have given rise to a wealth of literature on what is now known as the «resource curse».

In line with Auty and Warhurst (1993) and Sachs and Warner (2001), we define the resource curse as the phenomenon by which some resource-dependent countries experience slower or even negative growth, compared to less resource-endowed countries. The literature related to resource curse in developed countries is large (e.g. Auty and Warhurst, 1993; Auty, 2002; Sachs and Warner, 2001; Ross, 1999; Ross, 2015; Sachs and Warner, 1995; Frankel, 2010; Stevens, 2003; Torvik, 2002; Robinson et al., 2006; Badeeb et al., 2017; Brollo et al., 2013; Mehlum et al., 2006; Stevens and Dietsche, 2008; Sala-i Martin and Subramanian, 2013; Boyce and Emery, 2011; Arezki and Van der Ploeg, 2010; Badeeb et al., 2021; etc.). Several reasons are provided to explain the curse associated with the rent of natural resources (see, for instance, Sachs and Warner, 2001; Saha and Ali, 2017). Firstly, economic mechanisms are examined with the aim of establishing a link between the resource curse and the economic performance of resource-rich countries. For example, Sachs and Warner (1995), Haggard and Tiede (2011), and Badeeb et al. (2017) based on the specialization of the economies of resource-rich countries, and find that economies specializing in the extraction and export of natural resources experience relatively low rates of economic growth. Some studies report that natural resource extraction processes consume economic resources that could otherwise be allocated to industries that are supposed to promote long-term economic growth, such as manufacturing or services (Chen et al., 2024), thus creating the dilemma of Dutch disease (Yang et al., 2021; Li et al., 2021; Li et al., 2023; Wijnbergen, 1984; Sachs and Warner, 1995; Sachs and Warner, 1999; Sachs and Warner, 2001; Torvik, 2001; Matsuyama, 1992). Basically, Dutch disease occurs when a resource boom leads

to a shift in production factors towards extractive activities, to the detriment of other traditional export sectors such as manufacturing and agriculture. It causes the real exchange rate to appreciate, triggering inflation and leading to a consequent loss of competitiveness for the national economy. Consequently, there is a decline in the global demand for non-resource products, which in turn leads to a decline in the supply of non-resource goods and a reduction in the wealth created in non-resource industries (Badeeb et al., 2017). An interesting study is that of Corden (1992), who referred to the Dutch disease as an economic phenomenon that occurs when a country experiences significant short-term gains from the rent of natural resources. In the spirit of Benigno and Fornaro (2014), abundant foreign capital inflows stimulate demand for domestic nonexchangeable goods, leading economic activity to specialize in the non-exchangeable goods sector at the expense of exchangeable goods. This will result in a significant reduction in investment, innovation and the overall productivity of domestic companies (Gylfason et al., 1999).

In addition to natural resources, public debt plays a crucial role in economic development when governments use it to finance spending and invest in strategic sectors that promote a sustainable future (see Ruiz et al., 2025). For their part, Woodford (1990) and Aiyagari and McGrattan (1998), believe that public debt effectively relaxes borrowing restrictions by increasing liquidity, which can be used to smooth consumption if households face the constraint. According to Albanesi (2008) and Floden (2001), public debt could be an effective way to improve risk sharing and therefore general well-being. In times of recession, the existence of social safety nets, financed in part by public deficits, can play an important role as automatic economic stabilizers to cope with rising unemployment (Barro, 1979). Consequently, public debt can increase to support the action of automatic stabilizers. According to World Bank (2023), developing countries spent a record \$443.5 billion servicing their public and publicly guaranteed external debt in 2022¹. These statistics show just how important sovereign debt is in financing sustainable development in developing countries. However, it can also become a major burden when it grows excessively, reducing economic growth (see Chen et al., 2024) and increasing cyclical fiscal policy (Olaoye and Olomola, 2023). This could slow the financing of sustainable development objectives. Augustine and Rafi (2023), analysis of 39 developing lower debt levels,

¹<https://www.bancomundial.org/es/news/press-release/2023/12/13/developing-countries-paid-record-443-5-billion-on-public-debt-in-2022>.

development dampens, while higher debt levels stimulate it. Developing countries have been found to generate a large part of their revenue from debt (Chiu and Lee, 2017; Owusu-Nantwi and Erickson, 2016). However, a high dependency on public debt could be detrimental to the financing of sustainable development. According to Gonzalez-Redin et al. (2018), a debt-based economy is doomed to fail. In the same vein, Ostry et al. (2015) find evidence that living with higher debt could be the best policy only when countries have fiscal space and no real prospect of a sovereign crisis.

When examining the effects of external debt on economic development in various nations, Makun (2021) demonstrated that the non-linear analysis revealed an uneven influence, while the linear estimate of foreign debt had a negative long-term impact. The conclusion drawn by Benli (2020) is similar: Turkey's heavy foreign debt impedes economic growth. In the same spirit, Matandare and Tito (2018) discovered that Zimbabwe's economic progress is severely and adversely impacted by foreign debt. However, research from Ghana by Asafo and Matuka (2019) and Pakistan by Chandia and Javid (2013) shows a different outcome. As a substantial positive link is established between the surplus-to-GDP ratio and the lagged Debt-to-GDP ratio, Chandia and Javid (2013) concluded that Pakistan's current fiscal strategy is sustainable. Asafo and Matuka (2019) argue that an increase in foreign loan inflows has a multiplicative effect on economic development in Ghana.

In the economic literature, debt has been argued to be a double-edged sword in that it can stimulate or retard economic growth (Cecchetti et al., 2011; Karadam, 2018; Sandow et al., 2022; Turan and Yanikkaya, 2021). High debt levels have a non-linear impact, with negative consequences for growth due to over-indebtedness and crowding-out effects (Baum, 2012; Cecchetti et al., 2011; Kumar and Woo, 2010; Reinhart and Rogoff, 2010). The optimality of public debt is at the heart of the analysis by these authors (see also Omotosho et al., 2016). They concluded that countries whose debt exceeds their optimal limits should take steps to resolve their fiscal problems and bring their debt levels down to sustainable levels. These results have been confirmed by Greene and Khan (1990) who have suggested that beyond a certain point, debt begins to stifle progress. The authors argue that slow economic growth is the real cause of excessive debt and that priority should instead be given to stimulating economic growth. Using a sample of 71 developing countries, Law et al. (2021) established that the threshold value for debt is 51.65%, and that debt significantly and negatively influences progress at increasing

levels of public debt, while debt only insignificantly affects economic progress at decreasing levels of public debt. In line with the optimality of public debt, Zaghdoudi (2020) found that some middle and low-income countries benefit economically from debt, as it helps finance public spending. Using a panel of 109 middle- and low-income countries from 2002 to 2016 and a dynamic panel threshold regression model to account for a potential non-linear link between external debt and economic growth, the author shows that external debt has a statistically significant negative relationship with economic growth in low- and middle-income countries after exceeding a threshold level of 15.28%. In the same spirit, Lau et al. (2022) reported different thresholds between 30% and 90% in 16 Asian countries, with the conclusion that external debt significantly affects economic growth in most of the selected countries. At the same time, the study of Greene and Khan (1990) has suggested that beyond a certain point, debt begins to stifle economic progress. The authors argue that slow economic growth is the real cause of excessive debt and that priority should instead be given to stimulating growth.

The process by which an increase in external debt could affect economic development seems to be a complex issue (Çiftçioğlu and Sokhanvar, 2018). Its effect on economic activity may depend on a time perspective of more than two years (Albu and Albu, 2021). Bandiera and Tsiropoulos (2020) have shown that 28% of countries that benefit from BIS investments are likely to experience a high vulnerability to debt in the medium term. Although Juergen (2019) reached similar conclusions for 25 developed and developing countries, concluding that debt has a negative impact on short- and long-term economic performance.

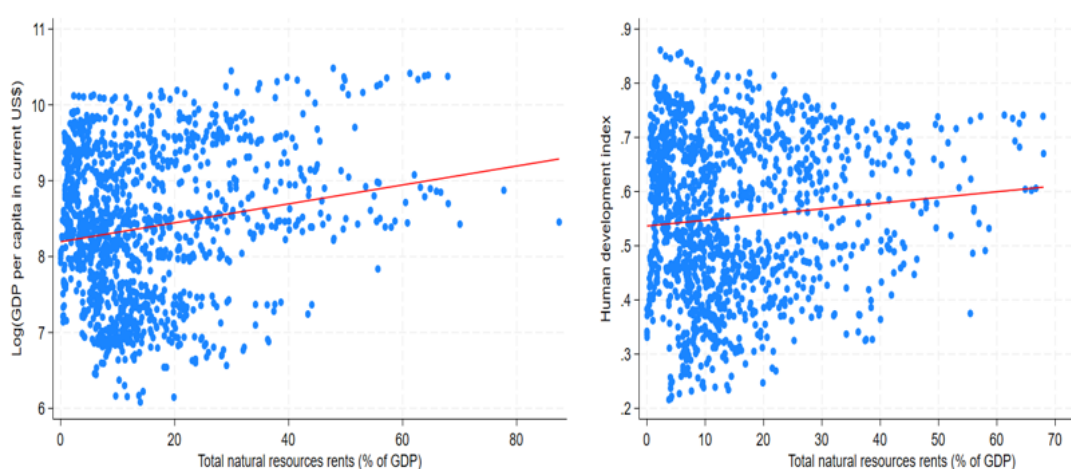
Some studies have identified public debt (over-indebtedness) as the main cause of the curse of natural resources (see, e.g., Prebisch, 1950; Singer, 1950). The current economic conditions of some resource-rich African countries (such as Angola, Chad, the Democratic Republic of Congo, and Nigeria) further confirm this characterization. According to Manzano and Rigobon (2001), the curse of natural resources identified by Sachs and Warner (1997) could be linked to over-indebtedness. They noted that resource-rich countries that use these assets as collateral for loans would face extreme debt in the event of a significant drop in commodity prices. Few years later, Lederman and Maloney (2006) also found similar results, according to which excessive and irresponsible lending of the 1970s, based on the idea of continuous rise in oil prices, led to inevitable debt crises and slow growth in the 1980s after oil prices fell. These results motivated Melina et al. (2016) to analyze the macroeconomic and debt sustainability

effects of increasing public investment in resource-rich developing countries using a DIGNAR model (debt, investment, growth, and natural resources). These authors conclude that, while investing resource revenues in public capital is generally known to foster economic development, borrowing on the basis of future revenues or spending without savings will expose the economy to debt sustainability risks. However, in their study, Manzano and Rigobon (2001) show that the curse of natural resources leads to over-indebtedness. Similarly, some studies examine the role of natural resources in the cyclical response of public debt (see, e.g. Stiglitz, 2005). In this literature, numerous studies point to the collateral aspect of natural resources as one of the factors that can affect the level of lending to developing countries (Budina et al., 2007; Stiglitz, 2005; Lane, 2004) in different phases of the economic cycle. According to Manzano and Rigobon (2006), natural resources interact with the economic cycle, since expansion phases can be explained in part by rising commodity prices and recession phases in part by falling commodity prices. Assuming that the state is an agent with financing needs, we can see, for example, that creditors grant loans backed by natural resources (considered as collateral) to countries that export them. In addition to this guarantee, which attracts loans, it should be noted that the prices of natural resources are more volatile (see Ploeg, 2008; Devlin and Lewin, 2004). In other words, when natural resource prices are high (which corresponds to the expansion phase in resource-rich countries), agents with the capacity to finance believe that the profits derived from natural resources by resource-exporting countries are increasing (and that the net position of resource-exporting countries is therefore improving). As a result, creditors grant loans to the countries concerned. In times of falling prices (which implies a recession in resource-dependent countries), creditors assume that resource profits are falling in resource-exporting countries. In this case, creditors demand the repayment of their loans at a time when countries need financing. For his part, Okombi (2021) argues that there is a mining rent threshold that conditions the reaction of fiscal policy (measured by the budget balance) to cyclical fluctuations in African countries.

For a contrasting result with supporting evidence, some studies have shown that advanced resource-rich countries such as Canada and Norway historically display good economic performance and an enviable welfare status, as has also been found, albeit to a lesser extent, in some resource-rich African countries such as South Africa, Botswana, and until recently, Libya. As we can observe in Figure 1 below, natural resources play a major role in the economic

development process in 48 resource-rich developing countries over the period 1990-2020. This figure shows a positive correlation between natural resources, economic growth, and human development, which confirms the beneficial nature of natural resource rents. Probably, such a correlation could be explained by the boom in extractive resources since the 2000s, marked by rising commodity prices. Theoretically, commodity booms should create a trade surplus that can be used to acquire capital for welfare-enhancing investment projects.

Figure 1: Natural resources, GDP per capita and human development



Source: Author's elaboration using WDI dataset

However, current economic conditions in some developing countries, particularly resource-rich African countries such as Angola, Chad, the Democratic Republic of Congo, Niger, Mali, the Central African Republic, Nigeria, Zambia, etc., do not confirm this characterization. Although rich in natural resources, these countries have underperformed in terms of economic prosperity. Most of the literature on natural resource endowment focuses on the weakness of economic institutions as the main cause of this economic bad performance (see, e.g. Collier and Goderis, 2007; Leite and Weidmann, 1999; Petermann et al., 2007; etc.). For example, more than 380 billion dollars in public funds have been stolen or wasted by various governments since independence in 1960, due to corruption in the country². Similarly, according to some estimates, more than a billion dollars in Angolan oil revenues have disappeared due to corruption every year since the early 2000s (McMillan, 2005). Figure 2 shows that political stability, government stability, bureaucracy quality, and corruption control are much lower in devel-

²<http://news.bbc.co.uk/2/hi/africa/6069230.stm>.

oping countries compared to developed countries between 1990 and 2020. This weakness of economic institutions undermines the tax revenues of countries in the extractive sector and leads them to finance so-called “*white elephant*”³ projects.

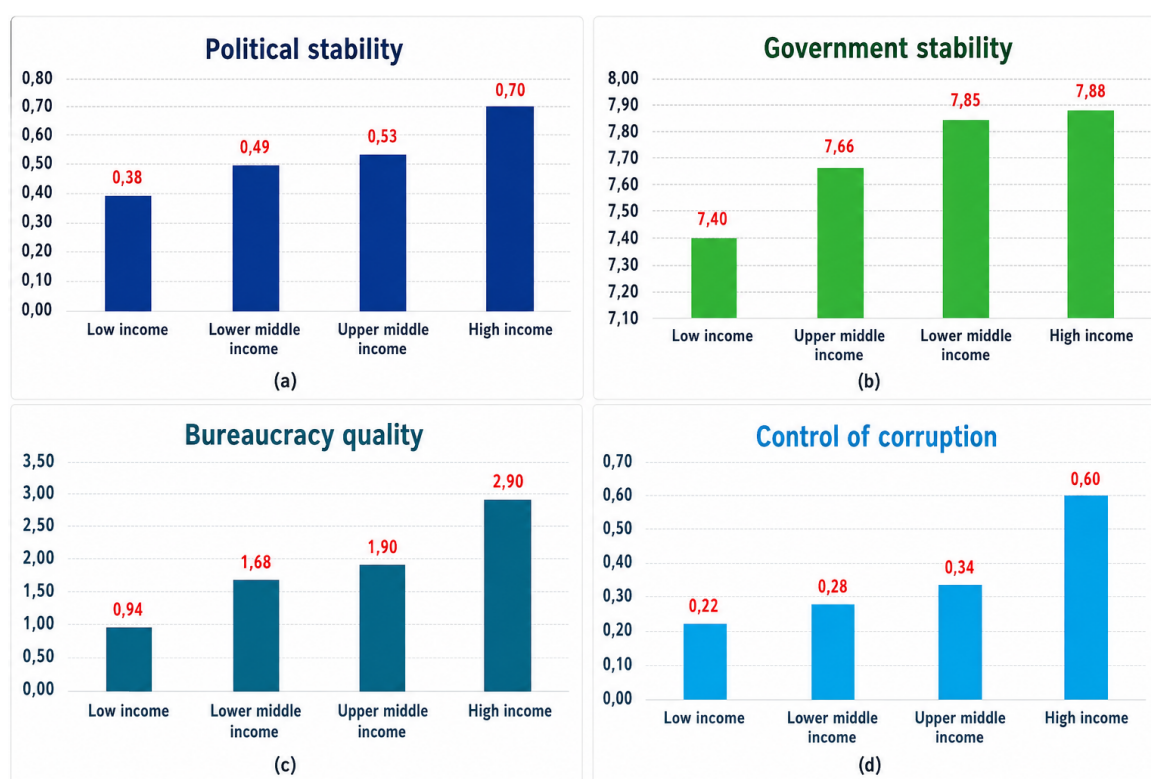
Indeed, good governance (quality institutions) actually promotes better management of resource endowments in resource-rich, high-middle-income countries; and this better management, in turn, also translates into increased well-being for countries. Therefore, for a country to maintain sustainable debt, it must be aware of the important differences between resource endowments and the deceptive lure of rents; and the complementary importance of quality institutions; and, as such, consciously manage these effectively. The issue here is that programs that try to combat corruption to some degree are not based on basic viewpoints on what causes the curse of natural resources (Kolstad and Wiig, 2009). A common issue with oil-related aid programs is the disregard for the institutions involved and corruption (Kolstad and Wiig, 2009). Some programs may even make matters worse by neglecting to specifically consider how they affect corruption and rent seeking. For example, the establishment of a multi-stakeholder committee to supervise the process is a crucial component of the EITI. The government appoints the multi-stakeholder group, which may be another opportunity for clientelism (Kolstad and Wiig, 2009). Although this initiative is beneficial for a number of countries (Kinda and Mien, 2024; Kinda and Thiombiano, 2024a; Villar and Papyrakis, 2017), there is a risk that it will increase clientelism and reduce government accountability, which would be contrary to its fundamental objective (Kasekende et al., 2016).

In addition to the institutional variables shown in Figure 2, there are other variables that act as channels through which institutions can have an impact on sustainable development. Firstly, through the rule of law (Kardos, 2012; Mombeuil, 2020). The rule of law can be defined as a system in which independent and equitable access to justice is available to all. It promotes efficient legal processes and enables good governance. Second, through the protection of natural resource property rights (Acemoglu, 2010; Bhattarai and Hammig, 2001; Redmond and Nasir, 2020). Third, through the channel of transaction costs, including the negotiation of control costs that play a role in governance. When institutional quality is low or absent, formal agreements between parties become difficult to enforce, leading to higher transaction costs

³By definition, “White elephants” signify inefficient allocation and/or redistribution of benefits of resource booms (Robinson and Torvik, 2005).

(Shirley, 2005). Finally, institutions can have an impact on sustainable development through implementation channels. A well-established institution encourages the enforcement of official rules and regulations through taxes, fines, and imprisonment. Shahzad (2020) argues that this enforcement builds financial capacity through strong tax collection, which can be used to promote the sustainable development agenda. Dietz et al. (2007) report a negative impact of corruption on SD in resource-rich economies, while Barbier (2010) finds similar results in African and Asian countries.

Figure 2: Poor quality of institutions in developing countries



Source: Author's elaboration using WGI dataset.

In summary, the literature described above, which focuses on the management of natural resource rents, highlights three important points. Firstly, countries with abundant resources are expected to enjoy greater prosperity and a faster development path than those without these precious natural assets. However, this assumption applies only to a limited number of resource-rich countries (see Hordofa et al., 2022). This means that while natural resource rents can serve as a source of public revenue for investment in economic development, they can also cause corruption, inequality, and environmental degradation if not managed effectively (Ah-

mad et al., 2023a). Secondly, the experience gained in terms of default and debt restructuring over these decades does not seem to have enabled many resource-exporting countries to avoid the sovereign debt trap. Third, the debate surrounding the curse of natural resources, over-indebtedness, limited fiscal space, and climate vulnerability has repeatedly highlighted the key role that public debt plays in moderating / amplifying the influence of natural resources on sustainable development. Furthermore, the Global Crisis Response Group (GCRG) of the United Nations has estimated that, in total, 48 countries are home to 3.3 billion people whose lives are directly affected by underinvestment in education or health due to large interest payments of the sovereign debt (see [UNDP's latest Debt Insights update](#)).

In view of these shortcomings and the current challenges highlighted in the literature, this thesis adopts a simplistic approach by analyzing the macroeconomic and environmental implications of two types of development financing instruments, namely *resource-backed loans* and *debt-for-nature swaps*, in order to enrich the policy debate on climate change, public debt, and the exploitation of natural resources in developing countries. This thesis focuses on developing countries and two main related issues, which are structured in five interconnected chapters.

0.1 Resource-backed loans and financing sustainable development

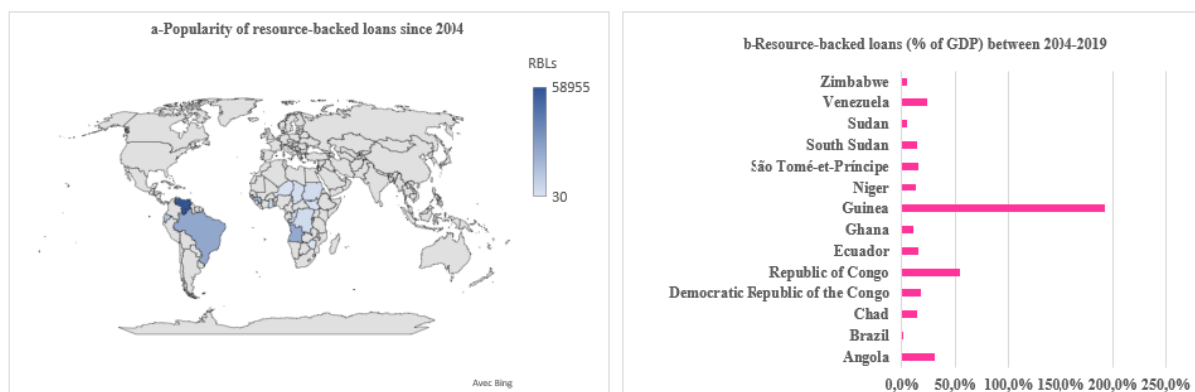
Resource-backed loans have become an alternative financing tool for resource-rich developing countries that have had difficulty mobilizing resources on financial markets over the past two decades (Coulibaly, 2024a; Coulibaly, 2025; Mihalyi et al., 2020; Mihalyi et al., 2022; Mihalyi and Scurfield, 2021; Manzano and Rigobon, 2001). Resource-backed loans became popular shortly after the resource boom at the beginning of the millennium. As Figure 3a shows, since 2004, many resource-rich developing countries have signed up for resource-backed loans. This growing popularity is probably not unrelated to the advantages of resource-backed loans, particularly in terms of their ability to act as an economic policy tool to promote the financing of economic development, for a number of reasons. First, one of the main problems facing developing countries is that investors often perceive them as presenting a high financial risk, which limits their ability to access international capital markets (Mihalyi

et al., 2022). Resource-backed loans allow this risk to be quickly overcome, providing access to funds for investment in large-scale projects (Coulibaly, 2024a). Second, the collateral nature of resource-backed loans is an advantage, since natural resources represent an asset that serves as collateral and repayment to lenders (government, public enterprise, private sector and/or international financial institutions) unlike traditional loans (Coulibaly, 2025). Third, the interest rates offered by resource-backed loans are relatively low compared to other traditional loans and offer the possibility of renegotiating in the event of repayment difficulties at maturity (Sub-Saharan Africa: fixed rates=0.25% to 2% and floating rates= 1.0% to 2.95%; Latin America: fixed rates=6.0% to 7.25% and floating rates=2.8%). Fourth, resource-backed loans are becoming increasingly popular, as this source of financing often comes without the standard conditionalities attached to multilateral and bilateral loans. This allows countries to direct funds according to their needs and economic reality.

This financing instrument is of particular interest to two regions: sub-Saharan Africa, with around 11 countries, and Latin America, with around 3 countries (see Figure 3a). In fact, African countries are the main recipients of resource-backed loans. In fact, between 2004 and 2018, 30 of the 52 resource-backed loans identified during this period in developing countries were signed by African countries, while the remaining 22 were signed by Latin American countries (Coulibaly, 2024a; Coulibaly, 2025; Mihalyi et al., 2020; Mihalyi et al., 2022). Furthermore, the structure of these 52 resource-backed loans identified in natural resources indicated that 43 of these loans were backed by oil, 6 by minerals, 2 by cocoa, and 1 by tobacco. The total amount of resource-backed loans signed during the period 2004-2018 was valued at \$164 billion, of which \$98 billion went to Latin American countries and \$66 billion to sub-Saharan African countries (see Figure 3b). These amounts are perhaps not surprising given the advantages offered by resource-backed loans, notably the low interest rate and the deferral of payment maturities in the event of a complicated public finance situation, as explained above. Guinea is Africa's largest recipient of resource-backed loans (see Figure 3b). In 2017, the country signed a \$20 billion resource-backed loan (almost 200% of the country's GDP) with a consortium of Chinese institutions. The second largest recipient of resource-backed loans in Africa is the Republic of Congo, which signed a \$1.6 billion resource-backed loan in 2006, equivalent to 21% of the country's GDP that year. Close behind was the Democratic Republic of Congo's Sicomin infrastructure agreement signed with China in 2008. The loan amounted

to 3 billion USD, equivalent to 16% of the country's GDP (Coulibaly, 2024a; Coulibaly, 2025; Mihalyi et al., 2020; Mihalyi et al., 2022). In the case of extraction rights, countries often use a natural resource already developed and in production as a source of repayment for a loan. However, other resource-backed loans are contracted with the aim of developing new assets, such as when the granting of extraction rights is an essential element of the RBL. In an ordinary transaction of this type, a company obtains a mining right and then undertakes to build a social utility infrastructure alongside the mine, in exchange for a reduction in future tax obligations on the mining operation. It should be noted that China is the country that grants the largest amount of resource-backed loans to other countries, making it the largest creditor. In terms of loan use, they are signed to finance infrastructure projects to a large extent, but not exclusively. In fact, some resource-backed loans are used to finance fiscal imbalances.

Figure 3: Resource-backed loans in developing countries from 2004 to 2019



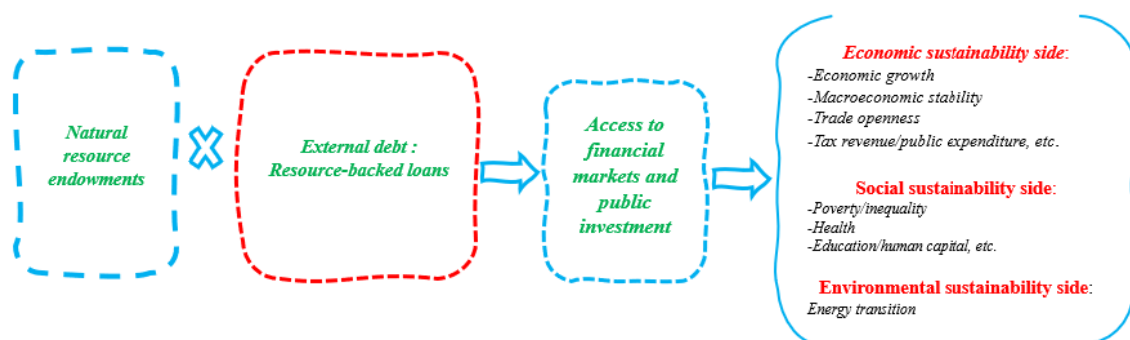
Source: Author's elaboration using NRGi dataset

How do resource-backed loans promote sustainable development?

In recent years, sustainable development (SD) has attracted considerable attention worldwide as a fundamental objective of national and international policy frameworks. The term "sustainable development" was first coined in the 1987 Brundtland Commission report and has since become a widely recognized concept that emphasizes the need to address environmental, social and economic challenges in an integrated way. The report explains that "sustainable development aims to meet the needs of the present generation without compromising the ability of future generations to meet their own needs" (Brundtland et al., 1987). This broad agenda serves as a road map towards a better, more sustainable existence for all. At the heart of Agenda

2030 by example are the 17 Sustainable Development Goals (SDGs), which are broadly related to issues such as clean and affordable energy, research and development and infrastructure, environmental degradation, strong institutions, peace and justice, decent work, and economic growth (Brundtland et al., 1987). The link between natural rent and sustainable development is a fascinating area of study that attracts significant academic interest and critical policy debate. Natural resource rents (NRR), ranging from minerals and fossil fuels to forestry and fisheries, have proven to be an integral part of some economies. As a result, countries with abundant resources are expected to enjoy greater prosperity and a faster development path than those without these precious natural assets. To achieve sustainable development, natural resources must be carefully managed to ensure that they are used in a way that benefits present and future generations (Ahmad et al., 2023b). Based on the argument that the joint effects of mineral/oil rents and debt improve well-being (Muhanji et al., 2019), we believe that resource-backed loans can promote sustainable development. As shown in Figure 4, the interaction between natural resource endowments and resource-backed loans leads to greater access to financial markets to mobilize funds and invest in public capital stock. This will result in strong economic, social and environmental sustainability. In fact, resource-backed loans, by increasing public investment, create certain benefits such as facilitating trade (through road infrastructure), boosting economic growth, and increasing the share of educated, healthy and less poor population, which are key pillars of Sustainable Development Goals. In the same vein, it is possible that the financial resources of resource-backed loans can be used to finance renewable energy sources and green projects to improve the environment and living conditions of people. In addition, resource-backed loans backed by minerals can accelerate the pace of minerals production, which may likely increase the supply of minerals that are critical to producing batteries for the energy transition. At the same time, resources from resource-backed loans could be used to finance environmental policies. Investments made by resource-backed loans can generate revenue, which in turn can increase government tax revenues essential for financing biodiversity and environmental sustainability. Although this thesis defends the idea that such loans can finance projects aimed at promoting environmental sustainability, such as conservation or restoration initiatives, it must be recognized that using natural resources as collateral for loans can lead to over-exploitation and environmental deterioration, which runs counter to the principles of sustainable development.

Figure 4: Channels transmission of resource-backed loans to sustainable development



Source: Author's elaboration

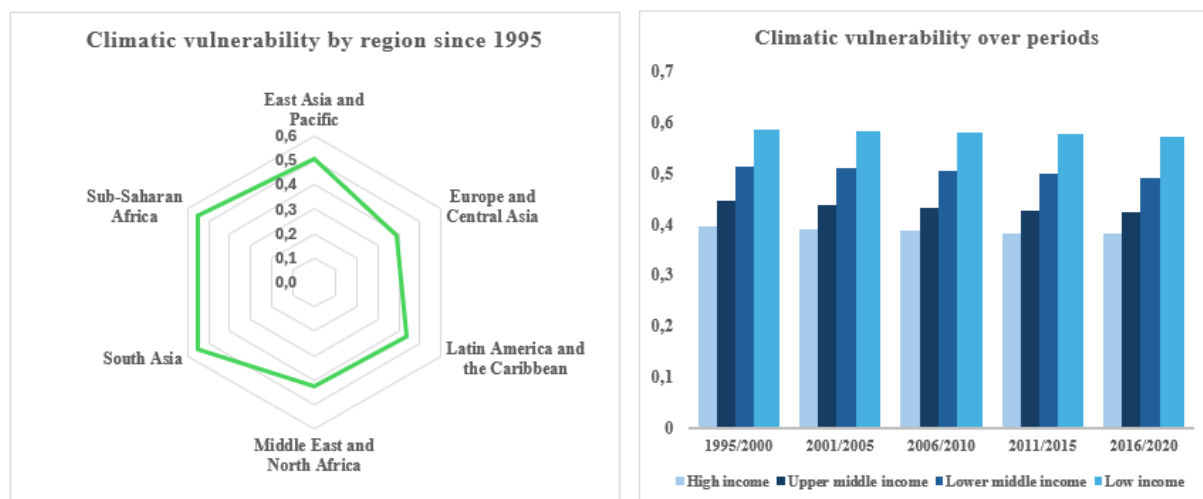
0.2 Debt-for-nature swaps and financing sustainable development

Climate change poses a considerable threat to the macroeconomic and financial stability of countries, as well as to the development efforts of emerging and low-income economies. The ability of these economies to adapt is closely linked to their fiscal capacity and the cost of doing so. Countries with a high fiscal capacity are better placed to implement effective mitigation and adaptation strategies (Cevik and Jalles, 2022 and Cevik and Jalles, 2023). In contrast, the limited fiscal capacity prevalent in emerging markets and low-income developing economies is an obstacle to their adaptation efforts, amplifying their vulnerability to climate change, a vulnerability that exceeds that of advanced economies (Bolton et al., 2022; Cevik and Jalles, 2023). For illustration, Figure 5 shows that the East Asia and Pacific, South Asia and Sub-Saharan Africa regions have been the most vulnerable to climate change since 1995. This climate vulnerability is more pronounced in low-income countries than in their high-income peers. Concerning the debt situation, their level of public debt in 2021 was higher than before the Covid-19 crisis: 49.6% of GDP for low-income countries and 66.1% for middle-income countries, compared with 43.5% and 54.6% in 2019, respectively (IMF, 2022). In a recent report, UNDP (2025) estimates that by 2024, 26 developing countries had total payments on public and publicly guaranteed debt in excess of 20% of total government revenues. The same report indicates that the average low-income country spends 2.3 times more on net interest payments than on social welfare, 1.4 times more than on national health spending or 60% of what it spends on education. Despite the progress made in recent years in terms of domestic resource

mobilization in developing countries, on average tax revenues as a proportion of GDP are still relatively lower compared to developed countries (see Figure 6). They represent around 15% of GDP on average in emerging markets and developing economies, compared to almost 25% of GDP in developed countries (see Figure 6, making it urgent to build the capacity to "*mobilize additional financial resources for developing countries from multiple sources*" to achieve sustainable development as suggested by the 17.3 SDG objective. This figure clearly shows that developing countries lack the budgetary space to face the major challenges they face, which continue to grow. In line with Besley and Persson (2013), we define fiscal capacity as the amount of tax that any government could potentially raise given its available tax system structure and enforcement power. This low fiscal capacity observed in developing countries exacerbates the sustainability of public debt and compromises the challenges of climate financing in developing countries. So, in the face of these many challenges, many environmentalists have proposed "debt-for-nature swaps" as a solution to both problems.

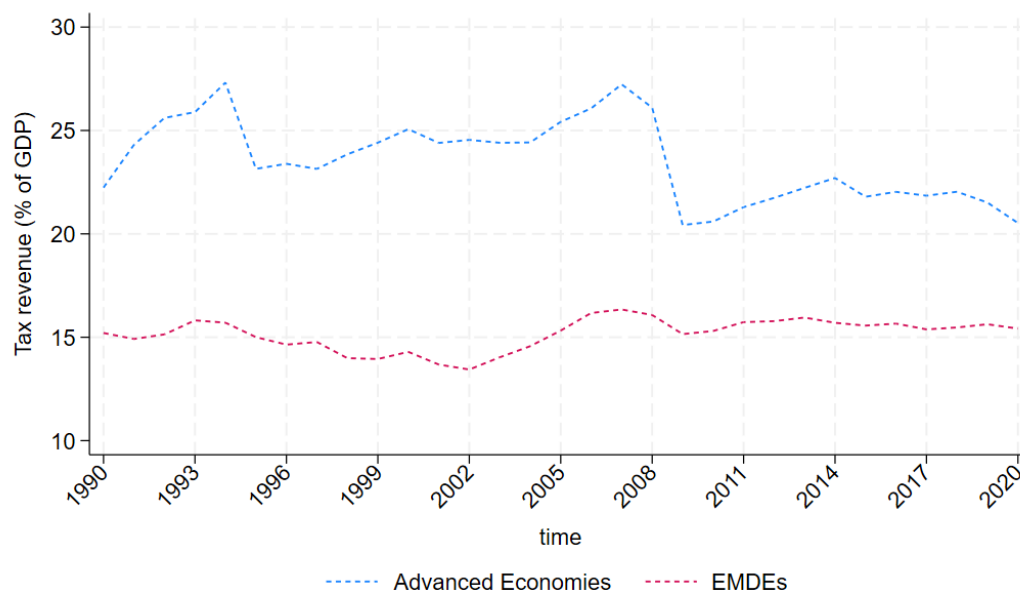
Basically, a debt-for-nature swap is defined as the exchange of a debtor country's external obligation for the agreement of that country to use the debt service to support a specific environmental project, such as the designation and management of protected areas, the development of conservation management plans, the training of park staff and environmental education activities (Occhiolini, 1990; Sheikh, 2010). Debt-for-nature swaps are not new financial instruments; they have been around since the Latin American debt crisis and are gaining ground after a decline in the number of agreements in the 2000s (see the discussion in Simeth, 2025; d Chamon et al., 2022). In April 2021, Kristalina Georgieva, Managing Director of the International Monetary Fund (IMF), announced that the IMF and World Bank planned to develop a joint framework to guide low-income countries in financing climate and conservation initiatives. The major multilateral development banks and the IMF announced their intention to expand debt-for-nature swaps. According to Barclays, the debt-for-nature swap market is set to exceed 800 billion dollars (White, 2023). Recently, countries such as Belize in 2021, Barbados in 2022, Ecuador, and Gabon in 2023 have announced debt-for-nature swaps. Among these countries, Ecuador announced the world's largest debt-for-nature swap, buying back around 1.6 billion dollars of debt at a discount of almost 60% (Jiang and Cao, 2024).

Figure 5: Climate vulnerability in developing countries from 1995 to 2020



Source: Author's elaboration

Figure 6: Trends in fiscal capacity by level of development



Source: Author's elaboration

Principles and implementation of debt-for-nature swaps

There are two types of debt-for-nature swaps namely bilateral and multilateral (Sommer et al., 2020). The main idea of a bilateral debt-for-nature swap is to reduce the debt of a low- or middle-income country in exchange for investments by that country in environmental conservation and protection (Hamlin, 1989). To implement it, the creditor country cancels or waives a certain portion of the foreign debt owed, and the debtor country commits to an environmental project. Eligibility for a bilateral debt-for-nature swap depends on, but is not limited to, the level of the country's debt. In fact, there are various economic, political and environmental requirements that a country must meet to participate in a bilateral debt-for-nature swap (Sheikh, 2010). In terms of economic requirements, a debtor government must have unsustainable public debt and show progress in implementing reforms involving an International Monetary Fund (IMF) or World Bank (WB) structural adjustment agreement. In the political sphere, a debtor country must have a democratically elected government and demonstrate its commitment to guaranteeing human rights. Finally, in the environmental field, an indebted nation must meet certain environmental criteria, including the existence of at least one tropical forest with substantial biodiversity, or a forest representing a large block of intact forest on a regional, continental or global scale. According to Sheikh (2010), the most important environmental requirement is the urgency of the demand, which relates to threats to biodiversity in the area to be protected. Concerning a multilateral swap, a debt repurchase (often below par) is carried out on secondary debt markets (Cassimon et al., 2011; Fresnillo, 2023; Grund and Fontana, 2023). This type of swap involves one or more third parties, such as non-governmental organizations (NGOs), facilitating the transaction (Fresnillo, 2023; Grund and Fontana, 2023). According to d Chamon et al. (2022), the process of a multilateral debt-for-nature swap can be described in five stages. First, the process begins with an NGO raising funds from ESG investors. Second, a Special Purpose Vehicle (SPV) is created, in which its activities are generally limited to this transaction, with the sole aim of facilitating the transaction. Third, financing "blue bond" is lent to the SPV, which acts as a "blue loan lender" and makes a loan to the debtor government. Fourth, the debtor government then uses the funds to redeem its existing bonds. Finally, the debtor government's debt service payments are paid back to the SPV, then to the NGO, and to the investors who provided the initial financing (see d Chamon et al., 2022). Overall, the process of implementing debt-for-nature swaps can in-

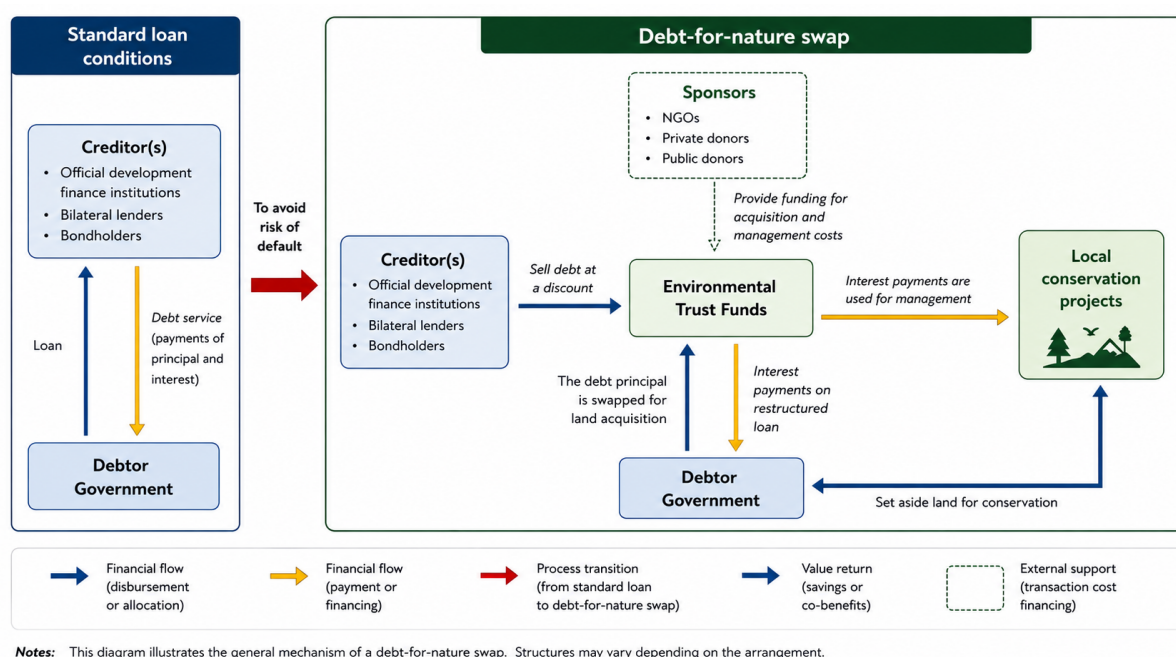
involve several players, with the aim of facilitating the operation and limiting potential risks. As shown in Figure 7, sponsors intervene between creditor and debtor countries in the interest of reducing the cost of debt through a repurchase operation, and putting the debtor country in a comfortable position to reduce its debt. The advantage of this operation for the debtor government is that the amount it has to repay is now lower than it would have been without the debt buyback. The debtor government undertakes to devote part of the savings generated by the transaction to conservation activities. However, while many studies have shown the effectiveness of debt-for-nature swaps in improving nature conservation outcomes, such as reducing forest loss (see Sommer et al., 2020), studies also highlight the challenges associated with applying debt-for-nature swaps (Bird, 1988; Essers et al., 2021; Nedopil et al., 2024), such as the complexity of debt-for-nature swaps operations, which involves many stakeholders and lengthens the time required to implement debt-for-nature swaps.

Does debt-for-nature swap promotes sustainable development and fiscal discipline?

The question of whether debt-for-nature swaps promote sustainable development and fiscal discipline remains unanswered. Some studies estimate that, beyond the simple and already impressive debt reduction for developing countries (Cassimon et al., 2011; Gockel and Gray, 2011; Heller, 2005; Krugman, 1988; Nedopil et al., 2024), these financial instruments also play a truly crucial role in promoting not only nature conservation, but above all in protecting fragile biodiversity that deserves our attention and efforts (Sheikh, 2010; Sommer et al., 2020). These advantages of debt-for-nature swaps have attracted the attention of many authors, who are calling for the program to be extended to several countries (Caliari, 2020; Essers et al., 2021; Volz et al., 2021). For example, using a two-stage instrumental variable regression model to analyze a sample of 85 low- and middle-income countries from 2001 to 2014, Sommer et al. (2020) found that debt-for-nature reduced the loss of vegetation cover. In fact, these innovative financial instruments also make a substantial contribution to the mitigation of climate change, by encouraging the implementation of highly targeted projects dedicated to carbon sequestration, as well as other sustainable development initiatives aimed at preserving our precious environment for future generations. With these financial mechanisms, which are well designed and adapted to the local realities of the countries concerned, debt-for-nature

swaps thus make it possible to encourage more sustainable and responsible management of natural resources. However, some studies believe that debt-for-nature swaps have no budgetary or environmental impact (Cassimon et al., 2011; Hansen, 1989) due to their small size (d Chamon et al., 2022), lack of control of the debtor government over environmental measures (Jha and Schatan, 2001). According to Krugman (1988), the debt-for-nature swaps have no significant effect, raising questions about the effectiveness of these financial instruments. For Sheikh, 2010, debt-for-nature swaps are not effective in achieving their dual objectives due to the weakness of the institutions of the beneficiary countries. Given the current climate and debt crisis in developing countries and the ambiguous effect of debt-for-nature swaps, a closer look at this financial instrument is needed to promote the sustainability of public debt and the environment.

Figure 7: Conceptual representation of debt-for-nature swap mechanisms



Source: Author's elaboration

0.3 Outline of thesis

According to the 2030 Sustainable Development Agenda of the United Nations, financing has a direct impact on sustainable development and the achievement of the SDGs (United Nations, 2015). "Sustainable debt financing is an important element for mobilizing resources for

public and private investment", according to the Monterrey consensus of 2002. As developing countries grapple with a number of issues, including mobilizing domestic revenue (Coulibaly and Camara, 2022a), attracting sufficient productive investment (Boly et al., 2019), building human capacity, stopping capital flight, and preventing illicit capital flows (Combes et al., 2021; Kar and Spanjers, 2015), they must mobilize external funds to improve fiscal space for optimal financing of public goods in the pursuit of economic growth, poverty eradication, and sustainable development (Coulibaly and Camara, 2022a; United Nations, 2015). Another big problem facing developing countries is that donors perceive them as high financial risk countries; thus limiting their ability to better mobilize funds on financial markets to finance sustainable development. Consequently, resource-backed loans are an effective response to these problems, enabling developing countries with a wealth of natural resources to access financial markets to raise funds to finance sustainable development. This thesis addresses the political challenges, economic and environmental risks, and opportunities of this financing instrument, which is seen as an essential tool to eradicate poverty and achieve sustainable development. On the economic and social side, we link our thoughts with the vast studies that have investigated the determinants of the human development index in developing countries (e.g. Lamb et al., 2014; Jeffrey et al., 2016; Hickel, 2020; Anand and Sen, 1994; Kelley, 1991; UNDP, 1992; Gough, 2015; Sagar and Najam, 1998; Ramanathan, 1999; Desai, 1995; Neumayer, 2001; Morse, 2003; Pelenc et al., 2016; Hirai, 2017; Togtokh and Gaffney, 2010; Bravo, 2014; Türe, 2013; Biggeri and Mauro, 2018). We contribute to this literature in several ways. First, we examine the causal effect of resource-backed loans on the human development index (in particular in Chapter 1). To better capture these effects, we use as outcome variables the ecological impact adjusted human development index constructed by Hickel (2020). This variable best reflects the goals of sustainable development, as it divides human development by a composite measure of ecological impact that integrates the two key indicators: per capita CO₂ emissions and per capita material footprint (Hickel, 2020). Second, we extend the literature by exploring both the heterogeneity and interactive effects of different types of resource-based lending on the dependent variable. In doing so, we reveal important differences between oil-backed loans, mineral-backed loans, tobacco-backed loans, and cocoa-backed loans.

However, countries must not lose sight of environmental issues in their economic development. The environmental risks to which countries are exposed by signing up for these

resource-backed loans need to be closely analyzed. As these loans are repaid with natural resources, they could accelerate the rate of exploitation of natural resources and cause major environmental damage (deforestation). Relying on the popular literature on the determinants of deforestation in developing countries (see, e.g. Hirons, 2013; Kinda and Thiombiano, 2024a; Bridge, 2004; Sonter et al., 2018; Hosonuma et al., 2012; Kinda and Thiombiano, 2021; Siqueira-Gay et al., 2020; Ranjan, 2019; Brusseau and Artiola, 2019; Pepper et al., 2011; Evangelinos and Oku, 2006; Motel et al., 2009; Benhin and Barbier, 2004; Combes et al., 2018b), the novelty of this thesis lies in assessing the risks of natural resource-backed loans on forest cover in developing countries (Chapter 2). In fact, analyzing the ways in which resource-backed loans promote deforestation is an important issue in developing countries for two main reasons. First, there is a formal agreement in resource-backed loan agreements to repay lenders via the exploitation of natural resources (see the discussion in Mihalyi et al., 2022; Coulibaly, 2025), which would put implicit pressure on debtor countries to over-exploit natural resources; an activity presenting great environmental risk. Second, deforestation is now recognized as the main cause of climate change (Gatti et al., 2021), threatening the conservation of biodiversity and promoting the spread of infectious diseases that damage human health and the economy in developing countries (FAO, 2022; Santos and Almeida, 2018).

It is increasingly being argued that most of the countries that have signed up to resource-backed loans are in difficulty with their public finances, i.e. in a situation of debt overload (see, e.g. Mihalyi et al., 2020; Mihalyi et al., 2022). This means that resource-backed loans could compromise fiscal sustainability, reduce economic growth, and weaken the government's capacity to finance sustainable development if debt is too high. Several strands of the literature aim to assess the consequences of high public debt ratios. For example, Reinhart and Rogoff (2010) and Cecchetti et al. (2011), among others, highlight the possibility of a high public debt threshold in relation to economic growth. In the same vein, for example, Ilzetzki et al. (2013) and Nickel and Tudyka (2014), reveal lower fiscal multipliers above a certain public debt/GDP ratio. In developing countries, several other arguments have been put forward to explain the procyclical nature of fiscal policy (Kaminsky et al., 2004). For example, Gavin and Perotti (1997) argue that procyclical fiscal policies result from tighter debt constraints during recessions. Borrowing limits in a recession force restrictive policies; when limits are relaxed in an expansion, policies tend to be expansionary. Some economists point the finger at dysfunc-

tional political systems in developing countries as being responsible for procyclical policies (see, e.g. Lane and Tornell, 1998; Tornell and Lane, 1999). In addition, other studies closer to our own have shown that natural resource endowments are one of the sources of procyclicality of public debt (Stiglitz, 2005), and that the mechanisms by which natural resource endowments affect the cyclicity of public debt are based on the collateral aspect of natural resources (Brundtland et al., 1987). We contribute to this radiant literature by analyzing the impact of resource-backed loans on the cyclicity of fiscal policy in developing countries (Chapter 3). The SDGs constitute a set of 17 integrated and indivisible goals that promote progress towards the social, economic, and environmental dimensions of sustainable development (SD). According to its goal 17.4, developed nations are encouraged to *"assist developing countries in attaining long-term debt sustainability through coordinated policies aimed at fostering debt financing, debt relief and debt restructuring as appropriate, and address the external debt of highly indebted poor countries to reduce debt distress"*⁴. In order to reduce poverty, achieve sustained economic growth and promote fiscal discipline and sustainable development, debt relief programs such as debt-for-nature are an effective solution, in which a country's debt is reduced in exchange for the commitment to devote a portion of the reduction to environmental protection (AfDB, 2022; d Chamon et al., 2022; Essers et al., 2021; Paul et al., 2023; Sommer et al., 2020). As a result, this thesis addresses the issue of "debt sustainability" in the second part, through the debt-for-nature swap initiative, analyzed in two chapters. We analyze the impact of debt-for-nature swaps on fiscal discipline (Chapter 4). Finally, we evaluate the impact of debt-for-nature swaps on the ecological efficiency of human development (Chapter 5).

0.4 Contributions and main results of thesis

This thesis studies the macroeconomic and environmental impacts of the fiscal policy of debt and natural resource management, in particular resource-backed loans and debt-for-nature swaps, and how they affect the performance of the economy. So, the thesis makes a variety of contributions to the economic literature, public finance specialists, policy makers, national and international organizations, and NGOs in terms of analysis, recommendations, and guidance on the economic and environmental implications of external debt and natural

⁴https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf.

resources for achieving sustainable development goals. As mentioned above, the thesis is divided into five chapters.

In Chapter 1, we investigate the impact of resource-backed loans on the ecological efficiency of human development in African countries. Given the financial challenges faced by many resource-rich African countries, including high default risks and limited access to financial markets, RBLs have emerged as a viable financing option for infrastructure and sustainable development projects. We show that overall resource-backed loans have a positive and statistically significant impact on ecological efficiency in human development in a sample of 45 countries from 1990 to 2019. The use of the entropy balancing method strengthens the causal claims of the analysis. When disaggregating the types of resource-backed loans, the study finds that oil and mineral-backed loans contribute positively to ecological efficiency. In contrast, loans tied to cocoa and tobacco appear to have a detrimental effect, highlighting the importance of including environmental considerations in loan agreements. The findings suggest that RBLs can facilitate significant public investments in sectors such as infrastructure, education, and healthcare, which, in turn, can enhance indicators of sustainable development measured by ecological efficiency. The positive impacts are attributed to improvements in education levels and economic indicators such as Gross National Income (GNI) per capita. We strongly advise politicians to include ecological clauses in RBL agreements and to prioritize sustainable public spending in order to minimize any potential negative environmental effects.

Then Chapter 2 moves to the analysis of the effect of resource-backed loans on deforestation in developing countries. The study discusses how RBLs can exacerbate the exploitation of natural resources, increasing pressure on forests as countries seek to generate revenue for loan repayment. In a large panel of 64 developing countries, propensity score matching estimates reveal that RBLs significantly increase deforestation, particularly from mineral, tobacco, and cocoa-backed loans, while oil-backed loans do not show a significant effect. We emphasize the need for policy frameworks that incorporate environmental protection measures in RBL agreements to mitigate their adverse effects on deforestation and promote sustainable development goals.

Chapter 3 revisits the literature according to which the endowment of natural resources is considered one of the sources of the procyclical nature of public debt. According to this liter-

ature, the mechanism by which natural resource endowments affect the cyclicity of public debt is based on the collateral aspect of natural resources. Starting from the observation that most loans in resource-rich countries are secured by the supply of raw materials, we defend the hypothesis that natural resources affect the reaction of public debt to cyclical fluctuations. Although the literature has examined the determinants of cyclicity in public debt, little is yet known about the role of natural resources in the cyclical response of public debt. This analysis explores the relationship between resource-backed loans and fiscal cyclicity in developing countries, with the aim of filling a gap in the existing literature on the impact of such loans on fiscal policy. The analysis uses a large panel dataset of 127 developing countries from 1990 to 2020 and the entropy balancing method, examining the fiscal policy reactions in countries that utilized RBLs compared to those that did not. The study also employs various statistical techniques to analyze the effects of resource-backed loans on fiscal cyclicity while controlling for institutional quality and macroeconomic conditions. Our results reveal that fiscal policy tends to be countercyclical in countries without RBLs, while it becomes procyclical in countries that rely on these loans. Another result highlighted in this analysis is that RBLs significantly increase fiscal policy volatility and can lead to unfavorable fiscal outcomes, particularly in countries with weak governance structures.

Chapter 4 evaluates the causal effect of debt-for-nature swaps (DNS) on fiscal policy volatility using propensity score matching. Firstly, this study takes into account the problem of self-selection in the implementation of a debt-for-nature swaps program. Secondly, our analysis is more comprehensive, taking into account the two main debt-for-nature swaps: bilateral and multilateral. Third, we use a control function regression approach to analyze the heterogeneity of treatment effects on fiscal policy volatility as a function of country structural factors. Using a sample of 134 developing countries (39 DNS countries and 95 non-DNS countries) over the period 1990-2019 and propensity score matching, the results show that these debt-for-nature swaps not only have positive effects on environmental sustainability as shown in the related literature, but also bring immediate economic benefits by reducing fiscal pressures. We argue that reducing or canceling public debt through these swaps enhances fiscal space, allowing countries to increase public investment without jeopardizing their economic stability. We believe that debt-for-nature swaps can diminish fiscal policy volatility, creating a more robust financial environment,, and call for its extension in developing countries.

Furthermore, we investigate the effectiveness of debt-for-nature swaps as a tool to achieve sustainable development in developing countries in Chapter 5, using the entropy balancing method. The advantages of the debt-for-nature mechanism lie in the fact that it offers developing countries a way to reduce their foreign debt while promoting environmental conservation. It also supports sustainable development by encouraging governments to adopt responsible environmental policies. However, these views do not seem to be shared by all. Some authors believe that debt-for-nature swaps have limitations, notably the risk of diverting financial resources from basic social needs, such as education and health, to nature conservation projects. In addition, the implementation of debt-for-nature swaps can be complex due to the difficulty in measuring the concrete impact of debt-financed environmental projects. This chapter attempts to settle this fascinating debate by analyzing the causal effect of debt-for-nature swaps on the ecological efficiency index of human development in 127 developing countries over the period 1990 to 2020. The results indicate that the countries that adopted debt-for-nature swaps experienced a significant increase in their ecological efficiency of human development indices. In addition, we use endogenous switching regression models for counterfactual analysis. The results show that if these countries had not benefited from the debt-for-nature swaps, their ecological efficiency of human development indices would have fallen by 11%, while the untreated countries could have experienced an increase of 2% if they had participated in the debt-for-nature swap program. To improve the effectiveness of the debt-for-nature swap mechanism, it is recommended to encourage transparency and accountability among stakeholders, notably by establishing rigorous monitoring and evaluation mechanisms. In addition, it is essential to strengthen the capacities of borrowing countries, particularly in terms of natural resource management, so that they can better negotiate debt conditions (by easing eligibility requirements). In addition, it would be beneficial to explore the possibility of incorporating positive financial incentives for debtor countries that achieve conservation objectives of nature. Finally, in the future, it will be crucial to develop policies and international agreements that promote a more balanced and equitable approach to debt management in exchange for nature.

Finally, we conclude, draw some policy recommendations, and suggest some areas in which future research is needed ([General Conclusion](#)).

RESOURCE-BACKED LOANS AND ECOLOGICAL EFFICIENCY OF HUMAN DEVELOPMENT: EVIDENCE FROM AFRICAN COUNTRIES

Abstract¹: Budgetary pressures caused by defaults and economic recessions, combined with difficulties in accessing financial markets, which are often triggered by a series of restructurings and defaults of sovereign debt, and have led some resource-rich African countries to turn to resource-backed loans to finance infrastructure projects to achieve long-term sustainable development goals. In this chapter, we use the entropy balancing method to test whether resource-backed loans have a causal impact on the ecological efficiency of human development in African economies. With a series of robustness checks, the estimation results indicate that resource-backed loans have a positive and statistically significant impact on the ecological efficiency of human development. Nonetheless, when resource-backed loans are disaggregated to run the regressions, we find that oil-backed loans and minerals resource-backed loans increase ecological efficiency of human development while cocoa and tobacco resource-backed loans are negatively associated to ecological efficiency of human development. The main findings of the study suggest that resource-backed loans agreements in general, and cocoa and tobacco in particular, should include strict clean development provisions and the implementation of actions to mitigate the negative environmental impact of these loans for borrowing countries.

Keywords: • Resource-backed loans • Environment • Entropy balancing.

JEL Codes: O13, Q43, Q54, H63.

¹An earlier version of this chapter is published in *Ecological Economics*

1.1 Introduction

Resource-backed loans (RBL) have emerged as an alternative financing tool for resource-rich developing countries that find it difficult to mobilize resources on the financial markets to finance their economic development due to their high financial risks (Coulibaly, 2023b; Wang et al., 2023; Mihalyi et al., 2020; Mihalyi et al., 2022)². To benefit from this type of loan, the debtor country must necessarily have natural resources. In fact, in the clauses of these loans, natural resources represent an asset that serves as collateral, and repayment to lenders (government, public enterprise, private sector, and/or international financial institutions) can be made using the income stream from natural resources or using the natural resources as payment in kind (Coulibaly, 2023b; Mihalyi et al., 2020; Mihalyi et al., 2022).

Latin American and sub-Saharan African countries are the main signatories of these resource-backed loans, but African countries are the main beneficiaries of resource-backed loans³. By way of illustration, from 2004 to 2018, 30 of the 52 resource-backed loans identified during this period in these two regions were signed by African countries, while the remaining 22 were signed by Latin American countries (Coulibaly, 2023b; Mihalyi et al., 2020; Mihalyi et al., 2022). By financing large-scale projects, resource-backed loans can improve the well-being of the populations concerned and thus affect the ecological efficiency of human development. This is the case, for example, with the Sicomines agreement in the DRC, which lists 25 major projects (road, rail and health), and the various road and health projects in Guinea, as well as the construction of a university (Mihalyi et al., 2020; Mihalyi et al., 2022). A great deal of funding has been provided in the energy sector. For example, the Bui dam in Ghana, the rural electrification programme in Zimbabwe and numerous hydroelectric dams. A road project in Southern Sudan and a housing project in Angola complete the list (see, for instance, Mihalyi et al., 2020). In fact, resource-backed loans, by increasing public investment, create certain benefits such as in facilitating trade (through road infrastructure), boosting GDP, increasing the share of educated, healthy and less poor population which are key pillars of Sustainable Devel-

²These are countries that have defaulted on their sovereign debt and have undergone a series of sovereign debt restructurings.

³These countries are : Angola, Brazil, Chad, Democratic Republic of Congo, Ecuador, Ghana, Guinea, Niger, Republic of Congo, Sao Tome and Principe, Sudan, South Sudan, Venezuela, and Zimbabwe (see, Coulibaly, 2023b; Coulibaly et al., 2022; Mihalyi et al., 2020).

opment Goals. Consequently, resource-backed loans will end up affecting ecological efficiency and human development. In the same vein, it is possible that the financial resources from resource-backed loans can be used to finance renewable energy sources and green projects to improve the environment, and people's living conditions, which will have a positive impact on ecological efficiency and human development. In addition, resource-backed loans backed by minerals can accelerate the pace of minerals production which may likely increase the supply of minerals that are critical to produce batteries for energy transition. In the same vein, it is possible that resources from resource-backed loans could be used to finance environmental policies.

However, the collapse in commodity prices could increase the nominal amount of resource-backed loans already signed (Mihalyi et al., 2020; Mihalyi et al., 2022; Coulibaly, 2023b), as these are usually contracted in U.S. dollars and consequently cause borrowing countries to overexploit natural resources to repay the loans. As a result, resource-backed loans could affect the country's ecological efficiency by accelerating hydrocarbon production. Indeed, repayment of the resource-backed loans could lead the government either to begin exploiting oil resources or to accelerate the rate of production of minerals and hydrocarbons in order to meet the repayment schedule. This could accelerate the rate of depletion of natural resources and increase greenhouse gas emissions in the country, as fossil fuels are responsible for 73% of global greenhouse gas emissions (UN, 2021). This will lead to a deterioration in the ecological efficiency of human development. In the same vein, debt repayment is likely to lead to government budget cuts in environmental spending, adversely affecting environmental quality (Gullison and Losos, 1993). Similarly, by accelerating the loss of forest cover, resource-backed loans could affect ecological efficiency through CO₂ and greenhouse gas emissions, as forests are known for their carbon sequestration. Resource-backed loans may also jeopardize the public debt situation (Horn et al., 2021), and prevent countries from mobilizing financial resources to fund sustainable development policies, as unsustainable public debt reduces fiscal space and weakens national capacity to respond to climate change and environmental problems combined with inequality, poverty and food insecurity. Given that resources-backed loans offer a wide range of public policies, they can have a negative impact on environmental sustainability, as public policies have a significant negative impact on deforestation (Motel et al., 2009). They can have a negative impact on ecological sustainability by intensifying the extraction activ-

ities of mining and oil companies. In fact, it has been shown that the activities of extractive industries cause great damage to the forest landscape (Hirons, 2013; Kinda and Thiombiano, 2021).

Theoretically, the environmental impact of resource-backed loans is somewhat ambiguous. Although there are a handful of studies on the impact of public debt on the environment (Boly et al., 2022; Bese, 2021; Fodha and Seegmuller, 2014; Culas, 2006), the literature is still silent on the impact of resource-backed loans on the ecological efficiency of human development, while the ecological and environmental impact of resource-backed loans could be different from the ecological and environmental impact of other types of public debt. In practice, the mechanism by which natural resource-backed loans affect ecological efficiency is different from those by which other non-resource-related public debt affects the ecological efficiency of human development. In fact, resource-backed loans put implicit pressure on the borrowing country to undertake fossil fuel production, an activity associated with significant ecological and environmental risks, whereas with other types of loans there are no constraints and no formal obligation on the government to exploit natural resources to repay the loans. Furthermore, due to the lack of transparency around resource-backed loans (Coulibaly, 2023b; Horn et al., 2021; Rivetti, 2021; Mihalyi et al., 2020; Mihalyi et al., 2022), previous studies on the impact of public debt on the ecological efficiency of human development in developing countries may not take into account the ecological and environmental impact of resource-backed loans, as resource-backed loans may not be reflected in public debt statistics (Coulibaly, 2023b; Horn et al., 2021; Rivetti, 2021; Mihalyi et al., 2020; Mihalyi et al., 2022). In this context, the purpose of this study is to fill this gap in the economic literature by analyzing the impact of resource-backed loans on the human development index measured by the ecological efficiency of human development in African countries to enrich the political debate on climate change, public debt, and the exploitation of natural resources.

We took interest in the human development index measured by the ecological efficiency of human development constructed by Hickel (2020). The purpose of using this index is to integrate both human development and ecological impact. Unlike other development indices, such as the one developed by the index Kovacevic et al. (2010) and Hickel (2020) illustrates how and when it comes to development in the 21st century, poor nations are the «easy» part. This means that it is possible for poor countries to achieve high levels of human development

with sustainable levels of ecological impact, and this, for example, can be done by investing in universal social goods.

The fact is that sub-Saharan African countries are now suffering disproportionately from the negative impacts of climate change and environmental degradation, with significant costs to economies and livelihood systems; climate change is now beginning to reverse key development indicators in some regions as agricultural yields decline and hunger rates increase (Hickel, 2020). In this regard, HDI embodies a contradiction in which the process of generating high levels of development in some countries curbs development or even leads to underdevelopment in others. According to Hickel (2020), a development indicator that claims to be universal, such a contradiction is indefensible. In fact, the idea is that any ecologically rational vision of human development must respect the principle of planetary boundaries. In other words, resources must be mobilized to enhance human development, but without violating the parameters of ecological sustainability, as recommended by Raworth (2012) and Raworth (2017). The aim is to achieve both human development and ecological sustainability. Given that the Sustainable Development Index (SDI) developed by Hickel (2020) addresses these concerns by focusing on the ecological efficiency of nations in achieving human development, this article examines the link between this variable and resource-backed loans in African countries.

To identify the causal effect of resource-backed loans on the ecological efficiency of human development, we rely on entropy balancing, an impact analysis method developed by Hainmueller (2012). Using a sample of 45 African countries during the period 1990-2019, we show that the adoption of resource-backed loans increases the ecological efficiency of human development in countries with resource-backed loans, relative to countries without resource-backed loans. Moreover, we emphasize that this finding is robust to a wide set of specifications, including a placebo test, adding several additional control variables, modifying the sample design, and using alternative estimation methods such as propensity score matching, Difference-in-Difference, panel fixed effects, IV-2SLS, and system-GMM estimator. Analysis of transmission channels shows that the positive effect of resource-backed loans on ecological efficiency of human development is mediated by education level, GNI per capita, expected years of schooling. The possible explanation for this result is that public investments (housing, roads, schools, hospitals, dams, etc.) made by RBLs will boost GDP and GNI, human capital through the level of education and the expected years of schooling, which in turn improve

the sustainable development index measured by ecological efficiency of human development. However, heterogeneity tests show that the impact of resource-backed loans can depend on the type of resource-backed loans, public debt level, implementation of EITI and certain structural factors, in particular, government effectiveness, interest on debt, urban population, fiscal discipline, and abundant natural resources.

The rest of the chapter is organized as follows. Section 1.2 reports some stylized facts. Section 1.3 reviews previous studies. Then, Section 1.4 describes the empirical methodology, while Section 1.5 presents the data and descriptive statistics. The main results are presented in Section 1.6, while in Sections 1.7 and 1.8, we examine the sensitivity of these results and analyze the possible transmission channels. Section 1.9 explores heterogeneity tests. Finally, Section 1.10 concludes the study and presents the main policy recommendations.

1.2 Stylized facts

Before performing the main analysis, it is instructive to look at some stylized facts on the link between ecological efficiency of human development and resource-backed loans. To do this, we begin by analyzing some statistics on resource-backed loans in Africa. Thus, looking at the composition of the 52 loans backed by natural resources listed by Mihalyi et al. (2020) and Mihalyi et al. (2022), 43 were backed by oil, 6 by minerals, 2 by cocoa, and 1 by tobacco. The total amount of resource-backed loans underwritten between 2004 and 2018 was valued at \$164 billion, of which \$98 billion went to Latin American countries and \$66 billion to sub-Saharan African countries. It should be noted that Guinea is Africa's largest recipient of resource-backed loans over the last few decades after Angola (see Fig. 1.1a). In 2017, the country signed a \$20 billion resource-backed loan (almost 200% of the country's GDP) with a consortium of Chinese institutions. The Republic of Congo is the second largest recipient of resource-backed loans in Africa, having signed a resource-backed loan of \$1.6 billion in 2006, equivalent to 21% of the country's GDP that year. The Sicomines infrastructure agreement signed by the Democratic Republic of Congo with China in 2008 follows closely behind. The loan amounted to \$3 billion, equivalent to 16% of the country's GDP (Coulibaly, 2023b; Mihalyi et al., 2020; Mihalyi et al., 2022). The unconditional correlation between the two variables (see the Appendix, Table A11) is positive and significant at the 1% level. Next, we compare the

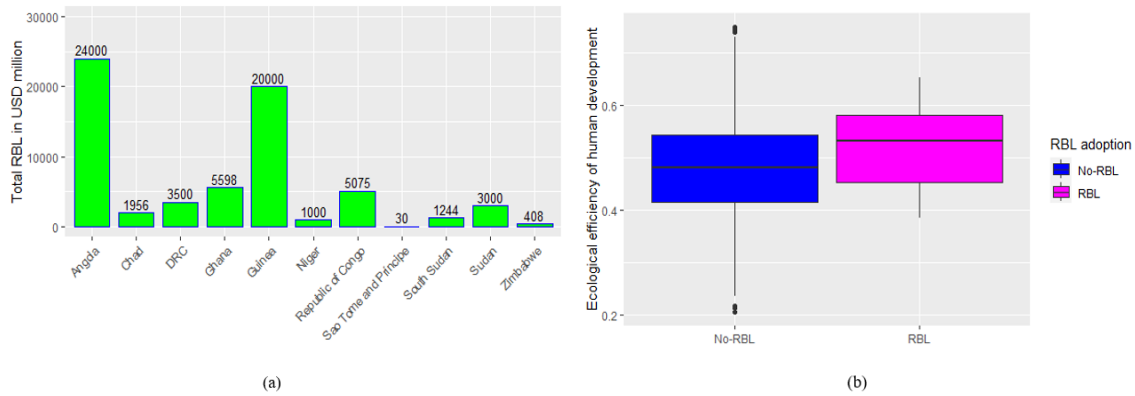
sustainability development index (SDI) measured by the ecological efficiency of human development level in RBL and non-RBL countries, respectively; Fig.1.2a shows that this ecological efficiency tends to be higher in RBL countries (on average around 0.49% for RBL countries versus around 0.47% for non-RBL countries). Moreover, based on the approach of Neuenkirch and Neumeier (2016), we compare the sustainability development index before and after the adoption of resource-backed loans in RBL countries with the sustainability development index in non-RBL countries; Fig.1.2b shows that despite the lower development of sustainability before the adoption of RBL, the average development of sustainability increases after the adoption of resource-backed loans in RBL countries compared to non-RBL countries. Finally, we check how the sustainability development index changes in the control countries using a before-after analysis of the adoption of RBL in both groups of countries⁴. Fig.1.2c shows that although the sustainability index increases after RBL adoption in both groups, the increase is significant and more pronounced in the RBL countries (with an increase of 15%, t-stat = 6.51 and p-value = 0.00) compared to the countries without RBL (with an increase of only 7%). In addition, a closer look at Fig.1.1b reveals a difference in the sustainable development index between RBL and non-RBL countries. In fact, RBL countries exhibit median percentiles (the middle line of the box), 25th (bottom hinge of the box), and 75th (top hinge of the box) of sustainable development index higher than non-RBL countries. This finding is justified by the fact that the median line, bottom hinge, and top hinge of the box for RBL countries are respectively higher than those of non-RBL countries.

To conclude this section, when we graphically analyze the scale of resource-backed loans by comparing the level of the sustainable development index (SDI) measured by the ecological efficiency of human development, we realize that countries that have signed a resource-backed loan have, on average, a higher level of ecological efficiency of human development than non-signatory countries (see Fig.1.1b; Fig.1.2a; and Fig.1.2c). However, the upward trend observed in both groups of countries indicates that it would be misleading to estimate the effect of resource-backed loans on the sustainable development index simply by comparing the sustainable development index before and after RBL adoption, because this does not reflect a causal relationship. To avoid overestimating the effect of RBL, we use observations from non-

⁴Given that 2004 is the first year of RBL adoption (see, Coulibaly, 2023b; Coulibaly et al., 2022; Mihalyi et al., 2020; Mihalyi et al., 2022), we use it as a deviation date to determine the year of adoption of RBL by non-RBL countries in our sample.

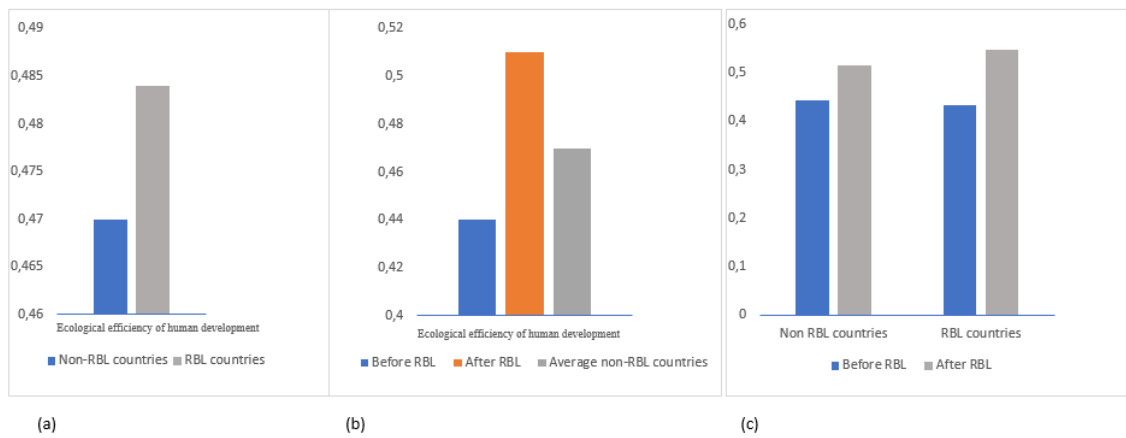
RBL countries selected on the basis of the matching procedure as a control group to estimate the counterfactual result.

Figure 1.1: Total amount of resource-backed loans by country and SDI by RBL adoption



Source: Author's elaboration using data from NRGI, Mihalyi et al. (2020) and Hickel (2020). **Note:** We consider 116 treated observations and 1234 untreated in Fig. 1.1a. In box plots, the lower and upper hinges of each box show the 25th and 75th percentiles of the samples, the line in the box indicates the respective medians, and the end-points of whiskers mark next adjacent values.

Figure 1.2: Sustainable development index and resource-backed loans



Source: Author's elaboration using data from NRGI, Mihalyi et al. (2020) and Hickel (2020).

1.3 Relevant literature

The literature on the economic, social and environmental impacts of resource-backed loans in developing countries, particularly in Africa, is nascent and relatively few studies have been performed (Coulibaly, 2023b; Mihalyi et al., 2020; Mihalyi et al., 2022; Coulibaly et al., 2022; Rivetti, 2021; Bräutigam and Gallagher, 2014). From this point of view, our work joins the few studies on sovereign debt, the environment, and sustainable development, since resource-backed loans are a special type of external debt. In subsection 1.3.1, we discuss the theoretical

link, while subsection 1.3.2 explores the existing empirical link. Finally, in subsection 1.3.3, we discuss and formulate our various testable hypotheses.

1.3.1 Review of the theoretical framework

This subsection analyzes the transmission mechanisms by which budgetary instruments, and sovereign debt, in particular, can affect environmental sustainability and human development. We start the discussion on how sovereign debt affects the quality of the environment through economic growth. In fact, high public debt could harm economic growth (Eberhardt and Presbitero, 2015; Reinhart and Rogoff, 2010) and harm environmental quality by hindering the implementation of environmental protection policies. This could compromise the ability of indebted countries to engage in a sustainable energy transition in the long term. In addition, Van den Bergh (2013) argues that public debt can limit the ability to mobilize national resources and therefore invest in adaptation to climate change in the context of developing countries. In the same vein, the repayment of the debt burden can force highly indebted economies to increase the pressure on the natural environment to increase public revenues (Combes et al., 2015; Coulibaly, 2023b), leading to heavy deforestation and depletion of natural resources (Coulibaly, 2023b; Kinda and Thiombiano, 2021). Similarly, a recent study by Osakede and Adeleke (2022) showed that public borrowing negatively affects human development and education in several African countries. Akam et al. (2022) studied the effects of sovereign debt on the environment in just four African countries and found that increasing sovereign debt does not contribute to environmental sustainability, but rather degrades the quality of the environment.

The model of overlapping generations of endogenous environmental growth (OLG) could also be mobilized to explain the mechanism of the relationship between public debt and environmental policy. This model predicts that production deteriorates the quality of the environment, which harms the well-being of future generations. Public spending to reduce pollution is financed by taxes and public debt, but the government is not restricted to increase the ratio of public debt to production (Fodha and Seegmuller, 2014; Fodha et al., 2018). According to these authors, there are two stable states with opposite properties: in the stable state, higher debt reduces capital but improves environmental quality, while opposite effects are observed in the unstable state. Boly et al. (2022) also used this same model but with configurations

different from those used by Fodha et al. (2018) and Fodha and Seegmuller (2014). In the configuration of Boly et al. (2022), two major aspects are incorporated. Firstly, they relax the classic balanced budget assumption to take account of long-term deficits and debt, in line with the current state of public finances in most countries of the world. Secondly, they go beyond studies (see, for instance, Barrage (2020); Bovenberg and Smulders (1996); Fullerton and Kim (2008); Karydas and Zhang (2019); Rosendahl (1997), etc.) that limit the exclusive financing of government emission reduction spending to taxation (i.e. with zero deficit and public debt) by taking public debt into account in their environmental endogenous growth model, and define environmental debt as the gap between natural capital in its pristine state (i.e. the state with no economic activity) and in its current state. To put it simply, in Boly et al. (2022), in the long term, economic growth is strictly positive and public debt is endogenous, unlike in the OLG context. These authors demonstrate the uniqueness of the steady state and prove that the link between the debt/GDP ratio and the quality of the environment depends on the time horizon. Their conclusions show that public debt and environmental debt are complementary in the long term and generally substitute each other in the short term. In other words, an increase in public debt generates a flow of environmentally damaging resources (the public debt burden) and a flow of environmentally improving resources (the public deficit that finances abatement spending). In the long term, the first effect offsets the second, so that public debt has an overall negative effect on pollution abatement spending; whereas in the short term, the second effect outweighs the first, provided that public debt is not too high.

Indubitably, external debt contributes to the depletion of environmental resources on the basis that foreign debt financing and repayment require increased natural resources extraction. So, more debt leads to more resources extraction. The non-reproducible exhaustible environmental resources necessarily exhaust since they cannot regenerate at least in the short run. Tietenberg and Lewis (2018) suggest external debt as a powerful contributor to a rapid depletion of environmental resources. Given that repayment of resource-backed loans can be made through in-kind resources, this would lead to more excessive mining and affect forest cover. For instance, the exploitation of the Carajás project mine in Brazil has resulted in annual deforestation of 6,100 km^2 as wood from the surrounding forest is converted into charcoal to fuel the smelters (Moran et al., 1994). Similarly, Ranjan (2019) shows that mining contributed to deforestation in 314 districts of India between 2001 and 2014. Kinda and Thiombiano (2021)

have also shown that mining and gas rents contribute to accelerating the loss of forest cover. On the other hand, oil rents and resource tax revenues help to reduce the loss of forest cover. In addition, resource-backed loans could undoubtedly increase public spending. This increase in public spending affects deforestation-related activities in developing countries more than non-deforestation-related activities (Combes et al., 2018b). However, López et al. (2011), focusing on the composition of public spending, argue that increasing the share of revenues allocated to public and social goods reduces environmental pollution. This argument corroborates with Daniel et al. (2013) that, thanks to effective fiscal policy, revenues from the extractive industries can make a significant contribution to financing productive expenditure. This will strengthen the government's capacity to invest in climate change adaptation and mitigation policies, thereby improving ecological efficiency and environmental quality. Lack of transparency in resource-backed loans can compromise political, institutional and ecological stability, as corruption increases in many sectors of the economy. Indeed, by attracting extractive industries to the signatory country with massive investments, resource-backed loans offer vast opportunities for corruption and illegal behavior involving significant private capture of resource rents, inducing additional pressure that weakens forest protection. This is the background to the study by Bebbington et al. (2018), who highlighted that corruption accelerates the expansion of extractive industries and is sometimes a direct driver of it. However, mineral-backed resource loans can accelerate the pace of mineral production, which could probably increase the supply of minerals strategic to battery manufacturing for the energy transition. As a result, resource-backed loans could improve environmental quality by accelerating the energy transition. In the spirit of IEA (2019), given the close relationship between climate change and energy consumption, renewable energies (RE) are a global solution for sustainable development. It offers an environmentally-friendly, low-emission technology (Malerba, 2019). Based on this argument, it can be argued that natural resource-backed loans offer excellent opportunities for a sustainable development process in line with the UN's development goals and meeting Henderson and Loreau (2023)'s definition. Many infrastructure investments are made with RBL (see, Table A9 for more information). It is therefore possible that resources from these RBL investments could be used to finance environmental policies to reduce the loss of forest cover (Kinda and Thiombiano, 2021). Following Coulibaly et al. (2022), who argue that resource-backed loans reduce the level of public debt after 5-years of adoption and

realization of public investments in the projects concerned. This implies that resource-backed loans can provide signatory countries with budgetary leeway to invest in biodiversity and environmental protection, thereby improving ecological efficiency.

At the same time, financing growth in real income and energy consumption through external debt can lead to environmental degradation (Katircioglu and Celebi, 2018). Furthermore, countries (especially energy-dependent countries) whose real income growth is influenced by the volume of debt affect CO₂ emissions through additional energy needs. More explicitly, when foreign debt is invested in real estate, heavy industry, and the construction sector, energy demand increases, which can have a negative effect on the environment (Bese, 2021; Sun and Liu, 2020). Drawing a parallel with resource-backed loans, these could therefore increase energy demand and negatively affect the ecological efficiency of human development in adopting countries, since 85% of the amounts of resource-backed loans are invested in major construction projects such as hydroelectric dams, public buildings, bridges and social housing (Mihalyi et al., 2020).

1.3.2 Review of the empirical literature

On the empirical side, the few studies that attempt to measure the link between public debt and ecological efficiency or environmental quality refer to the evaluation of public debt measured as a percentage of GDP. The consensus is that the link between public debt and environmental quality – most often measured by forest cover – is unambiguously negative. For example, Culas (2006) examines the hypothesis that high sovereign debt is the cause of high rates of tropical deforestation, mainly due to clearing forest land for agricultural expansion. The results indicate that debt and deforestation are positively linked. Similarly, Didia (2001) and Kahn and McDonald (1995), using classical ordinary least squares regressions, showed that an increase in debt led to an increase in deforestation in tropical countries. In a similar vein, Sommer et al. (2020) looked at the hypothesis of debt reduction and forest cover protection. Using the instrumental variables method, the author confirms that larger debt reductions are associated with lower rates of forest loss in the context of debt-for-nature swaps involving the USA. These results are in line with Bese (2021) who estimate the effect of foreign debt on carbon dioxide emissions for China over the period 1974-2014. They find that foreign debt has a positive and significant impact on CO₂ emissions. In fact, the studies conducted by Bese (2021)

and Katircioglu and Celebi (2018) are restricted and country specific, focusing on emerging countries (Turkey and China, respectively). In contrast to them, Akam et al. (2021) will extend the emerging literature on debt and the environment to a panel of low-income countries to broaden the understanding of the debate. They estimate the impact of external debt on CO2 emissions for thirty-three (33) heavily indebted poor countries (HIPCs) over the period 1990-2018 using panel data macro-econometric models. The results show that external debt has a positive but not statistically significant impact on CO2 emissions, suggesting that external debt does not contribute significantly to environmental degradation in HIPCs. Using a propensity score matching approach in a sample of 64 developing countries during the period 2004-2018, Coulibaly (2023b) shows that resource-backed loans contribute to an increase in the level of deforestation in developing countries. The author explains this link through several factors such as natural resource rents, resource depletion, commodity price, and overindebtedness.

However, it should be noted that policies that do not curb public debt growth can reduce the concentration of CO2 and greenhouse gas emissions and improve environmental quality in the short term. However, it is important to note that such policies can have long-term harmful environmental consequences. This has been proven by Boly et al. (2022), who use a cointegration technique to establish the link between public debt and environmental debt. The results show that there is a significant and positive long-term link between public debt and environmental debt, but that it may be negative in the short term. These results suggest that public debt could have a positive effect on the environment through green financing. Indeed, public debt can improve the quality of the environment by financing investments in low carbon technologies, clean energy projects or environmental R&D activities that will primarily benefit future generations (Bénassy-Quéré, 2010). Some authors believe that debt-for-nature swap programs could improve environmental quality and establish fiscal discipline in low-income countries (Cassimon et al., 2011; d Chamon et al., 2022; Essers et al., 2021; Hansen, 1989; Kahn and McDonald, 1995; Nedopil et al., 2023; Sommer et al., 2020; Thapa, 1998; etc.). For instance, Kahn and McDonald (1995) outline a significant positive association between public debt and deforestation in LDCs and defend debt alleviation to reduce the pressure to deforest (Hansen, 1989). According to Gullison and Losos (1993), the public debt could be exchanged for the reform of the forest and agricultural sectors, which would have very significant positive effects on forest conservation and management.

1.3.3 Testable hypotheses

Since the literature review provides extensive empirical evidence on the influence of public debt on environmental quality through CO₂ emissions, deforestation, etc. However, existing studies are struggling to provide clear evidence as existing studies come with mixed findings, that is, some studies have found the positive association, while others found a negative association between the two. Therefore, it is important to reinvestigate this nexus to design a comprehensive economic policy in African economies. In addition, several studies analyze the association between public debt and human development (see, for example, Osakede and Adeleke, 2022; Zaghdoudi, 2018). However, no existing studies identify the association between resource-backed loans and human development, which is of significant importance. Although the studies by Osakede and Adeleke (2022) and Zaghdoudi (2018) retain their quality, they suffer from two major shortcomings. Firstly, their studies do not take into account the typology of public debt, i.e., distinguishing the effect of debts whose repayment directly affects human development from those that do not. Secondly, their human development index does not take into account ecological sustainability, which is very important for African countries to pursue and achieve sustainable development goals. This limitation is becoming increasingly evident given the growing crisis of climate change and ecological breakdown (see Hickel, 2020). The use of a Sustainable Development Index (SDI) addressing this concern, i.e. focusing on the ecological efficiency of nations in achieving human development, would have enabled the authors to draw a conclusion and recommendation policies in the direction of the sustainable development process.

The testable hypotheses explored in this chapter directly echo the extensive literature reviewed in this section. First, resource-backed loans are expected to have their own importance for the ecological efficiency of human development. *We would therefore reject the null hypothesis that resource-backed loans do not affect the education index, the life expectancy index, and the income index.* Secondly, the literature highlights the direct and indirect effects of public debt on the environmental framework. In particular, RBLs may be less effective in maintaining the boundary planetary at its desired optimal level, unless the debtor and creditor governments incorporate an ecological dimension into RBL agreements. *Empirical, this means that we would expect to reject the null hypothesis that the effects of RBL do not influence CO₂ emissions and*

material footprint. Third, and finally, an interesting empirical question arises from the presumption of heterogeneous effects between different types of resource-backed loan. In fact, offshore mining and oil extraction generate CO₂ emissions and destroy forest cover (see Kinda and Thiombiano, 2021), while forests are crucial for carbon sequestration. However, it must be recognized that the exploitation of minerals could increase the supply of minerals used in battery production for the energy transition and thus reduce global carbon emissions (Cox et al., 2022). This could mitigate or even offset the overall negative environmental impacts of mining compared to those of oil.

Although we have posed null hypotheses in this chapter, we do not report the statistical results of these tests for reasons of document size and to avoid confusing the reader. However, tables of results could be provided on request.

1.4 Methodology

1.4.1 Motivation and entropy balancing framework

The general objective of this analysis is to estimate the impact of the adoption of resource-backed loans on the ecological efficiency of development in African countries in a more specific context of climate change, energy transition and weak access to capital markets. Our analysis considers that observation is treated when the country has signed a resource-backed loan. Given that most countries that have signed up to resource-backed loans face numerous macroeconomic and institutional problems such as sovereign debt default, sovereign debt restructuring, restricted market access, and corruption, there are concerns about selection bias, as the adoption of resource-backed loans may be correlated with unobservable variables that may also affect the overall performance of the economy and thus potentially ecological efficiency of human development. We must use an impact estimation technique that can minimize this selection bias that is found in the RBL adoption policy. To achieve this objective, our study focused on cross-sectional contexts with a binary treatment in which the observational data obtained required covariate adjustments to truly capture the causal effects of RBL on the ecological efficiency of human development. So, a reweighting approach called entropy balancing developed by Hainmueller (2012) was used to make covariate adjustments and perform a binary treatment. This entropy-balancing approach has many advantages and is widely used in

the economic literature. For example, Apeti and Edoh (2023) use this approach to assess the impact of mobile money on tax revenue mobilization, Apeti (2023a) evaluate the effect of mobile money adoption on household consumption volatility, Balima and Sy (2021) examine the role of IMF-supported programs in reducing the likelihood of subsequent sovereign defaults in borrowing countries, and Jacolin et al. (2021) investigate the impact of mobile financial services, in particular, mobile money, mobile credit, and savings on the informal sector. Kinda and Thiom-biano (2024b) examine the implementation of the Extractive Industries Transparency Initiative (EITI) standard on deforestation in resource-rich developing countries. The approach used in this study is based on the principle that the adoption of resource-backed loans is the treatment and that the ecological efficiency of human development is the outcome variable. Units of observation are country years. Observations with RBL constitute the treatment group and those without RBL constitute the control group. The effect of treatment on treated individuals (ATT) is defined as follows:

$$ATT = E[Y_{(1)}|T=1, X = 1] - E[Y_0|T=1, X = 1] \quad (1.1)$$

where $Y_{i(.)}$ is the outcome variable that measures the ecological efficiency of human development. T_i indicates whether the observation unit is subject to the adoption of resource-backed loans ($T_i = 1$) or not ($T_i = 0$). $E[(Y_{i(1)}|T_i=1)]$ is the level of ecological efficiency of human development during the resource-backed loan adoption period, $E[(Y_{i0}|T_i=1)]$ is the counterfactual result for countries that had adopted resource-backed loans, i.e., the ecological efficiency of human development in countries that had adopted resource-backed loans if they had not.

The issue is that $E[Y(0)|T = 1]$ is not observable due to the non-random nature of the adoption of RBL. If this were the case, the ATT could easily be identified by comparing the ecological efficiency of human development in RBLs countries with non-RBLs countries. Identifying ATT then requires a good proxy for $E[Y(0)|T = 1]$. To do so, we match RBL units with non-RBL units (after purging for some specific factors) that are as close as possible on observable characteristics that meet two criteria: correlated with RBL adoption and ecological efficiency of human development. Under the condition that the non-RBLs units are fairly close to the RBLs units, any difference in consumption volatility is attributable to RBL adop-

tion. Based on these details, we can rewrite equation 1.1 as follows:

$$ATT = E[Y_{(1)}|T=1, X = x] - E[Y_0|T=1, X = x] \quad (1.2)$$

where $X = x$ is a vector of observable covariates that can affect both the decision to adopt RBL and the ecological efficiency of human development, $E[Y(1)|T = 1, X = x]$ is the ecological efficiency of human development of RBL units and $E[Y(0)|T = 0, X = x]$ is the expected ecological efficiency of human development for the synthetic control units.

Entropy balancing is a two-step estimation method. First, the weights assigned to the control units (in this case, the non-RBL countries) are calculated in the entropy balancing. In the second step, the weights obtained in the first step are used in a regression analysis with the treatment variable (RBL countries) as the explanatory variable. We then weigh the countries with RBL and non-RBL based on observable characteristics. Thus, the average difference in the ecological efficiency of human development between countries with RBL and the "*closest*" countries without RBL should be explained by adoption of RBL.

1.4.2 Advantages of entropy balancing

Unlike other methods for estimating effects and treatment effects, such as propensity score matching even difference-in-difference, entropy balancing has several advantages due to its ability to combine both matching and regression analysis (Apeti, 2023a; Balima and Sy, 2021; Hainmueller, 2012; Neuenkirch and Neumeier, 2016; Sawadogo, 2020). In fact, this method outperforms the classical approach based on regression and matching based on propensity score methods because it is non-parametric, which allows one to avoid the problem of misspecification of the functional form of the model that could bias the results. Moreover, it is a method that also eliminates multicollinearity problems since the mechanism of re-weighting makes the treatment variable orthogonal to the covariates (Hainmueller, 2012). Another advantage is that entropy balancing uses more flexible reweighting schemes compared to conventional balancing, where control units are either discarded or balanced. Here, units are reweighted with the goal of achieving a balance between processed and unprocessed units, keeping the weights as close to the base weights to avoid information loss. Its most attractive feature is to allow a high degree of covariate balance between RBL countries and non-RBL

countries, even in small samples, by creating a synthetic control group that is as close as possible to the program group. Finally, classical matching methods and pooled probit models rely on the assumption of conditional independence, i.e., based on a vector of observable covariates, the treatment is independent of unobservable factors. In addition, the use of entropy balancing allows us to account for the panel dimension of the data by controlling for country- and time-specific factors in the second stage of the regression analysis. It is necessary to include country-specific effects to account for potential unobserved heterogeneity between countries that have never signed the RBL and those that have. In fact, the macroeconomic environment of these two groups may differ beyond the covariates used in the entropy balancing approach. Country effects also control for time-invariant and country-specific conditions that may lead to differences in ecological efficiency of human development between countries. However, entropy balancing may not control for potential endogeneity biases due to unobserved temporal factors that may affect both RBL and ecological efficiency of human development, as well as the reverse causality problem that may exist between the treatment variable and the outcome variable and cannot successfully deal with the inertia of ecological sustainability and the pursuit of sustainable development goals. This can lead to potentially biased results. For this reason, we complement entropy balancing method with alternative estimation methods (see the details in Section 1.7).

1.5 Data

1.5.1 Treatment variable

The treatment variable used in this study is the adoption of RBL, a binary that we constructed based on the information contained in the NRG database (Institute for Natural Resources Governance Institute). So far, NRG remains the only institution that provides reliable and solid evidence on the existence and many details of resource-backed loans in developing countries. A team of researchers led by Mihalyi, D., Adam, A., and Hwang, J. collected as much information as possible on resource-backed loans to obtain a somewhat larger database. They compiled two original databases maintained by institutions dedicated to research China's overseas activities: the China-Africa loan database produced by the China-Africa Research Initiative (CARI) at Johns Hopkins SAIS and the China-Latin America financial database of the

Inter-American Dialogue and Global Development Policy Center at Boston University (Mihalyi et al., 2020). The authors then supplemented these databases with additional literature searches to present their dataset. It should be noted that the data on these resource-backed loans are not fully comprehensive due to the relative opacity of these transactions (Rivetti, 2021). There could certainly be other resource-backed loans in both regions than those listed by the authors, as they are limited by publicly available information (Mihalyi et al., 2020). However, it is the most comprehensive database on resource-backed loans for African and Latin American economies over a long period. Following Coulibaly (2023b); Coulibaly et al. (2022); Coulibaly (2025); Mihalyi et al. (2020); Mihalyi et al. (2022); Bräutigam and Gallagher (2014), we construct a dummy variable that takes the value 1 if country i at a period t has taken out a resource-backed loan and 0 otherwise.

1.5.2 Outcome variable

The dependent variable used in this chapter is captured by the new sustainable development index constructed by Hickel (2020). To construct this index, Hickel (2020) starts from the premise that the Human Development Index (HDI) introduced in the 1990s and modified by UNDP⁵ is not a perfect measure for millennium goals and that it was necessary to implement a new method, technique and methodology to build an index that would take into account the limitations of the HDI that have become evident in the 21st century, given the growing crisis of climate change and ecological degradation. In fact, before Hickel (2020), numerous studies have attempted to propose indicators for correcting the HDI (O'Neill et al., 2018; Raworth, 2012; Raworth, 2017; Steffen et al., 2015; Gough, 2015; Rockström et al., 2009), particularly those that cross ecological boundaries (Morse, 2003; Neumayer, 2001; de La Vega and Urrutia, 2001; Neumayer, 2001; Sagar and Najam, 1998; Ramanathan, 1999), other studies have looked at how the environmental dimension is taken into account in the design of the HDI (Hirai, 2017), more specifically, to integrate CO2 emissions per capita (Bravo, 2014), incorporates material footprint (Zhang and Kai, 1998). However, not all of these studies address the question of human development in its entirety and all suffer from notable weaknesses that make them ultimately unsuitable (Hickel, 2020). As a result, Hickel (2020) proposes an index with two specific objectives, namely: correct the HDI according to its ecological impact and propose a

⁵See, Kovacevic et al. (2010).

simple alternative that retains the logic and basic structure of the original.

Basically, the sustainable development index proposed by Hickel (2020) comprises five indicators: education, life expectancy, income, CO2 emissions, and material footprint. The formula is as follows:

$$SDI = \frac{\text{Development Index (DI)}}{\text{Ecological Impact Index (EII)}} \quad (1.3)$$

The development index is calculated as the geometric mean of the education index, the life expectancy index, and the modified income index. This gives the following formula:

$$DI = \sqrt[3]{\text{Education Index} * \text{Life Expectancy Index} * \text{Income Index}} \quad (1.4)$$

In this formula, the education index and the life expectancy index are similar to the HDI developed by Mahbub ul Haq (UNDP, 1997). So, we obtain the income index using the following formula:

$$\text{Income Index} = \frac{\ln(GNI_{pc}) - \ln(100)}{\ln(20,000) - \ln(100)} \quad (1.5)$$

Concerning the denominator of equation 1.1, the ecological impact index, it is obtained using the following formula:

$$EII = 1 + \frac{e^{AO} - e^1}{e^4 - e^1} \quad (1.6)$$

We can see that if $AO > 4$, then $EII = AO - 2$. This is how we obtain the AO formula:

$$AO = \sqrt{\left(\frac{MF}{boundary} \geq 1\right) * \left(\frac{CO2}{boundary} \geq 1\right)} \quad (1.7)$$

The author proceeds to a kind of AO normalization by dividing the material footprint and emissions values by the per capita planetary boundary. The idea behind this task is that a country cannot compensate for overshooting one boundary by undershooting the other because overshooting either boundary will result in an average overshoot greater than 1. After the calculation, Hickel (2020) builds a database with 163 countries having data points for the five indicators included in the IDS from 1990 to 2019. However, the sustainable development index devised by Hickel (2020), while incorporating new perspectives in the improvement of the HDI, may suffer from the bias of missing relevant variables. In fact, the author does not include in his calculation certain indicators related to basic physical needs, such as access to food, electricity, improved sanitation and housing, literacy, and child mortality, all of which are targeted by the SDGs. Despite this, we must acknowledge that it is the only indicator that captures both development, economic growth, and environmental issues, and has data for many countries over a long period, unlike the other indicators, for example, the one designed by O'Neill et al. (2018). Data are collected directly in "Sustainable Development Index".

1.5.3 Controls or matching variables

Following the literature, we control several variables that are likely to have an impact on environmental sustainability. These variables are inflation rate, ODA, foreign direct investment, natural resource rents, and resource depletion. For robustness, other relevant variables will be controlled in future sections. We measure the **inflation rate** using the consumer price index. The use of this variable is justified by the fact that there is a direct relationship between the inflation rate and the environment (Ronaghi et al., 2020). In fact, Ronaghi et al. (2020) has shown that inflation has a statistically significant negative impact on CO2 emissions. It is well known that higher inflation is accompanied by higher commodity prices in the country. As a result, consumer demand for goods decreases, and, by reducing production, CO2 emissions eventually decrease. This is a boon for environmental sustainability. Another reason could be that inflation reduces trade, so CO2 emissions will fall indirectly.

However, both effects are observed with **foreign direct investment (FDI)**. According to Pazenza et al. (2015), there is a negative relationship between foreign direct investment (FDI) and CO2 emissions. Basically, higher levels of foreign direct investment and employment will increase production, leading to more emissions (Ronaghi et al., 2020). Likewise, according to Lee (2013), FDI flows are a catalyst for economic growth through technology transfer, the introduction of new processes and productivity gains, as well as management skills. Under these conditions, technology transfer, for example, could generate economies of scale, accelerate the energy transition, and improve environmental sustainability. Taking a closer look at oil-exporting countries, FDI is a major factor in environmental degradation. This is because higher levels of economic activity (production and consumption) require more energy and raw materials, increasing CO2 emissions. **Official development assistance (ODA)** could have a rather positive effect on the environment, as donors and development partners actively support developing countries in their quest for environmentally friendly development. This corroborates the results found by Kwakwa et al. (2020), which showed that official development assistance contributes to reducing long-term carbon dioxide emissions in Ghana. **Natural resources rents** are the sum of oil rents, natural gas rents, coal rents, mineral rents, and forest rents. The effect of natural resource extraction on the environment is somewhat ambiguous in the literature. Although the results of the study reveal that natural resource rents improve the natural environment by reducing carbon emissions (Joshua and Bekun, 2020; Wang et al., 2020), other results reveal that natural resource rents cause more carbon emissions (Anh Tu et al., 2023; Kinda and Thiombiano, 2021). Finally, we control **Natural resource depletion**⁶ which is the sum of net forest depletion, energy depletion, and mineral depletion. Resource depletion can have a devastating impact on the environment. For example, mining can cause habitat destruction, water bodies pollution, and soil erosion. These environmental impacts can have considerable effects on ecosystems and biodiversity. Due to soil erosion and soil fertility are considerably affected and rendered useless, resulting in the drying out and aridity of certain parcels of land over time, and thus leading to a loss of wildlife and vegetation. On the other hand, resource depletion can call on political decision makers to implement adaptation

⁶Net forest depletion is unit resource rents times the excess of round wood harvest over natural growth. Energy depletion is the ratio of the value of the energy resource stock to the remaining reserve lifetime (capped at 25 years). Covers coal, crude oil, and natural gas. Mineral depletion is the ratio of the value of the stock of mineral resources to the remaining reserve life (capped at 25 years). Covers tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate.

strategies, sustainable investments, and biodiversity protection for future generations, given that depleted resources are generally non-renewable. This can undermine the sustainability of development in these countries.

1.6 Results

1.6.1 Descriptive statistics

We present the descriptive statistics for the first stage equation in Table 1.1. This is a simple comparison of sample means before weighing for all matching covariates between treated units (column [1]) and control units (column [2]), which represent the potential synthetic group. Table 1.1 shows that on average the treated observations report lower inflation and receipt of official development assistance, greater attraction of FDI and natural resource rents, and a higher rate of resource depletion. Next, we note that the differences between the two groups are significant (column [5]), except for the inflation rate, which could bias the effect of the measure due to a potential selection problem if we estimate the effect of treatment using traditional econometric methods such as OLS estimators. To overcome this problem, we constructed a synthetic control group by reweighting the control units using the pretreatment covariates of the base specification. In fact, this approach makes the pretreatment covariates of the synthetic group on average as comparable as possible to those of the treated units based on several similar characteristics. Table 1.2 shows in columns [1] and [2], the sample mean after weighting between the treatment group and the synthetic group obtained by entropy balancing, and column [3] shows the difference between the first two. Analysis of the two groups in this table reveals the effectiveness of entropy balancing, as the difference shown in the previous table seems to disappear. Consequently, we can consider the synthetic group as an «near perfect» counterfactual of the treated group (RBL countries).

Table 1.1: Descriptive statistics before weighting

	[1] <i>RBL</i>	[2] <i>Non RBL</i>	[3]=[2]-[1] <i>Difference</i>	[4] <i>t-Test</i>	[5] <i>P-value</i>
Log Inflation rate	1.91	1.80	-0.11	0.5	0.489
Log ODA	1.41	1.74	0.33	4.2	0.040
Log FDI	1.57	0.53	-1.04	30.3	0.000
Log Natural resources rents	2.56	1.75	-0.81	17.9	0.000
Log Resource depletion	2.05	0.87	-1.18	18.6	0.000
Observations	240	1110			

This table shows the sample means before weighting for matching covariates for country-year observations where RBLs were signed (the treatment group) in column [1] and country-year observations where no RBLs were ever signed (the potential control group) in column [2]. Column [3] shows the differences in means between the treatment and control groups, while the corresponding t-test statistics and p-values are columns [4] and [5] respectively.

Table 1.2: Descriptive statistics after weighting

	[1] <i>RBL</i>	[2] <i>Non RBL</i>	[3]=[2]-[1] <i>Difference</i>
Log Inflation rate	1.906	1.906	0.000
Log ODA	1.407	1.407	0.000
Log FDI	1.57	1.569	-0.001
Log Natural resources rents	2.563	2.562	-0.001
Log Resource depletion	2.049	2.048	-0.001

This table shows the sample means after weighting for matching covariates for country-year observations where RBLs were signed (the treatment group) in column [1] and country-year observations where no RBLs were ever signed (the potential control group) in column [2]. Column [3] shows the differences in means between the treatment and control groups.

1.6.2 Treatment effects

Table 1.3 presents the average effect of treatment in RBL countries on the ecological efficiency of human development, obtained from different sets of treatment effect estimates. First, in columns [1] to [4], we present the basic results highlighting the effect of the adoption of resource-backed loans on sustainable development. Next, we add a country fixed effect, a time fixed effect, and country/year fixed effects. In columns [5]-[8], we include all control variables in our equation. The results indicate that the adoption of a resource-backed loan significantly increases the ecological efficiency of human development. The magnitude of the coefficients suggests that adopting resource-backed loans improves the ecological efficiency of human development by around 2.41 percentage points. These results are robust; whatever the specifications, the estimated effects are positive and statistically significant. In addition, when the country signs a resource-backed loan, the ecological efficiency of human development varies by up to 1.2% more than countries observed without a resource-backed loan (these two groups of countries are similar in terms of pre-treatment factors). This effect is statistically significant at 1%, especially when we include control factors. These results could be explained by the fact that countries taking out resource-backed loans have taken advantage of RBL to invest in their energy sector, road infrastructure, healthcare, and education. In addition, several social housing construction projects have been carried out thanks to resource-backed loans. According to Mihalyi et al. (2020), governments allocated more 85% RBL and more 90% of the value of RBL to capital expenditure. Given that achieving development goals contributes to improving the well-being of the population, raising the education index, life expectancy, and income levels will increase the development index. As a result, resource-backed loans will eventually have a positive impact on the ecological efficiency of human development. The positive impact of resource-backed loans on the ecological efficiency of human development suggests that policymakers in borrowing countries might consider negotiating with creditors of resource-backed loans with a focus on public investment. However, they will need to include key provisions in loan agreements for the financing of biodiversity components and the implementation of actions to mitigate the negative environmental impact of resource-backed loans, which should mitigate the ecological impact that is in the denominator of ecological efficiency of human development calculated by Hickel (2020).

Our results are in perfect harmony with and even corroborate those already found by some, who believe that nations with abundant subsoil assets in the form of oil, gas and minerals can derive significant revenues from extraction that can be mobilized for economic development (Brunnschweiler, 2008; Carbonnier et al., 2011; Hordofa et al., 2022; Hsu et al., 2023; Viner, 1952). Intentionally, we have decided not to report covariate coefficients in the tables, but a complete table with covariate signs and coefficients can be provided on request. Then, in Section 1.7, we decided to confound our results with a series of robustness tests to ensure that these results are not affected by any modification.

Table 1.3: Resource-backed loans and ecological efficiency—Baseline results

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Resource-backed loans	0.109*** (0.0205)	0.163*** (0.0132)	0.0515*** (0.0194)	0.0286*** (0.00797)	0.0831*** (0.0176)	0.114*** (0.0123)	0.0315* (0.0165)	0.0241*** (0.00718)
Constant	-0.695*** (0.0101)	-0.768*** (0.0284)	-0.743*** (0.0668)	-0.775*** (0.0390)	-0.503*** (0.0254)	-0.629*** (0.0409)	-0.525*** (0.0642)	-0.696*** (0.0455)
Covariates	No	No	No	No	Yes	Yes	Yes	Yes
Country/FE	No	Yes	No	Yes	No	Yes	No	Yes
Year/FE	No	No	Yes	Yes	No	No	Yes	Yes
Observations	799	799	799	799	799	799	799	799
R-squared	0.098	0.813	0.214	0.938	0.394	0.854	0.486	0.940

This table presents the effect of resource-backed loans on sustainable development obtained by weighted least squares regressions. The treatment variable is the presence of a resource-backed loan. The outcome variable is the occurrence of ecological efficiency of human development. The control variables include inflation rate, ODA, FDI, Natural resource rents, and Resource depletion. Robust standard errors are in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

1.7 Robustness checks

Our estimates show that the adoption of resource-backed loans significantly increases the ecological efficiency of human development. In this section, we test the robustness of these results with the aim of strengthening our confidence.

1.7.1 Alternative estimation method

Difference-in-Differences estimators. The difference-in-differences (DiD) method is a more robust and most popular method used to assess the causal effects of policy interventions using observational data (Callaway and Sant’Anna, 2021; Sant’Anna and Zhao, 2020). In its canonical or basic form, it is based on two periods and two groups. In the first period, no units are treated, and in the second period, some units are treated (treatment group) and

some units are not (comparison group). In this case, if the average scores of the treated and the comparison subjects without treatment would have evolved in parallel over time (parallel trends hypothesis), we can estimate the average effect of treatment for the treated subpopulation (ATT) by comparing the average change in scores observed by the treated group with the average change in scores recorded by the comparison group (Abadie, 2005; Botosaru and Gutierrez, 2018; Callaway and Sant’Anna, 2021; de La Vega and Urrutia, 2001; Sant’Anna and Zhao, 2020). There are several reasons for using this technique. Firstly, we are exposed to a phased adoption problem (Sant’Anna and Zhao, 2020), that is, in our data set, once countries have signed a resource-backed loan agreement, they continue to benefit from resource-backed loans in subsequent periods, as the maturity of resource-backed loans for borrowing countries goes beyond the last observation period of the panel we are working on (the year 2019). In this case, we are dealing with average treatment effects with several time periods and parallel trends that are potentially valid only after conditioning on the observed covariates. Indeed, we have used entropy balancing for the basic regression, which uses linear regression (OLS) in its second stage. This estimate, which includes unit-specific time averages and period-specific cross-sectional averages, is referred to as the Two-Way Fixed Effects (TWFE) estimator by Wooldridge (2021). However, the empirical literature on impact evaluation methodologies shows that the TWFE estimator produces biased estimates when the treatment effect is heterogeneous within countries due to negative weights in the calculation of the average treatment effect (Athey and Imbens, 2022; Borusyak and Jaravel, 2018; de La Vega and Urrutia, 2001; Nichols et al., 2019; Sun and Abraham, 2021). This seems to be the case in our context, where some countries are accumulating resource-backed loans. In addition, the second reason for using difference-in-difference is that there may be endogeneity in the resource-backed loans variable, as countries with poor ecological efficiency of human development performance may face a higher risk premium for borrowing, and therefore may resort to resource-backed loans. Finally, to circumvent the potential endogeneity problem of resource-backed loans, we follow Callaway and Sant’Anna (2021) who develop a difference-in-difference (DiD) estimator not only for staggered adoption but also to address the potential endogeneity problem. Indeed, the advantage of this difference-in-differences estimator is that it effectively bypasses the negative weight problem, the endogeneity problem associated with the TWFE estimator and estimator, and considers the heterogeneity and dynamics of treatment effects (Callaway

and Sant’Anna, 2021). To achieve this, we estimate three different types of DiD estimators under staggered treatment adoption always following Callaway and Sant’Anna (2021). The first is based on outcome regressions (Heckman et al., 1997; Heckman et al., 1998a), the second is based on doubly robust methods (Sant’Anna and Zhao, 2020), and the third is based on inverse probability weighting (Abadie, 2005). Finally, in the regressions, we consider observations never processed and those not yet processed as a control group (see, for instance, Athey and Imbens, 2006, De Chaisemartin and d’Haultfoeuille, 2018).

We report the results in Table 1.4. In column [1], we present the doubly robust DiD estimator based on stabilized inverse probabilistic weighting and ordinary least squares (dripw) without covariates. In column [3], we report the results of the inverse probability weighted DiD estimator (ipw), also without covariates. In columns [3]-[4], we repeat the same regressions, augmenting our model with the covariates used in the base model. The overall effect of treatment (ATT) is positive and statistically significant, suggesting that the main results of the study remain qualitatively unchanged when estimates are made with DiD estimators.

Table 1.4: Resource-backed loans and ecological efficiency: Diff-in-Diff estimations

	[1]	[2]	[3]	[4]
	dripw	ipw	dripw	ipw
ATT	0.0437** (0.0170)	0.0438** (0.0170)	0.0071* (0.0039)	0.0392*** (0.0115)
Covariates	No	No	Yes	Yes
Observations	1,044	1,044	654	654

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

Propensity score matching estimates (PSM). The principle of the PSM method is to match countries that have signed RBLs with countries that have not signed, but share certain observable characteristics linked to both signing an RBL and ecological efficiency. These observable characteristics are summarized in a propensity score (PS) which indicates the probability that a country will sign an RBL (treatment group), subject to the observable character-

istics (Dehejia and Wahba, 2002; Heckman et al., 1997; Rosenbaum and Rubin, 1983; Smith and Todd, 2005). The propensity score is then used to determine a group of countries that have not signed an RBL (control group). This group of countries serves as a counterfactual for the treatment group. In fact, assuming that the determinants of ecological efficiency of human development are statistically independent of the RBL signature, given the common characteristics between the treatment and control groups, the difference in the outcome between the two groups, the average effect of treatment on treated (ATT), is attributable to the adoption of the RBL. In addition, this method consists of two steps. First, we calculate a propensity score (PS) using a logit model with RBL as a dependent variable. Following Apeti et al. (2023a, 2024b); Chapel (2022); Combes et al. (2024); Dehejia and Wahba (2002); Heckman et al. (1997); Rosenbaum and Rubin (1983); Smith and Todd (2005), we use different matching algorithms to test the robustness of our results. The matching techniques used include nearest-neighbor matching with replacement, which matches each treated country to the n control countries with the closest PS (we consider $n = 1$, $n = 2$ and $n = 3$). Next, radius matching is also used to match an RBL country to non-RBL countries whose propensity score is within a radius of length r (we consider a wide radius $r = 0.045$, a medium radius $r = 0.09$ and a narrow radius $r = 0.18$). Next, we follow Fan (1993) and Heckman et al. (1998b) using local linear regression adjusted to pair the covariate-adjusted results for the treatment group with the corresponding covariate-adjusted results for the control group using local linear regression weights. Finally, we use kernel matching as a matching algorithm to associate a treated country with all control countries, weighted proportionally to their proximity in terms of PS to the treated country. Before interpreting the results, we perform a number of validation tests. First, we follow Dehejia and Wahba (2002) and calculate standard errors using the bootstrap technique to obtain robust standard errors for valid inference. Next, we use the diagnostic tools of Rosenbaum and Rubin (1985) to check the validity of the conditional independence hypothesis (no evidence of significant differences in observable characteristics within the matched data between RBL and non-RBL countries) and hence the validity of the matching results. The conditional independence assumption holds when the p-value associated with its standardized bias score t-test statistics is greater than 5%. In addition, we used Rosenbaum (2002)'s sensitivity tests to check the extent to which unobserved heterogeneity could alter the results of the RBL impact estimate on ecological efficiency of human development. We report the new ATTs in Table 1.5,

together with the quality matching tests, while the results of the propensity score estimation are presented in Table 1.6, column [1]. First, the results are stable and confirm the positive effect of RBLs on the ecological efficacy of human development. Secondly, all Pseudo-R2 of our estimates are below 10%, suggesting that the matching provided balanced scores. In other words, our results are robust to the common support hypothesis.

OLS estimates. After testing the robustness of our results with the impact estimates (PSM), we re-estimate our model using the Ordinary Least Squares (OLS). The results presented in column [1]-[6] of Table A1 in the appendix suggest a positive and significant effect of RBL on the ecological efficiency of human development, with a magnitude of around 3.22 percentage points, qualitatively comparable to that of the main model (2.4 percentage points, Table 1.3, column [8]).

Table 1.5: Resource-backed loans and ecological efficiency: using PSM

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Ecological efficiency	Matching			r=0.045	r=0.09	r=0.18	Matching	Matching
ATT	0.0855** (0.0404)	0.0916*** (0.0312)	0.0904*** (0.0350)	0.0931*** (0.0221)	0.0998*** (0.0287)	0.1069*** (0.0251)	0.0835*** (0.0299)	0.0949*** (0.0286)
Observations	799	799	799	799	799	799	799	799
Treated	65	65	65	65	65	65	65	65
Untreated	734	734	734	734	734	734	734	734
Matching Quality								
Pseudo-R2	0.000	0.007	0.005	0.006	0.024	0.078	0.000	0.006
Rosenbaum bounds sensitivity test	1.55	2.9	1.85	3.00	3.00	3.00	3.00	3.00
Standardized bias (p-value)	1.000	0.944	0.967	0.964	0.529	0.015	1.000	0.964

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

System-GMM estimates. We discuss the econometric problems that can arise when estimating the baseline specification. In fact, the ecological efficiency of the human development index is likely to be endogenous, due to the reverse causality of RBL to the ecological efficiency of human development. In fact, countries with a low ecological index of human development could be tempted to sign an RBL to finance sustainable development and combat poverty and income inequality. In addition, endogeneity may also arise due to measurement error in the ecological efficiency of the human development index, since the ecological efficiency data that we used in this study was estimated by Hickel (2020). We follow the literature on dynamic panel data estimation to solve these endogeneity problems using the system-GMM estimator (Blundell and Bond, 1998). This method has several advantages. Controls for the persistence of ecological results, notably ecological efficiency of human development, controls for the Nickell

bias (Nickell, 1981) that appears in a dynamic panel model, a model with lagged endogenous control variables, with fixed effects, limits the influence of unobservable time-varying factors that can influence both outcome and treatment variables, and alleviates the difficulty of finding an exogenous instrument to estimate the effect of RBLs. One of the main advantages of the systemic GMM estimator lies in the fact that this estimation technique can instrument other explanatory variables that could potentially be endogenous in addition to the main regressor (in our case, RBL), which is endogenous. However, one limit of the GMM estimator is that lagged levels of variables may be poor instruments (weak instrument problem) if those variables follow a random walk process, as lagged values of the variables in level provide less information about future changes (Blundell and Bond, 1998). Moreover, this method is considered by some researchers to be a black box (Soto, 2009), in the sense that it offers researchers the possibility and ease of manipulating the number of lag until they obtain the desired results.

We present the results in column [2] of Table 1.6. Unsurprisingly, the results lead to conclusions that are qualitatively similar to the baseline results. In addition, with regard to the instrument selection criteria, the Hansen test does not reject the hypothesis of instrument validity. Finally, the AR (1) test for the absence of autocorrelation of the first-order error term and the AR (2) test for the absence of autocorrelation of the second-order error term do not raise concerns about the validity of our estimates.

IV estimates. In addition to the aforementioned robustness checks, it would also be reassuring to display the system's GMM estimation results obtained with external instruments in addition to the internal ones, in order to mitigate the RBL endogeneity problem. Commodity prices and crude oil prices are expected to affect the probability of signing a resource-backed loan, without having any direct effect on the ecological efficiency of human development of African economies. Consequently, commodity prices and crude oil prices could be good candidates (not perfect) as instrumental variables for RBL. Although the instrumental variable method uses external instruments not only to overcome the problems of instrument proliferation and the black-box problem highlighted in the literature, it has limitations. The main limitation of this method is that, in theory, it is difficult, if not impossible, to obtain a perfect external instrument, i.e. one that is correlated with the endogenous variable without impacting the dependent variable. We present the results in Table 1.6, column [3]. The main result of the study remains qualitatively unchanged when systemic GMM estimation includes

an external instrument. Resource-backed loans have a positive impact on ecological efficiency.

Table 1.6: Results from Propensity Score, GMM and IV-2SLS estimators

VARIABLES	[1]	[2]	[3]
	Propensity Score	GMM	IV-2SLS
Lag Ecological efficiency		0.4176*** (0.0332)	
RBL		0.0148** (0.0070)	0.7963*** (0.2563)
Log Inflation	0.0300 (0.1030)	-0.0025*** (0.0008)	0.0050 (0.0074)
Log ODA	-0.2256*** (0.0727)	-0.0357*** (0.0024)	-0.0549*** (0.0084)
Log FDI	0.4983*** (0.1307)	0.0091*** (0.0009)	0.0044 (0.0066)
Log Natural resources rents	0.3504*** (0.1298)	-0.0193*** (0.0014)	-0.0454*** (0.0062)
Log Resource depletion	0.0789 (0.0787)	0.0152*** (0.0010)	0.0189*** (0.0041)
Constant	-3.5461*** (0.2808)	-0.3336*** (0.0191)	-0.6186*** (0.0195)
AR(1) test, p-value		0.005	
AR(2) test, p-value		0.969	
Hansen, p-value		0.682	
Sargan, p-value		0.000	
Kleibergen-Paap LM test, p-value			0.0043
Observations	926	776	716
R-squared	0.1190		
Number of countries		38	45
Number of instruments		20	2

Robust standard errors in brackets. * p < 0.1, ** p < 0.05, *** p < 0.01

1.7.2 Additional control variable and modification of sample

We examine the robustness of the main result of the chapter when various considerations are taken into account in the analysis. We have grouped these variables into four categories defined as follows: *i*- economic variables: GDP per capita volatility, investment volatility, total investment, stock price volatility, financial openness, rich-resources, trade openness, re-

mittance inflows, public debt, exchange rate; **ii-** political and institutional conditions: rule of law, corruption, external conflict, internal conflict, political stability; **iii-** climate considerations: climate vulnerability, disasters index, exposure index, shock index, natural shock index; **iv-** infrastructure and structural issues: ICT infrastructure, education, innovation, doing business, electric power consumption, access to urban electricity, access to rural electricity. To capture the common characteristics of the variable categories used, we calculate a composite outcome index for each category following Anderson (2008), to apply generalized least squares estimators. The steps and advantages of this method will be discussed in the Appendix.

Indeed, we begin this exercise by including these four groups of variables one at a time in our baseline model, thus mitigating any potential multicollinearity problems we may encounter. The results in Table A2, columns ([1]-[5]) in the appendix present the conclusions from the inclusion of economic variables, political and institutional conditions, climatic considerations, and infrastructural and structural factors, respectively. The principles remain unchanged when these four categories of variables are included in the baseline equation, despite some loss in the magnitude of coefficients and observations compared to the Table A1 in the Appendix. However, despite the consistency of our results, they may potentially suffer from omitted-variable bias, as we conveniently decided to include these four variables separately in our regressions. Consequently, in column [5], we simultaneously include our four previous groups in the base model. The findings remain consistent with those reported previously. Next, we disaggregated each variable category to run the regressions, allowing us to capture the effect or modification that each variable used to construct the variable categories exerts on our basic results. We report the new results in Tables [A3]-[A4], columns [1]-[27] in the Appendix. The conclusions remain unchanged and robust resource-backed loans have a positive and statistically significant impact on the ecological efficiency of human development.

Finally, we take the rather crude step of modifying our overall sample and testing the robustness of our results. To achieve this, we first run regressions on different sub-samples. Following Lin and Ye (2013) and Reinhart and Rogoff (2004), we exclude hyperinflation episodes defined as an annual inflation rate of 40% or more. Secondly, we exclude newly signed RBLs from our sample. In fact, new RBLs may not have an effect on the ecological efficiency of human development because of the time it takes for an investment to have a significant effect on the economy. In this way, RBLs may not have an effect in Guinea, which signed up in 2017

and Ghana in 2018, for example, as our sample is limited to 2019. We limit our sample to 2004. This allows us to exclude all observations before 2004, which is considered to be the starting point for the adoption of RBL in African countries (Mihalyi et al., 2020; Mihalyi et al., 2022). In addition, we exclude the collapse of the world economy due to the 2008-2009 financial crisis, as well as the year of the oil crises. Some countries actively participate in various environmental conventions and adopt environmentally friendly policies. This enables them to establish a sound policy for the management of natural resources and human capital. These results may affect the ecological efficiency of human development and bias our conclusions. We therefore exclude participants in these environmental conversions who score well⁷. To complete this part of our robustness checks, we exclude countries whose GDP per capita growth exceeds the average for the overall sample. This is justified by the fact that the causal effect of RBL on ecological efficiency may reflect the country's greater economic needs, not RBL. The results reported in Table A4, columns [28]-[34] show that despite the alternative samples, our results remain robust and consistent with the baseline results, reinforcing our confidence.

1.7.3 Combined entropy balancing and time perspective

Resource-backed loans have been on an upward trend during our period since the resource boom began in the early millennium (Mihalyi et al., 2020). Similarly, we can assume a significant improvement in life expectancy, education, and income and respect for ecological overshoot over time in African countries, leading to an upward trend in ecological efficiency of human development (Hickel, 2020), without this completely being explained by resource-backed loans. To account for the improvement in ecological efficiency over time and the increasing trend in the number of countries adopting resource-backed loans during our study period, we augment our base model by introducing a trend to redo the regressions. The new ATTs are shown in Table A5, columns [1]-[8] in the appendix. The new estimates remain similar to those of the baseline model (Table 1.3, columns [1]-[8]).

1.7.4 Placebo test

So far, our results reveal that RBLs have a statistically significant causal effect on the ecological efficiency of human development in African countries. The effect considered in this

⁷The highest score for this environmental convention is 1. A country with a score of 1 means that it is an active participant in environmental conventions.

chapter may suffer from certain economic biases. In fact, the adoption of resource-backed loans can trigger a change in the economic environment, including increased investment, boosting GDP, increasing the share of educated, healthy and less poor population, which are Sustainable Development Goals, and civil unrest. In this sense, it can be argued that the effect observed may not be due to resource-backed loans but to changes in institutional, political, social, or economic conditions after the adoption of these loans. Similarly, any other characteristic that may determine the adoption of resource-backed loans but is not included in the econometric specification may be a source of endogeneity even if we have added an additional variable battery for controls. We are aware that the non-transparency evoked in RBLs, according to the study of Mihalyi et al. (2020), may suggest that our control group may be contaminated. To avoid these problems, it would be interesting to randomly assign a new treatment to the RBL variable. In fact, this new treatment, apart from the actual dates, is expected to not affect the ecological efficiency of human development. If we find a significant effect, this would mean that our results are affected by unobservable counterfactuals and that our control group constructed from the information collected by Mihalyi et al. (2020) is indeed contaminated. We report the ATT results in Table 1.7, columns [1]-[8]. We find no significant effect regardless of the specifications, which clearly indicates that our results are not affected by an unobservable phenomenon and that our basic control group defined from the database of Mihalyi et al. (2020) does not suffer from any bias.

Table 1.7: Resource-backed loans and ecological efficiency : Placebo test

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
RBL dummy (random)	0.0141 (0.0392)	-0.0007 (0.0284)	0.0267 (0.0329)	-0.0094 (0.0094)	-0.0227 (0.0405)	0.0025 (0.0174)	-0.0147 (0.0378)	-0.0053 (0.0071)
Constant	-0.6795*** (0.0127)	-0.7164*** (0.0440)	-0.7430*** (0.0668)	-0.7807*** (0.0366)	-0.5270*** (0.0324)	-0.7127*** (0.0483)	-0.5450*** (0.0631)	-0.6345*** (0.0477)
Covariates	No	No	No	No	Yes	Yes	Yes	Yes
Country/FE	No	Yes	No	Yes	No	Yes	No	Yes
Year/FE	No	No	Yes	Yes	No	No	Yes	Yes
Observations	611	611	611	611	611	611	611	611
R-squared	0.0006	0.7927	0.1636	0.9275	0.2769	0.8469	0.4098	0.9310

Notes: This Table presents the effect of resource-backed loans on ecological efficiency of human development obtained by entropy balancing method. The treatment variable is resource-backed loan (random assignment). The outcome variable is ecological efficiency of human development. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

1.8 Transmission channels

This section empirically tests the main channels through which the causal effects of RBL can be exerted. Since the literature does not impose any explicit or singular methods for evaluating transmission channels, we adopt a simple two-step approach. First, we estimate a simple uni-variate regression of the potential channel on ecological efficiency of human development, using the OLS estimator. Second, we re-estimate our base model using a simple OLS estimator and replacing our dependent variable with the potential channel. In fact, the aim of this exercise is to test whether, for example, if stimulating economic activity through wealth creation positively affects ecological efficiency, and GDP per capita is a relevant channel through which RBL is effective, then GDP per capita should in turn increase ecological efficiency. In columns [1]-[3] of Panel A (Table A6), we estimate a uni-variate regression of education level, income and expected years of schooling. All coefficients are positive and statistically significant at the level 1%. These results corroborate those found by Hickel (2020). Finally, the results reported in Panel B show that resource-backed loans have a positive and significant impact on all three variables. These results reveal that the positive effect of resource-backed loans is mediated by an increase in education level, an improvement in expected years of schooling, and income. In fact, resource-backed loans will increase public investment in infrastructure (health, education, and roads), boosting GDP, and increasing the share of educated, healthy, and less poor population.

1.9 Heterogeneity

1.9.1 Effect by type of resource-backed loans

In this section, we desagregated resource-backed loans into three types of resource-backed loans based on information from the Mihalyi et al. (2020) database. The three types of loans signed by countries include oil-backed loans, mineral-backed loans, and cocoa- and tobacco-backed loans. In fact, oil-backed loans are simply loans that must be repaid through the exploitation and sale of oil. Mineral-backed loans are those whose repayment is directly related to bauxite, copper, cobalt, platinum, gold, and diamond, while cocoa and tobacco-backed loans are repaid by the exploitation and sale of cocoa and tobacco. These different forms of loan can have a heterogeneous effect on the ecological efficiency of human development in African

countries. This will be discussed in this subsection. The results reported in Table 1.8, columns [1]-[3] show that only loans backed by cocoa and tobacco have a negative impact on the ecological efficiency of human development. In contrast, oil and mineral-backed loans have a positive and significant impact on the outcome variable. In fact, the negative impact of cocoa and tobacco loans could be explained by the fact that cocoa and tobacco production is not sustainable and does not meet environmental standards in terms of sustainable development in African countries. In addition, these results are in perfect harmony with those found by Ruf et al. (2015) that cocoa farming is one of the main drivers of deforestation in Africa.

Although our results indicate that mineral and oil-backed loans have a positive impact on the ecological efficiency of humans, they can also be the cause of significant environmental degradation. In fact, according to Coulibaly (2023b), mineral-backed loans exert a strong pressure on forest cover. The author explains the positive effect of mineral-backed loans on deforestation by the instability of commodity prices, which increases the value of the debt to be repaid, given that the loans are signed in US dollars. This will lead to overexploitation and depletion of natural resources, affecting forest cover. However, the key idea of the Sustainable Development Index designed by Hickel (2020) is to incorporate the ecological dimension, that is, CO₂ emissions and material borrowings that do not exceed a well-defined planetary limit. If this is the case, a related question in this chapter would be to analyze the scale of resource-backed loans on ecological impact and planetary boundaries, in order to draw solid recommendations for individual countries.

Table 1.8: Heterogeneity by type of resource-backed loans

VARIABLES	[1]	[2]	[3]
Cocoa and tobacco-backed loans	-0.0285*** (0.0100)		
Minerals resource-backed loans		0.0068* (0.0098)	
Oil resource-backed loans			0.0099** (0.0060)
Constant	-0.6753*** (0.0444)	-0.6759*** (0.0446)	-0.6788*** (0.0446)
Covariates	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes
Observations	799	799	799
R-squared	0.9395	0.9393	0.9395

Notes : This Table presents the results of desegregated resource-backed loans obtained by entropy balancing method. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

1.9.2 Effect by public debt level

In this subsection, we attempt to capture resource-backed loans by the level of public debt. Our aim is to capture the level of debt that would be compatible with the ecological efficiency of human development for countries adopting RBL. In fact, one method that is well suited for this type of exercise is the use of threshold models (Granovetter, 1978). However, the unbalanced format of our panel data means that this technique cannot be applied rigorously. To this end, we used the entropy balancing method, setting conditions on public debt. In other words, we look at the effect of resource-backed loans on the ecological efficiency of human development when the level of public debt is below the sample average and when it is above the average. The idea is that a high public debt could exacerbate the country's public debt situation and reduce the financing capacity for clean, favorable and sustainable development. We will test this hypothesis. The results presented in Table 1.9, column [1] indicate that resource-backed loans have a positive and statistically significant impact on the ecological efficiency of human development when the level of public debt is relatively low, while no effect is found when

the level of debt exceeds the average for the entire sample (Table 1.9, column [2]). These results are not surprising, as unsustainable public debt reduces budgetary space and prevents the government from taking action to protect the environment and biodiversity. Countries should therefore avoid taking on too much debt at the risk of losing fiscal discipline and should not use resource-backed loans. These results corroborate those found by Boly et al. (2022) according to which public debt and environmental debt are complementary in the long term and generally substitute each other in the short term. This means that in the long term, public debt offsets environmental debt, so that public debt has an overall negative effect on pollution control spending; whereas in the short term, the second effect outweighs the first, provided that public debt is not too high.

Table 1.9: Heterogeneity by debt level

VARIABLES	[1]	[2]
	Public Debt<mean	Public Debt>mean
RBL dummy	0.0463*** (0.0092)	0.0004 (0.0148)
Constant	-0.6147*** (0.0391)	-0.8410*** (0.0442)
Covariates	Yes	Yes
Country/FE	Yes	Yes
Year/FE	Yes	Yes
Observations	509	290
R-squared	0.9721	0.9764
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1		

1.9.3 Does ecological impact and planetary boundaries matter?

The analysis of the transmission channels in Section 1.8 shows that resource-backed loans have a positive effect on the GNI of signatory countries. In fact, analysis of 2015 HDI data clearly shows that some countries are approaching an achievable state while achieving very high levels (0.8 or more) on the life expectancy index with as little as \$3,300 per capita (or 0.9 with as little as \$11,000), and very high levels on the education index with as little as \$8,700 per capita, while maintaining ecological impact at sustainable levels (Hickel, 2020). In addition, other countries are achieving fairly high levels of sustainable development, with per

capita figures of \$10,000 to \$14,000 (Hickel, 2019; O'Neill et al., 2018). However, when the GNI exceeds this level, it begins to have clear negative social and ecological consequences (Deaton, 2008; Inglehart, 2020; Kubiszewski et al., 2013; Lamb et al., 2014; Max-Neef, 1995).

Our concern here is that if resource-backed loans help boost GNI beyond ecologically compatible levels, they could adversely affect environmental sustainability. We are testing this hypothesis to ensure that resource-backed loans do not affect the environment and achieve an achievable planetary limit. To achieve this, we have calculated a composite⁸ environmental sustainability index that captures CO₂ and greenhouse gas emissions, the key determinants of ecological impact (Han and Chatterjee, 1997; Jiang et al., 2019; Karakurt and Aydin, 2023; etc.). The results presented in Table A7, Panel A confirm our hypothesis that resource-backed loans contribute to increase ecological impact in signatory countries compared to non-signatory countries. Further analysis in Panels B and C shows that the impact is stronger on CO₂ emissions than on greenhouse gases (Table A7, column [8]). One possible explanation for this result is that RBLs, by depleting natural resources and destroying forest cover (Coulibaly, 2023b), accelerate CO₂ and greenhouse gas emissions, since forests sequester carbon and protect the ozone layer. These results reveal that the environmental concerns of RBLs are significant in the context of the so sought after sustainable development and energy transition around the world and will need to be brought to the attention and information of policymakers in resource-rich countries.

1.9.4 Does implementing the Extractive Industries Transparency Initiative (EITI) matter?

In this subsection, we examine the effectiveness of resource-backed loans in the presence of the Extractive Industries Transparency Initiative (EITI). Indeed, the EITI specifically encourages transparency, particularly with regard to RBLs (Mihalyi et al., 2020), and prevents poor governance of natural resources. For instance, Kinda and Thiombiano (2024b) using entropy balancing methods in a sample of 83 resource-rich developing countries from 2001 to 2017, find that the implementation of EITI significantly reduces the loss of forest cover by around 300 to 760 ha. These results confirm that the implementation of EITI is an effective policy program to limit the negative environmental impacts caused in part by the extractive industries. Re-

⁸The index is calculated using the Anderson (2008) method.

garding resource-backed loans, countries that have signed an RBL and are EITI members were required to comply with the 2019 EITI standard, which includes a transparency requirement related to payments associated with RBLs as part of the payment flows that EITI-implementing countries must disclose. Other requirements relate to the disclosure of barter transactions in which oil or mining products are exchanged for goods or services, including infrastructure or even loans, not only for countries but also for companies involved in the exploitation of natural resources (Mihalyi et al., 2020). In contrast, Mawejje (2019) believes that EITI is not a panacea to eliminate the curse of tax revenues in resource-rich African countries. Using panel fixed effect econometrics and dynamic panel GMM on a panel of 31 resource-rich sub-Saharan African countries, the author shows that EITI membership has had a small positive effect on non-oil revenue mobilization and only partially offsets the negative impact of resource dependence on non-resource tax revenues. This result suggests that although improving governance and transparency in the management of natural resource revenues through EITI is seen as essential to mitigate the negative consequences that characterize resource-rich countries, its impact remains rather ambiguous.

This chapter therefore tests whether EITI membership can still help to improve the ecological efficiency of human development for RBL signatory countries. To test this hypothesis, we include an interaction interaction between each of the EITI and RBL variables. Consequently, a statistically significant interaction means the presence of heterogeneity and the effectiveness of resource-backed loans in the presence of EITI membership.

The results presented in Table 1.10, columns [1]-[3] support our hypothesis even if the amplitudes of the coefficients remain quite similar to the baseline results (slight improvement). Indeed, the positive and statistically significant sign of the interaction between RBL and each of the EITI variables, i.e. EITI full, EITI comitment, and EITI candidate, suggests that the effect of RBL may be amplified in situations of EITI implementation, comitment, and EITI candidate. These results are corroborated with those found in Kinda and Thiombiano (2024b).

Table 1.10: Effect of EITI implementing

	[1]	[2]	[3]
VARIABLES	Ecological efficiency of human development		
RBL*EITI countries	0.0211*** (0.0068)		
RBL*EITI comitment		0.0211*** (0.0068)	
RBL*EITI candidate			0.0257*** (0.0066)
Constant	-0.7190*** (0.0276)	-0.7190*** (0.0276)	-0.7212*** (0.0276)
Covariates	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes
Observations	602	602	602
R-squared	0.9707	0.9707	0.9711

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

1.9.5 Do financial market access conditions matter?

Given that the financing of sustainable development for African countries requires the mobilization of resources in the financial markets, we link resource-backed loans to interest rates in the bond market. In other words, we test whether resource-backed loans replace or complement access to credit. The idea of understanding whether resource-backed loans and access to financial markets are complementary or substitutable answers two arguments. The first is that if a resource rich country with high financial risk limiting its access to financial markets uses its natural resource endowment as collateral, lenders may perceive this behavior as a risky debtor. In fact, they can say because the country has a fragile financial situation and it is likely that it will not be able to repay its debt and, therefore, it uses its natural resources as collateral. As a result, resource-backed loans will replace access to credit since traditional lenders will either refuse to lend or will lend at high interest rates which will ultimately discourage debtors and they will move towards the resource-backed loan market. The second argument is that donors may perceive the resources as a good guarantee and think that whatever the situation prevails, the debtor country will be able to repay since there is a guarantee.

From this point of view, resource-backed loans will complement other loans and strengthen access to financial markets.

Table 1.11: Resource-backed loans and credit access

VARIABLES	[1] Interest rate	[2] Interest rate	[3] Credit rating	[4] Credit rating
Resource-backed loans	0.5723*** (0.1560)	1.1318*** (0.3196)	-1.4910*** (0.3318)	-0.9115** (0.4205)
Constant	2.0051*** (0.0578)	1.8003*** (0.6462)	8.4003*** (0.1998)	8.6407*** (1.0496)
Country/FE & Year/FE	No	Yes	No	Yes
Covariates	No	Yes	No	Yes
Observations	538	538	302	302
R-squared	0.0913	0.6601	0.1062	0.9118

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

To test this, we use two indicators of access to financial markets. Firstly, we use the interest rate on the bond market as the first instrument that conditions the evolution of the bond market. Second, following Sawadogo (2020), we use the credit rating as an indicator of access to financial markets. The results reported in Table 1.11, columns [1]-[2] show that resource-backed loans have a positive and statistically significant impact on the interest rate of the bond market. Naturally, a higher interest rate limits the ability of debtor countries to access the financial markets. By evaluating its impact on the credit rating, our results show that resource-backed loans have a negative and statistically significant impact (Table 1.11, columns [3]-[4]). This suggests that, rather than being a complement to ordinary loans, resource-backed loans would replace them.

1.9.6 The contribution of structural factors

We explore the important structural differences that shape the effect of resource-backed loans on the ecological efficiency of human development in African countries despite a number of common characteristics. To achieve this, we apply the control function regression approach of Lin and Ye (2009). Using this method, we investigate the sensitivity of our different baseline results to certain country structural characteristics, such as age dependency ratio, financial development, government revenue, interest on debt, urban population, government effective-

ness, credit rating, public debt, and resource depletion. To do that, we include an interaction between each of these variables and resource-backed loans. Consequently, a statistically significant interaction means the presence of heterogeneity. The Table A8 in the Appendix, presents the estimate of the treatment effect of resource-backed loans based on the control function regression approach. In the first column, we perform a simple OLS regression of resource-backed loans on an ecological efficiency of human development variable, including the estimated propensity score (Pscore) obtained from our basic probit model as the control function. The estimated coefficients, which capture the difference between the mean resource-backed loans of beneficiaries and non-beneficiaries, are positive and statistically significant. A statistically significant coefficient on the propensity score means that there is self-selectivity in the model. However, the coefficient is not significant even when certain structural factors are controlled (columns [2]-[10]). The results indicate that resource-backed loans are more effective in increasing ecological efficiency of human development in countries that have them, particularly when: *(i)*- the government is more effectiveness, *(ii)*- interest on debt is low, *(iii)*- there is a small urban population, *(iv)*- fiscal discipline is captured by low debt levels, *(v)*- natural resources are abundant. More specifically, the effect of resource-backed loans on the ecological efficiency of human development is greater in countries where the depletion of natural resources is lower.

1.10 Conclusion and policy recommendations

This chapter analyzes the causal effect of resource-backed loans on the Sustainable Development Index measured by the ecological efficiency of human development using a large sample of 45 African countries over the period 1990-2019. To achieve this, we began by exploring the correlation between the two variables through a graphical analysis of the stylized facts. Although we obtained graphical evidence that RBLs are likely to go hand in hand with the ecological efficiency of human development, we have deepened our analysis by determining the causal effect of these RBLs through the use of the entropy balancing method. We show that irrespective of the specifications, the adoption of resource-backed loans increases the ecological efficiency of human development in resource-backed loans countries compared to non resource-backed loans countries. The magnitude of the coefficients varies between 0.024 percentage points (column [8]) and 0.163 percentage points (column [2]) of Table 1.3. This result is

robust given the relative stability of the coefficients across the eight specifications in the table, with an average effect of 0.076 percentage points. In other words, the adoption of resource-backed loans increases the ecological efficiency of human development by 0.076 percentage points in countries with resource-backed loans compared to non resource-backed loans. This result is robust to various tests, including alternative specifications and alternative estimation methods. Analysis of transmission channels indicates that the expected level of education, income, and years of schooling drive the stabilizing effect of resource-backed loans. However, the results reveal some heterogeneity in the type of resource-backed loans, in the burden of public debt, and structural factors such as interest on debt, urban population, government effectiveness, public debt, and resource depletion. Additional results highlighted in this article show that resource-backed loans contribute to CO₂ and greenhouse gas emissions in African countries. This result is not surprising, as it has been shown in the literature that financing real income growth through external public debt can lead to increased CO₂ emissions and environmental degradation (e.g. Boly et al., 2022; Katircioglu and Celebi, 2018). This result should attract the attention of policymakers in countries that wish to sign a resource-backed loan agreement.

In addition, it appears that the positive impact is conditioned by the level of sovereign debt. Finally, EITI membership has a stabilizing effect on the positive impact of resource-backed loans. This result corroborates those found in the literature on the beneficial effects of joining EITI (see, for example, Kinda and Thiombiano, 2024b; Villar, 2022; Villar and Papyrakis, 2017). In the literature, this study contributes, based on a cross-national analysis, to the debate on the role of new sources of sustainable development financing in well-being and environmental sustainability in African countries.

In this chapter, we present two aspects of the risk of leveraged loans beyond their benefits, namely debt risk and environmental risk. Our results point to the existence of an inverted U-shaped Environmental Kuznets Curve (EKC) between economic development and the environmental performance of African economies. Therefore, it would be convenient for resource-backed loans, particularly from cocoa and tobacco, to include biodiversity-related elements and strict provisions for the implementation of actions to mitigate their adverse impact on the environment. Policymakers must heed these observations to take advantage of resource-backed loans, circumvent the curse of natural resources, and ensure cleaner, more inclusive

long-term sustainable development. Consequently, EITI membership would be the best policy choice to achieve these goals, as the initiative's standards are based on good governance, transparency, and environmental compliance. When it comes to sovereign debt management, the leaders of African countries need to work towards a climate finance goal, i.e. adopt a long-term plan to protect nature and biodiversity; and to do this, they need to engage in debt consolidation programs (e.g. by implementing tax increases, public spending cuts, or debt relief agreements). In fact, debt servicing reduces the government's ability to finance emissions reduction spending, which degrades environmental quality and increases long-term climate debt. By reducing public debt, the government provides more fiscal space to finance nature protection policies in the long term.

Finally, one of the main limitations of this chapter lies in the use of a binary variable to capture resource-backed loans, rather than using actual data on these resource-backed loans. Future research could aim to correct this by using data on resource-backed loans. In addition, the chapter says nothing about the effect of resource-backed loans on the loss of forest cover, which is a good indicator of ecology and environmental quality. We intend to explore this avenue in the future.

THE EFFECT OF RESOURCE-BACKED LOANS ON DEFORESTATION: EVIDENCE FROM DEVELOPING COUNTRIES

Abstract:¹ Resource-backed loans are used today by many resource-rich countries as an effective means of providing public goods and services. However, this type of financing can undermine environmental sustainability through deforestation. In this chapter, we first use propensity score matching, which allows self-selection bias in signature policies, to test whether resource-backed loans have a causal impact on deforestation in 64 developing countries from 2004 to 2018. Through a series of alternative and econometric specification tests, we find that resource-backed loans increase deforestation, measured by forest cover loss. Nevertheless, when we disaggregate resource-backed loans to capture the heterogeneous effects, our results indicate that mineral, tobacco, and cocoa-backed loans increase deforestation, whereas oil-backed loans have no significant direct impact on deforestation. We conclude the article by providing recommendations for research, policy, and practice, particularly on environmental protection and biodiversity, transparency through improved institutional variables, and the management of natural resource revenues.

Keywords: • Resource-backed loans • Energy transition • Forest cover loss • Resource taxation • Environment • Climate Change • Propensity score matching.

JEL Codes: O13, H81, C12, Q54, Q01.

¹A prior version of this chapter is published in *World Development*

2.1 Introduction

Etymologically, natural capital includes the stocks of natural resources, land, and ecosystems that are essential for the sustainability of economic development (World Bank, 2005) and the reduction of poverty in developing countries (Celentano et al., 2012; Wunder, 2001). Through the exploitation and rational use of natural capital, the extractive industries played a crucial economic, social, and political role in the lives of nearly 3.5 billion people living in 81 countries around the world (Kinda and Thiombiano, 2021). Indeed, statistics show that the exploitation of natural capital accounts for at least 20% of exports and government revenues in twenty low- and middle-income countries (Halland et al., 2016), and several countries have developed thanks to the exploitation and transformation of their natural resources (Halland et al., 2016)². However, backed certain sources of financing heavily on natural capital to achieve the early stages of development can lead to serious environmental problems such as deforestation, pollution, conflict, depletion of non-renewable resources and disruption of ecosystems, endangering the health and safety of workers and the general well-being of local communities. This could be the case with resource-backed loans (RBL).

Basically, resource-backed loans are defined as an alternative financing tool for resource-rich developing countries that have difficulty mobilizing resources on financial markets (Mihalyi et al., 2020; Mihalyi et al., 2022), whose natural resources represent an asset that serves as collateral and repayment to lenders (government, public enterprise, private sector and/or international financial institutions). Similarly, payment can be made using the income stream from natural resources or using natural resources in kind as payment in kind (Mihalyi et al., 2020; Mihalyi et al., 2022). Numerous resource-backed loan agreements have been signed over the decades by countries in sub-Saharan Africa and Latin America³. Indeed, 30 of the 52 resources-backed loans identified in developing countries during 2004-2018 went to African countries, while the remaining 22 went to Latin American countries (Mihalyi et al., 2020). A total of 14 countries in these two regions have subscribed to these loans totaling \$164 million, including \$98 million for Latin American countries and \$66 million for Sub-Saharan African

²More recently, developing countries such as Botswana, Chile, Malaysia and South Africa have achieved the highest level of income, thanks in part to the extraction of natural resources.

³These 14 countries are: Angola, Brazil, Chad, Democratic Republic of Congo, Ecuador, Ghana, Guinea, Niger, Republic of Congo, Sao Tome and Principe, Sudan, South Sudan, Venezuela, and Zimbabwe (see Mihalyi et al., 2020; Mihalyi et al., 2022 or Coulibaly et al., 2022).

countries (Mihalyi et al., 2020; Mihalyi et al., 2022). The NRGi report indicates that the largest beneficiary of these loans is Guinea Conakry, which subscribed US\$20 billion in 2017, backed by bauxite. This amount was equivalent to about 200% of the country's GDP at the time (Mihalyi et al., 2020). The country has used this large sum to build multi-sectoral infrastructure, including the Coyah-Dabola road, the Conakry road network and sanitation, and university buildings. The composition of these 52 loans secured by natural resources showed that 43 were secured by oil, 6 by minerals, 2 by cocoa, and 1 by tobacco (see Coulibaly, 2024b; Mihalyi et al., 2020). Looking at the payment component of resource-backed loans in the definition given by Mihalyi et al., 2020; Mihalyi et al., 2022), this means that in any case the amount described above should be repaid by relying heavily on natural capital, especially natural resources.

To exploit natural resources, debtor countries will increase mining activities by granting more operating permits to extractive industries. Although the literature has identified mining and extractive industries as one of the main causes of deforestation in developing countries, For example, Kinda and Thiombiano (2021) have shown that activities in the extractive industry increase deforestation on several spatial scales in developing countries (site, local, and regional). According to Sonter et al. (2017), mining activities caused 11.67 km² of deforestation in the Amazon forest between 2005 and 2015. Bebbington et al. (2018) have shown that the extractive industries and their associated infrastructures are the main causes of greenhouse gas emissions, the reduction of forest landscapes and threats to the rights of forest communities in forested areas. In addition, some studies show that credit can be used to finance infrastructure investments that encourage deforestation (Combes et al., 2015; Pacheco, 2006). If mining activities consume space and contribute directly to deforestation (Kinda and Thiombiano, 2021), then resource-backed loans could be a cause of deforestation, as they enable debtor countries to grant mining permits and attract more FDI to the extractive sector.

In addition, the literature shows that there are many factors linked to deforestation. These include agricultural activity, access to credit, public policy (Combes et al., 2015; Motel et al., 2009; Pacheco, 2006), population growth (Cropper and Griffiths, 1994; Rudel, 2023), timber harvesting (Damette and Delacote, 2011), real exchange rate (Arcand et al., 2008), policy program such as EITI membership (Kinda and Thiombiano, 2024a), impact of plantations on forests (Heilmayr, 2014), the public debt (Culas, 2006; Kahn and McDonald, 1995), the economic growth (Ehrhardt-Martinez et al., 2002; Jorgenson, 2006), agricultural land area (Austin,

2010), the democracy (Li and Reuveny, 2006), the structural adjustment of the International Monetary Fund (Benhin and Barbier, 2004; Rich, 2014), the bilateral environmental aid (Bare et al., 2015), and the debt-for-nature swaps (Cassimon et al., 2011; Hamlin, 1989; Hansen, 1989; Sommer et al., 2020). However, the literature is silent on the effect of resource-backed loans on deforestation. Although resource-backed loans are also a form of external debt, authors such as Kahn and McDonald (1995); Didia (2001); Culas (2003); etc. have subsequently shown a negative correlation between public debt and deforestation, these authors were not interested in assessing the causal effect of resource-backed loans. This is surprising because the mechanism by which resource-backed loans affect deforestation is different from those by which other non resource-related public debts do. In fact, resource-backed loans put implicit pressure on the borrowing country to undertake natural resource exploitation, an activity associated with significant deforestation risks, whereas for other types of loans, there are no constraints and no formal obligation for the government to exploit natural resources for loan repayment. The pioneering study on resource-backed loans by Mihalyi et al. (2020) and Mihalyi et al. (2022) says nothing about environmental quality in general and deforestation in particular. The authors have carried out descriptive studies, and even if they are concerned with quality, these studies suffer from a lack of use of an appropriate statistical method that takes into account the potential problems that may arise due to selection bias in adoption. However, due to the lack of transparency around resource-backed loans (Horn et al., 2021; Mihalyi et al., 2020; Rivetti, 2021), previous studies on the impact of public debt on deforestation in developing countries may not take into account the environmental impact of resource-backed loans, as resource-backed loans may not be reflected in public debt statistics (Horn et al., 2021; Mihalyi et al., 2020; Rivetti, 2021). An in-depth analysis based on a more advanced impact assessment method is required to compare countries with RBL and those without RBL on the basis of similar characteristics.

In this context, the aim of the article is to fill this gap in the economic literature by analyzing the environmental impact of resource-backed loans to enrich the political debate on climate change, public debt, and the exploitation of natural resources. Thus, our research question is to analyze the causal effect of the adoption of resource-backed loans on deforestation in developing countries. Indeed, three major motivations led us to this research question. Firstly, the scale of resource-backed loans and their impact on public finances in developing

countries in the last few decades (Horn et al., 2021; Mihalyi et al., 2020; Rivetti, 2021). In fact, resource-backed loans are becoming increasingly popular, as they often come with the usual conditionality of multilateral and bilateral loans (Mihalyi et al., 2020). Secondly, the increasing trend of deforestation in developing countries in recent years. According to statistics, it is estimated that deforestation leads to a loss of 46 to 58 thousand square kilometers of forest per year (Adams, 2012; Bennett, 2017), and the rate of deforestation has been identified as 10 million hectares per year between 2015 and 2020 FAO and UNEP (2020). Deforestation is the main cause of climate change (Gatti et al., 2021), threatens the conservation of biodiversity, and harms human health and the economy (FAO, 2022; Santos and Almeida, 2018). Third, and finally, the link between resource-backed loans and the environment via deforestation. Indeed, repayment of resource-backed loans could lead the government either to undertake over-exploitation of natural resources to meet the repayment schedule. This could accelerate the rate of depletion of natural resources, deforestation and increase greenhouse gas emissions in the country, as fossil fuels – coal, oil and gas – are responsible for 75% of global greenhouse gas emissions and almost 90% of all global carbon dioxide emissions (United Nations, 2022). In addition, resource-backed loans can jeopardize the public debt situation (Coulibaly, 2024b; Horn et al., 2021) and can prevent the country from mobilizing financial resources to fund policies to combat deforestation.

Based on the mechanisms of transmission of the resource-backed loan to environmental quality, in particular deforestation, the resulting hypotheses are as follows: **(i) resource-backed loans increase deforestation through the maximization of natural resource rents and resource depletion; (ii) resource-backed loans accelerate deforestation by exacerbating debt viability and affecting the quality of institutions.** To test these hypotheses, we use propensity score matching to address the self-selection bias associated with the adoption of RBL. We found that the adoption of resource-backed loans encourages a significant increase in annual deforestation in adopting countries compared to non-adopting countries. Our study contributes to the literature in several ways. Firstly, it sheds new light on the environmental damage caused by RBL. It also provides evidence that resource-backed loans can contribute to intensifying the curse of natural resources in resource-rich countries, rather than being a blessing in disguise due to their infrastructure-investing nature. Secondly, to our knowledge, this study is the first to empirically and rigorously assess the environmental impact of RBLs to

solve the self-selection problem. We have used the PSM method, which enables us to consider the factors that motivate countries to sign an RBL. In addition, the distinction between the two main resource-backed loans, namely minerals and oil, is crucial in assessing the scope of this financing instrument. In fact, the way mining and cocoa/tobacco exploitation affect forest cover is different from onshore oil exploitation, even though they all generate CO₂ emissions and destroy forest cover, whereas forests are crucial for carbon sequestration. Finally, we controlled for time- and country-fixed effects with methods such as entropy balancing and fixed effects estimates, sensitivity to time elapsed since RBL adoption, and other governance indicators such as governance effectiveness, corruption control, and rule of law. The main findings support the conclusion that while RBLs represent a good opportunity to finance essential development needs, they can also weaken debt sustainability and put pressure on borrowing countries to increase the rate of natural resource production to repay the loan, a factor that increases the rate of deforestation.

The rest of the chapter is organized as follows. Section 2.2 uses the existing literature to derive some insights on the relationship between RBL and deforestation. Section 2.3 reports some stylized facts. Then, Section 2.4 describes the empirical methodology, while Section 2.5 presents the data and descriptive statistics. The main results are presented in Section 2.6, while in Sections 2.7 and 2.8, we examine the sensitivity of these results and explore the heterogeneity tests. Section 2.9 analyses the possible transmission channels. Finally, Section 2.10 concludes the study and presents the main policy recommendations.

2.2 Related literature

The literature on the macroeconomic impacts of resource-backed loans is nascent and short (Mihalyi et al., 2020; Mihalyi et al., 2022; Coulibaly et al., 2022; Rivetti, 2021; Coulibaly, 2024a), and there is no literature on deforestation. To do so, we explore the channels through which resource-backed loans could affect deforestation.

On the theoretical side, given that resource-backed loans are generally contracted in US dollars, a collapse in the nominal value of these loans (Mihalyi et al., 2020; Mihalyi et al., 2022), and thus lead borrowing countries to exploit more natural resources to pay the loan repayments. As a result, resource-backed loans could accelerate deforestation in signatory countries.

Similarly, the repayment of resource-backed loans could lead the government either to begin exploiting oil resources or to accelerate the pace of mineral and hydrocarbon production to meet the repayment schedule. This could accelerate not only the rate of depletion of natural resources, but also the rate of deforestation. In addition, loans backed by natural resources can jeopardize the public debt situation (Horn et al., 2021) and can prevent the country from mobilizing financial resources to finance climate change adaptation and mitigation policies such as desertification, afforestation, etc. According to Van den Bergh (2013), the public debt can limit the ability to mobilize more national resources and therefore invest in climate actions in the context of developing countries. In a similar vein, the repayment of the debt service can force highly indebted economies to increase the pressure on natural capital to increase public revenues (Combes et al., 2015), leading to heavy deforestation and depletion of natural resources (Kinda and Thiombiano, 2021).

Indeed, resource-backed loans can attract FDI into the extractive sector by increasing the number of operating permits, which in turn will intensify mining activities. As a result, resource-backed loans indirectly affect forest cover. According to Sonter et al. (2017), mining can also lead to deforestation in surrounding areas. Kinda and Thiombiano (2021) defend this argument and believe that mining activities consume space and directly contribute to deforestation. In fact, the development of the infrastructures associated with this mining operation leads to direct clearing of forests and opens up forest areas to new settlers and immigrants, who bring with them agricultural, forestry and hunting activities that have an even greater impact on forests (Laurance et al., 2009).

The lack of transparency highlighted by Mihalyi et al. (2020) in resource-backed loans can be mobilized to explain how these loans can reach the forest canopy. Indeed, the opacity of resource-backed loans leads to high levels of corruption. Corruption, on the other hand, leads to illegal behavior, involving a high level of private capture of resource rents, which induces additional pressure that weakens forest protection (Bebbington et al., 2018). This is why Kinda and Thiombiano (2024a) recommend that countries join the EITI, which will help reduce deforestation by improving the quality of environmental institutions and regulations. The authors plaid for the vital role of the EITI in combating forest cover loss and financing sustainable development. In the same vein, Culas (2007) supports that the economic resources of forests (particularly timber) can encourage preservation and management as mature and dynamic

ecosystems, but the absence of enforceable and appropriate regulations leads to overexploitation and environmental degradation that could take decades, even centuries, to repair.

In the spirit of Boly et al. (2022), policies that do not curb the growth of public debt can reduce carbon concentration and improve environmental quality in the short term. However, such policies can have long-term adverse environmental consequences. The authors go further, arguing that policies that limit public debt, such as strict fiscal rules, can lead to a reduction in environmental debt and improved environmental quality in the long term, but with harmful consequences in the short term. In any case, this declaration calls for prudent use of public debt to achieve long-term climate change goals.

The collapse of commodity prices can be attributed to two consequences of resource-backed loans on forest cover loss. First, resource-backed credits can jeopardize the public debt situation Horn et al. (2021) and prevent the country from mobilizing fiscal resources to finance public expenditures related to climate change. Second, the loss of tax revenues due to price rip-offs will increase the face value of the debt as it is denominated in US dollars, forcing countries to increase their exploitation activities to comply with the trade. This will adversely affect forest cover loss, as activities related to the exploitation and exploration of natural resources increase forest cover loss in resource-rich countries. To illustrate, Kinda and Thiombiano (2021) conducted a theoretical analysis, supported by empirical evidence, and found an adverse effect of the rents of the extractive industry on forest cover loss, but pointed out that the effects are not homogeneous depending on the type of rent. They argue that maximizing rents is strongly associated with deforestation and that this can be offset by adopting a «polluter pays» model. Recent impact studies on resource-backed loans, such as. Coulibaly et al. (2022), have shown that resource-backed loans improve debt dynamics over a 5-years after signing due to the investments made and the tax revenues generated by those investments, which would allow for the financing of public expenditures directed toward green projects related to climate change or investments that meet environmental standards.

On the empirical side, we relate our empirical literature to studies that analyze the relationship between public debt and environmental quality. In fact, the consensus is that the link between public debt and environmental quality - most often measured by the area of rain forests in the tropical zone — is unambiguously negative. For instance, Culas (2006) estimated

the relationship between debt and deforestation through a cross-country regression analysis using a set of panel data from 23 African countries between 1971 and 1994, and the results show that debt and deforestation are positively related in tropical developing countries. The author recommends reducing the debt burden of developing countries to expand opportunities for better environmental governance. These findings are consistent with those of Shandra et al. (2008), which used a cross-country model to estimate the impact of debt on deforestation in 62 countries between 1990 and 2005. These authors find that debt and structural adjustment increase deforestation. However, the increasing number and density of international non-governmental organizations is reducing deforestation. In the same vein, Gullison and Losos (1993) examined the role of sovereign debt in deforestation in Latin America. They found that external debt has contributed to economic stagnation and an associated increase in poverty in Latin America, which in turn has led to the degradation of marginal lands that affect the loss of forest cover. The authors suggest that debt could be exchanged for forest⁴ and the reform of the agricultural sector, which would have a very positive impact on forest conservation and management. Using instrumental variable methods, Lawell et al. (2018) estimates the global relationship between income and pollution over the period 1980 to 2012. They find that debt service may be correlated with deforestation as countries liquidate natural assets to pay their debts. Boly et al. (2022), however, have found a long-term complementary relationship and a short-term substitution relationship between sovereign debt and the environment. The authors note that in the short run, government debt generates new resources that can be invested in mitigation activities, improving the quality of the environment⁵. In contrast, the government must pay the debt burden.

In addition, some authors have examined the relationship between public debt relief programs, in particular debt-for-nature swaps, and the loss of forest cover. These mixed results have been found in related literature. For instance, Kahn and McDonald (1995) and Didia (2001), using classical ordinary least squares regressions, showed that an increase in debt led to an increase in deforestation in tropical countries. However, Kraemer and Hartmann (1993) analyzed cross-national data for 34 low- and middle-income countries using ordinary least

⁴e.g., debt-for-nature swaps (see, for instance, Kahn and McDonald (1995); Hansen (1989); Sommer et al. (2020); Cassimon et al. (2011); Chamon et al. (2023); Karaki and Bilal (2023); Cassimon et al. (2023); Nedopil et al. (2022); Haughton and Keane (2021)).

⁵e.g. financing green projects or low carbon policies.

squares regression and found no relationship between participation in a debt-for-nature swap and forest loss. Although the study by Kraemer and Hartmann (1993) would be promising and counterintuitive due to its use of the OLS method, which obviously does not control for selection bias, Hermanrud and de Soysa (2017) has addressed these issues in their study by using a two-stage model to control for potential donor selection bias. The authors find that the bilateral Norwegian conservation aid has no impact on forest loss when using such a model.

Resource-backed loans could help governments increase public spending to finance public goods and services. However, such spending has been shown to have negative environmental consequences. Indeed, an increase in public spending could trigger forest clearing for agricultural production in the short term, increasing deforestation. This idea is confirmed by several authors. For instance, Galinato and Galinato (2012) found that increased public spending and the expansion of social safety nets in developing countries significantly affect the loss of forest cover. In fact, increased deforestation and carbon dioxide emissions are caused by changing land use. These results are consistent with those of Combes et al. (2018b), which uses both a theoretical model and the generalized method of moments (GMM) to estimate the impact of public spending and credit on forest cover loss in 63 developing countries during 2001-2012. The results show that public spending has a positive impact on forest cover loss. However, López et al. (2011) have modeled the environmental impact of the composition of public spending. The results show that shifting the composition of public spending towards social and public goods reduces pollution. This improves the quality of the environment. In contrast, increasing total public spending without changing its composition does not reduce pollution.

2.3 Stylized facts

Before proceeding to the main analysis, it is instructive to examine some stylized facts about the link between deforestation and resource-backed loans. Before that, we take a look at the evolution and breakdown of resource-backed loans signed in developing countries during the period 2004-2018. Fig.4 in the Appendix shows that Venezuela is the biggest beneficiary of RBLs, with an amount of \$58 billion. Brazil is the second largest recipient of resource-backed loans, with a total value of \$25 billion. Angola is Africa's largest recipient of resource-backed

loans, with a total of \$24 billion signed between 2004 and 2018. In addition, the second largest beneficiary in Africa is Guinea. The country signed a \$20 billion resource-backed loan (nearly 200% of the country's GDP) with a consortium of Chinese institutions in 2017. The Republic of Congo is also one of Africa's top recipients of resource-backed loans. The country signed a \$1.6 billion resource-backed loan in 2006, equivalent to 21% of the country's GDP that year. Shortly after, the neighboring Democratic Republic signed the Sicomines infrastructure agreement with China in 2008. The loan amounted to \$3 billion, equivalent to 16% of the country's GDP (Coulibaly, 2024b; Mihalyi et al., 2020).

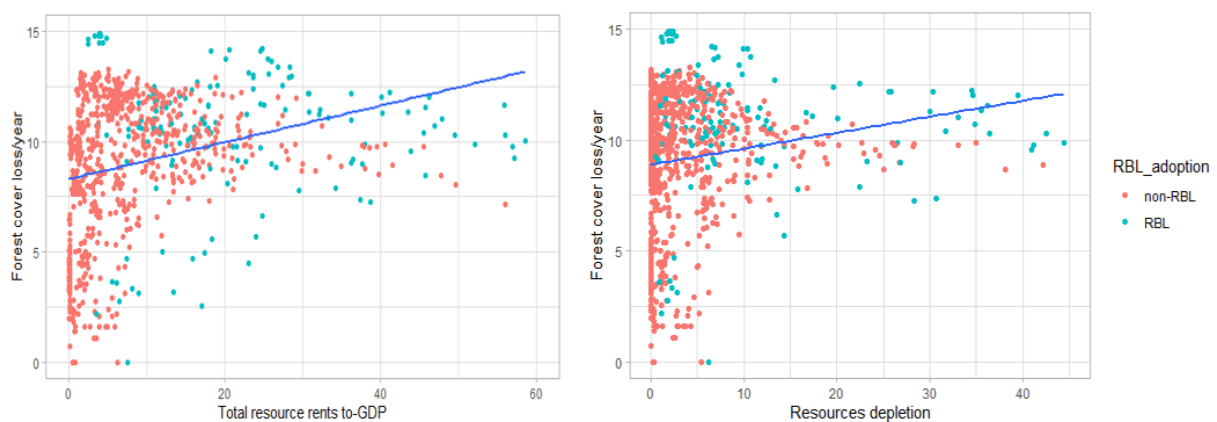
Fig.2.1 shows the positive relationship between total extraction rents, resource depletion, and deforestation in RBL and non-RBL countries. The slopes of the fitting line are stronger for both variables (rents and resource depletion). This unconditional correlation between the two variables and deforestation (see the appendix, Table B3) is positive and significant at the threshold 1%. This observation suggests that resource-backed loans are associated with greater resource exploitation. Thus, RBLs accelerate resource depletion through increased production and worsen the deterioration of environmental indicators such as deforestation. Next, we compare deforestation in RBL and non-RBL countries, respectively; Fig.2.2a shows that this deforestation rate tends to be higher in RBL countries (on average around 11% for RBL countries versus around 9% for non-RBL countries).

Finally, inspired by the approach of Neuenkirch and Neumeier (2016) applied by Apeti et al. (2023a), we verify the evolution of deforestation in treated countries using a before-after analysis of the adoption of resource-backed loans. Fig.2.2b shows that although deforestation increases after the adoption of resource-backed loans, the increase is significant and more pronounced (an increase of 1.948 percentage points, t-stat=6.00 and p-value=0.00). A closer look at this figure reveals a difference in deforestation between RBL countries and non-RBL countries. Indeed, RBL countries exceed the median (central line of the box), a 25th (lower hinge of the box) and a 75th (upper hinge of the box) percentile of deforestation higher than those non-RBL countries. In fact, these results are justified by the fact that the median line, lower hinge and upper hinge of the box for RBL countries are respectively higher than those for non-countries.

Although not causal, these simple statistics suggest a positive correlation between the

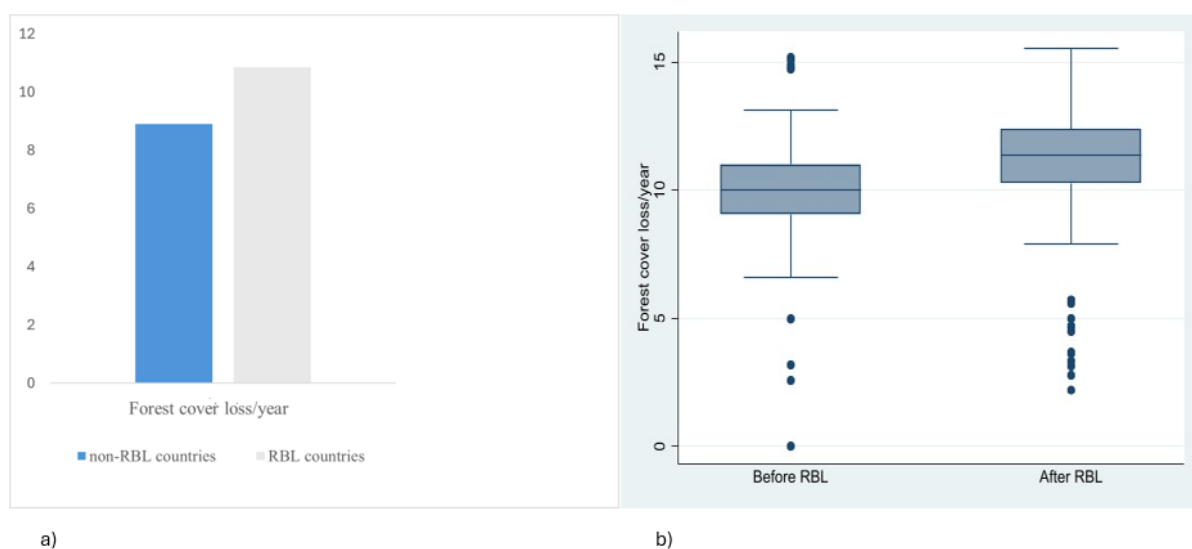
adoption of resource-backed loans and deforestation. However, the upward trend observed in both groups of countries indicates that it would be misleading to estimate the causal effect of resource-backed loans on deforestation simply by comparing deforestation before and after the adoption of resource-backed loans. To avoid overestimating the causal effect of resource-backed loans, we use observations from non-RBL countries selected on the basis of the matching procedure as a control group to estimate the counterfactual result.

Figure 2.1: Relationship between rents, resource depletion and forest cover loss



Source: Author's construction

Figure 2.2: Distribution of forest cover loss by RBL adoption



Source: Author's construction

2.4 Methodology

2.4.1 Identification strategy

The main objective of this chapter is to test the causal effect of resource-backed loans on deforestation. However, estimating the causal effect of resource-backed loans on deforestation is not such an easy task, insofar as the selection criteria for countries benefiting from resource-backed loans are probably not a random event, but are linked to specific macroeconomic conditions (generally referred to as preconditions, i.e. high debt levels, unsustainable debt, access to financial market limit, etc.), natural resource endowment and are therefore subject to selection bias. These factors — which can also affect deforestation — make the adoption of resource-backed loans endogenous (non-random) through the problem of selection bias. To tackle this source of endogeneity, we recognize the difficulty of finding time-varying external instrumental variables for the RBL variable, and resort to impact analysis methods. After reviewing the literature on assessing the macroeconomic and environmental impact of resource-backed loans, we chose propensity score matching (PSM) as our main estimation method. There are two reasons for this choice. Firstly, it enables us to compare our results with recent studies on resource-backed loans, which also use PSM (see, for instance, Coulibaly, 2024b; Coulibaly, 2024c; Coulibaly et al., 2022). Secondly, PSM avoids the problems encountered by alternative impact assessment methods, and in particular the difference in difference, arising from the fact that in the presence of serial dependence in both the dependent variable (deforestation, which is persistent) and the variable treatment (no country has abandoned resource-backed loans due to macroeconomic, environmental imbalances, for example), standard errors are misleading and therefore inappropriate.

2.4.2 Propensity score matching

Developed by Rosenbaum and Rubin (1983), propensity score matching allows addressing the issue of self-selection in the adoption of resource-backed loans by pairing resource-backed loans countries (treated group) with non resource-backed loans countries (control group) that are comparable in terms of the observable characteristics that influence both the adoption of resource-backed loans and the deforestation. Several recent macroeconomic and environmental studies have used this method. For instance, Chapel (2022) uses it to evaluate the impact of

official projects of renewable energy development assistance on electrification in sub-Saharan Africa. Apeti et al. (2023a) uses it to establish the relationship between inflation targeting and fiscal policy volatility. Similarly, Apeti et al. (2023b) uses it to examine inflation targeting on the composition of public expenditure. Kinda and Thiombiano (2024a) also used robustness to establish the link between EITI membership and deforestation in developing countries. According to these authors, PSM is a two-step process: first, using a probit or logit model, we generate for each country a propensity score $p(x)$, which estimates the probability that this country, with its vector of characteristics, will adopt resource-backed loans. Thus :

$$p(X)=Pr(T = 1|X) = E(T|X)$$

Where, $T = \{0,1\}$ is the binary variable indicating whether the country has benefited from resource-backed loans and X is the vector of characteristics observed before treatment. Secondly, we assess the impact of debt-for-nature swaps by estimating the average treatment effect on treated countries (ATT), expressed as follows.

$$ATT=E[Y_{(1)}|T=1, X = 1]-E[Y_0|T=1, X = 1] \quad (2.1)$$

where $Y_{i(.)}$ is the outcome variable that measures deforestation. T_i indicates whether the observation unit is subject to the adoption of resource-backed loans ($T_i = 1$) or not ($T_i = 0$). $E[Y_{i(1)}|T_i=1]$ is the level of deforestation during the adoption period of resource-backed loans, $E[(Y_{i0}|T_i=1)]$ is the counterfactual result for countries that had adopted the adoption period of resource-backed loans, that is, the deforestation in countries that had adopted resource-backed loans if they did not. The issue is that $E[Y(0)|T = 1]$ is not observable due to the non-random nature of the adoption of resource-backed loans. If this were the case, the ATT could easily be identified by comparing the deforestation in resource-backed loans countries with non resource-backed loans countries. Identifying ATT then requires a good proxy for $E[Y(0)|T = 1]$. To do that, we match resource-backed loans units with non resource-backed loans units (after purging for some specific factors) that are as close as possible on observable characteristics that meet two criteria: correlated with resource-backed loans adoption and deforestation. Under the condition that the non resource-backed loans units are fairly close to the resource-backed loans units, any difference in deforestation is attributable to resource-backed loans adoption. For this purpose, Rosenbaum and Rubin (1983) and Smith and Todd

(2005) propose to replace in equation 2.1 the unobservable term $E[(Y_{i_0}|T_{i_1})]$ by the observable term $E[(Y_{i_0}|T_{i_0}, X_i)]$ to satisfy the conditional independence assumption. Based on these details, we can rewrite equation 2.1 as follows:

$$ATT = E[Y_{(1)}|T=1, X = x] - E[Y_0|T=1, X = x] \quad (2.2)$$

where $X = x$ is a vector of observable covariates that can affect both the decision to adopt resource-backed loans and the deforestation, $E[Y(1)|T = 1, X = x]$ is the deforestation of resource-backed loans units, and $E[Y(0)|T = 0, X = x]$ is the expected deforestation for synthetic control units.

A second assumption based on the existence of a common support, also called the overlap condition, must be verified ($0 < p(X) < 1$). This hypothesis assumes that for each treated country, there is at least one comparable untreated country with a fairly similar propensity score. We finally obtain the following equation :

$$ATT = E[E\{Y_{i_1}|RBL_i=1, p(X_i)\} - E[(Y_{i_0}|RBL_i=0, p(X_i))]] \quad (2.3)$$

In practice, treated countries are matched to untreated countries according to their propensity scores using different matching methods, and the ATT is the difference in deforestation level results between treated and untreated countries matched on similar propensity score criteria. It is also possible to match each treated country with more than one control country. Thus, we match each treated country with the two and then the three closest neighbors in terms of the propensity score. However, it should be noted that with this method, it is possible for a treated country to be matched with one or more control countries with a very distant propensity score, leading to a poor match and potentially biased results. Dehejia and Wahba (2002) proposed a radius caliber matching method to resolve this bias. This method consists of matching each treated country with all control countries that are within a well-defined neighborhood threshold, called a caliper. Following the empirical literature described above, we employ four types of matching to estimate the equation 2.3. Firstly, N nearest neighbors matches each RBL country-year observation (treated) with the N nearest non-RBL country-year observations (untreated) with the nearest PS - we use the nearest ($N = 1$), two nearest

neighbors ($N=2$) and three nearest neighbors ($N=3$). Secondly, we use the radius method of Dehejia and Wahba (2002), which matches treated observations with untreated observations located at a certain distance; on the basis of PS, we distinguish a small ($r=0.005$), medium ($r=0.01$) and large ($r=0.05$) radius. Third, we use the kernel method developed by (Heckman et al., 1998b), which associates each treated observation with the distribution of untreated observations in the common support, with weights inversely proportional to the difference between the PS of treated and untreated observations. Fourth, we use the local linear matching developed by Heckman et al. (1998b), which is close to kernel matching, except for the use of a linear term in its weight function.

Finally, PSM is based on several important assumptions that must be verified before any analysis can be performed. Firstly, the common support assumption, which requires the availability of comparable counterfactual data for each country-year observation with RBL (i.e., treated unit). To ensure that the treated and control groups are comparable (that is, to check for overlap and the region of common support between the two groups), we rely on the comparison of minima and maxima as suggested by Caliendo and Kopeinig (2008). In addition, after estimation, we assess the validity of the matching procedure using the *pseudo-R²* test to verify comparability between the treated and control groups after matching (see, e.g., Chapel, 2022; Apeti et al., 2023a; Balima, 2017; etc.). Secondly, we need to test the hypothesis of conditional independence, according to which the difference in the outcome (i.e., deforestation) between the treated and untreated groups results solely from the adoption of resource-backed loans. Although there is no threshold or criterion imposed in the literature (Chapel, 2022), following, for example, Rosenbaum (2002) and Caliendo and Kopeinig (2008), we test this hypothesis using Rosenbaum bounds sensitivity tests, which give an idea of the extent to which unobservable characteristics can bias the results of the matching exercise, and the standardized bias for testing the conditional independence hypothesis against observable characteristics.

2.5 Data

Treatment variable. The variable of interest is a dummy for the adoption of RBL. We use information on the existence of a resource-backed loan from NRGI. To date, NRGI remains the only institution that provides reliable and solid evidence on the existence and many details

of resource-backed loans in developing countries. A team of researchers led by Mihalyi, D., Adam, A., and Hwang, J. collected as much information as possible on resource-backed loans to obtain a somewhat larger database. They compiled two original dataset maintained by institutions dedicated to researching China's overseas activities: the China-Africa loans dataset produced by the China-Africa Research Initiative (CARI) at Johns Hopkins SAIS and the China-Latin America financial database of the Inter-American Dialogue and Global Development Policy Center at Boston University (Mihalyi et al., 2020). The authors then supplemented these databases with additional literature searches to present their dataset. It should be noted that the data on these resource-backed loans are not fully comprehensive due to the relative opacity of these transactions (Rivetti, 2021). In both regions, there may well be resource-based loans, the full amount of which is not disclosed by the borrowing countries, but which are not listed in the NRGI report because they are limited by publicly available information (Mihalyi et al., 2020). However, it is the most comprehensive dataset on resource-backed loans for African and Latin American economies over a long period. Based on this information, we construct a binary variable that takes the value 1 if country i in a period t has taken out a resource-backed loan and 0 otherwise.

Outcome variable. Following Kinda and Thiombiano, 2021; Kinda and Thiombiano, 2024a; and Combes et al. (2018b) we use annual deforestation or forest cover data from global forest change. The global forest change contains a dataset mainly from the Department of Geographic Sciences of the University of Maryland and has recently been published and made freely available by Hansen et al. (2013). In this dataset, trees are defined as vegetation more than 5 m in height expressed as a percentage per output grid cell as "2000% tree cover". Secondly, "forest cover loss" is defined as a stand-replacing disturbance, or a change from a forested to a non-forested state. For example, the "Forest Cover Gain" is defined as the inverse of loss, or a non-forest to forest change entirely within the period 2000–2012. And finally, 'Forest Loss Year' is a disaggregation of total 'Forest Loss Year' to annual time scales (Hansen et al., 2013). Although all of these data based on Landsat satellite imagery published by Hansen et al. (2013) may suffer from potential bias due to inaccuracies in distinguishing between forests and plantations at the local level (Tropek et al., 2014), it remains a potentially valuable source of information on forest cover. Unlike Combes et al. (2018b) using a canopy cover >10%; Kinda and Thiombiano (2021) and Kinda and Thiombiano (2024a), canopy cover >20%, this study

considers a forest as any area with more than 25% trees in 2000, thus excluding all areas with a lower percentage of trees. We will use other cover thresholds in the robustness tests to take into account the forest typology.

Controls or matching variables. Following the literature, we select some variables that can affect the level of deforestation (the key drivers). First, we capture the effect of the **credit variable** which is measured by the domestic credit provided by the banking sector as a percentage of GDP. In the literature, it has been shown that the more credit the private banking sector provides agents, the more agricultural activities intensify. Consequently, deforestation accelerates the more (Combes et al., 2018b; Culas, 2003). In the short term, its sign is positive in relation to deforestation. However, in the long term, if the income from agricultural activities is reinvested into conservation and environmental protection, it will have a negative effect on deforestation. As for his sign on the probability of adopting RBLs, we agree that he will reduce it because the more credit banks extend to the private sector, the greater the private investment and the greater the activity that provides additional income for governments. We control for the effect of **net official development assistance (ODA)**, which includes the disbursement of loans and grants to promote the economic development and well-being of countries and territories ⁶. Similarly to Kinda and Thiombiano (2021), we expect a negative impact of the net ODA received on the loss of forest cover. Its sign on RBL must be negative due to its character as a source of development financing. Similarly, we control for **gross capital formation (GCF), or gross domestic investment**, which consists of expenditures on the acquisition of fixed assets in the economy and net changes in the level of inventories in our model. As for its sign on the probability of adopting RBL, it is ambiguous because increased investment leads to positive economic growth, the creation of added value, and public revenue for the government. In this case, it will reduce the RBL. However, a government may have an incentive to sign an RBL agreement to increase its investment and public capital, thus increasing the likelihood of adopting a resource-backed loan. Next, we add **public expenditure** which measures government consumption expenditure as a percentage of GDP. Previous studies have found significant positive impacts on deforestation (Galinato and Galinato, 2016; Gupta and Barman, 2009; López et al., 2011; Combes et al., 2018b; Kinda and Thiombiano, 2021). In our study, we expect a positive effect on deforestation. Public spending must have a positive impact on the

⁶Defined by the World Bank in the context of the construction of the ODA variable in the dataset.

probability of adopting RBL. The effect of **natural resource rents** is controlled. This variable measures the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents as a percentage of GDP. Kinda and Thiombiano (2021), in their recent study, they found a significant positive effect of resource rents, excluding forest rents, on deforestation. We believe that its sign on deforestation will be positive in our study. Given that the RBLs are repaid with natural resource rents, a high level of natural resource rents reduces the amount of RBLs in the short term but offers the possibility of signing a new RBL agreement. Its sign is therefore positive for the probability of adopting RBL. Finally, we capture the effect of **natural resource depletion**, which is the sum of net forest depletion, energy depletion, and mineral depletion⁷. Its sign on deforestation is ambiguous because it depends on the level of depletion of natural resources. Its sign on RBL is negative, as repayment is made through income from natural resources and resources in kind. Resource depletion therefore negatively affects the probability of signing a resource-backed loan.

2.6 Results

2.6.1 The estimation of the propensity scores

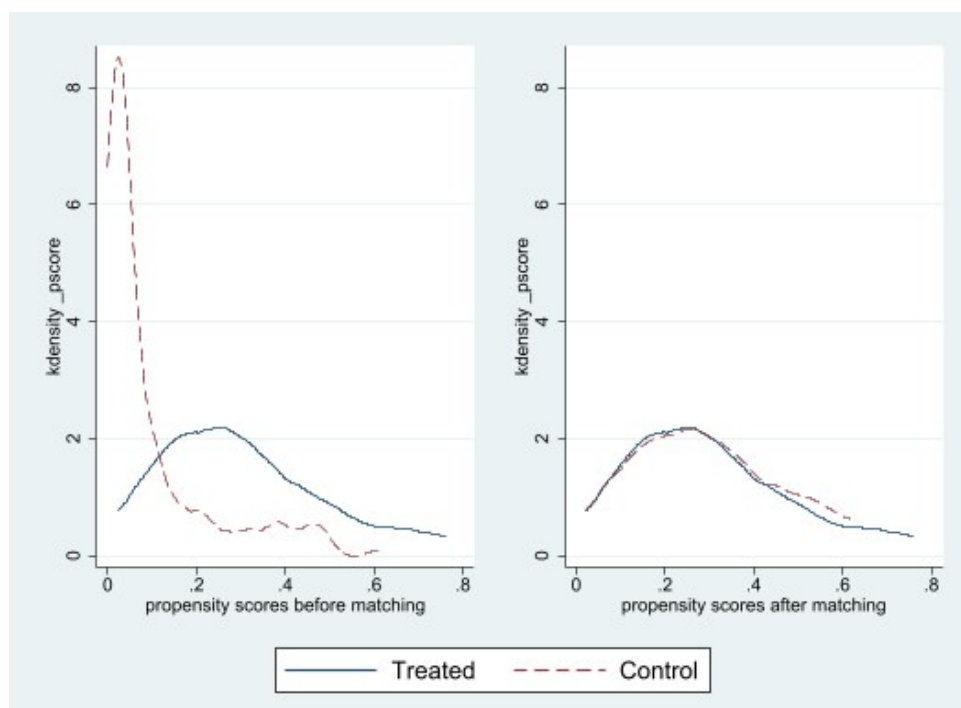
First, we present the results of the probit model used to predict the propensity scores for the matching algorithms in Table 2.1. In column [1], we report the results of our basic model. Net official development assistance and depletion of natural resources reduce the probability of a country signing a resource-backed loan. However, natural resource rents and final consumption expenditure are positively correlated with resource-backed loans. The overall regression fit is acceptable with a Pseudo- R^2 of 0.1894 for our baseline model. Secondly, we start by checking the quality of our results with probabilities close to 0. Indeed, Fig. 5 shows that most of our treated individuals have a probability very close to 0. It would be very easy to match treated units with low propensity scores but not so easy to match treated units with a high propensity score. Note that there is no consensus in the literature on the best test to judge the effectiveness of this test (Chapel, 2022). Following Simone and Bazilian (2019), we re-estimate

⁷Net forest depletion is unit resource rents times the excess of round wood harvest over natural growth.. However, energy depletion is the ratio of the value of the stock of energy resources to the remaining reserve lifetime. Concerning mineral depletion, it is the ratio of the value of the stock of mineral resources to the remaining reserve lifetime (see, World Bank definition for more details).

our propensity score only for matched individuals and compare the obtained Pseudo R^2 with the one obtained before the matching process. If the matching worked well, the pseudo R^2 of the probit model with only matched individuals had to be reduced considerably and turned out to be very low. This is the case in our study, as we see in Table 2.2 that it has gone from 0.1894 to almost 0. Some authors rely instead on the standardized bias which calculates the percentage bias on each covariate. The bias must have decreased significantly compared to the pre-matching bias for each covariate, and the closer it is to 0, the more efficient our matching is. Finally, the p-value associated with the standardized bias must be greater than the critical value of 10% (Rosenbaum and Rubin, 1983). This is the case in our study.

Fig.2.3 shows the distributions of the estimated propensity score before and after the matching (left and right, respectively). Before matching, the common support appears to be quite large, but the graph shows that treated units with a high propensity score may not be matched because of the small number of nearby control units. After matching, the distribution of the propensity score in the treated and untreated groups is similar, which proves that the treated units were indeed matched with untreated units having a similar propensity score in our matches.

Figure 2.3: Common support before and after matching



Source: Author's construction

Regarding the sign of our control variables, column [1], Table 2.1 shows that all variables have expected signs and, with the exception of credit and GFC, are significant at conventional statistical levels. In fact, ODA and the depletion of natural resources are negatively associated with the probability of adopting RBL. However, public spending and natural resource rents are positively associated with the probability of adopting RBL.

Table 2.1: Propensity scores estimates using probit model

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
Resources rents	0.0859*** (0.0113)	0.1120*** (0.0135)	0.1124*** (0.0138)	0.0895*** (0.0119)	0.0828*** (0.0121)	0.0785*** (0.0118)	0.0756*** (0.0116)	0.0902*** (0.0117)	0.0831*** (0.0114)	0.0860*** (0.0120)	0.1150*** (0.0142)	0.0756*** (0.0118)	0.0779*** (0.0116)	0.0794*** (0.0150)
Resources depletion	-0.0548*** (0.0127)	-0.0819*** (0.0157)	-0.0835*** (0.0161)	-0.0497*** (0.0134)	-0.0309** (0.0140)	-0.0532*** (0.0130)	-0.0487*** (0.0131)	-0.0557*** (0.0131)	-0.0518*** (0.0128)	-0.0507*** (0.0143)	-0.0888*** (0.0168)	-0.0575*** (0.0130)	-0.0559*** (0.0128)	-0.0623*** (0.0168)
Log GFC	-0.0373 (0.1573)	0.0375 (0.1775)	0.0124 (0.1794)	-0.0518 (0.1607)	0.0031 (0.1739)	-0.3141* (0.1770)	0.0395 (0.1589)	-0.0772 (0.1596)	-0.0675 (0.1590)	-0.1103 (0.1718)	-0.0922 (0.1661)	0.1540 (0.1675)	0.1245 (0.1650)	0.0766 (0.1810)
ODA	-0.0690*** (0.0165)	-0.0809*** (0.0184)	-0.0832*** (0.0190)	-0.1192*** (0.0248)	-0.0515*** (0.0172)	-0.0725*** (0.0166)	-0.0459*** (0.0161)	-0.0737*** (0.0171)	-0.0757*** (0.0172)	-0.0885*** (0.0180)	-0.0945*** (0.0184)	-0.0708*** (0.0177)	-0.0875*** (0.0182)	-0.1106*** (0.0222)
Log Credit	-0.0143 (0.1004)	-0.0604 (0.1017)	-0.0811 (0.1028)	0.1360 (0.1197)	-0.0192 (0.1091)	0.0659 (0.1092)	-0.0769 (0.0991)	0.0482 (0.1066)	-0.0123 (0.1030)	-0.1266 (0.1050)	-0.0673 (0.1003)	0.2581** (0.1224)	0.3166*** (0.1279)	0.0925 (0.1303)
Public expenditure	0.0277*** (0.0098)	0.0266** (0.0105)	0.0280*** (0.0105)	0.0322*** (0.0098)	0.0552*** (0.0129)	0.0364*** (0.0106)	0.0291*** (0.0099)	0.0231** (0.0098)	0.0361*** (0.0113)	0.0476*** (0.0125)	0.0366*** (0.0103)	0.0398*** (0.0116)	0.0304*** (0.0104)	0.0501*** (0.0127)
Public debt		0.0203*** (0.0068)												
Lag Debt			0.0174** (0.0069)											
Log GDP per capita				-0.3263*** (0.1048)										
Log Population total					0.4805*** (0.0628)									
Resource rich country						0.6382*** (0.1787)								
Oil reserve horizon							0.9162*** (0.1876)							
Rainfall shocks								-0.0031*** (0.0011)						
Temperature shocks									0.0499** (0.0237)					
Log Total ODA Biodiversity										0.2119*** (0.0379)				
Log Agricultural land											0.1779* (0.1072)			
Control corruption												-1.0958*** (0.1707)		
Government Effectiveness													-0.9325*** (0.1624)	
Rule of law														-4.1243*** (0.8280)
Constant	-1.6774*** (0.5598)	-1.8683*** (0.6077)	-1.6945*** (0.6263)	0.5094 (0.9005)	-10.3363*** (1.3070)	-1.4788** (0.5744)	-1.8996*** (0.5573)	-1.3586** (0.5790)	-2.8938*** (0.8100)	-4.7272*** (0.8177)	-2.0528*** (0.6926)	-3.8837*** (0.6733)	-3.6740*** (0.6835)	-0.9001 (0.6354)
Pseudo R ²	0.1894	0.2368	0.2330	0.2054	0.3112	0.2103	0.2229	0.2024	0.1968	0.2451	0.2208	0.2656	0.2463	0.2599
Observations	776	771	724	776	776	776	761	776	776	656	679	776	776	714

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

2.6.2 The results of matching on propensity scores

As the results in Table 2.2 show, irrespective of the matching methods, all ATTs are positive and statistically significant at the 1% significance level: in other words, the adoption of resource-backed loans significantly increases deforestation on average in adopting countries compared to their non-adopting peers. Moreover, the magnitude of this effect ranges between 1.31 percentage points (for the local linear regression matching) and up to 1.65 percentage points (for the last radius matching), with an average of around 1.50 percentage points. These effects seem sizeable: for example, a country with a deforestation equal to the mean value in our sample (around 9%, see the Appendix, Table B2) would experience an increase of around

1.50 percentage points of this deforestation after adopting RBL. This finding provides support for the first group of theoretical arguments previously emphasized, by showing that in our sample, RBL adoption significantly increases on average the deforestation in RBL countries relative to non-RBL countries.

Our results corroborate those found in the literature (Culas, 2006; Didia, 2001; Kahn and McDonald, 1995; Tietenberg and Lewis, 2018), confirming the existence of a "debt-resource hypothesis" relationship. Indeed, according to this hypothesis, many low-income countries have large stocks of debt. As a result, most of these countries, in an attempt to repay the debt in addition to the accumulated interest, are motivated to over-exploit their natural resources in order to obtain the necessary funds. In addition, repaying foreign debt reduces a country's ability to increase its foreign exchange earnings. Even if a less substantial amount of foreign earnings is still accumulated, in the regime of a high real interest rate, this little accumulated foreign earnings must be used for debt servicing, so that, most of the time, the countries concerned end up overexploiting their natural resources in order to meet other national needs. Unlike other types of external debt, as explained above, with RBLs there is implicit pressure on borrowing countries to exploit their natural resources in order to repay the loans. A practice associated with heavy deforestation. This positive effect of RBLs on deforestation could also be explained by the way extractive industries are granted operating permits. In fact, once an RBL agreement has been signed with the creditor country, generally China, the mining permit is granted directly to Eximbank, CDB, or ICBC, the Chinese banks responsible for exploiting the natural resource, as they are the entity responsible for the loans. These banks call on FDI in the mining sector to start the process of exploiting the natural resources needed to repay the loans. By over-exploiting natural resources, these extractive industries increase resource rents and ultimately increase the rate of depletion of natural resources, which in turn indirectly increases deforestation. In short, RBLs attract foreign direct investment in the extractive sector, which intensifies mining activities through drilling and exploitation that destroy forest cover. This result was found by Kinda and Thiombiano (2021); Ranjan (2019); etc. Another possible explanation for indirect channels is the collapse in commodity prices in 2014, which increased the nominal size of these loans (Mihalyi et al., 2020)⁸ and plunged countries into

⁸It should be noted that of the fourteen (14) signatory countries, ten (10) were exposed to over-indebtedness following the commodity price shock.

a debt-overloaded situation, leading them to exploit more natural resources to pay back the loan. Finally, another potential channel for the positive effects of RBL on deforestation is corruption. In fact, the lack of transparency in the RBL agreements (Mihalyi et al., 2020) leads to high levels of corruption in the extractive sector. This corruption adds to the burden of debt and accelerates the expansion of the extractive industries through increased investment in infrastructure. Although extraction and infrastructure have been shown to offer vast opportunities for corruption and illegal behavior involving significant private capture of resource rents, this induces additional pressure that weakens forest protection (Bebbington et al., 2018).

Table 2.2: Average Treatment Effect on Treated (ATT)

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Log forest loss	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
Baseline								
ATT	1.6365*** (0.5976)	1.5401*** (0.5547)	1.4751*** (0.4171)	1.5311** (0.6206)	1.4389*** (0.3466)	1.6501*** (0.5059)	1.3083*** (0.3645)	1.4115*** (0.4142)
Observations	727	727	727	727	727	727	727	727
Treated	92	92	92	92	92	92	92	92
Untreated	635	635	635	635	635	635	635	635
Matching Quality								
Pseudo-R ²	0.010	0.008	0.009	0.087	0.007	0.051	0.010	0.007
Rosenbaum bounds sensitivity test	2.05	2.15	2.5	1.85	2.5	2.1	2.4	2.45
Standardized bias (p-value)	0.860	0.905	0.894	0.014	0.937	0.120	0.860	0.946

Bootstrapped standard errors based on 50 replications in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1

2.7 Robustness

2.7.1 Modification of sample

The main objective of the theory of clean development is to meet environmental standards. In order to combat illegal and abusive deforestation, several developing countries have introduced restrictions on the export of timber both at the national and international levels. These bans aim to reduce the export of forest products, which could have a significant effect on the level of deforestation (Burgess et al., 2012; Apeti and N'Doua, 2023). Forest Trends has identified 72 countries in their database that actually restrict or have restricted the international export of one or more forest products. The extent of deforestation in those countries that impose one or more of these measures may differ depending on whether or not it is addressed in our sample. To obtain a homogeneous sample and robust results, we excluded all countries that have adopted export bans on forest products. The results of the ATTs are reported in Table 2.3 (lines [2]-[6]). In line [2], we report the results of excluding countries that have adopted a

forest product export ban. Then we move on to countries that have introduced a national ban on natural forest logging [3]. Next, in line [4], we exclude countries that have introduced a sawnwood export ban. Our results remain robust (see Table 2.3). Furthermore, given that the oil crisis has plunged many countries adopting RBL into a debt overload situation, as highlighted by Mihalyi et al. (2020), it is possible that the rate of deforestation observed in these countries is caused by the oil crisis and not by RBL. In addition, resource depletion rates during periods of collapse in oil and commodity prices for all countries could fall because it is not financially viable to exploit natural resources during periods of falling prices. For this reason, we exclude from our sample the year 2014, which marks the year of the major oil crisis. The new coefficients of ATT are shown in Table 2.3, line [5]. Finally, we exclude newly signed RBLs from our sample. Indeed, the idea behind this exercise is that new RBLs may not have an immediate effect on deforestation because of the time it takes for extractive industries to establish themselves. To this end, we excluded observations from countries with new RBLs whose years were 2017 and 2018. The new ATTs are reported in line [6] of Table 2.3. Despite all these changes in our sample, our results remain statistically unchanged.

2.7.2 Adding control variables

After modifying the sample, we also consider increasing the specificity of the baseline model to test the robustness of our results. To do this, we control for several additional variables that are likely to be positively or negatively correlated with both resource-backed loans and deforestation (Table 2.3, lines [7]-[14]). These variables are grouped into two categories namely: *i*- economic and environmental variables: public debt, GDP per capita, public debt($t-1$), demographic growth, rich countries, mineral reserve horizon, rainfall shocks and temperature shocks, bilateral environmental aid, and agricultural land area; *ii*- institutional variables: control corruption, government effectiveness, and rule of law. We begin with an explanation and discussion of this modification in controlling the effect of the public debt. Indeed, the literature has shown that an unsustainable level of debt leads to a high rate of tropical deforestation mainly through the clearing of forest land for agricultural expansion (Culas, 2003). In fact, heavy external debt can reduce the country's standing in the conventional financial market, causing it to move towards China to sign a resource-backed loan agreement (Mihalyi et al., 2020), whose repayment will require abusive deforestation. Next, we include debt($t-1$)

because indebted nations tend to increase exports of natural resources to earn cash to repay (Marquart-Pyatt, 2004). Secondly, we control GDP per capita, which measures the level of overall national wealth created per capita over a given period. Indeed, a higher level of GDP per capita can help governments finance their development goals without resorting to resource-backed loans, which finance green projects. That will improve environmental quality and avoid deforestation. We log this variable to correct for its skewed distribution. Cross-national research that examines how economic growth affects forest loss yields contradictory findings. On the one hand, economic growth is associated with higher rates of deforestation (Jorgenson, 2006). This is because there are large amounts of capital available for investment in activities (for instance, infrastructure) that accelerate forest loss during periods of economic expansion (Rudel, 2023). However, the absence of economic growth may increase forest loss. Lack of growth offers rural populations little incentive to migrate to urban centers for work and instead expand agriculture and forestry to survive (Ehrhardt-Martinez et al., 2002). According to Burns et al. (2003), higher levels of economic development are associated with lower rates of forest loss based on wealthier nations externalizing their environmental costs by importing natural resources and moving towards economic activities such as services that have less impact on forests. However, Combes et al. (2018b) have found a positive and significant impact of GDP on deforestation in developing countries. We take into account these discrepancies in the literature by controlling for GDP per capita.

We control for the effect of demographic growth. This variable can have an impact on the horizon and depletion of natural resources, the size of housing and farms. An increase in population fuels the demand for arable land, fuel wood, and charcoal (Kinda and Thiombiano, 2021). In addition, higher population growth rates correspond to greater forest loss, as the demand for resources by a growing population leads to increased resource consumption, with a negative impact on forests (Rudel, 2023). Next, we control the effect of natural resource endowments (minerals, gas, oil, etc.) and mineral reserve horizon on deforestation. In fact, the endowment of natural resources can easily attract foreign multinationals to rich countries (Manyika et al., 2013). This could accelerate not only resource depletion but also deforestation. This variable is a dummy, taking the value of 1 if the country is classified as rich in natural resources and 0 otherwise according to the IMF classification. Regarding the mineral reserve horizon, our intuition is based on the assumption that a long resource horizon leads to long

exploitation and keeps the extractive industries going for a long time. This would further increase the loss of forest cover. Mineral reserve is a dummy variable equal to 1 if a country's reserve horizon is greater than the median of all mineral-exporting countries, based on BP dataset.

We control for the effect of temperature and rainfall shocks, which captures the effect of climate variability. These two variables measure the deviation of the average annual rainfall and temperature from its long-term trend (average rainfall and temperature from 1901 to 2021). The data is extracted from the Climate Research Unit (CRU) database of the University of the Orient. Following Combes et al. (2018b) and Kinda and Thiombiano (2021), we control for the fact that, for example, high climate variability leads governments to tighten environmental standards which can reduce deforestation. According to Kinda and Thiombiano (2021), countries with lower levels of precipitation are often at risk of extreme weather. This is detrimental to vegetation in general and to plants in particular, leading to a loss of forest cover. We complete the control of economic and environmental variables with bilateral environmental aid and agricultural land area. Indeed, higher levels of environmental aid should correspond to lower levels of forest loss. In fact, this is because this aid often funds conservation projects that include protected areas, delimitation of forest boundaries, eco-tourism, agroforestry, and the monitoring of illegal logging, among others (Bare et al., 2015). We control the percentage of land within a nation used for agriculture or land that is permanently under crops or pastures (World Bank, 2016). This variable measures the size of the agricultural sector. We take the natural log of this variable to help deal with skewness. The idea is that higher amounts of agricultural land correspond to greater forest loss because forests are converted to pastures or fields (Austin, 2010).

We conclude this exercise by testing the effect of institutional quality on deforestation. We capture this institutional quality through three variables: corruption control, government effectiveness, and rule of law. In fact, improvements in institutions for secure property rights and better environmental policies can thus significantly reduce the rate of deforestation without affecting the level of economic growth. According to Culas (2007), the effect of agricultural production on deforestation could be stopped by strengthening institutional factors. We take this into account by including these three institutional variables.

We report the results of the propensity score in Table 2.1, columns ([2]-[14]). Most of the results corroborate our hypotheses. Indeed, public debt, public debt(t-1), demographic growth, rich countries, mineral reserve horizon, temperature shocks, bilateral environmental aid, and agricultural land area are positively correlated with the probability of adopting RBL. However, GDP per capita, rainfall shocks, corruption control, government effectiveness, and rule of law are negatively associated with the probability of signing a resource-backed loan. The new ATTs are reported in Table 2.3, lines ([7]-[19]). The coefficients remain qualitatively and quantitatively comparable to our baseline results (see Table 2.2).

Table 2.3: Resource-backed loans and deforestation: Alternative sample and control variable

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Log forest loss	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
Baseline								
[1]ATT	1.6365*** (0.5976)	1.5401*** (0.5547)	1.4751*** (0.4171)	1.5311* (0.6206)	1.4389*** (0.3466)	1.6501*** (0.5059)	1.3083*** (0.3645)	1.4115*** (0.4142)
Observations	727	727	727	727	727	727	727	727
Treated	92	92	92	92	92	92	92	92
Untreated	635	635	635	635	635	635	635	635
Excluding countries with								
[2] Forest product export ban	1.5163* (0.8998)	1.3467 (0.9406)	1.7255*** (0.6268)	-0.4744 (2.1421)	0.2052 (0.9534)	-0.7595 (1.2426)	1.5428* (0.6122)	0.2513 (1.040)
[3] Domestic natural forest logging ban	1.3958** (0.6386)	1.1740** (0.4681)	1.1624** (0.5081)	0.9939 (0.8119)	0.9482* (0.5112)	0.9823* (0.5916)	0.8148* (0.4469)	0.9486** (0.4901)
[4] Sawntwood Export Ban	1.2576** (0.6245)	1.6413* (0.6452)	1.5225*** (0.5010)	2.2579*** (0.7150)	1.6960*** (0.3662)	2.2153** (0.5922)	1.7433*** (0.4863)	1.6674*** (0.4314)
[5] Oil crisis 2014	1.850*** (0.503)	1.933*** (0.510)	1.951*** (0.463)	1.932*** (0.584)	1.534*** (0.334)	1.906*** (0.575)	1.414*** (0.445)	1.538*** (0.405)
[6] New RBL adopters	1.019* (0.585)	1.333*** (0.516)	1.392*** (0.477)	1.696*** (0.585)	1.505*** (0.478)	1.580*** (0.558)	1.387*** (0.409)	1.527*** (0.397)
Adding control variables								
<i>Economic and environmental variables</i>								
[7] Adding Debt	0.7522* (0.4326)	0.8738** (0.4625)	0.9919* (0.4174)	1.4455* (0.5768)	0.9971*** (0.3391)	1.2347*** (0.4635)	0.9679*** (0.3642)	1.0243*** (0.3791)
[8] Adding log GDP per capita	-0.2629 (0.3753)	-0.1359 (0.4243)	-0.1354 (0.4568)	-0.4148 (0.5729)	0.0621 (0.3078)	-0.3985 (0.4357)	0.0429 (0.3755)	0.0393 (0.2978)
[9] Adding Debt (-1)	0.8751* (0.5291)	1.0943* (0.4612)	1.2164** (0.5435)	1.1915* (0.6629)	1.3042*** (0.49135)	1.4021* (0.5452)	1.1982*** (0.3298)	1.3113*** (0.4933)
[10] Adding Log Demographic growth	-0.1688 (0.5369)	-0.2306 (0.4193)	-0.1562 (0.3909)	-0.3219 (0.5173)	-0.0853 (0.3452)	-0.2879 (0.5034)	0.0109 (0.3680)	-0.0330 (0.3701)
[11] Adding Rich countries	0.5970 (0.5960)	0.9624* (0.3989)	1.0041** (0.4324)	1.0738 (0.6711)	1.0988*** (0.3300)	1.2087*** (0.4137)	1.1038*** (0.3674)	1.1111*** (0.2824)
[12] Adding Minerals reserve horizon	0.9227* (0.4924)	0.9689* (0.5109)	1.2084*** (0.3836)	1.2143** (0.6098)	1.0196*** (0.3253)	1.3620* (0.5274)	0.8877*** (0.3363)	1.0119*** (0.3785)
[13] Adding Rainfall shocks	1.3601*** (0.4200)	1.3397* (0.5585)	1.3388*** (0.3933)	1.4861* (0.5761)	1.5543*** (0.4351)	1.5824*** (0.4643)	1.4386*** (0.3421)	1.5364*** (0.3864)
[14] Adding Temperature shocks	1.1218** (0.4872)	1.2439*** (0.4278)	1.1560*** (0.3945)	1.5156* (0.6313)	1.3422*** (0.3954)	1.3572*** (0.5130)	1.2743*** (0.3615)	1.3038*** (0.4022)
[15] Adding Bilateral environmental aid	1.044** (0.522)	0.825** (0.365)	0.835* (0.442)	0.869 (0.670)	0.779* (0.414)	1.143** (0.503)	0.774** (0.355)	0.778** (0.353)
[16] Adding Agricultural land area	1.092** (0.475)	1.443*** (0.472)	1.514*** (0.464)	1.876*** (0.646)	1.221*** (0.398)	1.500*** (0.523)	1.190*** (0.353)	1.249*** (0.340)
<i>Institutional variables</i>								
[17] Adding Control corruption	0.774** (0.375)	0.982** (0.403)	1.042*** (0.372)	1.182** (0.495)	0.900** (0.391)	1.003** (0.399)	0.872** (0.354)	0.861** (0.347)
[18] Adding Government effectiveness	1.071** (0.443)	1.037** (0.441)	1.006*** (0.390)	1.024* (0.604)	1.032*** (0.347)	1.161** (0.495)	0.948*** (0.342)	1.006*** (0.274)
[19] Adding Rule of law	0.902** (0.455)	1.227*** (0.418)	1.156*** (0.367)	1.000* (0.542)	1.079*** (0.321)	1.033* (0.543)	1.163*** (0.403)	1.006** (0.435)

Bootstrapped standard errors based on 50 replications in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1

2.7.3 Alternative matching method

Coarsened Exact Matching. The propensity score matching estimation technique may not provide robust evidence for our results. Indeed, propensity score matching has been widely

criticized in the literature for producing fragile and non-robust estimates that can vary widely depending on the outcome model used (King and Nielsen, 2019). These authors believe that the PSM method may produce biased results if units that are far apart are progressively removed, the equilibrium will eventually deteriorate even if units close to each other on the propensity score remain. In addition, the PSM method may not yield causal effects of resource-based loans on deforestation because this approach cannot account for unobserved variables that are correlated with both the RBL dummy variable and the dependent variable, deforestation, such as political instabilities. A related concern is that the NRGI report indicates that some borrowing countries may be hiding relevant information on resource-backed loans, which could contaminate our control group and provide biased estimates. To test the robustness of our results and avoid interpretation bias, we use coarsened exact matching as King and Nielsen (2019) and Chapel (2022). In this method, each unit processed by the nearest control unit is compared for a rough exact match by first expanding the data, which consists of recording indistinguishable values with the same values, and then comparing the processed and unprocessed units using this expanded data (Iacus et al., 2012). Using this method, our estimated ATTs remain positive with similar magnitudes and significant (see Table 2.4).

Table 2.4: Resource-backed loans and deforestation: using CEM

VARIABLES	[1]	[2]
RBL dummy	1.3283*** (0.2576)	0.3504** (0.1530)
Constant	9.6446*** (0.0882)	11.1315*** (0.5555)
Covariates	No	Yes
Country/FE & Year/FE	No	Yes
Observations	892	727
R-squared	0.0452	0.9442

Standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Entropy balancing method. The results may always suffer from interpretation bias because coarsened matching cannot capture the selection biases that would result from contamination of our control group, such as the hidden information on exist of resource-backed loans, as detailed above. For this reason, we use yet another more advanced matching method in terms of identification strategy, namely the entropy balancing method. This method was developed by Hainmueller (2012) and implemented a few years later by Neuenkirch and Neumeier (2016), which is done in two simple steps. The first step is based on the calculation of weights that are assigned to the control units (in our case, non resource-backed loans countries). In fact, this step calibrates the unit weights so that the re-weighted treatment and control group satisfies the predefined equilibrium conditions (one advantage of entropy balancing method). In the second step, the weights obtained in the previous step are used in a regression analysis with the treatment variable (resource-backed loans countries) as the explanatory variable. Thus, it becomes easy to balance resource-backed loan signatory and non-signatory countries on the basis of observable characteristics, also called "twins". Therefore, the average difference in forest cover loss between treated and untreated "twins" countries should be explained by the signing of a resource-backed loan. The literature has identified several advantages of the entropy balancing method, but we will not cite them here in this chapter (e.g., see Hainmueller, 2012 and Balima, 2017). However, an advantage that leads us to use this method is that it includes individual and time-fixed effects in the second step to control heterogeneity independently of treatment (Hainmueller, 2012). Another advantage is that unlike propensity score matching or difference-in-difference estimators, entropy balancing is a non-parametric approach that does not require specification of the functional form of the empirical model or the treatment assignment procedure, thus avoiding specification errors and selection bias in the control and treatment groups (Apeti, 2023a; Apeti and Edoh, 2023; Apeti and N'Doua, 2023; Balima, 2017; Hainmueller, 2012). This explains our motivation not to consider the difference-in-difference method even though this estimation technique is recognized for its quality in impact studies (see, for instance, Sant'Anna and Zhao, 2020; Abadie, 2005; Athey and Imbens, 2006; etc.).

The results are reported in Table 2.5. In column [1], we report the results of the baseline regression without adding covariates and fixed effects. Then, in columns ([2]-[4]), we report the results of time and/or individual fixed effects. In columns ([5]-[8]), we add the reference

covariates presented in the table. The fixed effects for the country and time are controlled in columns ([6]-[8]). After controlling for individual and time-fixed effects, the coefficients for resource-backed loans are positive and statistically significant except the column [4] and column [8] where the coefficients remain positive but insignificant. These results confirm our baseline finding that resource-backed loans have a positive impact on forest cover loss in signatory countries.

Table 2.5: Resource-backed loans and deforestation: using entropy balancing method

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Dependent variable: Log forest loss	Baseline	Adding Country/FE	Adding Time/FE	Adding Country/FE & Time/FE	Adding Covariates	Adding Country/FE	Adding Time/FE	Adding Country/FE & Time/FE
Resource-backed loans dummy	1.8185*** (0.3189)	0.4871*** (0.1844)	1.8982*** (0.2998)	0.1547 (0.1552)	1.8501*** (0.2987)	0.2428* (0.1331)	1.6956*** (0.3088)	0.1974*** (0.1233)
Constant	9.3341*** (0.1224)	11.5693*** (0.2126)	9.5304*** (0.3379)	11.4826*** (0.1727)	11.5429*** (1.4770)	10.6796*** (0.5149)	12.1181*** (1.4296)	9.9220*** (0.4544)
Observations	727	727	727	727	727	727	727	727
R-squared	0.0982	0.9562	0.1089	0.9653	0.3131	0.9649	0.3358	0.9695
Covariates	No	No	No	No	Yes	Yes	Yes	Yes

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

Table 2.6: Resource-backed loans and deforestation: using IPW and fixed effect

	[1]	[2]	[3]
VARIABLES	<i>IPW</i>	<i>AIPW</i>	<i>Fixed effect estimate</i>
RBL	1.8865*** (0.5272)	1.9647*** (0.5194)	0.3245** (0.1561)
Constant	-6.9645*** (1.3330)	9.3076*** (0.4354)	8.4106*** (0.4543)
Observations	727	727	727
R-squared			0.1052
Number of country			55

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

Inverse Probability Weighting (IPW). In addition, we use the IPW estimator as an identification strategy to reinforce the robustness of our results. Indeed, although estimating ATTs from propensity scores matching allows us to correct for the potential self-selection bias in policy adoption, as explained above, this estimator may have limitations, particularly in the

presence of a significant lack of data. The IPW estimator uses propensity scores to give more weight to observations that are similar to each other in their observable characteristics, enabling good matching even in the presence of missing data. The results of the estimates are reported in Table 2.6, columns [1]-[2]. Our results are robust to the use of this estimation method, insofar as the new ATTs are qualitatively comparable to those of the baseline results (see Table 2.2).

Fixed effect estimate. Our results remain unchanged and robust after the two alternative impact estimation methods. However, we suspect the presence of certain historical factors that are cited as causes of deforestation in developing countries. Although we have entropy-balancing controls for country-fixed effects, we switch to fixed effects for several reasons. First, the literature shows that the deforestation process varies from country to country and region to region. For instance, the main factors cited to explain excessive deforestation in Brazil are government subsidies for grazing and cattle breeding, and subsidies for commercial forestry (see Barbier and Burgess, 2001; Binswanger, 1991). In Latin America, and more specifically in Costa Rica, insecurity of land tenure and colonization of the frontiers are cited (Southgate et al., 1991). In Indonesia, the government's transmigration policy, changing agricultural practices, and forest concession rights are the main factors (Barbier and Burgess, 2001). In Malaysia, this is government support for the forest industry (Gillis, 1988; Rudel and Roper, 1997). In West Africa (Ghana, Liberia, etc.) and Zaire, which contains almost 10% of the world's tropical forest cover, the destruction of the forest cover is due to the displacement of agriculture and the use of fuelwood caused by increasing rural and urban poverty (Gillis, 1988). Through this literature, we understand the historical differences in the causes of deforestation in different regions. Second, in addition to historical differences that are not necessarily captured by the methods used above, certain similarities can be observed in the causes of deforestation. In fact, while the precise factors responsible for deforestation in Malaysia, for example, may differ from those responsible for deforestation in Indonesia, they do have general similarities and are much more closely linked than the cases of Latin America or Africa. We use the fixed effect panel data analysis technique to capture these specific factors⁹. We report the new ATTs in Table 2.6, column [3]. The main results of the study remain qualitatively unchanged when

⁹Significant Hausman statistics reject the random coefficient panel modeling technique as an alternative to the fixed effects technique (Greene, 2003).

specific effects are controlled.

GMM estimates. Finally, we need to address the econometric problems that can arise when estimating the baseline specification. In fact, forest loss is likely to be endogenous, due to a forest cover measurement error, since the deforestation data we used in this study are satellite estimates of global forest change imagery (Tropek et al., 2014). Furthermore, the literature has emphasized the dynamics of the forest over time such that deforestation can be interpreted as a stationary state (Combes et al., 2018b). Taking this dynamic into account gives us the following equation:

$$Lnforestloss_{it} = \alpha_0 + \alpha_{it} + (1 - \beta)lnforestloss_{it-1} + \gamma RBL_{it} + X'_{it}\delta + \varepsilon_{it} \quad (2.4)$$

Where $Lnforestloss_{it}$ is the present value of forest loss in hectares in the country in the year t . α_{it} is a country-fixed effect, and ε_{it} is the error term. RBL_{it} is our variable of interest. It represents the supply of man-made capital. In fact, the underlying assumption is that an increase in resource-backed loans leads to more deforestation because they are necessarily repaid with minerals. X'_{it} is a vector of control variables used in the baseline model.

The presence of the dependent variable lagged among the explanatory variables in Equation 2.4 creates a dynamic panel bias (Nickell, 1981) due to the correlation between the dependent variable lagged and the error term. dependent variable and the error term. This bias is particularly important for the panel data set with a short time dimension in such circumstances, a panel fixed effects estimator would not be the panel estimator (Roodman, 2006). We assume that the RBL variable is endogenous. According to Coulibaly (2024b) and Coulibaly (2024c), the adoption of resource-backed loans is not a random event; it depends on the country's macroeconomic, institutional and political conditions. If the adoption of resource-backed loans depends, for example, on non-access to conventional financial markets, this means that it is likely that the positive effect found in this chapter is due to the condition of access to financial markets and not to the resource-backed loans themselves. We follow the literature on dynamic panel data estimation to solve these endogeneity issues using the system-GMM

estimator (Blundell and Bond, 1998). For instance, Combes et al. (2018b) use this estimator to estimate expenditure and credit on forest cover loss for 12 years of panel data from 63 developing countries over the period 2001-2012. Kinda and Thiombiano (2021) also used this estimator in their study to estimate the effect of extraction industry rents on deforestation for a panel of 52 resource-rich developing countries over the period 2001-2017.

One of the main advantages of the systemic GMM estimator lies in the fact that this estimation technique can instrument other explanatory variables that could potentially be endogenous in addition to the main regressor, which is endogenous. In addition, with the GMM system estimator, it must be ensured that the total number of instruments does not exceed the number of countries to avoid the problem of «instrument proliferation» in the system. The number of countries that avoid the problem of «instrument proliferation» in estimates (Roodman, 2006). We reduce the number of instruments to avoid proliferation. We report the results of the GMM estimation in Table 2.7. The p-values at 5% of AR(1) and AR(2) and the Hansen tests support the validity of our results. In each specification, the lagged dependent variable is positive, significant at 1% and less than 1 showing that there is no fallacious regression. In column [1], we report the results of our basic model. Then we increase the density of our canopy in columns [2]-[3] as before (see Table 2.7). After endogeneity treatment, the resource-backed loan variable remains statistically significant at the 1% level with a coefficient that remains positive. Indeed, with the GMM estimator, as the canopy threshold increases, the magnitude of resource-backed loans on deforestation decreases but remains significant. Globally, all results can thus be comparable to the ATTs.

Table 2.7: GMM estimation results: using different canopy cover

Dependent Variable:	Baseline		
Forest loss	>25% canopy cover	>30% canopy cover	>75% canopy cover
	[1]	[2]	[3]
Log forest loss, Lagged	0.661*** (0.038)	0.721*** (0.028)	0.862*** (0.026)
Resource-backed loans	1.977*** (0.651)	1.483** (0.602)	0.734* (0.437)
Log Credit	-0.440** (0.205)	-0.415* (0.234)	-0.481* (0.280)
ODA	-0.204*** (0.028)	-0.195*** (0.033)	-0.152*** (0.029)
Log GFC	-1.917*** (0.442)	-2.317*** (0.464)	-0.800* (0.414)
Expenditure	0.003 (0.021)	0.066** (0.030)	-0.059** (0.026)
Natural resources rents	0.223*** (0.039)	0.215*** (0.042)	0.052* (0.028)
Natural resources depletion	-0.269*** (0.050)	-0.231*** (0.049)	-0.128*** (0.034)
Constant	10.398*** (1.455)	10.026*** (1.505)	6.579*** (0.830)
Number of observations	678	676	596
Number of countries	54	54	50
Number of instruments	39	39	39
AR(1) test, p value	0.000	0.000	0.001
AR(2) test, p value	0.218	0.283	0.183
Hansen, (p-value)	0.120	0.146	0.188

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, GMM-System - Generalized Method of Moments estimator with country fixed effects. The study period is 2004–2018. The lagged Forest Loss is endogenous; resource-backed loans are strictly exogenous while other variables are considered

2.7.4 Alternative canopy thresholds of forest

The literature has identified shortcomings in the measurement of forest cover published by Hansen et al. (2013). For example, Tropek et al. (2014) point out that the classification of high-resolution satellite data based on a single simplistic algorithm can only provide limited insight into real forest dynamics at the local scale. Furthermore, the authors believe that the definition of forest given by Hansen et al. (2013) includes any vegetation below 5 m that is considered forest. The inclusion of these vegetation types as forest further biases the estimates of forest cover gain and loss (Tropek et al., 2014). Furthermore, in the definition developed by Hansen et al. (2013), all areas deforested and converted to plantations were classified as forests before 2000, leading to an overestimation of the total forest area and biases the definition of forest

canopy (Tropek et al., 2014).

For these reasons, we perform a robustness analysis following Combes et al. (2018b) that have used narrower definitions of forest cover loss¹⁰. We report the results of the ATT in Table 2.8 with the different thresholds. The observation is that the results do not change substantially; therefore, they remain robust when we increase the density of the canopy.

Table 2.8 shows two major facts. First, when we increase the threshold for forest cover loss, resource-backed loans have a significant impact on deforestation. Second, the magnitude of resource-backed loans in deforestation is greater when the canopy threshold is higher than 75% (local linear regression). These results are confirmed by the GMM method (see Table 2.7, columns [2]-[3]).

Table 2.8: Robustness of the ATT with alternative the forest definition

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Log forest loss	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
Panel A: >25% canopy cover								
Baseline: ATT	1.6365*** (0.5976)	1.5401*** (0.5547)	1.4751*** (0.4171)	1.5311* (0.6206)	1.4389*** (0.3466)	1.6501*** (0.5059)	1.3083*** (0.3645)	1.4115*** (0.4142)
Observations	727	727	727	727	727	727	727	727
Panel A: >30% canopy cover								
ATT	0.9011 (0.6928)	1.2792* (0.5461)	1.5030*** (0.5444)	1.5623* (0.6277)	1.4331*** (0.4816)	1.7098*** (0.5980)	1.2941*** (0.4307)	1.3889*** (0.3941)
Observations	722	722	722	722	722	722	722	722
Panel A: >75% canopy cover								
ATT	1.4538*** (0.54046)	1.9148*** (0.5271)	1.7643*** (0.4429)	2.4374*** (0.6094)	1.9863*** (0.4126)	2.3103*** (0.6489)	1.9090*** (0.3730)	1.8884*** (0.3928)
Observations	648	648	648	648	648	648	648	648

Bootstrapped standard errors based on 50 replications in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1

2.7.5 Falsification tests

So far, all the robustness tests carried out confirm our findings that resource-backed loans have a positive impact on deforestation in adopting countries compared to non-adopting countries. However, as mentioned above, resource-backed loans suffer from a lack of transparency (Mihalyi et al., 2020; Mihalyi et al., 2022; Horn et al., 2021). The literature also mentions that the adoption of an economic policy is generally associated with other parallel reforms or even depends on macroeconomic conditions (Apeti, 2023a; Apeti and Edoh, 2023; Balima, 2017). It is therefore conceivable that unobservable variables correlated with policy adoption and po-

¹⁰Combes et al. (2018b) using a floss > 10%, in their baseline regression; floss > 15%, > 20%, > 25%, > 30%, > 50% and > 75% canopy cover as robustness. In this study, we chose two canopy densities: 30% and 75% higher thresholds, to distinguish between areas with closed forests and areas with open forests such as pineapple, soybean, or tea plantations.

tentially with the outcome variable could influence our results. In addition, the opacity of resource-backed loans may suggest that our control group may be contaminated and bias our results. Admittedly, the empirical method, that is, entropy balancing, used in the previous section for robustness in this study targets this type of concern. However, we reinforce our results by performing a few additional tests. Specifically, we perform a random assignment to treatment within the treated countries, considering false adoption dates. Our intuition is that, if the effects obtained are due to RBL, using placebo dates will lead to statistically non-significant effects. In fact, random assignment to treatment does not have a significant effect, suggesting that our results are not driven by confounding factors, reinforcing the robustness of our findings.

Table 2.9: Resource-backed loans and deforestation: Falsification Tests

Dependent Variable :	1-Nearest	2-Nearest	3-Nearest	Radius Matching			Local linear	Kernel
	Neighbor	Neighbor	Neighbor	r=0.005	r=0.05	r=0.01	regression	
Log forest loss	Matching						Matching	Matching
ATT	0.1170 (0.5303)	0.3981 (0.6044)	0.3930 (0.5267)	0.0387 (0.3569)	-0.0644 (0.4363)	-0.0181 (0.2977)	0.0263 (0.3308)	-0.0584 (0.3583)
Observations	727	727	727	727	727	727	727	727
Treated	92	92	92	92	92	92	92	92
Untreated	635	635	635	635	635	635	635	635

This table shows the results of various placebo tests using propensity score matching. For the treatment variable, we constrain the correct treatment dates by randomly assigning treatment to dates other than those actually treated in the sample observations.

2.8 Exploring heterogeneity

2.8.1 Effects by type of resource-backed loans and region

Many previous studies have attempted to show the negative effect of mining on the environment. For example, Cox et al. (2022) shows that the global metals and mining industry contributes about 8% of the global carbon footprint. The mining of certain minerals such as copper, nickel, lead, zinc, silver, gold, platinum, palladium, aluminum, steel, etc. destroys forest cover, yet forests are essential for the sequestration of CO₂. However, mining could help countries accelerate the energy transition process in the context of a low carbon apology, as the minerals will be used to manufacture the electric bacteria that are highly recommended for the energy transition. Therefore, the impact of mining on the environment may differ from that of oil exploitation. We therefore test whether the impact of resource-backed loans on environmental sustainability, in particular deforestation, is heterogeneous with respect to

the type of natural resource used as collateral. The results of the ATTs are reported in Table 2.10, (Panel A and B). We find that the impact of mineral, tobacco, and cocoa-backed loans is positive and statistically significant at the level 1% (local linear regression, Panel A), while no significant impact is found for oil-backed loans on deforestation (Table 2.10, Panel B). As we explained earlier, the insignificant effect of oil-backed loans observed is not surprising. It may be attributed to the collapse in oil and commodity prices in 2014-2015, as it is not financially viable to exploit natural resources during a period of falling prices. This would demotivate countries to commit to exploiting these resources. In Table 2.10 Panel C and D, we test the potential heterogeneity by region. The idea behind this exercise is that, as we explained above, the factors explaining deforestation can differ between regions and even between countries (see Barbier and Burgess, 2001; Binswanger, 1991; Southgate et al., 1991; Gillis, 1988; etc.).

When we desegregate countries by region, we find that the magnitude of resource-backed loans on forest cover loss increases in the sub-Saharan African region (Table 2.10, Panel C), while no effect is found in Latin America (Table 2.10, Panel D).

Four possible explanations can be drawn from these results. First, the fact that resource-backed loans have no impact on deforestation in Latin America is due to the resources used to repay the loans. Indeed, all Latin American countries have focused their repayment on oil, which does not directly affect forests, and not on minerals. On the other hand, most mineral-backed loans are signed by sub-Saharan African countries that are destroying forest cover considerably. Secondly, as we explained earlier, the insignificant effect of oil-backed loans observed is not surprising. It could be attributed to the collapse in oil and commodity prices in 2014-2015, as it is not financially viable to exploit natural resources during a period of falling prices. This would demotivate countries to commit to exploiting these resources. Third, all Latin American countries in our sample that have signed a resource-backed loan have benefited from several debt relief programs for nature conservation and conservation funds. With this type of "**debt-for-nature swaps**" program, when the creditor country grants debt relief to the debtors, the debtor country is obliged to use the funds for forest conservation, protection, and reforestation. The beneficiary country then feels compelled to achieve better results in terms of environmental protection and performance to benefit more. This would minimize the risk of deforestation (see, for instance, d Chamon et al., 2022 or Essers et al., 2021). We believe that the "**debt-for-nature swaps**" program has played a crucial role in the resource-

backed loan agreements for Latin American countries. Unlike sub-Saharan African countries, which benefit less from debt relief, their loans are much more heavily weighted towards minerals, tobacco and cocoa, which would explain the positive and significant impact in this region (Table 2.10, local linear regression in Panel C). Finally, these differences could be due to the varying financial constraints between these regions. Indeed, we have explored this avenue by looking at how RBLs affect access to capital markets in each region. A negative effect would mean that countries unable to mobilize funds on conventional markets would have no other recourse than to go to the resource-backed loan market. However, a positive effect means that the country can access other types of loan to finance its development. We follow Sawadogo (2020) in using credit rating as a key indicator of access to capital markets. Our results, reported in Table 2.11, confirm that RBL worsens access to financing for sub-Saharan African countries. However, no effect is found with Latin American countries, even though the coefficients remain negative. We can therefore say that the differences observed in Table 2.10 are due to the varying financial constraints between these regions.

Table 2.10: Heterogeneity by type of resource-backed loans and by region

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Log forest loss	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
Panel A: Minerals, tobacco and cocoa backed loans								
ATT	2.4063* (0.95760)	2.4334*** (0.7331)	2.4927*** (0.7102)	3.1577 *** (0.7049)	3.8842*** (0.7357)	3.4395*** (0.7184)	2.2840*** (0.8646)	3.9391*** (0.6661)
Observations	648	648	648	648	648	648	648	648
Treated	13	13	13	13	13	13	13	13
Untreated	635	635	635	635	635	635	635	635
Panel B: Oil backed loans								
ATT	0.2623 (0.6926)	0.3202 (0.7958)	0.2006 (0.5444)	0.4030 (0.7858)	0.6063 (0.6222)	0.5405 (0.7408)	0.5664 (0.6824)	0.5527 (0.5215)
Observations	690	690	690	690	690	690	690	690
Treated	55	55	55	55	55	55	55	55
Untreated	635	635	635	635	635	635	635	635
Panel C: sub-Saharan Africa								
ATT	1.3155** (0.6748)	0.8258 (0.5790)	0.8930 (0.5643)	1.0414 (1.0045)	1.0580* (0.5895)	0.9849 (0.6077)	0.9221** (0.5214)	1.0543** (0.5479)
Observations	475	475	475	475	475	475	475	475
Treated	64	64	64	64	64	64	64	64
Untreated	411	411	411	411	411	411	411	411
Panel D: Latin America and the Caribbean								
ATT	-0.1422 (1.4070)	0.4983 (1.0247)	0.1485 (0.7881)	-0.3283 (1.6414)	0.0926 (0.9810)	0.4254 (1.2986)	0.1980 (1.4866)	0.0543 (0.8781)
Observations	252	252	252	252	252	252	252	252
Treated	28	28	28	28	28	28	28	28
Untreated	224	224	224	224	224	224	224	224

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

Table 2.11: Financial constraints

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Log forest loss	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
sub-Saharan Africa								
ATT	-1.2054*** (0.4505)	-1.0620** (0.4485)	-0.8382** (0.4255)	-0.8416 (0.8611)	-1.1987** (0.4722)	-0.9318 (0.6872)	-1.2224*** (0.3539)	-1.1869*** (0.3432)
Observations	264	264	264	264	264	264	264	264
Latin America and the Caribbean								
ATT	-0.2604 (1.0893)	-0.6658 (0.8943)	-0.5860 (0.8903)	-1.9834 (2.7212)	-0.4759 (0.9465)	-2.4764 (1.7936)	-0.3346 (0.9465)	-0.5016 (1.1929)
Observations	225	225	225	225	225	225	225	225

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

2.8.2 Resource-backed loans and deforestation in time

Following, for example, Coulibaly (2024b); Coulibaly (2024c) or Fang and Miller (2011), we look at the evolution of the effect of RBL adoption on deforestation over time using a treatment effect that varies over time. This dynamic effect may allow isolating a potential time-lag separating the date of RBL adoption from its (significant) effect on deforestation. The idea is that the adoption of RBLs can take a long time to have an effect on deforestation. At the same time, deforestation in individual countries is a process that evolves over time.

To do this, we estimate the ATTs for the year of adoption ($t = 0$) and for the five years following the year of adoption ($t = 1, 2, 3, 4, 5$). The results compiled in Table 2.12, lines ([1]-[6]) reveal the existence of a dynamic effect of the adoption of resource-backed loans on deforestation. This effect appears as soon as resource-backed loans are adopted and increases over time (see local linear regression). Consequently, we can conclude that the effect of resource-backed loans on deforestation is time sensitive.

2.8.3 Treatment of conditional effects

We explore the important structural differences that shape the effect of resource-backed loans on deforestation in developing countries despite several common characteristics. The idea here is that structural factors can magnify or alleviate the effect of RBL on deforestation. We follow the literature on impact evaluation (Lin and Ye, 2009; Apeti et al., 2023b; Sawadogo, 2020; Combes et al., 2024; etc.) and assess the effects of such heterogeneities. Following these studies, we apply the control function regression method (see Heckman and Robb Jr, 1985), whose functioning is as follows. When estimating the effect of RBL on deforestation, we control the propensity score; in this way, we neutralize differences between treated and untreated observations that may arise from observable variables whose effect is summarized by the PS

(see Table 2.1). Table 2.13, columns ([1]-[2]) show the results of a simple OLS linking the adoption of RBL to deforestation while accounting for the estimated propensity score. A statistically significant coefficient of the propensity score means that there is self-selectivity in the model (this is the case in our model). The variable RBL dummy captures the mean difference in deforestation between countries with RBL and those without. This coefficient is positive in all columns. However, the coefficient is not significant when some structural factors are controlled (corruption dummy). The next columns show the coefficients of the interactive term between a resource-backed loan and a given structural factor.

Indeed, on the basis of existing studies on RBL determinants (see e.g. Mihalyi et al., 2020; Mihalyi et al., 2022; Coulibaly, 2024c; Coulibaly, 2024b; Coulibaly et al., 2022), we consider the structural characteristics of several key countries: resource rents volatility (captured by standard deviation of the natural resource rents estimated over a 5-year moving window), resource rich countries, political stability¹¹, level of development (captured by a dummy variable equal to one for low-income countries, and to zero for middle-income countries), business cycle (captured by a dummy for which equals 1 if GDP growth is above its mean value and 0 otherwise), ODA volatility (captured by standard deviation of the net ODA received estimated over a 5-year moving window), forest rents, commodity prices, investment volatility (captured by standard deviation of the public investment estimated over a 5-year moving window), revenue volatility (captured by standard deviation of the government revenue estimated over a 5-year moving window), fiscal stance (dummy equals 1 if the ratio of external debt stocks to GDP is above its mean value and 0 otherwise), corruption dummy (captured by a dummy variable equal to one if the level of corruption is above its median value), and debt rule.

Columns [3]-[15] of Table 2.13 show the estimated effect of resource-backed loans on deforestation, according to the structural characteristics of the countries concerned. The interaction between resource-backed loans and these variables, i.e., rent volatility, political stability, level of development, commodity prices, fiscal stance, and debt rule (see Table 2.13 columns [3], [5], [6], [10], [13] and [15]), suggests that resource-backed loans may be effective in reducing deforestation in countries characterized by high volatility of resource rents, high political stability, in low-income countries, high commodity prices, high fiscal stance and in the pres-

¹¹A composite index of political stability, bureaucracy quality, external conflict, internal conflict, government stability, socioeconomic conditions, and ethnic tensions obtained by Anderson (2008)'s method.

ence of a fiscal rule such as debt rule. Secondly, certain factors present opposite results, i.e., resource-backed loans amplify deforestation in countries rich in natural resources, in the presence of a high perception of forest rents, high investment volatility, high revenue volatility, and in the presence of high corruption (Table 2.13 columns [4], [9], [11], [12] and [14]).

The impact of resource-backed loans on deforestation appears insignificant when other types of political factors, such as corruption, are taken into account. This suggests that the effects of resource-backed loans on deforestation are sensitive, to some extent, to political conditions. In total, our results are sensitive to many structural characteristics. The effect of resource-backed loan adoption is unclear in some circumstances, mainly related to macroeconomic conditions and political situations.

Table 2.12: Heterogeneity: dynamic effects

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Log forest loss	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
ATT(t0)	1.6365*** (0.5218)	1.5402*** (0.5131)	1.4751*** (0.4721)	1.5312** (0.6108)	1.4389*** (0.3977)	1.6502*** (0.4548)	1.3083*** (0.3665)	1.4115*** (0.3886)
Observations	727	727	727	727	727	727	727	727
ATT(t1)	1.3669*** (0.4842)	1.5152*** (0.4184)	1.7047*** (0.4354)	1.8983** (0.8348)	1.5184*** (0.3768)	1.6866*** (0.4724)	1.4676*** (0.3345)	1.5315*** (0.3960)
Observations	679	679	679	679	679	679	679	679
ATT(t2)	1.6410*** (0.4856)	1.5558*** (0.4659)	1.5558*** (0.4659)	1.6250*** (0.4432)	1.6330** (0.6662)	1.5454*** (0.3898)	1.5122*** (0.3830)	1.5578*** (0.3438)
Observations	631	631	631	631	631	631	631	631
ATT(t3)	1.7621*** (0.5117)	1.5476*** (0.4032)	1.3692*** (0.3676)	1.6589** (0.7168)	1.4735*** (0.3409)	1.4862*** (0.3899)	1.4895*** (0.3943)	1.4933*** (0.3012)
Observations	583	583	583	583	583	583	583	583
ATT(t4)	1.1674** (0.4540)	1.3522*** (0.3225)	1.4309*** (0.4117)	1.5076*** (0.5555)	1.4567*** (0.2953)	1.3315*** (0.4246)	1.3991*** (0.3519)	1.4532*** (0.3670)
Observations	535	535	535	535	535	535	535	535
ATT(t5)	1.3022*** (0.3944)	1.2969*** (0.4558)	1.3750*** (0.4072)	1.7520** (0.7560)	1.6177*** (0.3093)	1.6377*** (0.5856)	1.5283*** (0.3442)	1.6150*** (0.3131)
Observations	484	484	484	484	484	484	484	484

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

Table 2.13: Resource-backed loans and deforestation: the role of structural factors.

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]
RBL	1.9482*** (0.3247)	1.1821*** (0.3678)	2.5438*** (0.5675)	5.4530*** (0.9064)	1.7015*** (0.4143)	1.8506*** (0.4255)	1.2057*** (0.3747)	1.2559*** (0.4457)	0.7745* (0.4256)	3.1541*** (0.7671)	2.7677*** (0.5380)	2.0969*** (0.6172)	1.5284*** (0.3853)	-0.4034 (0.5505)	1.5246*** (0.3877)
PS (Propensity score)		3.3813*** (0.8230)	5.0724*** (1.1380)	4.1144*** (0.8215)	1.7316* (0.8871)	3.1196*** (0.8227)	3.4180*** (0.8308)	4.2718*** (1.1492)	3.3814*** (0.8216)	4.3219*** (0.8820)	3.6346*** (1.1344)	4.6752*** (1.1514)	3.2511*** (0.8202)	3.6006*** (0.8173)	3.8076*** (0.8347)
RBL*Rents volatility			-0.3236*** (0.0898)												
RBL*Resource rich				4.9682*** (0.9669)											
RBL*Political stability					-1.9336*** (0.4057)										
RBL*Level of development						-2.0121*** (0.6551)									
RBL*Business cycle							-0.3621 (1.0802)								
RBL*ODA volatility								-0.1140 (0.1462)							
RBL*Forest rents									0.1047* (0.0553)						
RBL*Commodity prices										-0.0117*** (0.0038)					
RBL*Investment volatility											0.1509** (0.0747)				
RBL*Revenue volatility												0.3105** (0.1470)			
RBL*Fiscal stance													-2.6626*** (0.9262)		
RBL*Corruption dummy														2.3990*** (0.6243)	
RBL*Debt rule															-1.9963*** (0.7414)
Constant	8.9061*** (0.1103)	8.8558*** (0.1488)	8.6562*** (0.1877)	8.7714*** (0.1472)	9.1439*** (0.1516)	8.8859*** (0.1483)	8.8516*** (0.1495)	8.7453*** (0.1898)	8.8558*** (0.1486)	8.7590*** (0.1517)	8.8214*** (0.1841)	8.7003*** (0.1896)	8.8708*** (0.1482)	8.8305*** (0.1476)	8.8067*** (0.1493)
Observations	892	727	539	727	684	727	727	538	727	722	527	538	727	727	727
R-squared	0.0389	0.0668	0.0961	0.0997	0.0728	0.0788	0.0670	0.0752	0.0714	0.0829	0.1186	0.0818	0.0774	0.0855	0.0761

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

2.9 Transmission channels

Finally, we empirically test the different channels through which the impact of resource-backed loans can be transmitted. As already mentioned, we assume that resource rent maximization, combined with natural resource depletion, is the main channel likely to explain the positive effect of resource-backed loans on deforestation. The literature does not provide an explicit and singular method for assessing transmission channels. In this study, we adopt a simple two-step approach. In fact, the aim of this exercise is to verify whether, for example, strong maximization of natural resource rents by extractive industries and governments has a positive effect on deforestation, and if natural resource rents constitute a relevant channel through which RBL affects deforestation, then natural resource rents as a percentage of GDP should, in turn, increase deforestation. In panel A, columns [1]-[5] of Table 2.14, we perform standard OLS estimates to capture the relationship between our potential channels and deforestation. Unsurprisingly, resource rents, resource depletion, public debt, and procyclicality (volatility of debt)¹² are negatively correlated with deforestation. However, our results indicate that consumption expenditure is negatively associated with deforestation. In addition, our results show a strong magnitude of the relationship between the resource rent, which extends to 79%, and is significant at the level 1%. If the maximization of natural resource rents, leading to greater natural resource depletion, and public debt are channels explaining our previous results, then we should in turn observe a positive impact of resource-backed loans on the latter. In Panel B lines [1]-[5], we estimate the effect of resource-backed loans on the different variables identified as main channels in our main model, using propensity score matching methods. The results suggest that resource-backed loans increase resource rents, resource depletion, public debt, debt volatility, consumption expenditure, and China's FDI in line with previous studies. Our motivation for China's FDI variable is explained by the fact that China is a potential lender of resource-backed loans. When a country signs a resource-backed loan, CDB and Eximbank are entrusted with the exploitation of the country's natural resources, and contracts are allocated to China's FDI for the exploitation of natural resources. By taking global FDI, we risk missing out on the potential effect of this channel.

¹²We use the standard deviation of the public debt estimated over a 5-year moving window.

Table 2.14: Validity of transmission channels

Panel A	[1]	[2]	[3]	[4]	[5]	[6]		
Resources rents	0.7904*** (0.0500)							
Resource depletion		0.1505*** (0.0530)						
Public debt			0.5141*** (0.1574)					
Procycliclity (debt volatility)				0.0305** (0.0153)				
Consumption expenditure					-0.1753*** (0.0169)			
China's FDI						0.0442*** (0.0119)		
Constant	8.1328*** (0.1161)	9.4758*** (0.1089)	11.0063*** (0.5837)	9.0610*** (0.1662)	11.9049*** (0.2589)	8.9335*** (0.1524)		
Observations	864	767	883	641	747	506		
R-squared	0.2248	0.0105	0.0120	0.0062	0.1257	0.0171		
Panel B	N=1	N=2	N=3	Radius Matching			Local linear regression	Kernel
		Matching		r=0.005	r=0.05	r=0.01	Matching	Matching
[1] Resources rents	0.9371*** (0.2035)	0.8865*** (0.1774)	0.8290*** (0.1576)	0.9794*** (0.1113)	0.9778*** (0.1224)	0.9645*** (0.1111)	0.8868*** (0.1096)	0.9670*** (0.1169)
[2] Resource depletion	0.1388 (0.2285)	0.1470 (0.1759)	0.1415 (0.1668)	0.2244 (0.2155)	0.2964** (0.1451)	0.1964 (0.1543)	0.2034 (0.1519)	0.2786* (0.1678)
[3] Public debt	0.3739*** (0.1279)	0.4142*** (0.1053)	0.4450*** (0.1313)	0.3414*** (0.0987)	0.3530*** (0.1026)	0.3536*** (0.0796)	0.3947*** (0.0721)	0.3559*** (0.1035)
[4] Procycliclity (debt volatility)	1.9679* (1.1389)	2.0399* (1.1478)	2.4150** (1.1166)	1.7125 (1.2410)	2.6726*** (0.8779)	1.6447 (1.1204)	2.4637*** (0.8423)	2.6414*** (0.9993)
[5] Consumption expenditure	2.9415*** (0.7526)	2.4266** (0.9975)	2.1669** (0.9283)	1.8049* (1.0973)	1.8324** (0.7588)	2.0469** (0.9542)	1.9512*** (0.7379)	1.8217** (0.7586)
[6] China's FDI	0.4470** (0.1837)	0.4165* (0.2270)	0.3743** (0.1732)	0.3515 (0.2542)	0.4030** (0.1654)	0.3871* (0.2130)	0.4585*** (0.1173)	0.4013*** (0.1256)

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

2.10 Conclusion and policy implications

This chapter investigates the causal effect of the adoption of resource-backed loans on deforestation. Based on a sample of 64 developing countries during the period 2004-2018, estimates using the propensity score matching method reveal that the adoption of resource-backed loans significantly increases deforestation in countries that have signed resource-backed loans compared with countries that have not signed resource-backed loans. In addition, this result appears to be robust under many alternative specifications, including alternative control variables, different samples, placebo tests, and alternative impact evaluation methods. Nevertheless, additional estimates reveal that the effect of the adoption of resource-backed loans on deforestation is uneven and that, in particular, its role and magnitude may differ according to certain structural characteristics. Indeed, such characteristics can amplify or, in contrast, inhibit the effectiveness of these loans. Although there is no doubt that policymakers in resource-rich countries are looking for effective macroeconomic management to avoid procyclical resource policies and achieve higher-quality investments in human and physical cap-

ital, resource-backed loans can help them achieve these goals from an infrastructural point of view, provided that they are being accompanied by sound structural macroeconomic environments. In other words, while resource-backed loans represent a good opportunity to finance essential development needs, they can also weaken the sustainability of debt and put pressure on borrowing countries to increase the rate of mineral and fossil fuel production to repay the loan, a factor that could affect environmental sustainability due to the significant pressure of extractive industries on forest cover. To this end, natural resource-backed loans, and in particular mineral, tobacco, and cocoa-backed loan agreements, should include elements related to the protection of forest cover and robust provisions for the implementation of actions to mitigate their adverse impact on the environment.

RESOURCE-BACKED LOANS AND CYCLICALITY OF FISCAL POLICY IN DEVELOPING COUNTRIES

Abstract: Following the recent surge in debt levels associated with the COVID-19 shock, the Russo-Ukraine crisis and the subsequent tightening in global financial conditions, many emerging markets and developing economies (EMDEs) are grappling with rising debt service burdens that squeeze the space available for development spending. Added to this is the resource-backed loan burden that many countries have signed up to in recent years. This will have an impact on fiscal policy. In this chapter, we analyze the reaction of fiscal policy to the status of resource-backed loans in a large panel of 127 developing countries over the period 1990-2020 using a non-parametric regression method (LGWOLS) and the entropy-balancing method. Although we reinforce the established finding that fiscal policy is procyclical, this study also reveals additional results. We reveal a non-linear response of fiscal policy to resource-backed loans, conditioned by the business cycle and massive public investment. Interestingly, in a public investment range of 15% to 35% of GDP, resource-backed loans make fiscal policy countercyclical. Moreover, in good times, fiscal policy is acyclical to resource-backed loans, while in bad times (crisis), it is countercyclical. Finally, by examining possible transmission channels, our results reveal that the observed procyclical fiscal policy effects of resource-backed loans are mediated by sovereign debt defaults (domestic debt crisis), fiscal balance volatility, and weak institutional quality measured by rising corruption levels.

Keywords: • Resource-backed loans • Fiscal policy • Public debt • Cyclical of fiscal policy

JEL Codes: O13, E62, H63.

3.1 Introduction

Recent world events that have had unexpected effects on the price of food, the uncertainty by discouraging capital investments and energy globally include the start of the COVID-19 epidemic and Russia's conflict against Ukraine (Carrasco and Tovar-García, 2021). These global events have worsened the public finances situation in many developing economies and have led many of these economies to borrow more on national and international markets to cushion the effects of the crisis. To this end, several countries, especially in sub-Saharan Africa and Latin America, have resorted to resource-backed loans (see Coulibaly, 2025; Coulibaly, 2024a; Mihalyi et al., 2022; Mihalyi and Scurfield, 2021; Mihalyi et al., 2020). Basically, resource-backed loans are a form of external public debt designed to finance economic development, the payment of which is to be made using natural resources in kind or revenues derived from natural resources (Coulibaly, 2025; Coulibaly, 2024a; Mihalyi et al., 2022). Given that resource-backed loans are a particular type of sovereign debt, largely earmarked for public infrastructure investment (see the discussion in Coulibaly, 2025), they can be an important lever for sustainable financing (Coulibaly, 2024a), as when governments utilize public debt to fund investments and spending in key areas that support a sustainable future, it plays a critical role in economic development (see, e.g., Ruiz et al., 2025). However, resource-backed loans can also become a significant burden when they grow excessively, reducing economic growth, exacerbating debt sustainability, and fiscal policy.

Unsurprisingly, several studies in the literature aim to assess the consequences of high public debt ratios. For instance, Greene and Khan (1990) have shown that beyond a certain point, debt begins to stifle progress. In the spirit of Reinhart et al. (2012), high levels of public debt can pose a threat to the economy. These authors argue that countries with a sovereign debt/GDP ratio in excess of 90% have significantly lower economic growth rates on average. Similarly, some studies have shown that high debt levels have a non-linear impact, with negative consequences for growth, due to over-indebtedness and crowding-out effects (see, e.g. Baum, 2012; Ajayi and Oke, 2012; Ezeabasili et al., 2011; Ekperiware and Oladeji, 2012; Sulaiman and Azeez, 2012; Cecchetti et al., 2011; Reinhart and Rogoff, 2010; Kumar and Woo, 2010), lead to payment default crises (Manasse and Roubini, 2009), which in turn increase income inequality (Apeti, 2023b). In addition, there is a consensus that debt can be used as a tool to stimulate

economic growth if used correctly. In this literature, many studies focus on how debt could be described as a double-edged sword, i.e., its potential role in promoting growth when used up to a certain threshold, beyond which over-indebtedness exerts a negative pressure on economic performance (see, e.g. Turan and Yanikkaya, 2021; Sandow et al., 2022; Karadam, 2018; Omotosho et al., 2016). Using a panel of 71 developing countries, Law et al. (2021) established that the threshold value of debt is 51.65%, and that debt significantly and negatively influences progress at increasing levels of public debt, while debt only insignificantly affects economic progress at decreasing levels of public debt. Juergen (2019) reached similar conclusions for 25 developed and developing countries, concluding that debt has a negative impact on short- and long-term economic performance. In the same vein, IMF (2003) suggest that the primary surplus's response to the business cycle weakens as the debt/GDP ratio increases, and simply stops when debt exceeds 50% of GDP. Furthermore, some studies examine other dimensions of fiscal policy: for example, public debt significantly affects the cyclicity of fiscal policy (see, e.g. Combes et al., 2017; Gavin et al., 1996). For Gavin et al. (1996), procyclical fiscal policies are the result of tighter debt constraints during recessions. Borrowing limits in a recession force restrictive policies; when limits are relaxed in an expansion, policies tend to be expansionary. In an analysis close to ours, Olaoye and Olomola (2023) show that public debt is weakly sustainable and highly dependent on procyclical policies, particularly in resource-rich countries. This result indicates that governments' fiscal policy responses are expansionary during economic recoveries and contractionary during recessions. In the same vein, Chen et al. (2024) studied resource rich countries with higher debt levels and found that high public debt reduces economic growth and diminishes the competitiveness of these countries, as their revenues depend mainly on natural resources, which are subject to high volatility of natural resources prices (see, e.g., Devlin and Lewin, 2004; Ploeg, 2008). In this sense, the volatility of raw materials at the international level causes serious problems for the ability of countries to pay their obligations, which is why these countries tend to increase their risk in terms of fiscal sustainability (Sachs and Warner, 2001).

However, the macroeconomic disadvantages of public debt do not appear to be unanimous. As shown in the pioneering work of Woodford (1990) and Aiyagari and McGrattan (1998), public debt effectively relaxes borrowing restrictions by increasing liquidity, which can be used to smooth consumption if households face the constraint. Consequently, public debt

helps to “complete” the markets. Therefore, the issue of public debt could be an effective way to improve risk sharing and thus overall well-being (Albanesi, 2008; Floden, 2001).

In sum, we note two fairly important points in the literature described above. First, existing studies do not seem to point in a univocal direction for the effect of public debt on fiscal policy. Second, most studies that analyze the link between public debt and the cyclicity of fiscal policy use the overall debt/GDP ratio.

Relative to these studies, in the present article we follow a rather different path i.e., we focus on an important type of external public debt, namely resource-backed loans, which are increasingly attracting the attention of resource-rich developing countries. This gives our analysis a more disaggregated perspective on public debt to better grasp the existence of a heterogeneous effect on policy cyclicity. To our knowledge, existing studies on resource-backed loans focus mainly on environmental quality, with deforestation as the outcome variable (Coulibaly, 2025), the ecological efficiency of human development (Coulibaly, 2024a), and a descriptive analysis of risks and potentials (Mihalyi et al., 2022). None of these studies addresses the cyclical nature of resource-backed loans. This is surprising for many main reasons. Firstly, the collateral nature of resource-backed loans obliges signatory countries to intensify their exploitation of natural resources, which could undoubtedly increase their dependence on natural resource endowments. However, natural resource endowments are considered one of the sources of the procyclical nature of public debt (Stiglitz, 2005; Budina et al., 2007). Thus, explanations of the mechanism by which natural resource endowments affect the cyclicity of public debt are based on the collateral aspect of natural resources (Budina et al., 2007; Manzano and Rigobon, 2006). Secondly, resource-backed loans can exacerbate debt sustainability and affect the cyclicity of fiscal policy via over-indebtedness. For example, Mihalyi et al. (2020) found that ten of the 14 countries adopting resource-backed loans were plunged into a series of over-indebtedness that weakened their public finances after the drop in oil prices in 2014. Third, the non-transparency highlighted in resource-backed loan operations (Coulibaly, 2024a; Coulibaly, 2025; Mihalyi et al., 2020; Mihalyi et al., 2022) can have a considerable effect on the cyclicity of the policy. In fact, governments can conceal the actual amounts signed up to in resource-backed loans, which are sometimes not even recorded in public finance statistics and which have to be repaid with sometimes long maturities. Finally, the increasing level of debt over the past decade in many developing and emerging economies raises concerns

about future economic growth, macroeconomic stability, and fiscal sustainability (Eberhardt and Presbitero, 2015; IMF, 2020; Kassouri et al., 2021; Kose et al., 2021). From this point of view, an in-depth analysis of the typology of debt such as resource-backed loans is detrimental.

To this end, the purpose of this chapter is to fill this gap in the literature by examining the causal effect of resource-backed loans on fiscal policy cyclicity in order to enrich the debate on debt dynamics and fiscal policy consolidation in developing countries. Based on a large panel of 127 countries from 1990 to 2020, we apply the entropy balancing method developed by Hainmueller (2012) to address the selection bias issues associated with policy adoption. Our results suggest that resource-backed loans positively and significantly affect cyclical fiscal policy in developing countries. In other words, resource-backed loans trigger fiscal policy procyclicality in countries with such loans relative to countries without such loans. The results are robust against various tests, including alternative specifications and estimation methods. In addition, placebo tests indicated that our results are not due to spurious bias or confounders. Next, we explore the characteristics of heterogeneity in treatment and highlight some additional findings. A distinction between different types of resource-backed loans, nature of interest rate, and type of lending country suggests that the effect of mineral, tobacco, and cocoa-backed loans is slightly greater than that of other resource-backed loans. Resource-backed loans signed with a fixed interest rate amplify the cyclical of fiscal policy more than resource-backed loans signed with a floating rate. Resource-backed loans granted by lenders, such as Russia and Korea, etc. have a greater impact on the cyclical of fiscal policy than loans granted by China. Finally, analysis of transmission channels shows that the effect of resource-backed loans on fiscal policy is cyclical due to debt crises, fiscal balance volatility, and corruption.

This chapter is organized as follows. Section 3.2 details the motivation and builds the testable hypothesis, Section 3.3 presents the data and methodology, Section 3.4 reports the main finding, Section 3.5 investigates its robustness, Section 3.6 explores the potential transmission channels, Section 3.7 explores possible heterogeneity in the effect of adoption of RBL on fiscal policy cyclical, and Section 3.8 provides some concluding remarks.

3.2 Theoretical background and hypothesis building

3.2.1 Theoretical arguments on cyclicity of fiscal policy

We begin the discussion in this section with the genesis of fiscal cyclicity, which is based on the work of neoclassicals. From this starting point, the best known theoretical statement concerning fiscal cyclicity is the 'fiscal smoothing' hypothesis, according to which, for a given trajectory of public spending, tax rates should be kept constant throughout the economic cycle and the budget surplus should evolve procyclically (Barro, 1979). In summary, the typical assumption in neoclassical fiscal policy analysis is that public spending is determined exogenously, or even stochastically (Blanchard and Fischer, 1989; Lucas Jr and Stokey, 1983). However, from a Keynesian point of view, it is clear that public spending should act as a stabilizing force and move in a countercyclical direction. For stabilization purposes, the various public spending items should be ranked according to their multiplier values. Indeed, the debate has evolved to the point where the literature indicates that there are many arguments in favor of a procyclical fiscal policy. For instance, Gavin and Perotti (1997) show that fiscal policy is procyclical in Latin American countries. These results are corroborated by Kaminsky et al., 2004 and Acemoglu et al. (2001), who find that, in general, fiscal policy tends to be more procyclical in developing countries than in advanced ones. Ilzetzki and Végh (2008), however, find evidence of procyclical fiscal policies in high-income countries as well. Lane (1998) also finds procyclicality in a single country time series study of Irish fiscal policy. In addition, Talvi and Végh (2005) confirm with solid evidence that fiscal procyclicality is evident in a much larger sample of countries. In the spirit of Kaminsky et al. (2004), capital flows amplify the economic cycle and tend to make fiscal policy procyclical.

In recent work, some authors have pointed out that the political economy could generate a procyclical bias in public spending. For example, Lane and Tornell (1996); Lane and Tornell (1998); Tornell and Lane (1998); Tornell and Lane (1999) have developed a model based on tax competition in a decentralized economy to explain how the tax rate can lead to procyclical fiscal policy. The main idea behind this approach is that the intensity of tax competition increases during periods of recovery: the impact of this 'voracity effect' is that spending may even increase more than proportionally to the increase in income. To develop the concept, the authors based their intuition on the fact that the incentive to act prudently is weak in an

economy where the idea of multiple powerful tax groups is understood differently: each group knows that if it refrains from increasing its appropriation rate during periods of expansion, the result is not that the government registers a budget surplus, but that the other groups can increase their appropriate rate by an even greater amount (Lane, 2003). Consequently, political systems in which power is dispersed among a number of agents will experience a higher degree of fiscal procyclicality than a unitary system. However, it is plausible that the variation in procyclicality between different expenditure components is driven by the specific distribution of budgetary power. For example, powerful public-sector unions can generate procyclicality, particularly in the area of civil servant wages (see Lane, 2003).

According to Frankel et al. (2013), a countercyclical fiscal policy corresponds to fiscal stimulus during a downturn (collapse) in the economic cycle, followed by fiscal contraction and reduction of debt during a period of economic recovery. Fiscal policy is considered procyclical when governments choose to increase public spending and cut taxes during an economic boom, or cut spending and raise taxes during an economic recession. Frankel et al. (2013) argue that such a procyclical policy cannot be optimal, since it tends to reinforce the business cycle, exacerbating periods of expansion and worsening periods of recession. There are two fundamental reasons why fiscal policy is procyclical (Frankel et al., 2013). Firstly, limited access to international credit markets and lack of financial depth in times of economic crisis (Caballero and Krishnamurthy, 2004; Gavin et al., 1996; Gavin and Perotti, 1997; Riascos and Vegh, 2003). Secondly, the political-economic factors that explain how political incentives cause the budget to deteriorate in times of economic prosperity (Talvi and Vegh, 2005; Tornell and Lane, 1999; Velasco et al., 1997). In fact, restrictions on access to capital markets in times of crisis force governments to cut spending and raise taxes (Frankel et al., 2013). However, easy access to capital markets in times of crisis, and the design of rules and institutions as strategies to ensure that tax revenues are saved in good times so that they are available in times of crisis, would go a long way toward mitigating the scourge of procyclical fiscal policy (see Frankel et al., 2013).

In the spirit of Alesina et al. (2008), the procyclical bias of fiscal policy is the result of the demands of voters. In fact, since voters cannot directly observe government investment spending, they demand higher levels of public services in times of economic prosperity, fearing that the government will appropriate a portion of tax revenues for political rents. According to Diallo (2009), democratic institutions are associated with countercyclical fiscal policies, and

restrictions on executive power are considered the key factor explaining why democracies can smooth economic cycles better than autocracies. In contrast to Diallo (2009), Lledo et al. (2009) studied the cyclical patterns of public spending in sub-Saharan Africa since 1970 and showed that changes in political institutions have no impact on fiscal policy behavior. They also found that the procyclicality of fiscal policy is evident in sub-Saharan African countries, but has declined in recent years. In a similar vein, Calderón et al. (2016) examine the role of government administrative quality in achieving superior fiscal outcomes. Using a large sample of 115 advanced, emerging and developing countries during the period 1984 to 2008, they find that institutional quality plays a key role in countries' ability to implement countercyclical macroeconomic policies. Their results show that countries with strong (weak) institutions adopt countercyclical (pro)cyclical macroeconomic policies. These results are corroborated by Frankel et al. (2013), who show that good institutions fundamentally explain the reduction in the procyclicality of policy. They find that countries emerge from procyclicality as institutions improve.

Numerous empirical studies have established the countercyclical nature of fiscal policy. For example, Gavin et al. (1996) assess the cyclical behavior of fiscal policy using data from industrial economies compared to data from Latin American countries. Using the database that covers the time period 1970–1995 and applying OLS to obtain cyclicity coefficients, their findings indicate that fiscal policy in industrial countries is more countercyclical than in Latin American countries. Similarly, Galí and Perotti (2003) use data for 19 OECD countries over the period 1980–2001 to argue that discretionary fiscal policy in the euro zone has become more countercyclical over time, although not to the same extent as in other advanced economies. In the same vein, Céspedes and Velasco (2014) use data on 48 commodity-rich countries over the period 1990–2008 to argue that the presence of fiscal rules encourages countries to adopt a countercyclical fiscal policy.

3.2.2 Theoretical link between RBL and cyclical of fiscal policy

Firstly, on the procyclical side, resource-backed loans can exacerbate the debt sustainability of signatory countries and trigger a procyclical fiscal policy. In fact, most resource-backed loans are signed in US dollars; the collapse of natural resource prices could increase the nominal size of these loans (Coulibaly, 2024a; Mihalyi et al., 2022) and thus lead borrowing coun-

tries into a debt overhang situation, triggering the procyclicality of fiscal policy. In addition, resource-backed loans can jeopardize the public debt situation (Coulibaly, 2024a; Rivetti, 2021) and can prevent the country from mobilizing financial resources to finance public spending in times of crisis. Coulibaly (2024a) evaluates the causal impact of resource-backed loans on the ecological efficiency of human development in African countries. The author explored the access conditions of the financial markets to enrich the debate on resource-backed loans. Using the entropy-balancing method, the author shows that the adoption of resource-backed loans reduces the credit rating by 0.9 to 1.4 percentage points. At the same time, the author finds that resource-backed loans increase the interest rate due to the poor signal of the financial situation that these countries send to conventional capital markets using their natural resources as collateral. This is evidence that resource-backed loans could have a procyclical character. Lack of transparency in resource-backed loan transactions can increase the level of corruption in the country (see Coulibaly, 2024a; Horn et al., 2021; Rivetti, 2021), weaken the quality of institutions, and politico-economic indicators that provoke fiscal indiscipline in prosperity times. Consequently, resource-backed loans can trigger fiscal procyclicality via the institutional quality channel. In the same vein, given that resource-backed loans are repaid by natural resources in kind or with revenue from the sale of resources (Coulibaly, 2024a; Mihalyi et al., 2022), signatory countries could perceive these funds as budgetary leeway. This is why resource-backed loan operations are not reflected in the public debt statistics of signatory countries (see Mihalyi et al., 2020). This behavior may lead to discretionary policies on the part of governments, given the fiscal space obtained by signing resource-backed loans, which could trigger the procyclicality of fiscal policy.

Secondly, on the countercyclical side, we base our arguments on the fact that the resource-backed loan market could be an alternative to conventional financial markets, enabling countries rich in natural resources to access them and mobilize financial resources for development. Since this market offers more favorable conditions, such as low interest rates, the possibility of returning money from natural resources, and the re-negotiation of the payment schedule in the event of a crisis (Mihalyi et al., 2020). In addition, it is possible that investments made with resource-backed loans will generate tax revenues for the signatory countries, called return on investment, which will enable repayment of the public debt. In other words, resource-backed loans are an opportunity for governments to invest their natural resource revenues in

productive investments rather than recurrent expenditure to provide fiscal stimulus during a downturn (collapse) in the economic cycle. Looking at the structure of resource-backed loans, Mihalyi et al. (2020) indicate that part of the funds from resource-backed loans are allocated to supporting the country's budget. This would help them to increase spending (or reduce taxes) in times of expansion and reduce spending (or increase taxes) in times of recession.

3.2.3 Hypothesis building

We derive our testable hypothesis by linking two strands of literature—one devoted to the corollaries of resource-backed loans in terms of increasing macroeconomic instability and the other focused on the amplifying effect of macroeconomic instability on fiscal policy cyclical. We also analyze how they affect institutional quality as a secondary channel.

Resource-backed loans and macroeconomic instability. From a theoretical perspective and as explained above, resources-backed loans can jeopardize the viability of the public debt (Horn et al., 2021) and can prevent the country from raising financial resources on the capital market to fund economic development policies. Taking advantage of this idea, a growing body of literature (see, for example, Coulibaly, 2024a; Mihalyi et al., 2020; Coulibaly, 2023c; Mihalyi et al., 2022) provides evidence that resource-backed loans increase macroeconomic instability in developing countries. In particular, resource-backed loans are associated with increased volatility of the fiscal balance, low sustainability of public debt, and a lack of transparency that worsens institutional quality.

Macroeconomic instability and fiscal policy volatility. The central idea that a country improves its fiscal balance by being countercyclical in expansionary periods and procyclical in downturns implicitly assumes a more than proportional variation in public revenues in relation to variations in GDP. As a result, greater volatility in fiscal balance is likely to lead to macroeconomic instability and thus to an increase in the nominal value of public debt. Exploring the potential influence of public debt on the cyclical behavior of fiscal policy, Combes et al. (2017) found that the countercyclicality of fiscal policy is reduced as the public debt ratio increases. The authors find that the countercyclicality of fiscal policy loses half its magnitude for a debt ratio of approximately 58%, while the behavior of fiscal policy shifts from countercyclical to procyclical for relatively high debt ratios (around 117%). These results pave the way for further analysis of variables strongly correlated with public debt in a cyclical study of fiscal

policy. These results show the important role of public debt as a determinant of cyclical fiscal policy. Empirical studies seem to support this view: for example, Ilzetzki and Végh (2008); Kaminsky and Reinhart (2004); Talvi and Vegh (2005); Alesina et al. (2008); Masten et al. (2008) in the case of developing countries.

Institutional quality and fiscal policy volatility. As we have already seen, the literature has shown how institutional factors shape the evolution and effectiveness of fiscal policy and economic performance in developing countries. For example, Calderón et al. (2016) showed that countries with strong (weak) institutions are more likely to adopt countercyclical (pro-)cyclical macroeconomic policies. These results corroborate the findings of Frankel et al. (2013), who showed that good institutions fundamentally explain the reduced procyclicality of fiscal policy. Based on these studies and drawing a parallel with our topic of whether resource-backed loans affect fiscal policy cyclicity, the non-transparency identified in resource-backed transactions may increase corruption and cause the state to lose considerable tax revenues. As a result, resource-backed loans weaken institutions and cause fiscal policy to become procyclical. In light of these arguments, the hypothesis we test in this chapter is that resource-backed loans lead signatory countries to macroeconomic instability through rising debt, fiscal balance volatility, and deteriorating institutional quality, ultimately triggering fiscal policy procyclicality in these countries. In the sequel, we develop a quantitative analysis to test this hypothesis.

3.3 Data and Methodology

3.3.1 Data

We examine the effect of resource-backed loans on the cyclicity of fiscal policy, using a panel of 127 developing countries from 1990-2020. In our sample, 14 countries signed a resource-backed loan for at least one year between 1990 and 2020. As data are not available for all countries and all years, the number of observations depends on the explanatory variables used in the chapter.

Treatment variable. Our treatment variable is resource-backed loans (RBL) measured by a dummy variable that takes 1 when a country i has signed a resource-backed loan in year t , and 0 otherwise (see Coulibaly, 2024a). Information on this variable comes from the resource-backed loan database of the Natural Resource Governance Institute constructed by Mihalyi

et al. (2020). According to Coulibaly (2024a), this database may suffer from numerous biases, as it is based on information from institutions dedicated to researching China's activities abroad; the China-Latin America financial database of Boston University's Inter American Dialogue and Global Development Policy Center, and information taken from certain official journals of the subscribing countries. The author also points out that the database may not be complete given the lack of transparency in resource-backed loan transactions. Before him, Rivetti (2021) had raised the opacity of these resource-backed loans as a major problem that could harm the public finances of the signatory countries. However, it should be noted that this is still the only reliable database that provides solid information on the existence of resource-backed loans in developing countries. This is one of the reasons why we use it in this study, as in Coulibaly (2024a) and Coulibaly (2025).

Outcome variable / calculation of the cyclicity coefficient of fiscal policy. As indicated above, our objective is to evaluate the cyclicity of the fiscal policy of resource-backed loans, i.e., wherever this type of loan has fiscal policy countercyclical/procyclical character. To do this, we follow Guerguil et al. (2017) and Aghion et al. (2007) in calculating fiscal policy cyclicity coefficients using a non-parametric regression method: local Gaussian-weighted ordinary least squares (LGWOLS). The advantages of the local Gaussian-weighted ordinary least squares (LGWOLS) model are significant and can greatly improve the accuracy and reliability of data analysis. Firstly, LGWOLS offers a better fit to non-linear data compared to traditional ordinary least squares models. This is particularly important when dealing with real-world data, as many phenomena do not follow a linear pattern. By providing a more flexible and adaptive approach, LGWOLS can capture the non-linear relationships within the data, leading to more accurate and meaningful results. Furthermore, LGWOLS is effective in reducing edge effects, which are common in spatial data analysis. By incorporating a Gaussian-weighted function, LGWOLS assigns less weight to data points further away from the target location, thus mitigating the influence of edge effects and producing more reliable estimates. This is particularly valuable when working with geographic or spatial data, where edge effects can significantly impact the accuracy of the analysis. Overall, the advantages of LGWOLS make it a powerful tool for data analysis, especially in scenarios where non-linearity and edge effects are prevalent. One of the advantages of this approach is that it enables us to calculate country-specific cyclicity coefficients that vary over time. Finally, it takes into account the

fact that the government's response to business cycle fluctuations can vary over time and differ between the upward and downward phases of the business cycle. The cyclicity equation is as follows:

$$\Delta \text{Log}(SPEN_{ij}) = \alpha_{it} + \beta_{it} \Delta \text{Log}(GDP_{ij}) + \epsilon_{it} \quad (3.1)$$

Where $\epsilon_{it} \rightarrow N(0, \frac{\sigma^2}{w_t(\tau)})$ and $w_t(\tau) = \frac{1}{\sigma\sqrt{2\pi}} \exp(-\frac{(\tau-t)^2}{2\sigma^2})$

As explained above, the LGWOLS method weights all observations by a Gaussian centered on t , for country i and then performs a regression for each date t . This gives us the coefficients $\hat{\beta}_{it}$. We choose the value of the parameter σ equal to 5 following Aghion et al. (2007) and Guerguil et al. (2017). Following the literature, we define $\Delta \text{Log}(SPEN_{ij})$ by the growth rate of government real expenditure for country i at time t and $\Delta \text{Log}(GDP_{ij})$ by the growth rate of government real GDP for country i at time t . The predicted country-specific and time-varying coefficient $\hat{\beta}_{it}$ captures the cyclical behavior of public spending. Measures the cyclicity of public expenditure for country i at time t . Consequently, fiscal policy is considered procyclical if $\hat{\beta}_{it} > 0$ and counter-cyclical otherwise. Finally, when $\hat{\beta}_{it}$ is almost 0, fiscal policy is acyclical (see Aghion et al., 2007; Guerguil et al., 2017).

Covariates for matching. We follow Coulibaly (2024a) in including a set of economic and institutional covariates considered as determinants of the adoption of resource-backed loans, such as GDP per capita, natural resource rents, public debt, resource depletion, resource-rich countries, FDI and institutional quality (captured by corruption control). Firstly, we believe that GDP per capita is negatively correlated with the probability of signing a resource-backed loan. In fact, better economic performance is likely to intensify economic activity, i.e. production, and generate tax revenues for the government. In the same vein, resource rents should have a negative impact on the likelihood of signing a resource-backed loan, as they represent tax revenues from the extractive sector, which are used to repay them, according to resource-backed loan clauses. Secondly, public debt must increase the likelihood of signing a resource-backed loan. According to Coulibaly (2024a) and Mihalyi et al. (2020), resource-rich countries sign resource-backed loans because they do not have sound fiscal conditions due to the insustainability of their public debt. In addition, the improved fiscal situation may

reflect sounder fiscal policies, which may reduce the need for countries to resort to resource-backed loans. Third, given that resource-backed loans are repaid in kind, i.e., with natural resources (see Coulibaly, 2024a), the depletion of these natural resources should slow or discourage countries from borrowing more resource-backed loans. Consequently, resource depletion negatively affects the probability of signing a resource-backed loan. Fourth, based on the theory of the curse of natural resources, the endowment of natural resources negatively affects economic growth and forces the holders into fiscal indiscipline, especially when a discovery of natural resources is announced (see, for instance, Arezki et al., 2017; Bhattacharyya et al., 2017). In addition, one of the conditions for signing a resource-backed loan is having a natural resource, as repayment will have to be made via this natural resource (Coulibaly, 2024a; Mihalyi et al., 2020). Consequently, the endowment of natural resources should positively affect the probability of signing a resource-backed loan. This variable is a dummy that takes the value 1 if the country is rich in natural resources and 0 otherwise. Fifth, we monitor the impact of FDI in terms of its ability to promote economic growth, create wealth, reduce unemployment, and provide stable economic conditions for countries. As a result, FDI must have a negative impact on the probability of signing a resource-backed loan. Finally, the correlation between resource-backed loans and the level of corruption control can be ambiguous. On the one hand, good institutions can foster sound fiscal behavior, which can reduce the incentive for countries to tie their hands by adopting resource-backed loans. On the other hand, poor institutional quality can increase the level of corruption, making resource-backed loan transactions less transparent (Rivetti, 2021). This may encourage political decision-makers to sign a resource-backed loan.

3.3.2 Methodology

We ask whether resource-backed loans trigger procyclical or countercyclical fiscal policy in developing countries. According to Coulibaly (2024a), the adoption of resource-backed loans is not random and may be affected by economic and institutional performance. Such factors - which may also affect the cyclical fiscal policy - make resource-backed loans adoption endogenous, leading to a potential selection bias. To mitigate the potential endogeneity of resource-backed loans, we follow Coulibaly (2024a) employing a matching approach, entropy balance, developed by Hainmueller (2012). The approach has attracted much attention in re-

cent literature (see Coulibaly, 2024a; Neuenkirch and Neumeier, 2016; Kinda and Thiombiano, 2024a; Apeti, 2023a; Apeti and Edoh, 2023; Apeti et al., 2024a). The adoption of resource-backed loans is the treatment and the cyclical of fiscal policy is the outcome variable. We consider country-year observations, those with resource-backed loans being the treated units and those without resource-backed loans being the control units. The effect of treatment on treated units (ATT) is defined as follows:

$$ATT = E[Y_{(1)}|T=1, X = 1] - E[Y_0|T=1, X = 1] \quad (3.2)$$

where $Y_{i(.)}$ is the outcome variable that measures the cyclicity of fiscal policy ($\hat{\beta}_{it}$). T_i indicates whether the observation unit is subject to the adoption of resource-backed loans ($T_i = 1$) or not ($T_i = 0$). $E[Y_{i(1)}|T_i=1]$ is the cyclic of fiscal policy level during the resource-backed loan adoption period, $E[(Y_{i0}|T_i=1)]$ is the counterfactual result for countries that had adopted resource-backed loans, i.e., the cyclic of fiscal policy in countries that had adopted resource-backed loans if they had not. The issue is that $E[Y(0)|T = 1]$ is not observable due to the non-random nature of the adoption of resource-backed loans. If this were the case, the ATT could easily be identified by comparing the cyclical of fiscal in resource-backed loans countries with non resource-backed loans countries. Identifying ATT then requires a good proxy for $E[Y(0)|T = 1]$. To do so, we match resource-backed loans units with non resource-backed loans units (after purging for some specific factors) that are as close as possible on observable characteristics that meet two criteria: correlated with RBL adoption and cyclical of fiscal policy. Under the condition that the non resource-backed loans units are fairly close to the resource-backed loans units, any difference in cyclical of fiscal policy is attributable to resource-backed loans adoption. Based on these details, we can rewrite 3.2 to get 3.3 as follows:

$$ATT = E[Y_{(1)}|T=1, X = x] - E[Y_0|T=1, X = x] \quad (3.3)$$

where $X = x$ is a vector of observable covariates that can affect both the decision to adopt resource-backed loans and the cyclical of fiscal policy, $E[Y(1)|T = 1, X = x]$ is the cyclical of fiscal policy of resource-backed loan units and $E[Y(0)|T = 0, X = x]$ is the expected cyclical of fiscal policy for synthetic control units. Entropy balancing is carried out

in two stages, one after the other. The first step is to calculate the weights of the control group (group without treatment) so that they satisfy predefined balanced constraints involving the sampling moments of the observable characteristics (X). We choose equilibrium constraints that impose equal covariate means between the treatment and control groups (see Coulibaly, 2024a; Neuenkirch and Neumeier, 2016; Apeti et al., 2024a). In doing so, we ensure that the control group is composed, on average, of untreated units that are as similar as possible to the treated units. The second stage uses the weights from the first stage in a regression analysis where fiscal policy cyclicality is the dependent variable, and the dummy variable, resource-backed loans, is the main explanatory variable. We control for entropy balancing covariates as well as time and country-specific effects, as in a randomization experiment, to increase the efficiency of estimation as in Coulibaly (2024a). Entropy balancing has several advantages over many impact estimation methods (see Coulibaly, 2024a; Neuenkirch and Neumeier, 2016; Balima, 2020). Firstly, it allows us to identify the effect of resource-backed loans by comparing resource-backed loan signatory and non-signatory countries with the most similar observable characteristics possible, while taking into account country- and time-specific effects. Secondly, it combines a matching approach with a regression approach. Thirdly, entropy balancing is a non-parametric approach, which circumvents the problems of model misspecification. In addition, unlike regression-based analyzes, treatment effects estimated from entropy balancing do not suffer from multicollinearity, as the reweighting scheme orthogonalizes the covariates with respect to the treatment indicator. Fourth, unlike other matching methods such as propensity score matching, entropy balancing guarantees a high covariate balance between treatment and control groups, even in small samples, and a more flexible reweighting scheme. In other words, entropy balancing reweighs observations to achieve a balance between treated and untreated units, while keeping weights as close as possible to baseline weights to avoid loss of information. Finally, by combining a matching approach with regression analysis, entropy balancing allows us to properly address the panel structure of our data, by including country and time effects in the regression analysis, thus accounting for unobserved heterogeneity between the countries in our sample.

3.3.3 First views of data linking RBL to cyclicality: stylized facts

In this subsection, we examine some stylized facts on the link between fiscal policy cyclicality and resource-backed loans before proceeding to the main analysis. To do this, we com-

pare the fiscal policy cyclicity in RBL and non-RBL countries, respectively. Fig. 3.1a shows that fiscal policy is countercyclical in non resource-backed loan countries (averaging around 1.2%), while in RBL countries it tends to be procyclical (averaging around 4%). This statistic observed for non-adopting countries seems to contradict certain results found in the literature, which indicate that fiscal policy is always procyclical in developing countries (see Kaminsky et al., 2004; Acemoglu et al., 2001). Next, we deepen our analysis by comparing the cyclicity of fiscal policy before and after the adoption of resource-backed loans in countries that have signed resource-backed loans with the cyclicity of fiscal policy in countries that have not signed resource-backed loans. To do this, we draw on the technique of Coulibaly (2024a), who considers 2004 as the deviation date for countries that have never signed a resource-backed loan. The idea is that country-year observations before 2004 are considered as pre-treatment (for non-adopting countries) and country-year observations after 2004 are considered as post-treatment, given that this date marks the start of the very first resource-backed loan signed by Angola (see Mihalyi et al., 2020). Fig. 3.1b clearly shows that countries without RBL have, on average, negative fiscal policy cyclicity, which can be interpreted as fiscal policy countercyclicity before and after resource-backed loans. However, in countries with resource-backed loans, fiscal policy procyclicality is observed even after the adoption of resource-backed loans, even though it was countercyclical before adoption. For better comparability and to avoid mean bias, we constructed a box plot (Fig. 3.2). A closer look at this figure reveals a difference in cyclicity of fiscal policy between countries with and without resource-backed loans. Indeed, countries with resource-backed loans exceed the median (central line of the box), a 15th (lower hinge of the box) and a 35th (upper hinge of the box) percentile of cyclicity of fiscal policy higher than those without resource-backed loans. Although we obtain graphical evidence through this figure that the adoption of resource-backed loans is likely to go hand in hand with the cyclicity of fiscal policy, it does not allow us to assess their magnitude or significance. We used observations from non-RBL countries selected based on the matching procedure as a control group to estimate the counterfactual outcome to avoid overestimating the effect of RBL.

Figure 3.1: Cyclical of fiscal policy and resource-backed loans

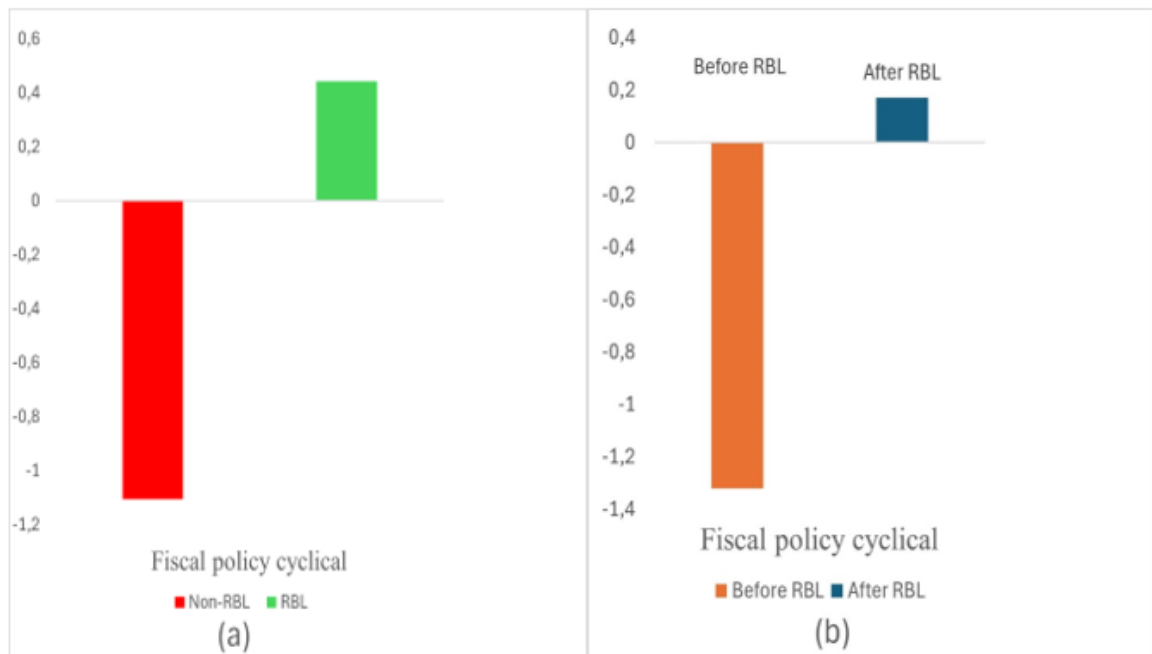
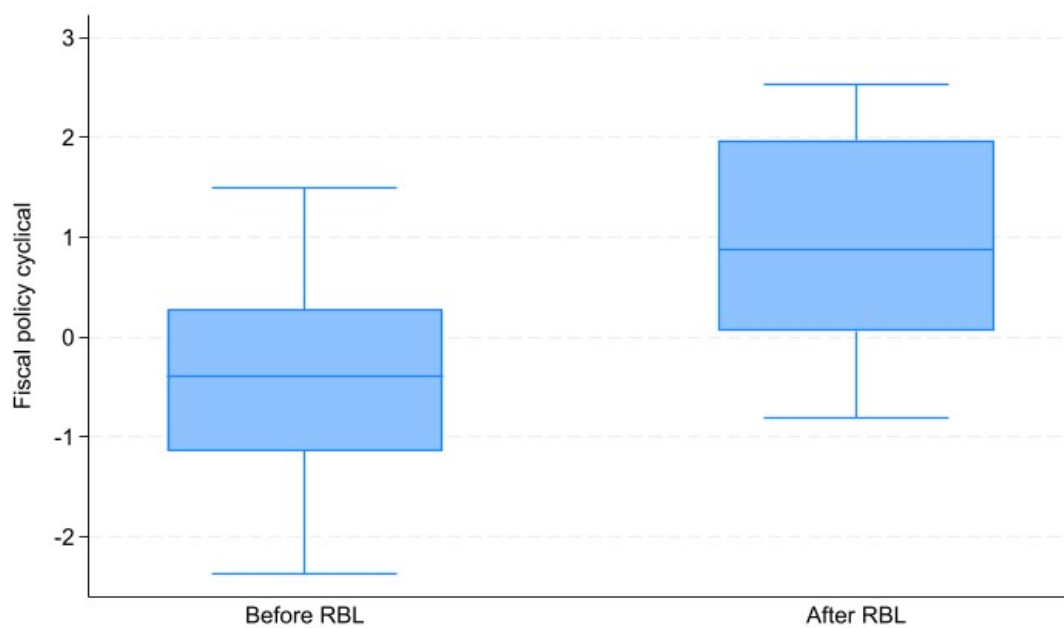


Figure 3.2: Fiscal policy cyclical by resource-backed loans adoption



3.4 Results

3.4.1 Sensitivity to outliers

Figure 6 shows the correlation between spending volatility and fiscal policy volatility over the period studied for the RBL (treated) and non-RBL (controlled) groups of countries. Although this representation shows a strong positive correlation between the two variables, it also enables us to identify values that would appear to be outliers to assess their relevance and treat them appropriately. The goal of this subsection is to identify and handle these outliers. The literature presents several methods for detecting outliers, each with its own advantages and limitations, drawing the attention of researchers to the need to avoid wrongly considering values as outliers (see Asatryan et al., 2018). We can simply remove from the observations (country - year) any values that appear to be outliers. However, it should be noted that this method of dealing with outliers is not encouraged by many researchers because attrition is not random, which could lead to selection bias, and we lose information in the process. This method estimates the equations by reducing the outliers of the dependent variable (cyclical fiscal policy) to a given threshold. For example, the maximum value (99 percentiles) of the fiscal policy cyclical variable in our sample is approximately 4,208. The dependent variable outliers are trimmed to the upper and lower percentiles of the distribution. Given that the literature does not impose a critical threshold, we reduce the outliers of the dependent variables to 2%. The results are reported in Table C6, columns [1]-[8]. We find that the main results are independent of influential outliers because, by winorizing the outliers, RBL positively affects the cyclical coefficient of fiscal policy.

3.4.2 Covariates balance

In this subsection, we perform an analysis of the descriptive statistics before and after weighting, before moving on to the main results themselves. The idea behind this exercise is to make a comparison of the sample means before weighting all the corresponding covariates that were detailed in Section 3.3.1 between the treated countries (column [1]) and the control countries (column [2]), which represent the potential synthetic group. In addition, this exercise will allow us to determine whether the entropy balancing method presented in Subsection 3.3.2 is well suited to our study or not.

As explained above, the first step is to calculate the weights for the control group (untreated group). We report these statistics in Table 3.1. Panel A shows a comparison of sample means before weighting for the corresponding covariates described in Subsection 3.3.1, between countries with resource-backed loans (column [1]) and control countries or the potential synthetic group (column [2]). Column [5] suggests statistically significant differences between units with budgetary rules and controls, as some p-values are below the 10% threshold. In this context, the simplest approach, often referred to as *naïve*, which consists of examining the impact of RBL on the cyclicalities of fiscal policy using a dummy variable equal to 1 if the country has adopted RBL and 0 otherwise, and estimating the equation using ordinary least squares (OLS), may produce biased estimates even if the coefficients are significant. Therefore, based on the pre-treatment covariates of the main model, we reweight the control countries to make the pre-treatment covariates of the control group, on average, as comparable as possible to those of the treated countries. The means of the synthetic group covariates are reported in column [2] of Panel B. Column [3] suggests that weighting has eliminated any statistically significant pre-treatment differences between the means of the treated and synthetic covariates. The synthetic group can therefore be considered an 'almost perfect' counterfactual of the treated group, thus resolving potential selection problems due to the adoption of resource-backed loans. In other words, the analysis of the two groups in this Panel B reveals the effectiveness of entropy balancing, as the difference shown in Panel A seems to disappear.

3.4.3 Main results

In this subsection, we present the main results of our analysis based on the second step of entropy balancing as explained above. To simplify understanding, we present the regression equation for the treatment effect of resource-backed loans on the cyclicalities of fiscal policy. In other words, we estimate the following model:

$$Y_{it} = \alpha + \beta RBL_{it} + \gamma X_{it} + \nu_i + \theta_t + \epsilon_{it} \quad (3.4)$$

where Y_{it} is the fiscal policy cyclicity coefficient of country i in year t , which is $\hat{\beta}_{it}$ presented in subsection 3.3.1. RBL_{it} is a dummy variable equal to 1 for a country i that has adopted a resource-backed loan in year t , and 0 otherwise. X_{it} is the set of the covariates described in section 3.3.1. The ν_i and θ_t represent effects fixed in country and time, respectively,

capturing the unobserved heterogeneity. Finally, ϵ_{it} is the term for idiosyncratic error. Table 3.2 shows the main results. In other words, it presents the average effect of the RBL treatment on the cyclical coefficient of fiscal policy obtained from different sets of estimates of the equation 3.4. First, in columns [1], we run a simple univariate regression also called 'naive regression' from entropy balancing to capture the only reactivity of fiscal policy after the adoption of resource-backed loans. Then, in column [2], we include all controls of the base model. In columns [3]-[4], we include country and year fixed effects, respectively. Column [5] presents the main results, i.e. considering both covariates and fixed effects by country and year. Finally, as it is recognized in the literature that distinctive trends in the outcome variable across countries could otherwise bias our estimates if they accidentally coincided with other changes in the adoption of resource-backed loans (see Coulibaly, 2024a), we include in our regressions in column [6] a time trend to capture the influence of some particular confounding factors that can pollute our effects. We find that all coefficients are positive and statistically significant at the 1% threshold (indicating that $\hat{\beta}_{it} > 0$). These estimates suggest that the adoption of resource-backed loans triggers procyclicality in fiscal policy in developing countries. This procyclicality is 2.16 percentage points higher on average in adopting countries than in countries that have not signed up to resource-backed loans. The results remain consistent with those of the baseline model when the time trend is taken into account in our regressions.

This procyclical character of resource-backed loans can be explained by several factors. Firstly, in terms of public debt, resource-backed loans can provoke procyclicality in fiscal policy via over-indebtedness. In fact, under the resource-backed loan contract, countries have the option of continuing to incur debt as long as they have a natural resource to guarantee repayment; countries also have the facility to renegotiate the maturity of loans when they run into repayment difficulties. Secondly, the lack of transparency of resource-backed loans may be a strong argument to explain this result. In fact, information about guarantee agreements or the terms and repayment schedule of loans is rarely disclosed to the public. Sometimes, the information is only revealed when repayment problems arise. This opaque aspect of resource-backed loans can compromise public debt sustainability and push the country towards a procyclical fiscal policy. In addition, non-transparency can push governments into discretionary spending, triggering procyclicality in fiscal policy. Finally, this result can be explained by the collapse in the prices of raw materials. In fact, as we have already explained, resource-backed

loans are signed in US dollars and indexed to natural resources. In such circumstances, a shock to commodity prices would significantly increase the size of public debt, pushing countries into a situation of over-indebtedness and insolvency, leading to a procyclical fiscal policy.

In terms of control variables, our results clearly indicate that GDP per capita reduces procyclicality, since we obtain a negative and statistically significant coefficient. The better a country's economy performs, the less procyclical its fiscal policy. Moreover, we find that resource depletion also reduces procyclicality. This result is not all that surprising, since the depletion of natural resources can lead countries to diversify their economies to obtain alternative sources of income, in order to rebalancing the economy. Our results show that better institutional quality, characterized by corruption control, significantly reduces the procyclicality of fiscal policy. This result is in line with those found in the literature. For instance, Muscatelli et al. (2012) explain that transparency in the decision-making process contributes to achieving fiscal solvency. These results corroborate those found by Calderón et al. (2016), who examined the role of government administrative quality in achieving better fiscal results. Using a global sample of 115 advanced, emerging and developing countries over the period 1984-2008, they find that institutional quality plays a key role in countries' ability to implement countercyclical macroeconomic policies. Similarly, Frankel et al. (2013) show that good institutions fundamentally explain the reduction in policy procyclicality. They find that countries emerge from procyclicality as institutions improve. The FDI coefficient is negative and statistically significant. This suggests that FDI reduces procyclicality. In fact, FDI is at the origin of a country's wealth creation through employment, the installation of production technology, which increases the performance of the economy of the country where the FDI is installed (see, for instance, Romer, 1990; Sala-i Martin and Barro, 1995). The coefficient for resource-rich countries is positive but not significant.

However, our results show that the coefficients of natural resource rents and public debt are positive and statistically significant. Firstly, the fiscal behavior of resource-rich developing countries is fundamentally different from that of countries without natural resources. As highlighted in the literature on resource curse (James and Aadland, 2011; Papyrakis and Gerlagh, 2007; Sachs and Warner, 2001), high levels of natural resource rents can trigger fiscal indiscipline, thus curbing economic growth. In addition, the announcement of a major discovery of a giant deposit can lead to anticipation in public spending and a reduction in aggregate savings,

leading to a current account deficit (see Arezki et al., 2017). Secondly, the positive coefficient of public debt in our analysis supports the existence of an important role for public debt. In the context of high public debt, it is more difficult for fiscal authorities to pursue countercyclical fiscal policies. It should therefore be noted that when the public debt/GDP ratio is high, fiscal policy changes its properties from countercyclical to procyclical. This result is in line with those found in the literature. According to Blanchard et al. (2013), in the current context of rising debt, investors are concerned about increased risk of default and demand higher yields on government bonds (owing to higher risk premiums), making it harder for governments to repay their debt, and thus leaving less room for fiscal policies to play the stabilizing role. In the same vein, a high level of public debt can reduce a country's credit rating, limiting its ability to access financial markets to borrow and invest in countries of sustainable development (Sawadogo, 2020). Moreover, using the GMM system on a sample of 56 countries, Combes et al. (2017) find that when the public debt/GDP ratio exceeds an endogenous threshold estimated at 87%, fiscal policy becomes procyclical. The coefficients, standard deviation, and p-values of these variables are not reported in Table 3.2. We have decided not to do so for reasons of document size, but we can make them available to readers on request.

Table 3.1: Covariate balance.

Panel A : Descriptive statistics before weighting.	[1] <i>RBL</i>	[2] <i>Non-RBL</i>	[3]=[2]-[1] <i>Difference</i>	[4] <i>t-Test</i>	[5] <i>P-value</i>
GDP per capita	1.306	2.572	1.266	6.7	0.010
Resource rents	16.71	7.184	-9.526	100.0	0.000
Public debt	56.93	55.67	-1.26	0.1	0.753
Resource depletion	11.37	4.803	-6.567	78.8	0.000
Resource-rich countries	0.7985	0.3579	-0.4406	108.7	0.000
FDI	4.984	5.159	0.175	0.0	0.881
Control of corruption	0.2281	0.3392	0.1111	56.6	0.000
<i>Observations</i>	134	2333			
Panel B : Descriptive statistics after weighting.	[1] <i>RBL</i>	[2] <i>Non-RBL</i>	[3]=[2]-[1] <i>Difference</i>		
GDP per capita	1.306	1.306	0	—	—
Resource rents	16.71	16.69	-0.02	—	—
Public debt	56.93	56.93	0	—	—
Resource depletion	11.37	11.36	-0.01	—	—
Resource-rich countries	0.7985	0.7976	-0.0009	—	—
FDI	4.984	4.987	0.003	—	—
Control of corruption	0.2281	0.2284	0.0003	—	—
<i>Observations</i>	134	2333			
<i>Total of weights</i>	134	134			

Table 3.2: Resource-backed loans and cyclicity of fiscal policy—Baseline results

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]
RBL adoption	0.941*** (0.150)	0.933*** (0.124)	1.544*** (0.186)	1.127*** (0.133)	2.164*** (0.183)	2.164*** (0.183)
Constant	-0.569*** (0.0826)	0.131 (0.240)	1.114*** (0.294)	0.921 (0.651)	1.853*** (0.589)	1.853*** (0.589)
Covariates	No	Yes	Yes	Yes	Yes	Yes
Country/FE	No	No	Yes	No	Yes	Yes
Year/FE	No	No	No	Yes	Yes	Yes
Trend	No	No	No	No	No	Yes
Observations	2,385	2,385	2,385	2,385	2,385	2,385
R-squared	0.056	0.237	0.668	0.272	0.705	0.705

This table presents the effect of resource-backed loans on fiscal policy cyclicity obtained by weighted least squares regressions. The treatment variable is the presence of a loan secured by natural resources. The outcome variable is the coefficient of fiscal cyclicity. Control variables include GDP per capita, FDI, natural resource rents, public debt, resource-rich countries, resource depletion and control of corruption. Robust standard errors are in brackets *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

3.5 Robustness

3.5.1 Additional controls

We extend the baseline specification describe in equation 3.4 to include other possible determinants of resource-backed loan adoption and/or fiscal policy cyclicalities. First, we control inflation targeting to capture the effect of institutional reforms. Indeed, institutional reform can influence the conduct of fiscal policy by limiting the scope of seigniorage revenues and imposing other constraints on spending. In addition, reforms to monetary policy management in the form of the adoption of inflation targeting can provide a useful policy to combat fiscal discretion with a view to reducing fiscal policy volatility (Apeti et al., 2023b). To address this point, we use a dummy variable equal to 1 if the country i has implemented inflation targeting at time t and 0 otherwise. Secondly, policy-makers may feel more constrained in their actions when their economies are highly integrated into global financial markets. For this reason, we add international financial openness. Thirdly, it is possible that in a fixed exchange rate regime, fiscal policy is the main and only stabilization tool, whereas in a flexible regime, it is the only stabilization tool. For this reason, we add the exchange rate regime as an additional control. Fourthly, in the literature some authors have shown that well-designed fiscal rules can reduce the procyclicality of fiscal policy (see Ayuso-i Casals et al., 2009; Debrun et al., 2008). For example, Guerguil et al. (2017) assess the impact of different types of flexible fiscal rules on the procyclicality of fiscal policy using propensity score matching techniques. The authors find that fiscal rules are pro-investment and reduce the procyclicality of aggregate and investment spending. In the spirit of Tapsoba (2012), fiscal rules are a credible remedy against fiscal indiscipline in developing countries. We take these observations into account when monitoring the impact of the adoption of budgetary rules. Sixth, recent studies have shown the role of institutional quality in reducing deficits and procyclicality. For instance, Muscatelli et al. (2012) explain that transparency in the decision-making process contributes to achieving fiscal solvency. In the same vein, Calderón et al. (2016) examine the role of government administrative quality in achieving superior fiscal outcomes. Using a global sample of 115 advanced, emerging and developing countries over the period 1984–2008, they find that institutional quality plays a key role in countries' ability to implement countercyclical macroeconomic reforms. Furthermore, their results show that countries with strong (weak) institutions adopt countercyclical

procyclical macroeconomic policies. In addition to controlling for corruption, we also control for bureaucracy quality. Seventhly, according to Apeti et al. (2023b), tax revenues (lagged) are a potential determinant of sound fiscal policy. This means that tax revenues modify the orientation of fiscal policy and have a direct impact on cyclicity. We take this observation into account. Finally, we control for the effect of inflation in our regressions for two reasons: firstly, inflation decreases the real value of tax-based government revenues between the time of taxation and the time of collection, as indicated by the Oliveira-Keynes-Tanzi effect (see Talvi and Vegh, 2005), and secondly, governments can use inflation as a source of funding, in the form of seigniorage revenues from money printing. The new ATTs are shown in Table 3.3, Panel A and columns [1]-[7]. The addition of further variables does not affect our baseline results.

3.5.2 Alternative samples

We carry out some further tests by re-estimating our main model using alternative samples. The results are shown in Panel B of table 3.3. First, given that the world and developing countries in particular have been affected by the consequences of major economic crises, we exclude from the sample observations marked by these crises, which have led to major macroeconomic imbalances. To do this, we exclude the years of the 2008-2009 financial crisis, the 2014-2015 oil crisis, and the Covid-19 pandemic¹. Finally, we exclude episodes of hyperinflation from the sample, given its fairly significant corollary for the economy. Secondly, we exclude episodes of hyperinflation from the sample, given its fairly significant corollary for the economy. To achieve this, we follow Talvi and Vegh (2005) and measure inflation using π' defined as $\pi' = \pi / (1 + \pi)$. Next, we construct a dummy variable which takes the value 1 for country i if π' is greater than the standard deviation and 0 otherwise. Similarly, in column [3], we exclude observations from before 2004, which is the year of first adoption, to situate our analysis on the starting point of RBLs, as Coulibaly (2024a) did. Fourth, many countries experienced a particular economic dynamic after the cold snap. For this reason, we excluded the post-Cold War years (1990-1995) to capture this dynamic. Although this rarely occurs, in the last column we exclude from the sample years in which resource-backed loans were canceled by the lending country. This is the case, for example, of Ghana in 2011 and Niger in 2013 (see

¹For the coronavirus crisis, we're excluding observations from the year 2020 because pandemic appeared in November 2019.

Coulibaly, 2024a; Mihalyi et al., 2022). In addition, one test consists in restricting the sample to countries that have contracted RBLs at least five years before the end of the observation period, in order to take account of the time lag in fiscal policy reactions. This makes it possible to assess the medium-term effects of RBL on the cyclical policy beyond immediate adjustments. Finally, we exclude the most macroeconomically unstable countries (i.e. those that have experienced a debt crisis), in order to check whether the estimated effect of RBLs persists in contexts of relative stability. The results presented in columns [1]-[7] of panel B (Table 3.3), respectively, remain unchanged after modification of our sample, reinforcing the confidence in our results.

Table 3.3: RBL and cyclical of fiscal policy: additional controls and sample modification

Panel A: adding variables	[1]	[2]	[3]	[4]	[5]	[6]	[7]
	Inflation targeting	Financial openness	Exchange rate regimes	Fiscal rules	Bureaucracy quality	Tax revenue (lagged)	Inflation rate
RBL adoption	2.164*** (0.183)	2.170*** (0.185)	1.774*** (0.195)	2.148*** (0.183)	1.498*** (0.160)	1.402*** (0.354)	2.192*** (0.194)
Constant	1.853*** (0.589)	1.889*** (0.582)	2.301*** (0.557)	1.845*** (0.590)	2.537*** (0.518)	2.852*** (0.710)	1.804*** (0.596)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country&Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,385	2,313	1,918	2,385	1,520	1,434	2,264
R-squared	0.705	0.706	0.809	0.708	0.797	0.760	0.715
Panel B: excluding observations	[1]	[2]	[3]	[4]	[5]	[6]	[7]
	Crisis years	Hyperinflation episode	Before first adoption of RBL (pre-2004)	Post-cold war period	RBL canceled without repayment	RBLs adopted < 5-years	Debt crisis episode
RBL adoption	2.096*** (0.207)	2.212*** (0.194)	2.088*** (0.214)	2.164*** (0.183)	1.850*** (0.207)	1.7481*** (0.1915)	2.1383*** (0.1962)
Constant	1.850*** (0.564)	1.660*** (0.595)	0.562 (0.409)	1.853*** (0.589)	1.812*** (0.625)	2.1673*** (0.5796)	1.4610** (0.6207)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country&Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,836	2,257	1,841	2,385	2,385	2,357	2,386
R-squared	0.718	0.715	0.747	0.705	0.700	0.7232	0.6960

Robust standard errors are in brackets *** p < 0.01, ** p < 0.05, * p < 0.1.

3.5.3 Alternative definition of fiscal policy cyclical

In our main estimates, we calculate the cyclical policy on the basis of the growth rate of real government spending. However, as mentioned above, to capture the complex and multifaceted concept of fiscal policy cyclical policy, we consider an alternative measure of it. We used the cyclical component of government expenditures to GDP and the cyclical component of the logarithm of real GDP that are obtained from the Hodrick-Prescott filter (HP filter). In fact, we could have used other measures such as the primary balance/GDP and the revenue/GDP. However, the use of these variables as a measure of fiscal policy cyclical policy has

been criticized in the literature, most recently by Kaminsky and Reinhart (2004). In other words, if a government wanted to influence economic activity over a given period, it would modify its spending program or change tax rates, and these effects would affect revenues and the budget balance. Furthermore, considering the budget variable as a proportion of GDP could lead to a misleading interpretation in the sense that the cyclical behavior of the budget variable could be dominated by the cyclical behavior of GDP. In this context, we follow the logic of Bergman and Hutchison (2015) who believe that the use of public spending has the advantage of allowing a clear distinction between procyclical, acyclical and countercyclical fiscal policy based on movements associated with GDP. For our smoothing parameter, we set it to 6.25 as in Ravn and Uhlig (2002). The new ATTs reported in Table C1 in Appendix, indicate that resource-backed loans significantly trigger and increase the procyclicality of fiscal policy, regardless of the alternative measure of the cyclical variable.

3.5.4 Alternative estimation methods

In this section, we check whether our basic results are sensitive to other econometric methods, such as endogenous switching regression models, DiD estimates, OLS (ordinary least squares) and IV / 2SLS (instrumental variables estimators).

Endogenous switching regression. We re-estimate our main model using endogenous switching regression models are estimated. Our preference for this method is dictated by two main advantages. Firstly, the main advantage of this model over others is the joint estimation of the selection and outcome equations through a full information maximum likelihood (FIML) estimator (see, for example, Asfaw et al., 2012; Carter and Milon, 2005; Nonvide, 2019). Secondly, endogenous switching regression models enable counterfactual analysis. In other words, the model will evaluate how much the cyclical level of a non-adopter of RBL would have improved if he had adopted RBL, and the loss to the adopter in the event of non-achievement of the objectives for which they were signed. Indeed, the estimation of the endogenous switching regression (ESR) model consists of separate estimates for countries with RBL and non-RBL. This suggests that the adoption of the RBL becomes the selection criterion indicating to which regime the country belongs. Next, the level of cyclical variable is observed for both groups (see Maddala, 1983; Di Falco et al., 2011; Nonvide, 2019). Table C2, Panel A shows the expected cyclical coefficients of fiscal policy under actual and counterfactual condi-

tions. Cells (a) and (b) represent the expected fiscal policy cyclicalities observed in the sample for RBL adopting and non-adopting countries, respectively. We observed that the cyclicalities of expected fiscal policy in the RBL-adopting countries were higher (procyclical) than in the non-adopting countries. Based on this simple comparison, it could be misleading to attribute the difference in fiscal policy cyclicalities to the simple adoption of RBL by countries. In case of *counterfactual (c)*, it has been clearly demonstrated that the effect of treatment for countries adopting RBL is 0.60. This is equivalent to 37.7% difference in average fiscal policy cyclicalities (the formula is $100 * [e^{TT} - 1]$, see Asfaw et al., 2012). In other words, if countries adopting RBL had not adopted RBL, their fiscal policy cyclicalities would have decreased by 37.7%. In *counterfactual (d)*, if adopters of RBL did not adopt RBL, their cyclicalities of fiscal policy would have increased by 266.9%. In this line, the transitional heterogeneity effect is positive, implying that the effect of RBL on fiscal policy cyclicalities is significantly higher (procyclical) for countries that have actually adopted RBL than for those that haven't adopted.

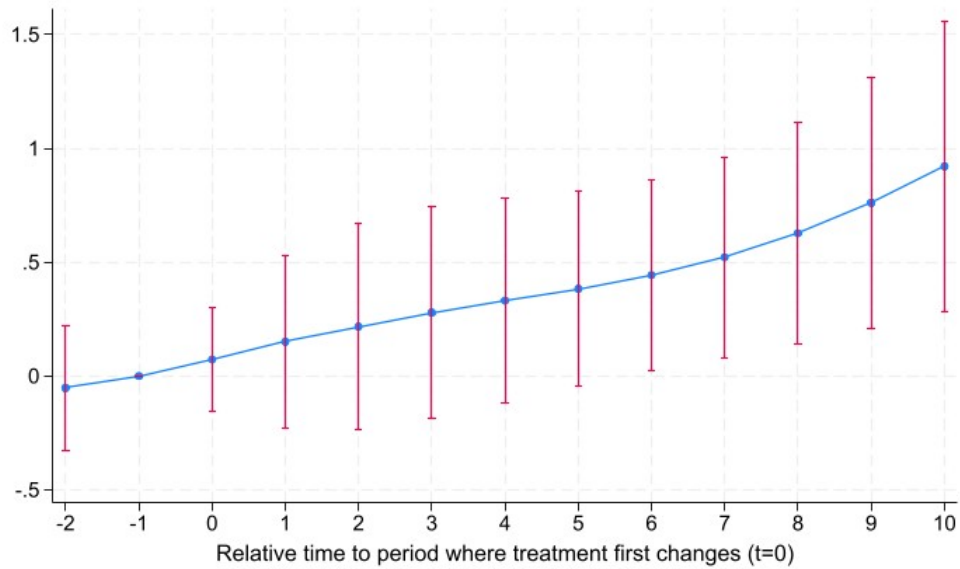
Difference-in-Difference estimates. Next, we test the robustness of our results using the Difference-in-Difference method à la De Chaisemartin and d'Haultfoeuille (2020) and Callaway and Sant'Anna (2021). The estimation methods used by Callaway and Sant'Anna (2021) and De Chaisemartin and d'Haultfoeuille (2020) are close to each other, but with slight differences in assumptions. Firstly, while Callaway and Sant'Anna (2021) pay particular attention to the dynamics of the treatment effect, De Chaisemartin and d'Haultfoeuille (2020) focuses on recovering an instantaneous measure of the treatment effect. Secondly, while Callaway and Sant'Anna (2021) pay particular attention to the role played by pre-treatment covariates, De Chaisemartin and d'Haultfoeuille (2020) focus primarily on unconditional DiD designs. Third, Callaway and Sant'Anna (2021) focus on the special case of «staggered adoptions», while De Chaisemartin and d'Haultfoeuille (2020) rely on a slightly more general configuration. As already explained, the two methods are very similar, but we use them for two main purposes. Firstly, with De Chaisemartin and d'Haultfoeuille (2020), we want to analyze the evolution of fiscal policy cyclicalities after the adoption of resource-backed loans. Secondly, the method of Callaway and Sant'Anna (2021) is used to address the issue of «staggered adoption» of resource-backed loans in our sample. The problem of «staggered adoption» arises only when the country once treated, remains with the treatment until the last year of the study. This is the case in our sample, since the adopting countries remain treated until 2020,

given the average repayment period for resource-backed loans, which averages 11 years (see Mihalyi et al., 2020). Thus, ignoring this nuance would bias our baseline results. For this reason, we use Callaway and Sant’Anna (2021), a method that is well suited to this type of situation.

Fig. 3.3 shows the results from De Chaisemartin and d’Haultfoeuille (2020)’s method. Two main conclusions emerge from this figure. Firstly, we observe that prior to the adoption date, there is no evidence of a pretrend. This evidence indicates a parallel trend between the two groups (RBL and non-RBL countries), since the effect is statistically insignificant in the pre-adoption episodes. Furthermore, it is important to note that the estimated coefficients over this period are negative but not statistically significant. After the adoption of resource-backed loans, we observe that the coefficient of the cyclical share of fiscal policy becomes positive from year 1 to year 10. We obtain evidence of significance from the sixth year onward, which leads us to conclude that the effect of resource-backed loans on fiscal policy procyclicality is not immediate, but requires a little more time before fiscal policy reacts. In addition, the time required to obtain a statistically significant effect reflects the delay between the adoption of resource-backed loans and the start of debt repayment. Since debt repayment affects fiscal policy from the moment the country starts to pay off its debt, it is debt repayment that affects fiscal policy. Finally, we report the results obtained from Callaway and Sant’Anna (2021)’s method in Fig 3.4 and Table C2, Panel B. The dynamics observed in Fig 3.4 are similar to those in Fig 3.3 in terms of fiscal policy reactions, confirming the relevance and robustness of our baseline results. Similarly, the new ATT reported in Table C2, Panel B remain positive and statistically significant indicates that the adoption of resource-backed loans leads countries to a procyclicality of fiscal policy, which reinforces confidence in our baseline results.

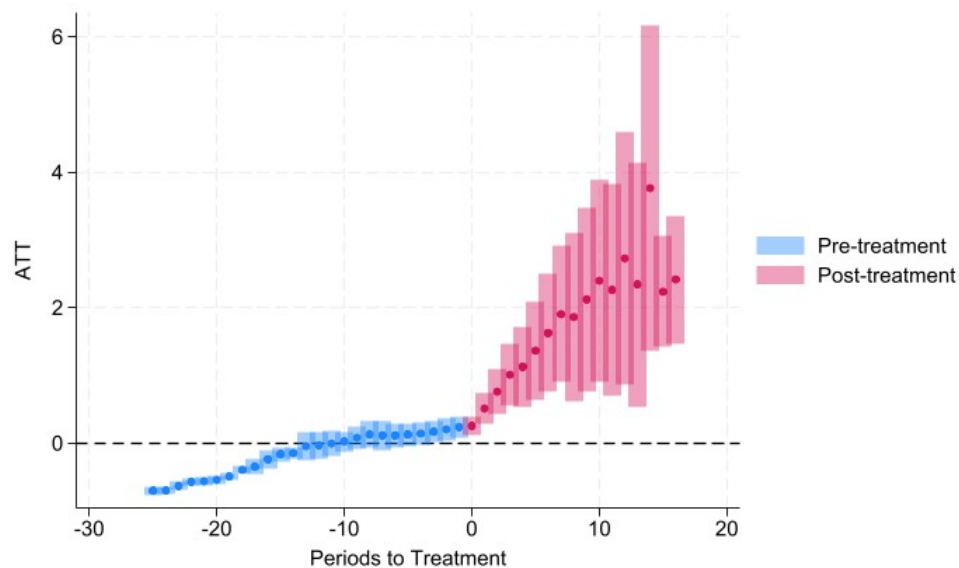
OLS estimates. Thirdly, we re-estimate our baseline model using a simple fixed-effects panel regression from the OLS estimator. The results reported in column [1] of Table C3 suggest a positive and statistically significant effect of resource-backed loans on the cyclical effect of fiscal policy. Moreover, the effect obtained from OLS (2.2 percentage points) remains qualitatively comparable to that of the baseline model obtained from entropy balancing (2.16 percentage points).

Figure 3.3: The cyclical of fiscal policy around resource-backed loans



Source: Author's elaboration using De Chaisemartin and d'Haultfoeuille (2020).

Figure 3.4: The cyclical of fiscal policy around resource-backed loans



Source: Author's elaboration using Callaway and Sant'Anna (2021).

IV-2SLS estimates. Finally, following Coulibaly (2024a), we provide estimates using the instrumental variable (IV). Instrumental variables mitigate potential endogeneity problems resulting from unobserved time-varying factors that can affect both resource-backed loans and the cyclical policy. The advantage of this method, unlike the GMM system, is that it uses external instruments and does not allow researchers to manipulate the lag number to obtain a desired result (see Soto, 2009; Coulibaly, 2024a). We are reinforcing our robustness by relying on two instruments: the resource-backed loans variable, lagged by one year, and credit ratings, which are an indicator of access to financial markets (see Sawadogo, 2020). We believe that these two variables could be a good (not perfect) candidate as an instrumental variable for resource-backed loans. The IV method gives unbiased and consistent estimates in the presence of hidden biases, however, the main drawback of the IV method is that it is often difficult to find at least one variable in the selection model to serve as an appropriate instrument that should influence the probability of treatment (resource-backed loan in our case), without being correlated with the error term (Wooldridge, 2010; Marwa et al., 2020). We are aware that this last condition is difficult to test, and the choice of a valid instrument depends largely on intuition and economic reasoning. Furthermore, the IV approach generally reduces the precision of causal estimates and introduces a new uncertainty, in addition to the difficulty of testing hypotheses (DiPrete and Gangl, 2004; Kiiza et al., 2011). Column [2] of Table C3 suggests that resource-backed loans have a significantly positive effect on fiscal policy cyclical policy (procyclicality), even when we reestimate our main model using instrumental variables. Although the new coefficients obtained from IV (around 1.3 percentage points) are slightly lower than those obtained from entropy balancing (around 2.16 percentage points), the magnitude of the coefficients does not differ substantially. Furthermore, the Kleibergen-Paap and Stock-Yogo statistics suggest that the instruments used are robust. Similarly, the Hansen test, with a p-value greater than the 10% threshold, supports the hypothesis of the exogeneity of the instruments used. This further reinforces the robustness of our baseline results.

3.5.5 Falsification test

In this section, we put our results under a placebo test, i.e., we want to confound the veracity of our baseline results. Indeed, several techniques exist in the literature for doing this exercise, but we have chosen the randomization method. This method consists in randomly

assigning a treatment to countries other than the real treatment dates. The underlying intuition is that if our results so far are driven by unobservables or a spurious model, randomly assigned adoption dates could also lead to statistically significant effects. In fact, our concern is that the adoption of RBL can lead to a chronic change in the economic, political, institutional, and social environment of the treated country, which could result in effects that overlap with those induced by the resource-backed loans themselves. In the same vein, it is possible that our treatment group is polluted by the non-transparency of resource-backed loans, as some countries may refuse to report any transactions involving RBLs for reasons of credibility on the international financial market. Using a random treatment, we can test for the existence of a confounding factor that could bias our results related to the treatment variable. The results are reported in Panel C of Table C2. In column [1], we randomly assign treatment to the sample without adding covariates and fixed effects. In column [2], we control for both country and time-fixed effects. Finally, in column [3], we add covariates and control for fixed effects of country / time. The regression results suggest that the dummy adoption dates have no statistically significant effect on the outcome variable. We can therefore reasonably rule out the hypothesis of unobservable or a spurious trend that influences our baseline results.

3.6 Testing transmission channels

Our results indicate that resource-backed loans trigger procyclical fiscal policy in developing countries. This section aims to shed light on the mechanisms underlying this result. Building on the discussion in the Introduction, we test the relevance of our three potential transmission channels, using debt default crisis, fiscal balance volatility, and corruption as indicators of fiscal policy conduct and institutional quality.

Before testing our channels, we assess their relevance to the procyclicality of fiscal policy using fixed-effects regression (OLS). The aim of this approach is to see whether the three identified channels are each correlated with the procyclicality of fiscal policy. The results presented in Panel A of Table C4 suggest that the debt crisis, volatility of the fiscal balance, and corruption are strongly correlated with the procyclicality of fiscal policy, representing potentially important transmission channels through which resource-backed loans can have a positive effect (trigger) on the procyclicality of fiscal policy in developing countries.

Based on entropy balancing method, we use the same covariates as in our baseline specification detailed in subsection 3.3.1, while taking care to control for country and time fixed effects to test whether our three channels are related to resource-backed loans. The results compiled in Table C4, Panel B show that resource-backed loans are associated with a significant increase in the volatility of the fiscal balance, the probability of a debt crisis and corruption. Indeed, resource-backed loans are generally higher than the GDP of the recipient country. In 2017, for example, Guinea Conakry subscribed for 200% of its GDP. In addition, Mihalyi et al. (2020) report that of the fourteen countries in our dataset that benefited from RBLs, ten of them experienced serious debt problems following the collapse in commodity prices and that RBLs often made a significant contribution. Similarly, the case of Ghana, which reached an agreement in principle to restructure \$5.4 billion of debt owed to its official creditors, is a perfect illustration. As a result, by significantly increasing the level of public debt, RBL exposes the country to a default or restructuring crisis, which reduces its credit rating on the financial market and prevents it from better mobilizing funds on this market to finance development policies. In addition, the country faces high interest rates, which limits its ability to access financial markets. Another explanation lies in the fact that RBL repayments are often made in kind and guarantees may be attached to them. This can complicate debt restructuring and put traditional lenders at a disadvantage, making them reluctant to lend to countries benefiting from RBL and exacerbating indebtedness (see Mihalyi et al., 2020). Consequently, the country is exposed to a procyclical fiscal policy. The same arguments apply to the volatility of the budget balance. Resource-backed loans trigger the procyclicality of fiscal policy through corruption, as revealed by our empirical test. In fact, the lack of transparency in RBL transactions can increase rent maximization, especially in the extractive sector, and limit the country's resource to debt repayment. In this context, corruption can also increase the nominal value of public debt, plunging the country into financial difficulties.

3.7 Heterogeneity

Our results reveal that the adoption of resource-backed loans increases the procyclicality of fiscal policy in developing countries. In this section, we test the sensitivity of the above results as a function of the type of resource-backed loan services following the decomposition made by Coulibaly (2024a), the time perspective and some structural factors.

3.7.1 Dynamic effects of resource-backed loans

Following Coulibaly (2024a), we highlight a time-varying treatment effect. This dynamic effect would allow us to isolate the lagged effect of resource-backed loan adoption. Our intuition behind this approach is the potential time lag between the adoption of resource-backed loans and its effect on the cyclicity of fiscal policy. To do this, we estimate the ATTs from the first year after adoption ($t = 1$) to the fifth year following the year of adoption ($t = 5$). The results compiled in Table C2, Panel D reveal the existence of a dynamic effect of the adoption of resource-backed loans on the cyclicity of fiscal policy (columns [1]-[5]). This effect appears as soon as resource-backed loans are adopted, but decreases in magnitude over time. We can therefore conclude that the effect of resource-backed loans on the cyclicity of fiscal policy is time-sensitive. This result may reflect the fruit of investments made with resource-backed loans over time, thus corroborating the leverage effect. Secondly, budget support through resource-backed loans may explain this effect (see Mihalyi et al., 2020). In fact, part of the amounts of resource-backed loans are allocated to budget support and debt rollover, which may attenuate the amplitude over time of resource-backed loans on the cyclicity of fiscal policy.

3.7.2 Effect by type of collateral arrangement

The NRG database built by Mihalyi et al. (2020) can be used to disaggregate various operations, including oil-backed loans, minerals-backed loans, and tobacco, cocoa-backed loans. In contrast to Coulibaly (2024a), we retain only two types of resource-backed loan transaction, since cocoa- and tobacco-backed loans are not numerous, with only three transactions in all (2 for cocoa and 1 for tobacco). However, since the impact of these resource-backed loans on the cyclicity of fiscal policy does not necessarily depend on the number of loans signed, but rather on their size, we do the same as Coulibaly (2024a), disaggregating into three types of transactions to capture the size effect of each type of operation. The new disaggregated ATTs are shown in Table C8, Panel A. In column [1], we report the ATTs of oil-resource-backed loans, while in column [2], we report those of mineral, tobacco and cocoa-backed loans combined. Finally, in columns [3]-[4], we enter the isolated effect of mineral-backed loans and tobacco- and cocoa-backed loans. The results show that resource-backed loans significantly and positively affect fiscal policy cyclicity (procyclicality) in developing countries, regardless

of the type of resource-backed loans signed.

3.7.3 Effect by interest rates and type of lender

In this section, we check whether resource-backed loans can produce heterogeneous effects depending on the type of lender and the interest rate. According to Mihalyi et al. (2020), 7 RBLs have fixed interest rates, while 10 have floating interest rates in African countries. We take this observation into account and resume our basic regressions. The results in columns [1]-[2], Panel B of Table C8 indicate that resource-backed loans have a positive and statistically significant effect on the cyclical policy (procyclical) regardless of the type of interest rate chosen at the time of negotiation and signature. On the other hand, RBLs signed with a fixed interest rate seem to have a greater impact on the cyclical policy (procyclical) than those with a floating rate (see Table C8).

Regarding the lenders, Mihalyi et al. (2020) grouped them according to their economic functions or their classification as bilateral official creditors or private / commercial creditors. In this grouping, the lending entities are as follows: China, Russia, Nigeria, Korea, and private natural resource companies. We have decided to group these entities into two donor groups. China's RBL are loans granted by China, while others RBL are loans granted by entities other than China. Our motivation is that China has potentially lent more RBL than other entities and that some entities often have only 1 or 2 RBL, which could potentially expose us to econometric problems in the estimates. The results in columns [3]-[4], Panel B of Table C8 show that regardless of the lender, resource-backed loans have a positive and significant impact on the cyclical policy (procyclical). In addition, the results show that the loans granted by China seem to have a smaller impact than other RBLs.

3.7.4 Macroeconomic, political and institutional factors

Taking into account the heterogeneities of macroeconomic conditions, political and institutional situations in developing countries that are highlighted in the empirical literature (Acemoglu et al., 2014, 2001; Apeti et al., 2023b; Apeti and Edoh, 2023; Balima et al., 2017), we explore the sensitivity of our results to these factors. The idea here is that structural factors can magnify or alleviate the effect of resource-backed loans on cyclical fiscal policy. We follow the literature on impact evaluation (Coulbaly, 2024a; Lin and Ye, 2009; Tapsoba, 2012) and assess

the effects of such heterogeneities. We report the results in Table C5 in the Appendix. From a macroeconomic perspective, potential sources of heterogeneity include commodity price volatility, fiscal rules, tax revenue volatility, primary balance volatility, financial openness, total investment, and sovereign credit rating. The results indicate that resource-backed loans are effective in triggering countercyclical fiscal policy in the presence of macroeconomic reform such as fiscal rules, strong access to capital markets, and a high level of public investment.

Indeed, the countercyclical effect of fiscal policy indicated by the interaction between RBL and fiscal rules may be due to the ability of fiscal rules to improve fiscal discipline in countries adopting RBL. As proponents of fiscal rule point out, it has the ability to impose effective restrictions to prevent governments from accumulating excessive deficits and unsustainable debt levels; for example, Tapsoba (2012) reveals that fiscal rules have significant disciplinary effects on budget balances. Similarly, Debrun et al. (2008) and Ayuso-i Casals et al. (2009) show that a well-designed fiscal rule can reduce procyclicality in the EU and this is verified in developing countries with a particular focus on fiscal rule typology (Bova et al., 2014; Guerguil et al., 2017). The adoption of fiscal rules enables these countries to prevent fiscal profligacy, strengthen the credibility of fiscal policy, and reduce borrowing costs. This reinforces the effectiveness of resource-backed loans in countercyclicality. More favorable conditions for access to financial markets reinforce the effectiveness of resource-backed loans in countering the cyclicity of fiscal policy. In fact, a good credit rating gives countries credibility and enables them to better mobilize resources on international markets. These alternative sources of financing are a substitute for these countries and reduce their dependence on RBLs. Our results indicate that resource-backed loans increase the procyclicality of fiscal policy in the presence of high primary balance volatility. This suggests that countries with high volatility in primary balance do not necessarily need to sign a resource-backed loan.

The impact of resource-backed loans on the cyclicity of fiscal policy appears insignificant when other types of macroeconomic factors are taken into account. This suggests that the effects of resource-backed loans on the cyclicity of fiscal policy are sensitive, to some extent, to macroeconomic conditions. From a political and institutional standpoint, we take into account governance effectiveness, regulatory quality, rule of law, and adoption of EITI. The results indicate that, in the presence of good institutional quality, resource-backed loans lead the country to a countercyclical fiscal policy. Based on this result, we argue that countries with

strong (weak) institutions are more likely to adopt countercyclical (pro)cyclical macroeconomic policies and that the effect of resource-backed loans on the cyclical coefficient would depend on the quality of the institutions in place. These results corroborate those found in the literature, which show that the quality of institutions plays a key role in a country's ability to implement countercyclical macroeconomic policies (see, for instance, Calderón et al., 2016; Frankel et al., 2013; Bergman and Hutchison, 2015).

Finally, we analyze the sensitivity of resource-backed loans following the adoption of EITI. Our intuition is that countries join the EITI with the intention of fighting corruption by improving transparency and implementing an effective strategy for the governance of natural resource revenues. This political program has been very effective in fighting corruption in resource-rich countries (see, e.g., Papyrakis and Gerlagh, 2007). Reducing corruption can improve credit ratings and send a strong signal to financial markets, which can shape the effect of resource-backed loans on the cyclical policy. Our results indicate that resource-backed loans are associated with a countercyclical fiscal policy when the signatory country adheres to EITI. This suggests that membership in EITI reinforces the beneficial effect of resource-backed loans, a result in line with those found in Coulibaly (2024a).

3.7.5 Is there a threshold effect for public investment?

The literature on resource-backed loans suggests that the main purpose of signing an RBL is to finance infrastructure investment, but not exclusively (Coulibaly, 2024a; Mihalyi et al., 2020). According to Mihalyi et al. (2020), more than 90% of the value of RBL is allocated to infrastructure investment, the remainder being used to support the budget and refinancing existing debt. If countries sign up to RBLs and allocate them to public investments, this can generate additional income not only for repaying loans to themselves but also for existing debts and even for financing new economic development projects. Otherwise, the country will be exposed to enormous public finance difficulties. More specifically, the relevance of our threshold analysis is expressed in the following question: *given that RBLs are signed to invest in the public capital stock, what are the potential effects in terms of fiscal policy cyclical policy resulting from an increase in public investment if there is a 1% increase in the probability of adopting a resource-backed loan?*

To answer this question, we adopt an empirical approach based on regressions with inter-

action terms. In other words, we retain our basic model and include interactions between the RBL and the level of public investment. We then calculate the net effects by setting thresholds for the level of public investment. For the specification of the interaction model, we refer the reader to the pioneering article of Brambor et al. (2006). The results of the first stage are shown in Table C3 in the Appendix, column [3]. A first look shows that the interaction term is negative and statistically significant. We then report the results of the net effects in Table C7. The results indicate a non-linear effect of the public investment rate. In fact, countries characterized by an investment rate as a percentage of GDP between 0 and 5% have a procyclical fiscal policy when adopting resource-backed loans. However, with an investment rate of between 15% and 35% of GDP, countries adopting resource-backed loans are likely to face a countercyclical fiscal policy. The higher the threshold, the greater the net effect, suggesting that priority should be given to public investment in order to reap the benefits of resource-backed loans.

3.8 Conclusion and policy recommendations

Achieving Sustainable Development Goals requires considerable investment, particularly in infrastructure, human capital, and resilience against climate change. However, in developing countries, governments often have limited means of mobilizing public revenues or private investment, while external aid is also limited. Debt financing plays a crucial role in development, provided that debt is well managed, transparent, and used as part of a credible growth strategy. In fact, unsustainable levels of public debt are harmful to growth, with detrimental consequences for fiscal policy. This has the effect of curbing private investment, increasing pressure on social and infrastructure spending, and limiting governments' ability to implement reforms. This, in turn, triggers procyclical fiscal policy. In this chapter, we investigate the cyclical behavior of the fiscal policy of a new development financing instrument that is generally of interest to resource-rich countries. This new instrument, known as resource-backed loans, enables resource-rich developing countries to access financial markets to mobilize funds for development financing. As such, they constitute a special type of external public debt. Using a large panel of 127 developing economies over the period 1990-2020, we show that resource-backed loans trigger fiscal policy procyclicality in developing countries, making this instrument an important determinant of fiscal policy cyclicity. Moreover, this result is

robust under many alternative specifications, including alternative control variables, different samples, different measures of key variables, and alternative impact assessment methods. However, additional estimates reveal that the effect of the adoption of RBL on fiscal policy cyclicalities is uneven, and its importance and magnitude may differ according to certain structural characteristics. Indeed, such characteristics may favor or, on the contrary, inhibit the effectiveness of the public finance framework of the RBL and suggest that certain conditions must be met to expect a favorable effect of the RBL in terms of reducing the procyclicality of fiscal policy. Clearly, we show that resource-backed loans significantly affect the cyclicalities of fiscal policy, as they introduce a dynamic based on the volatility of commodity markets. When prices are rising, the resources generated enable budgetary constraints to be relaxed and public spending increased, thus artificially stimulating the economy. However, when prices fall, governments may be forced to cut spending drastically to meet their repayment obligations. This can lead to a procyclical fiscal policy, amplifying economic cycles and making macroeconomic stabilization more difficult. Our results have implications for economic policy. First, the literature points out that developing countries are characterized by rather erratic and procyclical fiscal policies. Our results are in line with this literature. Second, careful monitoring of the public debt trajectory is necessary. Measures could be taken to promote sustainability because the fiscal policy response to the economic cycle depends on the debt stock. Third, we highlight the support for restrictive fiscal rules in our study. The favorable effects of fiscal rules could stem from the fiscal discipline they induce: by imposing restrictions on fiscal policy, restrictive fiscal rules can force governments to avoid running excessive deficits and accumulating unsustainable debt and to resort to resource-backed loans to refinance the economy. Fourth, our analysis calls for resource-backed loans to be made transparent by including various players in the discussions and signing of such loans. Fifth, to mitigate these effects, prudent management and diversification of the economy could be an alternative solution, to reduce the impact of fluctuations in these loans on long-term budget management. Finally, in a world where the consequences of climate change are being felt by the economies of developing countries, most of which are experiencing budgetary difficulties, it is crucial that prudent, sustainable and transparent sovereign debt management be undertaken to ensure better financing of sustainable development for future generations.

DEBT-FOR-NATURE SWAPS AND FISCAL POLICY VOLATILITY: EVIDENCE FROM DEVELOPING COUNTRIES

Abstract¹: The growing difficulty of many developing countries in repaying their public debt combined with problems of environmental degradation (such as climate change and loss of biodiversity) is now widely recognized as two sources of potential risk to the stability financial system. This has given rise to numerous debates, culminating in recent proposals to solve these two problems jointly through debt-for-nature swaps, whereby a country's debt is reduced in exchange for a commitment to devote part of the reduction to environmental protection. Although its effectiveness on the environment has been widely studied in the literature, very little has been said about one of the main components of fiscal policy, namely fiscal policy volatility. So, this chapter uses the propensity score matching method to test whether debt-f-nature swaps have a causal effect on fiscal policy volatility in a large sample of 134 developing countries over the period 1990-2020. Through a series of robustness checks, the estimation results indicate that debt-for-nature swaps have a negative and statistically significant effect on fiscal policy volatility. When we disaggregate debt-for-nature swaps to run the regressions, the results show a surprising effect. Only bilateral debt-for-nature swaps have a negative effect on fiscal policy volatility.

Keywords: • Debt swap operation • Debt relief debt swap • Debt conversion • Fiscal policy volatility • Developing countries

JEL Codes: E51, Q43, Q54, Q56

¹A version of this chapter was revised and resubmitted to *International Economics*

4.1 Introduction

The current challenge for developing countries is to mobilize the financial resources needed to finance public investment and improve social well-being, without compromising long-term environmental sustainability (Raworth, 2012; Raworth, 2017). It is therefore crucial, indeed imperative, that we redouble our efforts to mobilize domestic resources to meet this challenge, and even to finance the budgetary tensions caused by the COVID-19 crisis, the war in Ukraine, and the climatic shocks (Coulibaly, 2021; Coulibaly and Camara, 2022b). In the economic literature, it is argued that the COVID-19 pandemic has exacerbated the vulnerability to debt of many low- and middle-income sovereign states (Augustin et al., 2022). Although debt levels were already high for many of them even before the outbreak of the COVID pandemic. This situation is exacerbated by the fact that government revenues have declined due to limited economic activity, while the timing and amount of debt service payments remain unchanged. In addition, exchange rate fluctuations can increase the burden of debt service payments denominated in foreign currencies.

However, despite their efforts to mobilize domestic resources, these countries do not reach their potential to mobilize tax revenue due to weak tax administration, corruption, and tax evasion (Baum et al., 2017; Besley and Persson, 2014; Cusi et al., 2020). The argument or idea of refinancing in international financial markets is no longer tenable, as many of these countries present a high financial risk and have limited access to financial markets due to sovereign debt default episodes and rounds of sovereign debt restructuring (Wang et al., 2023; Coulibaly, 2023b; Mihalyi et al., 2020; Mihalyi et al., 2022). In addition, exogenous shocks such as COVID-19, combined with the Russian-Ukrainian crisis and the corollaries of climate change, have also aggravated debt viability problems in these developing countries and undermined the budgetary resources needed to finance climate change mitigation and adaptation efforts (AfDB, 2022; ECA, 2022; Essers et al., 2021). According to Paul et al. (2023), the fight against the pandemic has increased the risk of public debt sustainability for low- and middle-income countries, due to the budgetary efforts required. Their level of public debt in 2021 was higher than before the crisis: 49.6% of GDP for low-income countries and 66.1% for middle-income countries, compared with 43.5% and 54.6% between 2021 and 2019 respectively (IMF, 2022). According to World Bank 2021 statistics, the total amount of this debt increased by

almost 3.5 trillion dollars between 2006 and 2020 (World Bank, 2021b). In fact, unsustainable public debt reduces the government's fiscal space and its ability to finance policies to combat climate change (d Chamon et al., 2022). Today, the scale of environmental degradation caused by climate change and biodiversity loss, and the growing difficulty for many low- and middle-income countries to repay their public debt, are two sources of potential risk to the stability of the international financial system (Paul et al., 2023), which calls on the international community to find a common solution. In this regard, certain authors (d Chamon et al., 2022; Picolotti et al., 2020; Ruiz, 2007; Sheikh, 2018; Sommer et al., 2020), institutions (AfDB, 2022; Paul et al., 2023), and conservation organizations have proposed the sovereign debt relief program in the form of «debt-for-nature swaps»² as a powerful response to this dual challenge.

Basically, the central idea of a debt-for-nature swap involves reducing the debt of a low- or middle-income country in exchange for that country's investment in environmental conservation and protection (AfDB, 2022; d Chamon et al., 2022; Essers et al., 2021; Hamlin, 1989; Paul et al., 2023; Picolotti et al., 2020; Sheikh, 2018; Sommer et al., 2020; Steele and Patel, 2020; Volz et al., 2021). Debt-for-nature swaps, in particular bilateral debt-for-nature swaps, have allowed the cancellation of more than \$1 billion canceled debt and generated around \$500 million for conservation (Sommer et al., 2020). As a result, debt-for-nature swaps could be a more effective form of budget support than conditional grants (d Chamon et al., 2022). In 2017, the United Nations Development Program estimated that the total value of debt processed through debt swaps was \$2.6 billion and financed development or natural-related expenditure of approximately \$1.2 billion (UNDP, 2017). This amount has risen to \$17 billion in 2019 according to OECD. (2021).

Indeed, climate-conditioned subsidies (or subsidy/loan combinations) —which are supposed to be designed in such a way as to make it impossible to divert them to debt servicing or other spending purposes — have only one objective, namely climate investment, while debt-for-nature swaps³ support climate investment by committing a country to redirect debt

²The realities on the ground show that swaps are complex financial transactions involving many different players, even if the concept itself seems simple (Sommer et al., 2020). Actors can include indebted governments, creditor governments, as well as international nongovernmental organizations, national nongovernmental organizations, private foundations, and commercial banks (Bryant and Bailey, 1997).

³In fact, debt-for-nature swaps aim to free up budgetary resources so that governments can improve their resilience without triggering a fiscal crisis or sacrificing spending on other development priorities (see, Georgieva et al., 2023; Paul et al., 2023).

servicing expenditure towards an agreed public investment (d Chamon et al., 2022). This would increase the fiscal maneuverability of the debtor country, reduce its volatility in fiscal policy, and stabilize its macroeconomic situation. In other words, for developing countries, debt-for-nature swaps can help meet the growing dual challenge of reducing excessive public debt and combating climate change, to which they are particularly vulnerable (Paul et al., 2023). Debt-for-nature swaps are gaining in importance, as many countries have recently successfully executed such swaps⁴. This is the case for countries such as the Seychelles in 2015 (blue bond issued in 2018), Belize in 2021 (d Chamon et al., 2022), Barbados in 2022, Ecuador, and Gabon in 2023. In addition, Ecuador's recent \$1.6 billion debt swap has generated considerable interest in this instrument in more than 50 developing countries that are currently in debt distress or at high risk of an imminent debt crisis, many of which, including Cape Verde, Eswatini, Gambia, Kenya, Pakistan and Sri Lanka, are considering debt-for-nature swaps to achieve debt relief and create fiscal space⁵. Our intuition is that debt-for-nature swaps, by reducing or canceling public debt, increase the resources available to the debtor country and increase fiscal space, boost public investment in the country, and ultimately reduce fiscal policy volatility. In fact, debt-for-nature swaps are often seen to generate additional fiscal space (Heller, 2005) in the recipient country's budget, which the country can spend without jeopardizing the stability of its fiscal and macroeconomic situation. Similarly, high debt service payments in a highly indebted country precipitate, or should lead to, punitive taxation against the most productive sectors of the economy, thereby reducing public and private investment, economic stability, public revenues and, finally, the ability to service the debt (Cassimon et al., 2008; Occhiolini, 1990). As a result, debt-for-nature swaps could help break this vicious circle and restore a self-sustaining process of economic stability. This, in turn, should lead to greater mobilization of domestic resources in the future (for example, through more efficient tax practices or increased private sector investment).

However, even if debt-for-nature swaps have had a desired positive impact on the environment, such as reducing deforestation (Essers et al., 2021; Gockel and Gray, 2011; Shandra et al., 2011; Sommer et al., 2020), their effectiveness on fiscal policy is the subject of serious

⁴<https://www.bloomberg.com/news/articles/2023-08-02/bofa-led-debt-swap-for-gabon-moves-ahead-with-500-million-bond>.

⁵<https://www.imf.org/en/Blogs/Articles/2022/04/07/restructuring-debt-of-poorer-nations-requires-more-efficient-coordination>.

debate in the literature and call for greater emphasis to be placed on improving the design of debt-for-nature swaps (Essers et al., 2021). By way of illustration, we cite the case of Indonesia, which canceled around \$22 million in debt owed to the United States. Despite this, the debt-for-nature swap did not generate any additional budgetary space in the Indonesian budget, as the payments were redirected to a conservation fund (Cassimon et al., 2011). Several reasons have been put forward in the literature for debt-for-nature swaps still not achieving their budget targets. Firstly, implementation poses numerous technical, financial and governance-related challenges (Paul et al., 2023). Secondly, genuine fiscal space is only created when there is a positive difference between the debt service payments canceled under the debt swap and the counterpart payments that replace them. Without such a rebate, no additional fiscal space is freed up for the benefit of the recipient government. Thirdly, a poorly structured debt-for-nature swap, in which annual domestic counterpart payments are made before the savings from debt relief are realized, can quickly worsen rather than improve the government's fiscal position. Fourthly, the size of debt-for-nature is too small to have a positive effect on the debtor government's budget. In fact, debt-for-nature swaps have always been piecemeal interventions whose scale, in relation to the overall debt stock of the recipient countries, is deemed insufficient to have a significant impact (Hamlin, 1989; Hansen, 1989; Patterson, 1990; Thapa, 1998). It should also be remembered that most debt swaps are in the double-digit million US dollar range; the largest swap to date took place in 1992 between Poland and a group of creditors, for a total value of \$580 million, as highlighted by d Chamon et al. (2022). Finally, the lack of statistical data on debt-for-nature swaps makes it difficult to know to what extent the debt-for-nature swap has generated subsequent investment and tax revenue for the debtor country. We are the first to assess the impact of debt-for-nature swaps on fiscal policy, particularly on fiscal policy volatility in developing countries. So far, no study has addressed this aspect of debt-for-nature swaps for a large sample; almost all previous studies have focused on the effectiveness of this type of debt relief on climate change, the environment and biodiversity. This is surprising because climate vulnerabilities and budgetary risks are correlated. According to d Chamon et al. (2022), countries most vulnerable to climate change face higher risks of fiscal crisis and a large majority of countries with climate risks also run a high risk of fiscal crisis. In fact, climate change exacerbates debt viability by having a negative impact on countries' production capacity and tax base, creating fiscal costs (including for reconstruction

after natural disasters) and making external borrowing more expensive. Consequently, any macroeconomic policy aimed at combating climate change is bound to have an impact (+/-) on the conduct of fiscal policy. It is this aspect of debt-for-nature swaps that we address in this chapter. In other words, the main objective of this chapter is to analyze the impact of debt-for-nature swaps on fiscal policy, more particular on fiscal policy volatility.

To achieve this, given that the adoption of debt-for-nature swaps is probably not a random phenomenon as explained above, but rather subject to specific conditions creating a selection bias, we address this source of endogeneity using impact analysis methods to the popular propensity score matching (PSM) method to mimic a random experiment and identify the causal effect of debt-for-nature swaps on fiscal policy volatility. Our estimates, based on a large sample of 134 developing countries over the period 1990-2020, show that debt-for-nature significantly reduces the volatility of fiscal policy. Furthermore, we point out that this result is robust to a range of specifications, including alternative samples, alternative measures of fiscal policy volatility, and falsification tests constraining date adoption, or when using alternative estimation methods to deal with endogeneity. Subsequently, heterogeneity tests highlighted in this chapter show that the effect of debt-for-nature swaps may depend on the type of debt-for-nature swaps, i.e. the type of agreement (bilateral or multi-party), and the level of debt viability. Finally, additional estimates show that the reduction in fiscal policy volatility is triggered from the first year that the country benefits from this relief program, and the effect continues until five years, and that the effectiveness of debt-for-nature swaps in reducing fiscal policy volatility can be reinforced, or on the contrary weakened, by various structural characteristics including institutional factors.

The rest of the chapter is organized as follows. Section 4.2 reports the conceptual issues. Then, Section 4.3 reports the stylized facts. Section 4.4 describes the empirical methodology, while Section 4.5 presents the data used in the study. The main results are presented in Section 4.6, while in Section 4.7 we examine the sensitivity of these results. Section 4.8 explores the heterogeneity tests. Finally, Section 4.9 concludes the chapter and presents the main policy recommendations of the results.

4.2 Debt-for-nature swaps: Conceptual issues

4.2.1 Historical and typology of debt-for-nature swaps

By definition, debt-for-nature swaps involve canceling part of a country's foreign debt in exchange for investment in conservation programs (Visser and Mendoza, 1994). This type of transaction was proposed by the famous ecologist Dr. Thomas Lovejoy to establish a link between debt repayment and forest loss. This preceded the great debt crisis of the 1980s, which left many countries unable to generate enough revenue to repay their foreign debts (George, 1992). The author stated: «*The international debt crisis should remind us of the ecological and economic links between rich and poor... Debtor nations willing to protect natural resources could benefit from discounts or credits on their debts... Stimulating conservation while improving debt would encourage progress on both fronts.*» (see, Lovejoy, 1984). In fact, the author's concern was that the growing pressure on highly indebted countries to service their external debt would lead to an increase in exports of raw materials such as timber, oil, gold, bauxite, etc., (often the main source of foreign exchange earnings in these economies), which would harm the environment. In July 1987, Bolivia signed its first debt-for-nature swaps agreement with Conservation International.⁶

Subsequently, Nature Conservancy, World Wildlife Fund, and Conservation International have negotiated many similar swaps of unnatural debt with commercial debt, mainly in Latin American countries (Sheikh, 2018). Several years later, debt-for-nature swap transactions decreased from the 2000s⁷ onward due to a general rise in secondary market debt prices and a move toward large-scale, comprehensive debt relief programs such as the Heavily Indebted Poor Countries (HIPC) initiative and the Multilateral Debt Relief Initiative (MDRI) (Cassimon and Essers, 2017; Ruiz, 2007; Sheikh, 2018). In addition, debt swaps have been the subject of extensive criticism. The main reason is that they have generally failed to provide debtor countries with additional resources or more resources for sectoral or public goods purposes, and have been conducted on an insufficient scale with inappropriate conditionalities. However, and despite these criticisms, since the 2010s, following the numerous debates on climate finance, the

⁶With a grant of \$100,000 from the Frank Weeden Foundation, Conservation International acquired a Bolivian commercial debt with a face value of \$650,000. It then repurchased this security from the Bolivian government in exchange for a commitment to conserve 3.7 million acres of forest and a contribution of \$100,000 in new bolivianos to a \$250,000 fund for the management of the biosphere reserve (Occhiolini, 1990).

⁷see, Figure 4.3.

debt-for-nature approach has been reinvigorated under the guise of debt-for-climate swaps (e.g. Mitchell, 2015; Fenton et al., 2014; Hurley, 2010), and a few isolated swaps have been conducted to finance specific mitigation or adaptation activities (Warland et al., 2015).

Indeed, these types of debt restructuring can result from a bilateral agreement between debtor and creditor, or from a multi-party arrangement in which existing debt is purchased at a reduced price by one or more philanthropic entities in order to reallocate part of the savings to conservation efforts. In this way, all parties can benefit from the transaction, including the original creditors in the case of a multi-party swap, and the structure is versatile enough to be used in conjunction with other forms of climate- and nature-related debt transactions.

4.2.2 Mechanics of debt-for-nature swaps

4.2.2.1 *Bilateral debt-for-nature*

By definition, bilateral swaps can be described very simply as the cancellation of a bilateral loan by a creditor in exchange for something else, usually environmental results in the debtor country. The United States is the largest single creditor to have performed DNS swaps, mainly bilateral debt-for-nature swaps (AfDB, 2022; Sommer et al., 2020). According to Sommer et al. (2020), bilateral debt-for-nature swaps account for 64% of the total debt cancellation and generate 44% of total conservation financing. According to data from (AfDB, 2022), the total amount of bilateral debt-for-nature swaps is 927 million dollars, 13 times greater than multiparty debt-for-nature swaps (see Figure 4.1).

Indeed, the operating mechanism on which bilateral debt-for-nature is based is made up of various economic, political, and environmental conditions. First, in terms of economic requirements, a debtor government must have reached debt servicing thresholds and demonstrate progress in implementing reforms involving an international Monetary Fund structural adjustment agreement. Secondly, in political terms, a debtor nation must have a democratically elected government and demonstrate its commitment to guaranteeing human rights. Finally, an indebted nation must meet certain environmental criteria, including the existence of at least one tropical forest with substantial biodiversity or a forest that represents a vast block of intact forest on a regional, continental or global scale, and a strong commitment to protecting biodiversity. To reach a debt-for-nature swap agreement, the various parties involved negotiate the amount of debt available for cancellation, the repurchase instrument, and a deadline

to conclude the agreement (Visser and Mendoza, 1994). In addition, government officials discuss where conservation projects will be implemented, what the projects will involve and how they will be managed (Visser and Mendoza, 1994). The emphasis is placed on the participation of local stakeholders, which tends to occur well in advance of negotiations (Sheikh, 2018). A non-governmental organization then prepares an independent assessment of the feasibility of the agreement, highlighting any potential problems that need to be resolved before the agreement comes into force. Finally, once negotiations have been completed, the newly approved debt-limiting agreement is implemented (Visser and Mendoza, 1994). This may take the form of a debt reduction or purchase. It should be remembered that in most bilateral debt-for-nature swaps, many transactions involve the cancellation of more debt than an indebted country will pay into a trust fund.

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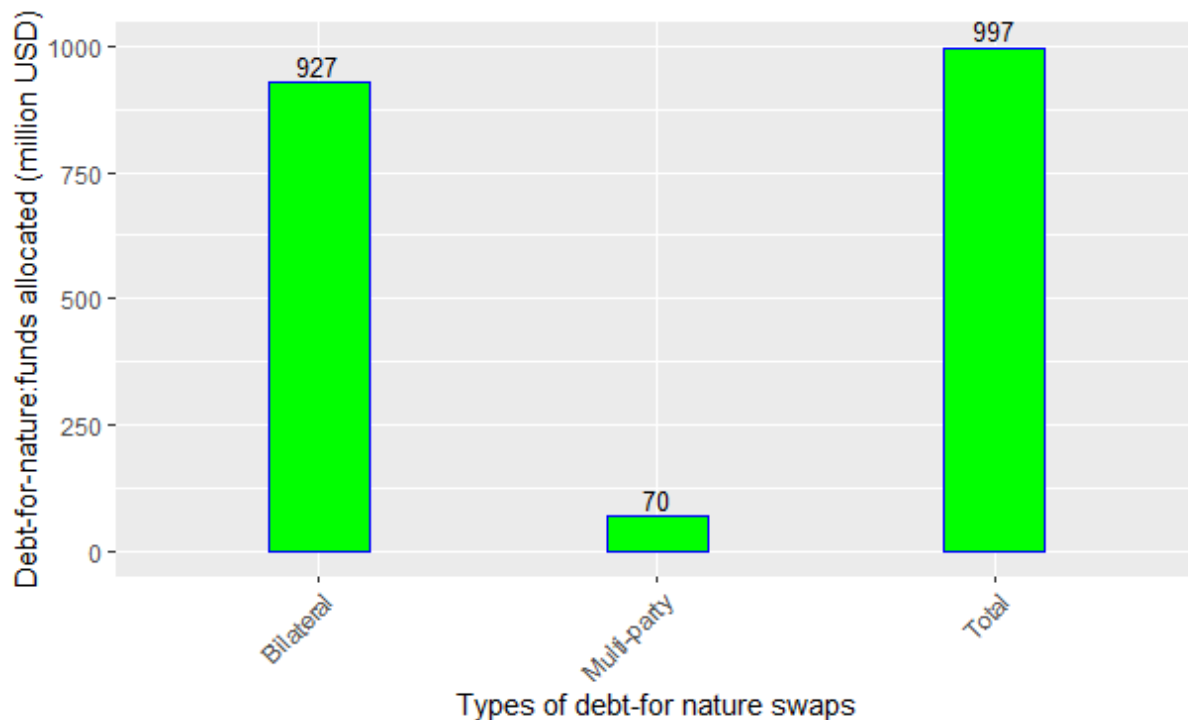
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4.2.2.3 *Multi-party debt-for-nature*

Whereas bilateral debt-for-nature swaps involve the United States and these creditors, multi-party debt-for-nature swaps involve third-party donors with the intention of buying back an existing sovereign debt instrument from the original (or current) creditors. The main intermediary in this type of agreement is often an environmental NGO, such as CI, TNC, or WWF, although it is not uncommon for a group of donor institutions to coordinate and share the burden of a single transaction (see AfDB, 2022, p.67-73). Under a multi-party swap agreement, the donor or intermediary offers to buy the debt from the creditors who currently hold it, at a substantial discount. In exchange for this reduction in the debt burden, the debtor country allocates part of the savings to a local conservation fund, with the aim of protecting its own natural environment. Figure 4.1 clearly shows that multi-party debt-for-nature swaps are very small in size compared to bilateral swaps, confirming the argument that debt-for-nature swaps are too small to have a significant impact on the economy of the debtor country. Indeed, multiparty debt-for-nature swaps are versatile, enabling a variety of unique structures to be set up to handle different types of debt. This creates further opportunities from a tax point of view (which is the subject of this chapter). Although the environmental benefits of a swap do not depend on the amount of debt relief it provides, a swap that also improves debt sustainability could help a government pursue not only longer-term sustainable development

policies, but also short-term fiscal policies. This would involve broadening the transaction to relieve a country's debt sufficiently to create sustainable fiscal room for maneuver.

Figure 4.1: Total amount of debt-for-nature: environmental funds allocated



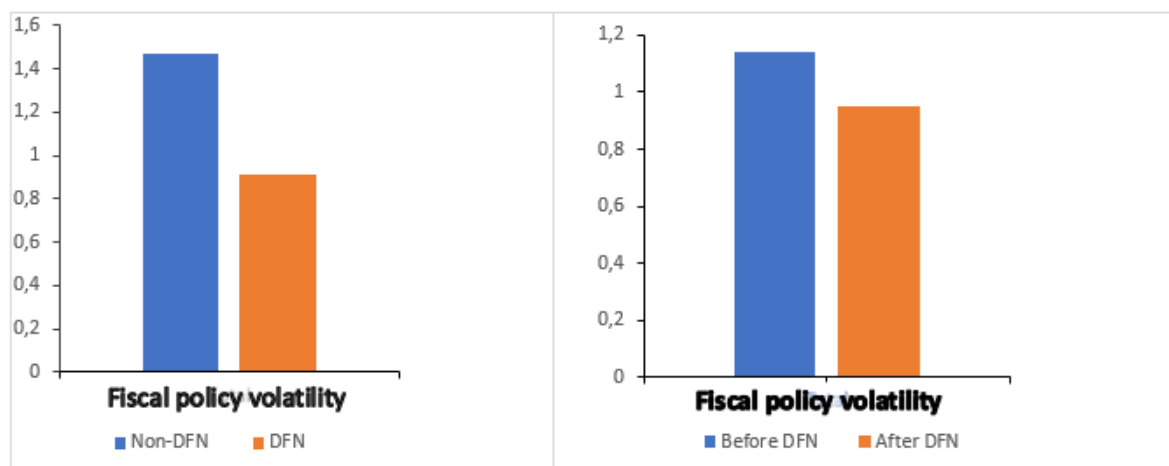
Source: Author's elaboration using data from AfDB (2022).

4.3 Stylized facts

In this section, we analyze some stylized facts about fiscal policy volatility and debt-for-nature swaps over the period covered by our study (1990-2020). This exercise gives us an idea of the evolution of the budgetary situation through fiscal policy volatility even before we begin the econometric analysis. Looking at the correlation between the two variables, there is an unconditional correlation that is negative and significant at the 1% level (see Table D4). We advance our analysis by comparing fiscal policy volatility in DNS countries and non-DNS countries. Indeed, Figure 4.2 on the left shows that this volatility tends to be lower in DNS countries (on average around 1% for DNS countries compared with around 1.5% for non-DNS countries). However, this reduction was substantial in DNS compared to non-DNS. In addition, to go a little further, we are inspired by the comparative technique of Apeti et al. (2023a) and Neuenkirch and Neumeier (2016), which consists of comparing the volatility of fiscal policy be-

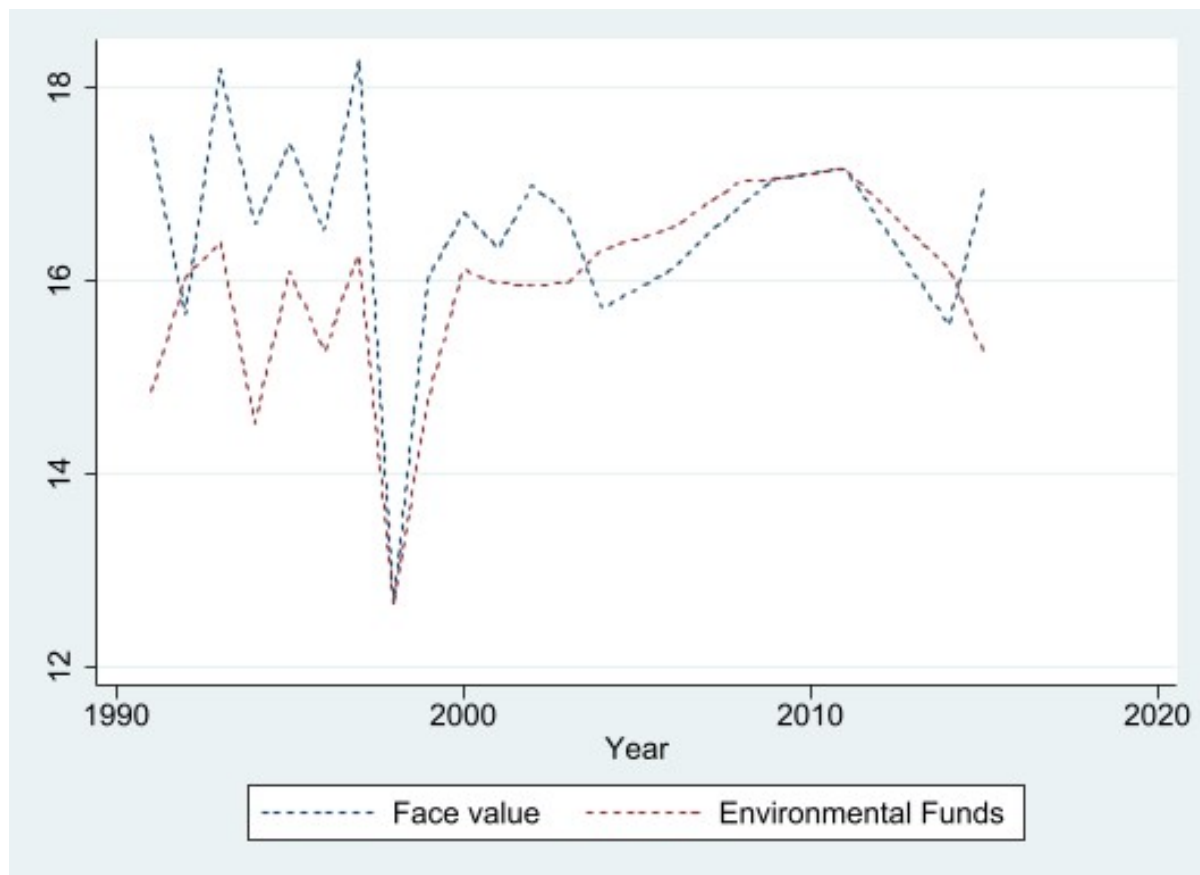
fore and after the policy of sovereign debt relief (debt-for-nature swaps). Figure 4.2 on the right shows a higher volatility before the adoption of debt-for-nature swaps; however, this average volatility becomes lower after the adoption of debt-for-nature swaps in beneficiary countries compared to non-beneficiary countries. Figure 4.2 provides highlights and draws our attention to a fairly in-depth analysis of the possible link between the two variables. Attention is drawn to the fact that although countries had high fiscal policy volatility before reaching a debt-for-nature agreement, this decreases after reaching debt-for-nature swaps. The gap is a significant difference of around 0.5 percentage points. This graphical evidence shows that the adoption of debt-for-nature swaps is likely to go hand in hand with fiscal policy volatility. However, the difference of 0.5 percentage points is only a difference obtained from a simple correlation between the two variables (fiscal policy volatility and DNS) and not a causality. To avoid over- or underestimating the effect of DNS, hereafter we here use non-DNS country observations selected on the basis of the matching procedure as a control group to estimate the counterfactual result.

Figure 4.2: Fiscal policy volatility and debt-for-nature swaps



Source: Author's elaboration.

Figure 4.3: Trend of debt-for-nature swaps in developing countries



Source: Author's elaboration using data from AfDB (2022); World Wildlife Fund (WWF), Congressional Research Service, U.S. Agency for International Development (USAID), and The Nature Conservancy (TNC).

Figure 4.3 clearly shows that debt-for-nature transactions have been on an upward trend in recent years. Between the first transaction in 1985 and 1996, debt-for-nature swaps involved almost USD 40 billion of debt (World Bank, 1998, P.89). However, this trend fell sharply around 1999, as shown in Figure 4.3. This sudden drop was due to debt relief under the Heavily Indebted Poor Countries (HIPC) initiative, initiated jointly by the IMF and the World Bank. This made them a somewhat rarer financing instrument in the 2000s (Cassimon and Essers, 2017). After the 2000s, the trajectory of debt-for-nature began to pick up again, which explains the attention that has been and continues to be paid to this funding instrument. Although there is no doubt that unsustainable debt levels in low- and middle-income developing economies combined with climate vulnerability are urgent problems, it is necessary to examine carefully whether and how this type of instrument (debt-for-nature swaps) can actually be designed to benefit or, at the very least, not harm countries, particularly those that are most indebted and

face the greatest climate change challenges. One of the main contributions of this chapter lies in the use of sophisticated and adapted empirical methods, which were lacking in the literature on this issue.

4.4 Methodology

4.4.1 Identification strategy

The main objective of this chapter is to test the causal effect of debt-for-nature swaps on fiscal policy volatility. However, estimating the causal effect of debt-for-nature swaps on fiscal policy volatility is not such an easy task, insofar as the selection criteria for countries benefiting from debt-for-nature swaps is probably not a random event, but are linked to specific macroeconomic conditions (generally referred to as preconditions, i.e. high debt levels, unsustainable debt, etc.), climatic conditions (in this case, climate vulnerability and commitment to environmental measures in particular) and are therefore subject to selection bias. These factors - which can also affect the volatility of fiscal policy - make the adoption of debt-for-nature swaps endogenous (nonrandom) through the problem of selection bias. To avoid this problem and identify the effect of debt-for-nature swaps, we use an impact analysis method, since it is difficult to find perfect external instrumental variables. Although some authors, such as Sommer et al. (2020), have been able to find an external instrument and apply method IV, we have to admit that their sample differs from ours, as they were only interested in United Nations bilateral debt-for-nature swaps. After reviewing the literature on assessing the macroeconomic impact of debt-for-nature swaps, we chose propensity score matching (PSM) as our main estimation method. In fact, the PSM technique is a method that avoids the problems encountered by alternative impact evaluation methods, in particular the difference in the difference, arising from the fact that in the presence of serial dependence, both in the dependent variable (in our case, the volatility of fiscal policy, which is persistent) and in the variable treatment.

4.4.2 Propensity score matching framework

Proposed by Rosenbaum and Rubin (1983), propensity score matching allows addressing the issue of self-selection in the adoption of debt-for-nature swaps by pairing debt-for-nature swaps countries (treated group) with non-debt-for-nature swaps countries (control group) that

are comparable in terms of observable characteristics that influence both debt-for-nature swap adoption and fiscal policy volatility (including, in particular, past fiscal policy volatility). Basically, as explained in more detail by Chapel (2022); Balima et al. (2017); Apeti et al. (2023a); Minea and Tapsoba (2014); Apeti et al. (2023b); Vega and Winkelried (2005); Lucotte (2012); Gong and Qian (2022); Lin (2010); Combes et al. (2018a); etc., PSM is a two-step process: first, using a probit or logit model, we generate for each country a propensity score $p(x)$, which estimates the probability that this country, with its vector of characteristics, will adopt debt-for-nature swaps. Thus :

$$p(X)=\Pr(T = 1|X) = E(T|X)$$

Where, $T = \{0;1\}$ is the binary variable indicating whether the country has benefited from debt-for-nature swaps and X is the vector of characteristics observed before treatment. Secondly, we assess the impact of debt-for-nature swaps by estimating the average treatment effect on treated countries (ATT), expressed as follows.

$$ATT=E[(Y_{i1})|T=1, X = 1]-E[Y_0|T=1, X = 1] \quad (4.1)$$

where $Y_{i(.)}$ is the outcome variable that measures the volatility of fiscal policy. T_i indicates whether the observation unit is subject to adoption of debt-for-nature swaps ($T_i = 1$) or not ($T_i = 0$). $E[(Y_{i1})|T_i=1]$ is the level of fiscal policy volatility during the debt-for-nature swap adoption period, $E[(Y_{i0}|T_i=1)]$ is the counterfactual result for countries that had adopted the debt-for-nature swap adoption period, i.e. the fiscal policy volatility in countries that had adopted debt-for-nature swaps if they had not. The issue is that $E[Y(0)|T = 1]$ is not observable due to the non-random nature of debt-for-nature swap adoption. If this were the case, the ATT could easily be identified by comparing the fiscal policy volatility in debt-for-nature swaps countries with non debt-for-nature swaps countries. Identifying ATT then requires a good proxy for $E[Y(0)|T = 1]$. To do that, we match debt-for-nature swaps units with non debt-for-nature swaps units (after purging for some specific factors) that are as close as possible on observable characteristics that meet two criteria: correlated with debt-for-nature swaps adoption and fiscal policy volatility. Under the condition that the non debt-for-nature swaps units are fairly close to the debt-for-nature swaps units, any difference in fiscal policy volatility is attributable to debt-for-nature swaps adoption. For this purpose, Rosenbaum and Rubin

(1983) and Smith and Todd (2005) propose to replace in equation 4.1 the unobservable term $E[(Y_{i_0}|T_{i_1})]$ by the observable term $E[(Y_{i_0}|T_{i_0}, X_i)]$ to satisfy the conditional independence assumption. Based on these details, we can rewrite equation 4.1 as follows:

$$ATT = E[(Y_{(1)}|T=1, X = x)] - E[Y_0|T=1, X = x] \quad (4.2)$$

where $X = x$ is a vector of observable covariates that can affect both the decision to adopt debt-for-nature swaps and fiscal policy volatility, $E[Y(1)|T = 1, X = x]$ is the fiscal policy volatility of debt-for-nature swap units and $E[Y(0)|T = 0, X = x]$ is the expected fiscal policy volatility for synthetic control units.

A second assumption based on the existence of a common support, also called the overlap condition, must be verified ($0 < p(X) < 1$). This hypothesis assumes that for each treated country, there is at least one comparable untreated country with a fairly similar propensity score. We finally obtain the following equation :

$$ATT = E[E\{Y_{i_1}|DNS_i=1, p(X_i)\} - E[(Y_{i_0}|DNS_i=0, p(X_i))]] \quad (4.3)$$

4.5 Data

We use a panel of 134 low- and middle-income developing countries for the period 1990-2019. Our sample includes 39 DNS countries (treated units) and 95 non-DNS countries (control units).

Treatment variable. The treatment variable is debt-for-nature swaps (DNS), defined as a dummy variable equal to 1 if country i in year t has benefited a DNS, and to 0 otherwise. We collected data on DNS using several sources including: AfDB (2022); d Chamon et al. (2022); Picolotti et al. (2020); Sommer et al. (2020); Sheikh (2018); Cassimon et al. (2014); Egolf (2001), and the websites on debt-for-nature swaps such as: World Wildlife Fund (WWF), Congressional Research Service⁸, U.S. Agency for International Development (USAID), and The Nature Conservancy (TNC); and press releases describing various debt-for-nature transactions.

Outcome variable. Given that there is no ideal singular method for estimating fiscal policy volatility in the literature, we follow the calculation method used by Apeti et al. (2023a);

⁸see, Kamel and Tooma (2005).

Alesina and Perotti (1995); and Blanchard (1990). This approach, known as the residual approach (Fatás and Mihov, 2003; Fatás and Mihov, 2013), defines fiscal policy volatility as the standard deviation of the discretionary component (Apeti et al., 2023a). To obtain the residuals, we regress a dynamic equation of real government consumption expenditure. This equation is as follows:

$$\Delta \ln(G)_{it} = \alpha_i + \gamma_i \Delta \ln(G)_{it-1} + \beta_i \Delta \ln(Y)_{it} + \rho_i X_{it} + \varepsilon_{it} \quad (4.4)$$

After regressing this equation, we then calculate the country-specific residual ε_{it} as an estimate of discretionary fiscal policy, by extracting from the government's real consumption expenditure growth rate G its one-period lagged value (which explains its persistence), the economic growth rate (based on real GDP Y) and a set X of other determinants, namely public debt, public debt squared (to better capture debt dynamics), and a deterministic time trend (to account for other unobserved time-varying variables). Unlike Apeti et al. (2023a), which uses inflation, inflation squared, we have taken debt and its square, given the context of our study, which focuses on debt relief policy to increase climate action in countries with limited fiscal space. However, we remain faithful to him by applying the 2SLS method to correct for potential endogeneity between public consumption expenditure and real GDP, using as instruments the second lag of output growth, lagged public debt, and lagged public consumption by one period. Finally, our dependent variable, fiscal policy volatility, is then defined as the standard deviation of ε_{it} . Despite its popularity, one of the limitations of this method is that it neglects the revenue and transfer aspects of fiscal policy. For this reason, we will use several alternative measures of fiscal policy volatility, based, for example, on total public spending (instead of public consumption), tax revenues, or the primary balance, to assess the robustness of our main findings.

Controls or matching variables. From the existing literature, we include a set of economic and institutional covariates considered as determinants of debt-for-nature swap adoption, such as GDP per capita, GDP growth, ODA, total ODA Biodiversity, Agricultural land, Public debt, Population total, and Democracy. Given that better economic performance is likely to promote public debt sustainability and influence the signing of debt-for-nature swaps, GDP per capita and GDP growth may be negatively correlated with the likelihood of adopt-

ing debt-for-nature swaps. Secondly, in practical terms, donors seek to increase the overall effectiveness of official development assistance by channeling funds to countries where the impact of aid on poverty reduction is greater, rather than for environmental purposes. As a result, they will have a negative influence on debt-for-nature agreements. Third, it is important to dissociate the ODAs from the ODA Biodiversity. In fact, higher levels of environmental aid should correspond to lower levels of forest loss (Sommer et al., 2020). This should have a positive effect on debt-for-nature swaps. We take the natural logarithm of this variable to help manage the asymmetry. Fourth, we include the percentage of land within a country used for agriculture or land that is permanently cultivated or grazed. This variable measures the size of the agricultural sector. We expect that a larger area of agricultural land will correspond to more deforestation because forests are converted to pastures or fields (Austin, 2010), thus negatively impacting debt-for-nature swaps. In fact, one of the requirements to reach a debt-for-nature swap agreement is environmental, that is, having good forest cover (Sommer et al., 2020). Fifth, we include the level of public debt to control its impact on debt-for-nature swap agreements. Its sign on debt-for-nature could be ambiguous for two reasons. Firstly, it has been shown in the literature that higher levels of debt are associated with higher rates of forest loss, as indebted countries tend to increase their exports of natural resources to obtain cash to repay (Coulibaly, 2023b; Culas, 2006). If this is the case, public debt would undoubtedly prevent countries from meeting all the conditions to benefit from a debt-for-nature. However, and this is the second reason, if all the other conditions are met *ceteris paribus*, a country with a higher level of debt could easily benefit from debt-for-nature agreements, which will have a positive impact. Sixth, we control population growth. We expect this variable to have a negative sign on debt-for-nature because higher population growth rates correspond to greater forest loss, as the demand for resources from a growing population leads to increased consumption of resources which have a negative impact on forests. Finally, we add the variable democracy. We believe that this variable has a positive impact on the debt-for-nature because, according to Li and Reuveny (2006), democratic nations have more political activism than repressive nations. In fact, this occurs in democratic countries because they guarantee freedom of speech, press, and assembly while being able to hold leaders to account through elections.

4.6 Results

4.6.1 Propensity score, matching quality and hypothesis validity

Before turning to the interpretation of the baseline results, i.e. effect of average treatment on treatments (ATT), it is important to discuss the propensity scores. The main thrust of this exercise is based on the objective of our chapter, which is to match treated and untreated countries on the basis of their propensity scores using a variety of matching methods. ATTs are the difference in fiscal policy volatility outcomes between treated and untreated countries matched on the basis of a similar propensity score. To achieve this, we remain consistent with the related literature, and estimate PS using DNS as the dependent variable in a binomial probit model. Following existing studies (see, for instance, Sommer et al., 2020), we retain three groups of control variables. In the first group, we include those identified as preconditions for debt-for-nature swaps, namely lag gross domestic product per capita, lag (GDP per capita), lag (public debt), lag (ODA), lag (ODA of biodiversity) and lag agricultural land. We expect a negative impact of lag (ODA), lag (agricultural land) and lag (GDP per capita) on the probability of DNS adoption, and a positive impact of the other variables. The second group includes the social condition captured by the total population growth. We expect a positive correlation between DNS and total population growth, as existing studies suggest that high deforestation would be related to total population growth (Rudel, 2023); in other words, and as explained above, higher population growth rates correspond to increased consumption of resources that have a negative impact on forests (Rudel, 2023). The third group corresponds to the institutional and political dimension of the democratic regime. We expect a positive correlation between DNS and the democratic regime because according to Li and Reuveny (2006), democracy should reduce forest loss because democratic nations have more political activism than repressive nations.

Table 4.1 shows the results of the propensity score (PS). At this stage, we focus on the basic results highlighted in column [1]. All variables show expected signs and, with the exception of GDP per capita, are significant at conventional statistical levels (1%). In fact, lag (population growth total), lag (public debt), lag (GDP per capita), democratic regime, and lag (biodiversity ODA) are positively associated with the probability of adopting DNS, with opposite effects of lag (natural resource rents), lag (gross domestic product per capita) and lag (ODA). Finally, the

explanatory power of the model as assessed by the pseudo-reference is relatively high, around 17%, confirming all our basic hypotheses. The idea here is to compare the R^2 of the first stage (PS) with those of the second stage (matching). Indeed, if the matching has worked well, the pseudo R^2 after matching should drop considerably and turn out to be very low compared to that obtained in the first stage, i.e. with the binomial probit model. This is the case in our study, where it has dropped from 0.1742 (Table 4.1) to almost 0 (Table 4.2).

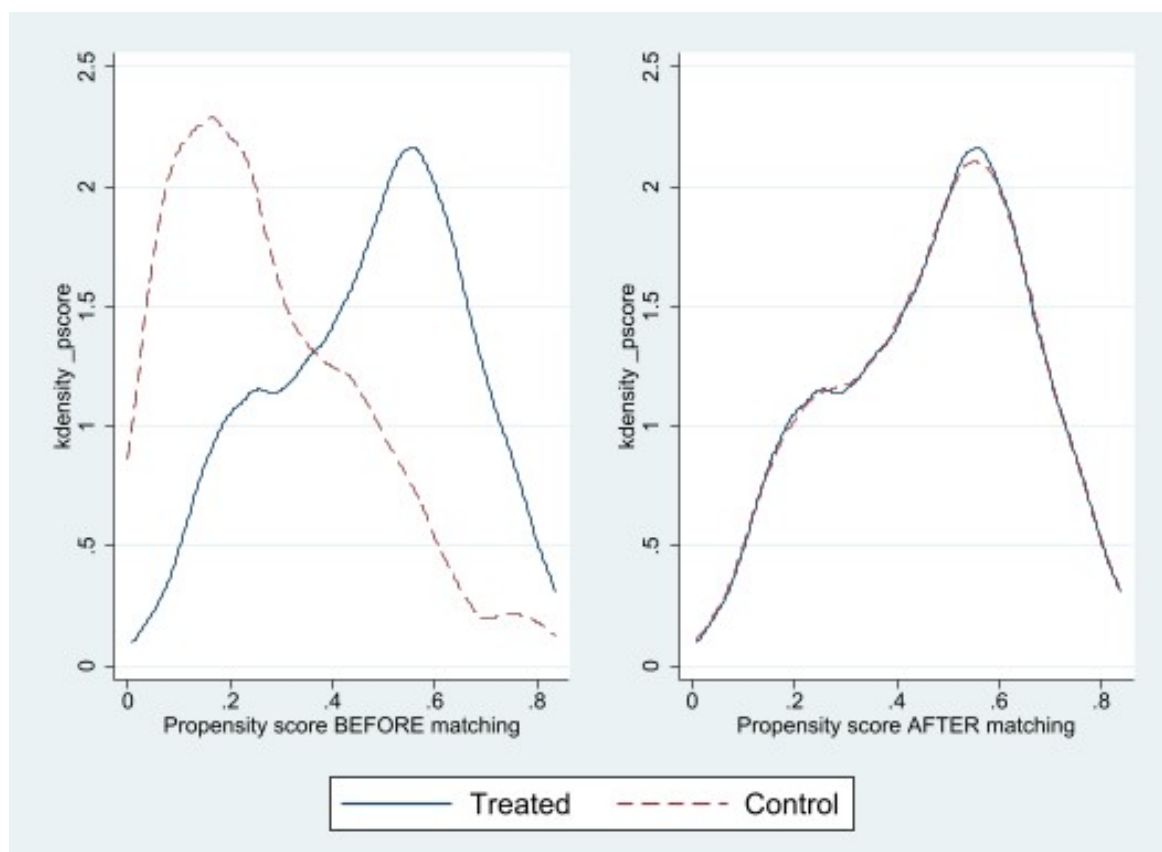
Table 4.1: Probit estimation of debt-for-nature swaps adoption likelihood (propensity score)

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
Lag ODA	-0.0638*** (0.0076)	-0.0585*** (0.0082)	-0.0657*** (0.0083)	-0.0515*** (0.0078)	-0.0525*** (0.0075)	-0.0600*** (0.0076)	-0.0642*** (0.0076)	-0.0647*** (0.0076)	-0.0635*** (0.0080)	-0.0651*** (0.0077)	-0.0585*** (0.0077)	-0.0578*** (0.0079)	-0.0579*** (0.0087)	-0.0557*** (0.0087)	-0.0583*** (0.0090)	-0.0542*** (0.0089)	-0.0642*** (0.0081)	-0.0484*** (0.0086)	-0.0714*** (0.0086)	-0.0544*** (0.0080)
Lag Total ODA Biodiversity (log)	1.6172*** (0.2941)	1.5979*** (0.3050)	2.0040*** (0.3340)	1.3126*** (0.3345)	1.4816*** (0.3038)	1.6871*** (0.2964)	1.6506*** (0.2944)	1.5840*** (0.2948)	1.4296*** (0.3093)	1.6141*** (0.2940)	1.5667*** (0.2964)	1.5023*** (0.2993)	1.5722*** (0.2980)	1.9601*** (0.3381)	1.5722*** (0.3433)	1.8482*** (0.3463)	1.8627*** (0.3169)	1.5941*** (0.3170)	1.8533*** (0.3140)	1.9036*** (0.3264)
Lag Agricultural land area	-0.0059*** (0.0017)	-0.0095*** (0.0018)	-0.0080*** (0.0019)	-0.0043*** (0.0021)	-0.0066*** (0.0018)	-0.0067*** (0.0018)	-0.0056*** (0.0017)	-0.0059*** (0.0017)	-0.0089*** (0.0019)	-0.0061*** (0.0017)	-0.0069*** (0.0018)	-0.0079*** (0.0018)	-0.0069*** (0.0018)	-0.0076*** (0.0020)	-0.0084*** (0.0020)	-0.0083*** (0.0020)	-0.0049*** (0.0019)	-0.0059*** (0.0019)	-0.0046*** (0.0019)	-0.0027 (0.0019)
Lag GDP per capita	-0.0715*** (0.0293)	-0.0788*** (0.0303)	-0.0846*** (0.0317)	-0.0224*** (0.0360)	-0.0642*** (0.0305)	-0.0868*** (0.0295)	-0.0582*** (0.0307)	-0.0727*** (0.0293)	-0.0783*** (0.0321)	-0.0790*** (0.0297)	-0.0790*** (0.0298)	-0.0797*** (0.0303)	-0.0907*** (0.0347)	-0.0690*** (0.0363)	-0.1056*** (0.0369)	-0.0225*** (0.0339)	-0.0281*** (0.0339)	-0.0778*** (0.0355)	-0.0311*** (0.0338)	-0.0806*** (0.0348)
Lag GDP growth	0.0641*** (0.0291)	0.0756*** (0.0302)	0.0290*** (0.0320)	0.0224*** (0.0356)	0.0551*** (0.0306)	0.0800*** (0.0293)	0.0514*** (0.0303)	0.0635*** (0.0292)	0.1030*** (0.0323)	0.0700*** (0.0295)	0.0685*** (0.0296)	0.0650*** (0.0303)	0.0790*** (0.0301)	0.0601*** (0.0349)	0.0895*** (0.0363)	0.0131*** (0.0371)	0.0166*** (0.0359)	0.0653*** (0.0355)	0.0182*** (0.0339)	-0.0143*** (0.0345)
Lag Public debt	0.0035*** (0.0009)	0.0045*** (0.0010)	0.0044*** (0.0010)	0.0041*** (0.0013)	0.0029*** (0.0009)	0.0038*** (0.0009)	0.0037*** (0.0009)	0.0034*** (0.0009)	0.0034*** (0.0009)	0.0034*** (0.0009)	0.0034*** (0.0009)	0.0034*** (0.0009)	0.0034*** (0.0009)	0.0033*** (0.0009)	0.0033*** (0.0010)	0.0033*** (0.0010)	0.0033*** (0.0010)	0.0033*** (0.0009)	0.0033*** (0.0009)	0.0033*** (0.0009)
Lag Population total (log)	1.8836*** (0.1501)	1.6115*** (0.1709)	1.3968*** (0.1708)	1.0164*** (0.1245)	3.0168*** (0.1306)	1.4598*** (0.1040)	1.8273*** (0.1048)	2.6287*** (0.1466)	2.3200*** (0.1430)	1.9355*** (0.1460)	2.2355*** (0.1427)	2.4657*** (0.1504)	2.780*** (0.1519)	2.0643*** (0.1747)	1.0340*** (0.1741)	1.8422*** (0.1746)	1.9899*** (0.1746)	2.5220*** (0.1746)	1.5827*** (0.1746)	1.5827*** (0.1746)
Democracy	0.6966*** (0.0708)	0.7337*** (0.0743)	0.6391*** (0.0737)	0.3244*** (0.0854)	0.5985*** (0.0737)	0.7083*** (0.0741)	0.7080*** (0.0714)	0.5994*** (0.0709)	0.7157*** (0.0751)	0.6224*** (0.0720)	0.5513*** (0.0754)	0.5816*** (0.0736)	0.6224*** (0.0746)	0.5988*** (0.0830)	0.5817*** (0.0830)	0.5817*** (0.0830)	0.5817*** (0.0830)	0.5817*** (0.0830)	0.5817*** (0.0830)	0.5817*** (0.0830)
Trade openness	-0.0002 (0.0013)																			
Total debt service			-0.0251*** (0.0074)																	
Government revenue				-0.0212*** (0.0049)																
Financial openness					1.0480*** (0.1056)															
Inflation targeting						0.4111*** (0.0923)														
Resource-rich countries							0.1059 (0.0729)													
FDI								0.0089 (0.0057)												
Resource rents									-0.0283*** (0.0047)											
Fiscal rules										-0.1106 (0.0697)										
Rule of law											0.7443*** (0.3359)									
Political stability												2.4324*** (0.3288)								
Control corruption													1.1727*** (0.2828)							
Governance stability														0.0023 (0.0272)						
Internal conflict															0.2602*** (0.0316)					
External conflict																0.3403*** (0.0374)				
Disasters index																	-0.0019 (0.0016)			
Economic structure index																		-0.0123*** (0.0026)		
Exposure index																			0.0085* (0.0048)	
Natural shock index																				-0.0110*** (0.0028)
Constant	-10.3476*** (1.0153)	-9.4435*** (1.2709)	-10.3553*** (1.1708)	-6.7718*** (1.2245)	-13.4371*** (1.1306)	-9.4160*** (1.0404)	-10.3316*** (1.0168)	-10.6856*** (1.0390)	-10.6998*** (1.0537)	-10.4419*** (1.0159)	-11.3780*** (1.0630)	-17.0458*** (1.3519)	-12.1225*** (1.0837)	-6.4700*** (1.3724)	-14.1263*** (1.6668)	-11.3207*** (1.4786)	-10.6692*** (1.0952)	-9.9158*** (1.1103)	-12.9140*** (1.6121)	-9.7369*** (1.1021)
Observations	1,902	1,745	1,765	1,394	1,812	1,902	1,902	1,898	1,791	1,902	1,879	1,879	1,879	1,264	1,264	1,264	1,604	1,601	1,601	1,509

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

Finally, figure 4.4 shows the distributions of estimated propensity scores before and after the matching process (left and right, respectively). Before matching, common support appears to be quite high, but the graph shows that treated units with high propensity scores may not be matched due to the small number of nearby control units. After matching, the propensity score distribution in the treated and untreated group is similar, proving that treated units were indeed matched with untreated units with similar propensity scores in our matches. Given that we have this graphical evidence that our results are not biased by matching, we can safely move on to analyze the results.

Figure 4.4: Common support before and after matching



Source: Author's elaboration

Table 4.2: Debt-for-nature swaps and fiscal policy volatility—Baseline results

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Fiscal policy volatility	Matching			r=0.045	r=0.09	r=0.18	Matching	Matching
Baseline								
ATT	-0.2293*** (0.0674)	-0.2118*** (0.0523)	-0.2075*** (0.0560)	-0.1842*** (0.0413)	-0.1906*** (0.0407)	-0.2362*** (0.0383)	-0.1760*** (0.0391)	-0.1852*** (0.0392)
Observations	1,664	1,664	1,664	1,664	1,664	1,664	1,664	1,664
Treated Obs	570	570	570	570	570	570	570	570
Untreated Obs	1,094	1,094	1,094	1,094	1,094	1,094	1,094	1,094
Matching Quality								
Pseudo-R ²	0.008	0.008	0.009	0.009	0.009	0.013	0.008	0.009
Rosenbaum bounds sensitivity test	1.65	2.05	2.2	2.6	2.2	2.55	2.5	2.6
Standardized bias (p-value)	0.157	0.117	0.072	0.064	0.069	0.007	0.157	0.066

Notes: Bootstrapped standard errors based on 50 replications in brackets. *** p<0.01, ** p<0.05, * p<0.1.

4.6.2 The results from matching, ATT

As mentioned above, we have perfect confidence in the quality of the estimate based on the results of Table 4.2 (matching quality) and Figure 4.3 (common support). Based on this information, Table 4.2 presents the average effect of treatment in treated countries (ATT) of the adoption of debt-for-nature swaps on fiscal policy volatility in countries that have benefited from debt-for-nature swaps (DNS) compared to non-recipient countries (non-DNS). First, we report the estimation results from nearest-neighbor matching ($N=1$, $N=2$, and $N=3$), followed by the radius matching ($r = 0.045$, $r = 0.09$ and $r = 0.18$) in the first three columns. Then, in the next three columns, we report those of kernel matching and local linear regression matching in the last two columns. It should be noted that no choice is imposed in the literature regarding the choice of matching algorithms. However, we choose our algorithms based on recent studies such as Traore et al. (2023); Chapel (2022); Sawadogo (2020); Apeti et al. (2023a), among others. It is possible that the PS estimation does not provide good variances. In this case, we judge the significance of the estimated coefficients using the bootstrap to calculate the variances (see Caliendo and Kopeinig, 2008). As the baseline results in Table 4.2 show, irrespective of the matching methods, the ATTs are negative and statistically significant at the 1% significance level: in other words, the adoption of DNS significantly reduces fiscal policy volatility on average in our sample of developing countries, whatever the given specification.

Moreover, the magnitude of this effect varies between -0.18 percentage points (for local linear regression matching) and up to (in absolute value) -0.24 percentage points (for last-radius matching), with an average of around 0.203 percentage points. These effects appear to be significant: for example, a country whose fiscal policy volatility is equal to the average value in our sample (around 1.3%, see Table D3) would see this volatility fall by around 20% (or 0.203 percentage points) after benefiting from DNS. In addition, this result supports the first group of theoretical arguments outlined above, by showing that in our sample, the fact that a country benefits from DNS significantly reduces the volatility of fiscal policy in beneficiary countries, on average, compared with non-beneficiary countries.

Contributing to the literature that documents various tools for establishing fiscal discipline by restricting the volatility of fiscal policy, our result corroborates with current efforts devoted to the search for mechanisms that limit not only fiscal debauchery, but also government discre-

tion in fiscal matters. In contrast to the various studies on the determinants of fiscal discipline, which range from various forms of political institutions to fiscal rules and even constraints on monetary policy, the handle of our analysis unveils a new strategy that frees up fiscal space for individual countries — in the form of debt-for-nature swaps — in order to combat fiscal discretion and thus enable more effective and optimal financing of climate change policies in developing countries.

4.7 Robustness checks

Our baseline result shows that the adoption of debt-for-nature swaps significantly reduces fiscal policy volatility in the beneficiary developing countries compared with the non-recipient countries in our sample. This result may be affected by certain biases that escape our basic specification. Firstly, it is important to note that this result is obtained in a model that tests the assumptions of the propensity score matching model, whose coefficients cannot be interpreted as mean effects (1st order moment). Secondly, although the common support hypothesis is confirmed by pseudo- R^2 values close to zero and Figure 4.1, while the conditional independence hypothesis is supported by sensitivity tests at Rosenbaum bounds well above 1 (with regard to unobservable variables) and by standardized bias p-values above the usual significance levels (with regard to observable variables), other confounding or unobservable factors may affect our results. For the above reasons, we perform a series of robustness tests to ensure that debt-for-nature swaps do not have a negative impact on fiscal policy volatility in developing countries.

4.7.1 Alternative measures of fiscal policy volatility

We begin our robustness series exercise with alternative measurements of our dependent variable, fiscal policy volatility. First, we recall that in our main estimates we calculate the volatility of fiscal policy on the basis of public consumption expenditure following Apeti et al. (2023a). Using several measures, this allows us to grasp the complex and multifaceted concept of fiscal policy volatility, as explained above. Therefore, in addition to public consumption expenditure, we use total public spending (net of interest payments) to calculate fiscal policy volatility in the first instance. Next, we go beyond public spending and calculate the volatility of fiscal policy using tax revenues as a percentage of GDP. Third, we follow Afonso and

Jalles (2020), and calculate fiscal policy volatility using the standard deviation of the cyclically-adjusted balance (CAB). Finally, we conclude by using the fiscal balance as a percentage of GDP in the calculation of fiscal policy volatility. The new ATTs estimates reported in lines ([1]-[4]) of Table 4.3 are consistent with our baseline results: benefiting from debt-for-nature swaps significantly reduces fiscal policy volatility, regardless of how the latter is calculated, i.e. on the basis of different types of government expenditure, tax revenue, the cyclically-adjusted balance, or fiscal balance.

Finally, it is useful to characterize the magnitude of these effects. According to lines [1]-[4], the estimated ATT averages around -0.50, -0.25, -0.27 and -0.59 when fiscal policy volatility is captured by total government expenditure, government consumption, tax revenues, and the cyclically adjusted primary balance, respectively. These results are consistent with our basic findings that the average reduction in fiscal policy volatility (calculated based on real public consumption) after a country has benefited from debt-for-nature swaps is around 20% compared to the average value in our sample.

Table 4.3: Debt-for-nature swaps and fiscal policy volatility: alternative measures of fiscal policy volatility

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Fiscal policy volatility	Matching			r=0.045	r=0.09	r=0.18	Matching	Matching
Alternative measures of fiscal policy volatility: total government expenditure in % of GDP								
[1] ATT	-0.5381*** (0.1169)	-0.5134*** (0.1028)	-0.4707*** (0.1203)	-0.4788*** (0.0733)	-0.4823*** (0.0807)	-0.5396*** (0.0771)	-0.4692*** (0.0824)	-0.4755*** (0.0852)
Observations	1,394	1,394	1,394	1,394	1,394	1,394	1,394	1,394
Treated Obs	488	488	488	488	488	488	488	488
Untreated Obs	570	570	570	570	570	570	570	570
Alternative measures of fiscal policy volatility: tax revenues in % of GDP								
[2] ATT	-0.2735* (0.1506)	-0.2849** (0.1312)	-0.3101*** (0.1098)	-0.2116*** (0.0817)	-0.2134** (0.0846)	-0.3105*** (0.0886)	-0.2185*** (0.0711)	-0.2073** (0.0913)
Observations	1,394	1,394	1,394	1,394	1,394	1,394	1,394	1,394
Treated Obs	488	488	488	488	488	488	488	488
Untreated Obs	906	906	906	906	906	906	906	906
Alternative measures of fiscal policy volatility: the cyclically-adjusted balance in % of GDP								
[3] ATT	-0.2365 (0.1735)	-0.2011 (0.1379)	-0.2138 (0.1355)	-0.2370** (0.1000)	-0.2980** (0.1374)	-0.4829*** (0.1039)	-0.2566*** (0.0892)	-0.2364** (0.0929)
Observations	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407
Treated Obs	557	557	557	557	557	557	557	557
Untreated Obs	850	850	850	850	850	850	850	850
Alternative measures of fiscal policy volatility: fiscal balance in % of GDP								
[4] ATT	-0.5580*** (0.1430)	-0.5286*** (0.1877)	-0.5665*** (0.1283)	-0.5774*** (0.0895)	-0.6139*** (0.0952)	-0.7133*** (0.0863)	-0.5986*** (0.0968)	-0.5809*** (0.0971)
Observations	1,859	1,859	1,859	1,859	1,859	1,859	1,859	1,859
Treated Obs	580	580	580	580	580	580	580	580
Untreated Obs	1,279	1,279	1,279	1,279	1,279	1,279	1,279	1,279

Notes: Bootstrapped standard errors based on 50 replications in brackets. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.7.2 Alternative sample and additional controls

Having used several alternative measures of fiscal policy volatility, we now proceed to a broader modification of our overall sample. We do this in two ways (exclusion of observation and inclusion of the control variable). The economic literature has not remained on the sidelines when it comes to the effect of economic crises on fiscal policy. The economic literature has not remained on the sidelines when it comes to the effect of economic crises on fiscal policy. Indeed, studies have concluded that episodes of sovereign default, overindebtedness, and public debt restructuring are associated with a prolonged period of mediocre growth (Reinhart et al., 2012; Reinhart and Rogoff, 2011, 2013; Reinhart et al., 2003; Reinhart and Trebesch, 2016), which has a significant impact on fiscal policy. Moreover, given that monetary and fiscal policy are closely linked (Sims, 2004), authors such as Reinhart and Rogoff (2013), show that banking crises weaken fiscal positions, invariably contract public revenues and increase central government debt by around 86% three years after the crisis. Next, following Sheikh (2018); Lane and Milesi-Ferretti (2012); Reinhart and Rogoff (2008); Gorton and Metrick (2012); Aizenman and Noy (2013); Berkmen et al. (2012), countries with financial systems featuring higher levels

of indebtedness and credit growth are those where downward revisions to GDP growth rates and the greatest impact on trade volume reduction are highest during the 2008 financial crisis. We take these considerations into account by excluding all observations of crises, including periods of hyperinflation when the inflation rate exceeded a threshold of 500% (Reinhart and Rogoff, 2004). Finally, we exclude countries that have recently benefited from debt-for-nature swaps because of the potential time lag between reforms and their expected effects. The results of these tests compiled in lines [1]-[9] of Table 4.4 show the consistency of our findings with these different specifications.

Based on the literature on debt-for-nature swaps and fiscal policy volatility, we then test the robustness of our results using a set of additional control variables. These variables cover a wide range of characteristics that we conceptually group into three main clusters: **i- economic variables**: trade openness (% GDP), total debt service, government revenue (% GDP), financial openness, inflation targeting, rich-resource, FDI (% GDP), resource rents (% GDP), and fiscal rules; **ii- climate considerations**: disasters index, economic structure index, exposure index, natural shock index, climatic vulnerability score; **iii- political and institutional conditions**: rule of law, political stability, control corruption, government stability, internal conflict, and external conflict. We calculate a synthetic index for each category following Anderson (2008), and then lagged each index by one period for reasons of reverse causality.

Lines [1]-[20] of Table 4.6, which report the results of these specifications, show their consistency with our baseline findings. In other words, adding these additional covariates does not alter our results. Finally, we augment our baseline model by adding these additional control variables by category group. The results presented in Table 4.5 support those reported earlier: debt-for-nature swaps reduce fiscal policy volatility.

Table 4.4: Debt-for-nature swaps and fiscal policy volatility: Excluding year-observations

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Fiscal policy volatility	Matching			r=0.045	r=0.09	r=0.18	Matching	Matching
Excluding observations								
[1] ATT : Debt restructuring episode	-0.1637** (0.0752)	-0.2066*** (0.0609)	-0.2258*** (0.0576)	-0.1918*** (0.0328)	-0.1992*** (0.0384)	-0.2469*** (0.0332)	-0.1835*** (0.0404)	-0.1925*** (0.0336)
Observations	1,601	1,601	1,601	1,601	1,601	1,601	1,601	1,601
[2] ATT : Banking crisis episode	-0.1720*** (0.0614)	-0.2020*** (0.0610)	-0.1987*** (0.0625)	-0.1906*** (0.0400)	-0.1938*** (0.0440)	-0.2385*** (0.0362)	-0.1778*** (0.0407)	-0.1897*** (0.0382)
Observations	1,643	1,643	1,643	1,643	1,643	1,643	1,643	1,643
[3] ATT : Systemic crisis episode	-0.2119*** (0.0676)	-0.1900*** (0.0670)	-0.2003*** (0.0526)	-0.1930*** (0.0456)	-0.1957*** (0.0442)	-0.2399*** (0.0393)	-0.1805*** (0.0361)	-0.1922*** (0.0410)
Observations	1,643	1,643	1,643	1,643	1,643	1,643	1,643	1,643
[4] ATT : Debt default crisis episode	-0.2402*** (0.0627)	-0.2091*** (0.0621)	-0.2042*** (0.0565)	-0.1907*** (0.0377)	-0.1934*** (0.0342)	-0.2365*** (0.0394)	-0.1789*** (0.0347)	-0.1891*** (0.0431)
Observations	1,608	1,608	1,608	1,608	1,608	1,608	1,608	1,608
[5] ATT : Currency crisis episode	-0.2179*** (0.0650)	-0.2011*** (0.0694)	-0.2062*** (0.0620)	-0.2132*** (0.0483)	-0.2186*** (0.0378)	-0.2613*** (0.0341)	-0.2029*** (0.0383)	-0.2136*** (0.0369)
Observations	1,612	1,612	1,612	1,612	1,612	1,612	1,612	1,612
[6] ATT : Inflation crisis episode	-0.2436*** (0.0769)	-0.2200*** (0.0490)	-0.2552*** (0.0547)	-0.1931*** (0.0503)	-0.1961*** (0.0390)	-0.2383*** (0.0333)	-0.1824*** (0.0384)	-0.1926*** (0.0427)
Observations	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641
[7] ATT : Financial crisis (2008-2009)	-0.2210*** (0.0796)	-0.2383*** (0.0746)	-0.2292*** (0.0554)	-0.1911*** (0.0330)	-0.1987*** (0.0377)	-0.2425*** (0.0402)	-0.1813*** (0.0373)	-0.1909*** (0.0356)
Observations	1,479	1,479	1,479	1,479	1,479	1,479	1,479	1,479
[8] ATT : Hyperinflation episode	-0.2228*** (0.0685)	-0.2510*** (0.0624)	-0.2327*** (0.0621)	-0.1997*** (0.0428)	-0.2038*** (0.0382)	-0.2454*** (0.0397)	-0.1865*** (0.0461)	-0.1997*** (0.0301)
Observations	1,574	1,574	1,574	1,574	1,574	1,574	1,574	1,574
[9] ATT : New debt-for nature swaps	-0.2026*** (0.0699)	-0.1853*** (0.0509)	-0.1777*** (0.0560)	-0.1713*** (0.0350)	-0.1787*** (0.0325)	-0.2204*** (0.0443)	-0.1647*** (0.0334)	-0.1710*** (0.0330)
Observations	1,575	1,575	1,575	1,575	1,575	1,575	1,575	1,575

Notes: Bootstrapped standard errors based on 50 replications in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Table 4.5: Debt-for-nature swaps and fiscal policy volatility: control variables by group

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Fiscal policy volatility	Matching			r=0.045	r=0.09	r=0.18	Matching	Matching
Adding control variables by category								
[1] ATT : Economic variables	-0.2267*** (0.0561)	-0.2096*** (0.0658)	-0.2121*** (0.0593)	-0.1878*** (0.0338)	-0.1927*** (0.0384)	-0.2384*** (0.0330)	-0.1765*** (0.0401)	-0.1872*** (0.0324)
Observations	1,664	1,664	1,664	1,664	1,664	1,664	1,664	1,664
[2] ATT : Climate considerations	-0.1215* (0.0720)	-0.1385** (0.0624)	-0.1558*** (0.0519)	-0.1620*** (0.0360)	-0.1691*** (0.0326)	-0.2132*** (0.0406)	-0.1535*** (0.0345)	-0.1629*** (0.0400)
Observations	1,624	1,624	1,624	1,624	1,624	1,624	1,624	1,624
[3] ATT : Political and institutional conditions	-0.1650** (0.0714)	-0.1756*** (0.0499)	-0.1626*** (0.0526)	-0.1940*** (0.0397)	-0.1998*** (0.0405)	-0.2401*** (0.0406)	-0.1833*** (0.0380)	-0.1939*** (0.0394)
Observations	1,645	1,645	1,645	1,645	1,645	1,645	1,645	1,645

Notes: Bootstrapped standard errors based on 50 replications in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Table 4.6: Debt-for-nature swaps and fiscal policy volatility: control variables

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Fiscal policy volatility	Matching	Matching	Matching	r=0.045	r=0.09	r=0.18	Matching	Matching
Adding control variables								
[1] ATT : Lag trade openness	-0.2244*** (0.0634)	-0.2152*** (0.0572)	-0.1993*** (0.0540)	-0.1835*** (0.0447)	-0.1900*** (0.0377)	-0.2344*** (0.0349)	-0.1763*** (0.0375)	-0.1829*** (0.0370)
Observations	1,662	1,662	1,662	1,662	1,662	1,662	1,662	1,662
[2] ATT : Lag total debt service	-0.1813** (0.0774)	-0.1813** (0.0752)	-0.1696** (0.0709)	-0.1957*** (0.0497)	-0.2004*** (0.0446)	-0.2351*** (0.0394)	-0.1847*** (0.0459)	-0.1966*** (0.0403)
Observations	1,556	1,556	1,556	1,556	1,556	1,556	1,556	1,556
[3] ATT : Lag government revenue	-0.1839** (0.0776)	-0.1631*** (0.0627)	-0.1450** (0.0586)	-0.1399*** (0.0423)	-0.1491*** (0.0459)	-0.1768*** (0.0415)	-0.1403*** (0.0406)	-0.1404*** (0.0406)
Observations	1,251	1,251	1,251	1,251	1,251	1,251	1,251	1,251
[4] ATT : Lag financial openness	-0.2692*** (0.0662)	-0.1776*** (0.0616)	-0.1643*** (0.0547)	-0.1654*** (0.0402)	-0.1568*** (0.0421)	-0.1853*** (0.0393)	-0.1631*** (0.0382)	-0.1640*** (0.0421)
Observations	1,589	1,589	1,589	1,589	1,589	1,589	1,589	1,589
[5] ATT : Inflation targeting	-0.1477* (0.0847)	-0.1569** (0.0639)	-0.1659*** (0.0572)	-0.1648*** (0.0413)	-0.1744*** (0.0482)	-0.2192*** (0.0331)	-0.1626*** (0.0406)	-0.1648*** (0.0401)
Observations	1,664	1,664	1,664	1,664	1,664	1,664	1,664	1,664
[6] ATT : Rich-resource	-0.1909*** (0.0638)	-0.1917*** (0.0643)	-0.1866*** (0.0633)	-0.2007*** (0.0368)	-0.2142*** (0.0368)	-0.2556*** (0.0439)	-0.1955*** (0.0456)	-0.1991*** (0.0344)
Observations	1,664	1,664	1,664	1,664	1,664	1,664	1,664	1,664
[7] ATT : Lag FDI	-0.2303*** (0.0529)	-0.2114*** (0.0514)	-0.2263*** (0.0602)	-0.1921*** (0.0366)	-0.1963*** (0.0365)	-0.2393*** (0.0400)	-0.1804*** (0.0366)	-0.1917*** (0.0451)
Observations	1,662	1,662	1,662	1,662	1,662	1,662	1,662	1,662
[8] ATT : Resources rents	-0.1073** (0.0546)	-0.1089* (0.0603)	-0.1375** (0.0562)	-0.1207*** (0.0385)	-0.1298*** (0.0396)	-0.1710*** (0.0351)	-0.1153*** (0.0347)	-0.1220*** (0.0340)
Observations	1,664	1,664	1,664	1,664	1,664	1,664	1,664	1,664
[9] ATT : Fiscal rules	-0.1598** (0.0720)	-0.2368*** (0.0700)	-0.2183*** (0.0634)	-0.2082*** (0.0459)	-0.1809*** (0.0465)	-0.1872*** (0.0382)	-0.2286*** (0.0355)	-0.1709*** (0.0414)
Observations	1,645	1,664	1,664	1,664	1,664	1,664	1,664	1,664
[10] ATT : Rule of law	-0.1598*** (0.0618)	-0.1871*** (0.0534)	-0.1883*** (0.0623)	-0.1874*** (0.0429)	-0.1939*** (0.0384)	-0.2359*** (0.0376)	-0.1778*** (0.0388)	-0.1893*** (0.0310)
Observations	1,645	1,645	1,645	1,645	1,645	1,645	1,645	1,645
[11] ATT : Political stability	-0.2045** (0.0865)	-0.2040*** (0.0614)	-0.1875*** (0.0559)	-0.1796*** (0.0487)	-0.1825*** (0.0402)	-0.2148*** (0.0351)	-0.1659*** (0.0506)	-0.1791*** (0.0435)
Observations	1,645	1,645	1,645	1,645	1,645	1,645	1,645	1,645
[12] ATT : Control corruption	-0.1944*** (0.0714)	-0.2374*** (0.0517)	-0.2277*** (0.0603)	-0.1785*** (0.0452)	-0.1842*** (0.0424)	-0.2261*** (0.0387)	-0.1669*** (0.0454)	-0.1803*** (0.0367)
Observations	1,645	1,645	1,645	1,645	1,645	1,645	1,645	1,645
[13] ATT : Government stability	-0.1939** (0.0774)	-0.2002** (0.0780)	-0.2275*** (0.0711)	-0.2208*** (0.0735)	-0.2389*** (0.0626)	-0.2759*** (0.0452)	-0.2098*** (0.0729)	-0.2215*** (0.0607)
Observations	1,104	1,104	1,104	1,104	1,104	1,104	1,104	1,104
[14] ATT : Internal conflict	-0.1702* (0.0898)	-0.2077* (0.1183)	-0.2141*** (0.0772)	-0.2041*** (0.0715)	-0.2192*** (0.0622)	-0.2620*** (0.0552)	-0.1824*** (0.0534)	-0.2043*** (0.0578)
Observations	1,104	1,104	1,104	1,104	1,104	1,104	1,104	1,104
[15] ATT : External conflict	-0.4979*** (0.1230)	-0.3801*** (0.1108)	-0.3831*** (0.1066)	-0.3664*** (0.0758)	-0.3567*** (0.0672)	-0.3550*** (0.0581)	-0.3486*** (0.0724)	-0.3653*** (0.0772)
Observations	1,104	1,104	1,104	1,104	1,104	1,104	1,104	1,104
[16] ATT : Disasters index	-0.1967*** (0.0631)	-0.1664*** (0.0669)	-0.1657*** (0.0516)	-0.1504*** (0.0486)	-0.1622*** (0.0469)	-0.2060*** (0.0436)	-0.1454*** (0.0492)	-0.1505*** (0.0431)
Observations	1,391	1,391	1,391	1,391	1,391	1,391	1,391	1,391
[17] ATT : Economic structure index	-0.1269 (0.0785)	-0.1504** (0.0671)	-0.1304** (0.0581)	-0.1158*** (0.0438)	-0.1189*** (0.0407)	-0.1646*** (0.0446)	-0.1051** (0.0442)	-0.1143** (0.0493)
Observations	1,388	1,388	1,388	1,388	1,388	1,388	1,388	1,388
[18] ATT : Exposure index	-0.1678** (0.0712)	-0.1449* (0.0811)	-0.1867** (0.0904)	-0.1732*** (0.0605)	-0.1982*** (0.0569)	-0.2389*** (0.0533)	-0.1805*** (0.0502)	-0.1750*** (0.0597)
Observations	1,388	1,388	1,388	1,388	1,388	1,388	1,388	1,388
[19] ATT : Natural shock index	-0.1554* (0.0834)	-0.1032 (0.0659)	-0.1139* (0.0647)	-0.1285*** (0.0456)	-0.1358*** (0.0461)	-0.1837*** (0.0449)	-0.1248*** (0.0477)	-0.1268** (0.0501)
Observations	1,308	1,308	1,308	1,308	1,308	1,308	1,308	1,308
[20] ATT : Climatic vulnerability score	-0.0595 (0.0601)	-0.1011** (0.0499)	-0.1004* (0.0513)	-0.0920** (0.0415)	-0.1098*** (0.0410)	-0.1546*** (0.0399)	-0.0951** (0.0397)	-0.0908** (0.0389)
Observations	1,470	1,470	1,470	1,470	1,470	1,470	1,470	1,470

Notes: Bootstrapped standard errors based on 50 replications in brackets. *** p<0.01, ** p<0.05, * p<0.1.

4.7.3 Alternative estimation methods

So far, our results show that debt-for-nature swaps reduce fiscal policy volatility in beneficiary developing countries, results obtained using the propensity score matching method. However, the PSM method has been the subject of serious criticism in the literature, not least because of the propensity score paradox. This paradox implies that this method mimics a completely randomized experiment (King and Nielsen, 2019). We further test the robustness of our results using several alternative methods to reinforce the quality of our results.

Entropy balancing method. We re-estimate our base model using a very sophisticated

impact estimation method, the entropy balancing method proposed by Hainmueller (2012). Entropy balancing allows us to identify the effect of debt-for-nature swaps by comparing debt-for-nature swaps and non-debt-for-nature swaps countries (or units) that are similar in terms of observable characteristics. In addition, this method offers certain advantages over competing impact analysis methods, such as propensity score matching (PSM) or difference-in-differences (Hainmueller, 2012). We can highlight three advantages that distinguish this method. Firstly, this method allows for a high degree of balance between the treatment and control groups by creating a synthetic group as close to the treatment group as possible, thus eliminating self-selection bias in the sample. Secondly, unlike other impact analysis methods, such as PSM, it does not require an empirical model for the adoption of debt-for-nature swaps, thus limiting specification and multicollinearity problems. Third, unlike conventional matching methods, entropy balancing uses a more flexible reweighting approach, keeping the weights closer to the base weights to avoid loss of information. Entropy balancing requires two steps. The first is to calculate the weights of the control group (untreated group) so that they satisfy predefined equilibrium constraints. The second step uses the weights from the first step in a regression analysis where fiscal policy volatility is the dependent variable, and debt-for-nature swaps are the main explanatory variable. The result of the estimation presented in column [1] of Table 4.7 shows that DNS adoption significantly reduces the volatility of fiscal policy in DNS relative to non-DNS countries.

Coarsened exact matching. Next, we test the robustness of our results using a second impact estimation method, coarsened exact matching. Indeed, the coarsened exact matching method has many advantages. Firstly, it has the power to sort all observations into strata, each with identical values for all covariates prior to treatment, and then discard all observations within a stratum that do not have at least one observation for each unique value of the treatment variable (Iacus et al., 2012; Blackwell et al., 2009; Iacus et al., 2009). Secondly, the coarsened exact matching method has the ability to limit both the error in estimating the mean treatment effect and the degree of model dependence. Finally, the coarsened exact matching complies with the congruence principle, which stipulates that the data space and the analysis space must be identical. In fact, methods that do not respect this principle often produce strange or counter-intuitive results. It goes even beyond the principle of convergence by automatically restricting matched data to domains with common empirical support (King

and Zeng, 2006). The results in columns [2] of Table 4.7 present conclusions similar to our baseline finding: debt-for-nature swaps reduce the volatility of fiscal policy.

IPW method. In addition, we use the IPW (Inverse Probability Weighting) estimator as an identification strategy to reinforce the robustness of our results. Indeed, although estimating ATTs from propensity scores matching allows us to correct for the potential self-selection bias in policy adoption, as explained above, this estimator may have limitations, particularly in the presence of a significant lack of data. The IPW estimator uses propensity scores to give more weight to observations that are similar to each other in their observable characteristics, enabling good matching even in the presence of missing data. The results of the estimates are reported in Table 4.7, columns [3]-[4]. Our results are robust to the use of this estimation method, insofar as the new ATTs are qualitatively comparable to those of the baseline model obtained from the matching of propensity scores (see Table 4.2).

Moment higher order (variance)/Mahalanobis distance matching. So far, the methods used have only allowed us to determine the average effect, the moment of order 1 (mean). We test the robustness of our results using second-order moments (variance). The Mahalanobis distance method was developed to correct the shortcomings of the propensity score matching method (see, King and Nielsen, 2019). The handle of this method is that it compares each treated unit to the nearest control unit in terms of estimated Mahalanobis distance, and it does not suffer from the problems associated with imitating a completely randomized experiment. The new ATTs reported in Table 4.7, columns [5], and [6] are in perfect harmony with our baseline results (see Table 4.2).

OLS estimates. We test the robustness of our results using the Ordinary Least Squares (OLS). The results reported in column [7] of Table 4.7 suggest a negative and significant effect of debt-for-nature swaps on the volatility of fiscal policy, with a magnitude of approximately 0.204 percentage points, qualitatively comparable to that of the main model (20% percentage points on average).

Difference-in-Differences estimators. We use this method to resolve certain nuances in our sample. First, the timing of DNS adoption varies from country to country, which means that some countries may end up as treated in one part of our sample and as controls in other parts. Secondly, in our dataset, once countries have benefited from a debt-for-nature agree-

ment, they remain with debt-for-nature in subsequent periods, as the maturity of debt-for-nature for debtor countries is negotiated according to the debt service payment schedule, this extends beyond the last observation period of the panel (the year 2020). This is a proof of the presence of «staggered adoption» in our sample. Third, there could be an endogeneity of debt-for-nature variables, as countries with high climate vulnerability may face a higher risk premium for borrowing on the market and, consequently, may resort to resource-backed loans. To circumvent these issues, which could have a considerable effect on our results, we resort to a semi-parametric approach as an alternative estimation method. We use the difference-in-difference (DiD) estimator for staged adoption developed by Callaway and Sant’Anna (2021) to address the potential endogeneity problem of debt-for-nature (Bertrand et al., 2004; Meyer, 1995). This difference-in-differences estimator bypasses the problem of negative weights and, therefore, the endogeneity problem, and takes into account the heterogeneity and dynamics of treatment effects (Callaway and Sant’Anna, 2021). Following Callaway and Sant’Anna (2021), we estimate a different type of DiD estimate in the context of adoption of a staggered treatment: a regression based on the inverse probability weighting (Abadie, 2005). We recall that in the regression we consider using observations never treated and those not yet treated as a control group (Athey and Imbens, 2006; De Chaisemartin and d’Haultfoeuille, 2018). Table 4.8, column [1] presents the full sample result based on the stabilized inverse probability weighting (IPW). In column [2], we disaggregate our sample by treatment group, while column [3] presents the estimation results by Calendar Period. The results indicate that the overall ATT is negative and statistically insignificant. However, the disaggregated effects are negative and statistically significant, suggesting that the main results of the article remain unchanged when the «staggered adoption» problem is taken into account.

GMM estimates. Fiscal policy volatility can have a significant dynamic effect, which is not taken into account in the static models carried out to date. Consequently, we rely on the two-stage system-GMM dynamic panel estimator proposed by Blundell and Bond (1998), which controls for the persistence of fiscal policy volatility, while taking into account the Nickell bias (Nickell, 1981). Its advantage is that it combines equations in levels and first differences and uses lagged differences and levels of explanatory variables as instruments to mitigate endogeneity problems. The results show a positive and statistically significant effect of the lagged variable of fiscal policy volatility (not presented in the Table 4.7 but available on

request), which corroborates the hypothesis of the dynamic effect of fiscal policy volatility. In addition, the coefficient of the interest variable shows a negative and statistically significant effect of debt-for-nature swaps on fiscal policy volatility, of a magnitude comparable to that obtained with propensity score matching (see Table 4.2), confirming our baseline conclusions.

Instrumental variable estimates. Finally, following Sommer et al. (2020), we provide estimates using the instrumental variable estimator. This method is appropriate and effective because it uses an external instrument for the suspected endogenous variable. In our case, the debt-for-nature variable is suspected to be endogenous due to the fact that donor selection bias on the debt-for-nature variable can lead to distorted coefficients and ineffective statistical significance tests (Easterly, 2006b). For external instruments, we use the climatic vulnerability score and engagement in international environmental conventions. Indeed, climatic vulnerability score and engagement in international environmental conventions should affect the probability of benefiting from a debt-for-nature, without having any direct effect on fiscal policy volatility. Consequently, the climate vulnerability score and participation in international environmental conventions could be good (but not perfect) candidates as instrumental variables for debt-for-nature swaps. We present the results in Table 4.7, column [9]. The main result of the study remains qualitatively unchanged when we use the IV-2SLS method. Debt-for-nature has a negative impact on fiscal policy volatility.

Table 4.7: Debt-for-nature and fiscal policy volatility: alternative estimation methods

Panel A	[1] Entropy balancing	[2] Coarsened exact matching	[3] IPW method	[4] IPWRA method	[5] 2nd-order moments (variance) method	[6] Mahalanobis distance matching	[7] OLS standard	[8] System-GMM method	[9] IV-2SLS method
DNS adoption	-0.1826*** (0.0363)								
DNS adoption		-0.1866*** (0.0497)							
DNS adoption			-0.1486*** (0.0375)						
DNS adoption				-0.1486*** (0.0369)					
DNS adoption					-0.1358*** (0.0376)				
DNS adoption						-0.2112*** (0.0629)			
DNS adoption							-0.2035*** (0.0421)		
DNS adoption								-0.3351*** (0.0614)	
DNS adoption									-1.0966*** (0.3384)
Observations	1,664	1,664	1,664	1,664	1,664	1,664	1,664	1,651	1,470
Country/FE	Yes	Yes			Yes		Yes	Yes	Yes
Year/FE	Yes	Yes			Yes		Yes	Yes	Yes
Number of countries								105	134
Number of instruments								54	2
AR(1) test, p-value								0.00	
AR(2) test, p-value								0.10	
Hansen, p-value								0.74	0.17
Kleibergen-Paap LM test, p-value									0.00

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

Table 4.8: Debt-for-nature and fiscal policy volatility: Diff-in-Diff results

	[1]	[2]	[3]
	ATT full sample	ATT by group	ATT by Calendar Period
ATT	-0.1012 (0.0662)	-0.0992** (0.0485)	-0.1195*** (0.0303)
Covariates	Yes	Yes	Yes
Observations	898	898	898

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

4.7.4 Placebo test

Our results suggest that benefiting from debt relief through debt-for-nature has a negative and significant effect on fiscal policy volatility. The robustness tests carried out so far confirm our findings. In Table 4.9, we perform falsification tests. Specifically, we perform a random assignment to treatment in the treated countries, taking into account false adoption dates. Our intuition is that, if the effects obtained are due to debt-for-nature swaps, the use of placebo dates will lead to statistically insignificant effects. This process was repeated 50 times. Indeed, random assignment to treatment does not result in significant effects, as we can see in Table 4.9, suggesting that our results are not due to confounding factors, which reinforces the robustness of our conclusions. This indicates that the baseline regression successfully passed the placebo test and that our results are not affected by a confounding factor.

Table 4.9: Threats to identification : Falsification tests

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Fiscal policy volatility	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
ATT	0.0315 (0.2708)	-0.0343 (0.2061)	0.0298 (0.2504)	-0.1529 (0.1428)	-0.2154 (0.1394)	-0.2154 (0.1976)	0.0618 (0.1635)	-0.1657 (0.1533)
Treated Obs	25	25	25	25	25	25	25	25
Untreated Obs	1,639	1,639	1,639	1,639	1,639	1,639	1,639	1,639
Observations	1,601	1,601	1,601	1,601	1,601	1,601	1,601	1,601

Notes: Bootstrapped standard errors based on 50 replications in brackets. *** p<0.01, ** p<0.05, * p<0.1.

4.8 Heterogeneity

Our results show that the adoption of debt-for-nature swaps reduces fiscal policy volatility. In this section, we test the sensitivity of the above results to the type of debt-for-nature swaps, the time perspective, the role of institutions, and certain structural factors.

4.8.1 Effect by type of swaps

Following AfDB (2022), we deaggregate the debt-for-nature swaps dummy into two major agreements: bilateral and multi-party. The aim of this exercise is to test the hypothesis that fiscal policy volatility would react differently depending on the debt-for-nature agreements considered. Indeed, bilateral debt-for-nature swaps can have an immediate and stronger effect on fiscal policy volatility than multi-party debt-for-nature swaps. In fact, the size of bilateral debt-for-nature agreements is greater (64% total debt cancellation),⁹ and they are based on fairly solid economic and political requirements. With regard to economic requirements, a debtor government must have reached debt service thresholds and demonstrate progress in implementing reforms involving an international Monetary Fund (IMF) or World Bank (WB) structural adjustment agreement (Sommer et al., 2020). In the political sphere, a debtor nation must have a democratically elected government and demonstrate its commitment to guaranteeing human rights. These measures, when respected, have an important effect on fiscal policy, in particular on the country's fiscal policy volatility. In a multiparty swap, the donor or intermediary offers to buy the debt from the creditors who currently hold it, at a substantial discount (AfDB, 2022). The results in Table 4.10 present the conclusions of this hypothesis. We find that only bilateral debt-for-nature swaps have a statistically significant negative effect on fiscal policy volatility, while multi-party debt-for-nature swaps have no significant effect.

As we have just explained, the negative and significant effect of bilateral debt-for-nature swaps is explained by the fact that they are largely based on the cancellation of public debt, whereas multi-party debt-for-nature swaps are negotiated on the basis of debt repurchase, which is discussed between several intermediaries.

Table 4.10: Heterogeneity: effects by type of swaps

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Fiscal policy volatility	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
[1] ATT : Bilateral	-0.1637** (0.0752)	-0.2066*** (0.0609)	-0.2258*** (0.0576)	-0.1918*** (0.0328)	-0.1992*** (0.0384)	-0.2469*** (0.0332)	-0.1835*** (0.0404)	-0.1925*** (0.0336)
Observations	1,601	1,601	1,601	1,601	1,601	1,601	1,601	1,601
[2] ATT : Multi-Party	0.0749 (0.0868)	0.0770 (0.0921)	0.0792 (0.0705)	0.0435 (0.0571)	0.0313 (0.0471)	0.0014 (0.0481)	0.0459 (0.0640)	0.0455 (0.0610)
Observations	1,483	1,483	1,483	1,483	1,483	1,483	1,483	1,483

Notes: Bootstrapped standard errors based on 50 replications in brackets. *** p<0.01, ** p<0.05, * p<0.1.

⁹see, Sommer et al. (2020).

4.8.2 The effect of debt-for-nature swaps over time

The effects obtained to date from the implementation of a debt-for-nature swaps program are a comparison of conditional efficiency averages in periods when debt-for-nature is in place versus periods when it is not. The effect taken into account in this chapter may have certain problems. In fact, the adoption of debt-for-nature can trigger a change in a country's economic, political, institutional, social, and climatic environment (Visser and Mendoza, 1994). In this sense, it can be argued that the effect captured may not be due to debt-for-nature, but to changes in institutional, political, social, economic, or even climatic conditions after benefiting from this debt relief program. Similarly, any other characteristic that may determine the adoption of debt-for-nature but is not included in the econometric specification, may be a source of endogeneity (Sommer et al., 2020). In addition, it is argued that debt relief savings are only realized gradually, depending on the contractual terms of the repayment and the timing of the underlying debt (Essers et al., 2021). To circumvent these problems, we test whether benefiting from a debt-for-nature swap has a persistent or temporary effect in this sub-section. To do this, we estimate the effect of debt-for-nature swaps over five years after adoption. This dynamic effect may allow isolating a potential time-lag separating the date of DNS adoption from its (significant) effect on fiscal policy volatility. The results in Table 4.11 for the five years ($t=1, 2, 3, 4, 5$) after adoption show that the effect of debt-for-nature swaps is persistent. This effect appears as soon as debt-for-nature swaps are adopted and increases over time to approach the (average) magnitude of our reference effect five years after the policy's adoption. In other words, a country that concludes a debt-for-nature swaps agreement should benefit immediately from robust effects compared to comparable countries that have not, suggesting that the benefits of debt-for-nature swaps in terms of reducing fiscal policy volatility do not require patience or time — the effect is immediate.

Table 4.11: Heterogeneity: dynamic effects

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Fiscal policy volatility	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
ATT1 (t+1)	-0.2293*** (0.0609)	-0.2118*** (0.0674)	-0.2075*** (0.0577)	-0.1842*** (0.0407)	-0.1906*** (0.0434)	-0.2362*** (0.0363)	-0.1760*** (0.0377)	-0.1852*** (0.0387)
Observations	1,664	1,664	1,664	1,664	1,664	1,664	1,664	1,664
ATT2 (t+2)	-0.1976** (0.0785)	-0.1807*** (0.0559)	-0.1821*** (0.0468)	-0.1477*** (0.0364)	-0.1544*** (0.0433)	-0.2054*** (0.0478)	-0.1398*** (0.0421)	-0.1466*** (0.0520)
Observations	1,483	1,483	1,483	1,483	1,483	1,483	1,483	1,483
ATT3 (t+3)	-0.2080*** (0.0707)	-0.1984** (0.0776)	-0.1942*** (0.0641)	-0.1541*** (0.0434)	-0.1588*** (0.0441)	-0.2128*** (0.0519)	-0.1456*** (0.0340)	-0.1539*** (0.0450)
Observations	1,394	1,394	1,394	1,394	1,394	1,394	1,394	1,394
ATT4 (t+4)	-0.1432** (0.0693)	-0.1780*** (0.0636)	-0.1793*** (0.0581)	-0.1645*** (0.0408)	-0.1766*** (0.0431)	-0.2282*** (0.0462)	-0.1597*** (0.0508)	-0.1663*** (0.0547)
Observations	1,302	1,302	1,302	1,302	1,302	1,302	1,302	1,302
ATT5 (t+5)	-0.1670** (0.0772)	-0.2202*** (0.0811)	-0.1913*** (0.0718)	-0.1873*** (0.0629)	-0.2007*** (0.0558)	-0.2479*** (0.0458)	-0.1821*** (0.0547)	-0.1867*** (0.0450)
Observations	1,211	1,211	1,211	1,211	1,211	1,211	1,211	1,211

Notes: Bootstrapped standard errors based on 50 replications in brackets. *** p<0.01, ** p<0.05, * p<0.1

4.8.3 The role of institutions

According to Llanto and Gonzalez (2007), institutions play an essential role in the conduct and effectiveness of economic policies. Given that one of the essential conditions to benefit from debt-for-nature swaps is to have a strong institution (Sommer et al., 2020), it can be argued that debt-for-nature swaps are more likely to be effective in countries with good institutions or those that have implemented solid institutional reforms. At the same time, successful DNS cases have been implemented in countries with weak governance, such as Belize and Colombia (see Nedopil et al., 2024). This means that the argument of institutional quality is not necessarily important for the effectiveness of DNS. We are now testing this hypothesis.

To do this, we re-estimate our main equation by distinguishing between different institutional quality. In a first step, we distinguish between loose and sound institutions based on the median value of the Polity 5 control of corruption. The results in Table 4.12, lines ([1]-[2]) show that debt-for-nature swaps reduce fiscal policy volatility regardless of the level of institutional quality. However, we note that the effect of debt-for-nature swaps on fiscal policy volatility is greater in the context of better institutional quality, i.e. a lower level of corruption. Second, we examine the role of democracy in more detail. Estimates on lines ([3]-[4]) of Table 4.12 show that in the context of a political regime led by a good democracy (captured by values above the median of the Teorell et al., 2016), democracy variable), the effect of debt-for-nature swaps on fiscal policy volatility is larger and statistically significant, regardless of the matching algorithm used, while the significant reduction in the volatility of fiscal policy is not sufficiently reinforced by a weak application of democracy whose significance starts at the radius matching (captured by democracy values below the median). Finally, we take a closer look at the impact of major changes in the institutions we capture through a popular measure, namely, government stability. Using the median of the sample, we show in lines ([5]-[6]) of Table 4.12 a greater effect of debt-for-nature swaps in the presence of strong government stability compared to a country with loose government stability. The results show that regardless of the level of institutional quality, debt-for-nature swaps are effective in reducing fiscal policy volatility. This is also in line with Freytag and Pehnelt (2009), who argue that debt relief does not necessarily depend on the quality of governance. This leads us to the conclusion that a DNS assessment is relevant in all types of economies.

Table 4.12: Heterogeneity: the role of institutions

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Fiscal policy volatility	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
[1] ATT: Loose institutions	-0.1737** (0.0829)	-0.1852** (0.0915)	-0.1651* (0.0985)	-0.1258** (0.0598)	-0.1078* (0.0587)	-0.1378** (0.0564)	-0.0924* (0.0500)	-0.1239** (0.0616)
Observations	732	732	732	732	732	732	732	732
[2] ATT: Sound institutions	-0.2084* (0.1168)	-0.1928** (0.0815)	-0.1983** (0.0966)	-0.2706*** (0.0638)	-0.2782*** (0.0646)	-0.3229*** (0.0570)	-0.2574*** (0.0585)	-0.2684*** (0.0801)
Observations	932	932	932	932	932	932	932	932
[3] ATT: Good democratic governance	-0.5974*** (0.1702)	-0.5047*** (0.1581)	-0.4748*** (0.1605)	-0.5589*** (0.1377)	-0.5741*** (0.0913)	-0.5370*** (0.0789)	-0.5966*** (0.1020)	-0.5519*** (0.1355)
Observations	601	601	601	601	601	601	601	601
[4] ATT: Poor democratic governance	-0.0776 (0.0916)	-0.0835 (0.0618)	-0.0831 (0.0665)	-0.0974** (0.0479)	-0.1111** (0.0444)	-0.1667*** (0.0449)	-0.1044** (0.0425)	-0.0980** (0.0461)
Observations	962	962	962	962	962	962	962	962
[5] ATT: Strong government stability	-0.2659*** (0.0871)	-0.2112** (0.0849)	-0.2217*** (0.0655)	-0.1902*** (0.0447)	-0.1931*** (0.0597)	-0.2450*** (0.0445)	-0.1840*** (0.0554)	-0.1888*** (0.0604)
Observations	1,140	1,140	1,140	1,140	1,140	1,140	1,140	1,140
[6] ATT: Loose government stability	-0.2084* (0.1253)	-0.1456 (0.0939)	-0.2002* (0.1041)	-0.1861*** (0.0716)	-0.1948*** (0.0638)	-0.2138*** (0.0577)	-0.1589* (0.0824)	-0.1825** (0.0867)
Observations	524	524	524	524	524	524	524	524

Notes: Bootstrapped standard errors based on 50 replications in brackets. *** p<0.01, ** p<0.05, * p<0.1

4.8.4 Combined debt-for-nature swaps with fiscal rules

In the spirit of Ter-Minassian (2010); Fatás and Mihov (2006) and Brzozowski and Siwińska-Gorzelak (2010), a well-designed and effectively implemented fiscal rule can help to reduce time inconsistencies in fiscal policy or reinforce the credibility of the government's commitment to fiscal sustainability. Similarly, FRs can help internalize the externality resulting from the fact that the beneficiaries of public spending do not fully internalize the cost borne by taxpayers (Wyplosz, 2012). We evaluated the effectiveness of debt-for-nature in the presence of these fiscal institutions. In line [1] of Table 4.13, we cross-reference our treatment variable with another binary variable (FR) equal to 1 if a fiscal rule is effective, for a given country, in a given year, and zero otherwise. The idea behind this interaction term is that we seek to capture the non-linear effect of the two variables (DNS and FRs), since debt-for-nature swaps and the FR are assumed to act non-linearly on fiscal policy volatility. The negative and economically significant average effects suggest that debt-for-nature swaps are more effective in reducing the volatility of fiscal policy when implemented in conjunction with fiscal rules, corroborated by the results of Brzozowski and Siwińska-Gorzelak (2010). This result can be explained by the positive effect of fiscal rules on fiscal discipline, which limits discretion in fiscal policy and promotes the effectiveness of public policies.

Given that not all types of FR are equally suited to support fiscal policy sustainability and economic stabilization as well as fiscal reforms, even when their characteristics are refined, we follow Combes et al. (2018a); Tapsoba (2012); Lledó et al. (2017); Debrun et al. (2008); Combes et al. (2017); etc, in considering other types of FR. First, we differentiate between budget balance rules (BBR), debt rules (DR), expenditure rules (ER), and revenue rules (RR). Second, following Tapsoba (2012), we differentiate between national and supranational fiscal rules and focus on national fiscal rules due to the problem of inadequate enforcement and compliance that suffer supranational rules in developing countries. The results in lines [4] and [5] are consistent with those of line [1], suggesting that debt and balanced budget rules appear to be complementary to debt-for-nature swaps. However, the joint effect of DNS and ER and RR is not significant (lines [2]-[3]). These results are not surprising, because, as Sawadogo (2020) has shown, both types of rules (BBR and DR) considerably improve access to financial markets, while expenditure rules (ER) do not, allowing the economy to recover through public

and private investment and maintaining macroeconomic stability. Furthermore, the insignificant coefficients of the interaction between DNS and RR could be explained by the difficulty of implementing RR in developing countries, while the insignificant effect of the DNS and ER interaction could be explained by the fact that expenditure rules would be restrictive for public investments, thus undermining the effectiveness of DNS, which is basically designed to finance public environmental investments.

Table 4.13: Heterogeneity: combined debt-for-nature swaps with fiscal rules

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Fiscal policy volatility	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
[1] DNS*FRs : ATT	-0.2891*** (0.0894)	-0.2861*** (0.0901)	-0.2743*** (0.0576)	-0.1993*** (0.0458)	-0.2015*** (0.0410)	-0.2662*** (0.0492)	-0.1739*** (0.0509)	-0.1981*** (0.0447)
Observations	1,664	1,664	1,664	1,664	1,664	1,664	1,664	1,664
[2] DNS*ER : ATT	-0.0492 (0.1120)	-0.0645 (0.0645)	-0.0438 (0.0692)	-0.0573 (0.0567)	-0.0814 (0.0628)	-0.1771 (0.0607)	-0.0384 (0.0473)	-0.0562 (0.0679)
Observations	1,664	1,664	1,664	1,664	1,664	1,664	1,664	1,664
[3] DNS*RR : ATT	-1.2607 (0.8644)	-1.1622 (0.6374)	-1.0643 (0.6472)	-0.9892 (0.4830)	-0.8371 (0.5663)	-0.1690 (0.4973)	-1.1888 (0.5667)	-0.9589 (0.5341)
Observations	838	838	838	838	838	838	838	838
[4] DNS*BBR : ATT	-0.1543 (0.1077)	-0.1957** (0.0844)	-0.2118*** (0.0806)	-0.2431*** (0.0486)	-0.2476*** (0.0404)	-0.3176*** (0.0377)	-0.2118*** (0.0446)	-0.2387*** (0.0670)
Observations	1,664	1,664	1,664	1,664	1,664	1,664	1,664	1,664
[5] DNS*DR : ATT	-0.5604*** (0.2112)	-0.4158** (0.1753)	-0.3749*** (0.1064)	-0.3574*** (0.0814)	-0.3403*** (0.0745)	-0.3381*** (0.0898)	-0.3708*** (0.0721)	-0.3569*** (0.0748)
Observations	1,664	1,664	1,664	1,664	1,664	1,664	1,664	1,664

Notes: Bootstrapped standard errors based on 50 replications in brackets. *** p<0.01, ** p<0.05, * p<0.1

4.8.5 Does debt viability matter?

Several studies have highlighted the level of indebtedness and solvency as quantitative criteria (relatively strict) to judge the suitability or effectiveness of debt-for-nature swaps (Lütkehermöller et al., 2021; Simmons et al., 2021; Steele and Patel, 2020; Warland et al., 2015). In other words, there could be considerable heterogeneity in the effectiveness of debt-for-nature swaps in reducing fiscal policy volatility between countries with sustainable debt levels and their peers with unsustainable debt levels. We test this hypothesis in this subsection. To do this, we use an indicator commonly used in debt sustainability analyses, namely international reserves as a ratio of short-term external debt¹⁰. This indicator simply shows whether reserves

¹⁰We could have used solvency or liquidity, but given their limitations, we preferred reserves. In fact, solvency compares the burden of debt with the resource base. This indicator is commonly used, but can be misleading. For example, a low debt-to-GDP ratio can coexist with a high debt-to-exports ratio if exports account for very little of GDP, while liquidity compares the debt burden with the country's ability to secure foreign exchange earnings. A debt-to-exports ratio that, for a given interest rate, increases over time implies that total debt is growing faster than the economy's main source of external income. This ratio is more accurate than the debt/GDP ratio, but it can be volatile (owing to the volatility of export prices) and incomplete (because countries may have other important sources of external income, such as workers' remittances).

are sufficient in countries with significant but uncertain access to capital markets and can be used to forecast the future vulnerability of a country in the event of a liquidity crisis (Beddies et al., 2009). We create a new debt sustainability variable with a value of 1 if the reserves are above the sample median, and 0 otherwise. The results presented in Table 4.14, lines ([1]-[2]) show that debt-for-nature swaps reduce fiscal policy volatility around the debt sustainability threshold, but with a more significant effect in countries with unsustainable debt levels. This result draws the attention of donor countries to the distinction between highly indebted countries with sustainable debt and highly indebted countries with unsustainable debt when negotiating debt-for-nature swaps.

4.8.6 Treatment of conditional effects

In this sub-section, we test the sensitivity of our results to the different characteristics prevailing in the DNS. Referring to Lin and Ye (2009), we explore conditional effects using a control function regression approach. By using this method, we study the sensitivity of our various baseline results to some structural characteristics of the countries, such as: government effectiveness, level of public debt, total external debt stocks, resource-rich countries, socioeconomic conditions, and natural resource rents. To achieve this, we estimate the latter equation 4.5 below.

$$Y_{it} = \alpha + \beta DNS_{it} + \gamma Pscore_{it} + \psi X_{it} + \phi DNS_{it} X_{it} + \varepsilon_{it} \quad (4.5)$$

Where Y is the outcome variable, Pscore is the propensity score estimated from the reference model, X is the vector of variables that may be a source of heterogeneity.

Table 4.15 below reports the estimated treatment effect of fiscal policy volatility based on the control function regression approach. In the first column, we run a simple OLS regression of fiscal policy volatility on a DNS dummy within the common support. The estimated coefficient, which catches the difference in mean fiscal policy volatility between DNS and non-DNS, is negative and statistically significant. We then include the estimated propensity score (Pscore) obtained from our baseline probit model as a control function in the column [2]. The estimated coefficient on the propensity score is statistically significant at the level 1%, which is strong evidence of the presence of self-selectivity. The coefficient in the DNS dummy is

negative and significantly different from zero, and the magnitudes are close to the coefficients of the matching exercise in Table 4.2 above. Indeed, estimated average treatment effect after controlling for self-selection is about -0.13 percentage points, which is close to the average treatment effect obtained from our matching exercise.

In the other columns following the first and second columns, we present the heterogeneity of the treatment effect. The columns [3] and [4] test the role of the government effectiveness by introducing an interaction term of the debt-for-nature swaps dummy and the government effectiveness. We find that the interaction term is negative and significant, suggesting that the performance of a debt-for-nature is affected by the government effectiveness. In columns ([5]-[6]), in addition to the propensity score, we also include an interaction term of the DNS dummy and the level of sovereign debt default. This is a dummy variable that takes the value 1 if i at period t has defaulted on its sovereign debt or restructured its debt, 0 otherwise. The results show a reversionary effect, i.e. a positive effect on fiscal policy volatility. This result is explained by the fact that the applicability of debt-for-nature swaps for defaulting states is more complex, given the need to tackle the insolvency problem first. In columns ([7]-[8]), we test the importance of socioeconomic conditions. Our intuition is that good socioeconomic conditions can help debtor governments make progress in implementing reforms involving an International Monetary Fund (IMF) or World Bank (WB) structural adjustment agreement, thus making debt-for-nature swaps more effective. The interactive term in column [8] is negative and significant, suggesting that debt-for-nature swaps are more effective in countries with more favorable socioeconomic conditions.

In columns ([9]-[10]), we investigate the role of natural resource rents. Indeed, it should be noted that fiscal behavior is fundamentally different in resource-rich developing countries and in their resource-poor peers (Sawadogo, 2020). The literature shows that high levels of resource rents can trigger lax fiscal and monetary policies, affecting economic growth (James and Aadland, 2011; Papyrakis and Gerlagh, 2007; Sachs and Warner, 2001). Our results are not new; they corroborate those found in the literature. In fact, debt-for-nature swaps are not effective in reducing fiscal policy volatility in countries with natural resource endowments. On the contrary, they amplify fiscal policy volatility in the presence of natural resource rents.

Table 4.14: Heterogeneity: financial capacity

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Fiscal policy volatility	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
[1] ATT: Sustainability debt	-0.1304 (0.0820)	-0.1692** (0.0802)	-0.1680** (0.0716)	-0.1501*** (0.0519)	-0.1611*** (0.0408)	-0.2097*** (0.0399)	-0.1386*** (0.0463)	-0.1502*** (0.0433)
Observations	1,170	1,170	1,170	1,170	1,170	1,170	1,170	1,170
[2] ATT: Unsustainable debt	-0.2039* (0.1202)	-0.2147** (0.0951)	-0.1901* (0.1011)	-0.2137** (0.0844)	-0.2113*** (0.0693)	-0.2411*** (0.0836)	-0.2026** (0.0793)	-0.2123** (0.0991)
Observations	494	494	494	494	494	494	494	494

Notes: Bootstrapped standard errors based on 50 replications in brackets. *** p<0.01, **

p<0.05, * p<0.1

Table 4.15: Heterogeneity: structural factors

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Debt-for-nature swaps	-0.5537*** (0.0456)	-0.1252** (0.0497)	-0.1181** (0.0486)	-0.1925*** (0.0535)	-0.1115* (0.0602)	-0.1093* (0.0597)	-0.1464*** (0.0560)	0.1868* (0.1107)	-0.1217** (0.0484)	-0.2854*** (0.0495)
Pscore		-0.2605*** (0.0256)	-0.2124*** (0.0267)	-0.2469*** (0.0270)	-0.2317*** (0.0287)	-0.2307*** (0.0286)	-0.1309*** (0.0225)	-0.1598*** (0.0256)	-0.2566*** (0.0252)	-0.2785*** (0.0262)
Government effectiveness			-0.2636*** (0.0550)							
DNS*Government effectiveness				-0.1491** (0.0616)						
Debt default dummy					0.6458*** (0.1972)					
DNS*Debt default dummy						0.3070*** (0.1148)				
Socioeconomic conditions							-0.1392*** (0.0209)			
DNS*Socioeconomic conditions								-0.0796*** (0.0198)		
Resource rents									0.0913*** (0.0141)	
DNS*Resource rents										0.1623*** (0.0253)
Constant	1.4692*** (0.0331)	1.0529*** (0.0329)	0.9377*** (0.0376)	1.0637*** (0.0333)	1.0228*** (0.0403)	1.0474*** (0.0405)	1.6926*** (0.1183)	1.0902*** (0.0426)	0.9448*** (0.0364)	1.0358*** (0.0331)
Observations	2,944	1,664	1,662	1,662	1,195	1,195	1,104	1,104	1,664	1,664
R-squared	0.0333	0.0868	0.1060	0.0876	0.0959	0.0773	0.1327	0.0809	0.1106	0.0983

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

4.9 Conclusion and policy recommendations

The main aim of this chapter is to shed light on the impact of a particular form of conservation aid, debt-for-nature swaps, on fiscal policy volatility. We situate our study at the crossroads of two literature's: the theoretical literature on the importance of conservation aids for improving the natural environment; and existing cross-national research and case studies that seem to contradict the effectiveness of such a reform on fiscal policy. In order to resolve the apparent mismatch between theory and empirical research on the problem, we refine existing research in two ways. First, we focus our attention on two types of debt-for-nature swaps: bilateral debt-for-nature swaps and multi-party debt-for-nature swaps, with the aim of identifying the effect of each on fiscal policy volatility. Secondly, we adopt an improved and sophisticated analytical strategy proposed by Rosenbaum and Rubin (1983) which attempts to solve the selection bias problem, if it is known that there could be a selection bias in the donor's choice of recipient countries. Using the propensity score matching method based on a large sample of 134 developing countries over the period 1990-2020, our results show that countries that have benefited from debt-for-nature swaps have low fiscal policy volatility compared to their peers that have not benefited from this type of public debt relief. This result is robust to a variety of tests, including alternative specifications, alternative non-residual measures of consumption volatility, including skewness and standard deviation, and alternative estimation methods. However, the results reveal some heterogeneity in the type of debt-for-nature, the time perspective, the viability of the debt, the type of fiscal rules adopted, the institutional quality, and structural factors such as natural resource rents, socioeconomic conditions, the default dummy debt, and government effectiveness. In terms of economic policy implications and recommendations, it is important that future research, policy makers and stakeholders conceive of debt-for-nature swaps, not in its entirety, but rather in terms of its particularities and another specificity not mentioned in this article, but which would be of interest: the way in which funds from specific donors are used to achieve specific policy objectives (Sommer et al., 2020). Our focus on both bilateral debt-for-nature swaps and multi-party swaps shows the extent to which nuances need to be made between these two types of debt-for-nature swaps in terms of their effectiveness in reducing fiscal policy volatility. Finally, our results obtained through propensity score matching corroborate Hermanrud and de Soysa (2017)'s assertion that it will be important to use an appropriate statistical method that takes into ac-

count potential problems that may arise due to donor selection bias to assess and capture the effectiveness of this type of aid. In fact, this is what we have done throughout this work. Even using a two-stage instrumental variable and system-GMM approach, we are more confident that the empirical results reported here are not the result of a mistaken inference (due to the endogeneity problem) regarding the underlying theory of aid effectiveness (Easterly, [2006a](#)), as failure to account for this form of endogeneity can lead to biased regression coefficients or ineffective statistical significance tests.

ACHIEVING SUSTAINABLE DEVELOPMENT AND DEBT SUSTAINABILITY IN DEVELOPING COUNTRIES: TO WHAT EXTENT DO DEBT-FOR-NATURE SWAPS MATTER?

Abstract¹: This chapter evaluates the impact of debt-for-nature swaps on sustainable development in developing countries, using entropy balancing on a large sample of 127 countries from 1990 to 2020. The findings indicate that debt-for-nature swaps have a positive and statistically significant effect on sustainable development, operating through several key channels: public debt reduction, increased public investment, lower CO2 emissions, and improved human development. The additional results found in this chapter show that if the treated countries had not benefited from debt-for-nature swaps, their sustainable development index would have decreased by 11%. At the same time, if the untreated countries had benefited from debt-for-nature swaps, their sustainable development index would have increased by around 2%. The analysis also reveals a non-linear relationship between the size of debt-for-nature swaps and the sustainable development index, with an optimal threshold estimated at 42% of the public debt level, beyond which diminishing returns are observed. These results suggest that debt-for-nature swaps can serve as an effective financing tool for sustainable development, provided that they are appropriately designed. From a policy perspective, expanding debt-for-nature swap programs requires broadening eligibility criteria, strengthening transparency and governance of environmental funds, and more systematically integrating climate objectives into multilateral debt relief mechanisms. Enhanced coordination between public and private creditors, as well as environmental organizations, is also crucial to ensure that debt-for-nature swaps support the ecological transition effectively in the most vulnerable countries.

Keywords: • Debt swap operation • Debt relief debt swap • Sustainable development

JEL Codes: E51, Q43, Q54, Q56

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5.1 Introduction

The sovereign debt crisis in developing countries after COVID-19 has strained the availability of financial resources for sustainable development and risks exacerbating the funding gap for nature (Barbier, 2022), while efforts to provide jobs and job security have led to stimulus policies that have potentially resulted in economic growth without regard to negative environmental consequences (Fodha and Seegmuller, 2014). Indeed, these corollaries of COVID-19, combined with the Russo-Ukrainian crisis and possible evaluations of sovereign debt restructuring (AfDB, 2022; ECA, 2022; Essers et al., 2021), have provided a window of opportunity to reassess development models (Elliott et al., 2020; Oldekop et al., 2020).

To achieve sustainable development, developing countries, international institutions, NGOs, etc., are committed to finding a solution to the sovereign debt crisis, to enable indebted countries to have budgetary leeway for the climate. The resolution of the sovereign debt crisis is more crucial than ever to achieving sustainable development goals, because unsustainable debt reduces fiscal space and weakens the government's capacity to tackle climate change (Boly et al., 2022; Van and Azomahou, 2007). In this regard, debt relief programs have been initiated. Despite efforts made, these programs have not succeeded in keeping debt levels at a sustainable level for a long time, particularly in times of crisis. At the same time, these programs have shown their limitations in terms of climate financing. For example, the G20 Debt Service Suspension Initiative (DSSI) and the Common Framework (World Bank, 2021a) temporarily suspended debt service payments between May 2020 and December 2021 for up to 73 eligible countries whose debt levels had become unsustainable during the COVID-19 crisis. It should be noted that DSSI had only been initiated once and had only provided \$12.9 billion in Aid to 48 countries, while the Common Framework had not led to any significant debt reorganization by May 2023, with only four countries having requested treatment under it (Alkhareif and Moulin, 2023)². In addition, debt reduction has been adopted through the joint initiative of the International Monetary Fund-World Bank Heavily Indebted Poor Countries and the Multilateral Debt Reduction Initiative. However, the higher levels of debt reduction granted to eligible countries by these programs have not been linked to the protection of environmental and biodiversity (Sommer et al., 2020). This highlights the challenges of these approaches as

²https://findevlab.org/news_and_event/what-the-chad-debt-deal-means/

a tool for debt reduction and sustainable growth. The fundamental question for developing countries is to find a financing model capable of fulfilling two major functions, i.e., providing countries with budgetary resources by reducing public debt and increasing their capacity to combat climate change (Raworth, 2012; Raworth, 2017). The debt-for-nature swaps (DNS) initiative, via the cancellation of debt services for conservation, could therefore be an effective way of achieving these dual objectives. Basically, the central idea of a debt-for-nature swap involves reducing the debt of a low- or middle-income country in exchange for that country's investment in environmental conservation and protection (AfDB, 2022; d Chamon et al., 2022; Essers et al., 2021; Hamlin, 1989; Hansen, 1989; Paul et al., 2023; Picolotti et al., 2020; Sheikh, 2018; Simmons et al., 2021; Sommer et al., 2020; Steele and Patel, 2020; Volz et al., 2021). Historically, DNS was initially developed in the 1980s to address this dual environmental and sovereign debt problem by exchanging sovereign debt for conservation or restoration of nature (Nedopil et al., 2024). In fact, this debt relief program has proven effective in countries such as the Seychelles, which adopted the program in 2015, and Belize in 2021 (d Chamon et al., 2022). This has surpassed the appeal of some to adopt the policy³. DNS has restructured around 3 billion dollars (Jones and Campos, 2023); with a single DNS exchange debt worth up to 1.6% of national GDP since 2015 after its drastic fall in the 1990s due to the HIPC program. According to Sommer et al. (2020), in total, US-led debt-for-nature swaps have canceled around \$1.8 billion in favor of 21 low- and middle-income countries. The swaps generated \$400 million for conservation.

However, the effectiveness of DNS is rather ambiguous in the literature. For instance, Jones and Campos (2023) based on the recent case of Ecuador and the Maldives illustrate the potential of DNS to provide a fund mobilization solution for conservation, resolving the debt crisis, and also enabling national credit ratings to revive the economy. These results were confirmed by Heller (2005). In addition, Gockel and Gray (2011) evaluated two projects funded by a US debt-for-nature swap signed in 2002 that canceled \$14.3 million of Peruvian debt and generated \$10 million for conservation. The authors conclude from a survey of 57 villagers living near the reserve and interviews with non-governmental organization staff that the first project effectively improved species conservation and socioeconomic well being, and the second succeeded in improving the capacity of local people to manage forest resources, while improving

³This countries are Barbados in 2022, Ecuador and Gabon in 2023 (see Nedopil et al., 2024).

the capacity of national non-governmental organizations to manage the projects described above. Using a two-stage instrumental variable regression model to analyze a sample of 85 low- and middle-income countries from 2001 to 2014, Sommer et al. (2020) find that higher amounts of debt reduction and higher amounts of conservation funds generated as a result of such swaps are associated with lower rates of forest loss. However, Kraemer and Hartmann (1993) analyzed cross-national data for 34 low- and middle-income countries using ordinary least squares regression and found no relationship between participation in a debt-for-nature swap and forest loss. Even the World Bank and the International Monetary Fund (IMF), two of the largest creditors in developing countries, had evaluated the inclusion of DNS to restructure their debt by May 2021 (Shalal, 2021). Although this was seen as a potentially powerful solution for overall debt sustainability (Georgieva and Thakoor, 2022), progress stalled due to uncertainties about DNS scalability (Shalal, 2022). Our research contributes to this fascinating debate by assessing the effectiveness of DNS in developing countries.

The literature, while rich, has two major limitations. On the one hand, existing studies are descriptive and lack a clear method to analyze the effectiveness of DNS on macroeconomic and environmental variables (see, for example, Hansen, 1989; Paul et al., 2023; Sheikh, 2018). On the other hand, the analyses carried out have focused on national cases (see, for example, Essers et al., 2021 and Cassimon et al., 2011 for a discussion), thus limiting their external validity. In addition, most existing studies focus on assessing the effectiveness of DNS in reducing forest cover (see Sheikh, 2018; Sommer et al., 2020). None of these studies analyzes the effect of DNS on a variable that takes into account both human development and environmental sustainability. In this context, the aim of the article is to fill this gap in the economic literature by analyzing the impact of DNS on ecological efficiency to enrich the political debate on climate change and debt relief programs. To achieve this, we use the ecological efficiency index constructed by Hickel (2020). This index takes into account all the factors involved in improving human development and measuring ecological impact (Hickel, 2020). In fact, the Sustainable Development Index (SDI) corrects the Human Development Index (HDI), which has long been criticized for not taking ecological sustainability into account. Our intuition is that DNS on the budgetary level, by enlarging the fiscal space of beneficiary countries via debt relief, enables them to invest in numerous development projects which create jobs and wealth, boosting the level of global income. Regarding the environmental plan, the DNS obliges countries to invest

in the conservation and protection of biodiversity, enabling them to achieve ecological efficiency. These combined effects will have a positive impact on the Sustainable Development Index.

Based on DNS transmission mechanisms for sustainable development, the resulting hypotheses are as follows: *(H1) DNS reduce environmental degradation (deforestation) and CO2 emissions by improving ecological efficiency indicators; (H2) DNS increase the sustainable development index by reducing debt burden, increasing economic growth, and improving well-being.*

To empirically test these main hypotheses, we use the entropy-balancing method, which deals with the self-selection bias associated with DNS adoption. We found that benefiting from debt-for-nature significantly increases sustainable development in developing countries. This chapter contributes to the literature in several ways. Firstly, it sheds new light on the important role of DNS in achieving sustainable development. It provides empirical evidence in response to the pessimistic view held by some international institutions that DNS is an effective instrument for achieving sustainable development and should therefore be extended to several debtor countries. Secondly, to our knowledge, this chapter is the first to empirically and rigorously evaluate the effectiveness of DNS in achieving sustainable development by addressing the problem of self-selection, as suggested by Bare et al. (2015). In addition, the distinction between the two main types of DNS, namely bilateral debt-for-nature and multi-party debt-for-nature swaps, is crucial for assessing the scope of the policy. Finally, we controlled for time- and country-fixed effects as recommended by Sommer et al. (2020), sensitivity to the time elapsed since DNS adoption, and several other governance indicators. The main results support the conclusion that DNS is an effective debt relief program to achieve sustainable development.

The rest of the chapter is organized as follows. Section 5.2 examines the effectiveness of DNS as an instrument to reduce debt burdens and improve environmental quality. Then, Section 5.3 describes the empirical methodology. Section 5.4 presents the data used in this chapter, while the main results are presented in Section 5.5. Section 5.6 examines the sensitivity of these results, while Section 5.7 explores the heterogeneity tests. Section 5.8 discusses the channels through which DNS affects sustainable development. Finally, Section 5.9 concludes the chapter and presents the policy recommendations from the results.

5.2 Investigating the effectiveness of debt-for-nature swaps as a debt and nature sustainability tools

Given that DNS have been designed to achieve two main objectives, namely debt and environmental sustainability, we examine in this section the theoretical and empirical debates on its effectiveness in promoting debt and environmental sustainability.

5.2.1 *On the fiscal space side*

The economic literature seems to be pessimistic about the effectiveness of DNS in creating fiscal space for the debtor country due to the size of the canceled debt. For instance, Cassimon et al. (2011) evaluated the effectiveness of the largest bilateral debt-for-nature swap carried out by the United States with Indonesia in 2011. To achieve this, the authors analyzed exchange documents and statistical data to determine how it performed in the face of several identified limitations of these transactions. The authors determined that Indonesia had canceled approximately \$22 million in debt owed to the United States. However, the debt-for-nature swap did not generate any additional budgetary space in the Indonesian budget, as the payments were redirected to a conservation fund (Cassimon et al., 2011). At the same time, the authors estimate that the amount of debt canceled thanks to this debt-for-nature swap represented only a fraction of Indonesia's outstanding debt, making it unlikely that the amount of debt canceled would have had a considerable effect on the country's fiscal space. Similarly, although the US debt-for-nature swap with the Peruvian government canceled \$14.3 million and generated \$10 million for conservation, it did not generate any budgetary space for the country (Gockel and Gray, 2011). Moreover, since the nominal value of debt-for-nature transactions generally represents an overestimate of both the benefit to the debtor and the cost to the creditor (Cassimon et al., 2011), an exchange may provide fewer resources than, say, direct budget support (Birdsall et al., 2003; Bulow and Rogoff, 1991). In fact, the savings from debt relief are only realized gradually, usually over several years or even decades, depending on the contractual repayment terms and timing of the underlying debt (Cassimon et al., 2011). In this respect, the declared nominal value of debt canceled under a swap is not necessarily a reliable measure of the increase in resources available to the debtor country (Cassimon et al., 2011). According to d Chamon et al. (2022), despite the frequency of debt swaps, the total volume of debt

relief they have generated has remained modest. In fact, as explained above, the main reason for this is the small size of the transactions: most debt swaps are in the double-digit million US dollar range; the largest swap to date took place in 1992 between Poland and a group of creditors, for a total value of \$580 million. Another reason is that debt swaps generally replace an old debt with a new one. This leads Cassimon et al. (2011) to say that genuine fiscal space is only created when there is a positive difference between the debt service payments canceled under the debt swap and the counterpart payments that replace them. Going a step further, Cassimon et al. (2011) point the finger at the structuring of debt-for-nature swaps. For the authors, a poorly structured debt-for-nature swap, in which annual domestic counterpart payments take place before debt relief savings are realized, can therefore worsen rather than improve the government's fiscal position, depending on the NPV of debt service payments and domestic counterpart payments. The idea defended by these authors is that debt relief must reach a critical mass and be granted in a harmonized manner if it is to have any chance of freeing a country from its debt burden and the ensuing economic impasse. However, debt-for-nature swaps have always been piecemeal interventions whose scale, in relation to the overall debt stock of recipient countries, is deemed insufficient to have a significant impact (see also, Hamlin, 1989; Patterson, 1990; Hansen, 1989; Thapa, 1998).

The above suggests that unnatural debt swaps, which appear generous at first glance, can only lead to minor hard currency gains for the recipient country. However, debt-for-nature swaps are often seen as generating additional fiscal space (Heller, 2005) in the recipient country's budget, which it can spend without jeopardizing the stability of its fiscal and macroeconomic situation. Indeed, the pre-adoption conditions of debt-for-nature swaps can lead to an improvement in macroeconomic and institutional indicators, generating fiscal space for the beneficiary country. In fact, there are various economic, political, and environmental conditions that a nation must meet to participate in an unnatural bilateral debt swap with the United States (Sheikh, 2016). In terms of economic requirements, a debtor government must have reached debt service thresholds and demonstrate progress in implementing reforms involving an international Monetary Fund (IMF) or World Bank (WB) structural adjustment agreement (see UNCBD, 2001). This may lead to the adoption of certain fiscal reforms, such as fiscal rules to prevent possible fiscal debauchery and create fiscal space for the country (Sawadogo, 2020). In the political sphere, a debtor nation must have a democratically elected government

and demonstrate its commitment to guaranteeing human rights (UNCBD, 2001). This will undoubtedly improve institutional indicators and reinforce the effectiveness of budget reforms in dissuading the government from discretionary spending (see Nerlich and Heinrich Reuter, 2015). In addition, given that DNS offers the possibility of ongoing interest payments from the debtor government on the remaining debt to the environmental trust fund, this reduces moral hazard, i.e. the debtor country taking unjustified future risk and reexposing itself to debt obligations due to its previous experience of debt cancellation (Nedopil et al., 2024). DNS also guarantees local benefits from national investments (Ferry, 2019), creating jobs for people living in the periphery. This, in turn, broadens the government's tax base.

Although there is some controversy in the literature about the effectiveness of DNS in generating fiscal space, it must be acknowledged that DNS has helped to reduce the debtor country's stock of debt for the preservation of the environment (UNDP, 2017). For instance, the first debt-for-nature agreement signed in 1987 between Bolivia and Conservation International (CI) enabled the purchase of US \$650,000 of Bolivia's foreign debt on the secondary market at a reduced price of US \$100,000 (see Nedopil et al., 2024). Furthermore, the value of debt restructured under the DNS agreements exceeded US \$2.6 billion, resulting in approximately US \$1.2 billion in transfers to conservation projects between 1987-2015 (UNDP, 2017). DNS in Seychelles represented in 2018 more than 1.5% of GDP (UNCBD, 2001) and DNS increased the amount of debt exchanged, from several million per exchange in the 1980s to 1.6 billion US dollars in a single exchange in 2023 (Jones and Campos, 2023).

5.2.2 *On the environmental sustainability side*

On the environmental side, it should be noted that most studies have only evaluated the relationship between DNS and deforestation, and the related literature shows that the effectiveness of DNS is ambiguous. For example, Sheikh (2010) argues that debt-for-nature swaps are seen as a way to raise funds to reduce environmental degradation while mitigating the desperate search of debtor countries for hard currency. Similarly, Nedopil et al. (2024) evaluated the effectiveness of DNS, focusing on the nature, amount, and beneficiary. They constructed a dataset on biodiversity conservation and debt restructuring in 67 countries threatened by sovereign debt overhang and holding over 22% of the world's priority biodiversity areas, 82.96% of which are unprotected. Using conservative cost estimates, the authors show

that for 35 of the 67 countries, 100% of unprotected biodiversity priority areas could be protected for a fraction of the debt; for the remaining countries, application of DNS would protect 11-13% of currently unprotected biodiversity priority areas. Shandra et al. (2011) are interested in the effectiveness of DNS, particularly commercial DNS, in forest loss. Using transnational models of forest loss for the period 1990-2005, the authors find that poor countries that implement such exchanges tend to have lower deforestation rates than poor countries that do not. In addition, poor countries with higher levels of international non-governmental organizations have lower rates of forest loss.

In the same vein, Sommer et al. (2020) looked at the effectiveness of debt-for-nature swaps in promoting environmental protection, more specifically US bilateral debt-for-nature swaps. Using a two-stage instrumental variable regression model to analyze a sample of 85 low- and middle-income countries from 2001 to 2014, the authors find that higher amounts of debt reduction and higher amounts of conservation funds generated as a result of such swaps are associated with lower rates of forest loss. Picolotti et al. (2020) call for the extension of debt swaps as a means of helping countries build climate resilience and support pandemic recovery. Steele and Patel (2020) argue for debt swaps in favor of spending programs rather than projects, i.e., spending related to climate resilience, adaptation, and biodiversity protection, which gives recipient governments flexibility in the use of funds. Volz et al. (2021) propose swapping existing debt for "recovery bonds" linking payment terms to the fulfillment of policy and spending commitments set out in a green and inclusive recovery strategy developed by debtor governments in consultation with civil society, creditors, international financial institutions (IFIs), and UN agencies.

Some studies suggest that DNS has not reduced deforestation. For example, using OLS regressions, Kraemer and Hartmann (1993) found no relationship between participation in a debt-for-nature swap and forest loss in 34 countries. Mak Arvin and Lew (2009) find that higher levels of bilateral conservation aid actually correspond to increased, not decreased, forest loss. For Bryant and Bailey (1997), the agroforestry project carried out in Ecuador as part of a debt-for-nature swap failed shortly after it started because members could not agree among themselves how much time each person should allocate to the project. Livernash and Paden (1992) think that debt-for-nature swaps may have no impact on deforestation because they are small-scale operations.

By assessing the effectiveness of DNS in protecting the environment and, by extension, well-being, Bryant and Bailey (1997) argue that conservation projects funded by debt-for-nature swaps do not help enough people in a large enough geographical area to have a meaningful impact on forest loss. This is also in line with Bare et al. (2015), who found in a sample of sub-Saharan African countries that programs such as DNS that create protected areas contribute to the displacement of local populations where the project is implemented, who then leave to clear forests elsewhere.

In summary, based on the discussions above, it is clear that there is a debate on the efficacy of debt-for-nature swaps in decreasing forest loss. Specifically, the discussion of these potential limitations suggests that swaps may be ineffective in part because they are small-scale (d Chamon et al., 2022; Essers et al., 2021; Livernash and Paden, 1992), ineffective management (Watson et al., 2014), limited in geographical scope (Jakobeit, 1996), or conducted without due consideration of the livelihoods of people (Bryant and Bailey, 1997; Gockel and Gray, 2011). They may also be less effective in nations with weak property laws, high levels of repression, or high levels of corruption (Shandra et al., 2011).

However, these studies may produce counterintuitive results by not addressing donor selection bias, examining a single geographic region, or based on descriptive analyses. For instance, Kraemer and Hartmann (1993) and Shandra et al. (2011) use the OLS method, which obviously does not control for selection bias. A more advanced impact evaluation method would have compared DNS and non-DNS individuals on the basis of similar characteristics. Indeed, it is not surprising that Kraemer and Hartmann (1993) found no significant effect of DNS. Firstly, their empirical results are based on a very small time span ($t=1$, $N=8;16;34$). A wider time frame would have captured the effect over time and over the long term, since, according to Jones and Campos (2023) DNS increases in amount over time. Secondly, their results suffer from an endogeneity problem. Ignoring this problem leads to biased regression coefficients or ineffective statistical significance tests (see Sommer et al., 2020). Regarding the study of Sommer et al. (2020), the endogeneity problem is addressed but suffers from the lack of availability of data at several time points of the forest loss variable. Moreover, this study says nothing about DNS and non-DNS observations, so that we can have a clear idea of the post-treatment period and the pre-treatment period. Even if the study retains all its quality, a weighting between DNS and non-DNS individuals to obtain a certain balance between pre-

treatment and post-treatment periods would have enabled us to better identify the impact of DNS. Following the logic of Hermanrud and de Soysa (2017), we postulate that it is important to use an appropriate statistical method that takes into account the potential problems that arise from donor selection bias. Consequently, this chapter uses a sophisticated impact evaluation approach that takes into account the problem of selection bias and compares treated and untreated individuals on the basis of a number of observable characteristics.

5.3 Methodology

The conviction that debt relief for environmental quality and the fight against climate change will free up budgetary space and enable climate financing to achieve sustainable development goals is what primarily motivates initiatives such as debt-for-nature swaps. Our objective is to analyze the causal effect of adopting debt-for-nature swaps on sustainable development measured by the ecological efficiency of human development. To do so, the simplest approach, often dubbed the *naïve* is to examine the impact of DNS on sustainable development by including a dummy variable equal to 1 in the equation for sustainable development if the country has adopted DNS and to estimate the equation using ordinary least squares (OLS). However, this approach followed by Shandra et al. (2011) and Kraemer and Hartmann (1993) suffers from a fundamental flaw. It assumes *de facto* that the DNS dummy variable is exogenous or equivalently that the decision to adopt DNS is random. If one takes seriously the work of Hermanrud and de Soysa (2017) and Bare et al. (2015), such an assumption is hardly tenable. Indeed, these authors provide evidence suggesting that the self-selection process of adopting DNS is endogenous rather than random and depends among others on a number of observable characteristics, as discussed earlier. The literature on DNS also provides ample evidence of country self-selection based on observable characteristics (see our discussion in subsection 5.2.2 referring to Livernash and Paden, 1992; Watson et al., 2014; Jakobeit, 1996; Bryant and Bailey, 1997; Shandra et al., 2011; Essers et al., 2021). In other words, DNS-countries have systematically different characteristics from non-DNS countries, and may have decided to adopt based on their own expected benefits. Unobservable characteristics of countries can also affect the decision to adopt DNS and sustainable development, resulting in biased estimates of the effect of adopting DNS on sustainable development. Practically, this implies that the so-called *naïve* treatment of DNS dummy as an exogenous variable in an OLS estimation as in Shandra

et al. (2011) is likely to be flawed (see Guo and Fraser, 2014 for a non-technical exposition of the sample selection problem).

Since there are good reasons to suspect the presence of non-random (endogenous) self-selection, the selection process must be modeled explicitly, otherwise the impact of DNS implementation is likely to be biased. Various methods have been developed to correct selection bias by explicitly modeling the endogenous treatment (here the decision of adopting DNS) in addition to the effect of the treatment on the sustainable development index. In this chapter, we use a treatment effect model, which simultaneously estimates the decision to adopt DNS and sustainable development, which is called in the literature the entropy balancing method developed by Hainmueller (2012). The entropy-balancing approach has many advantages and is widely used in the economic literature. For instance, Balima and Sy (2021) used it to examine the role of IMF-supported programs in reducing the likelihood of subsequent sovereign defaults in borrowing countries, Apeti and Edoh (2023) has used it to assess the impact of mobile money on tax revenue mobilization, Apeti (2023a) also used it to evaluate the effect of mobile money adoption on household consumption volatility, Kinda and Thiom-biano (2024b) have used to examine the implementing the Extractive Industries Transparency Initiative (EITI) standard on deforestation in natural resource-rich developing countries, and Jacolin et al. (2021) used it to investigate the impact of mobile financial services in particular, mobile money, mobile credit, and savings on the informal sector. The entropy method is a non-parametric model that allows us to obtain the treatment effect on treated individuals (ATT). Thus, ATT's equation is as follows:

$$ATT = E[Y_{(1)} | DNS=1, X = 1] - E[Y_0 | DNS=1, X = 1] \quad (5.1)$$

where $Y_{i(.)}$ is the outcome variable that measures the ecological efficiency of human development. DNS_i indicates whether the observation unit is subject to adoption of debt-for-nature swaps ($DNS_i = 1$) or not ($DNS_i = 0$). $E[Y_{i(1)} | DNS_i=1]$ is the ecological efficiency of the human development level during the debt-for-nature swap adoption period, $E[Y_{i0} | DNS_i=1]$ is the counterfactual result for countries that had adopted debt-for-nature swaps, i.e. the ecological efficiency of human development in countries that had adopted debt-for-nature swaps if they had not.

The issue is that $E[Y(0)|DNS = 1]$ is not observable due to the non-random nature of DNS adoption. If this were the case, the ATT could easily be identified by comparing the ecological efficiency of human development in DNS countries with non-DNS countries. Identifying ATT then requires a good proxy for $E[Y(0)|DNS = 1]$. To do so, we match DNS units with non-DNS units (after purging for some specific factors) that are as close as possible on observable characteristics that meet two criteria: correlated with DNS adoption and ecological efficiency of human development. Under the condition that the non-DNS units are fairly close to the DNS units, any difference in consumption volatility is attributable to DNS adoption. Based on these details, we can rewrite equation 5.1 as follows:

$$ATT = E[Y_{(1)}|DNS=1, X = x] - E[Y_0|DNS=1, X = x] \quad (5.2)$$

where $X = x$ is a vector of observable covariates that can affect both the decision to adopt DNS and the ecological efficiency of human development, $E[Y(1)|DNS = 1, X = x]$ is the ecological efficiency of human development of DNS units, and $E[Y(0)|DNS = 0, X = x]$ is the expected ecological efficiency of human development for synthetic control units. Entropy balancing is a two-step estimation method. First, the weights assigned to the control units (in this case, the non-DNS countries) are calculated in the entropy balancing. Following Neuenkirch and Neumeier (2016), we choose balance constraints that impose equal covariates means between the treatment and control groups. In doing so, we want to ensure that the control group, on average, has non-treatment units that are as similar as possible to the treated units. The second uses the weights from the first step in a regression analysis where sustainable development is the dependent variable. In the second step, we control for the covariates employed in the first step. This is equivalent to including control variables in a randomized experiment and increases the efficiency of estimation. In addition, time- and country-specific effects are included in the second step to respectively account for time-specific effects such as the debt crisis, debt restructuring, climate vulnerability, and country-specific heterogeneity arising from, for instance, differences with regard to political, economic, institutional environments, and climate change vulnerability. Thus, the average difference in ecological efficiency of human development between countries with DNS and "**closest**" non-DNS countries should be explained by DNS adoption.

Indeed, the advantage offered by the entropy balancing method of controlling for fixed effects of the country and time allows us to rigorously address one of the limitations of the study by Sommer et al. (2020), who felt that future DNS research should incorporate fixed effects of the country and time in their regression models. This would enable stricter control of the invariant characteristics of nations that can affect the outcome variable and could further prevent potential endogeneity problems (see Wooldridge, 1996). In addition, and as an advantage, entropy balancing allows us to identify the effect of DNS by comparing countries (or units) where DNS is present and others where it is not, which are similar in terms of observable characteristics, while taking care to account for country- and time-specific effects. By combining a matching and a regression approach, this method offers some additional advantages over several impact estimation methods, such as propensity score matching, Diff-in-Diff and coarse exact matching, as reported by Neuenkirch and Neumeier (2016). A particularly important advantage, as mentioned above, is that entropy balancing is non-parametric in the sense that there is no need to specify an empirical model for the outcome variable or selection into treatment. Consequently, potential types of misspecification, such as those concerning the functional form of the empirical model, which are likely to lead to biased estimates, are excluded. In addition, unlike regression-based analyses, entropy balancing based estimates of treatment effects do not suffer from multicollinearity, as the reweighting scheme orthogonalizes the covariates with respect to the treatment indicator. Unlike the matching methods mentioned above, entropy balancing guarantees a high degree of covariate balance between treatment and control groups, even in the case of small sample sizes. In fact, with the "conventional" matching methods we cited above, each treated unit is matched with the untreated unit that is closest in terms of the metric balancing score. As a result, the control group consists only of a subset of untreated units (Hainmueller, 2012). In other words, with conventional matching methods, each untreated unit is assigned a weight equal to 0, in the event that it does not represent the best match for a treated unit, or equal to 1, in the event that it represents the best match for a treated unit. However, when the number of untreated units is limited and the number of pre-treatment characteristics is high, this procedure does not guarantee a sufficient balance of pre-treatment characteristics between treatment and control groups. This is a serious problem, as poor covariate balance can lead to biased estimates of the treatment effect. In contrast, with entropy balancing, the vector of weights assigned to units not exposed

to treatment can contain any non-negative value. Thus, a synthetic control group is designed to represent a virtually perfect image of the treatment group.

Finally, compared with conventional matching where control units are either eliminated or matched, entropy balancing uses more flexible reweighting schemes. Reweights units with the aim of achieving a balance between processed and unprocessed units, while keeping weights as close as possible to base weights to avoid loss of information. By combining a reweighting system with regression analysis, entropy balancing allows us to properly handle the panel structure of our data to account for potential unobserved heterogeneity between countries that have never adopted DNS and those that have, given that the economic, political, and climatic conditions of these two groups of countries may differ beyond the set of covariates used in the entropy balancing approach.

5.4 Data and descriptive statistics

5.4.1 Data

To assess the effect of debt-for-nature swaps, we used an annual panel of 127 developing countries from 1990-2020. The choice of this sample is dictated by the availability of data and also by the fact that the adoption of debt-for-nature swaps is specific to developing countries (reduced fiscal space and very vulnerable to climate change). In other words, no developed country has adopted this policy to date (see Shandra et al., 2011).

Treatment variable. The treatment variable used in this chapter is DNS, which is participation in a country's debt-for-nature swap. In line with previous studies (AfDB, 2022; d Chamon et al., 2022; Picolotti et al., 2020; Sommer et al., 2020; Sheikh, 2018; Shandra et al., 2011), we measure the adoption of debt-for-nature swaps by a dummy variable, taking 1 if a country i at date t adopts debt-for-nature swaps and 0 otherwise. During the study period, 95 out of 127 countries have never adopted debt-for-nature swaps, and the remaining 32 countries adopted it. In addition, note that no country has adopted debt-for-nature swaps prior to the sample of analysis. How debt-for-nature swaps can affect the economy and achieve sustainable development is a matter of debate. For example, proponents of the swap, particularly those from the "World Polity" school of thought, assume that countries that have participated in a debt-for-nature swap should have lower deforestation rates. However, skeptics argue that

debt-for-nature swaps should have no impact on forest loss.

Outcome variable. Our outcome variable is the sustainable development index. The Sustainable Development Index (SDI) measures the ecological efficiency of human development, recognizing that development must be achieved within planetary boundaries.⁴ In fact, this variable was constructed by Hickel (2020) to address the limits of the Human Development Index (HDI) in terms of ecological realities. HDI was originally designed to take into account the progress of countries not only in terms of economic expansion, but also in terms of key social outcomes (PNUD, 1992). It is currently calculated as the geometric mean of three indicators: life expectancy at birth; education (the average of average years of schooling and expected years of schooling); and income (GNI per capita, PPP), which is placed on a natural logarithmic scale (Hickel, 2020). In this formula, it is clear that there are no indicators of ecological sustainability. This is surprising given the growing crisis of climate change and ecological degradation.

Indeed, some authors have attempted to address these ecological limitations of HDI (see Pelenc et al., 2016; Neuenkirch and Neumeier, 2016; Sagar and Najam, 1998). For instance, Biggeri and Mauro (2018) have recently developed an alternative index that incorporates not only an ecological indicator (CO2 emissions), but also an additional social indicator, freedom (defined as political rights and civil liberties). Togtokh and Gaffney (2010) included an index of CO2 emissions per capita in a geometric mean along with the three original HDI indicators to integrate environmental dimensions. Türe (2013) by simplifying, divides the HDI by the "ecological footprint", which takes into account not only carbon emissions but also the bio-capacity of cropland, grazing land, forests, and fisheries. However, and according to Hickel (2020), the attempts made to date all suffer from notable weaknesses that make them ultimately unsuitable for two reasons. Firstly, for the author, most of the alternatives described above are indicators of weak sustainability, insofar as they allow compromises between development and ecology.⁵ Second, existing alternatives do not take sufficient account of the scale of ecological impact. Even if the inclusion of CO2 emissions is a sound decision, it represents only one dimension of ecological impact, leaving other crucial dimensions unexamined (see Hickel, 2020 for an explanation of weaknesses). These are the limits that Hickel (2020) corrects

⁴For simplicity, we refer to sustainable development index as sustainable development.

⁵Except the study of Türe (2013).

in his HDI calculation. The author divides human development into a composite measure of ecological impact that integrates the two key indicators: per capita CO₂ emissions and per capita material footprint. It is the first development index to adopt this dual approach. This measure of SDI is complete and better suited to the objective of our study insofar as we seek to assess the effectiveness of debt-for-nature swaps, which are implemented to meet a dual challenge (improving environmental sustainability and reducing public debt). Debt reduction can raise funds to finance the economy, which in turn will boost economic growth, create jobs, and reduce poverty. We refer the reader to the article by Hickel (2020) for more details on index construction, formulas, and equations. Data updated to 2021 are available and can be accessed via this link [SDI](#).

Controls/matching variables. For the control variables, we select the control group of units with no debt-for-nature swaps that is on average as similar as possible to the treatment group of debt-for-nature swaps units in terms of relevant pre-treatment characteristics. Following the literature on the determinants of the adoption of debt-for-nature swaps and sustainable development, we select the following control variables. GDP per capita, total debt service, climatic vulnerability, property rights, and democracy policy. Given that better economic performance is likely to free up financial resources for the country and improve its financial conditions to cope with climate change, GDP per capita may be negatively correlated with the probability of adopting debt-for-nature swaps. Secondly, for a country to benefit from debt-for-nature, the government in power must have reached debt service thresholds and demonstrated progress in implementing fiscal reforms. As a result, total debt service is positively associated with the probability of adopting debt-for-nature (Sommer et al., 2020). Third, and on the environmental criterion, a country can benefit from debt-for-nature provided that it has at least one tropical forest with substantial biodiversity, or a forest that represents a large block of intact forest on a regional, continental, or global scale (UNCBD, 2001). In addition, the urgency of the request must also be taken into account, focusing on threats to biodiversity in the area to be protected in that country (UNCBD, 2001). As a result, high climatic vulnerability should be assigned to the probability of adopting a debt-for-nature swap. Finally, we turn to the importance of institutions in the implementation of debt-for-nature. Indeed, repressive governments may not have well-institutionalized property law systems, which can hamper the effective implementation of a debt-for-nature swap (Rudel, 2005). According to

Rudel (2005), countries lacking institutionalized systems of property law can hamper the effectiveness of non-governmental organizations, which in turn negatively affects the effectiveness of debt-for-nature. According to Lewis (2000), debt-for-nature swaps are more likely to be implemented in democratic rather than repressive nations. In the same vein, UNCBD (2001) argues that to benefit from debt-for-nature, a debtor nation must have a democratically elected government and demonstrate its commitment to guaranteeing human rights. However, it should be noted that some democratic or repressive governments in poor countries may not participate in unnatural debt swaps due to threats to national sovereignty (Rudel, 2005). Following Rudel (2005); Lewis (2000); and UNCBD (2001), we support the hypothesis that democracy and property rights are positively correlated with the probability of adopting a debt-for-nature. The definitions and sources of all variables, as well as sample countries, are presented in Table 5.5 in the Appendix. For robustness concerns, we add to these variables several other potential determinants of DNS adoption (and sustainability development). We lagged these variables by one period because of the econometrics problem (reverse causality), except for the democracy and property rights variables, which are institutional variables.

To conclude this variable explanation exercise, we assess the performance of our entropy-balancing method. To do so, we present some descriptive statistics obtained before and after weighting used to estimate the treatment effect of DNS adoption. We present the sample mean before weighting for country-year observations for the treatment group (DNS countries) and the control group (non-DNS countries) in Table 5.1, columns ([1]-[2]). In column [3] of this table, we report the difference in means between the two groups. In fact, DNS countries are characterized by high GDP per capita, high debt service total, high property rights, high democracy policy, and low vulnerability to climate. These findings are consistent with the expected relationship between the probability of DNS adoption and the various control variables discussed above, except GDP per capita and climate vulnerability. These differences across DNS and non-DNS countries demonstrate the importance of selecting an appropriate control group when computing the treatment effect of DNS to avoid incorrectly estimated treatment effects. Table 5.2 shows in columns [1]-[2] the sample mean after weighting between the treatment group and the synthetic group obtained by entropy balancing, and column [3] shows the difference between the first two. Analysis of the two groups in this table reveals the effectiveness of entropy balancing, since the difference shown in the table is equal

to 0. Consequently, entropy balancing allows us to construct a perfect control group, closely similar to the DNS countries based on observable characteristics, i.e. in terms of the mean values of the pre-treatment covariates.

Table 5.1: Descriptive statistics before weighting.

	[1]	[2]	[3]=[2]-[1]
	DNS	non-DNS	Difference
Lag GDP per capita (log)	8.901	8.307	-0.594
Lag debt service total	5.534	4.901	-0.633
Lag climate vulnerability	0.459	0.502	0.043
Property rights	39.84	36.18	-3.66
Democracy policy	5.824	2.22	-3.604
Obs	461	1161	

Table 5.2: Descriptive statistics after weighting.

	[1]	[2]	[3]=[2]-[1]
	DNS	non-DNS	Difference
Lag GDP per capita (log)	8.901	8.901	0
Lag debt service total	5.534	5.534	0
Lag climate vulnerability	0.459	0.459	0
Property rights	39.84	39.84	0
Democracy policy	5.824	5.824	0
Obs	461	461	
Total of weights	461	1161	

5.4.2 Descriptive statistics

A first look at the relationship between sustainable development and DNS can be revealed by exploring the unconditional correlation between these two variables. The results in line [2]

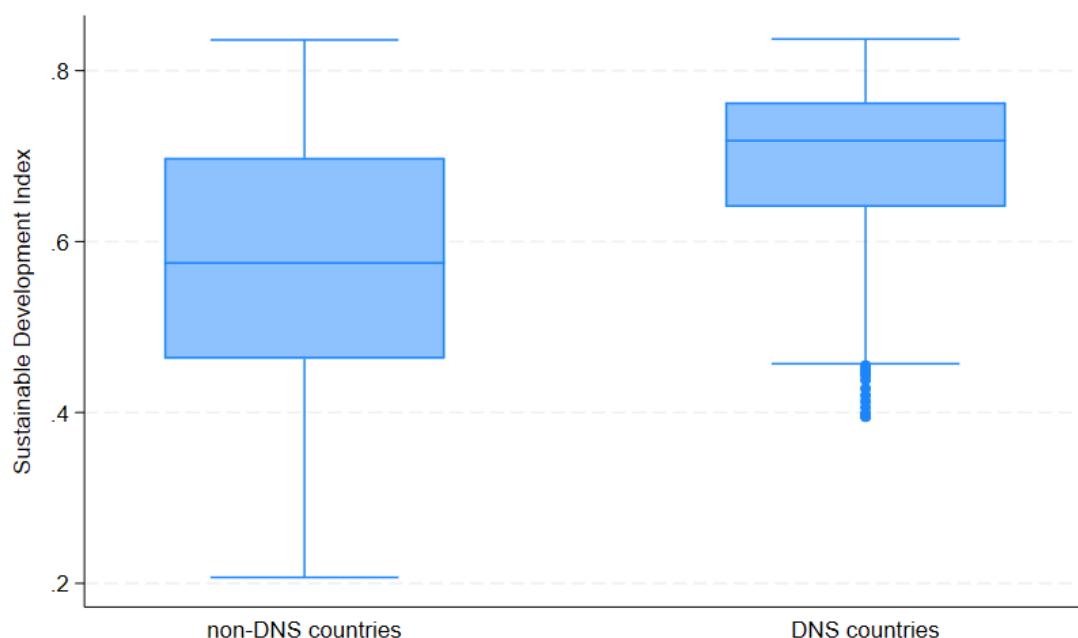
of Table E4 in the appendix, which presents the unconditional correlation between these two variables, reveal that DNS is positively and significantly correlated with sustainable development at the confidence level 1%.

We now turn to the comparison of sustainable development between DNS et non-DNS countries. We explore this comparison in three ways. Firstly, we graphically analyze some key statistics offered in Fig.5.1. A closer look at this figure reveals a difference in the sustainable development between DNS and non-DNS countries. Indeed, DNS countries exhibit a median (the middle line of the box), 25th (bottom hinge of the box), and 75th (top hinge of the box) percentiles of sustainable development higher than non-DNS countries. This finding is justified by the fact that the median line, bottom hinge, and top hinge of the box for DNS countries are, respectively, higher than those of non-DNS countries. Although this figure exhibits a difference between DNS and non-DNS countries, it cannot assess its magnitude or significance. In other words, the simple comparison between the two groups may be biased. Based on the statistics reported in Table 5.3, we are able to judge the significance of the difference between these two groups of countries through the statistics of the tests of difference of means. In panel A, we compare average sustainable development between the two groups of countries, revealing that DNS adoption is associated with higher sustainable development. In fact, compared to the control group, countries that benefit from DNS have a higher sustainable development, with a significant difference of 0.12 percentage points ($t\text{-stat}=458$ and $p\text{-value}=0.000$).

Finally, we analyze the change in the average sustainable development within countries by calculating the average sustainable development before and after the adoption of DNS in the Panel B. To avoid biasing the comparison between countries and to have a homogeneous sample, we have excluded countries that have not benefited from DNS. Unsurprisingly, the results show that sustainable development increases after DNS adoption. Compared with the results of the comparison between countries that have benefited from DNS and those that have not, the difference is 0.07 percentage points ($t\text{-stat}=207$ and $p\text{-value}=0.000$). These relationships, while not causal, give an idea of the treatment effect of DNS adoption and how to identify it. However, it would be misleading to estimate the effect of DNS on sustainable development simply by comparing sustainable development before and after DNS adoption. To avoid overestimating the effect of the policy, we use, as we saw above, countries without

DNS as a synthetic control group to estimate the counterfactuals result.

Figure 5.1: Sustainable development by debt-for-nature swaps adoption



Note: In box plots, the lower and upper hinges of each box show the 25th and 75th percentiles of the samples, the line in the box indicates the respective medians, and the end-points of whiskers mark next adjacent values.

Table 5.3: Sustainable development by DNS adoption: mean-comparison tests

	<i>DNS</i>	<i>non-DNS</i>	<i>Diff</i>	<i>t-Test</i>	<i>P-value</i>
Panel A: Sustainable development	0.69	0.57	-0.12	457.9	0.000
Panel B: DNS adoption	<i>Before</i>	<i>After</i>	<i>Diff</i>	<i>t-Test</i>	<i>P-value</i>
Sustainable development	0.61	0.68	0.07	206.7	0.000

5.5 Results

Using the synthetic controls in Table 5.2, we estimate the effect of the adoption of DNS on sustainable development (ATT) in developing countries using the weighted least squares method. The results are reported in Table 5.4. Columns [1]-[4] show the results of the second stage without the addition of the covariates used in the first stage of the synthetic group construction. Column [1] excludes country and time-fixed effects. Columns [2]-[3] include

country- and time-specific effects, respectively, while column [4] includes these two effects jointly. Finally, columns [5]-[8] repeat the exercise of columns [1]-[4] except that by adding in each second-stage regression the covariates used in the first stage, namely GDP per capita, total debt service, climate vulnerability, property, and democracy policy. By including matching covariates in the second stage of entropy balancing, we have a strong chance of seeing matching quality increased (as in a randomized experiment), while controlling for country and year fixed effects eliminates any country or year-specific effects, as explained above. In each specification, the adoption of DNS significantly increases sustainable development at the threshold 1% in our sample of countries (columns [1]-[8]). In fact, this result ranges from 0.07 percentage points (column [7]) to 0.15 percentage points (column [2]) - a robust result given the relative stability of the coefficients in the 8 specifications of Table 5.4, with an average effect of 0.092 percentage points. In other words, DNS adoption increases on average sustainable development by 0.092 percentage points in DNS countries compared to non-DNS countries.

These results indicate that DNS can help to achieve both human development and ecological sustainability - a goal now widely accepted and officially reflected in the Sustainable Development Goals. In fact, by increasing new investment, DNS boosts economic growth through the creation of jobs for the population. Moreover, by reducing the debt burden, DNS enable governments to use financial resources for other, more productive public policies. In other words, by reducing the debt burden, DNS increases the government's capacity to finance sustainable development objectives. On the institutional level, given that the adoption of DNS requires the improvement of certain institutional and political indications such as democracy, the rule of law, and property rights, this would contribute to human development. Environmentally, DNS helps protect biodiversity by combating deforestation and improve ecological efficiency by reducing CO2 emissions and material footprints.

Our results contradict much of transnational research and support theoretical arguments concerning the effectiveness of DNS in improving sustainable development (see the discussion in Section 5.2). We note that it does not appear that these exchanges are limited by their small size, as some authors argue in relation to the scale of the sustainable development problem, nor that they are rendered totally ineffective due to the potential inability to solve the livelihood problems of local populations and the capacity problems of exchange participants.

Table 5.4: Debt-for-nature swaps and sustainable development—Baseline results

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
DNS adoption	0.0930*** (0.0098)	0.1455*** (0.0155)	0.0976*** (0.0098)	0.0886*** (0.0130)	0.0714*** (0.0070)	0.0876*** (0.0150)	0.0701*** (0.0069)	0.0809*** (0.0143)
Constant	-0.4568*** (0.0077)	-0.6035*** (0.0026)	-0.5067*** (0.0248)	-0.7124*** (0.0132)	-0.4931*** (0.1349)	-0.5857*** (0.2148)	-0.5141*** (0.1319)	-0.5647*** (0.2146)
Covariates	No	No	No	No	Yes	Yes	Yes	Yes
Country/FE	No	Yes	No	Yes	No	Yes	No	Yes
Year/FE	No	No	Yes	Yes	No	No	Yes	Yes
Observations	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
R-squared	0.0673	0.8841	0.0807	0.9200	0.5928	0.9202	0.5952	0.9253

Robust standard errors are in parentheses ***p < 0.01, **p < 0.05, *p < 0.1

5.6 Robustness

5.6.1 Alternative specifications

We examine the robustness of the main result of the chapter when various considerations are taken into account in the analysis. We do this in two ways. Firstly, we control the effect of certain variables. Secondly, we exclude certain observations from our sample. Let's start with the control of additional variables. Based on the literature on DNS and sustainable development, we select these variables and group them into four categories: *i- economic variables*: FDI, remittance inflows, net ODA, public expenditure, inflation rate, trade openness, public debt, exchange rate, total ODA biodiversity, agricultural value added, industry value added, commodity prices, and natural resources rents; *ii- political and institutional conditions*: internal conflict, external conflict, corruption control, government effectiveness, rule of law, political stability, investment profile and government stability; *iii- climate variables*: average temperature, average rainfall and natural disasters; *iv- infrastructure and structural conditions*: ICT, human capital, electricity access and electricity consumption.

Let turn now to explanation and motivation on the use of each variable. Many researchers argue that FDI stimulates economic growth in developing countries, either directly or indirectly through interactions with human capital (see Makiela and Ouattara, 2018; Choong et al., 2010). For instance, Gohou and Soumaré (2012) argue that FDI can promote human development by reducing poverty and improving well-being. We take this into account by controlling for the effect of FDI. We control remittance flows because they stimulate economic growth (Kraemer and Hartmann, 1993), improve quality of life by reducing poverty (Adams Jr and

Page, 2005; Taylor et al., 2003), improve health outcomes, promote well being and help reduce inequalities (Nguea et al., 2022). Remittances increase the productive capacity of households ex ante, helping to smooth consumption and growth (Apeti, 2023a), and ex post protect households against unexpected shocks (Combes and Ebeke, 2011). However, remittances can adversely affect CO₂ emissions and compromise sustainable development. Ahmad et al. (2019) explain how remittances can have a positive impact on CO₂ emissions. For these authors, remittances do not directly influence CO₂ emissions but indirectly through higher GDP per capita, higher consumption and savings, higher aggregate demand and bank deposits, financial development and industrial production, all of which contribute positively to economic growth.

Foreign aid inflows can also influence sustainable development through the protection of environmental quality. In fact, the higher the flow of foreign aid, the lower the level of environmental degradation (Mahalik et al., 2021). Indeed, an emerging economy that receives more foreign financial aid will be able to increase its investments in running various programs to raise awareness of the protection of environmental quality for its population at different levels. However, foreign energy financing will deteriorate the quality of the environment if it is invested more in the extraction of the mining and metal resources needed to strengthen economic growth (Mahalik et al., 2021). We take these declarations into account by adding ODA and ODA biodiversity as additional controls in our baseline regressions. In developing countries, in particular, the basic needs of citizens are met mainly by public spending. At the same time, a large proportion of public financing comes from debt (see, for example, Gockel and Gray, 2011). For this reason, we introduced the public debt as an additional control variable to take into account government financial constraints because the debt ratio is expected to have a negative impact on welfare (Gockel and Gray, 2011), since the higher the country's debt, the more limited the government's ability to finance sustainable development (Boly et al., 2022).

We also control the effect of inflation to capture macroeconomic instability. Inflation is expected to have a negative impact on welfare, as high inflation increases commodity prices and has a direct impact on the poor (Gockel and Gray, 2011). In the same spirit, inflation can increase macroeconomic instability, which in turn will influence the volatility of household consumption and affect welfare. We control the effect of trade openness given its crucial role in raising average incomes and significantly stimulating economic growth (Dollar and Kraay,

2004), combined with its positive impact on sustainable development and its negative environmental effects (Kindo et al., 2024). The exchange rate can induce risk premiums for long-term agreements and increase production costs, thus reducing the growth of household consumption (see Apeti, 2023a). In the same vein, exchange rate uncertainty can lead to high risk in investment decisions, threatening the performance of macroeconomic variables that are positively correlated with economic growth. Furthermore, given that developing countries are highly dependent on raw materials to ensure national production, fluctuations in exchange rates can affect the prices of domestic goods, thus shaping households' consumption patterns (Oseni, 2016), affecting macroeconomic aggregates and reducing the index of sustainable development. To take these provisions into account in our base regressions, we control for the effects of exchange rate, commodity prices, and natural resources. Agricultural value added can affect sustainable development in developing countries. In fact, in most developing countries, the agricultural sector is recognized as a key factor in national development (FAO, 2009; WTO, 2014). At the same time, a large area of forest has been destroyed due to the intensification of agricultural activity (see Angelsen, 1999; Delacote, 2007; Galinato and Galinato, 2016; Liu et al., 2017). The effect of industrialization is controlled by the industry value added variable because industrialization can explain the strong correlation between investment in equipment and economic growth in developing countries (Temple and Voth, 1998). This can improve the well-being of the population and affect the variables of sustainable development.

Secondly, we assume that political and institutional conditions can influence the relationship between DNS adoption and sustainable development. For example, a good application of the rule of law and a good level of corruption control can influence the relationship between DNS and sustainable development. This idea goes in the same direction as Rudel (2005), who shows that countries lacking institutionalized property law systems can first hamper the effectiveness of nongovernmental organizations in the fight against deforestation and second prevent DNS from achieving their objectives. We control for these effects with variables related to the control of corruption, internal and external conflicts, government effectiveness, rule of law, political stability, investment profile, and government stability. These variables can affect sustainable development in different ways. According to Shahzad (2020), law enforcement increases financial capacity through strong tax collection, which can be used to advance the sustainable development program. The rule of law can promote efficient legal processes

and good governance and ensure the protection of natural resource property rights (Bhattarai and Hammig, 2001). Conflicts can worsen sustainable development indicators through the use of chemical weapons and forced displacement of people from one area to another, reducing their well-being. Considering the effect of the conflict in Colombia, Ibáñez and Vélez (2008) finds that the internal conflict has caused forced displacement of people, resulting in welfare losses of 37% of the net present value of overall rural consumption over the lifetime. Third, we assume that our results may be influenced by climate conditions. As shown by Diwakar and Lacroix (2021), climate shocks prolong poverty through direct biophysical impacts, but also indirectly through various negative consequences and distress coping mechanisms in which vulnerable households participate. For Riley (2018) and Jack and Suri (2014), climate shocks have a negative impact on household consumption. According to Donadelli et al. (2017), the temperature risk is associated with welfare costs that amount to 18.4% of the utility of the economic agent over the lifetime, increasing exponentially with the magnitude of the temperature impact on the productivity of the total factor. To control this effect, we include three climate variables, namely average temperature, average rainfall, and natural disasters.

Finally, we control the influence of infrastructure and structural factors. Today, ICTs offer significant opportunities to improve household living conditions in a wide range of areas, including social life, education, health, and economic activities. For example, its use can improve farmers' well-being by providing them with the information they need on inputs and technologies to improve farming activities and by putting farmers in touch with profitable markets. According to Mdoda and Mdiya (2022), households with access to ICTs will succeed in increasing their agricultural production, by accessing market-oriented information, agricultural practices, climate information, information on new technologies and financial information. As a result, increased agricultural production combined with marketing information will help farmers increase their yields and improve household welfare. This in turn would increase sustainable development. For example, in Kenya, the use of ICT as an agricultural extension tool by smallholder farmers has the potential to improve yields and farmer income, which will result in improved welfare (Marwa et al., 2020). This led Nonvide (2023) to assert that ICTs have the potential to effectively combat poverty and improve people's well-being. We use the ICT variable to control the effect of infrastructure. The ICT variable is a composite index of four sub-indicators that take into account both access to and use of ICT infrastructure: cell

phone subscription per 100 people, fixed-line telephone subscription per 100 people, fixed-line broadband telephone subscription per 100 people, and percentage of individuals using the internet. Herrera and Vincent (2008) argue that cell phones (or mobile cell phones) could reduce the unpredictability of income and help smooth consumption. Next, we control the role of human capital, captured by years of schooling and enrollment in tertiary education on sustainable development and the adoption of DNS. Indeed, countries with higher-performing systems, higher levels of education, and a large, better-educated majority may have better sustainable development indicators than their peers without such systems. In fact, the best educated people easily understand climate issues and very often adopt eco-responsible behavior. We control the impact of access to energy, in particular access to electricity and electricity consumption. In fact, energy and electricity, in particular, are recognized as the driving force behind economic, social, and human development (ESCAP, 2000; World Bank, 2001). Basically, access to electricity helps to guarantee environmental sustainability (Goal 7 of the United Nations Millennium Development Goals). In fact, electricity can be used to power water pumps that provide drinking water, facilitating the achievement of Goal 7, which is to reduce the proportion of the population without access to safe drinking water. Using renewable energy to supply electricity to the poor can contribute to the sustainable use of natural resources, as well as reducing greenhouse gas emissions, thus protecting the local and global environment.

Let us turn to the second and final part of this exercise, which is the modification of our sample. Firstly, we exclude the pre-2000 period because of the major economic and political changes that can affect sustainable development. Secondly, we exclude countries that have recently benefited from DNS because of the potential time delay between the reforms and their expected effects. During the period of our study, several shocks occurred that could affect sustainable development: political, economic, financial, ecological, and climatic. To do this, we exclude from our sample the years marked by the financial crisis in 2008, the oil crisis in 2014, and the COVID-19 crisis in 2019. Finally, we know that developing countries are highly dependent on natural resource revenues. This dependence could put implicit pressure on countries to over-exploit natural resources to finance development policies. For example, Coulibaly (2023a) explains that countries that have signed up to resource-backed loans have a higher deforestation rate than their peers who have not. However, Coulibaly (2024a) argues that resource-backed loans could help countries overcome difficulties in accessing financial

markets and be an effective instrument to finance sustainable development. In fact, the signing of these loans is based on the assumption of a natural resource endowment (see Coulibaly, 2023a; Coulibaly, 2024a). Using a panel study for five European Union countries, Balsalobre-Lorente et al. (2018) posit that all natural resources contribute to greenhouse gas emissions. The study concluded that there was an offset to the degradation of the environment due to abundant natural resources, renewable energy, and energy innovation. Other studies have examined the effects of natural resource extraction activities on the environment. In their study, Kinda and Thiombiano (2021) examined the relationship between rents in the extractive industry and the loss of forest cover in developing countries. At the same time, revenues from natural resources can be used to finance development, even if their extraction contributes to resource depletion (Coulibaly, 2024a). We take account of these considerations by excluding from our observations the strong dependence on natural resource revenues captured by a dummy variable taking the value 1 if the revenue from oil, coal, natural gas, and minerals production is greater than the sample standard deviation and 0 otherwise. We also exclude countries with high natural resource depletion rates, captured by a dummy variable taking the value 1 if the resource depletion rate is greater than the sample standard deviation and 0 otherwise.

We report the new ATTs in Tables 5.5 and E6. In Table 5.5, we report the results of the supplementary checks by group (columns [1]-[3]). In column [4], we test all four groups simultaneously. In Table E6, we report the results of the variables in a disaggregated form (columns [1]-[29]). This allows us to take into account the heterogeneous effect that each variable might have. Finally, in columns [30]-[36] we report the results of the exclusion of observations likely to nuance our baseline results. Our results remain unchanged when numerous additional control variables are taken into account, and also the sample is modified.

Table 5.5: DNS and sustainable development: additional variables by group

	[1]	[2]	[3]	[4]	[5]
	Economic variables	Political and institutional conditions	Climate variables	Infrastructure and structural	All
VARIABLES	group	group	group	conditions group	group
DNS dummy	0.0431*** (0.0081)	0.0570*** (0.0190)	0.0800*** (0.0140)	0.0214*** (0.0067)	0.0191* (0.0107)
Constant	0.1154 (0.2594)	-0.3362 (0.2928)	-0.4046* (0.2268)	-1.1614*** (0.2146)	-1.9891*** (0.3360)
Covariates	Yes	Yes	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes	Yes
Observations	885	759	1,383	933	382
R-squared	0.9666	0.9579	0.9403	0.9540	0.9895

Notes: Robust standard errors are in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Table 5.6: DNS and sustainable development: additional variables desegregated and excluding observations

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
<i>Additional variables</i>												
	FDI	Remittance inflows	ODA	Public expenditure	Inflation rate	Trade openness	Public debt	exchange rate	ODA biodiversity	Agricultural value added	Industry value added	Commodity prices
DNS dummy	0.0725*** (0.0135)	0.0809*** (0.0143)	0.0747*** (0.0131)	0.0859*** (0.0141)	0.0522*** (0.0098)	0.0813*** (0.0134)	0.0635*** (0.0154)	0.0822*** (0.0137)	0.0557*** (0.0131)	0.0880*** (0.0149)	0.0828*** (0.0139)	0.0853*** (0.0133)
Constant	-0.6275*** (0.2136)	-0.6480*** (0.2152)	-0.6712*** (0.2069)	-0.4893* (0.2509)	-0.7182*** (0.2127)	-0.2390 (0.2125)	-0.5391*** (0.2087)	-0.5395*** (0.2083)	-0.5173** (0.2351)	-0.2065 (0.2150)	-0.5201** (0.2241)	0.4419* (0.2294)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,499	1,441	1,467	1,268	1,393	1,422	1,342	1,458	1,097	1,474	1,470	1,403
R-squared	0.9268	0.9269	0.9272	0.9239	0.9294	0.9241	0.9367	0.9334	0.9405	0.9273	0.9259	0.9430
	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]	[23]	[24]
	Resources rents	Internal conflict	External conflict	Control of corruption	Governance effectiveness	Rule of law	Political stability	Investment profile	Government stability	Average temperature	Average rainfall	Disasters index
DNS dummy	0.0804*** (0.0141)									0.0797*** (0.0142)	0.0810*** (0.0142)	0.0822*** (0.0144)
Constant	-0.5983*** (0.2187)	-0.3819 (0.2347)	-0.4358* (0.2348)	-0.3933 (0.2436)	-0.5906** (0.2319)	-0.6536** (0.2735)	-0.5408** (0.2179)	-0.4212* (0.2379)	-0.4314* (0.2364)	-0.4939** (0.2187)	-0.5640** (0.2332)	-0.6947*** (0.2042)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,500	1,186	1,186	1,329	1,329	976	1,500	1,186	1,186	1,500	1,472	1,411
R-squared	0.9254	0.9324	0.9314	0.9297	0.9297	0.9458	0.9253	0.9314	0.9313	0.9255	0.9268	0.9375
<i>Excluding observations</i>												
VARIABLES	[25]	[26]	[27]	[28]	[29]	[30]	[31]	[32]	[33]	[34]	[35]	[36]
	ICT	Tertiary education	Years of schooling	Access to electricity	Electric power consumption	Pre-2000	New DNS adopters	Financial crisis	Petroleum crisis	COVID-19 crisis	Dependence on income resources	Resource depletion
DNS dummy	0.0376*** (0.0093)	0.0699*** (0.0128)	0.0701*** (0.0127)	0.0652*** (0.0117)	0.0527*** (0.0114)	0.0636*** (0.0142)	0.0791*** (0.0157)	0.0834*** (0.0145)	0.0809*** (0.0146)	0.0809*** (0.0143)	0.0280*** (0.0092)	0.0732*** (0.0126)
Constant	-1.0298*** (0.2046)	-0.3909* (0.2153)	-0.9795*** (0.2195)	-0.9943*** (0.2109)	-0.8032*** (0.1915)	-0.2968 (0.2216)	-0.5888** (0.2411)	-0.5550** (0.2195)	-0.5976*** (0.2214)	-0.5647*** (0.2146)	-1.1348*** (0.2719)	-0.6944*** (0.2427)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,500	1,463	1,500	1,427	1,012	1,283	1,285	1,435	1,428	1,500	627	1,186
R-squared	0.9395	0.9304	0.9320	0.9305	0.9422	0.9337	0.9253	0.9222	0.9248	0.9253	0.9821	0.9292

Robust standard errors are in brackets. *** p<0.01, ** p<0.05, * p<0.1.

5.6.2 Alternative specifications

Our results show that DNS has a positive and statistically significant impact on sustainable development. We have seen that these results are robust to alternative specifications. We now check the robustness of these results using five different estimation methods: three impact estimation methods (propensity score matching, Difference-in-Difference, and endogenous switching regression) and two methods to deal with potential endogeneity bias (GMM system and instrumental variable). We start this exercise with the **propensity score matching method**. Indeed, as explained above, estimating a causal effect of DNS on sustainable development is a difficult task, as DNS adoption is probably not random but linked to specific macroeconomic, climatic and institutional conditions (generally referred to as preconditions) and therefore subject to selection bias. Although the method used in this chapter addresses this selection bias problem, we use the propensity score matching method to strengthen our confidence. Developed by Rosenbaum and Rubin (1983), the matching of propensity scores allows addressing the issue of self-selection in DNS adoption by pairing DNS countries (the treated group) with non-DNS countries (the control group) that are comparable in terms of observable characteristics that influence both DNS adoption and sustainable development (including, in particular, past sustainable development). As such, PSM allows mimicking DNS adoption as a randomized experiment, such as -conditional to some hypotheses that we discuss below - any difference in current sustainable development between matched DNS and non-DNS countries is attributable to the policy, i.e., DNS adoption.

As indicated by Rosenbaum and Rubin (1983) and detailed by Apeti et al. (2023b), the PSM method is carried out in two stages. In the first step, we calculate a propensity score (PS) using a logit or probit model with DNS as dependent variable. In this chapter, we use a probit regression. Second, we use the counterfactuals obtained from the first step for the matching (see, for instance, Chapel, 2022; Coulibaly, 2024a). To perform matching, the literature indicates that matching algorithms must be chosen. We follow Combes et al. (2024) in choosing eight matching algorithms. Firstly, we use N nearest neighbors, which matches each DNS country-year observation (processed) with the N nearest non-DNS country-year observations (unprocessed) with the nearest PS calculated in the first step - we choose the nearest (N=1), two nearest neighbors (N=2) and three nearest neighbors (N=3). Secondly, we use the radius

method of Dehejia and Wahba (2002), which associates processed observations with unprocessed observations located at a given distance. For this purpose, we consider a small ($r = 0.045$), a medium ($r = 0.09$), and a wide ($r = 0.18$) radius according to the literature (see Coulibaly, 2024a; Traore et al., 2023). Third, we use the kernel method developed by Heckman et al. (1998b), which associates each treated observation with the distribution of untreated observations in the common support, with weights inversely proportional to the difference between the PS of treated and untreated observations. Fourthly and finally, we use the local linear correspondence developed by Heckman et al. (1998b), which is close to the kernel correspondence, except for the use of a linear term in its weighting function.

The results are shown in Table 5.7. However, before interpreting the results, we check three tests for the validity and quality of our matching. First, we have the common support hypothesis, which requires the availability of comparable counterfactuals for each country-year observation with DNS (i.e., treated unit). To ensure that the treated and control groups are comparable (i.e., to check for overlap and the region of common support between the two groups), we rely on the comparison of minima and maxima as suggested by Caliendo and Kopeinig (2008). Secondly, after estimation, we assess the validity of the matching procedure using the pseudo- R^2 test to check the comparability between the treated and control groups after matching (see, for example, Sawadogo, 2020; Coulibaly, 2024a; Apeti et al., 2023b; Caliendo and Kopeinig, 2008). Finally, an important assumption is the conditional independence hypothesis, according to which the difference in outcome (i.e., sustainable development) between the treated and untreated groups results solely from the adoption of the DNS. Following Rosenbaum (2002) and Caliendo and Kopeinig (2008), we test this hypothesis using Rosenbaum's bound sensitivity tests, which give an idea of the extent to which unobservable characteristics can bias the results of the matching exercise and the standardized bias to test the conditional independence hypothesis against observable characteristics. All of these tests confirm the quality of our matching and the results remain unchanged and robust.

The second alternative method that we use in this chapter is **Difference-in-Difference**. We use this method for two main reasons. Firstly, the main basis for interpreting the coefficients in Table 5.4 as causal is the assumption that the treated and untreated countries would follow similar trends in the absence of adoption of DNS (Bertrand et al., 2004). However, recent studies suggest that this is still not the case and that this approach often produces biased

results (see Roth et al., 2023). In fact, the problem stems from the irregular timing of the DNS and their variable impact over time and from country to country. This problem is known in the literature as «staggered adoption», which relies on the presence of several groups and several treatment periods (see, for example, Athey and Imbens, 2022; Callaway and Sant’Anna, 2021). Consequently, the coefficient obtained in Table 5.4 may not accurately reflect the real average effect of treatment in countries that have benefited from DNS (ATT). Secondly, forbidden comparisons can introduce bias into estimates in the context of a two-factor fixed effect (TWFE) model (Bertrand et al., 2004; Callaway and Sant’Anna, 2021). In other words, when estimates use the first units as a control for units treated later, the entropy balancing method lacks validity in identifying the impact of DNS on sustainable development. With 32 cohorts of observations—country processed at different times throughout the year—the likelihood of heterogeneous effects is significant, increasing the risk of bias. Consequently, we adopted recently developed estimators that are robust to the biases inherent in conventional TWFE models. We follow Callaway and Sant’Anna (2021), who identify specific ATTs for each cohort g and year t and aggregate them to present «event study» type figures. This procedure allows for heterogeneity of treatment effects, thus avoiding incorrect comparisons. Callaway and Sant’Anna (2021) method is suitable for our model, as it calculates ATTs by group before and after DNS adoption. We estimate the model using inverse probability weighting, in which treated countries are compared to never-treated countries with the same probability of receiving debt relief in the form of debt-for-nature swaps. Next, we use doubly robust methods, two based on the inverse probability weighting (Abadie, 2005) and based on the combination of the inverse probability with the stabilized inverse probability weighting and ordinary least squares. Estimation of these probabilities is based on macroeconomic, political, environmental, geographical, and socioeconomic characteristics, captured by our covariates as defined in Tables [5.1] and [5.2]. The new ATTs reported in Table 5.8, Panel B show that DNS positively and significantly affects sustainable development.

Third, we use **endogenous switching regression models** for two main reasons: *i*- endogenous switching regression models jointly estimate selection and outcome equations through a full information maximum likelihood (FIML) estimator (see Asfaw et al., 2012; Carter and Milon, 2005; Nonvide, 2019); *ii*- endogenous switching regression models enable counterfactual analysis. In other words, the model will make it possible to assess how much the level of

sustainable development of a DNS non-beneficiary would have improved if he or she had benefited from DNS, and the loss for the DNS beneficiary in the event of rigorous non-monitoring. Indeed, the estimation of the endogenous switching regression (ESR) model consists of separate estimates for countries that have benefited from DNS and countries that have not. This suggests that the adoption of DNS becomes the selection criterion that indicates which regime a country belongs to. Next, the level of sustainable development is observed for both groups (see Nonvide, 2019; Di Falco et al., 2011). To compare the expected results (level of sustainable development) of DNS countries (a) with those of non-DNS countries (b), and to study the expected results in counterfactual cases (c) that countries have not adopted, and (d) that non-DNS countries have adopted, we follow recent studies such as Asfaw et al. (2012); Di Falco et al. (2011); Nonvide (2019); Heckman et al. (1998b); Carter and Milon (2005). Table E1 shows the expected levels of sustainable development under actual and counterfactual conditions. Cells (a) and (b) represent the expected sustainable development observed in the sample for DNS and non-DNS countries, respectively. We observed that the expected sustainable development of DNS countries was higher than that of non-DNS countries. However, on the basis of this simple comparison, it could be misleading to attribute the difference in sustainable development to the adoption of DNS by countries. In counterfactual case (c), it has been clearly demonstrated that the treatment effect for DNS countries is 0.1073. This equates to a difference of 11.33% in average sustainable development.⁶ In other words, if DNS countries had not benefited from DNS, their sustainable development would have been reduced by 11.33%. In counterfactual case (d), if non-DNS countries had benefited from DNS, their sustainable development would have been increased by 1.78%. From this point of view, the effect of transitional heterogeneity is positive, which implies that the effect of DNS on sustainable development is significantly higher for those countries that actually used DNS for their intended purposes than for those that did not. These results confirm our baseline hypothesis that DNS has a significant impact on sustainable development.⁷

Fourth, as we saw earlier, there are potential shortcomings due to data limitations, in particular, the use of a dummy variable defined by the year of DNS adoption, which does not take

⁶Note that the treatment effect in this unit is interpreted as a percentage difference. In fact, when the outcome variable is log-transformed, multiplying TT by 100 is an approximation. In other words, the exact percentage difference is given by $[100*(e^{TT} - 1)]$, where e is the exponential e and TT the average treatment effect provided by the analysis of the log-transformed variable (see Asfaw et al., 2012).

⁷The results of the treatment effects confirming our baseline results are shown in Fig.7 in Appendix.

into account the level of evolution of the amounts of funds allocated to countries under DNS transactions. We use AfDB (2022) information on DNS transactions to build a database. There are two types of transaction in AfDB (2022) that we have identified, namely transactions on the face value of canceled debt and funds that were designated for the environment. We collect these data and carry out a **cross-sectional analysis**. Using these data in **cross-sectional regression**, our results show that debt relief in the form of DNS positively affects sustainable development, with environmental funds being more significant (see Table E2, columns [3]-[4]). This is in line with our baseline results, but also draws the attention of policy makers in debtor countries and donors to the fact that debt cancellation alone is not enough, and that funds need to be deployed in the projects concerned in order to grasp the real impact of DNS.

Finally, we use **two-stage GMM systems** and the **instrumental variable method** to address potential endogeneity biases that could arise in DNS processing and adoption. Although the endogenous switching regression models method addresses this concern, we are keen to reinforce the confidence and quality of our results. First, the two-stage GMM method combines the level and first-difference equations into a system and estimates them using lagged differences and levels of explanatory variables as instruments. As a result, and given that, compared to the GMM difference estimator, the GMM system takes more instruments into account by adding a second equation to improve the efficiency of the estimation, we address the problem of instrument proliferation by reducing the instrument matrix (Blundell and Bond, 1998; Roodman, 2009). In addition, we use Windmeijer (2005)'s finite-sample correction to reduce the possibility of erroneous precision, so that standard errors are not biased downwards. In addition to the two-stage GMM method, which uses only internal instruments, we address the endogeneity problem with the instrumental variable method (IV), which uses external instruments (see Sommer et al., 2020). This method allows us not only to overcome the problem of instrument proliferation in GMM, but also the main criticism of GMM, which is the «black box» for certain researchers (see Soto, 2009). The results reported in Table E2, columns [1]-[2] confirm our baseline finding: The adoption of DNS considerably increases sustainable development in developing countries after endogeneity treatment.

In sum, the robustness section confirms, by and large, our baseline finding. The adoption of DNS significantly increases sustainable development when considering alternative specifications, samples, measures of the main variables, or estimation methods.

Table 5.7: DNS and sustainable development: using propensity score matching

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Sustainable development	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
ATT	0.0627*** (0.0148)	0.0654*** (0.0146)	0.0629*** (0.0114)	0.0640*** (0.0078)	0.0698*** (0.0064)	0.0868*** (0.0066)	0.0682*** (0.0076)	0.0646*** (0.0083)
Observations	1,500	1,500	1,500	1,500	1,500	1,5	1,500	1,500
Untreated	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066
Treated	434	434	434	434	434	434	434	434
Matching Quality								
Pseudo-R2	0.002	0.003	0.003	0.004	0.004	0.011	0.002	0.004
Rosenbaum bounds sensitivity test	1.7	2.25	2.5	3.0	3.0	3.0	3.0	3.0
Standardized bias (p-value)	0.783	0.551	0.611	0.453	0.386	0.023	0.783	0.445

Bootstrapped standard errors based on 50 replications in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Table 5.8: Robustness: using entropy balancing and Diff-in-Diff estimations

<i>Panel A: Testing both DNS objectives</i>	[1]	[2]	[3]	[4]
VARIABLES	Total external debt stocks in % of GDP	Total external debt stocks in % of GDP	Forest land biocapacity per capita	Forest land biocapacity per capita
DNS adoption	-0.3665*** (0.0795)	-0.3024*** (0.0700)	0.1139*** (0.0405)	0.0784* (0.0413)
Constant	2.5943*** (0.1071)	0.6009 (1.3034)	0.7062*** (0.1479)	-5.8016*** (2.0361)
Covariates	No	Yes	No	Yes
Country/FE	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes
Observations	1,620	1,620	1,118	1,118
R-squared	0.6833	0.7383	0.9988	0.9988
<i>Panel B: Diff-in-Diff estimations</i>	[1]	[2]	[3]	[4]
	drimp	ipw	stdipw	rc1
ATT: DNS adoption	0.0432*** (0.0148)	0.0895*** (0.0329)	0.0554*** (0.0193)	0.0432*** (0.0148)
Covariates	Yes	Yes	Yes	Yes
Observations	1,025	1,025	1,025	1,025

Note: in column [1] of Panel B, we present the doubly robust DiD estimator based on inverse probability of tilting and weighted least squares (drimp) (see Sant'Anna and Zhao, 2020). In column [2], we report the results of the inverse probability weighted DiD estimator (ipw) (see Abadie, 2005). In column [3], we report the results of the inverse probability weighting DiD estimator with stabilized weights (stdipw). Finally, we use the combination with the methods (drimp) and (dripw) in column [4]. Robust standard errors in

5.6.3 Is the debt-for-nature achieve its both main objectives?

The main objectives of debt-for-nature swaps are to improve environmental sustainability and public debt, thereby contributing to the stability of the international financial system. However, the effect of DNS on each of these variables is controversial in the literature. No consensus has yet been reached on the ability of DNS to achieve its objectives. In practice, debt cancellation undoubtedly frees up fiscal space for the country to finance the fight against climate change, poverty, inequality, and so on. At the same time, additional fiscal space can lead to discretionary spending by the government (see Neuenkirch and Neumeier, 2016), so that the country returns to its original fiscal position. In any case, the first objective feeds the second; i.e., when the first is achieved, it boosts the government's ability to pursue the second objective. Although the focus of our chapter is very much on the second objective that debt-for-nature swaps seek to achieve, in this section we deepen the debate by examining the effect of DNS on public debt and deforestation. This will enable us to make fairly comprehensive policy recommendations for all stakeholders involved in DNS transactions (NGOs, government creditors and debtors, national and international institutions, etc.). The results reported in Panel A, columns [1]-[2] of Table 5.8 show that DNS significantly reduces the stock of external debt. These results confirm that DNS can be an effective instrument for reducing debt, contradicting the studies of Cassimon et al. (2011) and are in line with Heller (2005). In columns [3]-[4], our results indicate that DNS significantly increases the biocapacity of forests per capita in developing countries.

5.7 Heterogeneity test

Having established the robustness of our baseline results under various alternative specifications, the current section explores its sensitivity according to DNS type, over time, and in relation to several structural characteristics.

5.7.1 Disaggregated effects of debt-for-nature swaps

We disaggregate DNS into two types of transaction: bilateral and multi-party DNS. The idea behind this exercise is that these two types of transaction could have a heterogeneous effect on sustainable development, given their size, survival, requirements, etc. We report

the results in Table 5.9, columns [1]-[2]. The results suggest that both types of DNS have a significant impact on sustainable development, with a higher amplitude for bilateral DNS.⁸ A possible explanation for this heterogeneous effect lies in the size, type and requirements of donors and stakeholders involved in DNS agreements. In terms of size, this effect can be explained by the fact that bilateral DNS are large and multi-party DNS in terms of transaction volume. In fact, DNS are subject to a great deal of criticism due to the insignificant amounts of debt canceled. As a result, the larger the size, the greater the impact. The second channel is the donor's requirement, which can be observed in two areas: pre-agreement and post-agreement. In the pre-agreement phase, the DNS bilateral agreement requires the country to present a sound economic situation, and to possess governance based on the rule of law and democracy. The post-agreement phase is linked to an examination of the DNS granted in the past, and whether the funds were actually directed towards improving environmental quality. Another possible explanation for this result is that multi-party DNS involves many partners in the transactions (NGOs, private and public institutions, etc.), which slows down the signing of agreements, making it even more tedious for countries that need a fairly simple and fast system for obtaining funds and investing. We refer the reader to the studies of Sommer et al. (2020) and AfDB (2022) for a better understanding of the mechanisms of the two types of DNS.

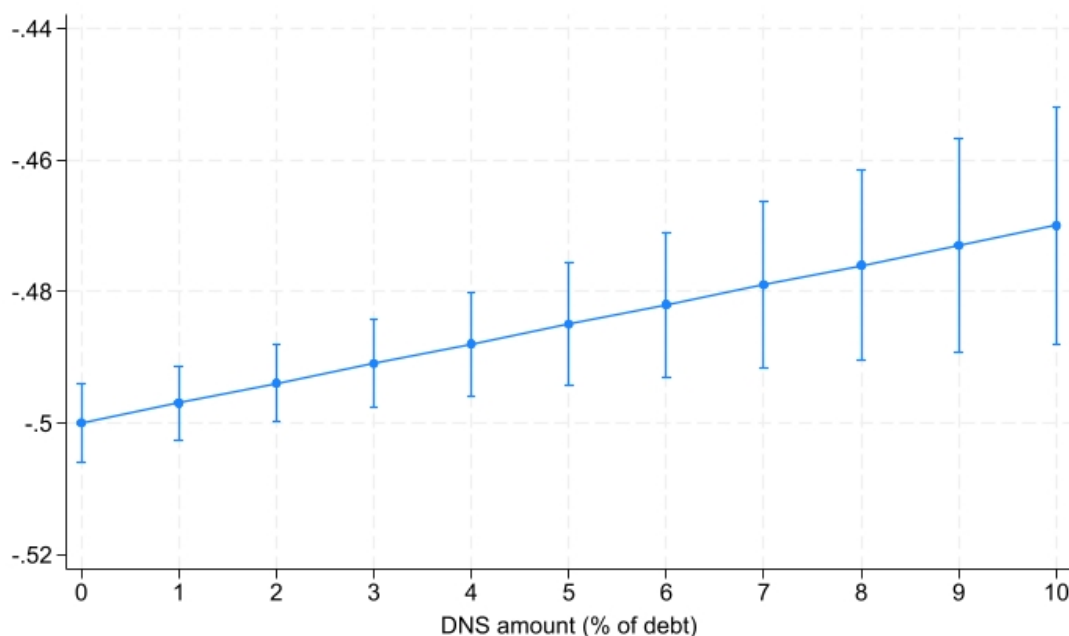
5.7.2 Non-linear effect between debt and the size of debt-for-nature swaps

In this section, we investigate whether size plays an important role and whether there is a non-linear effect of DNS. We do this in two ways. First, we estimate a quadratic model and then determine the DNS turning point. Secondly, we perform a slice analysis: small, medium, and large DNS. Estimation of a quadratic model for the size of debt-for-nature swaps (expressed as a percentage of public debt) reveals a non-linear effect on Sustainable Development Index (see Table E5, column [1]). The calculated turning point is 42.21%, which means that the sustainability benefits increase with the size of the DNS up to this threshold, then begin to decrease beyond it (see Fig.5.2). In other words, the marginal effect of a DNS decreases when it exceeds about 42% of public debt. This result suggests that there is an optimal level of relief through DNS, beyond which environmental and social returns begin to diminish. Several explanations

⁸It should be noted that most bilateral DNS are granted by the United States.

can be put forward: the complexity of managing large-scale operations, limited institutional capacity in beneficiary countries, or budget saturation effects that reduce the marginal efficiency of swap investments. However, below this threshold, DNS appears to be an effective tool for reconciling debt relief and environmental objectives. By categorizing DNS into three groups — small ($< 20\%$ of debt), medium (between 20% and 42%), and large ($> 42\%$) — we estimate their relative effects on the Sustainable Development Index in column [2]. The results indicate that the marginal effects vary significantly between these brackets, as confirmed by the test of equality of coefficients ($p < 0.05$).

Figure 5.2: Marginal effect of DNS by size relative to debt



5.7.3 The effect of debt-for-nature swaps over time

In this section, we examine the evolution of the effect of DNS adoption on sustainable development over time using a time-varying treatment effect. This dynamic effect can be used to isolate a potential time lag between the date of DNS adoption and its (significant) effect on sustainable development. The estimated ATTs for the year of DNS adoption ($t=0$) and for the four years following the year of adoption ($t=1, 2, 3, 4$) in Table 5.10 reveal the existence of a dynamic effect of DNS adoption. This effect appears as soon as DNS is adopted and increases

over time to approach the (average) magnitude of our reference effect five years after policy adoption. This dynamic effect, which appears as soon as the policy is adopted, can be explained by the improvement in macroeconomic, institutional, and political conditions imposed by certain donors such as the United States (see Sommer et al., 2020), which will eventually improve the indicators of sustainable development. Donor and debtor countries should therefore work harder on these conditions and requirements to maintain the persistence effect of DNS over time.

5.7.4 The role of structural and institutional factors

Our results show that the adoption of DNS increases sustainable development in developing countries. In this section, we explore the sensitivity of the effect of DNS adoption on sustainable development in relation to various structural characteristics, namely fiscal conditions, business cycle phase, institutional quality, commitment to environmental conventions, and political program.

Firstly, we distinguish the countries in our sample according to their level of development, using IMF classifications as in Apeti and Edoh (2023). Even if geographically close countries have a certain degree of simultaneity in terms of the structure of their economies, as **Waldo Tobler's** law shows (see Klemm and Van Parys, 2012), developing countries present significant heterogeneity. To account for this heterogeneity, we divide the countries in our sample into two groups: low-income countries and emerging countries. The results presented in the columns of Table 5.11 [1]-[2], show that the adoption of DNS increases sustainable development in both groups. However, the effect of DNS is greater in low-income countries than in emerging countries.

Secondly, we analyze the degree of vulnerability of each country. To do this, we divided our sample into two groups, according to the standard deviation of the sample: countries with high climate vulnerability and those with low climate vulnerability. In other words, we construct a dummy variable that takes the value 1 if the climate vulnerability score exceeds the standard deviation and 0 otherwise. The results in columns [3]-[4] of Table 5.11 show two possible effects. Debt-for-nature swaps are more effective in countries more vulnerable to climate shocks than their peers non-vulnerable. These results should draw the attention of donor countries to the criteria for selecting beneficiary countries. In fact, they should be more

interested in low-income countries that are more vulnerable to climate change.

Thirdly, we start from the idea that good institutions can promote the effectiveness of political reforms, and we analyze the sensitivity of our results to the role of institutions, and in particular to the control of corruption. We distinguish between countries with low and high levels of corruption control, based on the median of the sample. The results in Table 5.11, columns [5]-[6] show that DNS increase sustainable development regardless of the level of institutional quality. However, we note that the effect of DNS on sustainable development is greater in the context of better institutional quality, i.e., higher levels of corruption control.

Fourth, we analyze the role of democracy, since a necessary but not sufficient condition to benefit from DNS is to have a good application of democracy (see Sommer et al., 2020). We distinguish between low- and high-democracy countries according to the sample median. The results in Table 5.11, columns [7]-[8] show that DSN increases sustainable development regardless of the level of democracy. However, we note that the effect of DSN on sustainable development is greater in the context of better democracy application. These results reveal that the effectiveness of DNS does not necessarily depend on the political regime, but its magnitude can improve in the case of a democratic regime.

Fifth, we follow Sargent et al. (1981) and Leeper (1991), in examining the influence of fiscal policy in order to test the hypothesis of fiscal dominance. In fact, DNS could free up fiscal space for the country and lead to discretionary spending, thus inducing a flexible fiscal policy. The estimates in columns [9]-[10] of Table 5.11 indicate that a good fiscal stance favors (as measured by median government expenditure per percent of GDP) the effect of DNS on sustainable development, while poor fiscal conditions inhibit the effectiveness of DNS. The results in columns [11]-[12] show that DNS is also more effective in the presence of a strong fiscal policy (captured by the median of public debt) than in a situation of loose fiscal policy.

Sixth, we analyze the effectiveness of DNS in forest-endowed countries. To do this, we divide our sample into two groups, according to the median of the sample: countries with a strong forest planting policy and those with a weak forest planting policy based on the standard deviation of the planted forest (% of the forest area). The results in columns [13]-[14] of Table 5.11 show that the effect of DNS on sustainable development appears to be higher in countries that plant a lot of trees and protect the forests, although in two subsamples we found

that DNS improved forest protection. These results are perfectly in line with those found in the literature (see for instance Sommer et al., 2020; Shandra et al., 2011). Seventh, we analyze the effectiveness of DNS in the presence of membership in the Extractive Industries Transparency Initiative (EITI). Some studies have shown, for example, that membership in EITI improves the quality of institutions (Villar, 2022; Villar and Papyrakis, 2017), combats deforestation (Kindo et al., 2024), increases tax revenues (Kinda and Thiombiano, 2021), improves investment climate and economic development (Sovacool, 2020), and promotes governance reform (Arond et al., 2019). Under these conditions, we test the hypothesis that EITI can amplify the effect of DNS on sustainable development in developing countries. We follow Kindo et al. (2024) in constructing the EITI variable taking the value 1 if the country has joined EITI and 0 otherwise. The results in columns [15]-[16] of Table 5.11 show that the effect of DNS on sustainable development appears to be higher in countries that have joined EITI. In the eighth place, we analyze the effectiveness of DNS as a function of the country's engagement in international environmental conventions. To do this, we divided our sample into two groups, based on the sample mean: high-engagement countries and low-engagement countries. The results in columns [17]-[18] of Table 5.11 show that the effect of DNS on sustainable development appears to be higher in countries with a high level of commitment to environmental conventions.

Finally, columns [19]-[20] reveal that DNS increases sustainable development in both good and bad periods of the business cycle, but to a greater extent in the bad phase. One possible explanation could be that, in the high phase of the business cycle, the country may have less recourse to debt relief in the form of DNS. This could have an effect on the amount of DNS transactions during this period and in turn reduce their scale.

Table 5.9: Heterogeneity: effects by type of DNS adoption

VARIABLES	[1]	[2]
Bilateral DNS	0.2368*** (0.0374)	
Multi-party DNS		0.0243*** (0.0073)
Constant	-0.6615*** (0.2186)	-0.6935*** (0.2171)
Covariates	Yes	Yes
Country/FE	Yes	Yes
Year/FE	Yes	Yes
Observations	1,477	1,477
R-squared	0.9240	0.9244

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 5.10: Heterogeneity: dynamic effects

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]
DNS adoption (t0)	0.0105** (0.0138)					
DNS adoption (t+1)		0.0120* (0.0151)				
DNS adoption (t+2)			0.0096*** (0.0181)			
DNS adoption (t+3)				0.0102*** (0.0165)		
DNS adoption (t+4)					0.0866*** (0.0163)	
DNS adoption (t+5)						0.0866*** (0.0163)
Constant	-0.5592*** (0.2143)	-0.5592*** (0.2143)	-0.6351*** (0.2220)	-0.6934*** (0.2130)	-0.4603** (0.1955)	-0.5104*** (0.1960)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,500	1,500	1,500	1,426	1,352	1,280
R-squared	0.9253	0.9253	0.9239	0.9315	0.9378	0.9443

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 5.11: Heterogeneity: the role of structural factors

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
	Emerging countries	Low income countries	High climate change vulnerability	Low climate change vulnerability	High control of corruption	Low control of corruption	High democracy	Low democracy	High fiscal discipline	Low fiscal discipline
DNS adoption	0.0258** (0.0106)	0.0495*** (0.0082)	0.0489*** (0.0128)	-0.0703*** (0.0162)	0.0895*** (0.0178)	0.0394** (0.0196)	0.0470*** (0.0156)	0.0377*** (0.0098)	0.1640*** (0.0345)	0.0241** (0.0104)
Constant	-2.1927*** (0.3451)	-0.2551 (0.3403)	-2.0761*** (0.4775)	0.2637 (0.2325)	-0.3452 (0.2236)	-0.1106 (0.5956)	-2.4160*** (0.5996)	-0.0478 (0.1933)	-0.2747 (0.2456)	-0.7195** (0.3343)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	348	404	794	706	1,297	203	363	1,137	681	819
R-squared	0.9595	0.8570	0.9432	0.8318	0.9234	0.9454	0.9665	0.9424	0.9520	0.9477
	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
	Loose fiscal stance	Strong fiscal stance	High policy protection of forest	low policy protection of forest	EITI countries	non-EITI countries	High engagement in environmental conventions	low engagement in environmental conventions	Phase of the business cycle bad times	Phase of the business cycle good times
DNS adoption	0.0381*** (0.0089)	0.1600*** (0.0302)	0.0742*** (0.0139)	0.0650*** (0.0136)	0.0650*** (0.0136)	0.0479*** (0.0181)	0.1428*** (0.0211)	0.0436*** (0.0086)	0.1136*** (0.0392)	0.0598*** (0.0126)
Constant	0.2504 (0.1852)	-1.8466*** (0.4676)	-0.8550*** (0.2323)	-0.2854 (0.5375)	-0.2854 (0.5375)	-0.8100*** (0.2244)	-1.5420*** (0.4033)	0.4988** (0.2360)	-2.2470*** (0.6329)	-0.3794 (0.2489)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	881	619	1,240	334	334	1,166	750	750	265	1,235
R-squared	0.9416	0.9388	0.9242	0.9716	0.9716	0.9329	0.9152	0.9366	0.9650	0.9318

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

5.8 Transmission channels

Our results show that DNS increase sustainable development. In this section, we provide evidence on (some of) the potential channels through which DNS affect sustainable development. In this article, we identify five main channels⁹: (a) a reduction in the rate of natural resource depletion; (b) a reduction in CO2 emissions; (c) an increase in the stock of public capital captured by public investment; (d) an increase in economic output represented by GDP growth; (e) an improvement in well-being measured by the human development index (excluding the ecological dimension). Given that there is no single technique in the literature for testing transmission channels, we have kept our basic model for this exercise. In column [1] of Table 5.12, we show a negative and statistically significant relationship between DNS and resource depletion. In fact, DNS force governments to invest in green projects, biodiversity protection, and renewable and non-renewable resources, thereby curbing resource depletion. Another explanation is that in order to benefit from DNS, the country must have a resource that can be protected or preserved. This can act as a disincentive to the abusive exploitation of natural resources. In column [2] of Table 5.12, we show a negative and statistically significant relationship between DNS and CO2 emissions. As we saw above, DNS increases forest land biocapacity, which will necessarily affect CO2 emissions, as forests are known for their carbon sequestration. Reducing resource depletion and CO2 emissions improves the sustainable development index, as they are included in the SDI calculation (see Hickel, 2020). In columns [3];[4]; and [5], we show that DNS has a positive and statistically significant impact on public investment, economic growth, and well-being, respectively. Indeed, DNS are granted with the aim of investing in environmental preservation. These investments will create jobs for the population, reduce intensive agricultural activity that destroys forests, create additional revenue for the government, which will boost economic growth, which in turn will serve to reduce poverty and inequality, and improve the well-being of the population.

In addition to these channels, we found that the reduction of public debt is a potential one. As explained above, before us, evidence was found in the literature showing the negative effect

⁹It should be noted that these channels are not exhaustive and other channels such as: volatility of fiscal policy measured by the standard deviation of government expenditure 5-years of window; public debt; institutional quality measured by a composite index of corruption, government stability, political stability, democracy, rule of law; deforestation; greenhouse gas emissions; resource rents have been tested as part of this chapter but the statistics are not reported in the chapter which could be available on request.

of DNS on public debt. For example, Jones and Campos (2023) estimate that since 2015, DNS has restructured around 3 billion USD, representing up to 1.6% of national GDP. Thus, by reducing public debt, DNS provides governments with additional financial resources, which will enable them to finance poverty, income inequality, and climate change, thereby significantly increasing long-term sustainable development.

Table 5.12: Debt-for-nature swaps and sustainable development: transmission channels

VARIABLES	[1] Resource depletion	[2] CO2 emissions	[3] Total public investment	[4] GDP growth	[5] Well-being
DNS dummy	-0.7121*** (0.1384)	-0.1516*** (0.0425)	0.1771*** (0.0438)	0.0120*** (0.0046)	0.0089*** (0.0025)
Constant	8.1871*** (2.4316)	-6.9568*** (1.4863)	1.5616 (0.9660)	1.1256*** (0.1358)	0.2700*** (0.0410)
Covariates	Yes	Yes	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes	Yes
Observations	1,582	1,622	1,528	1,622	1,582
R-squared	0.8380	0.9752	0.6453	0.9979	0.9910

Robust standard errors based in brackets. *** p<0.01, ** p<0.05, * p<0.1.

5.9 Conclusion and policy recommendations

This chapter analyzes whether the adoption of debt-for-nature swaps improves sustainable development in developing countries. Using entropy balancing to control for endogeneity on a large sample of 127 developing countries over the period 1990-2020, our study concludes that debt-for-nature swaps increase sustainable development in countries that have benefited from them, compared with countries that have not benefited from this public debt relief program. This result is robust to several alternative specifications, including extending the vector of control variables, modifying the sample, using an alternative treatment definition, and using competing estimation methods. Further estimates show that if the treated countries had not benefited from DNS, their sustainable development indices would have decreased by 11%, whereas if the untreated countries had benefited from DNS, their indices would have increased by around 2%. In addition, our findings suggest that we should not be pessimistic about expanding the DNS, as they are effective in improving sustainable development and also help reduce external debt. However, heterogeneity tests show that the effect of debt-for-nature swaps may depend on the type of debt-for-nature swap transaction, the time perspective, and

certain structural factors. In fact, such characteristics can promote or, in contrast, inhibit the effectiveness of the environmental and budgetary framework and suggest that certain conditions need to be met to expect DNS to have a favorable effect in terms of increasing sustainable development. Finally, we provide evidence that reduced resource depletion and CO₂ emissions, increased investment, improved economic growth and well-being (measured by life expectancy at birth, expected years of schooling and average years of schooling, and gross national income per capita) are potential transmission channels through which debt-for-nature swaps affect sustainable development. This article contributes to the literature on the sustainable development process in developing countries by analyzing the role of public debt relief as debt-for-nature swaps. In a post-Covid-19 context marked by higher public debt, international and geopolitical tensions, combined with higher borrowing costs due to rising interest rates to combat climate vulnerability, this article may have significant economic policy implications for both creditor and debtor governments, as well as for national and international biodiversity conservation NGOs. This article calls on creditor governments to reauthorize and extend the program by allocating more funds to the program or by relaxing eligibility criteria to increase the number of countries eligible for the program. In addition, another promising approach could be to integrate climate concerns into existing debt relief programs such as HIPC/IADM, by raising awareness among policymakers and helping developing countries to take full account of climate change mitigation and adaptation issues when formulating their national development strategies. We were constrained by the availability of data on DNS amounts, forcing us to use a DNS dummy variable. This is a limitation of this study—future research should re-examine the relationship examined here using data on DNS amounts when they become available.

GENERAL CONCLUSION

“The master-economist must study the present in light of the past for the purposes of the future”

– John Maynard Keynes (1924)

This dissertation explores the importance of combining natural resource endowments and sovereign debt to promote sustainable development financing. This thesis, which is organized around five complementary political chapters, focuses on developing countries, specifically low-income countries (LICs) and middle-income countries (MICs). It pays significant attention to two primary related topics. The first part looks at the macroeconomic and environmental impact of resource-backed loans, while the second part looks at the socioeconomic and environmental efficiency of debt-for-nature swaps. We begin the first part of the thesis by analyzing the effect of resource-backed loans on the ecological efficiency of human development in African countries (particularly in Chapter 1). The results show that resource-backed loans are associated with an increase in the ecological efficiency index of human development. This effect, which can be explained by an increase in economic growth and national income, can vary according to the level of the debt ratio, the type of collateral, and the ability to access financial markets. In Chapter 2, the thesis contributes to the literature on the relationship between artificial capital (man-made) and natural capital in developing countries, with a specific focus on the impact of resource-backed loans on deforestation. In fact, while this strategy can offer rapid access to capital, it can also exacerbate deforestation and the destruction of ecosystems, particularly in developing countries. To do this, we tested two main : *i*-resource-backed loans increase deforestation through the maximization of natural resource rents and resource depletion; *ii*-resource-backed loans accelerate deforestation by exacerbating debt viability and affecting the quality of institutions. Our intuition is that if a country has difficulty repaying its debt, it is driven to accelerate the exploitation of its natural resources, particularly tropical forests. Furthermore, some agreements give creditors direct control over resource exploitation, reducing a country’s ability to regulate deforestation. Based on a large sample of 64 developing countries over a period spanning from 2004 to 2018, provide a rigorous econometric analysis comparing the effect of resource-backed loans on forest cover loss. Our results show that resource-backed loans increase deforestation. Nevertheless, when we

disaggregate resource-backed loans to capture heterogeneous effects, our results indicate that loans backed by minerals, tobacco, and cocoa increase deforestation, while loans backed by oil have no significant direct impact on deforestation. In addition, our results indicate that the effect of resource-backed loans on deforestation, rather than being transitory, is persistent and starts in the first year of adoption, then amplifies over the course of the loan. The main findings of this chapter suggest that resource-backed loan agreements should include strict clean development provisions and the implementation of actions to mitigate the negative environmental impact of these loans for borrowing countries. Finally, Chapter 3 analyzes the effect of resource-backed loans on fiscal policy cyclicity in developing countries. Using a sophisticated impact assessment study – entropy balancing estimation method on a large panel of 127 developing countries over the period 1990-2020, our results show that resource-backed loans trigger the procyclicality of fiscal policy. Tests on transmission channels reveal that sovereign debt defaults (domestic debt crisis), volatile budget balance and low institutional quality measured by rising levels of corruption are variables through which resource-backed loans affect the cyclicity of fiscal policy. Furthermore, our results indicate a heterogeneous effect of resource-backed loans in terms of interest rate, type of collateral and type of lender. However, the procyclical effect of resource-backed loans depends on the public investment threshold. There is a non-linear relationship between the investment rate and the procyclicality of resource-backed loans. In fact, with an investment rate of between 15% and 35% of GDP, countries adopting resource-backed loans are likely to obtain a counter-cyclical fiscal policy. The second part of the thesis analyses the macroeconomic and environmental impact of debt-for-nature swaps in two chapters (4 and 5). Chapter 4 assesses the macroeconomic impact of debt-for-nature swaps based on a sample of 134 developing countries over the period 1990-2020. The hypothesis tested is that debt-for-nature swaps can help stabilize fiscal policy by reducing public debt and providing countries with fiscal space. Through a series of robustness checks, the results indicate that debt-for-nature swaps have a negative effect on fiscal policy volatility. When we disaggregate debt-for-nature swaps to run the regressions, the results show a surprising effect. Only bilateral debt-for-nature swaps have a negative effect on fiscal policy volatility. Therefore, contributing to the ongoing literature on fiscal policy volatility and the emerging literature on debt-for-nature swaps, our results suggest that debt relief in the form of debt-for-nature can be a useful policy (but not a miracle solution) to combat fis-

cal discretion and fiscal debauchery through reduced fiscal policy volatility, and at the same time improve environmental sustainability. Chapter 5 which is the last of the thesis analyzes the effect of debt-for-nature swaps on ecological efficiency of human development. Based on a large sample of 127 developing countries over 1990-2020 and using entropy balancing, we show that debt-for-nature swaps are an effective instrument to increase ecological efficiency of human development in developing countries. Additional results show that if treated countries had not benefited from debt-for-nature swaps, their index of ecological efficiency of human development would have decreased by 11%, whereas if untreated countries had benefited from debt-for-nature swaps, their index would have increased by around 2%. Finally, by combining environmental conservation and improved living conditions, our results confirm that these debt relief mechanisms can be a powerful tool for fairer, more sustainable development. To explain this result, we highlight different transmission channels. The results show that resource depletion, CO2 emissions, public investments (% of GDP), economic growth and well-being are the potential channels through which debt-for-nature swaps positively affect ecological efficiency.

This thesis may have several implications. The central message that emerges from this thesis is that in a world where economies are seeking to balance economic growth and sustainability, the integration of public debt and natural resources into a sustainable development strategy is becoming essential. Faced with global challenges such as climate change and resource depletion, countries need to rethink their economic policies to ensure a viable future. Debt management, often perceived as a constraint, can be transformed into a lever for stimulating green investment, while preserving the ecosystem and improving social well-being. Similarly, the abundance or scarcity of natural resources offers unique opportunities and challenges to each nation. By combining prudent debt management with the responsible exploitation of these resources, states are moving towards development models that not only fuel economic growth but also foster more equitable and resilient societies — one of the key objectives of sustainable development. In fact, the policy guidance that could be drawn from the findings of Chapter 1 is that resource-backed loans could significantly boost human development if African countries use these loans to finance productive public investment. By enabling borrowers to access funds using natural resources such as oil, gas, or minerals as collateral, these loans facilitate investment in infrastructure and economic development projects. They

reduce the cost of borrowing by lowering the risk perceived by lenders, and promote economic stability by securing the financing needed for development. In addition, the use of guarantees based on real resources tends to boost the confidence of lenders, helping to attract foreign capital and support economic growth in a sustainable way. This helps reduce inequality and poverty and promotes sustainable development. The second chapter suggests that developing countries must not lose sight of the environmental issue in their drive to finance development. These countries need to be aware of the environmental implications of these external sources of financing. The chapter teaches that when natural resources, such as forests, oil reserves or mineral deposits, are used as collateral, this can encourage over-exploitation that threatens biodiversity and local ecosystems. For example, intensive extraction of these resources to repay loans can lead to increased deforestation, destruction of natural habitats and pollution from mining or oil extraction. In addition, economic pressures such as debt burdens can encourage unsustainable practices, increasing carbon emissions and disrupting natural balances. It is therefore crucial that borrowers, like lenders, integrate strict ecological standards and adopt sustainable management approaches to minimize these harmful impacts and ensure development that respects environmental sustainability. In terms of policy implications, the results of Chapter 3 suggest that resource-rich countries should avoid taking on too much debt on the resource-backed loan market, as these loans often amplify the cyclicity of fiscal policy, due to their propensity to accentuate periods of euphoria as well as phases of strict austerity. Indeed, when resource prices begin to decline, many borrowing countries find themselves in a delicate financial situation, unable to maintain stable and sustainable spending levels over the medium to long term. This economic instability leads to a chaotic alternation between periods of excessive spending and periods of severe austerity, complicating budget management and increasing its unpredictability. In sum, the major message from the first part of this thesis is that public debt plays a crucial role in sustainable development, being an essential source of funding for infrastructure and social projects, but it can also be an economic burden. Prudent debt management is vital to avoid financial crises, which can compromise sustainable development efforts. The conclusion of Chapter 4 and 5 vehicles the message that, in a world where debt levels are becoming increasingly preoccupying, combined with growing vulnerability to climate change in recent years, the extension of debt-for-nature swaps is an effective solution for promoting fiscal policy discipline and sustainable development, for a number of reasons.

On macroeconomic side, debt-for-nature swaps offer governments greater budgetary flexibility, enabling the dynamic and strategic reallocation of financial resources in line with changing priorities. This enables public authorities to respond quickly and effectively to unforeseen economic crises, adjusting investment and spending where it is most needed. In addition, by creating fiscal space and diversifying funding sources, these debt-for-nature swaps help to significantly reduce dependence on traditional debt markets, a factor that can prove particularly strategic in times of global economic instability or financial market tension. This allows more flexible management of fiscal policy, reducing the impact of external economic shocks. On development sustainable side, by redirecting funds that would otherwise have gone to debt repayment, these agreements enable governments to make substantial investments in sustainable practices and environmentally-friendly infrastructure improvements. Furthermore, these initiatives can ease the debt burden for countries facing economic challenges, enabling them to enhance their resilience in the face of climate change while stimulating the local economy by encouraging green sectors such as renewable energy. Moreover, unnatural debt is part of a scheme that prioritizes economic and ecological sustainability, facilitating the implementation of projects that improve biodiversity, natural resource management and help mitigate the impacts of climate change. It is therefore crucial to encourage the active participation of all stakeholders in order to maximize the impact of these swaps on sustainable development.

This thesis also provides and opens up avenues for possible interesting extensions and future research. The first complementary work analyzes the impact of resource-backed loans on income inequalities in developing countries, notably sub-Saharan Africa and Latin America. There are two reasons for this future research. Firstly, although efforts have been made to reduce income inequality in sub-Saharan Africa and Latin America, these regions continue to have some of the highest levels of inequality in the world. High income inequality can reduce the tax revenue mobilization efforts of tax authorities (Boustan et al., 2013), thereby weakening the government's ability to finance sustainable development. Secondly, while these loans may offer economic opportunities for resource-rich countries, they also risk exacerbating income disparities if the economic benefits are not wisely managed and distributed. For the future, it is crucial to develop robust policy frameworks and responsible financial practices to ensure that natural resources benefit society as a whole, not a narrow elite. The second future study identified by this thesis is the analysis of the determinants of tax revenue mobilization: the case

of resource-backed loans. In fact, tax revenue mobilization is a central concern of economic policy in many countries. In recent years, governments and multilateral institutions have shown a broader and renewed interest in strengthening fiscal capacity, in recognition of the fact that fiscal capacity is at the heart of state-building and development (Besley and Persson, 2009). UN member countries have set a specific target to increase tax revenues to finance the Sustainable Development Goals (SDGs) by 2030, focusing on strengthening domestic resource mobilization. Given these challenges, it would be essential to analyze how resource-backed loans affect tax revenue mobilization. The theoretical link between resource-backed loans and tax revenue collection is unclear—as they can increase tax base through public investments and reduce mobilization efforts—increasing dependency on the extractive sector. A third extension of this thesis concerns the link between debt-for-nature swaps and the composition of public expenditure. In fact, debt-for-nature swaps often force governments to allocate funds not according to national priorities or citizens' needs, but in a way that satisfies the interests of creditors or external actors with sometimes opaque motives. This can lead to chronic under-utilization of resources in essential sectors such as education or health, weakening the social fabric and long-term economic development.

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APPENDIX

Appendix A (Chapter 1): Resource-backed loans and Ecological Efficiency of Human Development: Evidence from African Countries

Table A1: Resource-backed loans and ecological efficiency : using OLS

	[1]	[2]	[3]	[4]	[5]	[6]
VARIABLES	OLS	OLS	OLS	OLS	OLS	OLS
RBL dummy	0.0043*** (0.0109)	0.0349*** (0.0101)	0.0400*** (0.0105)	0.0331*** (0.0110)	0.0315*** (0.0109)	0.0322*** (0.0109)
Log Inflation		0.0023 (0.0029)	0.0008 (0.0031)	0.0024 (0.0035)	0.0018 (0.0035)	0.0019 (0.0035)
Log ODA			0.0122** (0.0056)	0.0106* (0.0062)	0.0088 (0.0062)	0.0086 (0.0062)
Log FDI				0.0049* (0.0025)	0.0050* (0.0025)	0.0048* (0.0026)
Log Natural resources rents					0.0185** (0.0090)	0.0162* (0.0097)
Log Resource depletion						0.0023 (0.0027)
Constant	-0.8170*** (0.0281)	-0.8110*** (0.0367)	-0.8223*** (0.0398)	-0.8692*** (0.0490)	-0.9298*** (0.0601)	-0.9289*** (0.0604)
Country/FE & Year/FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,066	881	866	799	799	799
R-squared	0.8518	0.8477	0.8482	0.8491	0.8502	0.8503

Standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A2: Resource-backed loans and ecological efficiency : adding control variables by groups

	[1]	[2]	[3]	[4]	[5]
VARIABLES	Economic	Political and institutional	Climate	Infrastructure and structural	All groups
	variables group	conditions group	considerations group	issues group	
RBL dummy	0.0241*** (0.0073)	0.0180** (0.0073)	0.0240*** (0.0071)	0.0252*** (0.0070)	0.0187*** (0.0072)
Constant	-0.6971*** (0.0455)	-0.6832*** (0.0447)	-0.6959*** (0.0459)	-0.6464*** (0.0479)	-0.6442*** (0.0489)
Covariates	Yes	Yes	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes	Yes
Observations	799	755	796	773	745
R-squared	0.9403	0.9475	0.9398	0.9476	0.9483

Standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A3: Resource-backed loans and ecological efficiency : adding control variables desegregated

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
VARIABLES	GDP volatility	Investment volatility	Total investment	Stock price volatility	Financial openness	Rich-resources	Trade openness	Remittance inflows	Natural shock index	Public debt
RBL dummy	0.0341*** (0.0073)	0.0291*** (0.0070)	0.0216*** (0.0071)	0.2578*** (0.0242)	0.0227*** (0.0075)	0.0241*** (0.0072)	0.0277*** (0.0079)	0.0116* (0.0066)	0.0261*** (0.0072)	0.0345*** (0.0071)
Constant	-0.7076*** (0.0472)	-0.7244*** (0.0449)	-0.7090*** (0.0485)	-0.9352*** (0.0494)	-0.6665*** (0.0471)	-0.7055*** (0.0413)	-0.6950*** (0.0524)	-0.6314*** (0.0483)	-0.7202*** (0.0487)	-0.6129*** (0.0361)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	738	716	775	117	780	799	709	714	762	670
R-squared	0.9519	0.9517	0.9409	0.9685	0.9383	0.9401	0.9402	0.9456	0.9421	0.9610
	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
	Rule of law	Corruption	External conflict	Internal conflict	Political stability	Climatic vulnerability	Disasters index	Exposure index	Shock index	Exchange rate
RBL dummy	0.0239*** (0.0072)	0.0191** (0.0084)	0.0163** (0.0083)	0.0184** (0.0082)	0.0222*** (0.0074)	0.0462*** (0.0073)	0.0228*** (0.0071)	0.0223*** (0.0071)	0.0250*** (0.0070)	0.0209** (0.0084)
Constant	-0.8583*** (0.0478)	-0.6583*** (0.0474)	-0.7968*** (0.0614)	-0.6927*** (0.0535)	-0.7746*** (0.0495)	-1.4236*** (0.1711)	-0.6810*** (0.0470)	-0.3407*** (0.0873)	-0.7081*** (0.0452)	-0.6550*** (0.0453)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	706	553	553	553	706	638	774	760	762	708
R-squared	0.9550	0.9449	0.9482	0.9451	0.9517	0.9524	0.9401	0.9512	0.9420	0.9362

Standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01

Table A4: Resource-backed loans and ecological efficiency : adding control variables desegregated (continued) and modification sample

	[21]	[22]	[23]	[24]	[25]	[26]	[27]
VARIABLES	ICT infrastructure	Education	Innovation	Doing business	Electric power consumption	Access to electricity urban	Access to electricity rural
RBL dummy	0.0357*** (0.0067)	0.0379*** (0.0073)	0.0432** (0.0173)	0.0425*** (0.0079)	0.0157* (0.0083)	0.0287*** (0.0071)	0.0286*** (0.0067)
Constant	-0.4899*** (0.0531)	-0.7470*** (0.0527)	-0.6848*** (0.0654)	-0.7573*** (0.0542)	-0.5192*** (0.0435)	-0.7670*** (0.0334)	-0.6236*** (0.0493)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	638	638	393	638	367	731	627
R-squared	0.9610	0.9535	0.8991	0.9507	0.9635	0.9516	0.9594
	[28]	[29]	[30]	[31]	[32]	[33]	[34]
Excluding							
	Hyperinflation episode	New RBL	Pre-2004	Financial crisis year	Environmental convention	Global demand	Oil crisis year
RBL dummy	0.0171** (0.0073)	0.0167** (0.0078)	0.0216*** (0.0063)	0.0229*** (0.0079)	0.0224*** (0.0083)	0.0335** (0.0146)	0.0237*** (0.0071)
Constant	-0.6619*** (0.0469)	-0.6495*** (0.0451)	-0.6879*** (0.0269)	-0.7010*** (0.0479)	-0.6814*** (0.0471)	-0.7566*** (0.0571)	-0.7050*** (0.0461)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	773	708	524	729	686	333	768
R-squared	0.9415	0.9360	0.9788	0.9372	0.9319	0.9651	0.9397

Standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01

Table A5: Resource-backed loans and ecological efficiency: perspective time

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
RBL dummy	0.1165*** (0.0209)	0.0379*** (0.0107)	0.0611*** (0.0206)	0.0286*** (0.0080)	0.0899*** (0.0169)	0.0326*** (0.0092)	0.0443*** (0.0167)	0.0241*** (0.0072)
Constant	-0.7441*** (0.0210)	-0.9018*** (0.0201)	-0.7784*** (0.0725)	-0.7837*** (0.0402)	-0.6446*** (0.0279)	-0.8200*** (0.0308)	-0.6301*** (0.0685)	-0.7031*** (0.0465)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	799	799	799	799	799	799	799	799
R-squared	0.1216	0.9299	0.2255	0.9382	0.4606	0.9327	0.5275	0.9401

Notes: This Table presents the causal effect of RBL adoption on ecological efficiency of human development obtained by entropy balancing method introducing the trend. Standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Steps of Anderson's synthetic index

The six steps described by Anderson (2008) to calculate this synthetic index are as follows:

- 1- Select k indicators relevant for outcome j .
- 2- Adjust sign : For all k indicators, ensure the positive direction always indicates a “better outcome”.
- 3- Normalize indicators : Demean all k indicators by subtracting the mean of the indicator in the reference group (full sample is the default reference group). Then, convert them to effect sizes, $\tilde{y}_k$, by dividing each indicator by its reference group standard deviation.¹⁰
- 4- Construct weights : Create weights using Σ^{-1} , the inverse of the covariance matrix of the normalized indicators.¹¹ Specifically, set the weight $\tilde{w}_k$ on each indicator equal to the sum of its row entries in Σ^{-1} . With this rule, highly correlated indicators are assigned small or offsetting weights, while less correlated outcomes receive larger weights.

¹⁰Note that in some cases, particularly when all subindicators are of comparable scales, the normalization may not be necessary. The `swindex` command accommodates this special case using the `nostd` option (see, Schwab et al. (2020) on the command).

¹¹This is equivalent to using the correlation matrix in the special case that the normalization procedure described in step 3 standardizes against the full sample using the default option.

5- Construct index: Calculate the weighted average of $\tilde{y}_k$ for observation i . Formally, the weighted average $\bar{S}_i$ is calculated using $\bar{S}_i = (\mathbf{1}'\widehat{\Sigma}^{-1}\mathbf{1})^{-1}(\mathbf{1}'\widehat{\Sigma}^{-1}\tilde{y}_i)$ where $\mathbf{1}$ is a column vector of 1s and $\tilde{y}_i$ is a column vector of all outcomes for observation i . This is an efficient GLS estimator.

6- Normalize index: Demean index $\bar{S}_i$ by subtracting the mean index in the reference group and convert it to effect sizes by dividing it by its reference group standard deviation¹².

Table A6: Validity of transmission channels

Panel A	[1]	[2]	[3]
VARIABLES	Ecological efficiency	Ecological efficiency	Ecological efficiency
Education level	0.0555*** (0.0095)		
GNI per capita		0.1221*** (0.0220)	
Expected years of schooling			0.4484*** (0.0206)
Constant	-0.6282*** (0.0618)	-2.0011*** (0.2014)	-1.6067*** (0.0479)
Covariates	Yes	Yes	Yes
Country/FE & Year/FE	Yes	Yes	Yes
Observations	638	799	799
R-squared	0.8776	0.8556	0.9089
Panel B	[1]	[2]	[3]
	Education level	GNI per capita	Expected Years of Schooling
RBL dummy	0.4470*** (0.0762)	0.0505* (0.0278)	0.0608** (0.0250)
Constant	-5.1386*** (0.1970)	8.8337*** (0.0762)	1.4381*** (0.0686)
Covariates	Yes	Yes	Yes
Country/FE & Year/FE	Yes	Yes	Yes
Observations	731	854	854
R-squared	0.9048	0.9738	0.8786

Standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01

¹²This step is implicitly done by Anderson (2008), although it is not formally discussed. This step is optional using the swindex command with the norescale option. The default uses the reference group from step 3, but the full sample mean and standard deviation can alternatively be used to normalize the index with the fullrescale option.

Table A7: Resource-backed loans and environmental sustainability

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Panel A Ecological impact and planetary boundaries								
RBL dummy	0.2766*** (0.1044)	0.4036*** (0.0316)	0.1864* (0.1035)	0.0866*** (0.0324)	0.2766*** (0.0644)	0.2744*** (0.0424)	0.2617*** (0.0734)	0.1052*** (0.0314)
Constant	0.0787* (0.0462)	0.7746*** (0.0375)	-0.1728 (0.4989)	0.5927 (0.3720)	0.2946** (0.1273)	0.8130*** (0.1516)	0.2828 (0.3070)	0.4328 (0.3993)
Covariates	No	No	No	No	Yes	Yes	Yes	Yes
Country/FE	No	Yes	No	Yes	No	Yes	No	Yes
Year/FE	No	No	Yes	Yes	No	No	Yes	Yes
Observations	926	926	926	926	926	926	926	926
R-squared	0.0245	0.9247	0.0652	0.9567	0.5473	0.9483	0.5640	0.9643
Panel B CO2 emissions								
RBL dummy	0.1034 (0.1162)	0.5201*** (0.0537)	-0.0278 (0.1226)	0.1669*** (0.0526)	0.0670 (0.0932)	0.3945*** (0.0713)	0.0286 (0.0983)	0.1358** (0.0538)
Constant	-0.9411*** (0.0621)	-0.6675*** (0.0729)	-0.3587 (0.3308)	-0.2733* (0.1475)	0.7081*** (0.1292)	-0.4122* (0.2271)	1.7955*** (0.4111)	-0.2444 (0.2643)
Covariates	No	No	No	No	Yes	Yes	Yes	Yes
Country/FE	No	Yes	No	Yes	No	Yes	No	Yes
Year/FE	No	No	Yes	Yes	No	No	Yes	Yes
Observations	853	853	853	853	853	853	853	853
R-squared	0.0023	0.9016	0.0491	0.9304	0.4967	0.9112	0.5434	0.9337
Panel C Greenhouse emissions								
RBL dummy	0.2035 (0.2298)	0.3792*** (0.0278)	0.2021 (0.2281)	0.0549* (0.0298)	0.2035 (0.1659)	0.2253*** (0.0427)	0.2030 (0.1765)	0.0696** (0.0304)
Constant	9.6584*** (0.0729)	10.9164*** (0.0314)	8.9467*** (0.6937)	10.4880*** (0.4425)	8.6223*** (0.2757)	10.8984*** (0.1677)	7.9441*** (0.4807)	10.2625*** (0.4836)
Covariates	No	No	No	No	Yes	Yes	Yes	Yes
Country/FE	No	Yes	No	Yes	No	Yes	No	Yes
Year/FE	No	No	Yes	Yes	No	No	Yes	Yes
Observations	926	926	926	926	926	926	926	926
R-squared	0.0035	0.9786	0.0248	0.9884	0.4032	0.9860	0.4189	0.9905

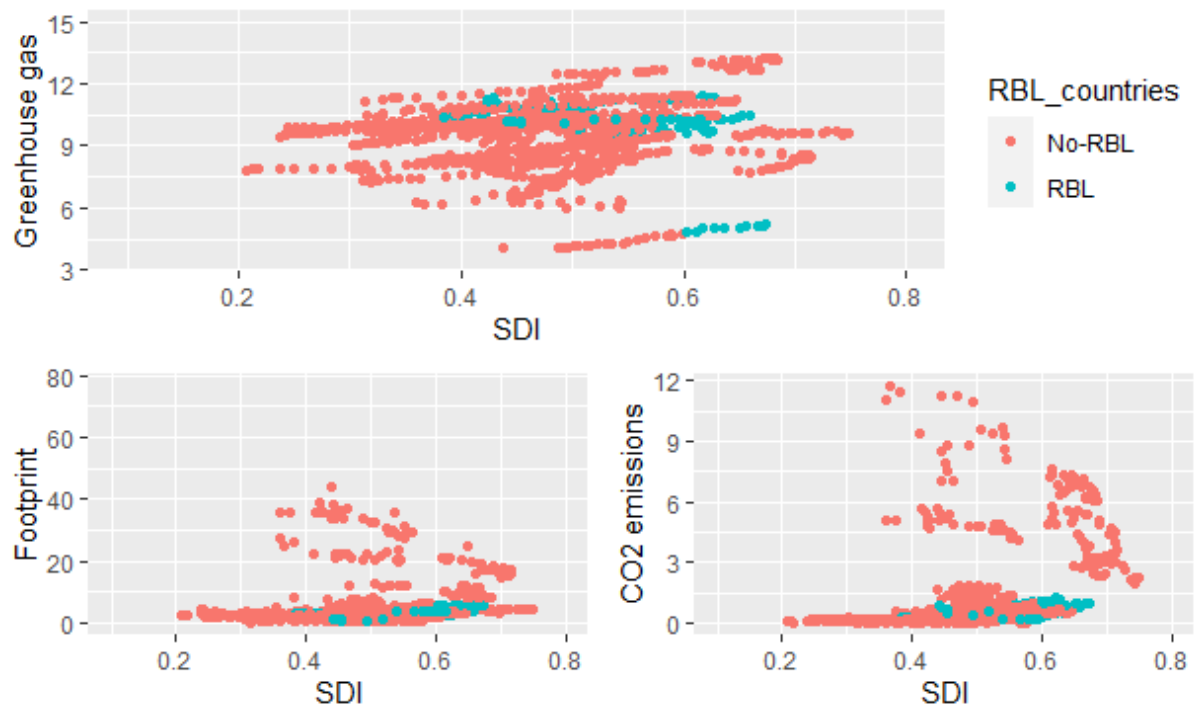
Standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01

Table A8: Resource-backed loans and ecological efficiency of human development: structural factors

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
RBL dummy	0.0305*** (0.0100)	0.0636 (0.0610)	0.0422** (0.0196)	0.0448** (0.0190)	0.0476*** (0.0149)	0.1437*** (0.0206)	0.0225* (0.0119)	-0.0055 (0.0468)	0.0770*** (0.0138)	0.0504*** (0.0137)
Pscore	-0.0437 (0.0375)	-0.0449 (0.0378)	-0.0456 (0.0376)	0.1262 (0.0443)	-0.1163 (0.0450)	-0.0277 (0.0362)	0.0028 (0.0337)	0.1470 (0.0777)	-0.0034 (0.0340)	-0.0325 (0.0371)
RBL*Age dependency ratio		-0.0060 (0.0099)								
RBL*Financial development			-0.1104 (0.1590)							
RBL*Government revenue				-0.0010 (0.0008)						
RBL*Interest on debt					-0.0125*** (0.0037)					
RBL*Urban population						-0.0023*** (0.0004)				
RBL*Government effectiveness							0.0159* (0.0089)			
RBL*Credit rating								0.0043 (0.0055)		
RBL*Public debt									-0.0007*** (0.0002)	
RBL* Resource depletion										-0.0014** (0.0007)
Constant	-0.8289*** (0.0413)	-0.8299*** (0.0414)	-0.8269*** (0.0414)	-0.7146*** (0.0317)	-0.7248*** (0.0320)	-0.8213*** (0.0427)	-0.8050*** (0.0376)	-0.5706*** (0.0264)	-0.7150*** (0.0384)	-0.8237*** (0.0420)
Country/FE & Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	799	799	792	483	483	799	645	304	670	799
R-squared	0.8477	0.8477	0.8469	0.8820	0.8824	0.8492	0.8867	0.9216	0.8913	0.8480

Standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01

Figure 3: Correlation between SDI, greenhouse gas, CO2 emissions, and footprint



Note: This graph is the authors' own elaboration, using data from Mihalyi et al. (2020) and Hickel (2020). Scatterplot of SDI, greenhouse gas emissions, CO2 emissions and material footprint (1990-2019).

Table A9: Details on resource-backed loans in African countries

Country	Loan year	Loans in millions of USD	Resources used	loans country	loans entity	Sectors targeted for investment
Angola	2004	2000	Oil	China	Eximbank	Infrastructure
Angola	2007	500	Oil	China	Eximbank	Infrastructure
Angola	2007	2000	Oil	China	Eximbank	Infrastructure
Angola	2009	2000	Oil	China	Eximbank	Infrastructure
Angola	2010	2500	Oil	China	ICBC	housing
Angola	2015	15000	Oil	China	CDB	Infrastructure
Chad	2013	600	Oil	International	Glencore	Budget support and debt refinancing
Chad	2014	1356	Oil	International	Glencore	Oil
RDC	2008	3000	Copper & Cobalt	China	Eximbank	Infrastructure
RDC	2011	500	Copper	Corée	Korea Exim	Infrastructure
Ghana	2011	1500	Oil	China	CDB	Infrastructure
Ghana	2011	1500*	Oil	China	CDB	Infrastructure
Ghana	2018	2000	Bauxite	China	Sinohydro	Infrastructure
Guinea	2017	20000	Bauxite	China	CCC	Infrastructure
Niger	2013	1000*	Oil	China	Eximbank	Oil
Republic of Congo	2006	1600	Oil	China	Eximbank	Infrastructure
Republic of Congo	2011	625	Oil	International	Gunvor	Oil
Republic of Congo	2012	1000	Oil	China	Eximbank	Infrastructure
Republic of Congo	2015	1000	Oil	International	Trafigura	Unknown
Republic of Congo	2015	850	Oil	International	Glencore	Unknown
Sao Tome and Principe	2010	30	Oil	Nigeria	Government	Oil
South Sudan	2015	75	Oil	International	CNPC	Unknown
South Sudan	2015	1000	Oil	China	Eximbank	Budget support
South Sudan	2016	169	Oil	China	Eximbank	Road
Sudan	2007	3000	Oil	China	Eximbank	Infrastructure
Zimbabwe	2006	200	platinum	China	Eximbank	Agricultural
Zimbabwe	2011	98	Diamond	China	Eximbank	Education

Source: Author's construction based on information from Mihalyi et al. (2022). Note: RBLs marked with * were subsequently canceled without disbursement.

Table A10: Summary statistics for all variables

Variable	Obs	Mean	Std. Dev.	Min	Max
SDI	1066	0.482	0.102	0.207	0.748
RBL 01	1350	0.086	0.28	0	1
RBL Oil	1350	0.012	0.108	0	1
RBL Mineral	1350	0.004	0.067	0	1
RBL Other	1350	0.001	0.038	0	1
Inflation rate	1048	1.895	1.37	-3.305	10.076
ODA	1260	1.778	1.289	-5.651	4.553
FDI	1170	0.433	1.828	-13.184	5.087
Natural resource rents	1267	1.859	1.574	-6.749	4.139
Resource depletion	1240	1.021	2.378	-8.822	4.634
GDP per capita volatility	1093	228.025	486.742	4.063	5387.647
Public Investment volatility	1032	4.148	4.618	0	32.959
Total investment	1196	22.664	12.622	2.663	115.102
Stock price volatility	125	13.12	6.81	1.973	34.384
Financial development	1290	0.118	0.094	0	0.643
Resources-rich	720	0.375	0.484	0	1
Natural shock index	1259	43.914	19.251	0	95.767
Public debt	1004	66.47	65.124	0	600.117
Rule of law	1075	0.365	0.127	0	0.721
Corruption	870	2.227	0.939	0	5
Internal conflict	870	7.854	2.149	0	12
External conflict	870	9.317	1.921	2	12
Political stability	1075	0.472	0.156	0	0.791
EVI	1218	39.356	10.483	16.382	70.049
Natural disasters index	1305	63.201	28.382	0	100
Exposure index	1262	39.597	9.786	21.993	66.881
Shock index	1259	39.196	17.009	2.373	88.173
Exchange rate	1167	6.351	4.763	1	15
ICT infrastructure	1000	0.237	0.065	0.18	0.58
Education	975	0.043	0.043	0.001	0.298
Innovation	525	0.014	0.033	0	0.142
Doing business	1000	0.324	0.121	0	0.827
Electric consumption	566	509.156	914.073	21.476	4766.652
Access to electricity urban	1092	60.631	24.65	3.5	100
Access to electricity rural	905	21.135	25.574	0.509	100

Table A11: Correlation matrix

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]	[23]	[24]	[25]	[26]	[27]	[28]	[29]
[1] SDI	1.000																												
[2] RBL	0.200***	1.000																											
[3] GDP volatility	0.443***	0.0656*	1.000																										
[4] Investment volatility	-0.0193	0.144***	0.0734*	1.000																									
[5] Total investment	0.278***	0.128***	0.134***	0.522***	1.000																								
[6] Stock price volatility	0.176	-0.165	0.0104	-0.340***	-0.243**	1.000																							
[7] Financial openness	0.174***	-0.0916**	0.0509	-0.0965**	0.0476	-0.323***	1.000																						
[8] Rich resources countries	-0.0849*	0.158***	0.0664*	0.2225***	0.152***	-0.135	-0.0347	1.000																					
[9] Trade openness	0.300***	0.0836**	0.389***	0.259***	0.393***	-0.430***	0.195***	-0.0255	1.000																				
[10] Remittance inflows	0.0421	-0.0251	-0.104**	-0.0151	0.269***	0.0151	0.00636	-0.196***	0.108***	1.000																			
[11] Public Debt	-0.107**	-0.0478	-0.102*	0.168***	0.0221	-0.180	0.123***	-0.0200	-0.0424	-0.0302	1.000																		
[12] Exchange rate	0.0400	-0.0570	-0.0659*	0.00204	-0.0255	0.277***	0.177***	0.0126	-0.0569	-0.151***	0.192***	1.000																	
[13] Rule of law	0.328***	-0.139***	0.0485	-0.134***	0.0873*	-0.303***	0.400***	-0.156***	0.259***	-0.181***	0.123***	1.000																	
[14] Corruption	-0.133***	-0.277***	-0.0828*	0.0272	-0.0457	-0.325**	0.104**	0.0384	0.0139	-0.199***	-0.0193	0.159***	0.479***	1.000															
[15] External conflict	0.232***	0.0681*	0.124***	0.142***	0.125***	-0.282**	0.0713*	0.124***	0.214***	-0.0457	-0.300***	-0.135***	0.555***	0.205***	1.000														
[16] Internal conflict	0.201***	0.0000808	0.0755*	0.0164	0.0898*	-0.311***	0.196**	0.0608*	0.319***	-0.0243	-0.196***	-0.171***	0.579***	0.218***	0.670***	1.000													
[17] Political stability	0.307***	-0.0733*	0.231***	0.0736*	0.170***	-0.400***	0.298**	-0.0706*	0.395***	0.0586	-0.122***	-0.0922*	0.739***	0.420***	0.682***	0.760***	1.000												
[18] Climatic vulnerability	-0.657***	0.0351	-0.456***	0.0319	-0.208***	-0.0419	-0.143***	-0.0294	-0.439***	-0.0623	0.198***	-0.135***	-0.477***	-0.293***	-0.375***	-0.363***	-0.474***	1.000											
[19] Disasters index	-0.119***	-0.0261	-0.369***	-0.172***	-0.0872**	0.168	-0.0459	-0.279***	-0.0773*	0.121***	0.0583	0.205***	0.0753*	-0.0528	0.00508	-0.00807	-0.0422	0.354***	1.000										
[20] Exposure index	-0.172***	-0.158***	0.0716*	0.173***	0.118***	-0.432***	0.228***	-0.199***	0.226***	0.138***	0.224***	-0.0404	0.0345	0.0905**	-0.0564	0.0638	0.391***	0.0942**	-0.0845**	1.000									
[21] Shock index	-0.230***	0.125***	-0.158***	0.0435	-0.0135	-0.0267	0.0888**	-0.197***	-0.193***	0.176***	0.220***	0.137***	-0.191***	-0.317***	-0.0377	-0.00700	-0.138***	0.660***	0.541***	0.157***	1.000								
[22] Natural shock index	-0.151***	-0.0510	-0.287***	-0.180***	-0.0939**	0.127	0.0921**	-0.333***	-0.0593	0.123***	0.0763*	0.201***	0.181***	-0.0109	0.0716*	0.0963**	0.08801*	0.330***	0.906***	0.0281	0.629***	1.000							
[23] ICT infrastructure	0.505***	0.179***	0.329***	-0.0962**	0.122***	-0.321***	0.274***	-0.0748*	0.431***	-0.0325	-0.175***	0.0574	0.352***	-0.0520	0.0522	0.105**	0.266***	-0.429***	-0.194***	-0.0286	-0.221***	-0.159***	0.664***	1.000					
[24] Education	0.582***	0.135***	0.197***	-0.159***	0.0238	-0.327***	0.290***	-0.0471	0.192***	-0.0339	-0.0463	0.159***	0.385***	0.0095	-0.0448	0.0510	0.185***	-0.498***	-0.210***	-0.196***	-0.221***	-0.169***	0.664***	0.664***	1.000				
[25] Innovation	0.120**	-0.0540	0.576***	0.0616	0.0934*	0.336***	0.212***	-0.300***	0.488***	-0.0842	0.306***	0.158***	0.313***	0.0958	0.0493	0.0705	0.300***	-0.371***	-0.123**	0.336***	-0.188***	-0.0560	0.464***	0.174***	1.000				
[26] Doing business	0.192***	-0.177***	0.140***	0.0694*	0.126***	-0.0787	0.311***	-0.225***	0.207***	-0.000537	0.246***	0.363***	0.141***	-0.0639	-0.234***	-0.252***	0.0495	-0.143***	0.00419	0.176***	-0.0735*	-0.0142	0.0501	0.255***	0.310***	1.000			
[27] Electric power consumption	0.516***	-0.0830*	0.505***	-0.171***	-0.0114	0.345***	0.181***	-0.292**	0.0883*	-0.194***	-0.155***	0.314***	0.505***	0.269***	0.173***	0.220***	0.337***	-0.439***	-0.0445	-0.0181	-0.228***	0.0329	0.466***	0.629***	0.826***	0.294***	1.000		
[28] Access to electricity urban	0.625***	0.0479	0.364***	-0.0638	0.215***	-0.0295	0.0732*	-0.101***	0.293***	-0.0630*	-0.0736*	0.0340	0.216***	-0.214***	-0.0561	-0.106**	0.159***	-0.612***	-0.236***	-0.166***	-0.326***	-0.256***	0.500***	0.505***	0.419***	0.301***	0.294***	1.000	
[29] Access to electricity rural	0.555***	0.0116	0.275***	-0.0510	0.108**	-0.0533	0.277***	-0.320***	0.386***	-0.0179	0.127***	0.149***	0.440***	-0.0283	-0.00532	-0.0217	0.325***	-0.543***	-0.247***	0.193***	-0.309***	-0.204***	0.615***	0.575***	0.662***	0.450***	0.595***	0.654***	1.000

* p < 0.10, ** p < 0.05, *** p < 0.01

Table A12: Sources and definitions of the data used

Variables	Definition	Sources
1. Dependent variable		
Sustainable Development Index (SDI)	Measures the ecological efficiency of human development, recognizing that development must be achieved within planetary boundaries.	Hickel (2020)
2.Treatment variable		
Resource-backed loans (RBLs)	Takes value 1 if country i at period t has signed a resource-backed loans	Mihalyi et al. (2020)
Oil resource-backed loans	Takes value 1 if country i at period t has signed a loans on oil	Mihalyi et al. (2020)
Minerals resource-backed loans	Takes value 1 if country i at period t has signed a loans on minerals	Mihalyi et al. (2020)
Other resource-backed loans	Takes value 1 if country i at period t has signed a loans on tobacco and cocoa	Mihalyi et al. (2020)
3. Baseline model control variables or covariates		
Inflation rate	Inflation, average consumer prices (Percent change)	WDI
Natural resources rents	Natural resources rents to % GDP	WDI
ODA	Net ODA received (% of GNI)	WDI
FDI	Foreign direct investment, net inflows (% of GDP)	WDI
Resource depletion	Natural resource depletion is the sum of net forest depletion, energy depletion, and mineral depletion	WDI
4. Additional control variables		
Financial development	Continuous	IMF Financial Development database
Public Investment volatility	Standard deviation of the public investment estimated over 5-year moving window	World Economic Outlook (WEO)
Total investment	Total investment, percent of GDP	IMF-WEO
Resources-rich	Dummy	IMF dataset, Lledó et al. (2017)
Natural shock index	Continuous	Guillaumont (2009), Feindouno and Goujon (2016)
Economic vulnerability index (EVI)	Continuous	Guillaumont (2009), Feindouno and Goujon (2016)
Natural disasters index	Continuous	Guillaumont (2009), Feindouno and Goujon (2016)
Exposure index	Continuous	Guillaumont (2009), Feindouno and Goujon (2016)
Shock index	Continuous	Guillaumont (2009), Feindouno and Goujon (2016)
Rule of law	Continuous	Guillaumont (2009), Feindouno and Goujon (2016)
Corruption	Continuous	Teorell et al. (2020)
Internal conflict	Continuous	Teorell et al. (2020)
External conflict	Continuous	ICRG
Political stability	Index ranging from -2 to 2	ICRG
Stock price volatility	Continuous	WGI, Kaufmann et al. (2011)
Public debt	Continuous	IMF-WEO
Exchange rate regime	Dummy	Kose et al. (2017)
ICT infrastructure	Continuous	Ilzetzi et al. (2017)
Education	Continuous	University of Notre Dame Global Adaptation Index
Innovation	Continuous	University of Notre Dame Global Adaptation Index
Doing business	Continuous	University of Notre Dame Global Adaptation Index
Electric consumption	Continuous	University of Notre Dame Global Adaptation Index
Access to electricity urban	Continuous	WDI
Access to electricity rural	Continuous	WDI
EITI countries	Dummy	WDI
		World Bank Group.2016 (2016); Kinda and Thiombiano (2024b)

Appendix B (Chapter 2): The Effect of Resource-Backed Loans on Deforestation Evidence from Developing Countries

Table B1: List of developing countries included in the dataset

Sub-Saharan Africa: 42		Latin America and the Caribbean: 22
Angola*	Mozambique	Argentina
Benin	Namibia	Brazil*
Botswana	Niger*	Colombia
Cabo Verde	Nigeria	Costa Rica
Cameroon	Republic of Congo*	Dominica
Central African Republic	Rwanda	Dominican Republic
Chad*	Senegal	Ecuador*
Comoros	Sierra Leone	El Salvador
Côte d'Ivoire	South Africa	Grenada
Democratic Republic of the Congo*	South Sudan*	Guyana
Equatorial Guinea	Sudan*	Haiti
Eswatini	São Tomé and Príncipe*	Honduras
Ethiopia	Tanzania	Jamaica
Gabon	Togo	Mexico
Ghana*	Uganda	Nicaragua
Guinea*	Zambia	Panama
Guinea-Bissau	Zimbabwe*	Paraguay
Kenya		Peru
Lesotho		St. Lucia
Liberia		St. Vincent and the Grenadines
Madagascar		Suriname
Malawi		Venezuela*
Mali		
Mauritania		
Mauritius		

Source: Author's construction based on information from Mihalyi et al. (2022). Note: Countries marked with * are signatories countries of resource-backed loans (Treatment group) the other countries are non-signatories (control group)

Figure 4: Total amount of resource-backed loans signed by developing countries

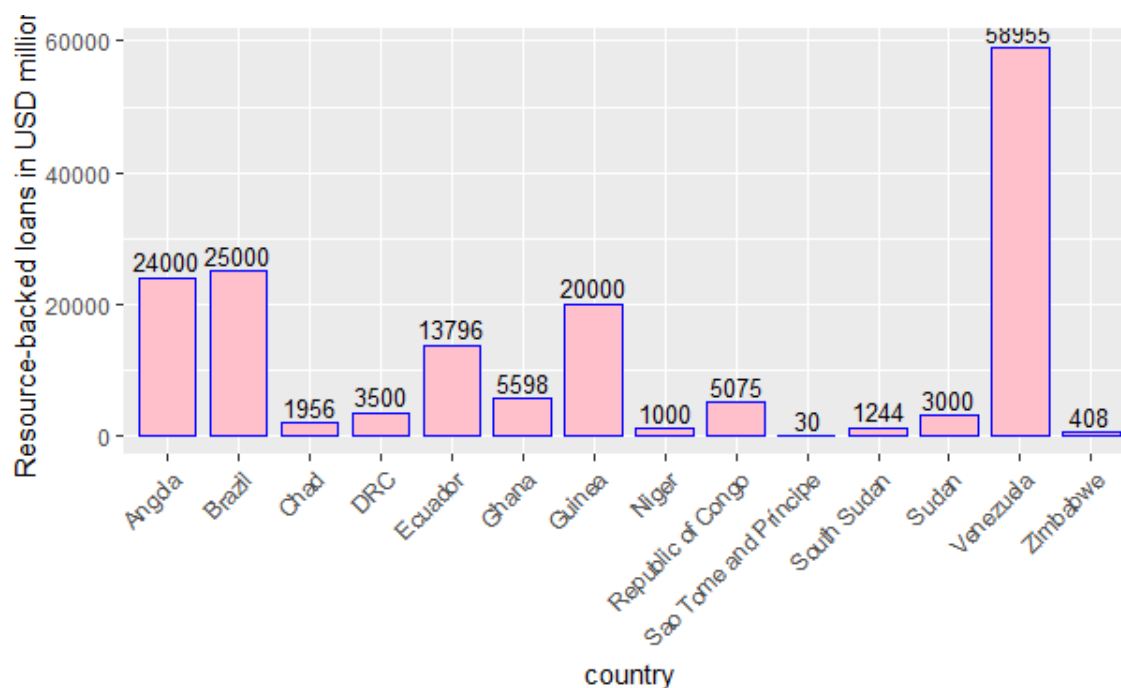
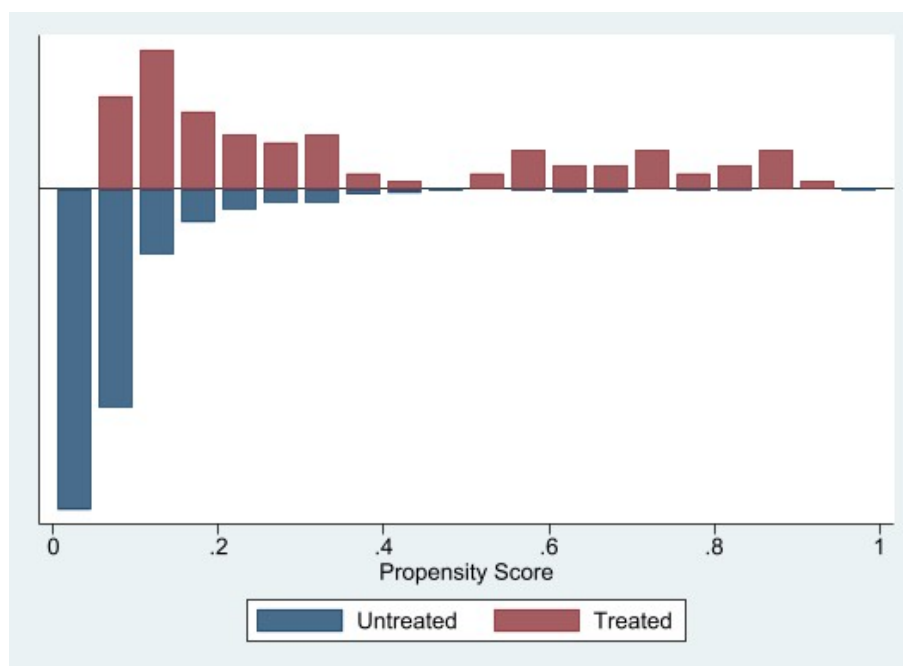


Figure 5: Graphs of propensity score by treatment status.



Source: Author's construction

Table B2: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Log Forest cover loss	892	9.131	3.16	0	15.508
RBL	960	0.139	0.346	0	1
Log Credit	932	2.891	0.905	-4.903	4.666
ODA	946	5.852	7.74	-2.313	92.141
Log GFC	811	3.093	0.398	0.422	4.375
Public expenditure	800	14.135	5.975	2.047	79.169
Resource rents	947	9.426	10.573	0	62.697
Resource depletion	922	5.136	8.393	0	71.291
Public debt	951	49.056	42.797	0	543.856
Lag Public debt	887	48.404	43.43	0	543.856
Log GDP per capita	758	0.911	0.982	-6.164	3.471
Log Population total	960	15.726	1.81	11.162	19.16
Resource rich country	960	0.641	0.48	0	1
Mineral reserve horizon	915	0.082	0.274	0	1
Rainfall shocks	960	118.014	66.398	7.172	414.894
Temperature shocks	960	24.483	3.082	12.309	29.376
Log Total ODA Biodiversity	794	15.741	2.374	9.21	20.275
Log Agricultural land	832	3.483	0.86	-0.801	4.399
Control corruption	954	-0.527	0.65	-1.816	1.219
Government effectiveness	953	-0.593	0.656	-2.475	1.057
Rule of law	870	0.39	0.119	0.056	0.712

Table B3: Correlation matrix

Variables	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]
[1] log Forest cover loss	1.000																				
[2] RBL	0.197***	1.000																			
[3] Log Credit	-0.210***	-0.127***	1.000																		
[4] ODA	0.001	-0.063*	-0.336***	1.000																	
[5] Log GFC	-0.045	0.018	0.187***	-0.135***	1.000																
[6] Public expenditure	-0.355***	0.011	0.281***	-0.030	0.076**	1.000															
[7] Resource rents	0.269***	0.301***	-0.538***	0.126***	0.116***	-0.154***	1.000														
[8] Resource depletion	0.125***	0.217***	-0.349***	-0.073**	0.229***	-0.094***	0.850***	1.000													
[9] Public debt	-0.109***	0.042	-0.040	0.353***	-0.038	0.101***	-0.019	-0.137***	1.000												
[10] Lag Public debt	-0.102***	0.021	-0.045	0.431***	-0.044	0.052	0.003	-0.127***	0.940***	1.000											
[11] Log GDP per capita	0.025	0.039	-0.025	0.020	0.195***	-0.054	0.149***	0.164***	-0.083**	-0.020	1.000										
[12] Log population total	0.675***	0.207***	-0.276***	-0.059*	-0.013	-0.246***	0.149***	0.055*	-0.206***	-0.217***	0.026	1.000									
[13] Resources rich country	0.329***	0.181***	-0.494***	0.188***	-0.054	-0.139***	0.552***	0.368***	-0.049	-0.053	0.004	0.339***	1.000								
[14] Mineral reserve horizon	0.311***	0.306***	0.054	-0.207***	0.011	-0.046	0.141***	0.133***	-0.049	-0.066*	0.024	0.401***	-0.046	1.000							
[15] Rainfall shocks	0.104***	-0.082**	0.195***	0.009	-0.054	-0.141***	-0.036	-0.027	0.153***	0.169***	0.003	-0.377***	-0.181***	-0.019	1.000						
[16] Temperature shocks	-0.031	0.053	-0.111***	0.084**	-0.016	-0.396**	0.145***	0.032	0.083**	0.084**	-0.080**	-0.083**	0.151***	0.008	0.126***	1.000					
[17] Log Total ODA biodiversity	0.420***	0.088**	0.008	0.018	0.131***	-0.136***	-0.044	-0.088**	-0.251***	-0.233***	-0.036	0.610***	0.151***	0.043	-0.226***	0.025	1.000				
[18] Log Agriculture land	-0.073**	0.018	0.011	0.037	-0.091**	0.088**	-0.333***	-0.299***	-0.014	-0.016	-0.059	0.359***	-0.202***	0.067*	-0.367***	-0.165***	0.186***	1.000			
[19] Control corruption	-0.485***	-0.299***	0.633***	-0.106***	0.187***	0.372***	-0.511***	-0.360***	0.048	0.063*	0.053	-0.460***	-0.467***	-0.144***	0.136***	-0.245***	-0.110***	0.056	1.000		
[20] Government effectiveness	-0.279***	-0.281***	0.699***	-0.304***	0.203***	0.259***	-0.500***	-0.315***	0.015	0.016	0.038	-0.250***	-0.422***	-0.019	0.133***	-0.257***	0.021	0.033	0.856***	1.000	
[21] Rule of law	-0.339***	-0.299***	0.580***	-0.178***	0.194***	0.304***	-0.454***	-0.283***	-0.021	-0.005	0.019	-0.308***	-0.422***	-0.172***	0.204***	-0.171***	0.009	0.015	0.899***	0.865***	1.000

*** p<0.01, ** p<0.05, * p<0.1

Table B4: Characteristic of treatment and control groups

Panel A: Before weighting	[1]	[2]	[3]=[2]-[1]	[4]	[5]
	RBL	Non RBL	Difference	t-Test	P-value
Resource rents	18.77	7.92	-10.85	110.5	0.000
Resource depletion	10.74	4.35	-6.39	52.7	0.000
Log GFC	3.152	3.09	-0.062	2.6	0.105
ODA	3.41	5.2	1.79	9.9	0.002
Log Credit	2.597	2.9	0.303	10.7	0.001
Expenditure	14.72	14.18	-0.54	0.8	0.379
Panel B: After weighting	[1]	[2]	[3]=[2]-[1]		
	RBL	Non RBL	Difference		
Resource rents	18.77	18.76	-0.01	—	—
Resource depletion	10.74	10.73	-0.01	—	—
Log GFC	3.152	3.152	0.000	—	—
ODA	3.41	3.418	0.008	—	—
Log Credit	2.597	2.598	0.001	—	—
Expenditure	14.72	14.72	0.000	—	—

Table B5: Robustness: Stratification matching results

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Log forest cover loss	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
ATT	0.1291 (0.2664)	0.3132 (0.2775)	0.3726 (0.2670)	0.2891 (0.2428)	0.2901 (0.2007)	0.2782 (0.2038)	0.1907 (0.2245)	0.2792 (0.1856)
Observations	727	727	727	727	727	727	727	727
Treated	359	359	359	359	359	359	359	359
Untreated	368	368	368	368	368	368	368	368

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

Table B6: Effect by level of dependence on resource rents

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Log forest loss	Matching			r=0.005	r=0.05	r=0.01	Matching	Matching
Resource rents>5%								
ATT	0.8342*	0.6432	0.7924*	0.7642	0.6407	0.7066	0.5276	0.6382*
	(0.4542)	(0.4408)	(0.4666)	(0.6225)	(0.4685)	(0.4757)	(0.4225)	(0.3676)
Observations	394	394	394	394	394	394	394	394
Resource rents>10%								
ATT	1.3418***	1.2559***	1.2722***	1.6163***	1.0712***	1.3548***	1.0847***	1.0734***
	(0.3835)	(0.3079)	(0.3231)	(0.4043)	(0.2692)	(0.3544)	(0.1923)	(0.3147)
Observations	241	241	241	241	241	241	241	241
Resource rents>15%								
ATT	1.9658***	1.7993***	1.7709***	2.2195***	1.7713***	2.2299***	1.6614***	1.7708***
	(0.4986)	(0.3162)	(0.3503)	(0.6776)	(0.3141)	(0.5407)	(0.3565)	(0.4178)
Observations	144	144	144	144	144	144	144	144
Resource rents>20%								
ATT	1.7621***	2.2770***	2.2919***	2.1978**	2.3549***	2.1885**	1.7904***	2.3584***
	(0.4942)	(0.5147)	(0.4588)	(1.1184)	(0.4838)	(0.8914)	(0.5656)	(0.4194)
Observations	90	90	90	90	90	90	90	90
Resource rents>25%								
ATT	1.8841**	1.6579***	1.5509***	1.2264	2.2973***	2.0595**	1.6591***	2.3318***
	(0.7359)	(0.3774)	(0.4936)	(1.4410)	(0.7668)	(1.0188)	(0.6057)	(0.5038)
Observations	64	64	64	64	64	64	64	64

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

Table B7: List of resource-backed loans in developing countries

Country	Loan year	Loans in millions of USD	Resources used	loans country	loans entity	Sectors targeted for investment
Angola	2004	2000	Oil	China	Eximbank	Infrastructure
Angola	2007	500	Oil	China	Eximbank	Infrastructure
Angola	2007	2000	Oil	China	Eximbank	Infrastructure
Angola	2009	2000	Oil	China	Eximbank	Infrastructure
Angola	2010	2500	Oil	China	ICBC	housing
Angola	2015	15000	Oil	China	CDB	Infrastructure
Brazil	2009	1000	Oil	China	CDB	Oil
Brazil	2015	3500	Oil	China	CDB	Oil
Brazil	2015	1500	Oil	China	CDB	Oil
Brazil	2016	5000	Oil	China	CDB and debt rollover	Budget support
Brazil	2017	5000	Oil	China	CDB	Oil
Chad	2013	600	Oil	International	Glencore	Budget support and debt refinancing
Chad	2014	1356	Oil	International	Glencore	Oil
RDC	2008	3000	Copper & Cobalt	China	Eximbank	Infrastructure
RDC	2011	500	Copper	Corée	Korea Exim	Infrastructure
Ecuador	2010	1000	Oil	China	CDB	Infrastructure
Ecuador	2011	2000	Oil	China	CDB	Infrastructure
Ecuador	2012	2000	Oil	China	CDB and debt rollover	Budget support
Ecuador	2015	5296	Oil	China	Eximbank	Infrastructure
Ecuador	2015	1500	Oil	China	CDB	Infrastructure
Ecuador	2016	1500	Oil	China	CDB	Infrastructure
Ecuador	2016	500	Oil	China	CDB and debt rollover	Budget support
Ghana	2011	1500	Oil	China	CDB	Infrastructure
Ghana	2011	1500*	Oil	China	CDB	Infrastructure
Ghana	2018	2000	Bauxite	China	Sinohydro	Infrastructure
Guinea	2017	20000	Bauxite	China	CCC	Infrastructure
Niger	2013	1000*	Oil	China	Eximbank	Oil
Republic of Congo	2006	1600	Oil	China	Eximbank	Infrastructure
Republic of Congo	2011	625	Oil	International	Gunvor	Oil
Republic of Congo	2012	1000	Oil	China	Eximbank	Infrastructure
Republic of Congo	2015	1000	Oil	International	Trafigura	Unknown
Republic of Congo	2015	850	Oil	International	Glencore	Unknown
Sao Tome and Principe	2010	30	Oil	Nigeria	Gouvernement	Oil
South Sudan	2015	75	Oil	International	CNPC	Unknown
South Sudan	2015	1000	Oil	China	Eximbank	Budget support
South Sudan	2016	169	Oil	China	Eximbank	Road
Sudan	2007	3000	Oil	China	Eximbank	Infrastructure
Venezuela	2006	6500	Oil	Russia	Rosneft	Infrastructure
Venezuela	2007	4000	Oil	China	CDB	Infrastructure
Venezuela	2009	4000	Oil	China	CDB	Infrastructure
Venezuela	2010	20255	Oil	China	CDB	Infrastructure
Venezuela	2011	4000	Oil	China	CDB	Infrastructure & Oil
Venezuela	2013	4000	Oil	China	CDB	Oil
Venezuela	2013	5000	Oil	China	CDB	Infrastructure
Venezuela	2014	4000	Oil	China	Eximbank	Infrastructure
Venezuela	2015	5000	Oil	China	CDB	Infrastructure
Venezuela	2016	2200	Oil	China	CDB	Oil
Zimbabwe	2004	110	Tobacco	China	CATIC	Power
Zimbabwe	2006	200	platinum	China	Eximbank	Agricultural
Zimbabwe	2011	98	Diamond	China	Eximbank	Education

Source: Author's construction based on information from Mihalyi et al. (2022)

Note: RBLs marked with * were subsequently canceled without disbursement.

Table B8: Definition and sources of variables

Variable	Source	Description
Forest cover loss	Hansen et al. (2013). Data available on-line from: http://earthenginepartners.appspot.com/science-2013-global-forest	Hectares of tree cover loss, by country, from 2001 to 2021 categorized by percent canopy cover, canopy cover >25%
Resource-backed loans	NRGI and Mihalyi et al. (2022)	Binary variable equal to 1 if country i in year t if the Country signed a resource-backed loans, and 0 otherwise.
Credit	WDI-World Bank	Domestic credit provided by the banking sector, percentages of GDP.
ODA	WDI-World Bank	Net ODA received per capita (current US\$)
GFC	WDI-World Bank	Gross capital formation, percentages of GDP
Expenditure	WDI-World Bank	General government final consumption expenditure, percentages of GDP
Natural resources depletion	WDI-World Bank	Natural resources depletion (% of GNI)
Mineral reserve horizon	British petroleum (BP) data	The Mineral reserve horizon is a dummy variable equal to 1 if a country's reserve horizon is median of all mineral-exporting countries
Natural resources rents	WDI-World Bank	Total natural resources rents (% of GDP)
Rainfall shocks	Climatic Research Unit, University of East Anglia and CERDI https://data.cerdi.org/	Deviation of the yearly average of rainfall levels (mm) from its 1901 to 2021 trend
Temperature shocks	Climatic Research Unit, University of East Anglia and CERDI https://data.cerdi.org/	Deviation of the yearly average of temperatures (°C) from its 1901 to 2021 trend
Rich countries	IMF Fiscal Rules Dataset, 2022 (see Lledó et al. (2017))	Dummy which equals 1 if a given country is a resource rich country and 0 otherwise. IMF Classification
Demographic growth	WDI-World Bank	Population growth (annual %)
GDP per capita	WDI-World Bank	GDP per capita, constant 2017 USD
Public Debt	WDI-World Bank	General government gross debt (% of GDP)
Tax revenue	WDI-World Bank	Tax revenue (% of GDP)
Government Stability	International Country Risk Guide (ICRG)	Government stability index from the ICRG database. It both assesses the government's ability to carry out its declared program(s), and its ability to stay in office Ranks from 0 to 12. An increase means an improvement
ODA	WDI	Net official development assistance received
Debt rule (DR)	IMF Fiscal Rules Dataset, 2022 (see Lledó et al. (2017))	Dummy equal to 1 if there is an debt rule rule and 0 otherwise
Total ODA Biodiversity	Our World in Data	Total amount donated for biodiversity conservation in developing countries, 2021
Commodity prices	IMF data-WEO	Commodity export price index, individual commodities weighted by ratio of exports to GDP
Agricultural land area	WDI	Agricultural land (% of land area)
Corruption	Teorell et al. (2016)	Corruption measures perceptions of corruption, conventionally defined as the exercise of public power for private gain

Appendix C (Chapter 3): Resource-backed loans and the cyclicality of fiscal policy in developing countries

Table C1: Alternative measures of fiscal policy cyclical: cyclical of government expenditures

VARIABLES	[1]	[2]	[3]	[4]	[5]
RBL adoption	0.447*** (0.172)	0.447*** (0.136)	0.950*** (0.141)	0.565*** (0.147)	1.224*** (0.147)
Constant	-0.370*** (0.0495)	1.319*** (0.251)	1.499*** (0.280)	2.218*** (0.641)	2.700*** (0.705)
Covariates	No	Yes	Yes	Yes	Yes
Country/FE	No	No	Yes	No	Yes
Year/FE	No	No	No	Yes	Yes
Observations	2,385	2,385	2,385	2,385	2,385
R-squared	0.018	0.229	0.724	0.238	0.739

Robust standard errors are in brackets *** p < 0.01, ** p < 0.05, * p < 0.1.

Figure 6: Correlation between spending volatility and fiscal policy cyclical

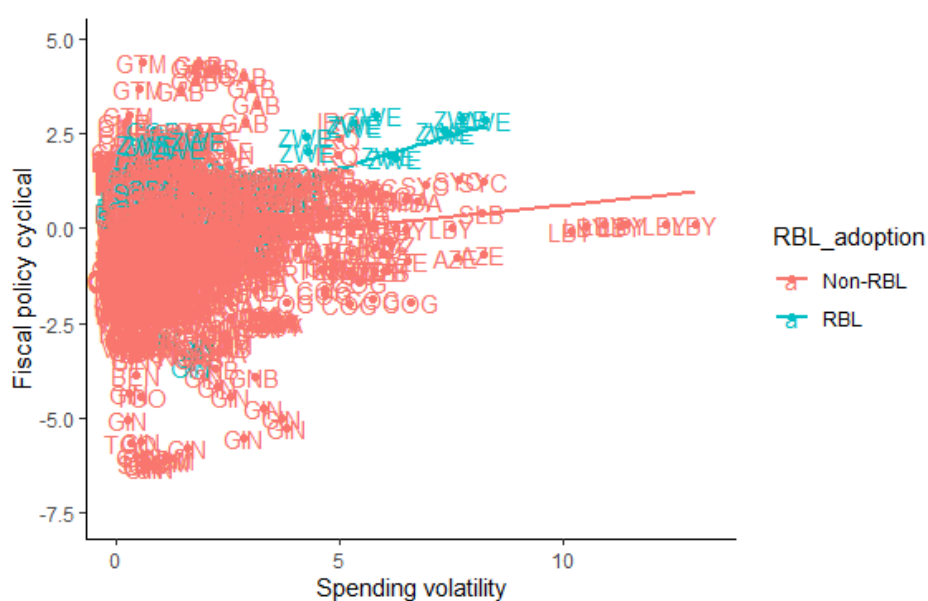


Table C2: Alternative estimation methods, falsification test and dynamic effect

Panel A: Endogenous switching regression	Decision stage		Treatments effects		
	DNS adopters	DNS non-adopters			
DNS adopters	(a) 0.602*** (0.0751)	(c) 0.283*** (0.0148)	TT = 0.319*** (0.0603)		
DNS non-adopters	(d) 2.7812*** (0.0267)	(b) 0.5914*** (0.0581)	TU= 2.1898*** (0.0314)		
	<i>stdipw</i>	<i>dripw</i>	<i>ipw</i>		
Panel B: Diff-in-Diff estimates	1.4805*** (0.3796)	1.4805*** (0.3796)	1.4806*** (0.3796)		
Covariates	Yes	Yes	Yes		
VARIABLES	[1]	[2]	[3]		
Panel C: Placebo test					
RBL random	0.388 (0.253)	0.151 (0.133)	0.0717 (0.126)		
Constant	-0.305** (0.148)	1.477*** (0.471)	3.545*** (0.567)		
Covariates	No	No	Yes		
Country/FE &Year/FE	No	Yes	Yes		
Observations	2,385	2,385	2,385		
R-squared	0.003	0.637	0.669		
VARIABLES	[1]	[2]	[3]	[4]	[5]
Panel D: Dynamic effects					
RBL adoption (t+1)	2.126*** (0.188)				
RBL adoption (t+2)		2.097*** (0.200)			
RBL adoption (t+3)			2.088*** (0.227)		
RBL adoption (t+4)				1.969*** (0.271)	
RBL adoption (t+5)					1.802*** (0.313)
Constant	1.883*** (0.581)	1.914*** (0.571)	2.022*** (0.555)	2.289*** (0.558)	2.439*** (0.567)
Covariates	Yes	Yes	Yes	Yes	Yes
Country/FE &Year/FE	Yes	Yes	Yes	Yes	Yes
Observations	2,274	2,162	2,051	1,940	1,829
R-squared	0.734	0.761	0.784	0.802	0.820

Robust standard errors are in brackets *** p < 0.01, ** p < 0.05, * p < 0.1.

Table C3: RBL adoption and cyclical of fiscal policy: robustness checks

VARIABLES	[1]	[2]	[3]
	OLS	IV-2SLS	Interactive term
RBL adoption	2.238*** (0.575)	1.297*** (0.270)	4.768*** (1.287)
GDP per capita (lag)	-0.0157* (0.00908)	-0.0461* (0.0266)	-0.0253*** (0.00878)
Natural resource rents (lag)	0.0136 (0.0207)	0.0857*** (0.0261)	0.0299** (0.0128)
Public debt (lag)	0.00152 (0.00396)	0.0168*** (0.00234)	-0.00658*** (0.00189)
Resource depletion (lag)	-0.0602** (0.0248)	0.0339 (0.0315)	-0.0686*** (0.0125)
Resource-rich countries	0.375 (0.729)	-0.654*** (0.217)	-0.362 (0.496)
FDI (lag)	0.00323 (0.00646)	-0.00217 (0.0129)	-0.0175*** (0.00583)
Control corruption	-3.337 (2.672)	-4.737*** (0.538)	-2.697** (1.261)
Total investment (log)			-0.211 (0.159)
RBL*Total investment			-0.891** (0.395)
Constant	2.581*** (0.793)	-1.233*** (0.297)	3.813*** (0.761)
Net effects			14.27
Country & Year/FE	Yes	Yes	Yes
Observations	2,385	1,150	2,167
R-squared	0.2136	0.141	0.669
Instruments	Lag RBL/Credit ratings		
Kleinberg-Paap rk test		56.513	
Stock-Yogo Stats test		19.93	
Hansen p-value		0.1207	

Robust standard errors are in brackets *** p < 0.01, ** p < 0.05, * p < 0.1.

Table C4: RBL adoption and cyclical of fiscal policy: transmission channels validity

Panel A: correlation with procyclicality of fiscal policy	[1]	[2]	[3]
VARIABLES			
Domestic debt crisis	1.893*** (0.324)		
Fiscal balance volatility		0.0277** (0.0168)	
Corruption			0.0400*** (0.0234)
Constant	-0.830*** (0.303)	-0.350** (0.169)	0.348*** (0.0608)
Covariates	Yes	Yes	Yes
Country & Year/FE	Yes	Yes	Yes
Observations	591	2,410	608
R-squared	0.252	0.114	0.280
Panel B: Transmission channels	[1]	[2]	[3]
VARIABLES	Domestic debt crisis	Fiscal balance volatility	Corruption
RBL adoption	0.201*** (0.0688)	0.846*** (1.226)	0.405*** (0.107)
Constant	0.917*** (0.0790)	-3.561** (1.657)	0.745*** (0.267)
Covariates	Yes	Yes	Yes
Country & Year/FE	Yes	Yes	Yes
Observations	592	2,451	1,582
R-squared	0.941	0.423	0.749

Robust standard errors are in brackets *** p < 0.01, ** p < 0.05, * p < 0.1.

Table C5: Exploring the heterogeneity

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
RBL adoption	2.226*** (0.227)	1.661*** (0.190)	0.524 (0.604)	2.340*** (0.216)	2.016*** (0.208)	4.768*** (1.287)	2.118*** (0.537)	1.270*** (0.343)	0.962*** (0.300)	2.589*** (0.295)	2.650*** (0.337)
Macroeconomic factors											
Commodity price volatility	-0.0448 (0.0323)										
RBL*Commodity price volatility	0.0607 (0.0396)										
Fiscal rules		-0.447** (0.183)									
RBL*Fiscal rules		-0.756** (0.298)									
Tax revenue volatility			-0.0579 (0.0775)								
RBL*Tax revenue volatility			0.0288 (0.113)								
Primary balance volatility				0.0230* (0.0122)							
RBL*Primary balance volatility				0.0227* (0.0119)							
Financial openness					0.107 (0.0787)						
RBL*Financial openness					-0.147 (0.0973)						
Total investment						-0.211 (0.159)					
RBL*Total investment						-0.891** (0.395)					
Sovereign credit rating							-0.0253*** (0.0521)				
RBL*Sovereign credit rating							-0.0885** (0.0661)				
Political and institutional factors											
Governance effectiveness								-0.377 (0.273)			
RBL*Governance effectiveness								-0.965*** (0.364)			
Regulatory quality									-0.230 (0.268)		
RBL*Regulatory quality									-1.178*** (0.276)		
Rule of law										-0.00897 (0.0374)	
RBL*Rule of law										-0.145** (0.0561)	
EITI adoption											-0.183 (0.152)
RBL*EITI adoption											-0.660* (0.372)
Constant	1.604*** (0.379)	2.124*** (0.576)	2.868*** (0.833)	2.245*** (0.402)	1.964*** (0.593)	3.813*** (0.761)	2.790** (1.203)	1.209* (0.657)	0.927 (0.715)	0.289 (0.418)	1.236* (0.651)
Main controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country & Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,163	2,385	1,196	2,236	2,313	2,167	1,465	2,047	2,052	1,649	2,385
R-squared	0.726	0.708	0.764	0.721	0.706	0.669	0.765	0.725	0.726	0.751	0.708

Robust standard errors are in brackets *** p < 0.01, ** p < 0.05, * p < 0.1.

Table C6: Resource-backed loans adoption and fiscal policy cyclical: Outliers treatment

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
RBL	1.1985*** (0.1127)	1.0893*** (0.1793)	1.1662*** (0.1203)	1.1164*** (0.1803)	1.2258*** (0.0928)	0.6743*** (0.1463)	1.2656*** (0.0965)	0.9912*** (0.1486)
Constant	-0.2832*** (0.0415)	0.5220*** (0.0809)	-0.3120 (0.2586)	0.9958** (0.4725)	1.2967*** (0.1387)	2.8455*** (0.2302)	1.5565*** (0.2272)	3.6678*** (0.3811)
Country/FE	No	Yes	No	Yes	No	Yes	No	Yes
Year/FE	No	No	Yes	Yes	No	No	Yes	Yes
Covariates	No	No	No	No	Yes	Yes	Yes	Yes
Observations	1,668	1,668	1,668	1,668	1,668	1,668	1,668	1,668
R-squared	0.2603	0.6897	0.3017	0.7159	0.4392	0.7722	0.4689	0.7995

Robust standard errors are in brackets *** p < 0.01, ** p < 0.05, * p < 0.1.

Table C7: Public investment thresholds and cyclical of fiscal policy

Effects nets	
Thresholds	cyclical of fiscal policy
0.6	4.233*** (1.0541)
0.7	4.144*** (1.0154)
0.8	4.055*** (0.9769)
0.9	3.966*** (0.9384)
1	3.877*** (0.9000)
5	0.312 (0.7335)
10	-4.146 (2.6837)
15	-8.603** (4.6529)
20	-13.061** (6.6242)
25	-17.518** (8.5961)
30	-21.975** (10.5683)
35	-26.432** (12.5406)

Robust standard errors are in brackets *** p < 0.01, ** p < 0.05, * p < 0.1.

Table C8: Effect by type of resource-backed loans

VARIABLES	[1]	[2]	[3]	[4]
Panel A: heterogeneity by type of RBL				
Oil-backed loans	0.199*** (0.197)			
Mineral, tobacco and cocoa-backed loans		0.692*** (0.229)		
Tobacco and cocoa-backed loans			0.165*** (0.131)	
Mineral-backed loans				0.371** (0.166)
Constant	3.574*** (0.563)	3.581*** (0.562)	3.583*** (0.562)	3.576*** (0.564)
Covariates	Yes	Yes	Yes	Yes
Country & Year/FE	Yes	Yes	Yes	Yes
Observations	2,385	2,385	2,385	2,385
R-squared	0.669	0.669	0.669	0.669
VARIABLES	[1]	[2]	[3]	[4]
Panel B: heterogeneity by interest rate and lenders				
Floating interest rates	0.745*** (0.248)			
Fixed interest rates		2.349*** (0.263)		
China's RBL			1.001*** (0.163)	
Others RBL				1.571*** (0.454)
Constant	3.657*** (0.555)	1.341** (0.603)	2.817*** (0.575)	3.501*** (0.554)
Covariates	Yes	Yes	Yes	Yes
Country & Year/FE	Yes	Yes	Yes	Yes
Observations	2,385	2,385	2,385	2,385
R-squared	0.670	0.696	0.676	0.683

Robust standard errors are in brackets *** p < 0.01, ** p < 0.05, * p < 0.1.

Appendix D (Chapter 4): Debt-for-nature Swaps and Fiscal Policy Volatility: Evidence from Developing Countries

Table D1: Alternative measures of fiscal policy volatility (non residuals method)

Dependent Variable :	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor	Radius Matching			Local linear regression	Kernel
Fiscal policy volatility	Matching	Matching		r=0.005	r=0.05	r=0.01	Matching	Matching
Alternative measures of fiscal policy volatility: Standard deviation of the total government expenditure in % of GDP estimated over a 5-year moving window								
[1] ATT	-0.1295** (0.0622)	-0.1297** (0.0543)	-0.1266*** (0.0447)	-0.1329*** (0.0454)	-0.1328*** (0.0459)	-0.1327*** (0.0418)	-0.1278** (0.0500)	-0.1333*** (0.0398)
Observations	1,664	1,664	1,664	1,664	1,664	1,664	1,664	1,664
Alternative measures of fiscal policy volatility: Skewness of the total government expenditure in % of GDP estimated over a 5-year moving window								
[2] ATT	-0.1295** (0.0584)	-0.1297*** (0.0457)	-0.1266* (0.0654)	-0.1329*** (0.0414)	-0.1328*** (0.0385)	-0.1327*** (0.0380)	-0.1278*** (0.0442)	-0.1333*** (0.0408)
Observations	1,664	1,664	1,664	1,664	1,664	1,664	1,664	1,664

Notes: Bootstrapped standard errors based on 50 replications in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Table D2: List of countries

DFN countries (39)	Non-DFN countries (39)	Non-DFN countries (39)	Non-DFN countries (17)
Argentina	Afghanistan	Iran	Sri Lanka
Bangladesh	Albania	Iraq	St. Lucia
Belize	Angola	Ireland	Sudan
Bolivia	Antigua and Barbuda	Kazakhstan	Suriname
Bosnia & Herzegovina	Armenia	Kenya	Tajikistan
Brazil	Azerbaijan	Kyrgyz Republic	Thailand
Bulgaria	Bahamas	Lebanon	Togo
Cameroon	Barbados	Lesotho	Tonga
Chile	Belarus	Liberia	Turkey
Colombia	Benin	Libya	Turkmenistan
Costa Rica	Bhutan	Malawi	Uganda
Dominican Republic	Botswana	Maldives	Ukraine
Ecuador	Burkina Faso	Mali	Uzbekistan
Egypt	Burundi	Mauritania	Vanuatu
El Salvador	Cambodia	Mauritius	Venezuela
Ghana	Central African Republic	Moldova	Yemen
Guatemala	Chad	Mongolia	Zimbabwe
Guinea-Bissau	Comoros	Montenegro	
Honduras	Congo, Dem Rep	Morocco	
Indonesia	Congo, Rep	Myanmar	
Jamaica	Cote d'Ivoire	Nauru	
Jordan	Croatia	Nepal	
Madagascar	Cuba	Niger	
Mexico	Cyprus	Pakistan	
Mozambique	Djibouti	Papua New Guinea	
Nicaragua	Dominica	Portugal	
Nigeria	Equatorial Guinea	Puerto Rico	
Panama	Eritrea	Romania	
Paraguay	Ethiopia	Rwanda	
Peru	Fiji	Samoa	
Philippines	Gabon	Sao Tome and Principe	
Poland	Gambia	Senegal	
Seychelles	Georgia	Serbia	
Syria	Greece	Sierra Leone	
Tanzania	Grenada	Slovenia	
Tunisia	Guinea	Solomon Islands	
Uruguay	Guyana	Somalia	
Vietnam	Haiti	South Africa	
Zambia	India	South Sudan	

Source: AfDB (2022); d Chamon et al. (2022); Sommer et al. (2020); Picolotti et al. (2020); Sheikh (2018).

Table D3: Summary statistics for all variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Fiscal policy volatility	2944	1.306	1.384	0	13.215
Debt-for-nature swaps (DFN)	4154	0.234	0.423	0	1
Lag ODA	3453	6.622	9.449	-2.313	137.588
Lag Total ODA Biodiversity (log)	2153	2.728	0.159	2.22	3.033
Lag Agricultural land area	3935	41.042	21.236	0.449	85.487
Lag GDP per capita	3818	2.076	6.74	-64.426	140.48
Lag GDP growth	3818	3.744	6.9	-64.047	149.973
Lag Public debt	3011	58.92	48.106	0.488	600.13
Lag Population (log)	4154	2.743	0.131	2.216	3.047
Democracy	3773	0.485	0.5	0	1
Trade openness	3576	75.228	37.962	0.021	347.997
Debt service total	3214	4.793	5.991	0.001	102.222
Government revenue	2784	22.996	9.932	2.764	62.669
Inflation targeting	4154	0.164	0.37	0	1
Resource-rich countries	4154	0.381	0.486	0	1
FDI	3849	4.328	10.95	-37.173	280.132
Resource rents	3822	7.488	10.746	0	87.459
Fiscal rules	4154	0.257	0.437	0	1
Rule of law	3380	0.422	0.148	0	0.857
Political stability	3380	0.512	0.159	0	0.843
Control corruption	3380	0.33	0.167	0	0.83
Governance stability	2582	7.653	1.915	0.667	12
Internal conflict	2582	8.47	2.083	0	12
External conflict	2582	9.665	1.711	0	12
Disasters index	3364	60.209	29.288	0	100
Economic structure index	3250	33.731	18.51	2.196	92.049
Exposure index	3250	36.662	13.653	3.295	82.239
Natural shock index	3142	42.214	17.34	0	95.767
Climatic vulnerability score	3016	0.48	0.084	0.304	0.707
Inflation crises	1155	0.187	0.39	0	1
Financial openness	3685	-0.224	1.415	-1.927	2.311
Socioeconomic conditions	2582	4.636	1.844	0	11
Corruption	2582	2.426	0.978	0	6
Debt restructuring	2726	0.136	0.343	0	1
Systemic crisis	1133	0.154	0.361	0	1
Domestic debt crisis	1096	0.059	0.236	0	1
Currency crisis	1161	0.211	0.408	0	1

Table D4: Correlation matrix

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]	[23]	[24]	[25]	[26]	[27]	[28]	[29]	[30]
[1] Fiscal policy volatility	1.000																													
[2] DFS	-0.115***	1.000																												
[3] Lag ODA	0.206***	-0.141***	1.000																											
[4] Lag Total ODA Biodiversity (log)	-0.200***	0.0735	-0.109**	1.000																										
[5] Lag Agricultural land area	-0.0533	-0.253***	0.0216	0.0549	1.000																									
[6] Lag GDP per capita	-0.0796*	-0.0149	-0.0948*	0.137***	0.125***	1.000																								
[7] Lag GDP growth	0.0440	-0.108**	0.0473	0.142***	0.0762*	0.933***	1.000																							
[8] Lag Public debt	0.0556	-0.0350	0.161***	-0.273***	-0.0639	-0.144***	-0.170***	1.000																						
[9] Lag Population total (log)	-0.240***	-0.0462	-0.332***	0.454***	0.261***	0.204***	0.173***	-0.245***	1.000																					
[10] Democracy	-0.264***	0.387***	-0.274***	0.202***	-0.147***	0.0653	-0.0667	-0.122**	0.189***	1.000																				
[11] Trade openness	0.110*	-0.0170	-0.0136	-0.203***	0.0239	0.0220	0.0937*	-0.428***	-0.0772**	0.189***	1.000																			
[12] Debt service total	-0.0951*	-0.0114	-0.176**	-0.0770*	-0.0456	-0.0352	-0.0745*	0.419***	-0.242***	0.0119	0.316***	1.000																		
[13] Government revenue	-0.0366	0.0683	-0.248***	0.0114	-0.292***	0.0260	-0.0164	0.111**	-0.107**	0.0851*	0.262***	0.271***	1.000																	
[14] Financial openness	-0.140***	0.307***	-0.0187	0.00988	-0.133***	0.00506	-0.0534	-0.00449	-0.258***	0.220***	0.0942*	0.200***	-0.00519	0.183***	1.000															
[15] Inflation targeting	-0.116**	0.261***	-0.264***	0.186***	-0.0496	0.0962*	0.0149	-0.255***	0.333***	0.341***	-0.120**	-0.0727*	-0.0869*	0.183***	0.0886*	1.000														
[16] Resource-rich countries	0.313***	-0.0422	0.102**	-0.00893	-0.0256	-0.0321	0.0749*	-0.252***	-0.0239	-0.101**	-0.0199	-0.121**	-0.00510	0.0192	0.0886*	0.0886*	1.000													
[17] DEI	0.0603	0.0166	0.0554	-0.0533	-0.0135	0.143***	0.151***	0.101**	-0.255***	-0.0594	0.335***	0.136***	0.130***	0.160***	-0.0828*	0.0542	1.000													
[18] Resource rents	0.417***	-0.285***	0.162***	-0.130***	0.0191	0.146***	-0.111**	-0.226***	-0.332***	0.160***	-0.0602	0.291***	-0.267***	-0.164***	0.591***	0.0972**	0.0890*	1.000												
[19] Fiscal rules	-0.0425	-0.0305	-0.0187	0.0457	-0.317***	-0.0437	-0.0279	-0.0121	0.113**	0.191***	-0.400***	-0.0736	0.0456	-0.0863*	-0.0472	0.0531	-0.141***	0.0890*	1.000											
[20] Rule of law	-0.221***	-0.00502	-0.190**	0.172***	-0.0140	0.0860*	0.0327	0.0449	0.133***	0.233***	0.167***	0.0868*	0.0904*	0.0404	0.193***	-0.313***	0.143***	-0.297***	0.0820*	1.000										
[21] Political stability	0.00762	0.195***	0.0362	-0.0880*	-0.151***	-0.0514	-0.0912*	-0.0451	-0.467***	0.192***	0.299***	0.104**	0.301**	0.130***	-0.00718	0.00824	0.145***	0.0886*	0.0161	0.399***	1.000									
[22] Control corruption	-0.241***	0.193***	-0.197***	0.117***	-0.108**	0.0573	-0.0215	0.0276	0.0525	0.344***	0.121**	0.0698	0.190***	0.0864*	0.173***	-0.274***	0.136***	-0.333***	0.101**	0.840***	0.444***	1.000								
[23] Governance stability	0.0438	-0.118**	0.0968*	-0.177***	0.0968*	0.0963*	0.135***	0.0554	-0.0631	-0.177***	0.146***	-0.0411	0.0753*	-0.105**	-0.0536	-0.00566	0.0451	0.154***	-0.280***	0.151***	0.175***	0.6005*	1.000							
[24] Internal conflict	-0.00271	0.230***	0.0618	-0.162***	-0.160***	-0.0290	-0.0690*	-0.00410	-0.426***	0.233***	0.332***	0.0933*	0.235***	0.202***	-0.0361	-0.0296	0.187***	0.00987	-0.0707	0.187***	0.763***	0.285***	0.171***	1.000						
[25] External conflict	-0.00818	0.350***	-0.153***	-0.0226	-0.168**	-0.00215	-0.0375	-0.0459	-0.0617	0.417***	0.243***	-0.00252	0.204***	0.0110	0.197***	0.108**	0.0257	0.0277	0.0114	0.314***	0.473***	0.347***	0.122***	0.467***	1.000					
[26] Diminuters index	-0.166***	-0.0667	0.104**	0.148***	0.0302	0.102**	0.0612	-0.0921*	0.150***	0.370***	-0.0437	-0.0906**	-0.188***	0.178***	0.0702	-0.190***	-0.00490	-0.266***	-0.0366	0.0109	-0.0491	-0.0264	-0.133***	0.0651	0.0704	1.000				
[27] Economic structure index	0.427***	-0.194***	0.535***	-0.229***	-0.0229	-0.0526	0.106**	0.00311	-0.224***	-0.401***	-0.159***	-0.247***	-0.195***	-0.300***	-0.383***	0.307***	-0.0946*	0.562***	0.139***	-0.505***	-0.170***	-0.542***	0.0109	-0.150***	-0.165***	0.0153	1.000			
[28] Exposure index	0.360***	0.0949*	0.445***	-0.367***	-0.313***	-0.141***	-0.0956*	0.0503	-0.622***	-0.0371	0.0775*	-0.101**	-0.00975	0.0153	-0.196***	0.252***	-0.0279	0.446***	0.152***	-0.441***	0.262***	-0.343***	-0.0756*	0.238***	0.0548	0.0828*	0.650***	1.000		
[29] Natural shock index	-0.180***	-0.139***	0.160***	0.109**	0.126***	0.108**	0.101**	-0.0866*	-0.0172	0.230***	0.129***	0.0109	-0.0666	0.0352	-0.135***	-0.274***	0.0573	-0.232***	-0.0719	0.201***	0.133***	0.135***	0.0830*	0.148***	0.211***	0.711***	-0.0164	-0.0281	1.000	
[30] Climate vulnerability score	0.291***	-0.313***	0.643***	-0.0541	0.0936*	-0.0316	0.129***	0.00238	0.0570	-0.256***	-0.349***	-0.368***	-0.462***	-0.283***	-0.266***	0.234***	-0.156***	0.219***	0.121**	-0.449***	-0.350***	-0.505***	0.0152	-0.263***	-0.272***	0.289***	0.726***	0.405***	0.173***	1.000

Table D5: Debt-for-nature and fiscal policy volatility: using OLS

VARIABLES	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Debt-for-nature swaps	-0.5537*** (0.0456)	-0.5007*** (0.0512)	-0.3660*** (0.0474)	-0.3955*** (0.0504)	-0.4126*** (0.0508)	-0.4134*** (0.0514)	-0.3114*** (0.0452)	-0.2949*** (0.0445)	-0.2035*** (0.0421)
Lag ODA		0.0402*** (0.0058)	0.0305*** (0.0059)	0.0310*** (0.0057)	0.0294*** (0.0059)	0.0298*** (0.0060)	0.0347*** (0.0066)	0.0303*** (0.0071)	0.0286*** (0.0073)
Lag Total ODA Biodiversity (log)			-1.3881*** (0.1850)	-1.3002*** (0.1768)	-1.1923*** (0.1768)	-1.1815*** (0.1810)	-1.0132*** (0.1651)	-0.6662*** (0.2055)	-0.7000*** (0.2112)
Lag Agricultural land area				-0.0081*** (0.0016)	-0.0069*** (0.0014)	-0.0070*** (0.0015)	-0.0043*** (0.0012)	-0.0030** (0.0013)	-0.0030** (0.0013)
Lag GDP per capita					-0.0476*** (0.0154)	-0.0383** (0.0192)	-0.0390* (0.0199)	-0.0521** (0.0213)	-0.0522** (0.0230)
Lag GDP growth						-0.0094 (0.0221)	0.0269 (0.0196)	0.0415* (0.0215)	0.0394* (0.0239)
Lag Public debt							0.0050*** (0.0013)	0.0049*** (0.0013)	0.0048*** (0.0013)
Lag Population total (log)								-0.9444*** (0.2927)	-1.6942*** (0.3072)
Democracy									-0.1804*** (0.0488)
Constant	1.4692*** (0.0331)	1.2827*** (0.0465)	4.9840*** (0.5179)	5.0953*** (0.5109)	4.8772*** (0.5000)	4.8665*** (0.5015)	3.7862*** (0.4741)	5.3885*** (0.6544)	7.6715*** (0.7511)
Country/FE & Year/FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,944	2,628	1,811	1,805	1,805	1,805	1,738	1,738	1,664
R-squared	0.0333	0.0856	0.1012	0.1197	0.1552	0.1553	0.1680	0.1740	0.2064

Standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1. Note: Differences between observations in columns [1] and those of Table 4.2 are due to differences in observations of additional covariates

Table D6: Debt-for-nature and fiscal policy volatility: using OLS

VARIABLES	[1]	[2]	[3]	[4]
Debt-for-nature swaps	-0.4274*** (0.1485)	-0.4702** (0.2207)	-0.0947** (0.2591)	-0.4978*** (0.1506)
Lag ODA	0.0242** (0.0120)	0.0022 (0.0100)	0.0065 (0.0110)	-0.0189 (0.0131)
Lag Total ODA Biodiversity (log)	-0.3449 (0.2220)	-0.3917 (0.2764)	-0.3596 (0.2692)	-0.2463 (0.3347)
Lag Agricultural land area	0.0292** (0.0118)	0.0340*** (0.0108)	0.0583*** (0.0160)	0.0527*** (0.0138)
Lag GDP per capita	0.0029 (0.0235)	0.0344 (0.0256)	0.0190 (0.0430)	-0.0337 (0.0241)
Lag GDP growth	-0.0142 (0.0251)	-0.0334 (0.0265)	-0.0302 (0.0421)	0.0172 (0.0253)
Lag Public debt	0.0023 (0.0016)	0.0050*** (0.0015)	0.0069*** (0.0018)	-0.0006 (0.0023)
Lag Population total (log)	-1.3234 (7.5458)	-4.2079 (7.5617)	-2.1314 (8.7590)	-23.0232** (10.4688)
Democracy	0.0841 (0.0647)	0.0047 (0.0615)	-0.0300 (0.0642)	0.0376 (0.0744)
Rule of law		-3.1088*** (0.8310)		-2.1607** (0.9814)
Political stability		0.8745** (0.4087)		0.9693* (0.5570)
Control corruption		0.0351 (0.5513)		1.0721 (0.6780)
Governance stability		-0.0270 (0.0205)		-0.0467** (0.0224)
Internal conflict		-0.0686** (0.0321)		-0.0174 (0.0366)
External conflict		-0.1056** (0.0420)		-0.0941* (0.0566)
Debt service total	0.0024 (0.0037)			0.0020 (0.0059)
Government revenue	-0.0074 (0.0083)			0.0002 (0.0132)
Financial openness	-0.6341*** (0.1564)			-0.1318 (0.2034)
Inflation targeting	-0.9872* (0.5873)			-1.9231*** (0.7085)
Resource-rich countries	2.0932*** (0.5554)			5.4097*** (0.9377)
FDI	0.0042 (0.0055)			0.0015 (0.0063)
Resource rents	-0.0124* (0.0067)			-0.0189* (0.0106)
Fiscal rules	-0.0975 (0.0872)			-0.0998 (0.1288)
Disasters index			-0.0162** (0.0068)	0.0018 (0.0080)
Economic structure index			-0.0309*** (0.0094)	-0.0311** (0.0134)
Exposure index			0.0245 (0.0240)	0.0150 (0.0316)
Natural shock index			0.0172* (0.0099)	-0.0120 (0.0122)
Climatic vulnerability score			-1.9476 (3.6414)	-1.7978 (4.1526)
Country/FE & Year/FE	Yes	Yes	Yes	Yes
Observations	1,076	1,104	1,169	706
R-squared	0.5715	0.6069	0.6099	0.5543

Unreported constant included. Standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1. Note: Differences between observations in columns [1]-[4] and those of Table 4.2 are due to differences in observations of additional covariates.

Table D7: List of variables and their sources

Variables	Definition	Sources
1. Dependent variable		
Fiscal policy volatility (main outcome variable: Public Spending)	Standard deviation measures discretionary fiscal policy	Authors' calculation based on WDI data
Fiscal policy volatility (using real government expenditure)	Standard deviation measures discretionary fiscal policy	Authors' calculation based on WDI data
Fiscal policy volatility (using tax revenues % of GDP)	Standard deviation measures discretionary fiscal policy	Authors' calculation based on WDI data
Fiscal policy volatility (using cyclically adjusted primary balance)	Standard deviation measures of fiscal balance	Authors' calculation based on WDI data
Fiscal policy volatility (using fiscal balance in % of GDP)	Standard deviation measures of cyclically adjusted primary balance	Authors' calculation based on WDI data
2.Treatment variable		
Debt-for-nature swaps	Takes value 1 if country i at period t has benefited from a debt-for-nature swaps agreement	AfDB (2022); Picolotti et al. (2020); Sheikh (2018)
Bilateral debt-for-nature swaps	Takes value 1 if country i at period t has benefited from a bilateral debt-for-nature swaps agreement	AfDB (2022); Picolotti et al. (2020); Sheikh (2018)
Multi-party debt-for-nature swaps	Takes value 1 if country i at period t has benefited from a multi-party debt-for-nature swaps agreement	AfDB (2022); Picolotti et al. (2020); Sheikh (2018)
3. Baseline model control variables or covariates		
ODA	Net official development assistance received	WDI
Total ODA Biodiversity	Total amount donated for biodiversity conservation in developing countries, 2021	Our World in Data
Agricultural land area	Agricultural land (% of land area)	WDI
GDP per capita	Fiscal balance (% of GDP)	WDI
GDP growth	Public debt (% of GDP)	WDI
Public debt	Public debt (% of GDP)	Kose et al. (2017)
Population total	Population growth	WDI
Democracy	Index ranging from -10 to 10	Policy 5
4. Additional control variables		
Interest on debt	Interest paid on public debt, percent of GDP	IMF
Government revenue	Government revenue, percent of GDP (% of GDP)	IMF
Corruption	Corruption measures perceptions of corruption, conventionally defined as the exercise of public power for private gain	Teorell et al. (2020)
FDI	Foreign direct investment, net inflows (% of GDP)	WDI
Rule of law	Rule of Law includes several indicators which measure the extent to which agents have confidence in and abide by the rules of society	Teorell et al. (2020)
Trade openness	Trade (% of GDP)	WDI
Political stability	Index ranging from -2 to 2	WGI, Kaufmann et al. (2011)
Debt service total	Total service debt (% of GDP)	WDI
Inflation crisis	Dummy	Reinhart and Rogoff (2009)
Inflation targeting	Dummy	Cizkowicz-Pekala et al. (2019); Roger (2009); Rose (2007)
Corruption control	Index ranging from 0 to 100	WGI, Kaufmann et al. (2011)
Banking crisis	Dummy	Reinhart and Rogoff (2009)
Currency crises	Dummy	Reinhart and Rogoff (2009)
Debt restructuring	Dummy	Reinhart and Rogoff (2009)
Systemic crisis	Dummy	Reinhart and Rogoff (2009)
Debt default crisis	Dummy	Reinhart and Rogoff (2009)
Disasters index	Homeless due to natural disasters	FERDI database, Guillaumont (2009); Feindouno and Goujon (2016)
Economic structure index	Probability that a country's economic development may be hampered by unforeseen exogenous shocks	FERDI database, Guillaumont (2009); Feindouno and Goujon (2016)
Exposure index	A weighted average of population size (50%), remoteness from world markets (25%), exports concentration (12.5%), and the share of agriculture, forestry and fishery in GDP (12.5%).	FERDI database, Guillaumont (2009); Feindouno and Goujon (2016)
Natural shock index	Homelessness due to natural disasters	FERDI database, Guillaumont (2009); Feindouno and Goujon (2016)
Climatic vulnerability score	Propensity or predisposition of human societies to be negatively impacted by climate hazards	University of Notre Dame Global Adaptation Index
Fiscal rules	Dummy	IMF Fiscal Rules Dataset, Lledó et al. (2017)
Socioeconomic conditions	Assessment of the socioeconomic pressures at work in society that could constrain government action or fuel social dissatisfaction	ICRG
Financial openness	Capital Account Openness index	Chinn and Ito (2006)
Resource-rich countries	Dummy	IMF Fiscal Rules Dataset, Lledó et al. (2017)
Resource rents	Natural resources rents to % GDP	WDI

Appendix E (Chapter 5): Achieving sustainable development and debt sustainability in developing countries: to what extent do debt-for-nature swaps matter?

Table E1: Robustness-using endogenous switching regression model: Conditional expectations, treatment and heterogeneity effects

	Decision stage		Treatments effects
	DNS adopters	DNS non-adopters	
DNS adopters	(a) 0.1654*** (0.0035)	(c) -0.0581*** (0.0051)	TT = 0.1073*** (0.0001)
DNS non-adopters	(d) 0.1220*** (0.0032)	(b) -0.1044*** (0.0086)	TU= 0.0176*** (0.0002)
Heterogeneity effects	BH1= 0.0463*** (0.0037)	BH0=0.0434*** (0.0049)	TH= 0.0029*** (0.0001)

Note: *** significant at 1%; Values in parentheses are standard errors. TT: Effect of the treatment on the treated; TU: Effect of the treatment on the untreated; BH1: Base heterogeneity effect for adopters; BH0: Base heterogeneity effect for non-adopters; TH: Transitional heterogeneity effect.

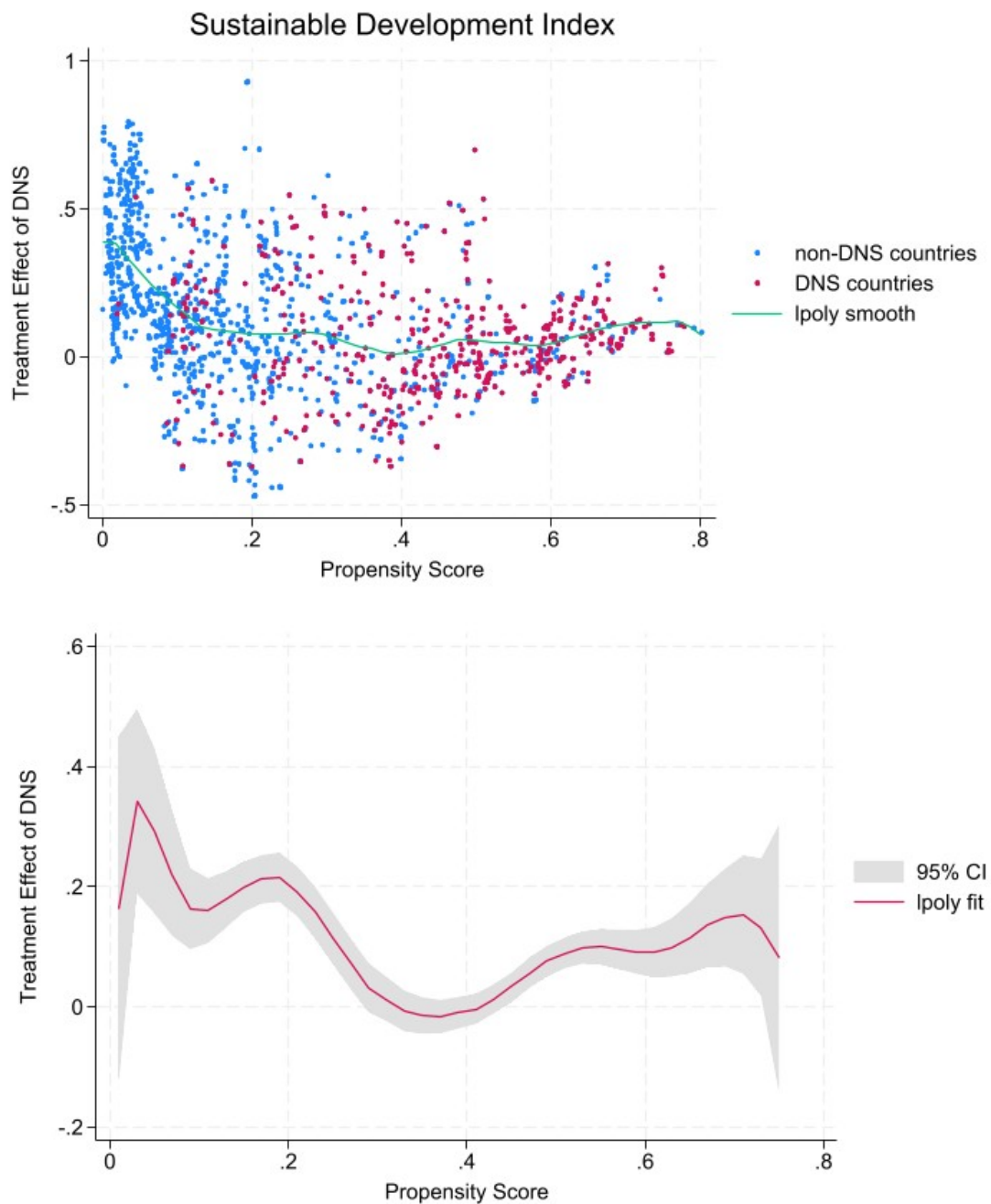


Figure 7: Robustness: using endogenous switching regression

Table E2: Robustness-using systems GMM and cross-sectional estimations

VARIABLES	[1] <i>Systems GMM</i>	[2] <i>IV-2SLS</i>		[3] <i>Cross-sectional</i>	[4] <i>Cross-sectional</i>
Lag.Dependent variable	0.9775*** (0.0029)			Environmental funds	Face value of debt canceled
DNS adoption	0.0152*** (0.0028)	0.1243*** (0.0398)	DNS amounts	0.0033* (0.0020)	0.0037* (0.0019)
Lag GDP per capita (log)	0.0135*** (0.0013)	0.0991*** (0.0107)		0.1299*** (0.0378)	0.1293*** (0.0381)
Lag debt service total	0.0024*** (0.0001)	-0.0039*** (0.0013)		-0.0077 (0.0055)	-0.0077 (0.0055)
lag climatic vulnerability score	0.2331*** (0.0198)	-1.3034*** (0.1187)		-1.3836*** (0.4111)	-1.3829*** (0.4042)
Property rights	0.0002*** (0.0000)	0.0010** (0.0004)		0.0002 (0.0017)	0.0002 (0.0017)
Democracy polity	-0.0001 (0.0003)	0.0023* (0.0013)		0.0049 (0.0044)	0.0044 (0.0045)
Constant	0.0030 (0.0214)	-0.7190*** (0.1175)		-0.9792* (0.4946)	-0.9762* (0.4934)
AR (2) test	0.011				
AR (1) test	0.801				
Sargan C-test/Kleibergen-Paap LM test, p-value	0.000	0.0000			
Hansen J-test	0.488	0.8892			
Number of instruments	72	2			
Observations	1,491	1,158		75	75
R-squared		0.6734		0.7571	0.7589
Number of country	74	127			

Note: we use the lag of the control variables as an internal instrument for the GMM systems, while the deforestation rate and the commitment to the environmental convention were used as external instruments for the IV-2SLS. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table E3: Descriptive statistics of the main variables

Variable	Obs	Mean	Std. Dev.	Min	Max
SDI	3100	0.6	0.141	0.207	0.837
Lag.GDP per capita (log)	3429	8.676	1.02	6.079	11.373
Lag.debt service total	2926	4.746	5.978	0.001	102.222
Lag.climatic vulnerability	2725	0.481	0.085	0.304	0.707
Property rights	2742	39.893	18.463	0	90
Democracy polity	3116	2.251	6.076	-10	10

Table E4: Correlation matrix of the main variables

Variables	[1]	[2]	[3]	[4]	[5]	[6]	[7]
[1] SDI	1.000						
[2] Debt-for-nature swaps	0.346 (0.000)	1.000					
[3] Lag.GDP per capita (log)	0.570 (0.000)	0.138 (0.000)	1.000				
[4] Lag.debt service total	0.194 (0.000)	0.056 (0.003)	0.320 (0.000)	1.000			
[5] Lag.climatic vulnerability	-0.544 (0.000)	-0.198 (0.000)	-0.818 (0.000)	-0.390 (0.000)	1.000		
[6] Property rights	0.030 (0.148)	0.052 (0.006)	0.441 (0.000)	0.190 (0.000)	-0.414 (0.000)	1.000	
[7] Democracy polity	0.229 (0.000)	0.205 (0.000)	0.337 (0.000)	0.103 (0.000)	-0.243 (0.000)	0.461 (0.000)	1.000

Note: the p-values are in brackets.

Table E5: Size and non-linearity of DNS

VARIABLES	[1]	[2]
DNS amount	0.00300*** (0.00098)	
DNS amount ²	-0.00004** (0.00001)	
Medium DNS		0.06237** (0.02565)
Large DNS		-0.10009*** (0.01122)
Constant	-1.19092*** (0.09756)	-0.56082*** (0.11402)
Covariates	Yes	Yes
Optimum threshold		42.21
Observations	1,140	1,500
R-squared	0.84437	0.71709

Robust standard errors are in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table E6: List of variables and their sources

Variables	Definition	Sources
1. Dependent variable		
Sustainable development index	Measures the ecological efficiency of human development	Hickel (2020)
2. Treatment variable		
Debt-for-nature swaps	Dummy	AfDB (2022); d Chamon et al. (2022); Picolotti et al. (2020); Sommer et al. (2020); Sheikh (2018); Shandra et al. (2011)
Bilateral debt-for-nature swaps	Dummy	AfDB (2022); d Chamon et al. (2022); Picolotti et al. (2020); Sommer et al. (2020); Sheikh (2018); Shandra et al. (2011)
Multi-party debt-for-nature swaps	Dummy	AfDB (2022); d Chamon et al. (2022); Picolotti et al. (2020); Sommer et al. (2020); Sheikh (2018); Shandra et al. (2011)
3. Baseline model control variables or covariates		
GDP per capita	GDP per capita, PPP (constant 2017 international \$)	WDI
Debt service total	Total service debt (% of GNI)	WDI
Climate vulnerability scores	Measure climate change vulnerability	ND-Gain Université Notre Dame
Property rights	Index ranging from 0 to 100	Economic Freedom Scores Database
Democracy regimes	Index ranging from -10 to 10	Policy V
4. Additional control variables		
Resources rents	Continuous	WDI
Internal conflict	Continuous	ICRG
External conflict	Continuous	ICRG
Control of corruption	Index ranging from 0 to 100	WGI, Kaufmann et al. (2011)
Governance effectiveness	Continuous	ICRG
Rule of law	Continuous	Teorell et al. (2016)
Political stability	Index ranging from -2 to 2	WGI, Kaufmann et al. (2011)
Investment profile	Continuous	ICRG
Disasters index	Index ranging from 0 to 100	FERDI database, Guillaumont (2009), Feindouno and Goujon (2016)
ICT	Continuous	ND-Gain Université Notre Dame
Years of schooling	Continuous	Hickel (2020)
Access to electricity	Continuous	WDI
Electric power consumption	Continuous	WDI
Fossil fuel production	Continuous	WDI
Resource depletion	Continuous	WDI
Total external debt stocks in % of GDP	Continuous	WDI
Forest land biocapacity per capita	Continuous	FAO
FDI	Continuous	WDI
Remittance inflows	Continuous	WDI
ODA	Continuous	WDI
Public expenditure	Continuous	IMF, WEO
Inflation rate	Continuous	WDI
Trade openness	Continuous	WDI
Public debt	Continuous	Ali Abbas et al. (2011)
Exchange rate	Continuous	Penn World Table 10.0
ODA biodiversity	Continuous	OECD – processed by Our World in Data
Agricultural value added	Continuous	WDI
Industry value added	Continuous	WDI
Commodity prices	Continuous	Gruss and Kebhaj (2019)

Table E7: List of debt-for-nature (DNS) and Non-DNS countries

Treated countries (DNS)	Untreated countries (non-DNS)		
Argentina	Afghanistan	Georgia	Portugal
Bangladesh	Albania	Greece	Puerto Rico
Belize	Angola	Grenada	Romania
Bosnia & Herzegovina	Antigua and Barbuda	Guinea	Rwanda
Brazil	Armenia	Guyana	Samoa
Bulgaria	Azerbaijan	Haiti	Sao Tome and Principe
Cameroon	Bahamas	India	Senegal
Chile	Barbados	Iran	Serbia
Colombia	Belarus	Iraq	Sierra Leone
Ecuador	Benin	Ireland	Slovenia
Egypt	Bhutan	Kazakhstan	Solomon Islands
El Salvador	Botswana	Kenya	Somalia
Ghana	Burkina Faso	Kyrgyz Republic	South Africa
Guatemala	Burundi	Lebanon	South Sudan
Guinea-Bissau	Cambodia	Lesotho	Sri Lanka
Honduras	Central African Republic	Liberia	St. Lucia
Indonesia	Chad	Libya	Sudan
Jamaica	Comoros	Malawi	Suriname
Jordan	Congo, Dem Rep	Maldives	Tajikistan
Mexico	Congo, Rep	Mali	Thailand
Mozambique	Cote d'Ivoire	Mauritania	Togo
Nicaragua	Croatia	Mauritius	Tonga
Nigeria	Cuba	Moldova	Turkey
Panama	Cyprus	Mongolia	Turkmenistan
Paraguay	Djibouti	Montenegro	Uganda
Peru	Dominica	Morocco	Ukraine
Seychelles	Equatorial Guinea	Myanmar	Uzbekistan
Syria	Eritrea	Nauru	Vanuatu
Tanzania	Ethiopia	Nepal	Venezuela
Tunisia	Fiji	Niger	Yemen
Uruguay	Gabon	Pakistan	Zimbabwe
Vietnam	Gambia	Papua New Guinea	

Yacouba COULIBALY

Ressources Naturelles, Politique Budgétaire et Financement du Développement dans les Pays en Développement

Résumé :

Le financement du développement durable demeure un enjeu crucial pour les pays en développement, confrontés à une insuffisance chronique de ressources budgétaires pour faire face aux besoins croissants liés à la lutte contre la pauvreté, les inégalités, l'insécurité alimentaire, le changement climatique, la perte de biodiversité et la transition énergétique. En parallèle, la vulnérabilité climatique croissante, les récentes crises de la dette souveraine combinée à un accès limité aux marchés financiers ont montré la nécessité de repenser les mécanismes de financement durable dans les pays en développement. Cette thèse analyse les effets macroéconomiques et environnementaux de deux instruments de financement innovants auxquels les pays ont fait recours ces dernières décennies: les prêts garantis par les ressources naturelles et les échanges dette-nature (debt-for-nature swaps), en évaluant leur capacité à favoriser un développement durable dans une perspective de soutenabilité faible et forte. Pour y parvenir, nous avons subdivisé la thèse en deux parties interconnectées. La première partie est consacrée à l'analyse des prêts adossés aux ressources naturelles, répartie en trois chapitres. Le premier chapitre examine l'effet des prêts adossés aux ressources sur l'efficacité écologique du développement humain dans un échantillon de 45 pays africains entre 1990 et 2019. En mobilisant la méthode d'entropy balancing, il est démontré que ces prêts peuvent améliorer cette efficacité via des canaux tels que le PIB par tête, le niveau d'éducation et les années de scolarisation prévues. Toutefois, l'impact varie selon les ressources (positif pour le pétrole et les minéraux, négatif pour le cacao et le tabac) et devient non significatif en cas de dette publique élevée. Un paradoxe est mis en évidence : ces prêts contribuent à l'amélioration sociale tout en exacerbant les émissions de gaz à effet de serre. Le deuxième chapitre explore leur relation avec la déforestation dans 64 pays en développement sur la période 2004–2018. À travers une approche par appariement de score de propension, les résultats montrent que ces prêts accentuent significativement la déforestation, notamment lorsqu'ils sont adossés à des ressources comme les minéraux, le cacao ou le tabac. L'effet est conditionné par la structure forestière, les institutions et la pression sur le remboursement de la dette. Le troisième chapitre analyse l'impact de ces prêts sur la cyclicité de la politique budgétaire dans 127 pays sur la période 1990–2020. À l'aide de la méthode LGWOLS et d'entropy balancing, il est établi que ces prêts déclenchent une politique budgétaire procyclique, mais cet effet devient contracyclique lorsque les investissements publics se situent entre 15 % et 35 % du PIB. La seconde partie de la thèse porte sur les échanges dette contre nature, un mécanisme d'allègement de la dette conditionné à des engagements environnementaux. Nous avons analysé dans le quatrième chapitre leur effet sur la volatilité budgétaire dans 134 pays en développement durant la période 1990–2020. Les résultats confirment leur capacité à stabiliser les finances publiques en réduisant la volatilité de la politique budgétaire, surtout lorsqu'ils sont bilatéraux. L'instauration de règles budgétaires apparaît comme un levier pour renforcer cet effet. Le cinquième chapitre s'attache à mesurer l'impact de ces échanges sur l'efficacité écologique du développement humain, en mobilisant une approche contrefactuelle. Il est démontré que ces swaps contribuent à l'amélioration conjointe de la performance sociale et environnementale, via des canaux tels que la réduction de l'épuisement des ressources, la baisse des émissions de CO₂, l'accroissement des investissements et la progression du bien-être. En conclusion, cette thèse montre que les prêts garantis par les ressources naturelles peuvent, sous certaines conditions, favoriser le développement durable mais comportent des risques environnementaux significatifs. À l'inverse, les debt-for-nature swaps, bien que modestes en volume, offrent un potentiel prometteur pour articuler allègement de la dette et la durabilité environnementale. Une généralisation de ces mécanismes, accompagnée de critères d'éligibilité assouplis et d'une gouvernance renforcée, est préconisée pour soutenir les trajectoires de développement soutenable.

Mots clés : Politique budgétaire, ressources naturelles, développement durable, instruments de financement.

Natural Resources, Fiscal Policy and Financing for Development in Developing Countries

Summary:

Financing sustainable development remains a crucial issue for developing countries, which face a chronic shortage of budgetary resources to meet the growing needs associated with combating poverty, inequality, food insecurity, climate change, biodiversity loss, and the energy transition. In parallel, growing climate vulnerability, recent sovereign debt crises, and limited access to financial markets have highlighted the need to rethink sustainable financing mechanisms in developing countries. This thesis analyzes the macroeconomic and environmental effects of two innovative financing instruments that countries have resorted to in recent decades: resource-backed loans and debt-for-nature swaps, assessing their ability to foster sustainable development from both low and high sustainability perspectives. To achieve this, we have divided the thesis into two interconnected parts. The first part is devoted to the analysis of resource-backed lending, divided into three chapters. The first chapter examines the effect of resource-backed loans on the ecological efficiency of human development in a sample of 45 African countries between 1990 and 2019. Using entropy balancing, it is demonstrated that these loans can enhance efficiency through channels such as GDP per capita, educational attainment, and expected years of schooling. However, the impact varies according to resources (positive for oil and minerals, negative for cocoa and tobacco) and becomes insignificant in the case of high public debt. A paradox is highlighted: these loans contribute to social improvement while exacerbating greenhouse gas emissions. The second chapter explores their relationship with deforestation in 64 developing countries over the period 2004-2018. Using a propensity score matching approach, the results show that these loans significantly accentuate deforestation, particularly when they are backed by resources such as minerals, cocoa, or tobacco. Forest structure, institutions, and pressure on debt repayment condition the effect. The third chapter analyzes the impact of these loans on the cyclical policy in 127 countries over the period 1990-2020. Using the LGWOLS method and entropy balancing, it is established that these loans trigger a pro-cyclical budgetary policy; however, this effect becomes counter-cyclical when public investment accounts for between 15% and 35% of GDP. The second part of the thesis focuses on debt-for-nature swaps, a debt-relief mechanism conditional on environmental commitments. In the fourth chapter, we analyze their effect on fiscal volatility in 134 developing countries over the period 1990-2020. The results confirm their ability to stabilize public finances by reducing fiscal policy volatility, especially when they are bilateral. The introduction of fiscal rules is a lever for reinforcing this effect. The fifth chapter measures the impact of these exchanges on the ecological efficiency of human development, using a counterfactual approach. It is demonstrated that these swaps contribute to the joint improvement of social and environmental performance through channels such as reduced resource depletion, lower CO₂ emissions, increased investment, and improved well-being. In conclusion, this thesis demonstrates that resource-based lending can, under certain conditions, promote sustainable development; however, it also entails significant environmental risks. Conversely, debt-for-nature swaps, though modest in volume, offer promising potential for linking debt relief and environmental sustainability. To support sustainable development trajectories, we recommend the widespread use of these mechanisms, accompanied by more flexible eligibility criteria and strengthened governance.

Keywords : Fiscal policy, natural resources, sustainable development, financing instruments.



Laboratoire d'Économie d'Orléans
Faculté de Droit d'Économie et de Gestion
Rue de Blois - BP 26739 45067 ORLÉANS
Cedex 2 Tél : (33) (0)2 38 41 70 37 Fax : (33)
(0)2 38 41 73 80