UNIVERSIDADE FEDERAL DA BAHIA - UFBA
ESCOLA DE ADMINISTRAÇÃO DA UFBA
NÚCLEO DE PÓS-GRADUAÇÃO EM ADMINISTRAÇÃO - NPGA

VIVIANE HELENA TORINELLI

ENVIRONMENTAL AND CLIMATE RISK MANAGEMENT: A FRAMEWORK FOR A RESILIENT MANAGEMENT OF THE INTERNATIONAL RESERVES BY CENTRAL BANKS

Salvador
2022

VIVIANE HELENA TORINELLI

GESTÃO DE RISCO AMBIENTAL E CLIMÁTICO: UMA ESTRUTURA ANALÍTICA PARA UMA GESTÃO RESILIENTE DAS RESERVAS INTERNACIONAIS PELOS BANCOS CENTRAIS

Tese apresentada para obtenção do grau de Doutora no Programa de Doutorado em Administração do Núcleo de Pós-Graduação em Administração – NPGA, da Escola de Administração da Universidade Federal da Bahia. Área de concentração: Tecnologia, Inovação e Competitividade.

Professor Orientador: Professor Antônio Francisco de Almeida da Silva Júnior.
Professor Coorientador: José Célio Silveira Andrade.

Salvador
2022

Escola de Administração - UFBA

T683 Torinelli, Viviane Helena.
Environmental and climate risk management: a framework for a resilient management of the international reserves by central banks = Gestão de risco ambiental e climático: uma estrutura analítica para uma gestão resiliente das reservas internacionais pelos bancos centrais / Viviane Helena Torinelli. – 2022.
210 f. : il.

Título em inglês e equivalente em português.
Orientador: Prof. Dr. Antônio Francisco de Almeida da Silva Júnior.
Coorientador: Prof. Dr. José Célio Silveira Andrade.
Tese (doutorado) – Universidade Federal da Bahia, Escola de Administração, Salvador, 2022.

1. Bancos centrais - Avaliação de risco. 2. Bancos centrais – Reservas internacionais. 3. Investimentos – Análise. 4. Gestão de riscos climáticos. 5. Gestão de riscos ambientais. 6. Finanças internacionais. 7. Framework (Arquivo de computador) – Metodologia – Análise e interpretação. I. Universidade Federal da Bahia. Escola de Administração. II. Título. III. Titulo: Gestão de risco ambiental e climático: uma estrutura analítica para uma gestão resiliente das reservas internacionais pelos bancos centrais.

CDD – 332.11

VIVIANE HELENA TORINELLI

ENVIRONMENTAL AND CLIMATE RISK MANAGEMENT: A FRAMEWORK FOR A RESILIENT MANAGEMENT OF THE INTERNATIONAL RESERVES BY CENTRAL BANKS

Tese apresentada para obtenção do grau de Doutora em Administração, pela Escola de Administração, da Universidade Federal da Bahia. Área de concentração: Tecnologia, Inovação e Competitividade.

Aprovada em 08 de março de 2022.

André Luis Rocha de Souza.
Doutor em Engenharia Industrial pela Universidade Federal da Bahia.
Universidade Federal da Bahia.

Annelise Vendramini Felsberg
Doutora em Administração pela Faculdade de Economia, Administração e Contabilidade da Universidade de São Paulo.

Antônio Francisco de Almeida da Silva Júnior – Orientador.
Doutor em Engenharia aeronáutica e Mecânica pelo departamento de Engenharia de Produção do Instituto Tecnológico de Aeronáutica (ITA), São Paulo, Brasil.
Universidade Federal da Bahia.

José Célio Silveira Andrade – Coorientador.
Doutor em Administração pela Universidade Federal da Bahia.
Universidade Federal da Bahia.

Juliano Almeida de Faria.
Doutor em Engenharia Industrial pela Universidade Federal da Bahia.
Universidade Federal de Sergipe.

Acknowledgment

To my father who taught me that the more I know, the more I realize I don't know, and who always told me I could do more and better. To my mother who always encourages me to guide my actions and thoughts towards self-development and the greater purpose of life, while also motivates and teaches by the example to be positive, proactive, and resolute. To my husband, my love and safe harbor, who has always been totally supportive. To my daughter, this wonderful being, the lighthouse guiding my actions in a broader purpose of life. To the family, mine, his and ours, who was crucial in many ways and moments.

A special thank you to my academic supervisors for all the excellent guidance during this long journey, as well as for the colleagues and friends who were very important in different means.

TORINELLI, Viviane Helena. **Environmental and climate risk management: a framework for a resilient management of the international reserves by central banks.** Thesis advisor: Antônio Francisco de Almeida da Silva Júnior; Thesis Deputy advisor: José Célio Silveira Andrade, 2022. 210 s. ill. Thesis (PhD in Business) – Business School, Universidade Federal da Bahia, Salvador 2022.

Abstract

Environmental and climate factors are a source of financial risks. Risks need to be identified, measured, and managed. Even though proper risk management is essential for efficient investment management, environmental and climate risk management is a challenge to investors, including central banks when acting as investment managers. Central banks are among the largest global investors, managing international reserves totaling trillions of dollars. The theoretical and practical gaps in this subject were highlighted by NGFS, the Network of Central Banks for Greening the Financial System. In this context, the objective of this research was to propose a framework to manage exposure to environmental and climate risks in the management of international reserves by central banks, without prejudice to their economic and financial objectives. To address this objective, this thesis is based on three studies. In the first one the risks were analyzed, and a framework was proposed for environmental and climate risk management of the international reserves. The second study discussed the application of the framework to a sample of central banks from Latin America and the Caribbean. The third study tested the application of the framework, including portfolio optimization and multi-objective analysis. The conclusion is that environmental and climate risk analysis should be included in the traditional approach to strategic asset allocation by central banks at least due to the relevance of the environmental and climate risks to which international reserves are exposed. As a result of the applied framework, with multi-objective analysis, the management of the international reserves can become more resilient to environmental and climate risks without undermining the financial and economic objectives of the central banks. Also, this management may eventually compose a strategy of positive impact in the real-world. This thesis is relevant to the investment management perspective of the international reserves, to safeguard the execution of the monetary and foreign exchange policies using those reserves and for the possible real-world effect of the strategic asset allocation.

Keywords: environmental and climate risk management, international reserves, central banks

TORINELLI, Viviane Helena. **Gestão de risco ambiental e climático: uma estrutura analítica para uma gestão resiliente das reservas internacionais pelos bancos centrais**. Orientador: Antônio Francisco de Almeida da Silva Júnior. Co-orientador: José Célio Silveira Andrade, 2022. 210 f. il. Tese (Doutorado em Administração) – Escola de Administração, Universidade Federal da Bahia, Salvador 2022.

Resumo

Fatores ambientais e climáticos são uma fonte de riscos financeiros. Os riscos precisam ser identificados, medidos e gerenciados. Embora a gestão de risco adequada seja essencial para uma gestão de investimento eficiente, a gestão de risco ambiental e climático é um desafio para os investidores, incluindo os bancos centrais, quando atuam como gestores de investimentos. Os bancos centrais estão entre os maiores investidores globais, administrando reservas internacionais que somam trilhões de dólares. As lacunas teóricas e práticas neste assunto foram destacadas pela NGFS, a rede de bancos centrais voltada a um sistema financeiro mais verde. Nesse contexto, o objetivo desta pesquisa foi propor uma estrutura analítica multicritério para gerenciar a exposição a riscos ambientais e climáticos na gestão de reservas internacionais por bancos centrais, sem prejuízo de seus objetivos econômicos e financeiros do gestor. Para atender a esse objetivo, esta tese é baseada em três estudos. Na primeira foram analisados os riscos e proposta uma abordagem para a gestão dos riscos ambientais e climáticos das reservas internacionais. O segundo estudo discutiu a aplicação da abordagem a uma amostra de bancos centrais da América Latina e do Caribe. O terceiro estudo testou a aplicação da abordagem, incluindo otimização de carteira de investimento e análise multiobjetivo. A conclusão é que a análise de riscos ambientais e climáticos deve ser incluída na abordagem tradicional de alocação estratégica de ativos pelos bancos centrais, pelo menos devido à relevância dos riscos ambientais e climáticos aos quais as reservas internacionais estão expostas. Como resultado da abordagem aplicada, com análise multiobjetivo, a gestão das reservas internacionais pode se tornar mais resiliente aos riscos ambientais e climáticos sem prejudicar os objetivos financeiros e econômicos dos bancos centrais. Além disso, essa gestão pode eventualmente compor uma estratégia de impacto positivo no mundo real. Esta tese é relevante para a perspectiva de gestão do investimento das reservas internacionais, para salvaguardar a execução das políticas monetária e cambial utilizando essas reservas e para o possível efeito real da alocação estratégica de ativos.

Palavras-chave: gestão de riscos ambientais e climáticos, reservas internacionais, bancos centrais

Summary

1 Introduction and problem situation

Environmental and climate factors are a source of financial risks (Bank for International Settlements, 2021; Calice & Miguel, 2021; FSB, 2020; NGFS, 2020a; Rudebusch, 2021). Risks need to be identified, measured, and managed. Even though proper risk management is essential for efficient investment management, environmental and climate risk management is a challenge to investors, including central banks when acting as investment managers (Grippa et al., 2019; NGFS, 2018, 2019, 2020b). Central banks are among the largest global investors, managing international reserves totaling around US$12,8 trillion in 2021 (IMF, 2021). The theoretical and practical gaps in this subject were highlighted by NGFS, the Network of Central Banks for Greening the Financial System:

> NGFS Members acknowledge that climate-related risks are a source of financial risk … against this backdrop, authorities and financial institutions need to develop some new analytical and supervisory approaches … Central Banks and Supervisors, as well as financial institutions, are beginning to deepen their understanding of these risks and the need for an improved approach … The tools and methodologies, however, are still at an early stage and there are a number of analytical challenges … Some Central Banks are also starting to play their part in scaling up green finance by accounting for climate and environment-related factors in their investment strategies for instance. (NGFS, 2018, p. 3)

In this **context**, this thesis addresses the **research problem** of how to manage the exposure to environmental and climatic risks of the international reserves, without prejudice to the economic and financial objectives of central banks.

As **assumptions** of this research, it is adopted that international reserves have the objective of precaution against liquidity needs in crises, attenuation of exchange rate volatility, among other attributions of monetary and exchange rate policy (Aizenman & Marion, 2002;

Allen et al., 2002; Detragiache, 1996; Hawkins & Rangarajan, 1970; Kohlscheen & O'Connell, 2004; Silva Jr., 2011). Thus, the management of international reserves consists of their application in asset classes available in the international financial market, and to consider environmental and climate risks is not among its primary objectives. Possibly for this reason, central banks are not significantly addressing the sustainable and responsible investment management and the green finance market as managers of the international reserves (Dafe & Volz, 2015; NGFS, 2018, 2020c, 2021; Sheng, 2015; Volz, 2017). However, environmental and climate risks are sources of relevant financial risk and must be managed (Andersson et al., 2016; WRI & UNEP-FI, 2015). The theoretical foundation of the premises is discussed in chapter 2.

The research **hypotheses** of this thesis were that: 1) International reserves are exposed to environmental and climate risk; 2) This exposure can be managed through strategic asset allocation; 3) This management can occur without prejudice to the economic and financial objectives of central banks. Hence, environmental and climate risk management should be included in the traditional approach to strategic asset allocation of international reserves, with each viable portfolio being evaluated considering these risks, without prejudice to the other objectives of the investors.

In this sense, this research **objective** was to propose a framework to manage exposure to environmental and climate risks in the management of international reserves by central banks, without prejudice to their economic and financial objectives. The specific research objectives were to: I) Identify the environmental and climate risks to which central banks are exposed as managers of international reserves; II) Identify/propose a methodology for assessing the exposure to environmental and climate risks of an investment portfolio with the investor profile of central banks; III) Propose a framework to address environmental and climate risk in the strategic allocation of assets of international reserves, without prejudice to the economic and financial objectives of central banks; IV) Validate the framework, quantifying the possible economic and financial impacts resulting from its application.

To address these objectives, this thesis is based on three studies and one policy brief. In the first study the risks were analyzed, and a framework was proposed for environmental and climate risk management of the international reserves (see chapter 2). The second study discussed the application of the framework to a sample of central banks from Latin America and the Caribbean (see chapter 3). The third study tested the application of the framework, including portfolio optimization and multi-objective analysis (see chapter 4). A policy brief addresses the final adjusted framework (see chapter 5).

The links among the research hypotheses, the specific objectives, the studies and the respective methodologies are detailed in Section 1.1. Further, Section 1.2 summarizes the theoretical references per study. Finally, Section 1.3 highlights the results, conclusion, future studies, limitations and products, per study.

The first study was published in the Latin American Journal for Central Banks (LAJCB), with scientific contribution (Torinelli & Silva Júnior, 2021). Previously it was presented in two PhD Workshops of the annual conferences of the Global Research Alliance of Sustainable Finance and Investment (GRASFI), in the University of Oxford (GRASFI, 2019) and virtually in the Columbia University (GRASFI, 2020). The paper was also presented in the CEMLA and Banco de México- Conference on Climate Change and its Impacts in the Financial System (CEMLA, 2019), in Mexico, in the FSI-CEMLA-BCB Seminar on Climate Risk Assessment in the Financial Sector (FSI-CEMLA-BCB, 2020), in the XXVI Meeting of the Central Bank Researchers Network - CEMLA (CEMLA, 2021) and in the first Depep Seminar of 2022 - Seminar 20/1, organized by the Department of studies and research from the Central Bank of Brazil (Banco Central do Brasil, 2022).

The second study was awarded with the honorable mention in the XXVI Award of the Brazilian National Treasury (DOU, 2021), and accepted to be published in 2022 in the publication of the National Treasury, "Cadernos do Tesouro Nacional" (in Portuguese and in English). Also, the second study was awarded as best paper on the thematic of Sustainable Finance in the XXIII Engema Congress (Torinelli et al., 2021). Previously it was presented in the PhD Workshops of the annual conference of the Global Research Alliance of Sustainable Finance and Investment, virtually hosted by the Central University of Finance and Economics, Beijing (GRASFI, 2021). The third study and the policy brief were just concluded and will be submitted for publication.

This research is justified by: the impacts that environmental and climate risks can have on the results of the international reserves; the importance of these reserves to execute the monetary and the foreign exchange policies, as well as their relevance in facing crises, such as the climate crisis that is on the horizon and whose intermediate effects are already being felt; the role that central banks can play as international reserve managers in fostering a resilient economy and a sustainable development; and the current relevance and timeliness of the sustainability agenda.

For example, the food and agriculture, fuel, and ores and metals sectors are significantly exposed to environmental risks, including the physical and transition climate ones. This exposure has implications for exports and capital flows, as well as, from this perspective, an indirect impact on international reserves. Some expected asset-price movements in crisis scenarios would reduce country exports and have an impact on the FX rate. The international reserves would be affected in terms of their economic objectives, such as the execution of payments, intervention in FX markets, and underpinning of investors' confidence in the country. This point is better explored in the following studies of this thesis.

Hence, this research contributes to filling knowledge gaps. This work indicates how to consider environmental risks in the strategic allocation of assets from international reserves, being able to subsidize central banks in the decision-making process, with potential for a relevant impact from the perspective of the manager, of the sustainable finance and economy, in addition to assisting in the construction of analysis methodologies.

1.1 Research hypotheses, specific objectives, respective studies and methodologies

The links among the research hypotheses, the specific objectives, the studies and the respective methodologies are detailed as follows:

The **hypothesis** “1) International reserves are exposed to environmental and climate risk” is covered by the **specific objectives** “I) Identify the environmental and climate risks to which central banks are exposed as managers of international reserves” and “II) Identify/propose a methodology for assessing the exposure to environmental and climate risks of an investment portfolio with the investor profile of central banks”. They are addressed in **study one (chapter 2)**, which identifies the risks and proposes the framework.

The **hypothesis** “2) This exposure can be managed through strategic asset allocation” is covered by the **specific objective** “III) Propose a framework to address environmental and climate risk in the strategic allocation of assets of international reserves, without prejudice to the economic and financial objectives of central banks”. They are addressed in the **studies one (chapter 2) and two (chapter 3)**, which proposes the framework (study one) and then discusses this framework with a sample of central banks in the Latin America and the Caribbean, as well as presents an initial test of the quantification of effects (study two).

The **hypothesis** “3) This management can occur without prejudice to the economic and financial objectives of central banks” is covered by the **specific objective** “IV) Validate the framework, quantifying the possible economic and financial impacts resulting from its application”. They are addressed in the **studies two (chapter 3) and three (chapter 4)**, which discusses the framework with a sample of central banks in the Latin America and the Caribbean (study two) and **tests the application of the framework, through portfolio optimization and multi-objective analysis** (study three).

The **methodology** used in the **first study** is review of literature, documents and public information on environmental and climate risks, international reserves, and central banks. In the **second study**, the methodology is like the one adopted in the first study, plus analysis of the applied framework on a sample of ten central banks from Latin America and the Caribbean. On top of that, it was performed a validation with peers, including people who work with international reserves or who are experts in the subject. The meetings were held within the scope of the project with the Center for Latin American Monetary Studies (CEMLA), with four central banks in the sample, one of which also responded to the applied questionnaire (see appendix).

The most detailed methodology is the one applied on **study three**. To evaluate the impacts of the proposed framework, the third study is based on investment portfolio simulation and optimization in R, with synthesized data of bond returns, data from foreign exchange rates, and data from commodities' prices. Several optimal mean-variance portfolios are calculated based on constraints that guarantee similarity to real international reserves portfolios from the selected countries. These constraints are chosen based on countries' international reserves data available on the internet. The methodology is detailed in section 4.4 of the chapter 4.

To sum up, the framework proposed in this thesis was built based on the literature, discussed, and improved with the interviews and validated with the third article. The final framework is detailed in the Policy Brief, which may be found in the chapter 5 of this document.

1.2 References

Aizenman, J., & Marion, N. (2002). International Reserve Holdings with Sovereign Risk and Costly Tax Collection. *NBER WORKING PAPER SERIES INTERNATIONAL*, *Setember*(Working Paper 9154). https://www.nber.org/system/files/working_papers/w9154/w9154.pdf

Allen, M., Rosenberg, C., Keller, C., Setser, B., & Roubini, N. (2002). A Balance Sheet Approach to Financial Crisis. *A Balance Sheet Approach to Financial Crisis*, *02*(210), 1–63. https://doi.org/10.5089/9781451957150.001.a001

Andersson, M., Bolton, P., & Samama, F. (2016). Hedging climate risk. *Financial Analysts Journal*, *72*(3), 13–32. https://doi.org/10.2469/faj.v72.n3.4

Banco Central do Brasil. (2022). *Seminários do Depep 20/1*. Conferences, Seminars and Workshops BCB. https://www.bcb.gov.br/en/publications/conferenceseminarworkshop

Bank for International Settlements. (2021). *Climate-related financial risks – measurement methodologies* (Issue April). https://www.bis.org/bcbs/publ/d518.htm

Calice, P., & Miguel, F. (2021). Climate-Related and Environmental Risks for the Banking Sector in Latin America and the Caribbean A Preliminary Assessment. *World Bank Group*, *Policy Res*(June). https://openknowledge.worldbank.org/bitstream/handle/10986/35764/Climate-Related-and-Environmental-Risks-for-the-Banking-Sector-in-Latin-America-and-the-Caribbean-A-Preliminary-Assessment.pdf?sequence=1&isAllowed=y

CEMLA. (2019). *Conference on Climate Change and its Impact in the Financial System*. https://www.cemla.org/actividades/2019-final/2019-12-climate-change-and-its-impact-in-the-financial-system.html

CEMLA. (2021). *XXVI Meeting of the Central Bank Researchers Network*. https://www.cemla.org/actividades/2021-final/2021-11-xxvi-meeting-of-the-central-bank-researchers-network.html

Dafe, F., & Volz, U. (2015). Financing Global Development: The Role of Central Banks. In *SSRN Electronic Journal* (Vol. 8). https://doi.org/10.2139/ssrn.2797226

Detragiache, E. (1996). Fiscal Adjustment and Official Reserves in Sovereign Debt Negotiations. *Economica*, *63*(249), 81–95. https://doi.org/10.2307/2554635

DOU. (2021). *Resultado do XXVI Prêmio Tesouro Nacional – 2021*. https://www.in.gov.br/en/web/dou/-/edital-stn-n-6-de-25-de-novembro-de-2021-362461171

FSB. (2020). *The Implications of Climate Change for Financial Stability* (Issue November). https://www.fsb.org/wp-content/uploads/P231120.pdf

FSI-CEMLA-BCB. (2020). *Seminar on Climate Risk Assessment in the Financial Sector*. https://www.cemla.org/actividades/2020-final/2020-12-seminar-on-climate-risk-assessment-in-the-financial-sector.html

GRASFI. (2019). PhD Workshop. *2nd Annual Conference- University of Oxford*. https://www.susfinalliance2019.org/phd-workshop-registration

GRASFI. (2020). PhD Workshop. *3rd Annual Conference- Columbia University*. https://easychair.org/cfp/GRASFI2020

GRASFI. (2021). PhD Workshop. *4th Annual Conference- International Institute of Green Finance (IIGF) of the Central University of Finance and Economics (CUFE)*. https://beijing2021.sustainablefinancealliance.org/about/phd-workshop/

Grippa, P., Schmittmann, J., & Suntheim, F. (2019). Climate Change and Financial Risk. *FINANCE & DEVELOPMENT*, *56*(4). https://www.imf.org/external/pubs/ft/fandd/2019/12/pdf/climate-change-central-banks-and-financial-risk-grippa.pdf

Hawkins, R. G., & Rangarajan, C. (1970). On the Distribution of New International Reserves.

The Journal of Finance, *25*(4), 881–891. https://doi.org/10.2307/2325423

IMF. (2021). *Currency Composition of Official Foreign Exchange Reserves*. https://data.imf.org/?sk=E6A5F467-C14B-4AA8-9F6D-5A09EC4E62A4

Kohlscheen, E., & O'Connell, S. A. (2004). A Sovereign Debt Model with Trade Credit and Reserves. *Mimeo*, *743*. https://doi.org/10.2139/ssrn.941107

NGFS. (2018). First Progress Report. *Network for Greening the Financial System, October*, 1–12. https://www.ngfs.net/sites/default/files/medias/documents/818366-ngfs-first-progress-report-20181011.pdf

NGFS. (2019). A sustainable and responsible investment guide for central banks' portfolio management. *Network for Greening the Financial System Technical Document, October*. https://www.ngfs.net/sites/default/files/medias/documents/ngfs-a-sustainable-and-responsible-investment-guide.pdf

NGFS. (2020a). Overview of Environmental Risk Analysis by Financial Institutions. *Network for Greening the Financial System, September*.

NGFS. (2020b). Progress report on the implementation of sustainable and responsible investment practices in central banks' portfolio management. In *NGFS Technical document* (Issue December). https://www.ngfs.net/sites/default/files/medias/documents/sri_progress_report_2020.pdf

NGFS. (2020c). Survey on monetary policy operations and climate change: key lessons for further analyses. *Network for Greening the Financial System*, *December*. https://www.ngfs.net/en/survey-monetary-policy-operations-and-climate-change-key-lessons-further-analyses

NGFS. (2021). Guide on climate-related disclosure for central banks. *NGFS Technical Document, December*. https://www.ngfs.net/sites/default/files/medias/documents/guide_on_climate-related_disclosure_for_central_banks.pdf

Rudebusch, G. D. (2021). *Climate Change Is a Source of Financial Risk*. https://www.frbsf.org/economic-research/publications/economic-letter/2021/february/climate-change-is-source-of-financial-risk/

Sheng, A. (2015). Central banks can and should do their part in funding sustainability. *Centre for International Governance Innovation - FIXING CLIMATE GOVERNANCE SERIES*, *1*, 1–20. https://wedocs.unep.org/bitstream/handle/20.500.11822/34564/FCP.pdf?sequence=1&isAllowed=y

Silva Jr., A. F. A. (2011). The Self-Insurance Role of International Reserves and the 2008-2010 Crisis. *Central Bank of Brazil Working Paper*, *256*, 1–26. https://doi.org/10.2139/ssrn.1956702

Torinelli, V. H., Silva Jr., A. F. A., Andrade, J. C. S., & Martinez-Jaramillo, S. (2021). Latin America (LatAm) Central Banks (CBs) environmental risk management of the international reserves: an applied framework discussion. In *XXIII ENGEMA* (pp. 1–20). http://engemausp.submissao.com.br/23/anais/arquivos/58.pdf?v=1643301635

Torinelli, V. H., & Silva Júnior, A. F. de A. da. (2021). Environmental risk analysis (ERA) in the strategic asset allocation (SAA) of the international reserves (IRs) managed by central banks (CBs). *Latin American Journal of Central Banking*, *2*(1), 100021. https://doi.org/10.1016/j.latcb.2021.100021

Volz, U. (2017). On the role of Central Banks in enhancing green finance. *United Nations Environment Programme, Inquiry Wo*(February), 1–27. http://unepinquiry.org/wp-content/uploads/2017/02/On_the_Role_of_Central_Banks_in_Enhancing_Green_Finance.pdf

WRI, & UNEP-FI. (2015). *Carbon Asset Risk: Discusssion Framework*. *13*(2), 255–270.

http://www.unepfi.org/fileadmin/documents/carbon_asset_risk.pdf%5Cnhttp://www.wri.org/sites/default/files/carbon-asset-risk-discussion-framework-ghgp_0.pdf

2 Study 1:

Environmental risk analysis in the strategic asset allocation of the international reserves managed by central banks

Viviane H. Torinelli[1,2] and Antônio F. A. Silva Júnior[1,2]

[1] Business School, Universidade Federal da Bahia, Salvador, Bahia, Brazil (UFBA)

[2] Brazilian Research Alliance for Sustainable Finance and Investment (BRASFI)

Author Note

Viviane H. Torinelli https://orcid.org/0000-0002-1330-6370

Antônio F. A. Silva Júnior https://orcid.org/0000-0002-4417-5991

Correspondence email: vivitorinelli@gmail.com

Abstract

This study addresses how to consider environmental risk analysis in the strategic asset allocation of the international reserves managed by central banks. For that, a multicriteria analytical framework is proposed for the evaluation of the environmental risk exposure of an investment portfolio, compatible with the investor profile of the central banks. Thus, the framework includes the environmental risk analysis in the traditional approach for strategic asset allocation of the international reserves. Environmental risks, as climate physical and transition ones, are resulting in a range of financial risks, but environmental risk analysis is still incipient in the financial investment sphere, especially among central banks. Reports of the NGFS, the Network of Central Banks for Greening the Financial System, and NGFS members were reviewed and we´ve found no specific indication of environmental risk analysis as input on strategic asset allocation of the international reserves. Thus, the main argument of this study is that since environmental risk analysis is included in the traditional approach for strategic asset allocation, international reserves' investments will be more resilient to environmental and climate risk exposures. The framework discussed in this paper suggests that for each viable portfolio the central bank should use scenarios of environmental risks along probabilities and potential impacts to choose the appropriate portfolio. The risk and return relationships of the portfolios in each scenario should be evaluated based on the environmental factors.

Keywords: environmental risk analysis, strategic asset allocation, central banks, international reserves

2.1 Introduction

Effective risk management, including risk identification, measurement, and control, is essential for efficient operation on financial markets. In the worldwide discussion about financial risk management, analyses of environmental externalities, trends and events are becoming recurrent and gradually more relevant (Bank of England et al., 2017; Caldecott et al., 2014; Cambridge Centre for Sustainable Finance, 2016; TCFD, 2017).

In December 2017, the Network for Greening the Financial System (NGFS) was established among central banks to define and promote the implementation of best practices inside and outside NGFS Members, and to develop analytical work on green finance. On 2019, the NGFS encouraged central banks to lead by example and to integrate sustainability factors into the management of some of the portfolios at hand (NGFS, 2019a), and issued a sustainable and responsible investment guide for central banks’ portfolio management (NGFS, 2019b).

Even though proper risk management is essential for efficient investment management, environmental risk analysis is incipient in the financial investment sphere, especially among central banks (NGFS, 2020d, 2020a). The theoretical and practical gaps in this subject were highlighted since the first reports of the NGFS (NGFS, 2018, 2019a).

The management of environmental risks has not been a primary objective of the international reserves management (NGFS, 2018, 2019a). Possibly for this reason, central banks are not significantly addressing environmentally sustainable management and the Green Finance market from the perspective of the international reserves managers (Sevillano & González, 2018). While most central banks are considering general climate-related measures in their monetary policy operations, the implementation of specific measures in their operational frameworks is still at a very early stage (NGFS, 2020f). Reports of the NGFS and NGFS members were reviewed and we´ve found no specific indication of environmental risk analysis as input on strategic asset allocation of the international reserves (Bank of England, 2020; Banque de France, 2020; NGFS, 2020b, 2020e, 2020d, 2020a).

The international reserves are investments held by central banks in foreign currency with the economic objectives of: intervention in the FX market within the monetary policy; execution of payment for goods and services; execution of payments for the government; granting of emergency liquidity assistance; underpinning of investor confidence in the country and investment of excess reserves (Fender et al., 2019). They ultimately allow for the capacity to meet liquidity needs in crises and mitigate exchange rate volatility, among other purposes related to monetary and FX policy (Aizenman & Marion, 2002; Allen et al., 2002; Detragiache, 1996; Hawkins & Rangarajan, 1970; Kohlscheen & O'Connell, 2004; Silva Jr., 2011). In order to address such a broad and diverse array of objectives, the management of the international reserves consists of the investment in asset classes available within the international financial market. International reserves totaled US$13.978 trillion in 2019 (The World Bank, 2020).

International reserves provide two important and widely accepted functions for central banks in emerging markets. One is self-insurance (Calvo et al., 2012) and the other is warning signaling (Kaminsky et al., 1998). Avoiding environmental risks, as climatic ones (physical and transition), is compatible with these two rationales.

The environmental risks, as climate physical and transition ones, are beginning to be understood as sources of financial risks, which may affect the investments performance (Bank of England et al., 2017; Cambridge Centre for Sustainable Finance, 2016; NGFS, 2020d). As a result, the management of environmental risk exposure of the international reserves is important for central banks.

The environmental risk analysis is prominently linked to the strategic asset allocation by means of the common time frame as the long-term horizon for the assessment. In this context, **the question that this research seeks to address is how to consider environmental risk in the strategic asset allocation of international reserves.**

For that, this study also discusses climate physical and transition risks to which central banks are exposed as managers of the international reserves. A multicriteria analytical framework is proposed for the evaluation of the environmental risk exposure of an investment portfolio compatible with the investor profile of central banks. This work may support central banks decision making from a managerial perspective, in addition to helping them with the construction of a related framework.

Other studies, which addressed the environmentally sustainable performance of central banks, had different objectives than those proposed in this study. They mostly focused on the environmental sustainability of central banks as financial market regulators and as oversight agents, but not as international reserves managers (e.g.: (Campiglio et al., 2018)). The theoretical studies of environmental risk analysis, detailed in the following section, were generally focused on other investors.

For the scope of this study, it must be clarified that it addresses climate and more broadly environmental factors (e.g.: biodiversity), but does not include social and governance factors, which are typically also included in ESG (Environmental, Social and Governance) and SRI (Socially Responsible Investing) analysis. SRI comprises a broad range of sustainable investment strategies (NGFS, 2019b). It incorporates ESG factors into investment decisions and active ownership. It considers both a) how ESG might influence the risk-adjusted return of an asset and the stability of an economy, as well as b) how investment in and engagement with assets and investees can impact society and the environment (CFA UK, 2020a). According to the NGFS (2019b), central banks may choose to adopt SRI to a) mitigate environmental risks in their portfolio, or b) to create a positive impact on the environment and society alongside financial returns. These objectives can be translated into different investment strategies. This article is focused on a) a risk/return management, not in b) a positive impact investment perspective.

The scope of this study includes only item “a” above, a risk-return perspective of the management of the environmental risk exposure of the international reserves. As it will be discussed in Section 2.3, environmental factors include climate physical and transition financial risks with short-, medium- and long-term impact, thus applicable to international reserves management. The outputs of the environmental risk analysis, which contemplate environmental factors in different scenarios, are estimated changes in the value of assets and portfolios, with potential subsequent impacts in the strategic asset allocation to mitigate risk exposure or to explore the opportunities. More details are found in Section 2.4.

This paper proceeds as follows: the three first following sections detail results of literature review. Section 2.2 is about the environmental risk analysis and concludes with an framework from theory and to praxis. Section 2.3 covers the international reserves management. Section 2.4 connects environmental risk analysis and the strategic asset allocation of the international reserves. Section 2.5 presents the multicriteria analytical framework. The paper concludes in Section 2.6 with an outlook for future research.

2.2 The environmental risk analysis

Environmental and climate challenges pose material risks for real economies and financial stability (Dafe & Volz, 2015; Volz, 2017). In addition to the usual risks already considered by financial market managers, the environmental factors are associated with a range of material financial risks. According to The Global Risks Report (WEF, 2020), the five top risks in terms likelihood are environmentally related, as well as three out of the top five risks in terms of impact. They include extreme weather events, climate action failure, natural disasters, biodiversity loss, human-made environmental disasters.

Evidence indicates that environmental factors, including climate physical and transition ones, are resulting in business, market, and credit risks. All these risks have financial implications that can be non-linear and disruptive (Bank of England et al., 2017; G20 Green Finance Study Group, 2016; TCFD, 2017).

The dimensions of the environmental physical risks are climatic, geologic and ecosystemic (Bank of England et al., 2017). Physical risks include shock events and changes in trends. Among the climatic physical risks, global warming is by far the most discussed one, strongly associated with anthropogenic carbon emissions. The devastating consequences of global warming are widely acknowledged, such as rising sea levels due to polar melting, drought-related fires destroying huge areas of forests on different continents, land degradation and landslide related to extreme weather events, as well as numerous other effects (IPCC, 2014). On the other hand, global warming benefits some nations and regions, like Canada, Alaska and Russia, by expanding arable land and increasing domestic production (Read, 2016).

The exact timing and severity of global warming physical effects are difficult to estimate. The geographically varied, large-scale and long-term nature of the problem, as well as the endogeneity and uncertainty of the effects and its transmission channels makes it exceptionally challenging, especially in the context of economic decision-making (UNEP FI, 2019).

Recent study from the McKinsey Global Institute (2020) characterizes the global climate physical risks as increasing, spatial, non-stationary, nonlinear, systemic, regressive (the poorest communities and populations are the most vulnerable) and under-prepared (regarding worldwide adaptation). The report recommends to decision-makers from financial institutions to consider the climate risk in their portfolios, pointing out that one of the biggest challenges could stem from using the wrong models to quantify risk.

The environmental physical risks and the associated transition risks may increase market volatility and sector instability, driving potential financial losses. For instance, physical shock events, as natural catastrophes, may impact corporate financials, especially in the insurance sector. In this way, changes in trends such as water scarcity, air pollution and natural capital degradation represent risks to corporate sectors like agriculture and power generation. A few examples include the devaluations (and even bankruptcies) that happened in the German electricity sector and in the United States (US) coal and automotive industries (Bank of England et al., 2017). In case of a fast transition process towards a low-carbon system, the possibility that this risk exposure may spread across the financial system shouldn't be underestimated (Faiella et al., 2018).

It is already known that the effects of global warming are not just long term. The worldwide policy effort to achieve a low-carbon economy affects virtually all industries and sectors, significantly and even disruptively (TCFD, 2017). Carbon pricing systems are already stimulating the alignment of the energy market with green public policies. The change in the energy matrix, incorporating clean technologies, already exemplifies potential medium-term developments and impacts.

The transition to a low-carbon economy, including mitigation and adaptation measures to minimize global warming and its impacts, signals that the primary environmental risks go beyond physical effects. They include the economic effects of developing climate and environmental policies, of new technologies and even of changes in the investors and consumers sentiment. The financial implications of moving to a green economy, with positive impacts on the environment, are significant; it will require reallocations in the order of tens of trillion dollars in investments (Scott et al., 2017).

The dimensions of the environmental transition risks can be categorized as policy, technological, and sentimental (Bank of England et al., 2017). The first dimension includes policy actions to mitigate, or adapt to, climate change. In the regulatory field, it includes the establishment of carbon pricing systems, as cap-and-trade regimes or carbon tax and government regulatory programs designed to reduce the total level of emissions of certain pollutants, particularly carbon dioxide, because of industrial activity. By contrast, the second dimension of transition risks include clean technologies, as the renewable energy sources and technology innovation in production, transports, and consumption. Finally, the third dimension is related to the sentiment of investors and public opinion, which influences asset price adjustments with direct impacts on financial markets.

Dietz et al. (2016) estimated the impact of twenty-first-century climate change on the present market value of global financial assets. The authors found that the expected "climate value at risk" (climate VaR) of global financial assets is 1.8% along a business-as-usual emissions path, which would total US$2.5 trillion based on a representative estimate of global financial assets. However, as much of the risk is in the tail, the 99th percentile climate VaR is 16.9%, or US$24.2 trillion. Cutting emissions, to limit warming in this century to no more than 2 degrees Celsius (2C) above pre-industrial levels, would reduce the climate VaR by an expected 0.6 percentage points, and the 99th percentile reduction is 7.7 percentage points. Including mitigation costs, the present value of global financial assets is an expected 0.2% higher when warming is limited to no more than 2C, compared with business as usual. The 99th percentile is 9.1% higher.

Benedetti et al. (2019) studied the climate change transition risk for investors and developed a model to capture the potential impact of carbon pricing on fossil fuel sensitive stocks. The authors propose the creation of smart carbon portfolios to face the transition to a lower-carbon economy. They suggest this can be achieved by lowering the weightings of some high-risk fossil fuel stocks while raising the weightings in lower-risk fossil fuel stocks and/or in the stocks of companies active in energy efficiency markets.

In this sense, Andersson, Bolton and Samama (2016) also presented an investment strategy to allow hedging climate risk to long-term passive investors, without sacrificing financial returns. With low tracking error in a decarbonized index, investors hold a “free option on carbon”.

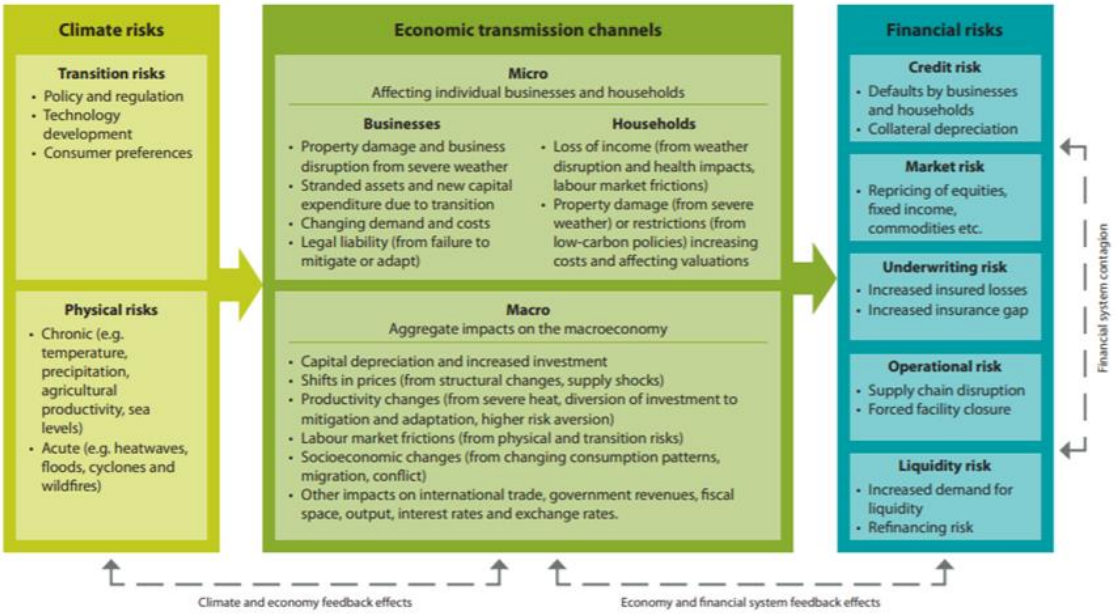
Cahen-Fourot et al. (2021) analyze the impact of decarbonization on productive asset utilization and developed a novel methodological framework to investigate the exposure of economic systems to the risk of capital stranding. Combining Input-Output (IO) and network theory, the authors defined measures to identify both the sectors likely to trigger relevant capital stranding cascades and those most exposed to capital stranding risk. The authors show how, in a sample of ten European countries, mining is among the sectors with the highest external assets stranding multipliers. According to the study results, the sectors most affected by capital stranding triggered by decarbonization include electricity and gas; coke and refined petroleum products; basic metals; and transportation.

According to Caldecott, Tilbury and Carey (2014), environment-related risks can cause “stranded assets”, the ones impacted by unanticipated or premature write-downs, devaluations or conversion to liabilities. This occurs due to a range of environment-related risks which are poorly understood and regularly mispriced. The result is a significant financial, economic, and potentially systemic over-exposure to environmentally unsustainable assets. These authors identified nearly 80 published scenarios from respected public and private institutions which could be relevant to the stranded assets agenda, thus serving as an information source to investors and decision-makers.

The NGFS (2020c) published climate scenarios that cover three of the following dimensions: orderly, disorderly, and hot house world. The first two scenarios explore a transition which is consistent with limiting global warming to below 2°C. The third scenario leads to severe physical risks. In the orderly scenario a significant amount of investment is needed to transition to a carbon-neutral economy but impacts from transition risk in the scenarios are relatively small (4% GDP loss by 2100). In a disorderly scenario, the impact would be 9% GDP loss in the same period. In the hot house world scenario, impacts from physical risk result in up to a 25% GDP loss by the end of the century. The transmission channels that connect climate risks to the economy and financial system were detailed as follows:

Figure 1

Transmission channels from climate risks to financial risks



Source: NGFS (2020c).

Boissinot and Samama (2018) understand that governments should seek to frame the climate change issue within a standard risk management approach, besides fostering financial innovation, supporting peer pressure/transfer of knowledge, and playing the role of catalysts. In this sense, the NGFS (2020c) provided a range of data on transition risks, physical risks and economic impacts, produced by a suite of models aligned and organized as Phase I. In Phase II, the NGFS will continue to work with academic partners to refine the scenarios and to expand the set of macroeconomic indicators. A summary of scenarios, related models, databases, outputs, and time horizon can be found in the following Figure 2.

Figure 2

Summary of the key aspects of NGFS Climate Scenarios - Phase I.

Comparison	Chronic climate impacts	Transition pathways
Scenarios[2]	**Orderly** (*Representative:* Immediate 2°C with CDR [GCAM]. *Alternate:* Immediate 2°C with limited CDR, Immediate 1.5°C with CDR) **Disorderly** (*Representative:* Delayed 2°C with limited CDR [REMIND]. *Alternate:* Delayed 1.5°C with limited CDR, Delayed 2°C with CDR) **Hot house world** (*Representative:* Current policies [MESSAGE]. *Alternate:* Nationally Determined Contributions)	
Models	Models participating in the ISIMIP project.[3]	3 Integrated Assessment Models (REMIND-MAGPIE 1.7-3.0, GCAM 5.2, MESSAGEix-GLOBIOM 1.0)
Database	ISIMIP	IIASA
Outputs	Chronic climate change impacts including temperature, precipitation, agricultural yields. GDP impacts calculated separately based on 3 damage functions	Energy demand,energy capacity, investment in energy energy prices, carbon price, emissions trajectories, temperature trajectories, agricultural variables, GDP
Time horizon	All variables are projected on incremental steps of 5 years, up to 2100	

Source: NGFS (2020c).

Also, on June 2020, NGFS published a guide to climate scenario analysis for central banks and supervisors (NGFS, 2020b). The guide provides practical advice on using scenario analysis to assess climate risks to the economy and financial system. Basically, the document proposes a four steps analysis: 1) Identify objectives, material risks and stakeholders; 2); Choose climate scenarios; 3) Assess economic and financial impacts and 4) Communicate and use results. For example, step one may include assessing risks to central bank's own balance sheet, focusing on credit and market risk analysis and stress testing. This would support managing risks to own operations and communicating exposures according to TCFD standard (the Financial Stability Board Task Force on Climate-related Financial Disclosures).

Still on the systemic perspective, a BIS (the Bank of International Settlements) and Banque de France (the French central bank) joint report classified the climate risk as a "green-swan" risk, which means it has the potential to cause extremely financially disruptive events which could start the next global financial crisis (Bolton et al., 2020). The authors go through methodological insights and challenges to identify and measure climate-related risks with scenario-based approaches.

An important study on climate change scenarios and its implications for strategic asset allocation was published by Mercer (2011) and addresses the investments impacts by asset classes and geographic regions. Examples of portfolio climate risk assessment tools are Mercer TRIP model and Sustainable Energy Investment Metrics (WWF et al., 2017). For carbon asset risk, a reference is the report issued by WRI and UNEP-FI (2015) to address all this environmental data and to incorporate them in the investment process.

The concept of environmental risk analysis contemplates tools and methodologies to integrate environmental data into the risk management and asset allocation processes. According to G20 GFSG (2017), environmental risk analysis contemplates risk identification (financial analysis of environmental factors), analysis (pricing and implications to investment portfolio) and management (actions to mitigate or transfer risks).

The inputs of an environmental risk analysis are physical and transition environmental risks, analyzed in different forward-looking scenarios, connected to specific metrics (e.g.: sudden stops, decrease in revenues, increase in costs, reduction in the present value of cash flows or dividends etc.) which are deployed in investment analysis. Thus, the outputs of an environmental risk analysis are estimated changes in the valuation of assets and portfolios under different scenarios (NGFS, 2020d).

Currently, to perform the environmental risk analysis is still a big challenge. The analysis involves the identification of environmental factors and the evaluation of the related direct or indirect risk exposure of the financial assets over time. These environmental risk factors must then be translated into quantitative measures of financial risk to support investment decisions on capital allocation. environmental risk analysis peculiarities across different asset classes that are usually invested withing the international reserves management are further detailed in Section 2.4, dedicated to the integration of the environmental risk analysis in the strategic asset allocation of the international reserves. As an example, transition scenarios may consider complex climate-economy models as IPCC (2014) or IEA (2016). Some environmental risk analysis tools already in use to manage the financial risks associated with environmental risk factors are detailed in Figure 3.

Figure 3

Summary of case studies on environmental risk analysis.

Environmental Risk Factor	Scenario Analysis	Financial Risk Tool	Results
Transition (impact of environmental regulation and carbon price)	Scenario analysis to assess the impact of carbon and energy regulation on margins of carbon intensive firms	ClimateXcellence model	Impact on company margin in terms of € cent per kWh
Transition (impact of carbon price linked to low-carbon scenario)	Analysis of impacts of transition risks on German electricity utilities	SOTP valuation methodology (DCF + EV/EBITDA)	Total and per share firm valuation
Transition (climate scenarios linked to various risk factors)	Examining the effect of transitions risks on SAA	Integrated assessment model incorporated in asset allocation investment model	Median additional annual returns to 2050
Physical (Climate Change)	Assessing physical effects of climate change on sovereign issuers	Consideration of climate change factors within Sovereign Rating Model	Assessment of susceptibility of sovereigns to climate change risks

Source: prepared by the authors, based on Bank of England et al. (2017).

Robins and McDaniels (2016) found that the spread of environmental risk analysis practice varies considerably across asset classes and may be very difficult to measure in certain sectors. In fact, the appropriateness of risk analysis tools and associated metrics primarily depend upon the asset classes and risk type exposure. For instance, fixed income investors may be most concerned with credit risk. In addition, especially for longer-dated securities, the impacts of environmental factors on future cash flow analysis requires more attention, including in rating decisions. Examples of environmental risk analysis at individual asset, portfolio and systemic levels are summarized in Figure 4:

Figure 4

Examples of environmental risk analysis at individual asset, portfolio and systemic levels

	Market risk		Credit risk		Financial system	Economy Wide
Analysis level	Asset	Portfolio	Asset	Portfolio	Systemic	Systemic
Environmental factor in focus	Transition: climate regulation and introduction of carbon price	Identify high-risk factor	Physical: cyclones and floods	Three scenarios of stricter regulation of air and water pollution	Identify key transition risk sectors	Physical risk: flooding in key coastal cities; Transition risk: global carbon pricing agreement
Financial risk metric	Reduced profit, DCF-based valuation	Relative performance against alternative portfolio	Impact on sovereign rating	Impact on the credit quality of commercial banks' portfolios	Total exposure of financial institutions	Effect of regulation and physical damages on financial market and GDP

Source: prepared by the authors, based on GFSG (2016) and Bank of England et al. (2017).

To sum up the information provided so far, Figure 1 well highlights the link between climate and financial risks; Figure 2 summarizes reference models, databases, outputs and time horizon related to climate scenarios; Figures 3 and 4 build a valuable framework with tools for assessing the exposure and measure risks stemming from environmental risks.

The integration of the above data into the strategic asset allocation may lead to a reallocation of investments among asset classes, or the inclusion of new ones, to reduce negative impacts of the analyzed environmental factors or to increase opportunities, in a risk/return analysis in the asset or portfolio level. Collinearity and diversification issues should be considered at portfolio level and woe across different risk profiles (credit, market, etc.). Further details are explored in Section 2.4.

The sovereign credit risk is particularly relevant for the management of international reserves due to the large share of sovereign bonds in the central bank's investment portfolios, as detailed in the next section. The Moody's Investor Service (2016) uses a methodology to capture the effects of physical climate change in a broad set of rating factors that influence a sovereign's ability and willingness to repay its obligations (principal and interest) linked to sovereign bonds. They monitor a series of climate trends and climate shock indicators which led to four primary transmission channels from physical climate change to sovereigns´ credit profiles. These four channels are: 1) impact on economic activity; 2) damage to infrastructure; 3) Social costs and 4) population migrations due to severe climate impacts in their homelands.

Battiston and Monasterolo (2019) developed a climate risk assessment methodology under uncertainty to price climate risk of sovereign bonds' portfolio. First, the authors estimated the change in green/brown energy sectors' market shares under forward-looking climate transition risk scenarios, using Integrated Assessment Models. Second, the authors modeled the shocks' transmission to specific sectors and integrated them in a climate enhanced financial pricing model for sovereign bonds. Third, the authors introduced climate in the calculation of the bonds spread considering specific country's debt conditions and the carbon-intensity of revenues. Finally, the authors assessed the largest losses (gains) on the Austrian National Bank's portfolio. The conclusion was that investments alignment to a credible 2C trajectory can strengthen the sovereign fiscal and financial position by decreasing the climate spread, while a misalignment to a 2C trajectory can increase it, with financial risk implications for its investors.

Institutional investors analyzed, evaluated, and tested state-of-the-art methodologies to enable climate scenario-based analysis of their portfolios in line with the recommendations of the TCFD- Task force on Climate-related Financial Disclosure (UNEP FI, 2019). The investors explored, enhanced and applied the Carbon Delta/MSCI methodology to road-test a 'Climate Value at Risk' (CVaR) for listed equities, corporate debt and real estate under several future scenarios. Inputs on strategic asset allocation decisions are further detailed in Section 2.4. Other relevant tools are also available, as PACTA and Transition Pathways Initiative- TPI (Portfolio Alignment Team, 2020).

Based on the concepts presented so far, the environmental risk analysis synthesis is comprised of the stages presented in Figure 5:

Figure 5

Environmental risk analysis framework from theory to praxis

ERA components:	Sub Components:	References:
1)Environmental risk factors:	Physical	Bank of England et al. (2017); Campiglio et al. (2018); CISL (2016); Dafe and Volz (2015); IPCC (2014); FTSE Russel (2019); Moody´s (2016); Scott et al. (2017); Volz (2017); WRI and UNEP-FI (2015).
	Transition	
2)Scenarios analysis:	Climate and other physical scenarios	Cahen-Fourot et al. (2021); Caldecott et al. (2014); CISL (2015); Lamperti et al. (2019); McKinsey (2020); Mercer (2011); NGFS (2020c); NGFS (2020b); TCFD (2017) and Scott et al. (2017).
	Regulation, carbon-market and other transition ones	
3) Risk assessment tools in each impact dimension:	Financial (business, market and credit)	Battiston and Monasterolo (2019); Bank of England (2020); Bank of England et al. (2017); Benedetti et al. (2019); Bolton et al. (2020); CISL (2016); CISL (2015); Dietz et al. (2016); G20 GFSG (2016, 2017); Moody´s (2016); NGFS (2020d); NGFS (2020a); UNEP-FI (2019); WWF (2017).
	Systemic	

Source: prepared by the authors.

2.3 The management of the international reserves

The objectives of international reserves management vary among central banks and among portfolios within the same investment manager. For some of them, the main objective is to hold liquid and safe FX assets for forex interventions within monetary policy tasks. For others, it is capital preservation as fiduciary duty. It can also be financial stability, through the management of a financial buffer for interventions in financial crises, among other strategies, as inflation management. According to the UBS Annual Reserve Manager Survey 2019, which collected responses over 30 international reserves managers, the primary investment objectives of international reserves management is capital preservation (74% of the answers), liquidity (52%), and return maximization (42%) and supporting monetary policy (6%). According to the survey, “several participants stressed that they consider return objectives to be important, but only as long as liquidity and capital preservation targets are fulfilled” (UBS, 2019, p. 17). On the liquidity side, 71% of the answers in the UBS survey indicated that central banks should not invest in illiquid asset classes such as real estate and infrastructure (UBS, 2018).

When asked about the investment instruments approved for international reserves management, 94% of respondents included Supranationals in their list, which was followed by

Sovereign Eurobonds (85%), US Agencies (85%), Inflation Protected Bonds (73%), Corporates (61%), Asset-Backed Securities (ABS)/ Mortgage-Backed Securities (MBS) (58%), Covered Bonds (45%), Banks Debt (45%), Emerging Market (36%), Equities (39%), Private Equity (18%) and Hedge Funds (15%) (UBS, 2019). What is common among international reserves managers is that reserves investments are oriented toward safe and liquid securities or other assets with low storage costs (i.e., precious metals). Most international reserves are invested in long-term fixed income securities from supranational issuers or highly-rated/investment grade governmental or government-related ones (Jones, 2018; McCauley & Rigaudy, 2011; UBS, 2018; Vecchio, 2009).

Indeed, most of the international reserves are primarily composed by US government debt, i.e. US Treasury bills (Jeanne, 2012; McCauley, 2019). The RMB is expected to become a leading reserve currency, on the level of USD and EUR today, according with 38% of over 30 central banks interviewed by UBS (2019).

The euro is currently the second most commonly held reserve currency, comprising about 20% of the global total (IMF, 2018). Besides the US dollar (USD) and euro, baskets of currencies called the Special Drawing Rights (SDR) are also present in international reserves portfolios. SDR are foreign-exchange reserve assets created by the International Monetary Fund. Since 2015, the SDR currency basket consists of five currencies: the US dollar (41.73%), the euro (30.93%), the Renminbi- Chinese yuan (10.92%), the Japanese yen (8.33%) and the British pound (8.09%) (IMF, 2019).

Other advanced country currencies usually considered by international reserves managers are the Swiss franc (CHF), the Australian dollar (AUD), the Canadian dollar (CAD), the New Zealand dollar (NZD), the Danish krone (DKK), the Norwegian krone (NOK) and the Swedish krona (SEK) (Morahan & Mulder, 2013).

The NGFS report about central banks’ portfolio management (2019b) divides the central bank´s investments in four typical portfolios, as detailed in the Figure 6. The international reserves would be mainly found in the policy portfolio but, depending on the central bank´s legal mandates, the third-party portfolio may also be the case (i.e., when the central bank manages international reserves on behalf of the government). An idea of the representativeness of each portfolio for the whole central banks community may be based on the status of the 40 respondents of the NGFS SRI portfolio management survey 2020 (NGFS, 2020e). In total, the surveyed central banks manage 82 portfolios: 29 policy portfolios, 11 pension portfolios, 18 third-party portfolios, and 24 own portfolios. The survey only included pension portfolios that are part of central banks’ balance sheets. This means central banks’ pension portfolios managed by an independent entity are not represented.

Figure 6

NGFS typical central bank portfolios and its characteristics

Characteristics	Policy portfolios	Own portfolios	Pension portfolios	Third-party portfolios
Dictated by	Policy goal – determined by central bank mandate.	Financial return goal – e.g. to help cover operating expenses.	Fiduciary duty – managed on behalf of beneficiaries.	Third-party mandate – managed on behalf of an external party.
Main objective	To support, implement and maintain confidence in monetary policy and currency management.	To generate returns within set risk tolerance levels. Secondary objective can be to gather market intelligence.	To provide for the retirement pension obligations of the central bank's employees.	Set by a third party. Varies, e.g. financial return, short-term liquidity provision or foreign exchange intervention.
Character	Assets meet high standards in terms of liquidity and credit quality in order to be able to absorb shocks in times of crisis or when access to borrowing is curtailed. Can be subject to market neutrality.	Subject to risk-return considerations. More freedom in investment decisions, but interference with monetary policy or currency management should be prevented.	Long term investment horizon in line with the pension liabilities. Short-term volatility is less of a concern.	Depends on main objective of funds. Cases where central bank manages foreign exchange reserves on behalf of the government.
Asset classes	Limited. Mostly (sub-) sovereigns, supranationals and agency (SSA) and some corporate/ covered bonds and equity.	Diverse. Mix between SSA, corporate/covered bonds and equity, and potentially private debt.	Diverse. Mix between SSA, corporate/covered bonds, equity, and private debt.	Diverse. Mainly SSA, followed by corporate/ covered bonds, and equity.
Duration	From short to medium term. From 3-6 years for majority. Less than 2 years for one-third of respondents.	Short term. Less than 2 years for majority.	Longer term. More than 6 years for two-thirds of the respondents.	Balanced. Varies from short term (0-2 years), medium term (3-6 years) and longer term (> 6 years).

Source: NGFS (2019b).

In crises, international reserves are fundamental to quickly mobilize funds in liquid portfolios, or even investment ones, to meet foreign currency needs of domestic banks or firms and to support the FX value of the domestic currency (McCauley & Rigaudy, 2011). The financial stability objectives are an important constraint to international reserves management, as well as to short-term liquidity needs and reputational concerns. Jones (2018) documented evidences which indicate procyclical behavior of the international reserves portfolio during the crisis. For the author, the evolution of related vulnerabilities justifies "cautious optimism and lingering concern" (p. 2). Special caution is necessary to synchronize investment practices among reserve managers and with other private sector investors.

Environmental factors will possibly be behind the next big crisis, as the one related to global warming, water, or biodiversity stress (details in Section 2.2). For this reason and for risk/return investment management purposes, environmental risk analysis should inform international reserves management process. The risk response management decision will lead the actions to align international reserves´ risk exposure with the central bank's risk tolerance, and/or to explore opportunities according to the central bank´s risk appetite. Among possible risk responses, reweighting in strategic asset allocation is an option, without necessarily implying any green investment strategy. Next section explores possible environmental risk analysis impacts in strategic asset allocation of the international reserves.

2.4 Environmental risk analysis in the management of the international reserves

2.4.1 Environmental risk analysis in the strategic asset allocation

The strategic asset allocation is an investment decision taken by asset owners to manage portfolio performance and risk over the long term. Each of the asset classes presents different risks and opportunities, demanding a multifaceted strategy across the total portfolio. In turn, the environmental risk analysis comprises a financial analysis of environmental factors, including pricing and implications to investment portfolio. Thus, environmental risk analysis allows an integration of environmental data into the risk management and asset allocation processes.

Traditional approaches to modelling strategic asset allocation fail to take account of environmental risk (e.g.: climate change) while relying mainly on quantitative historical data, which are not able to address key significant financial impacts associated to environmental factors, which required the addition of qualitative data and scenario analysis. This must be overcome, since more than 90% of the variation in portfolio returns over time is attributable to strategic asset allocation decisions (Campbell & Viceira, 2003). Also, as suggested by the "TIP™" framework, climate policy could contribute up to 10% to overall portfolio risk, besides other environmental factors (Mercer, 2011).

It is possible to incorporate environmental investment opportunities and mitigate risks through asset, region, sector and sub asset class allocation (PRI, 2019). Before that, the asset owners undertake scenario analysis and consider the impact of environmental risks and opportunities on expected risk, return and correlation assumptions. The result of this analysis may lead to the review of strategic asset allocation targets and ranges, including review of the opportunity set, widening the potential investment alternatives universe.

Top-down integration is highly recommended to incorporate environmental risk analysis into strategic asset allocation, instead of employing a case-by-case bottom-up approach to climate change and other environmental issues (Ortec Finance, 2020; WRI & UNEP-FI, 2015; WWF et al., 2017). In a climate guide to asset owners, WWF (2017) encourages the integration of investment beliefs and policies into strategic asset allocation, including a) the review of assumptions considering, for example, the risk of lower returns and higher volatility on high carbon assets; b) the measurement of estimated impacts and probabilities (e.g.: portfolio carbon footprint), with subsequent reduction in the risk exposure, or increase towards opportunities, within existing strategic asset allocation targets (e.g. review passive investments towards low carbon/environmental benchmarks; review investment priorities; engage with fund managers/companies and considering eventual change of asset managers; or even replace existing fund managers); c) the evolution of strategic asset allocation targets in time, following ERA outputs without undermining international reserves economic and investment objectives.

A practical example of top-down integration between environmental risk analysis and strategic asset allocation is the case study of Ortec Finance (Ortec Finance, 2020). They performed a climate scenario analysis from a top-down, systemic risk perspective. Macroeconomic consequences to physical and transition risks were estimated. These macroeconomic risk drivers affected risk-return expectations across all asset classes, regions, and sectors. This, in turn, provided relevant information to strategic asset allocation.

Also, according to Mercer (2011), the management of climate risks by investors includes the following pragmatic initial actions, including clear indication of changes in strategic asset allocation, but not only:

> introduce a climate risk assessment into ongoing strategic reviews; increase asset allocation to climate-sensitive assets as a climate "hedge"; use sustainability themed indices in passive portfolios; encourage fund managers to proactively consider and manage climate risks; and engage with companies to request improved disclosure on climate risks. It also highlights the need for investors to communicate with policymakers the need for a clear, credible, and internationally coordinated policy response and for dialogue to emphasize the potential economic and financial cost of delay. While many institutional investors might view engagement with policymakers as a separate function from strategic decision-making processes, the findings of this study suggest that it can play a vital role in overall portfolio risk management. (p. 2)

On top of the strategic asset allocation practical indications, the above guidance underscores that SRI strategies, as engagement, are crucial for portfolio risk management, thus relevant also in a risk-return investment perspective, not only in a positive impact one.

Also, Mercer strategic asset allocation updated approach (2015), based on environmental risk analysis, provided investors with an insight to potential impacts on return distribution expectations for the strategic asset allocation, enabling them to examine the implications of different climate scenarios in the context of their current asset allocation, and consider resulting actions and opportunities. The report indicates that climate change "will inevitably have an impact on investment returns, so investors need to view it as a new return variable" (p. 10). Industry sector impacts will be the most significant (e.g.: the energy one, with expressive losses in coal and gains in renewables), so climate-sensitive industry sectors should be the primary focus of investors. Asset class return impacts could also be material:

> For example, a 2°C scenario could see return benefits for emerging market equities, infrastructure, real estate, timber and agriculture. A 4°C scenario could negatively impact emerging market equities, real estate, timber and agriculture. Growth assets are more sensitive to climate risks than defensive assets. (p. 7)

The above information is also relevant considering other economic objectives of international reserves management, especially for some central banks with significant volume of international reserves under management and highly impacted in the analyzed scenarios.

In a risk/return analysis in the asset or portfolio level, collinearity and diversification issues should be taken into consideration at portfolio level and across different risk profiles to reduce negative impacts of the analyzed environmental factors or to increase opportunities. The integration of environmental risk analysis into the strategic asset allocation process may lead to a rebalance of investments among asset classes.

According to the PRI (2019), environmental factors can be embedded within the traditional strategic asset allocation approaches, which are Mean-variance optimization (MVO), Factor risk allocation, Total Portfolio Analysis, Dynamic asset allocation, Liability driven asset allocation and Regime Switching Models. The PRI report, after analyzing the outputs to reflect environmental issues for each strategic asset allocation approach, suggests a framework largely based on a traditional MVO. Notwithstanding, the extreme limitations of MVO and factor risk allocation in the context of a systemic risk must be considered. For Lydenberg (2016), one clear limitation is that by focusing on risks and rewards at the portfolio level only, the traditional strategic asset allocation approaches, within the Modern Portfolio Theory (MPT), fails to consider risks and rewards at a systemic level that takes into account environmental risk analysis.

As stated by Bose et al. (2019), despite MPT has facilitated essential aspects of asset owner's work, there are relevant limitations to be considered, "particularly its very limited portrayal of the nature of risk and the tendency to forget the interdependence of portfolio choice and systemic outcomes" (p. 246). For Bose, it is valuable the view that ESG (including environmental factors) investing could involve selecting positive impact securities and selling negative impact securities, generating ESG (including green) alpha from such security selection. Notwithstanding, it is challenging to implement for largest asset owners, as central banks, given their scale.

UNEP-FI investors pilot group members had a different understanding about scenario analysis methodologies informing strategic asset allocation decisions. For them, scenarios should not inform strategic asset allocation in the present, but maybe in the future with more reliable information (UNEP FI, 2019, p. 117).

It is critical to each central bank to assess the level of reliability required for environmental risk analysis outputs as a strategic asset allocation input, considering the economic objective of the reserves. One can then decide to calibrate which asset class is best suited to the investment pillars (safety, liquidity, return or even sustainability) given the objective of each portfolio and each central bank, in the management of the international reserves (Fender et al., 2019).

2.4.2 Environmental risk analysis and socially responsible investing in the management of the international reserves

Reports of the NGFS and NGFS members were reviewed and we´ve found no specific indication of environmental risk analysis as input on strategic asset allocation of the international reserves (Bank of England, 2020; Banque de France, 2020; NGFS, 2019b, 2020e, 2020d, 2020a). These reports provide us information about strategic asset allocation impacts on investment portfolios in different scopes, with shadow areas with the focus of this study, as detailed as follow.

Some strategic asset allocation impacts are related to SRI strategies in policy/international reserves portfolios, which include ESG financial (risk/return) and non-financial (positive impact) objectives (NGFS, 2020e). Environmental risk analysis may be part of it, as a financial input on the Environmental risk management process, which in turn is an input on the strategic asset allocation process. “Protecting portfolios against sustainability risks” and “Enhancing risk/return profile” are among the four main reasons why central banks adopt SRI investment strategies, alongside with “mitigate reputational risk” and “to set a good example” (NGFS, 2020e, p. 9).

The reports also provided information about the carbon-footprint of the investment portfolios related to policy purposes. This is related to the climate risk analysis, what is part of the environmental risk analysis scope besides other environmental factors (Bank of England, 2020). However, international reserves management and the policy portfolios are not representative in the total investments of the most prominent central banks in the worldwide environmental discussion so far (e.g.: BoE- British central bank, Banque de France and DNB-Dutch central bank).

Strategic asset allocation is one of the possible elements of an ESG integration investment strategy (CFA UK, 2020b). In policy portfolios, there is indication that ESG integration, including financially material ESG-criteria in the investment analysis to improve the risk-return profile of the portfolio, was considered for Sovereigns, Supranationals and Agencies (SSA) bonds by four central banks, for corporate bonds by two central banks and for equities by one central bank (NGFS, 2020e).

The most prominent sustainable investment strategies adopted by central banks are green bond investments, negative screening and ESG integration (NGFS, 2020e), which give us some information about strategic asset allocation, but not necessarily a consequence of an environmental risk analysis. The NGFS survey also indicates that many central banks hold green SSA, corporate and covered bonds in their policy portfolios. Thus, it is not clear if the investment strategy of holding these green bonds is a result of a risk/return analysis, including environmental risk analysis. Impact investment could be a reason, but it does not appear in the survey as a relevant investment strategy.

Negative screening was implemented in policy portfolios for corporate bonds (9 central banks), SSA and equities (by 6 central banks, each), and covered bonds (3 central banks). On the other hand, best-in-class strategy was only applicable within the policy portfolios by 2 central banks for corporate bonds and 1 central bank for equities (NGFS, 2020e).

Towards non-financial investment objectives, Banque de France significantly modified its strategic asset allocation by deciding that the investment in dedicated funds should prioritize unlisted funds, as they offer a more direct way to finance the energy and ecological transition. Previously, its strategic asset allocation included only listed asset classes. The decision was a result of Banque de France´ SRI strategy, which is organized around three pillars: 1) align investments with France's climate commitments; 2) include ESG criteria in asset management; and 3) exercise its right to vote and influence issuers. This strategic asset allocation change is not necessarily aligned with environmental risk analysis and this information was not specifically provided (NGFS, 2019b, 2020e).

Furthermore, the DNB signed the Principles of Responsible Investment (PRI)[1] for foreign exchange reserves and its own portfolios. The DNB applies four key SRI strategies for international reserves management: 1) exclusion of controversial weapons; 2) screening on the basis of the UN Global Compact Principles; 3) ESG integration in investment decisions; 4) voting and engagement (NGFS, 2019b). The SRI strategies have possible strategic asset

[1] PRI is the world's leading proponent of responsible investment. The PRI signatories are committed to six principles that offer a menu of possible actions for incorporating ESG issues into investment practice.

allocation implications aligned with positive impact investment objectives, but not necessarily connected to environmental risk analysis. However, DNB performed a climate stress test on its own balance sheet, based on the methodological framework developed for supervisory purposes by its Financial Stability (FS) department (NGFS, 2020e).

On top of that, the Swedish central bank divested from bonds issued by the Canadian province of Alberta and the Australian states of Queensland and Western Australia due to the large climate footprint of these issuers (Sveriges Riksbank, 2019). The main motivation behind the speech of the Bank´s Deputy Governor was a positive impact action, but this does not jeopardize eventual environmental risk analysis considerations. As demonstrated by Battiston and Monasterolo (2019), sovereign bonds' portfolio alignment to a credible 2C trajectory can strengthen the sovereign fiscal and financial position by decreasing the climate spread, while a misalignment to a 2°C trajectory can increase it, with financial risk implications for its investors.

In parallel, a recent BIS survey focused on ESG investing practices by central banks (Fender et al., 2019), what give us some insights towards international reserves management but not necessarily related to the risk/return investment perspective. According to this survey answered by 67 central banks, 62,7% of the respondents do not include sustainability considerations in the pursuit of its policy objectives (related to one of the four types of portfolios managed by central banks, as stated by NGFS). However, 62,7% think there is scope to include sustainability as a reserve management objective. Additionally, according to UBS (2018), 36% of international reserves managers do not consider sustainable and responsible investment aspects in the international reserves' investment process, while 32% considered but have not implemented yet, 27% consider but only use exclusion criteria, and 5% consider and allocate certain assets accordingly.

In this point, Jones (2018) understood that the ESG concerns are not applicable for international reserves managers. This information was presented in a taxonomy proposal of constraints to international reserves management, but the reasons for this conclusion were not discussed. This understanding contradicts with the other studies detailed in the previous sections of this paper. According to the others, the ESG factors may represent physical and transition relevant financial risks, thus applicable to international reserves management.

According to Fender et al. (2019), "green bonds may not be eligible for the liquidity or working capital tranches of central banks' reserve portfolios" (…) because "bid-ask term structures suggest that green bonds tend to be more costly to buy and sell, trading with wider spreads than their conventional counterparts" (p. 56), with similar results across the entire market. However, despite the liquidity concern, overall "sustainability objectives can be integrated into reserve management frameworks without forgoing safety and return" (p. 62). For the authors, the integration of sustainability into reserves management by central banks involve "additional trade-offs, turning the classical triad of liquidity, safety and return into a tetrad of reserve management objectives" (p. 61), including the sustainability factor. Further, the results of an illustrative portfolio construction exercise, performed by the authors, "suggest that adding both green and conventional bonds can help generate diversification benefits and, hence, improve the risk-adjusted returns of traditional government bond portfolios" (p. 62).

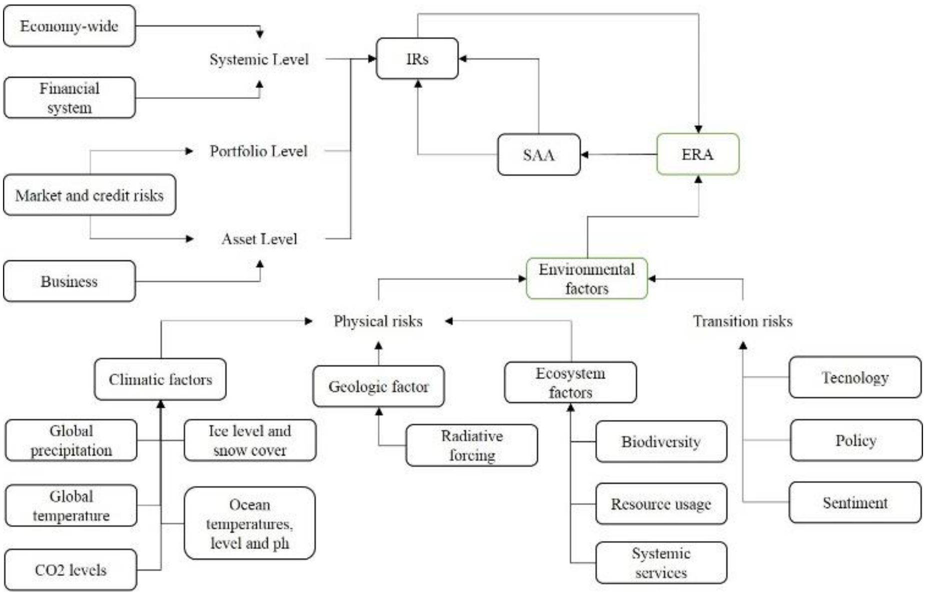
For investment in Green Bonds, a notorious alternative for central banks to consider in international reserves management is the BISIP Green Bond fund (Bank for International Settlements, 2019). It is an open-ended fixed income fund for central bank investments in green bonds, denominated in USD and managed in-house by BIS Asset Management. Eligible bonds have a minimum rating of A- and comply with the International Capital Market Association's Green Bond Principles and/or the Climate Bond Standard, from Climate Bonds Initiative.

Finally, as well-stated by Volz et al. (2020), central banks "need to understand their exposures to other countries' sovereign risks arising from climate change if they hold those countries' government bonds" (p. 40). Thus, environmental risk analysis is critical to strategic asset allocation of international reserves, since international reserves are mainly invested in SSA bonds which are highly exposed to sovereign risks, which in turn are highly impacted by climatic and other environmental factors.

Building off the concepts presented so far, the concept map for this study was constructed as follows:

Figure 7

Concept map



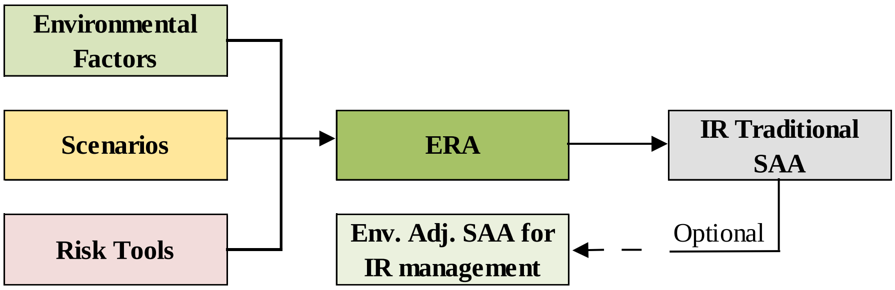
Source: prepared by the authors based on the theoretical references detailed above.

2.5 The multicriteria analytical framework.

The environmental risks (Section 2.2) to which the international reserves (Section 2.3) are exposed need to be assessed and quantified to enable a proper risk management process, including eventual changes in the strategic asset allocation (Section 2.4) to allow the achievement of central bank´s objectives. For this purpose, a multicriteria analytical framework was developed for the evaluation of these environmental risks, incorporation in the risk management process with outputs to the international reserves´ strategic asset allocation, as outlined in Figure 8:

Figure 8

Multicriteria analytical framework for environmental risk analysis and strategic asset allocation of international reserves



Source: prepared by the authors based on the references of this study.

The environmental risk analysis (Figure 9) is based on scenarios analysis to support the assessment of the environmental risk factors and the evolution in time of the associated environmental risk events and trends. The environmental risk factors include both physical and transition risks. The physical risks include the climatic, geologic and ecosystem factors, such as: global temperature; global precipitation; ice level and snow cover; ocean temperature, level, and pH; CO2 levels; radiative forcing; biodiversity; systemic services and resource usage. The transition risks include the policy aspects, such as green economy regulations; the technological factors, such as clean energy technology innovation, and changes in the public's and investors' sentiment towards a sustainable future.

Based on the analysis of environmental risk factors and scenarios, the environmental risk analysis evolves to the subsequent analysis of the impacts on financial portfolios, including the financial risks and systemic risks. The financial risks are considered in the following dimensions: business, market and credit. The systemic risks include the financial system and the economy-wide risks.

Measures for assessment value and risks include: operational Value-at-Risk (OpVar); discounted cash Flow (DCF) valuation; relative value and performance; Value at Risk (VaR);

portfolio value under various scenarios; credit rating; expected loss; rating level for industry; rating for securitized assets; financial firm exposure, size and concentration; system-wide losses on different scenarios; impact on GDP, consumption and financial conditions (scenarios, macro models and model-based risk assessment- MBRA); among others.

The **Multicriteria analytical framework** for the incorporation of the **environmental risk analysis in the strategic asset allocation of the international reserves**, is detailed in the following Figures **9 to 12**:

Figure 9

Environmental Risk Analysis (ERA)

RISK IDENTIFICATION

Analysis of environmental factors in time and related financial risk metrics.

1) Environmental factors:			**3) Measures for assessment value and risks in each impact dimension:**				
			Financial:			**Systemic:**	
			Business:	**Market:**	**Credit:**	**Financial System:**	**Economy-wide:**
Physical: **Climatic** **Geologic** **Ecosystem** **Transition:** **Policy** **Technology** **Sentiment**	**2) Assessment of environmen-tal risk in time (events and trends), based on stress testing, scenario analysis or other tehnique.**	**Risk metrics (e.g: decline in revenues; increase in costs)**	**Asset level: OpVaR.**	**Asset level: Discounted Cash Flow (DCF) valuation; relative performance. Portfolio level: VaR; portfolio value under various scenarios.**	**Asset level: credit rating; expected loss; DCF valuation. Portfolio level: expected loss; rating level for industry; rating for securitized assets.**	**Financial firm´s exposure, size and concentration; system-wide losses on different scenarios.**	**Impact on GDP, consumption, financial conditions (scenarios, macro models and MBRA).**

RISK ANALYSIS: EXPOSURE AND ASSESSMENT OF IMPACTS AND PROBABILITIES

Translating env. factors into measured financial risks (e.g.: transmission channels; general picture of scale and scope; proxies; stress testing, scenario analysis, portfolio and probabilistic modelling etc.)

Source: adjusted by the authors based on the references from this study, mainly Bank of England et al. (2017).

The output of environmental risk analysis (Figure 9) may provide new information to the international reserve's traditional strategic asset allocation framework (Figure 10). **It will be considered alongside international reserves´ economic objectives and international reserves´ investment guidelines. Thus, environmental risk analysis output will be incorporated on top of other main concerns of the international reserves managers**, since environmental risk management is not the primary concern of the international reserves managers, which is to adequately address the reasons which motivate the international reserves existence (which may vary from one central bank to another).

Hence, the environmental risk exposure will be considered jointly with the concerns on currency, asset type, countercyclicality (for crisis mitigation) and relevance of each of the three international reserves´ investment pillars: security, liquidity, and profitability. The relevance of each of the investment pillars depends on the strategic objectives of each international reserves manager, which ultimately reflect the reasons for which the reserves are being maintained. For example, SWFs can prioritize profitability to the detriment of liquidity, while emerging countries may need to give more weight to liquidity and security. This also depends on the objective of each specific portfolio, given that the same investor can prioritize different pillars in different portfolios.

The international reserves traditional strategic asset allocation framework, as explained above, is detailed in Figure 10:

Figure 10

International reserves traditional strategic asset allocation framework

IR economic objectives (Fender et al, 2019)	**Investment Guidelines**	**Three pillars of investment:**	**IRs focus (main exposure):**	**SAA model approaches:**	**Concern for crises mitigation:**
Intervention in the FX markets; Execution of payments for goods and services; Execution of payments for the government; Granting of emergency liquidity assistance; Support of domestic monetary policy; Underpinning of investor confidence in the country; Investment of excess reserves.	Investment Policy; Investment Strategy; Investment Driver; Investment Objectives	**Profitability** **Liquidity** **Security**	**Asset:** mainly Treasury Bonds, Supranationals, Sovereign Eurobonds, US Agencies, Inflation Protected Bonds, Corporates, MBS/ABS, Covered Bonds and Banks Debt. **Currency:** mainly USD, EUR, CNY, JPY, GBP.	Mean-variance optimization (MVO), Factor risk allocation, Total Portfolio Analysis, Dynamic asset allocation, Liability driven asset allocation and Regime Switching Models.	Countercyclicality

Source: prepared by the authors based on the references of this study, mainly Fender et al. (2019) and IMF (2001).

Based on the analysis of the environmental risk analysis outputs considered in the traditional international reserve's strategic asset allocation framework, central banks can evaluate the adequacy to adjust the **framework to include the environmental factor as a fourth pillar of international reserves management objectives, what may possibly generate diversification benefits and improve the risk-adjusted returns**.

Figure 11

Environmentally adjusted strategic asset allocation framework for international reserves management

IR economic objectives (Fender et al, 2019)	**Investment Guidelines**	**Four pillars of investment:**	**IRs focus (main exposure):**	**SAA model approaches:**	**Concern for crises mitigation:**
Intervention in the FX markets; Execution of payments for goods and services; Execution of payments for the government; Granting of emergency liquidity assistance; Support of domestic monetary policy; Underpinning of investor confidence in the country; Investment of excess reserves	Investment Policy; Investment Strategy; Investment Driver; Investment Objectives	**Enviromental Sustainability** **Profitability** **Liquidity** **Security**	**Asset:** mainly Treasury Bonds, Supranationals, Sovereign Eurobonds, US Agencies, Inflation Protected Bonds, Corporates, MBS/ABS, Covered Bonds, Banks Debt and Green Bonds. **Currency:** mainly USD, EUR, CNY, JPY, GBP.	Mean-variance optimization (MVO), Factor risk allocation, Total Portfolio Analysis, Dynamic asset allocation, Liability driven asset allocation and Regime Switching	Countercyclicality

Source: prepared by the authors based on the references of this study, highlighting Fender et al. (2019).

In the above context, environmental risk and opportunities are considered without undermining other central bank´s perspectives. To better clarify, environmental risk analysis is to quantify the financial risk exposure related to environmental factors of international reserves´ assets and portfolios. Strategic asset allocation is to identify the best risk/return profile for international reserves allocation according to international reserves objectives (liquidity, safety, return). The environmental risk analysis output as an input on the strategic asset allocation puts together financial and environmental risks assessment in order to provide an asset allocation for international reserves, which is sound from the two risk viewpoints. The decision is supported by central bank´s risk tolerance and appetite.

Traditional strategic asset allocation is adjusted to incorporate environmental considerations alongside traditional international reserves´ investment guidance, as asset classes, currencies, issuers, regions/countries, asset maturity, liquidity (bid-ask spread, turnover) and market depth (outstanding). On top of that specific environmental variables would be included to achieve an efficient investment portfolio, which may require a multi-objective optimization (this point is explored in more details in a second study of these authors, focused on the positive impact perspective). **This investment guidance may direct the partial allocation of the international reserves in green assets or indicate a rebalancing among**

existing assets. Thus, environmental risk analysis could measure risks and contribute to reweighting in strategic asset allocation without necessarily implying any green strategy.

To sum up, practical possible environmental risk analysis impacts on international reserves´ strategic asset allocation are demonstrated in Figure 12.

Figure 12

Practical possible environmental risk analysis impacts on international reserves´ strategic asset allocation.

1) Inclusion of new asset alternatives:
   1.1) Inclusion of Green Asset Classes (eg: Green Bonds, Green Funds, Green Indexes in passive portfolios etc);
   1.2) Inclusion of other asset alternatives, as unlisted funds, if appropriate for the enviromentally adjusted SAA model;
2) Rebalance among exiting asset classes, regions/countries, sectors and sub asset classes:
   2.1) Divestments from high carbon footprint and/or high temperature alternatives;
   2.2) Investments to explore opportunities towards lower carbon footprint and/or lower temperature
3) Inclusion of enviromental risk management considerations in the selection of asset managers, fund managers and companies.

Source: prepared by the authors based on BoE (2020); BdF (2020); Sveriges Riksbank (2019); PRI (2019); BIS (2019); WWF (2017); Mercer (2011).

The environmental risk analysis (Figure 9) allows the identification of the main concepts, relationships, and tools to be considered by the central banks. On top of it, **the multicriteria analytical framework supports the inclusion of the environmental risk analysis outputs in the strategic asset allocation analysis of the international reserves by the central banks** (Figures 10 to 12).

A short example of how applying the framework is discussed here. Consider a developing country that imports oil. The central bank of this country performs a traditional strategic asset allocation and decides to invest in Government Bonds, Agencies and Supranationals in an asset/liability management approach. Furthermore, consider also that the central bank decides to have a small amount of international reserves invested in assets that are positively correlated to the oil prices, in order to hedge its exposure to the commodity. An environmental risk analysis should consider the transition effects related to climate change and technology, which may imply in stranded assets in the Oil & Gas (O&G) sector with appreciation of the clean energy investment alternatives. In this case, the environmental risk analysis may show that the real exposure to the country is energy instead of oil asset prices, or even sovereign or systemic exposure. Hence, the country may benefit more from investing in green energy than in oil, or even from splitting investments in both energy sources as a way of diversifying investments. Also, in some scenarios some sovereign assets may be revalued, as well as some green ones. Of course, the discussion is not that simple, and this example helps only to understand the application of the framework discussed here.

A specific exercise could be done with Brazil, as case study. Brazilian international reserves totaled US$356.89 billion in 2019, representing 19% of the national GDP and 160% of total annual merchandise exports. Food and agriculture represented 40% of exports and fuel accounted for other 14% (11% crude oil). According to the Assessing Reserve Adequacy (ARA) metrics of the International Monetary Fund (IMF, 2020), 5% of total exports should be covered by international reserves assets allocated to hedge sudden stops in capital flows. In the Brazilian case, this would account for US$11.13 billion. Thus, 40% hedge for food & agriculture on total exports would accounts for US$4.44 billion and 14% hedge for fuel on total exports totaling US$1,53 billion. Environmental risks have a direct impact on exports, capital flows and, in this perspective, indirect impact on international reserves, considering the economic objectives of execution of payments, besides intervention in forex markets. In an environmental risk analysis for the strategic asset allocation of the international reserves, the environmental factors would be mainly food & agriculture and energy. Figure 13 shows details of this exercise.

The relevant scenarios may contemplate “climate change transition risk" and "climate change physical risk". The related environmental risks, with financial percentage impacts in some specific time horizons could be “increased CO2 emission cost” as well as “crop break due to physical climate impacts”. Some expected asset price movements due to the crises scenarios would reduce country exports and would have an impact in the foreign exchange rate.

The strategic asset allocation exercise may consider portfolios for the investment of the international reserves that are more resilient to these scenarios.

The strategic asset allocation should drive the choice of currencies in the portfolio to those currencies that are less correlated to the Brazilian Real in the relevant scenarios, in order to avoid procyclicality. The environmental risk analysis helps to quantify the size of the impact in the economy and the dimension of this impact in the international reserves' investments. Furthermore, the choice of asset classes should consider those related to clean energy and eco-friendly agriculture. The choice of currency is easier in a traditional perspective. Just as an example. On the other hand, the choice of asset classes is more difficult due to liquidity issues, since green asset classes eligible to central banks are traditionally agencies, supranational and some sovereign issuers. However, it would be possible to search for small amounts of investments on these kind of asset classes.

Figure 13

Environmental risk analysis- Strategic asset allocation: practical exercise

CB from Latin America (Brazil):		**US$ billion in 2019**
IR		356.89
GDP		1,839.80
% IRs/GDP		19%
Total merchandise exports		222.64
% IRs/Exports		160%
	Food & agriculture raw material exports	88.83
	% food & agriculture on total exports	40%
	Fuel exports	30.50
	% fuel on total exports	14%
Total merchandise imports		184.10
% IRs/Imports		194%
	Food & agriculture raw material imports	12.70
	% food & agriculture on total imports	7%
	Fuel imports	25.96
	% fuel on total imports	14%
% IR assets allocated to hedge sudden stops in capital flows (ARA IMF- exports)		**5%**
Total IR assets allocated to hedge of the external liabilities		11.13
	40% hedge for food & agriculture on total exports	4.44
	14% hedge for fuel on total exports	1.53

⇩

Environmental risk analysis-strategic asset allocation integration

Environmental factors: climate transition (CO2 emissions) + climate physical impacts (temperature and precipitation, with extreme events)
Economic sectors: energy + food & agriculture
Scenarios: NGFS Climate Scenarios for central banks and supervisors (2020)

⇩

Environmental risks with financial impacts: "increased CO2 emission cost" and "crop break due to physical climate impacts”

⇩

Possible related asset price movements: stranded-assets in the O&G sector; appreciation of clean energy assets; decrease non-regenerative agriculture average asset prices; increase biodiversity conservation asset-related prices; exports and foreign exchange rate impacts etc

⇩

Strategic asset allocation: hedge to environmental risk analysis-related asset price movements, considering also other traditional strategic asset allocation relevant data (e.g.: international reserves economic objectives; investment guidelines and investment pillars)

⇩

Migrate to assets less correlated with agricultural and oil commodities (example of relevant scenario to be mitigated)

Source: prepared by the authors.

2.6 Conclusions

This study discussed the environmental risk exposure of international reserves and developed a multicriteria analytical framework to consider environmental risk in the strategic asset allocation by central banks. The study is relevant to the construction of the investment portfolio of the international reserves because of the different angles that must be considered in the allocation among countries and instruments.

The main argument is that environmental risk analysis should be included in the traditional approach for strategic asset allocation by central banks due to the relevance of environmental risks to which the international reserves are exposed. Therefore, each viable portfolio should also be evaluated based on an environment risk analysis. This environment risk analysis should consider scenarios of environment risks along probabilities and potential impacts. The risk and return relationships of the portfolios in each scenario should be evaluated based on the factors discussed in this paper. In addition to traditional international reserves objectives, like hedging liabilities and evaluating countercyclicality to market movements, the central banks should also take environment risk into account.

This study only addresses the Environmental aspects of the ESG factors. Also, this research focus is the environmental and financial risk management, not the non-financial investment objectives as “to create a positive impact on the environment and society alongside financial returns” (NGFS, 2019b, p. 6). Further studies could focus on Social and Governance factors, as well as on the non-financial investment objectives under an international reserves management perspective.

2.7 References

Aizenman, J., & Marion, N. (2002). International Reserve Holdings with Sovereign Risk and Costly Tax Collection. *NBER WORKING PAPER SERIES INTERNATIONAL*, *Setember*(Working Paper 9154). https://www.nber.org/system/files/working_papers/w9154/w9154.pdf

Allen, M., Rosenberg, C., Keller, C., Setser, B., & Roubini, N. (2002). A Balance Sheet Approach to Financial Crisis. *A Balance Sheet Approach to Financial Crisis*, *02*(210), 1–63. https://doi.org/10.5089/9781451957150.001.a001

Andersson, M., Bolton, P., & Samama, F. (2016). Hedging climate risk. *Financial Analysts Journal*, *72*(3), 13–32. https://doi.org/10.2469/faj.v72.n3.4

Bank for International Settlements. (2019). *BIS launches green bond fund for central banks*. https://www.bis.org/press/p190926.htm

Bank of England. (2020). The Bank of England's climate-related financial disclosure 2020. In *Climate Change*. https://www.bankofengland.co.uk/prudential-regulation/publication/2020/climate-related-financial-disclosure-2019-20

Bank of England, UNEP Enquiry, & CISL. (2017). *Enhancing Environmental Risk Assessment in Financial Decision-Making* (Issue July). https://www.tcfdhub.org/resource/enhancing-environmental-risk-assessment-into-financial-decision-making/

Banque de France. (2020). *Responsible Investment Report 2019*. https://www.banque-france.fr/en/banque-de-france/corporate-social-responsibility/economic-and-civic-commitment/contributing-responsible-investment

Battiston, S., & Monasterolo, I. (2019). A Climate Risk Assessment of Sovereign Bonds' Portfolio. *SSRN Electronic Journal*, 1–27. https://doi.org/10.2139/ssrn.3376218

Benedetti, D., Biffis, E., Chatzimichalakis, F., Fedele, L. L., & Simm, I. (2019). Climate change investment risk: optimal portfolio construction ahead of the transition to a lower-carbon economy. *Annals of Operations Research (2021)*, *299*(1–2), 847–871. https://doi.org/10.1007/s10479-019-03458-x

Boissinot, J., & Samama, F. (2018). Climate Change: Policy-Making Case Study of Capital Markets’ Mobilization for Public Good. In R. Arezki, P. Bolton, K. Aynaoui, & M. Obstfeld (Eds.), *Coping with the Climate Crisis: Mitigation Policies and Global Coordination* (pp. 179–200). Columbia University Press. https://doi.org/10.7312/arez18756.17

Bolton, P., Despres, M., Pereira da Silva, L. A., Svartzman, R., & Samama, F. . (2020). *The green swan - Central banking and financial stability in the age of climate change* (Issue January). Bank for International Settlements (BIS). https://www.bis.org/publ/othp31.pdf

Bose, S., Dong, G., & Simpson, A. (2019). Sustainable Investing and Asset Allocation at Global Scale. In *Palgrave Studies in Impact Finance, in: The Financial Ecosystem* (pp. 225–251). Palgrave Macmillan. https://doi.org/10.1007/978-3-030-05624-7

Cahen-Fourot, L., Campiglio, E., Godin, A., Kemp-Benedict, E., & Trsek, S. (2021). Capital stranding cascades: The impact of decarbonisation on productive asset utilisation. *Energy Economics*, *103*, 105581. https://doi.org/10.1016/j.eneco.2021.105581

Caldecott, B., Tilbury, J., & Carey, C. (2014). Stranded Assets and Scenarios. In *Discussion Paper* (Issue January). https://www.smithschool.ox.ac.uk/research/sustainable-finance/publications/Stranded-Assets-and-Scenarios-Discussion-Paper.pdf

Calvo, G. A., Izquierdo, A., & Loo-kung, R. (2012). Optimal Holdings of International Reserves: Self-Insurance Against Sudden Stop. *NBER WORKING PAPER SERIES*, *July*(No. 18219), 1–35. https://doi.org/10.3386/W18219

Cambridge Centre for Sustainable Finance. (2016). *Environmental risk analysis by financial institutions – a review of global practice* (Issue September).

https://www.cisl.cam.ac.uk/system/files/documents/environmental-risk-analysis.pdf

Campbell, J. Y., & Viceira, L. M. (2003). Strategic Asset Allocation: Portfolio Choice for Long-Term Investors. *The Economic Journal*, *113*(488), F408–F409. https://doi.org/10.1093/0198296940.001.0001

Campiglio, E., Dafermos, Y., Monnin, P., Ryan-Collins, J., Schotten, G., & Tanaka, M. (2018). Climate change challenges for central banks and financial regulators. *Nature Climate Change*, *8*(6), 462–468. https://doi.org/10.1038/s41558-018-0175-0

CFA UK. (2020a). Curriculum - Chapter 1. In *Certificate in ESG Investing*. CFA Society UK.

CFA UK. (2020b). Curriculum - Chapter 7. In *Certificate in ESG Investing*. CFA Society UK.

CISL. (2015). *Unhedgeable risk: How climate change sentiment impacts investment*. https://www.cisl.cam.ac.uk/resources/sustainable-finance-publications/unhedgeable-risk

Dafe, F., & Volz, U. (2015). Financing Global Development: The Role of Central Banks. In *SSRN Electronic Journal* (Vol. 8). https://doi.org/10.2139/ssrn.2797226

Detragiache, E. (1996). Fiscal Adjustment and Official Reserves in Sovereign Debt Negotiations. *Economica*, *63*(249), 81–95. https://doi.org/10.2307/2554635

Dietz, S., Bowen, A., Dixon, C., & Gradwell, P. (2016). Climate value at risk' of global financial assets. *Nature Climate Change*, *6*(7), 676–679. https://doi.org/10.1038/nclimate2972

Faiella, I., Bernardini, E., Poli, R., & Giampaolo, J. Di. (2018). The impact of carbon risk on stock returns: Evidence from the European electric utilities. *Project: Climate-Related Financial Risk in Italy*. https://doi.org/10.13140/RG.2.2.29932.00641

Fender, I., McMorrow, M., Sahakyan, V., & Zulaica, O. (2019). Green Bonds: The Reserve Management Perspective. *BIS Quarterly Review*, *September*, 49–63.

FTSE Russel, Lorans, T., & Moussavi, J. (2019). How could climate change impact sovereign risk? *FTSE Russel*, *Market Nav*(November), 1–11. https://www.ftserussell.com/research/how-could-climate-change-impact-sovereign-risk

G20 Green Finance Study Group. (2016). G20 Green Finance Synthesis Report 2016. *UN Environment*, *July*. http://www.g20.utoronto.ca/2016/green-finance-synthesis.pdf

G20 Green Finance Study Group. (2017). G20 Green Finance Synthesis Report 2017. *UN Environment*, *July*. https://www.bundesfinanzministerium.de/Content/EN/Standardartikel/Topics/world/G7-G20/G20-Documents/Hamburg_reports-mentioned/G20-Green-Finance-Synthesis-Report.pdf

Hawkins, R. G., & Rangarajan, C. (1970). On the Distribution of New International Reserves. *The Journal of Finance*, *25*(4), 881–891. https://doi.org/10.2307/2325423

IEA. (2016). *World Energy Outlook 2016* (Issue 4). https://www.iea.org/reports/world-energy-outlook-2016

International Monetary Fund. (2001). *Guidelines for Foreign Exchange Reserve Management*. https://www.imf.org/external/np/mae/ferm/eng/index.htm

International Monetary Fund. (2018). *World Currency Composition of Official Foreign Exchange Reserves*. http://data.imf.org/regular.aspx?key=41175

International Monetary Fund. (2019). *Special Drawing Right (SDR)*. https://www.imf.org/en/About/Factsheets/Sheets/2016/08/01/14/51/Special-Drawing-Right-SDR

International Monetary Fund. (2020). *Assessing Reserve Adequacy (ARA)*. Research. https://www.imf.org/external/np/spr/ara/

IPCC. (2014). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on

Climate Change. In *Climate Change 2014 Mitigation of Climate Change*. https://doi.org/10.1017/cbo9781107415416

Jeanne, O. (2012). *The Dollar and Its Discontents: Vol. Working Pa* (Issues 12–10). https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjwkqj-i8z1AhVnGbkGHSkUB2cQFnoECAQQAQ&url=http%3A%2F%2Fciteseerx.ist.psu.edu%2Fviewdoc%2Fdownload%3Fdoi%3D10.1.1.638.146%26rep%3Drep1%26type%3Dpdf&usg=AOvVaw3ymkLL7PtP

Jones, B. (2018). Central Bank Reserve Management and International Financial Stability-Some Post-Crisis Reflections. *IMF Working Papers*, *18*(31), 1. https://doi.org/10.5089/9781484342008.001

Kaminsky, G., Lizondo, S., & Reinhart, C. M. (1998). Leading Indicators of Currency Crises. In *IMF Staff Papers* (Vol. 45, Issue 1, pp. 1–48). https://doi.org/10.2307/3867328

Kohlscheen, E., & O'Connell, S. A. (2004). A Sovereign Debt Model with Trade Credit and Reserves. *Mimeo*, *743*. https://doi.org/10.2139/ssrn.941107

Lamperti, F., Bosetti, V., Roventini, A., & Tavoni, M. (2019). The public costs of climate-induced financial instability. *Nature Climate Change*, *9*(11), 829–833. https://doi.org/10.1038/s41558-019-0607-5

Lydenberg, S. (2016). Integrating Systemic Risk into Modern Portfolio Theory and Practice. *Journal of Applied Corporate Finance*, *28*(2 Sustainability and Shareholder Value), 56–61. https://doi.org/10.1111/jacf.12175

McCauley, R. N. (2019). Safe Assets: Made, Not Just Born. *Ssrn*, *769*. https://www.bis.org/publ/work769.htm

McCauley, R. N., & Rigaudy, J.-F. (2011). Managing foreign exchange reserves in the crisis and after. *BIS Working Papers No. 58*, *58*, 19–47.

http://papers.ssrnhttps//www.bis.org/publ/bppdf/bispap58b.pdf

McKinsey Global Institute. (2020). Climate risk and response Physical hazards and socioeconomic impacts. *McKinsey Global Institute*, *January*, 164. https://www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts

Mercer. (2011). Climate Change Scenarios – Implications for Strategic Asset Allocation. *Public Report*. https://doi.org/10.2139/ssrn.1911824

Mercer. (2015). *Investing in a time of climate change*. http://www.mercer.com/services/investments/investment-opportunities/responsible-investment/investing-in-a-time-of-climate-change-report-2015.html

Moody's Investor Service. (2016). *Climate Change & Sovereign Credit Risk*. 1. https://www.moodys.com/sites/products/ProductAttachments/Climate_trends_infographic_moodys.pdf

Morahan, A., & Mulder, C. B. (2013). Survey of Reserve Managers: Lessons from the Crisis. *IMF Working Papers*, *13*(99), 1. https://doi.org/10.5089/9781484308486.001

NGFS. (2018). First Progress Report. *Network for Greening the Financial System*, *October*, 1–12. https://www.ngfs.net/sites/default/files/medias/documents/818366-ngfs-first-progress-report-20181011.pdf

NGFS. (2019a). A call for action: Climate change as a source of financial risk. *NGFS First Comprehensive Report*, *April*, 1–40. https://www.ngfs.net/sites/default/files/medias/documents/ngfs_first_comprehensive_report_-_17042019_0.pdf

NGFS. (2019b). A sustainable and responsible investment guide for central banks' portfolio management. *Network for Greening the Financial System Technical Document*, *October*. https://www.ngfs.net/sites/default/files/medias/documents/ngfs-a-sustainable-and-responsible-investment-guide.pdf

NGFS. (2020a). Case studies of Environmental Risk Analysis Methodologies. *NGFS Occasional Paper*, *September*, 1–603. https://www.ngfs.net/sites/default/files/medias/documents/case_studies_of_environmental_risk_analysis_methodologies.pdf

NGFS. (2020b). Guide to climate scenario analysis for central banks and supervisors. *Network for Greening the Financial System*, *June*. https://www.ngfs.net/sites/default/files/medias/documents/ngfs_guide_scenario_analysis_final.pdf

NGFS. (2020c). NGFS Climate Scenarios for central banks and supervisors. *Network for Greening the Financial System*, *June*. https://www.ngfs.net/sites/default/files/media/2021/08/27/ngfs_climate_scenarios_phase2_june2021.pdf

NGFS. (2020d). Overview of Environmental Risk Analysis by Financial Institutions. *Network for Greening the Financial System*, *September*.

NGFS. (2020e). Progress report on the implementation of sustainable and responsible investment practices in central banks' portfolio management. In *NGFS Technical document* (Issue December). https://www.ngfs.net/sites/default/files/medias/documents/sri_progress_report_2020.pdf

NGFS. (2020f). Survey on monetary policy operations and climate change: key lessons for further analyses. *Network for Greening the Financial System*, *December*. https://www.ngfs.net/en/survey-monetary-policy-operations-and-climate-change-key-lessons-further-analyses

Ortec Finance. (2020). Scenario Analysis for Systemic Climate Risk. In *Case Studies of Environmental Risk Analysis Methodologies*. NGFS.

https://eprints.soas.ac.uk/33510/1/case_studies_of_environmental_risk_analysis_methodologies.pdf

Portfolio Alignment Team. (2020). *Measuring Portfolio Alignment - Assessing the position of companies and portfolios on the path to net zero* (Issue Q1). https://www.tcfdhub.org/wp-content/uploads/2020/10/PAT-Report-20201109-Final.pdf

PRI. (2019). *Embedding ESG issues into strategic asset allocation frameworks - A discussion paper*. https://www.unpri.org/embedding-esg-issues-into-strategic-asset-allocation-frameworks-discussion-paper/4815.article

Read, C. (2016). Environmental Challenges and Financial Market Opportunities. In V. Ramiah & G. N. Gregoriou (Eds.), *Handbook of Environmental and Sustainable Finance* (pp. 293–305). Academic Press - Elsevier.

Robins, N., & McDaniels, J. (2016). Greening the Banking System: Taking Stock of G20 Green Banking Market Practice. *UNEP Inquiry*, *September*, 31. https://wedocs.unep.org/bitstream/handle/20.500.11822/10604/greening_banking_system.pdf?sequence=1&amp%3BisAllowed=

Scott, M., Huizen, J. van, & Jung, C. (2017). The Bank of England’s response to climate change. *Bank of England Quarterly Bulletin*, 98–109. https://www.unepfi.org/psi/wp-content/uploads/2017/06/BANKOFENGLAND_response_climatechange.pdf

Sevillano, J. M. M., & González, L. R. (2018). The risk of climate change for financial markets and institutions: challenges, measures adopted and international initiatives. *Financial Stability Review*, *34*, 113–134. https://www.bde.es/f/webbde/GAP/Secciones/Publicaciones/InformesBoletinesRevistas/RevistaEstabilidadFinanciera/18/MAYO/Articulo_Marques__Romo-en.pdf

Silva Jr., A. F. A. (2011). The Self-Insurance Role of International Reserves and the 2008-2010 Crisis. *Central Bank of Brazil Working Paper*, *256*, 1–26.

https://doi.org/10.2139/ssrn.1956702

Sveriges Riksbank. (2019). *Flodén: Riksbank selling bonds for climate reasons*. Speeches and Presentations. https://www.riksbank.se/en-gb/press-and-published/speeches-and-presentations/2019/floden-riksbank-selling-bonds-for-climate-reasons/

TCFD. (2017). Recommendations of the Task Force on Climate-related Financial Disclosures. *Task Force on Climate-Related Fiancial Disclosures, June*, 1–74. https://assets.bbhub.io/company/sites/60/2020/10/FINAL-TCFD-Annex-Amended-121517.pdf

The World Bank. (2020). *Total reserves (includes gold, current US$)*. https://data.worldbank.org/indicator/fi.res.totl.cd?view=chart.

UBS. (2018). UBS Annual Reserve Manager Survey 2018. *24th Reserve Management Seminar*. https://swfi-cdn.sfo2.cdn.digitaloceanspaces.com/partnerContent/ubs-annual-reserve-manager-survey.pdf

UBS. (2019). *UBS Annual Reserve Manager Survey 2019*.

UNEP FI. (2019). *Changing Course: A comprehensive investor guide to scenario-based methods for climate risk assessment, in response to the TCFD*. *May*, 129. https://www.unepfi.org/wordpress/wp-content/uploads/2019/05/TCFD-Changing-Course-Oct-19.pdf

Vecchio, F. (2009). *Questioning the U.S. Dollar's Status as a Reserve Currency*. https://www.jpmorgan.com/jpmpdf/1158630192140.pdf

Volz, U. (2017). On the role of Central Banks in enhancing green finance. *United Nations Environment Programme, Inquiry Wo*(February), 1–27. http://unepinquiry.org/wp-content/uploads/2017/02/On_the_Role_of_Central_Banks_in_Enhancing_Green_Finance.pdf

Volz, U., Beirne, J., Preudhomme, N. A., Fenton, A., Mazzacurati, E., Renzhi, N., & Stampe,

J. (2020). Climate Change and Sovereign Risk. In *SOAS Centre for Sustainable Finance* (Issue October). https://doi.org/10.25501/SOAS.00033524

WEF. (2020). The Global Risks Report 2020. *World Economic Forum*, 1–102. https://www3.weforum.org/docs/WEF_Global_Risk_Report_2020.pdf

WRI, & UNEP-FI. (2015). *Carbon Asset Risk: Discusssion Framework*. *13*(2), 255–270. http://www.unepfi.org/fileadmin/documents/carbon_asset_risk.pdf%5Cnhttp://www.wri.org/sites/default/files/carbon-asset-risk-discussion-framework-ghgp_0.pdf

WWF, Godinot, S., & Vandermosten, J. (2017). WWF Climate Guide To Asset Owners: Aligning Investment Portfolios With the Paris Agreement. *WWF Report EU 2017*, 72. https://www.wwf.org.uk/sites/default/files/publications/Dec17/WWF Climate Guide to Asset Owners Full version Dec17_0.pdf

3 Study 2:

Environmental risk management of the international reserves: an applied framework discussion with the central banks from Latin America and the Caribbean

Viviane H. Torinelli[1,2], Antônio F. A. Silva Júnior[1,2], Serafín Martinez-Jaramillo[3] and José Célio Silveira Andrade[1,2]

[1] Business School, Universidade Federal da Bahia, Salvador, Bahia, Brazil (UFBA),

[2] Brazilian Research Alliance for Sustainable Finance and Investment (BRASFI),

[3] CEMLA and Banco de México, Ciudad de México, México.

Author Note

Viviane H. Torinelli https://orcid.org/0000-0002-1330-6370

Antônio F. A. Silva Júnior https://orcid.org/0000-0002-4417-5991

Serafín Martinez-Jaramillo https://orcid.org/0000-0003-3320-0925

José Célio Silveira Andrade https://orcid.org/0000-0002-6794-8686

Correspondence email: vivitorinelli@gmail.com

Abstract

This is an applied framework discussion with central banks from Latin America and the Caribbean (LAC) regarding the environmental risk management of the international reserves. This study is based on a sample of central banks from LAC, taking into consideration the national exports of the respective countries, the risk of sudden stops in capital flows and the international reserves' economic objectives. Commodities are economically relevant for all analyzed countries. The specific environmental risk exposures are discussed, as are the alternatives to environmental risk management through the international reserves' strategic asset allocation. The framework discussed herein includes environmental risk analysis in the international reserves' traditional strategic asset allocation approach. As a result, international reserves' investments can become more resilient to environmental and climate risk exposure.

Keywords: environmental risk management, central banks, international reserves, Latin America and the Caribbean

3.1 Introduction

Environmental factors result in a range of financial risks that have important implications for investments. To manage risks, they must be identified and measured. Environmental risk management is a challenge for investors, including central banks, when they act as managers of international reserves.

International reserves are investments held by central banks in foreign currencies to implement monetary and foreign exchange (FX) policies (Aizenman & Marion, 2002; Allen et al., 2002; Detragiache, 1996; Hawkins & Rangarajan, 1970; Kohlscheen & O'Connell, 2004; Silva Jr., 2011). Thus, they are classified in the policy portfolios of central banks (NGFS, 2019). International reserves' economic objectives include intervention in the FX market, execution of payments for goods and services, execution of payments for the government, granting of emergency liquidity assistance, underpinning investors' confidence in the country, and investment of excess reserves (Fender et al., 2019). For these and related reasons, international reserves totaled US$13.978 trillion in 2019 (The World Bank, 2020).

In emerging markets such as Latin America and the Caribbean (LAC), international reserves provide two important and widely accepted functions for central banks: self-insurance (Calvo et al., 2012) and warning signaling (Kaminsky et al., 1998). Avoiding environmental risks, such as climatic ones, is compatible with these two rationales.

Environmental risks are also important for other implementation instruments of monetary policy by central banks (McKibbin et al., 2020), as well as for other key tasks, such as financial stability maintenance (Roncoroni et al., 2021). In some climate policy scenarios, effects in sectors as energy and utilities may lead to systemic losses and threaten financial stability (Roncoroni et al., 2021). On the monetary policy side, policy responses to climate change, such as carbon emission targets, may lead to negative supply shocks and affect central banks' ability to forecast and manage inflation (McKibbin et al., 2020). Our discussion of environmental risk management occurs in this context and makes the case for a new international reserves management framework, mainly due to the perceived urgency of climate action and possible short- and medium-term transition effects.

In this context, and in the search for contributions to this knowledge gap, this is an applied framework study of central banks from LAC aimed at the environmental risk management of the international reserves. The research question was as follows: What are the relevant environmental risk exposures to the management of the international reserves from LAC, taking into consideration the economic objectives of the international reserves and the risk of sudden stops in capital flows based on the respective national exports? In addition, how could the environmental risk management be performed through the international reserves' strategic asset allocation?

The methodology used in this work included literature and desk reviews, data analysis for ten central banks from LAC, a questionnaire, and meetings that included discussions with some selected central banks. The research findings confirmed the economical relevance of commodities for the analyzed countries and the related environmental risk exposure.

Among this study's contributions are discussions of the specific environmental risk exposures of LAC and alternatives to environmental risk management through the international reserves' strategic asset allocation. The framework discussed herein includes environmental risk analysis in the international reserves' traditional strategic asset allocation approach. Consequently, the management of the international reserves can become more resilient to environmental and climate risk exposure.

The most important distinction of this approach in comparison to a more general ESG[2] investment strategy is that we consider a more macro strategy that considers each country's

---

[2] ESG investment: investments which incorporate environmental, social and governance factors in the decision-making process.

reliance on certain exports and designs a strategy to deal with sudden stops of such income sources due to environmental factors. This is, to the best of our knowledge, the first time that this exercise has been done for such a variety of countries in a region that is exposed to severe negative impacts from environmental phenomena.

This paper proceeds as follows: Section 3.2 covers the environmental risk management of international reserves through strategic asset allocation from the discussion of environmental factors as sources of financial risks to the environmentally adjusted strategic asset allocation framework for international reserves management. Section 3.3 presents the methodology of this research with central banks from LAC. Section 3.4 presents the study's results and discussion. The paper concludes in Section 3.5 with an outlook for future research.

3.2 Environmental risk management of the international reserves through strategic asset allocation

The international reserves must be part of the environmental risk management of central banks, but the question is how this environmental risk management can be performed though strategic asset allocation of the international reserves. The contribution of this section will be to review the environmental factors as a source of financial risks (Section 3.2.1) and to discuss an environmentally adjusted strategic asset allocation framework for international reserves management (Section 3.2.2), as follows.

3.2.1 From environmental factors to financial risks

Environmental factors include climatic, geologic and ecosystem dimensions. Climatic factors imply the presence of physical and transition[3] climate risks. Climate risks lead to financial risks through micro and macroeconomic transmission channels. Some examples include property damage and business disruptions due to extreme weather events, stranded-

[3] Transition climate risk: the risk that results from changing policies, practices, and technologies towards a low-carbon future.

assets due to changes in policy or technology, price shifts due to supply shocks, and exchange rate volatility due to changes in capital flows. These impacts of the sources of different types of financial risks, including credit, market, underwriting, operational, and liquidity risks (NGFS, 2020b).

The environmental physical risks and associated transition risks may increase market volatility and sector instability, driving potential financial losses (Roncoroni et al., 2021). For instance, physical shock events, such as natural disasters, might impact corporate finances. In addition, changes in trends such as water scarcity, extreme weather events, air pollution, and natural capital degradation represent risks to corporate sectors such as agriculture and power generation.

LAC may be severely impacted by climate change (Bolton et al., 2020; Burke et al., 2015; McKinsey Global Institute, 2020; Mora et al., 2017). Humans may have to abandon many areas, and entire regions of South America and Central America could become uninhabitable due to a mixture of high temperatures and humidity levels (Bolton et al., 2020; Mora et al., 2017). Heat stress and a drought risk area are projected for the majority of LAC (McKinsey Global Institute, 2020). Finally, the change in GDP per capita by 2100 compared to a world without climate change might be minus 100% for many countries in LAC (Burke et al., 2015).

Most LAC countries are economically based on the agriculture and energy sectors. As foreseen in previous figures and in the climatic projections (IPCC, 2014), agriculture may be significantly impacted by new drought areas and changes in precipitation patterns and, consequently, in agricultural areas. In addition, impacts come from policies and economic preferences towards biodiversity preservation, as well as changes in food preferences, including the increase in veganism motivated by environmental discussions worldwide.

In addition, worldwide policy efforts to achieve a low-carbon economy significantly and even disruptively affects virtually all industries and sectors in the medium and long terms (TCFD, 2017), particularly the energy sector. Carbon pricing systems are already stimulating the alignment of the energy market with green public policies, and changes to the energy matrix that incorporate clean technologies already exemplify potential medium-term developments and impacts. All this has important implications for transition risks and stranded assets (Caldecott et al., 2014), which could also have implications at the national level for many LAC countries.

The 2021 Leaders' Climate Summit brought together the main global leaders and sent two important signals: concern about the physical risks associated with climate change, such as the increased incidence of natural disasters; and the risk that companies will have stranded assets that are not realizable due to the transition to low-carbon energy sources. As Kristalina Georgieva, head of the International Monetary Fund (IMF), highlighted:

> We have to make the invisible visible – the transition risks that banks are carrying because they're investing in high-carbon activities that over time are going to be phased out, and the physical risk, investments in highly vulnerable coastal areas, or in agriculture that could be affected by floods or by droughts". (Shalal, 2021, p. 1)

Thus, the environmental risks, including the climatic ones, are relevant sources of financial risk that impact the performance of investments. As a result, the environmental risk management of international reserves is important for central banks and includes risk identification, measurement, and control, taking into consideration environmental externalities, trends, and events (Bank of England et al., 2017; Cambridge Centre for Sustainable Finance, 2016; TCFD, 2017).

3.2.2 The management of the international reserves by central banks

The objectives of international reserves management vary among central banks and portfolios under the same investment manager. For some, the main objective is to hold liquid and safe foreign exchange (FX) assets for interventions within monetary policy implementation duties. For others, it is capital preservation as fiduciary duty. The objective can also be financial stability through the management of a financial buffer for interventions in financial crises, among other strategies, as inflation management.

According to the IMF's (2020) Assessing Reserve Adequacy (ARA) metrics, 5% to 7.5% of total exports should be covered by international reserves assets allocated to hedge sudden stops in capital flows.

In crises, international reserves are fundamental to quickly mobilizing funds in liquid portfolios (or even investment ones) to meet domestic banks or firms' foreign currency needs and to support the domestic currency's FX value (McCauley & Rigaudy, 2011). Financial stability objectives are an important constraint to international reserves management, short-term liquidity needs, and reputational concerns

Environmental factors may be behind the next big crisis, which might be related to global warming, water, or biodiversity stress. For this reason, and for risk–return investment management purposes, environmental risk analysis should inform international reserves' management processes. Risk response management decisions will align the international reserves' risk exposure with the central bank's risk tolerance and/or facilitate the exploration of opportunities according to the central bank's risk appetite. Among possible risk responses, reweighting strategic asset allocation is an option that does not necessarily imply any green investment strategy.

3.2.3 Environmental risk management through strategic asset allocation

Environmental risk analysis and environmental risk management are prominently linked to strategic asset allocation via a common time frame (i.e., the long-term horizon for the assessment). Strategic asset allocation is an investment decision made by asset owners to manage portfolio performance and risk over the long term. However, many investors now face the tragedy of the horizon (Carney, 2015). This means that investors seek short-term returns, but environmental risks have long-term horizons (Carney, 2015). Central banks are long-term investors, so the problem of the tragedy of the horizon should be managed via the strategic asset allocation process.

Different portfolio types have different vulnerability and resilience to environmental and climate change related risks. Each asset class presents different risks and opportunities, demanding a multifaceted strategy across the total portfolio. In turn, the environmental risk analysis comprises a financial analysis of environmental factors, including pricing and implications for an investment portfolio. Thus, environmental risk analysis facilitates the integration of environmental data into risk management and asset allocation processes.

It is possible to mitigate environmental risks and to incorporate investment opportunities through assets, regions, sectors, and sub-asset class allocations (PRI, 2019). environmental risk management by investors through strategic asset allocation may include, for example, increasing asset allocation to climate-sensitive assets as a climate “hedge,” as well as using sustainability themed indices in passive portfolios (Mercer, 2011). According to CISL (2015), “short-term shifts in market sentiment induced by awareness of future climate risks could lead to economic shocks and losses of up to 45 per cent in an equity investment portfolio value (23 per cent loss for a fixed income portfolio).” In addition, “around half (53 per cent) of this decline is ‘hedgeable’ if investments are reallocated effectively, but the other half (47 per cent) is ‘unhedgeable,’ meaning investors and asset owners are exposed unless some system-wide action is taken to address the risks” (CISL, 2015).

For climate hedges, industry-sector impacts are expected to be the most significant (e.g., energy, with significant losses in coal and gains in renewables), and asset class returns impacts could also be material. According to Mercer (2015), a 2°C scenario could lead to better returns for emerging market equities, infrastructure, real estate, timber, and agriculture, whereas a negative impact is expected in a 4°C scenario.

According to Mercer (2015), if more stringent policies are implemented, substantial capital should be made available to assist emerging market countries with farming method adaptations. In addition, Mercer (2015) expects agriculture investments to benefit from technological developments towards more productive and resilient crop varieties. However, agriculture is the asset class that is most negatively sensitive to resource availability, which, in turn, is related to long-term shifts in regional weather patterns and water stress. Finally, over a 35-year period, timber and agriculture were among the asset classes with the potential for the largest positive and negative returns (Mercer, 2015).

In an asset- or portfolio-level risk–return analysis, collinearity and diversification issues should be taken into consideration at the portfolio level and across various risk profiles to reduce negative impacts. Besides the tragedy of the horizon, the integration of environmental risk analysis, environmental risk management and strategic asset allocation has an additional challenge, as there is no guarantee that historical correlations will work on a scenario with an environmental impact. However, investors cannot simply disregard historical information. The integration of environmental risk analysis, environmental risk management and strategic asset allocation should analyze environmental factors and optimize risks and opportunities, taking into consideration both problems: the tragedy of the horizon and the weaknesses and strengths of historical data. The integration of environmental risk analysis into the strategic asset allocation process may lead to a rebalancing of investments among asset classes in a way that environment risks are considered in the investment scenarios.

It is critical for each central bank to assess the level of reliability required for environmental risk analysis outputs as strategic asset allocation input, considering the economic objective of the reserves. One can then decide to calibrate which asset class is best suited to the investment pillars (safety, liquidity, return, and maybe sustainability), given the objective of each portfolio and the central bank in charge of managing the international reserves (Fender et al., 2019).

Some strategic asset allocation impacts are related to sustainable responsible investing (SRI) strategies in policy and international reserves portfolios, which include ESG financial (risk–return) and nonfinancial (positive impact) objectives (NGFS, 2020b). Environmental risk analysis may be part of this as input in the environmental risk management process, which, in turn, produces an important input for the strategic asset allocation process: "Protecting portfolios against sustainability risks" and "enhancing risk–return profile" are among the four main reasons central banks adopt SRI investment strategies, along with "mitigate reputational risk" and the desire to "set a good example" (NGFS, 2020b, p. 9).

Strategic asset allocation is one of the possible elements of an ESG integration investment strategy (CFA UK, 2020). In policy portfolios, there is an indication that ESG integration (including financially material ESG criteria in the investment analysis to improve the risk–return profile of the portfolio) has been considered for sovereign, supranational, and agency (SSA) bonds by four central banks, for corporate bonds by two central banks, and for equities by one central bank (NGFS, 2020b).

According to the NGFS (2021), the selected stylized options for adjusting operational frameworks to climate-related risks in asset purchases, include tilt purchases and negative screening. Tilt purchases are aimed at biased asset purchases based on climate-related risks and/or criteria applied at the issuer or asset level, whereas negative screening excludes some assets or issuers from purchases if they fail to meet climate-related criteria.

As a case study, the Swedish central bank divested from bonds issued by the Canadian province of Alberta and the Australian states of Queensland and Western Australia due to these issuers' large climate footprints (Sveriges Riksbank, 2019). The main motivation behind the Swedish bank's deputy governor's speech was a positive impact action, but this did not exclude eventual environmental risk analysis considerations. As demonstrated by Battiston and Monasterolo (2020), sovereign bonds' portfolio alignment to a credible 2ºC trajectory can strengthen the sovereign fiscal and financial position by decreasing the climate spread, while a misalignment with a 2°C trajectory can increase it, with financial risk implications for its investors.

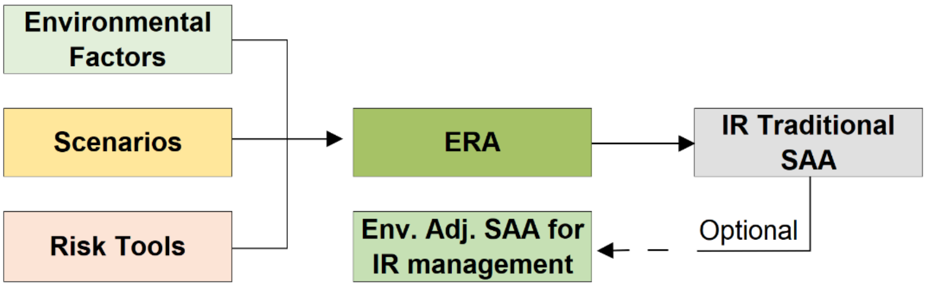
Finally, as Volz et al. (2020) stated, central banks "need to understand their exposures to other countries' sovereign risks arising from climate change if they hold those countries' government bonds". Thus, environmental risk analysis is critical to the strategic asset allocation of international reserves, as international reserves are mainly invested in strategic asset allocation bonds, which are highly exposed to sovereign risks (Volz et al., 2020), and highly impacted by climatic and other environmental factors.

3.2.4 Environmentally adjusted framework for strategic asset allocation of international reserves

The environmental risks to which international reserves are exposed must be assessed to enable a proper risk management process, including eventual changes in the strategic asset allocation intended to facilitate the achievement of the central bank's objectives. For this purpose, a multicriteria analytical framework was developed to evaluate these environmental risks and their incorporation into the risk management process with outputs to the international reserves' strategic asset allocation, as outlined in Figure 1:

Figure 1

Multicriteria analytical framework for environmental risk analysis and strategic asset allocation of international reserves management



Reproduced by permission from Torinelli and Silva Júnior (2021, fig. 8).

The output of the environmental risk analysis may provide new information for the international reserves’ strategic asset allocation framework of international reserves (Figure 2), and it will be considered alongside the international reserves’ economic objectives and investment guidelines. Thus, the environmental risk analysis output will be incorporated in addition to other main concerns of the international reserves managers, as environmental risk management is not their primary concern. Instead, their primary concern is to adequately address the reasons that motivate the international reserves’ existence (which may vary by central bank).

Hence, environmental risk exposure will be considered jointly with concerns about currency, asset type, countercyclicality (for crisis mitigation), and the relevance of each of the three international reserves investment pillars: security, liquidity, and profitability. The relevance of each pillar depends on the strategic objectives of each international reserves manager, which ultimately reflect the reasons for which the reserves are being maintained. For example, sovereign wealth funds (SWFs) can prioritize profitability instead of liquidity, whereas emerging countries may need to assign more weight to liquidity and security. This also depends on the objective of each specific portfolio, given that the same investor can prioritize different pillars in different portfolios.

Based on the analysis of the environmental risk analysis outputs considered in the traditional framework for the strategic asset allocation of the international reserves, central banks can evaluate the adequacy to adjust this framework to include the environmental factor as a fourth pillar of international reserves management objectives, which might diversify benefits and improve risk-adjusted returns.

Figure 2

Environmentally adjusted strategic asset allocation framework for international reserves management

IR economic objectives (Fender et al, 2019)	Investment Guidelines	Four pillars of investment	IRs focus (main exposure)	SAA model approaches	Concern for crises mitigation
Intervention in the FX markets; Execution of payments for goods and services; Execution of payments for the government; Granting of emergency liquidity assistance; Support of domestic monetary policy; Underpinning of investor confidence in the country; Investment of excess reserves	Investment Policy; Investment Strategy; Investment Driver; Investment Objectives	Enviromental Sustainability Profitability Liquidity Security	**Asset:** mainly Treasury Bonds, Supranationals, Sovereign Eurobonds, US Agencies, Inflation Protected Bonds, Corporates, MBS/ABS, Covered Bonds, Banks Debt and Green Bonds. **Currency:** mainly USD, EUR, CNY, JPY, GBP.	Mean-variance optimization (MVO), Factor risk allocation, Total Portfolio Analysis, Dynamic asset allocation, Liability driven asset allocation and Regime Switching Models	Countercyclicality

Reproduced by permission from Torinelli and Silva Júnior (2021, fig. 11), based on Fender et al. (2019) and other references.

In the above context, environmental risk and opportunities are considered without undermining the perspectives of a particular central bank. To better clarify, the purpose of an environmental risk analysis is to quantify the financial risk exposure related to environmental factors in an international reserves' assets and portfolios. The purpose of strategic asset allocation is to identify the best risk–return profile for international reserves allocation according to international reserves objectives (i.e., liquidity, safety, return). The combined assessment of financial and environmental risks, as an input for the strategic asset allocation, may guide international reserves asset allocation that is sound from these two risk viewpoints. The decision is supported by the central bank's risk tolerance and appetite.

Traditional strategic asset allocation is adjusted to incorporate environmental considerations alongside the traditional investment guidance of international reserves as asset classes, currencies, issuers, regions or countries, asset maturity, liquidity (bid-ask spread, turnover), and market depth (outstanding). In addition, specific environmental variables would be included to achieve an efficient investment portfolio, which might require multi-objective optimization.

This investment guidance may direct the partial allocation of the international reserves to green assets or indicate a rebalancing among existing assets. Thus, the environmental risk analysis could measure risks and contribute to reweighting in strategic asset allocation without necessarily implying any green strategy. Although there is growing pressure for central banks to adopt net-zero strategies (Robins et al., 2021), which are strongly associated with positive impact strategies.

The following are practical possible environmental risk analysis impacts on an international reserves' strategic asset allocation:

1. inclusion of new asset alternatives, such as
   1.1. inclusion of green asset classes (e.g., green bonds, green funds, green indexes in passive portfolios), and
   1.2. inclusion of other asset alternatives, such as unlisted funds, if appropriate for the environmentally adjusted strategic asset allocation framework;
2. rebalancing among existing asset classes, regions or countries, sectors, and sub asset classes such as:
   2.1. divestments from high carbon footprint and/or high-temperature alternatives,
   2.2. investments to explore opportunities to reduce carbon footprints and/or lower temperature options, and
   2.3. migration to assets less correlated with the environmental risks to be mitigated; and/or
3. inclusion of environmental risk management considerations in the selection of asset managers, fund managers, and companies.

3.3 Materials and methods

This study is based on a sample of ten central banks from LAC. The focus on LAC is based on the relevance of environmental physical and transition risks to the region and the relevance of international reserves to regional monetary and FX policies by central banks. The analysis was also part of a common project with the Center for Latin American Monetary Studies (CEMLA).

For the analysis, the sample of ten LAC countries was selected based on the criteria of a GDP higher than US$50 billion for year end 2019 (YE2019) and/or at least 10% of international reserves on GDP. Ecuador and Panama were excluded due to their lower international reserves/GDP (0% and 5%, respectively) and lower international reserves amounts (US$0.29 and US$3.42 billion, respectively).

Thus, the selected countries were México, Brazil, Argentina, Colombia, Chile, Peru, Jamaica, Costa Rica, Guatemala, and the Dominican Republic.

Economic data from the respective countries were gathered from the World Bank's public database. International reserves figures were collected in the public reports of the related central banks. Horizontal and vertical analysis were performed.

Meetings organized by CEMLA were held in February 2021 to discuss the framework with representatives from four out of ten central banks. One of the four central banks answered a detailed questionnaire (see Appendix A), and a second meeting was held in May 2021 to analyze the application of the framework according to its perceptions and reality. The results are detailed in the following section.

3.4 Results

A specific exercise was performed with central banks from LAC in the sample detailed in Table 1. LAC international reserves for the selected sample totaled US$782.4 billion in 2019, representing 17% of the national GDP and 84% of total annual merchandise exports. Food and agriculture represented 23% of exports, fuel accounted for 9%, and ores represented the other 8%.

Table 1

Applied framework discussion for the analyzed central banks from LAC

US$ billion in 2019	Mexico	Brazil	Peru	Colombia	Argentina	Chile
IR	183,06	56,89	67,71	52,65	45,22	40,66
GDP	1.258,30	1.839,80	226,80	323,80	449,70	282,30
% IRs/GDP	15%	19%	30%	16%	10%	14%
Total merchandise exports	461,12	222,64	47,77	39,46	65,12	69,68
% IRs/Exports	40%	160%	142%	133%	69%	58%
Food & agriculture raw material exports	35,51	88,83	11,23	7,38	39,98	22,58
% food & agriculture on total exports	8%	40%	24%	19%	61%	32%
Fuel exports	24,44	30,50	3,30	21,58	2,41	0,63
% fuel on total exports	5%	14%	7%	55%	4%	1%
Ores & Metals	8,30	2,89	21,73	0,39	0,33	36,65
% ores & metals on total exports	2%	1%	46%	1%	1%	53%
Manufactures exports	354,60	74,36	4,54	8,33	11,33	9,83
% manufactures on total exports	77%	33%	10%	21%	17%	14%
Total merchandise imports	467,34	184,10	42,26	52,70	49,12	69,59
% IRs/Imports	39%	194%	160%	100%	92%	58%
Food & agriculture raw material imports	25,70	12,70	5,41	7,11	3,68	7,52
% food & agriculture on total imports	6%	7%	13%	14%	8%	11%
Fuel imports	39,26	25,96	6,76	3,64	4,22	11,34
% fuel on total imports	8%	14%	16%	7%	9%	16%
Ores & Metals	8,88	6,44	0,51	0,90	1,23	0,90
% ores & metals on total imports	2%	4%	1%	2%	3%	1%
Manufactures imports	346,30	139,00	29,58	40,58	39,40	49,90
% manufactures on total imports	74%	76%	70%	77%	80%	72%
% IR assets allocated to hedge sudden stops in capital flows (ARA*)	**5%**	**5%**	**5%**	**5%**	**5%**	**5%**
Total IR assets allocated to hedge of the external liabilities related to exports	23,06	11,13	2,39	1,97	3,26	3,48
Hedge for food & agriculture on total exports (e.g.: 40% BR)	**1,78**	**4,44**	**0,56**	**0,37**	**2,00**	**1,13**
Hedge for fuel on total exports (e.g.: 14% BR)	1,22	1,53	0,16	1,08	0,12	0,03
Hedge for ores & metals on total exports	0,42	0,14	1,09	0,02	0,02	1,83
Hedge for manufactures exports	17,73	3,72	0,23	0,42	0,57	0,49

US$ billion in 2019	Mexico	Brazil	Peru	Colombia	Argentina	Chile
%Hedge for food & agriculture / IRs	1,0%	1,2%	0,8%	0,7%	4,4%	2,8%
%Hedge for fuel / IRs	0,7%	0,4%	0,2%	2,0%	0,3%	0,1%
%Hedge for ores & metals / IRs	0,2%	0,0%	1,6%	0,0%	0,0%	4,5%
%Hedge for manufactures / IRs	9,7%	1,0%	0,3%	0,8%	1,3%	1,2%

* ARA: Assessing Reserve Adequacy - International Monetary Fund (IMF)

Source: Data from The World Bank (2021).

According to the IMF's (2020) ARA metrics, 5% to 7.5% of total exports should be covered by international reserves assets allocated to hedge sudden stops in capital flows. In the LAC case, this would account for US$46.50 to US$69.76 billion. Thus, considering the 5% totaling US$46.50 billion, the portion to hedge for food and agriculture on total exports would account for US$10.83 billion (23.29%), fuel would account for US$4.17 billion (9%), and ores and metals would account for US$3.53 billion.

The food and agriculture, fuel, and ores and metals sectors are significantly exposed to environmental risks, including the physical and transition climate ones. This exposure has implications for exports and capital flows, as well as, from this perspective, an indirect impact on international reserves. The international reserves would be affected in terms of their economic objectives, such as the execution of payments, intervention in FX markets, and underpinning of investors' confidence in the country.

In an environmental risk analysis for the international reserves of the LAC sample, the relevant economic sectors are food and agriculture, fuel, and ores and metals. The environmental factors could be climatic transition (avoidance of GHG emissions), policy, technology, and sentiment-based or reputational dimensions, besides the physical climatic impacts (temperature and precipitation, as well as extreme events).

The relevant scenarios may contemplate climate-change transition risk and climate-change physical risk, considering, for example, NGFS (2020a) climate scenarios for central banks and supervisors. The related environmental risks, with potential financial impacts for some specific time horizons, could include increased GHG emission costs, assets stranded due to changes in policy and technology toward a more sustainable economy, and crop failures due to physical climate changes.

Some expected asset-price movements in crisis scenarios would reduce country exports and have an impact on the FX rate. The impacts could also be related to stranded assets in the Oil & Gas sector. appreciation of clean energy assets, variation in ore and metal demand due to technological changes, and the transition to a low-carbon economy, as well as potential decreased water availability and increased energy and operational costs, increased commodity prices due to crop failures, a decrease in non-regenerative agriculture average asset prices, stranding of assets related to policy and regulation changes toward biodiversity conservation (e.g., reduction in the legal deforestation zone on agricultural lands), and similar factors. The strategic asset allocation exercise might consider portfolios for the investment of the international reserves that are more resilient to these scenarios.

The international reserves allocation in currencies and asset classes YE2019 are detailed in Table 2:

Table 2

International reserves allocation in currencies and asset classes for YE2019

IRs in US$ billion on 2019	MEX		BRA		PER		COL		ARG	
Currencies	183,1	1,0	356,9	1,0	67,7	1,0	52,7	1,0	44,9	1,0
U.S. dollar	170,0	0,9	309,7	0,9	58,9	0,9	0,0	0,0	0,0	0,0
Euro	-0,1	0,0	26,2	0,1	0,0	0,0	0,0	0,0	0,0	0,0
Pound Sterling	0,2	0,0	7,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Japanese Yen	1,2	0,0	6,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Canadian Dollar	1,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Australian Dollar	0,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
SDR	2,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Singapore Dollar	1,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
New Zeeland Dollar	1,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Offshore Chinese Yuan	1,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Swiss Franc	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other currencies	0,7	0,0	3,9	0,0	6,1	0,1	0,0	0,0	0,0	0,0
Gold	1,2	0,0	3,4	0,0	2,7	0,0	0,0	0,0	0,0	0,0

IRs in US$ billion on 2019	MEX		BRA		PER		COL		ARG	
Asset Class	183,1	1,0	356,9	1,0	67,7	1,0	52,7	1,0	44,9	1,0
Sovereigns	0,0	0,0	325,0	0,9	0,0	0,0	0,0	0,0	0,0	0,0
Agencies	0,0	0,0	6,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Supranational	0,0	0,0	3,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Supranationals deposits	0,0	0,0	5,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Multilateral Entities	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Deposit in banks and currency	84,3	0,5	1,4	0,0	18,8	0,3	3,1	0,1	36,5	0,8
Interest bearing notes	53,2	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Capital Market Inv&Sec	0,0	0,0	0,0	0,0	46,0	0,7	47,4	0,9	1,2	0,0
Discounted instruments	35,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
IMF position (Reserve Tranche, Loans)	2,7	0,0	7,5	0,0	1,7	0,0	0,6	0,0	0,4	0,0
Gold (and local sov. bonds for BRA)	5,9	0,0	3,9	0,0	1,7	0,0	0,7	0,0	2,7	0,1
Special Drawing Rights (SDRs)	3,9	0,0	0,0	0,0	0,0	0,0	0,9	0,0	2,6	0,1
Stock Indices	0,0	0,0	3,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0
US MBS	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Liquidity Tranche	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
External Funds	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Emerging Latin Americans	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Working Capital Tranche	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Interest Receivable Fgn Entities&Org	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Deposits received maturities <6 months	-2,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other	0,0	0,0	0,0	0,0	-0,6	0,0	0,0	0,0	1,5	0,0

Table prepared by the authors based on IRs reports from each CB. Sources: Data from Banco Central de Chile (2019); Banco do México (2019); Banco Central de Costa Rica (2020); Banco Central de Reserva del Perú (2020); Banco Central do Brasil (2020); Banco Central Républica Dominicana (2021); Banco de Guatemala (2021); Bank of Jamaica (2021); International Monetary Fund (2021).

A hedge strategy for environmental risk analysis-related asset price movements is applicable, considering other traditional strategic asset allocation relevant data, such as international reserves economic objectives, investment guidelines, and investment pillars. For some central banks in the LAC sample, an alternative could be to migrate to assets less correlated with agricultural, metals and mining and oil commodities, as an example of a scenario to be mitigated in which are expected significant impacts on those sectors. As an asset alternative, commodity indices could be considered.

In addition, the strategic asset allocation could drive the choice of currencies in the portfolio to those currencies that are less correlated to the specific LAC economic exposure or FX rate exposure for each country in the relevant scenarios to avoid procyclicality. The environmental risk analysis helps to quantify the size of the impact on the economy and the dimension of this impact in the investments of international reserves. Furthermore, the choice of asset classes could include those related to clean energy. The choice of currency is easier from a traditional perspective. In contrast, the choice of asset classes is more difficult due to liquidity issues, since green asset classes eligible to central banks are traditionally agencies, supranationals, and some sovereign issuers. However, it would be possible to search for small amounts of investments in these kinds of asset classes.

3.4.1 Discussion per country

For Jamaica, international reserves totaled US$3.63 billion in 2019, representing 22% of the national GDP and 2201% of total annual merchandise exports. Thus, exports would not be as relevant in the discussion of the environmental risk analysis for the international reserves, as detailed in Table 3. However, environmental risk analysis is strongly recommended because Jamaica has the third highest economic risk worldwide from multiple hazards (Banco Mundial, 2010). Jamaica is located in "Hurricane Alley," so it also faces geophysical hazards. Tropical storms, floods, and hurricanes are the disasters that have had the greatest impact in Jamaica. Between 1980 and 2008, the country experienced 27 natural disasters, with total economic damages around US$2.6 billion. In this context, to test various hypotheses, a strategy of environmental risk analysis in the management of the international reserves could focus on hedging against variances in the local currency, with assets less correlated or negatively correlated to the Jamaican dollar (JMD) and/or with lower exposure to common physical climate risks (e.g., different geographical areas and conditions).

The Dominican Republic is in a similar situation. International reserves totaled US$8.87 billion in 2019, representing 10% of the national GDP and 781% of total annual merchandise exports. Although exports are not expressive in relation to international reserves volume, environmental risk analysis is strongly recommended because the country has the second-highest economic risk worldwide from multiple hazards (Banco Mundial, 2010).

For Mexico, based on its total manufacture's exports, 85% of sales are to the United States. Manufactures are 78% machinery and transport equipment, 33% road vehicles, 13% electrical equipment, 9% office and data processing machines, 9% telecoms equipment, 6% industrial equipment, and 8% other products.

In an environmental risk analysis-strategic asset allocation integration for international reserves, environmental factors could include ecosystemic physical risk (e.g., industrial water scarcity), as well as technological (e.g., electric vehicles) and policy transition risk (e.g., regulation towards CO2 emissions). Key economic sectors include industry (e.g., road vehicles, electrical and telecom equipment, office, and data processing machines). Scenarios could include future water availability and NGFS climate scenarios for central banks and supervisors. Environmental risks with financial impacts include increased water costs (or even unavailability) and increased CO2 emission costs.

For Costa Rica, based on total manufactures exports, 42% of sales are to the United States, with 6% to the Netherlands, 6% to Belgium, 5% to Guatemala, 5% to Panama, and 4% to Nicaragua. Manufactures are 23% fruits and vegetables, 23% medical instruments, 8% chemicals and related products, 7% machinery (mainly electrical), and 6% orthopedic appliances.

In an environmental risk analysis-strategic asset allocation integration for international reserves, environmental factors could include ecosystemic physical risk (e.g., industrial water and energy scarcity and extreme weather events) and policy transition risk (e.g., regulation of

CO2 emissions). Key economic sectors are fruits, medical instruments, chemicals and related products, machinery (mainly electrical), and orthopedic appliances. Scenarios could include future water availability and NGFS climate scenarios for central banks and supervisors. Environmental risks with financial impacts include increased water costs (or even unavailability), increased CO2 emission costs, and crop failures due to physical climate impact.

For Chile, based on total merchandise exports, 32% of sales are to China, with 14% to the United States, 9% to Japan, 7% to Canada, 7% to Korea, and 5% to Brazil. The merchandise is 48% copper, 11% vegetables and fruits, and 9% fish and similar products.

In an environmental risk analysis-strategic asset allocation integration for international reserves, environmental factors could include transition-related future copper demand (metals for renewable energy), ecosystemic physical risk (e.g., industrial water and energy scarcity and extreme weather events), and policy transition risk (e.g., regulation of CO2 emissions and sustainable mining). Key economic sectors are copper, fruits, and fish. Scenarios could include future water availability and NGFS climate scenarios for central banks and supervisors. Environmental risks with financial impacts could include transition-related copper price increases due to higher demand for electronics, electric vehicles (EVs), renewable energy sources, and energy efficiency; increased water costs (or even unavailability); increased CO2 emission costs with impacts on energy prices; interruptions in copper production due to extreme weather events (e.g., earthquakes), with impacts on copper production volumes and prices; and decreased crop and fish production due to physical climate impact, with impacts on fruit and fish production volumes and prices.

For Brazil, international reserves totaled US$356.89 billion in 2019, representing 19% of the national GDP and 160% of total annual merchandise exports. Food and agriculture represented 40% of exports, and fuel accounted for another 14% (11% crude oil). According to the IMF’s (2020) ARA metrics, 5% of total exports should be covered by international reserves assets allocated to hedge sudden stops in capital flows. In the Brazilian case, this would account for US$11.13 billion. Thus, a food and agriculture hedge of 40% of total exports would account for US$4.44 billion (1.2% of international reserves), and a fuel hedge of 14% of total exports would account for US$1.53 billion (0.4% of international reserves). Environmental risks have a direct impact on exports and capital flows and, from this perspective, an indirect impact on international reserves, considering their economic objectives of payment execution and intervention in FX markets. In an environmental risk analysis for the strategic asset allocation of the international reserves, the environmental factors would be mainly food, agriculture, and energy. The related environmental risks with financial percentage impacts in some specific time horizons could be increased CO2 emission costs and crop failures due to physical climate impacts. Some expected asset price movements due to these crisis scenarios would reduce the country's exports and impact the FX rate.

In all cases, strategic asset allocation could focus on hedging environmental risk analysis-related asset price movements, as detailed in Table 3, as well as considering other traditional strategic asset allocation-relevant data (e.g., international reserves economic objectives, investment guidelines and investment pillars).

Table 3

Environmental risk analysis-international reserves-strategic asset allocation: focus to be considered for hedge purposes

US$ billion in 2019	**Mexico**	**Brazil**	**Peru**	**Colombia**	**Argentina**	**Chile**	**Guatemala**	**Costa Rica**	**Dominican Republic**	**Jamaica**	**Total**
IR	183,06	356,89	67,71	52,65	45,22	40,66	14,78	8,94	8,87	3,63	782,40
GDP	1.258,30	1.839,80	226,80	323,80	449,70	282,30	76,70	61,80	88,90	16,50	
% IRs/GDP	15%	19%	30%	16%	10%	14%	19%	14%	10%	22%	
Total merchandise exports	461,12	222,64	47,77	39,46	65,12	69,68	11,19	11,80	1,14	0,17	930,08
% IRs/Exports	40%	160%	142%	133%	69%	58%	132%	76%	781%	2201%	
% IR assets allocated to hedge sudden stops in capital flows (ARA*)	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Total IR assets allocated to hedge of the external liabilities related to exports	23,06	11,13	2,39	1,97	3,26	3,48	0,56	0,59	0,06	0,01	46,50
Hedge for food & agriculture on total exports (e.g.: 40% BR)	1,78	4,44	0,56	0,37	2,00	1,13	0,29	0,25	0,02	0,00	10,83
Hedge for fuel on total exports (e.g.: 14% BR)	1,22	1,53	0,16	1,08	0,12	0,03	0,03	-	0,00	0,00	4,17
Hedge for ores & metals on total exports	0,42	0,14	1,09	0,02	0,02	1,83	0,00	0,01	0,00	0,00	3,53
Hedge for manufactures exports	17,73	3,72	0,23	0,42	0,57	0,49	0,24	0,33	0,04	0,00	23,76
%Hedge for food & agriculture / IRs	**1,0%**	**1,2%**	**0,8%**	**0,7%**	**4,4%**	**2,8%**	**1,9%**	**2,8%**	0,2%	0,1%	1,4%
%Hedge for fuel / IRs	**0,7%**	**0,4%**	**0,2%**	**2,0%**	**0,3%**	**0,1%**	**0,2%**	**0,0%**	0,0%	0,0%	0,5%
%Hedge for ores & metals / IRs	**0,2%**	**0,0%**	**1,6%**	**0,0%**	**0,0%**	**4,5%**	**0,0%**	**0,1%**	0,0%	0,1%	0,5%
%Hedge for manufactures / IRs	**9,7%**	**1,0%**	**0,3%**	**0,8%**	**1,3%**	**1,2%**	**1,6%**	**3,7%**	0,4%	0,0%	3,0%
- IR- SAA: focus to be considered for hedge purposes											
Exports/Commodities	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**No**	
Currency	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	

Source: prepared by the authors based on data from (Banco Mundial, 2021).

3.5 Conclusion

This study discussed the specific environmental risk exposures of ten central banks from LAC and respective international reserves, including hedge alternatives, and it proposed specific percentages to be considered. The study is relevant to the construction of international reserves investment portfolios in LAC. It considers national exposure, the international reserves' economic objectives, and the various angles that must be contemplated in the allocation of investment portfolios among countries and instruments.

The framework discussed herein includes environmental risk analysis in the traditional strategic asset allocation approach of international reserves. As result, environmental risk management is possible. The main argument is that central banks should include environmental risk analysis in the traditional strategic asset allocation approach because of the relevance of environmental risks to which international reserves are exposed. In this LAC sample, commodities are in focus due to the international reserves' economic objectives. The environmental risk exposures of the food and agriculture, fuel, and ores and metal sectors are identified, as are relevant exposures to physical climate risks in both countries located in the Caribbean (Jamaica and Dominican Republic), within the sample of ten countries.

For international reserves management, each viable portfolio should also be evaluated based on an environmental risk analysis. A hedging strategy is applicable for price movements of assets with relevant exposure to environmental risks, based on environmental risk analysis, considering other traditional strategic asset allocation relevant data, such as international reserves' economic objectives, investment guidelines, and investment pillars. An alternative to some central banks in the LAC sample could be to migrate to assets less correlated with commodities and currencies to mitigate relevant scenarios.

For instance, hedging alternatives might include assets that are less correlated, or even negatively correlated, to the commodities that are economically relevant to the national exports.

In addition, carbon intensity indicators can be considered in the review of strategic asset allocation to mitigate climate transition risks.

This study only addresses the environmental aspects of the ESG factors. Further studies could focus on social and governance factors from the international reserves management perspective. In addition, despite our holding initial meetings with the sample of central banks representatives from LAC, only one of them answered the questionnaire, which limits the applicable discussion of the framework. Our next study will focus on the risk–return analysis of the applied framework using specific asset alternatives and portfolios.

3.6 References

Aizenman, J., & Marion, N. (2002). International Reserve Holdings with Sovereign Risk and Costly Tax Collection. *NBER WORKING PAPER SERIES INTERNATIONAL*, *Setember*(Working Paper 9154). https://www.nber.org/system/files/working_papers/w9154/w9154.pdf

Allen, M., Rosenberg, C., Keller, C., Setser, B., & Roubini, N. (2002). A Balance Sheet Approach to Financial Crisis. *A Balance Sheet Approach to Financial Crisis*, *02*(210), 1–63. https://doi.org/10.5089/9781451957150.001.a001

Banco Central de Chile. (2019). *Gestión de Reservas Internacionales del Banco Central de Chile*. https://www.bcentral.cl/documents/33528/133286/GestionReservasInternacionales2019.pdf/7f296fee-2706-d6ca-dbc0-7dd596c5e496?t=1577374755637

Banco Central de Costa Rica. (2020). INFORME DE GESTIÓN DE LAS RESERVAS INTERNACIONALES NETAS DURANTE EL PRIMER SEMESTRE 2020. In *Informe Semestral de Reservas*. https://www.bccr.fi.cr/publicaciones/DocPoliticaCambiariaSectorExterno/Informe_GRI_I_sem_2020.pdf#search=reservas internacionales

Banco Central de Reserva del Perú. (2020). GESTIÓN DE LAS RESERVAS INTERNACIONALES: DICIEMBRE 2020. *NOTAS DE ESTUDIOS DEL BCRP*, *February*(15), 1–33. https://www.bcrp.gob.pe/docs/Publicaciones/Notas-Estudios/2021/nota-de-estudios-15-2021.pdf

Banco Central do Brasil. (2020). *Relatório de Gestão das Reservas Internacionais Relatório de Gestão das Reservas Internacionais* (Vol. 12, Issue Março). https://www.bcb.gov.br/content/estabilidadefinanceira/relgestaoreservas/GESTAORESERVAS202003-relatorio_anual_reservas_internacionais_2020.pdf

Banco Central Républica Dominicana. (2021). *Estadísticas - Sector externo*. https://www.bancentral.gov.do/a/d/2532-sector-externo

Banco de Guatemala. (2021). *Reservas Monetarias Internacionales*. https://www.banguat.gob.gt/es/page/reservas-monetarias-internacionales

Banco do México. (2019). *Financial Statements: Vol. December*. https://www.bcb.gov.br/content/estabilidadefinanceira/relgestaoreservas/GESTAORESERVAS202003-relatorio_anual_reservas_internacionais_2020.pdf

Banco Mundial. (2010). *Disaster Risk Management Caribbean Region: in Latin America and the GFDRR Country Notes*. https://openknowledge.worldbank.org/handle/10986/27336

Banco Mundial. (2021). *World Bank Open Data*. https://data.worldbank.org

Bank of England, UNEP Enquiry, & CISL. (2017). *Enhancing Environmental Risk Assessment in Financial Decision-Making* (Issue July). https://www.tcfdhub.org/resource/enhancing-environmental-risk-assessment-into-financial-decision-making/

Bank of Jamaica. (2021). *Annual Report 2020*. https://boj.org.jm/wp-content/uploads/2021/03/2020_boj_annual_report.pdf

Battiston, S., & Monasterolo, I. (2020). The Climate Spread of Corporate and Sovereign Bonds. *Working Paper*, 1–33. https://doi.org/10.2139/ssrn.3376218

Bolton, P., Despres, M., Pereira da Silva, L. A., Svartzman, R., & Samama, F. . (2020). *The green swan - Central banking and financial stability in the age of climate change* (Issue January). Bank for International Settlements (BIS). https://www.bis.org/publ/othp31.pdf

Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature*, *527*(7577), 235–239. https://doi.org/10.1038/nature15725

Caldecott, B., Tilbury, J., & Carey, C. (2014). Stranded Assets and Scenarios. In *Discussion Paper* (Issue January). https://www.smithschool.ox.ac.uk/research/sustainable-finance/publications/Stranded-Assets-and-Scenarios-Discussion-Paper.pdf

Calvo, G. A., Izquierdo, A., & Loo-kung, R. (2012). Optimal Holdings of International Reserves: Self-Insurance Against Sudden Stop. *NBER WORKING PAPER SERIES*, *July*(No. 18219), 1–35. https://doi.org/10.3386/W18219

Cambridge Centre for Sustainable Finance. (2016). *Environmental risk analysis by financial institutions – a review of global practice* (Issue September). https://www.cisl.cam.ac.uk/system/files/documents/environmental-risk-analysis.pdf

Carney, M. (2015). Breaking the Tragedy of the Horizon – climate change and financial stability. In *Speeches* (Issue 29 September). www.bankofengland.co.uk/publications/Pages/speeches/default.aspx

CFA UK. (2020). Curriculum - Chapter 1. In *Certificate in ESG Investing*. CFA Society UK.

CISL. (2015). *Unhedgeable risk: How climate change sentiment impacts investment*. https://www.cisl.cam.ac.uk/resources/sustainable-finance-publications/unhedgeable-risk

Detragiache, E. (1996). Fiscal Adjustment and Official Reserves in Sovereign Debt Negotiations. *Economica*, *63*(249), 81–95. https://doi.org/10.2307/2554635

Fender, I., McMorrow, M., Sahakyan, V., & Zulaica, O. (2019). Green Bonds: The Reserve Management Perspective. *BIS Quarterly Review*, *September*, 49–63.

Hawkins, R. G., & Rangarajan, C. (1970). On the Distribution of New International Reserves. *The Journal of Finance*, *25*(4), 881–891. https://doi.org/10.2307/2325423

International Monetary Fund. (2020). *Assessing Reserve Adequacy (ARA)*. Research. https://www.imf.org/external/np/spr/ara/

International Monetary Fund. (2021). *Data Template on International Reserves and Foreign Currency Liquidity (IRFCL)*. IMF Data. https://data.imf.org/?sk=2DFB3380-3603-4D2C-90BE-A04D8BBCE237&sId=1390030341854

IPCC. (2014). Climate Change 2014: Mitigation of Climate Change. Contribution of

Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. In *Climate Change 2014 Mitigation of Climate Change*. https://doi.org/10.1017/cbo9781107415416

Kaminsky, G., Lizondo, S., & Reinhart, C. M. (1998). Leading Indicators of Currency Crises. In *IMF Staff Papers* (Vol. 45, Issue 1, pp. 1–48). https://doi.org/10.2307/3867328

Kohlscheen, E., & O'Connell, S. A. (2004). A Sovereign Debt Model with Trade Credit and Reserves. *Mimeo*, *743*. https://doi.org/10.2139/ssrn.941107

McCauley, R. N., & Rigaudy, J.-F. (2011). Managing foreign exchange reserves in the crisis and after. *BIS Working Papers No. 58*, *58*, 19–47. http://papers.ssrnhttps//www.bis.org/publ/bppdf/bispap58b.pdf

McKibbin, W. J., Morris, A. C., Wilcoxen, P. J., & Panton, A. J. (2020). Climate change and monetary policy: Issues for policy design and modelling. *Oxford Review of Economic Policy*, *36*(3), 579–603. https://doi.org/10.1093/oxrep/graa040

McKinsey Global Institute. (2020). Climate risk and response Physical hazards and socioeconomic impacts. *McKinsey Global Institute*, *January*, 164. https://www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts

Mercer. (2011). Climate Change Scenarios – Implications for Strategic Asset Allocation. *Public Report*. https://doi.org/10.2139/ssrn.1911824

Mercer. (2015). *Investing in a time of climate change*. http://www.mercer.com/services/investments/investment-opportunities/responsible-investment/investing-in-a-time-of-climate-change-report-2015.html

Mora, C., Dousset, B., Caldwell, I. R., Powell, F. E., Geronimo, R. C., Bielecki, C. R., Counsell, C. W. W., Dietrich, B. S., Johnston, E. T., Louis, L. V., Lucas, M. P., Mckenzie, M. M., Shea, A. G., Tseng, H., Giambelluca, T. W., Leon, L. R., Hawkins, E., & Trauernicht, C. (2017). Global risk of deadly heat. *Nature Climate Change*, *7*(7), 501–506. https://doi.org/10.1038/nclimate3322

NGFS. (2019). A call for action: Climate change as a source of financial risk. *NGFS First Comprehensive Report*, *April*, 1–40. https://www.ngfs.net/sites/default/files/medias/documents/ngfs_first_comprehensive_report_-_17042019_0.pdf

NGFS. (2020a). NGFS Climate Scenarios for central banks and supervisors. *Network for Greening the Financial System, June*. https://www.ngfs.net/sites/default/files/media/2021/08/27/ngfs_climate_scenarios_phase2_june2021.pdf

NGFS. (2020b). Progress report on the implementation of sustainable and responsible investment practices in central banks' portfolio management. In *NGFS Technical document* (Issue December). https://www.ngfs.net/sites/default/files/medias/documents/sri_progress_report_2020.pdf

NGFS. (2021). Adapting central bank operations to a hotter world Reviewing some options NGFS Technical document. In *NGFS Technical document* (Issue March). https://www.ngfs.net/en/adapting-central-bank-operations-hotter-world-reviewing-some-options

PRI. (2019). *Embedding ESG issues into strategic asset allocation frameworks - A discussion paper*. https://www.unpri.org/embedding-esg-issues-into-strategic-asset-allocation-frameworks-discussion-paper/4815.article

Robins, N., Dikau, S., & Volz, U. (2021). Net-zero central banking: A new phase in greening the financial system Acknowledgements. In *Policy report* (Issue March). https://www.lse.ac.uk/granthaminstitute/publication/net-zero-central-banking-a-new-phase-in-greening-the-financial-system/

Roncoroni, A., Battiston, S., Escobar-Farfán, L. O. L., & Martinez-Jaramillo, S. (2021). Climate risk and financial stability in the network of banks and investment funds. *Journal of Financial Stability*, *54*, 100870. https://doi.org/10.1016/j.jfs.2021.100870

Shalal, A. (2021). *Climate-risk disclosure requirements will spark huge investments -U.S. official*. Reuters - Commodities. https://www.reuters.com/article/imf-world-bank-climate-idAFL1N2M034X

Silva Jr., A. F. A. (2011). The Self-Insurance Role of International Reserves and the 2008-2010 Crisis. *Central Bank of Brazil Working Paper*, *256*, 1–26. https://doi.org/10.2139/ssrn.1956702

Sveriges Riksbank. (2019). *Flodén: Riksbank selling bonds for climate reasons*. Speeches and Presentations. https://www.riksbank.se/en-gb/press-and-published/speeches-and-presentations/2019/floden-riksbank-selling-bonds-for-climate-reasons/

TCFD. (2017). Recommendations of the Task Force on Climate-related Financial Disclosures. *Task Force on Climate-Related Fiancial Disclosures*, *June*, 1–74. https://assets.bbhub.io/company/sites/60/2020/10/FINAL-TCFD-Annex-Amended-121517.pdf

The World Bank. (2020). *Total reserves (includes gold, current US$)*. https://data.worldbank.org/indicator/fi.res.totl.cd?view=chart.

Torinelli, V. H., & Silva Júnior, A. F. de A. da. (2021). Environmental risk analysis (ERA) in the strategic asset allocation (SAA) of the international reserves (IRs) managed by central banks (CBs). *Latin American Journal of Central Banking*, *2*(1), 100021. https://doi.org/10.1016/j.latcb.2021.100021

Volz, U., Beirne, J., Preudhomme, N. A., Fenton, A., Mazzacurati, E., Renzhi, N., & Stampe, J. (2020). Climate Change and Sovereign Risk. In *SOAS Centre for Sustainable Finance* (Issue October). https://doi.org/10.25501/SOAS.00033524

4 Study 3:

Portfolio optimization and multi-objective analysis, including environmental and climate risks: towards a more resilient management of international reserves by central banks.

Viviane H. Torinelli[1,2], Antônio F. A. Silva Júnior[1,2], Pedro H. Lofiego Sampaio da Silva[3], and José Célio Silveira Andrade[1,2]

[1] Business School, Universidade Federal da Bahia, Salvador, Bahia, Brazil (UFBA),

[2] Brazilian Research Alliance for Sustainable Finance and Investment (BRASFI),

[3] Pontifícia Universidade Católica de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil (PUC-MG)

Author Note

Viviane H. Torinelli https://orcid.org/0000-0002-1330-6370

Antônio F. A. Silva Júnior https://orcid.org/0000-0002-4417-5991

Pedro H. Lofiego Sampaio da Silva https://orcid.org/0000-0002-3679-6341

José Célio Silveira Andrade https://orcid.org/0000-0002-6794-8686

Correspondence email: vivitorinelli@gmail.com

Abstract

This study presents the portfolio optimization with multi-objective analysis under the scope of an environmental and climate risk management of the international reserves by central banks. This is the third study of a series. In the first one, a framework was proposed for environmental and climate risk management of the international reserves. The second study discussed the application of the framework to a sample of central banks from Latin America and the Caribbean. This third study presents a portfolio optimization with multi-objective analysis based on the applied framework, including specific asset alternatives and portfolios. The analysis included the risk/return perspective, alongside the evaluation of environmental exposures, hedge strategies to address the economic objectives of the international reserves, and the implications to the weighted average carbon intensity of the portfolios. As results, investment managers can consider portfolios more resilient to environmental and climate risks without undermining the financial and economic objectives.

Keywords: portfolio optimization, multi-objective, environmental and climate risk, international reserves, central banks

4.1 Introduction

Environmental factors are a source of financial risks. Risks need to be identified, measured, and managed. Even though proper risk management is essential for efficient investment management, environmental and climate risk management is a challenge to investors, including central banks when acting as managers of the International Reserves (NGFS, 2020b, 2020a). The theoretical and practical gaps in this subject were highlighted by NGFS, the Network of Central Banks for Greening the Financial System (NGFS, 2018, 2019, 2020c).

International reserves are investments held by central banks in foreign currencies to execute the monetary and foreign exchange (FX) policies, thus being classified in the policy portfolios of the central banks (NGFS, 2019; Silva Jr., 2011). The economic objectives of the international reserves include intervention in the FX market, execution of payment for goods and services, execution of payments for the government, granting of emergency liquidity assistance, underpinning of investor confidence in the country, and investment of excess reserves (Fender et al., 2019). For that, international reserves totaled US$15.239 trillion in 2020 (The World Bank, 2021a).

In emerging markets, as Latin America and the Caribbean, international reserves provide two important and widely accepted functions for central banks: self-insurance (Calvo et al., 2012) and warning signaling (Kaminsky et al., 1998). Avoiding environmental risks, such as climatic ones, is compatible with these two rationales.

In this context and in the search for contributions to this knowledge gap, this study presents portfolio optimization under the scope of an environmental and climate risk management of the international reserves by central banks. The research question is: which are the risk, return and Weighted Average Carbon Intensity (WACI) impacts of an environmental and climate risk management performed through strategic asset allocation of the international reserves? A multi-objective analysis was performed, considering the risk/return perspective, alongside the evaluation of environmental exposures, hedge strategies to address the economic objectives of the international reserves, and the implications to the WACI of the portfolios.

This is the third study of a series. In the first one it was proposed a framework for environmental and climate risk management of the international reserves (Torinelli & Silva Júnior, 2021). The second study discussed the application of the framework to a sample of central banks from Latin America and the Caribbean (Torinelli et al., 2021). This third study presents a risk/return analysis of the applied framework, including specific asset alternatives and portfolios. As results of the application of this study, portfolios may be more resilient to environmental and climate risks.

The methodology used to evaluate the impacts of the proposed framework included desk review and portfolio simulation and optimization using the software R, with synthesized data. The investment alternatives and the correlation matrix were discussed, alongside WACI and risk/return analysis, to test the application of the framework for the management of the international reserves by central banks.

This paper proceeds as follows: Section 4.2 covers Responsible and ESG Investment, based on Environmental, Social and Governance factors (ESG), alongside environmental and climate risk management through strategic asset allocation; Section 4.3 presents the methodology of this research; Section 4.4 present the results and discussions of this study. The paper concludes in Section 4.5 with an outlook for future research.

4.2 Responsible and ESG investment, alongside environmental and climate risk management through strategic asset allocation

Responsible and ESG Investment, alongside environmental and climate risk management, are intrinsically related to the strategic asset allocation of the investment portfolios. This section will discuss the specific risks, return, and impact in the responsible and

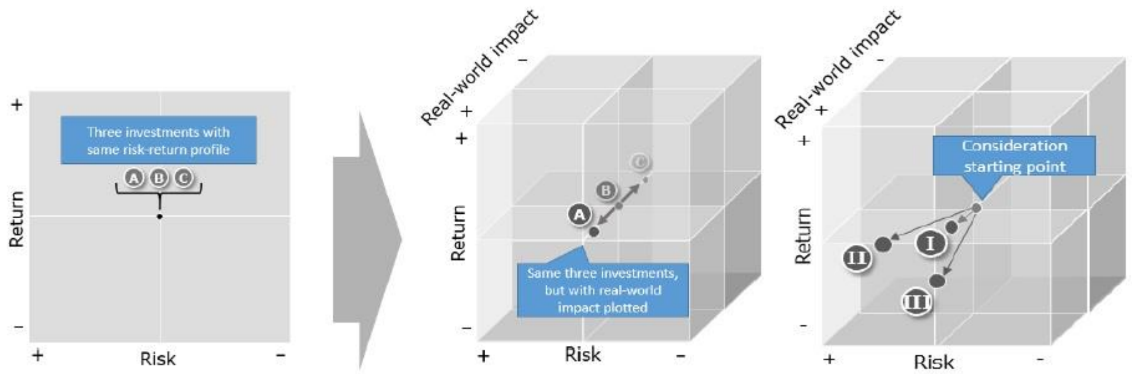
ESG investment (2.1); the environmental and climate risk management, alongside sustainable and responsible investment, for central banks (2.2); the environmentally and climate adjusted framework for strategic asset allocation of international reserves (2.3); and an applied framework discussion for a sample of analyzed central banks from Latin America and the Caribbean (2.4).

4.2.1 Risk, return and impact in the responsible and ESG investment

For responsible investment purposes, on top of the traditional risk and return dimensions, a third dimension of analysis is included: the real-world-impact (PRI, 2019). Investors can choose different investment portfolios prioritizing risk/return in the analysis or start the selection by the real-world-impact dimension (see Figure 1). In both cases, ESG factors may be among the choice criterion, including the Sustainable Development Goals (SDGs), with positive impact in the real-world.

Figure 1

Third dimension of investment analysis



Source: PRI (2019).

ESG factors embedded in the investment strategy, in a so called ESG integration strategy, led to implications in efficient investment frontier. Pedersen et al. (2021) compared the efficient frontiers with and without ESG information and found an increase in the maximum risk-adjusted return (Sharpe ratio) in the frontier based on ESG information, what demonstrates the benefits of this additional data. In the other hand, a drop in Sharpe ratio is noted when choosing a portfolio with better ESG characteristics than those of the portfolio with maximum Sharpe, what indicates the cost of ESG preferences. According with Pedersen et al. (2021), when analyzing ESG scores for firms:

> The maximum sharp ratio is achieved for a relatively high level of ESG. Increasing the ESG level even further leads to only a small reduction in sharp ratio, implying that ethical goals can be achieved at a small cost … screens that remove the lowest ESG assets from the investment universe can lead investors who maximize their Sharpe ratio to choose a portfolio with lower ESG scores than those chosen by unconstrained investors who allow investments in low-ESG assets. This result highlights nuances in optimally incorporating ESG into portfolio construction and suggests improvements to traditional approaches based on simple screening. (p. 593)

Risk-adjusted-returns are affected by sustainable investing, increasing the cost of capital of the most environmentally risky companies, and providing a premium to the most sustainable ones, whether through exclusionary screening or ESG integration. The exclusion of certain assets from the range of eligible investments is known as “exclusionary screening”, while ESG integration involves overweighting assets with high ESG ratings and underweighting those with low ESG ratings. According with Zerbib (2020) in a study based on 453 green funds investing in U.S. stocks between 2007 and 2019:

> The integration of environmental criteria by green investors impacts the different industries with an annual premium ranging from -1.12% for the most overweighted to +14 bps for the most underweighted industries, while the average annual exclusion effect of sin stocks is 1.43%. (pp. 3,4)

Meta-studies indicate that sustainability, responsibility and profitability are not incompatible, but complementary. According with Clark et al. (2015) after analysis of more than 200 different sources, 88% indicate that companies with robust sustainability practices demonstrate better operational performance, which ultimately translates into cashflows; and 80% demonstrate that prudent sustainability practices have a positive influence on investment performance. Also, Friede et al. (2015) combined the findings of about 2200 individual studies. The results show that around 90% of studies find a nonnegative relation between ESG and corporate financial performance (CFP) and most studies reports positive findings. Positive ESG impact on CFP appears stable over time.

The same positive relation between ESG and financial performance was found after analysis of aggregating evidence from 1,000 plus studies published between 2015 and 2020 (Whelan et al., 2021). What becomes even more clear over time is the positive relation between business strategy focused on material ESG issues, sustainability, good governance, quality, improved risk management, more innovation and then improved returns. Whelan et al. (2021) highlight that:

1. Improved financial performance due to ESG becomes more marked over **longer time horizons**; 2. ESG integration, broadly speaking as an investment strategy, seems to perform better than negative screening approaches; 3. **ESG investing appears to provide downside protection**, especially during a **social or economic crisis**.

In the other hand, there are still some questionings about the relationship between ESG and alpha (better returns). The main allegation is that quality and good management themselves are a proxy of better returns. As it is contained inside the concept of Governance and then ESG, they could be considered separately (Bruno et al., 2021; Johnson, 2021; Pucker, 2021). Bruno et al. (2021) do not question that ESG strategies can offer substantial value to investors, but they suggest that investors who look for value-added through outperformance are looking in the wrong place. They highlight the ESG investing benefits such as hedging climate or litigation risk, aligning investments with norms, and making a positive impact for society.

On the risk side, ESG investments outperformed during the 2020 and 2021 covid-19 crisis (Feuer, 2021; Whieldon & Clark, 2021). This provides some evidence of suitability of this investment strategy for improving the investment portfolios resilience to crisis linked to ESG factors, for countercyclicality purposes. Also, it may be considered that long term investors are more likely to invest in ESG alternatives, what may lead to lower withdraws, better multiples and possibly better returns.

Another specific risks to be considered for responsible and ESG investments are the greenwashing/rainbow washing, as well as higher rates been charged on ESG funds and ETFs (Taparia, 2021; Wursthorn, 2021). Investors may not get the positive impact they're paying for, and ESG investors may be paying for unreasonable higher rates. Increased transparency and comparability may help address this issue, alongside improved regulation.

4.3 Environmental and climate risk management, alongside sustainable and responsible investment, for central banks

In 2019, the Network of Central Banks for Greening the Financial System (NGFS) published a guide on how central banks could integrate Sustainable and Responsible Investment (SRI) practices into their portfolio management (NGFS, 2019), with update in 2020 (NGFS, 2020c). Reputational risk and setting a good example are considered as the key motivations for the adoption of SRI practices, followed by protecting against downward ESG and climate related risks. Other minor reasons are enhancing risk-return profile; complying with international standards or frameworks; generating positive impact (e.g., by investing in line with Paris Agreement, SDGs); required by beneficiaries/stakeholders; fiduciary duty; legal requirements and others.

According with NGFS (2020c), in policy portfolios, six central banks (29%) apply negative screening for Sovereign, Supranational and Agencies (SSA) bonds, nine (75%) apply for corporate bonds, six (29%) for equities and three (14%) for covered bonds. In turn, best in class strategy is applied only by two central banks (10%) for corporate bonds and one central bank (5%) for equities. Meanwhile, the ESG integration is adopted by four central banks (19%) for SSA bonds, two central banks for corporate bonds (10%) and one central bank (5%) for equities. Green bonds are included by 16 central banks (76%) for SSA bonds, nine central banks (43%) for corporate bonds and seven central banks (33%) for covered bonds. Impact investment is only adopted by two central banks, one for SSA bonds and another for covered bonds (5% each). Voting and engagement are also only considered by two central banks, one for SSA bonds and one for equities (5% each). In general, carbon footprints in portfolios are measured by seven central banks (33%) and reported by 3 of them (15%).

In 2021, the NGFS published a guide on climate-related disclosure for central banks (NGFS, 2021). The guide takes, as its starting point, the recommendations of the Financial Stability Board's Task Force on Climate-related Financial Disclosures (TCFD) and focus on climate-related financial exposures. The guidance has implications to governance, strategy, and risk management of central banks, including the **monetary policy portfolios with the international reserves**. Central banks are recommended to disclose their high-level approach to climate-related risks and opportunities, in a governance perspective, as well as their strategies for identifying and assessing the inward and outward impacts of climate-related risks. According to NGFS (2021), central banks:

> could describe whether there are any specific risk constraints attached to monetary policy portfolios that prevent sustainability and responsibility principles from being applied to these portfolios (p. 11) … are recommended to disclose whether they have a sustainable and responsible investment strategy (p. 16) … could start by using backward looking methodologies to identify, assess, and disclose their climate-related exposures associated with credit facilities and investment portfolios (p. 20) … are

recommended to use forward-looking methodologies, where possible, to identify and disclose climate-related risks. (p. 20)

Further, NGFS (2021) recommend the analysis and disclosure of physical and transition risks, as follows:

… to break down physical risks into chronic and acute risks, as well as by sectoral impact (p. 21) to disclose whether, and how, they have assessed the ability of monetary policy counterparties, as well as issuers in their portfolios, to prevent, withstand, or recover from impacts of natural disasters and substantially higher average temperatures (p. 22) to assess and disclose the impact of material transition risk on their credit facilities and investment portfolios. (p. 23)

The greenhouse gas footprint is the recommended backward-looking metric to initially assess central bank´s exposure to transition risk (NGFS, 2021). The main understanding is that issuers with high direct or indirect emissions would be more severely affected by future mitigation of climate change than the ones which are less exposed, resulting in higher potential losses on such investments. As stated by NGFS (2021):

financed greenhouse gas emissions can be computed using weighted average carbon intensity (p. 23) … For central banks' investment portfolios, weighted average carbon intensity can be computed as $\sum_{i=1}^{N}\left(\frac{market\ value\ of\ investment\ in\ issuer\ i}{market\ value\ of\ portfolio}\frac{emissions\ of\ issuer\ i}{economic\ activity\ of\ issuer\ i}\right)$, where N is the number of assets in the portfolio. (p. 23)

In the same direction, in 2021, the Basel Committee on Banking Supervision issued a consultative document on the principles for the effective management and supervision of climate-related financial risks (Bank for International Settlements, 2021c), one analytical report on climate-related risk drivers and their transmission channels (Bank for International

Settlements, 2021b) and another publication covering measurement methodologies to climate-related financial risks (Bank for International Settlements, 2021a).

On the strategic side, according with BIS (Bank for International Settlements, 2021b), investment strategies may contribute to the management of investment portfolios against climate risk, including diversification to mitigate the impact of idiosyncratic risks, however, "diversification strategies may become less effective as increasing global temperatures lead to more widespread and/or correlated extreme weather events" (p. 28).

On the methodological side, according with BIS (2021a), calculating the gross exposure of an asset or portfolio is important to understand the exposure and help inform the risk decision-maker about the present magnitude of climate-related risks and how these risks might evolve over time. Also, "methodologies that are less complex and more tolerant of sparse data may be more useful for strategic planning or portfolio allocation" (p. 7). Notwithstanding, the nature of climate risks demands more complex analyses, as follows:

> The systemic nature of climate change might imply many interconnections and feedback loops, as well as likely non-linearities and tipping points … a combination of multiple methods and models may be needed for a comprehensive understanding and measurement of the potential scope of climate change risks. (p. 43)

4.3.1 The environmentally and climate adjusted framework for strategic asset allocation of international reserves

The management of environmental and climate risks, alongside the sustainable and responsible investment, must be considered by central banks as managers of the international reserves, given the worldwide relevance of the sustainability discussion and the financial materiality of the ESG factors (NGFS, 2021).

The output of an environmental and climate risk analysis may provide new and relevant information to the framework for strategic asset allocation of international reserves by central banks (Torinelli et al., 2021; Torinelli & Silva Júnior, 2021). Thus, the output of an environmental and climate risk analysis may be considered alongside the international reserves' economic objectives and investment guidelines, in addition to other main concerns of the international reserves managers, since environmental and climate risk management is not their primary concern. Instead, their primary concern is to adequately address the reasons that motivate the international reserves' existence (which may vary by central bank).

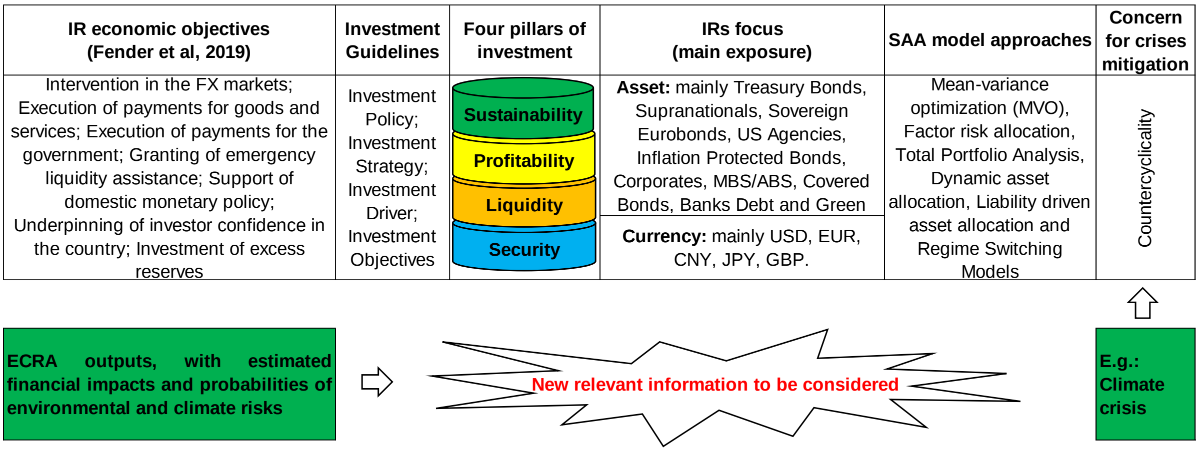
Hence, environmental and climate risk exposures will be considered jointly with concerns about currency, asset class, countercyclicality (for crisis mitigation), and the relevance of each of the three international reserves investment pillars: security, liquidity, and profitability. The relevance of each pillar depends on the strategic objectives of each international reserves manager, which ultimately reflect the reasons for which the reserves are being maintained.

Central banks can evaluate the adequacy to adjust the traditional framework for strategic asset allocation of international reserves to include sustainability as a fourth pillar of the international reserves management objectives, with highlights to the environmental and climate factors, based on the outputs of the environmental and climate risk analysis.

Thus, in a sustainable and responsible investment strategy, central banks may consider to a) mitigate environmental and climate risks in their portfolios; and/or b) to create a positive impact on the environment and society alongside financial returns, but this second alternative depends on the mandate of each central bank. See Figure 2 for the environmentally and climate adjusted framework for strategic asset allocation of international reserves:

Figure 2

Environmentally and climate framework for strategic asset allocation of international reserves.



Source: Torinelli and Silva Jr (2021), based on Fender et al. (2019).

The practical possible impacts of the environmental and climate risk analysis on the framework for strategic asset allocation of international reserves are: 1) Inclusion of new asset alternatives: 1.1) Inclusion of Green Asset Classes (e.g.: Green Bonds, Green Funds, Green Indexes in passive portfolios etc.); 1.2) Inclusion of other asset alternatives, as unlisted funds, if appropriate to the environmentally adjusted framework for strategic asset allocation; 2) Rebalance among existing asset classes, regions/countries, sectors, and sub asset classes: 2.1) Divestments from high carbon footprint and/or high temperature alternatives; 2.2) Investments to explore opportunities towards lower carbon footprint and/or lower temperature; 2.3) Migration to assets less correlated with the environmental and climate risks to be mitigated; 3) Inclusion of environmental and climate risk management considerations in the selection of asset managers, fund managers and companies (Torinelli & Silva Júnior, 2021).

4.3.2 An applied framework discussion for the analyzed central banks from Latin America and the Caribbean

The framework detailed in the previous section was discussed with some central banks from Latin America and the Caribbean (Torinelli et al., 2021). The study was based on a sample of ten central banks, taking into consideration the national exports of the respective countries, the risk of sudden stops in capital flows and the international reserves' economic objectives. The specific environmental and climate risk exposures were discussed, as well as the alternatives to environmental and climate risk management through the strategic asset allocation of the international reserves.

Emerging market and developing economies, as the ones in Latin America and the Caribbean, are less resilient to climate risks and have been hit much harder by climatic disasters than advanced economies (Bank for International Settlements, 2021b). The heterogeneity of the environmental and climate risk analysis by geography, by sector and by jurisdiction was highlighted by BIS (2021b), and similar portfolios may face very different levels of climate-related financial risks depending on where the related assets and the banks themselves are located. Thus, reinforcing the relevance of this analysis.

Commodities are economically relevant for all analyzed countries in the sample and are highly exposed to environmental and climate risks. This exposure may be partially hedged and managed through diversification. According to BIS (2021b):

> higher global temperatures are also expected to have an outsize impact on agriculture and tourism, resulting in larger adverse effects in countries with activity concentrated in these sectors, while transition risk drivers may have an outsize impact on economies that are heavily reliant on the production of fossil fuels (p. 24) … A derivatives market is crucial to hedging climate change risks affecting corporations or commodities (and agricultural commodities in particular) (p. 24) … Proactive actions include those that banks take to pre-emptively reduce their vulnerability to climate-related financial risks, e.g., through diversification. (p. 27)

According with UNEP-FI (2019), assets associated with the agriculture, mining, and petroleum sectors, alongside utilities and transportation, are the most exposure to climate-related losses, while:

> the value of manufacturing assets should decline by less but could pose a greater risk to banks' portfolios given their higher portfolio contribution … UNEP-FI considered a portfolio of 30,000 listed companies under a 1.5°C scenario by 2100 and estimated that the portfolio could lose 13.16% of its value as a result of the transition to a low carbon economy. (Bank for International Settlements, 2021b, pp. 14, 16)

As detailed in the Table 1, international reserves for the selected sample totaled US$782.4 billion in 2019, representing 17% of the national GDP and 84% of total annual merchandise exports. Food & agriculture represented 23% of exports, fuel accounted for 9% and ores represented other 8%. According to the Assessing Reserve Adequacy (ARA) metrics of the International Monetary Fund (IMF, 2020), 5% to 7,5% of total exports should be covered by international reserves assets allocated to hedge sudden stops in capital flows. In the sample case, this would account for US$46.50 to US$69.76 billion. Thus, considering the 5% totaling US$46.50 billion, the portion to hedge for food & agriculture on total exports would account for US$10.83 billion (23.29%), US$4.17 billion (9%) for fuel and US$3.53 billion for ores & metals.

The sectors of food & agriculture, fuel and ores & metals are significantly exposed to environmental and climate risks, including the physical and transition climate ones. This exposure has implications for exports, capital flows and, in this perspective, an indirect impact on international reserves. The international reserves would be affected in its economic objectives, since sudden stops of capital flows may lead to intervention in forex markets, underpinning investors' confidence in the country.

In an environmental and climate risk analysis for the international reserves of the sample, the economic sectors on spot would be food & agriculture, fuel and ores & metals. The environmental factors could be climatic transition, with avoidance of GHG emissions, besides the physical climatic impacts due to changes in temperature and precipitation patters, with extreme events.

The related environmental and climate risks, with potential financial impacts in different time horizons, could be increased GHG emission costs, stranded-assets due to changes in policy, regulation, and technology towards a more sustainable economy, as well as crop breaks due to physical climate changes, among others.

For example, Copper is essential to the clean energy transition, but social and environmental impacts of copper mines could jeopardize the long-term supply of this ore, which is among top exports in Chile and Peru. In case of higher policy and regulation barriers, as well as increase in technological substitutes, supply may be threatened, with negative impacts in the clean energy transition (Kemp et al., 2021). As stated by the European Critical Raw Material strategy, the EU sustainable finance taxonomy "will address the enabling potential of the mining and extractive value chain and the need for the sector to minimize its impacts on the climate and environment, taking into account life cycle considerations" (European Commission, 2020, p. 8). Also, regarding the mining sector, the EU Technical Working Group of the Platform on Sustainable Finance is working for on:

> setting criteria that ensure do no significant harm (DNSH) for all environmental objectives in accordance with the taxonomy criteria, in particular for the protection and restoration of biodiversity and ecosystems and the sustainable use and protection of water and marine resources. (Platform on Sustainable Finance, 2021, p. 19)

Table 1

An applied framework discussion for the analyzed central banks from Latin America and the Caribbean.

US$ billion in 2019	Mexico	Brazil	Peru	Colombia	Argentina	Chile	Guatemala	Costa Rica	Dominican Republic	Jamaica	Total
IR	183,06	356,89	67,71	52,65	45,22	40,66	14,78	8,94	8,87	3,63	782,40
GDP	1.258,30	1.839,80	226,80	323,80	449,70	282,30	76,70	61,80	88,90	16,50	4.624,60
% IRs/GDP	15%	19%	30%	16%	10%	14%	19%	14%	9,98%	22%	17%
Total merchandise exports	461,12	222,64	47,77	39,46	65,12	69,68	11,19	11,80	1,14	0,17	930,08
% IRs/Exports	40%	160%	142%	133%	69%	58%	132%	76%	781%	2201%	84%
Food & agriculture raw material exports	35,51	88,83	11,23	7,38	39,98	22,58	5,71	5,09	0,33	0,04	216,66
% food & agriculture on total exports	8%	40%	24%	19%	61%	32%	51%	43%	29%	23%	23%
Fuel exports	24,44	30,50	3,30	21,58	2,41	0,63	0,51	0,00	0,00	0,03	83,41
% fuel on total exports	5%	14%	7%	55%	4%	1%	5%	0%	0%	19%	9%
Ores & Metals	8,30	2,89	21,73	0,39	0,33	36,65	0,09	0,17	0,02	0,09	70,67
% ores & metals on total exports	2%	1%	46%	1%	1%	53%	1%	1%	2%	55%	8%
Manufactures exports	354,60	74,36	4,54	8,33	11,33	9,83	4,88	6,54	0,79	0,01	475,19
% manufactures on total exports	77%	33%	10%	21%	17%	14%	44%	55%	69%	3%	51%
% IR assets allocated to hedge sudden stops in capital flows (ARA*)	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Total IR assets allocated to hedge of the external liabilities related to exports	23,06	11,13	2,39	1,97	3,26	3,48	0,56	0,59	0,06	0,008	46,50
Hedge food&agro on exports (e.g.:40%BR)	1,78	4,44	0,56	0,37	2,00	1,13	0,29	0,25	0,02	0,00	10,83
Hedge fuel on exports (e.g.:14%BR)	1,22	1,53	0,16	1,08	0,12	0,03	0,03	-	0,00	0,00	4,17
Hedge for ores & metals on total exports	0,42	0,14	1,09	0,02	0,02	1,83	0,00	0,01	0,00	0,00	3,53
Hedge for manufactures exports	17,73	3,72	0,23	0,42	0,57	0,49	0,24	0,33	0,04	0,00	23,76
%Hedge for food & agriculture / IRs	1,0%	1,2%	0,8%	0,7%	4,4%	2,8%	1,9%	2,8%	0,2%	0,1%	1,4%
%Hedge for fuel / IRs	0,7%	0,4%	0,2%	2,0%	0,3%	0,1%	0,2%	0,0%	0,0%	0,0%	0,5%
%Hedge for ores & metals / IRs	0,2%	0,0%	1,6%	0,0%	0,0%	4,5%	0,0%	0,1%	0,0%	0,1%	0,5%
%Hedge for manufactures / IRs	9,7%	1,0%	0,3%	0,8%	1,3%	1,2%	1,6%	3,7%	0,4%	0,0%	3,0%

* ARA: Assessing Reserve Adequacy - International Monetary Fund (IMF)

Source: Torinelli et al. (2021).

The uncertainties around the mining sector in the sustainability agenda (Mellman et al., 2021) may lead to considering a hedge strategy for climate transition risks related to this industry in case the world finds alternatives to some raw materials or take decisions with material financial impacts to be considered. Notwithstanding, climate physical risk, as changes in weather patterns, may impact water and energy supply, with consequent implications to this water and energy intensive industry.

In general, for the sample from Latin America and the Caribbean, some expected asset-price movements in crisis scenarios would reduce country exports and have an impact on the foreign exchange rate. The impacts could also be related to stranded-assets in the O&G sector; appreciation of clean energy assets; variation in ores & metals demand due to technological changes and the transition to a low-carbon economy, as well as potential decrease in water availability and increase in energy and operational costs; decrease in total exports due to crop breaks or to physical and transition constraints in the mining sector; decrease on non-regenerative agriculture average asset prices; stranded-assets related to policy and regulation changes towards biodiversity conservation (e.g.: reduction in the legal deforestation zone on agricultural lands); etc.

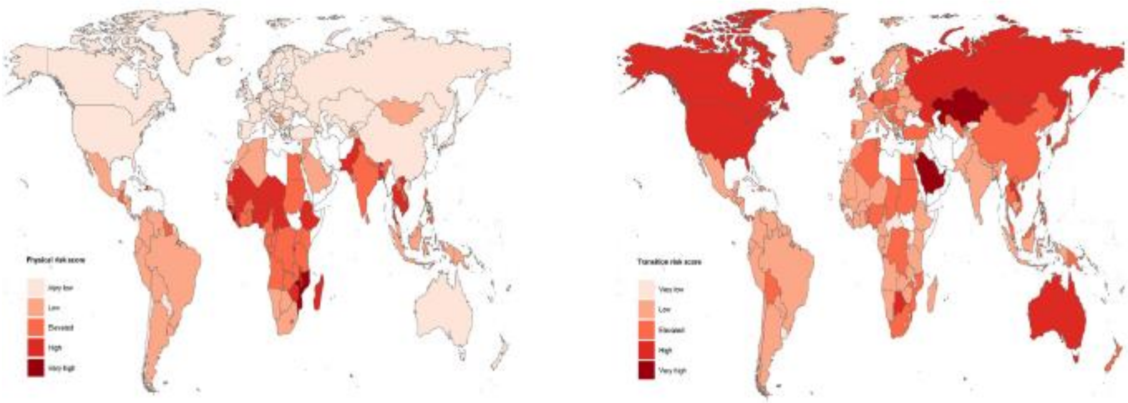
The exercise of strategic asset allocation may consider portfolios for the investment of the international reserves that are more resilient to these scenarios. It is applicable a hedge strategy to asset price movements related to an environmental and climate risk analysis, considering also other relevant data to the traditional strategic asset allocation, as international reserves economic objectives, investment guidelines and investment pillars. **An alternative to some analyzed central banks from Latin America and the Caribbean could be to migrate to assets less correlated with agricultural, metals & mining and oil commodities, as example of relevant scenario to be mitigated.**

Also, the strategic asset allocation could drive the choice of currencies in the portfolio to those currencies that are less correlated to the specific economic exposure or foreign exchange rate exposure, for each analyzed country from Latin America and the Caribbean, in the relevant scenarios, to avoid procyclicality. The environmental and climate risk analysis helps to quantify the size of the impact on the economy and the dimension of this impact in the investments of international reserves. Furthermore, the choice of asset classes could consider those related to clean energy. **The choice of currency is easier from a traditional perspective. On the other hand, the choice of asset classes is more difficult due to liquidity issues, since green asset classes eligible to central banks are traditionally agencies, supranationals, and some issuers of sovereigns. However, it would be possible to search for small amounts of investments in these kinds of asset classes.**

Further, central banks may avoid higher environmental and climate risk exposures in the selected sovereign investment alternatives. Some studies may support this analysis, as the EIB (Ferrazzi et al., 2021) providing physical (left) and transition (right) risk country scores in the world (see Figure 3); the Germanwatch (Eckstein et al., 2021), with a world map of the Global Climate Risk Index 2000 – 2019 (see Figure 4); the ND-GAIN (2021) with its Country Index (see Figure 5).

Figure 3

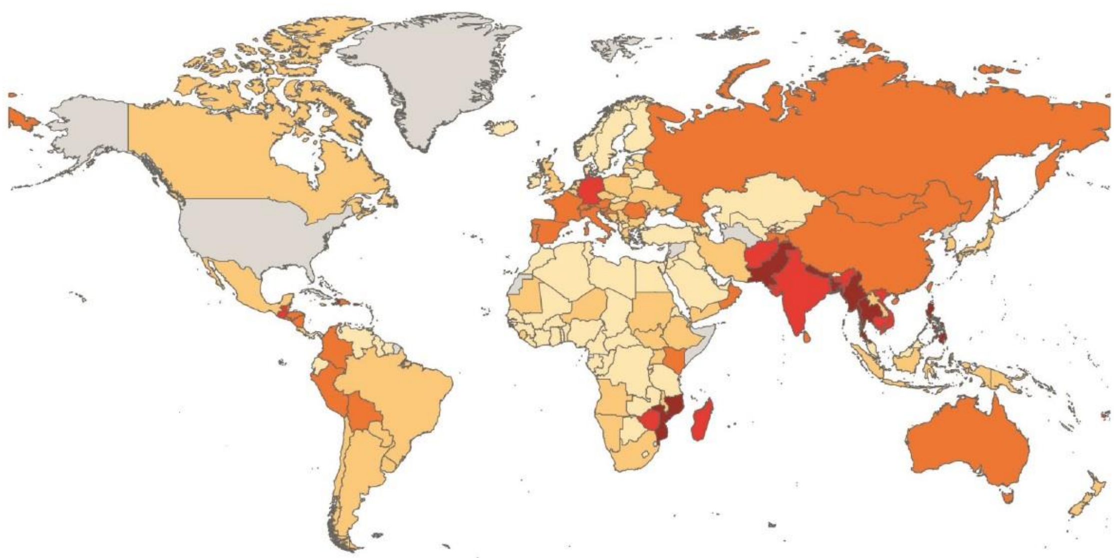
Physical (left) and transition (right) risk country scores in the world



Source: EIB, Ferrazzi et al. (2021).

Figure 4

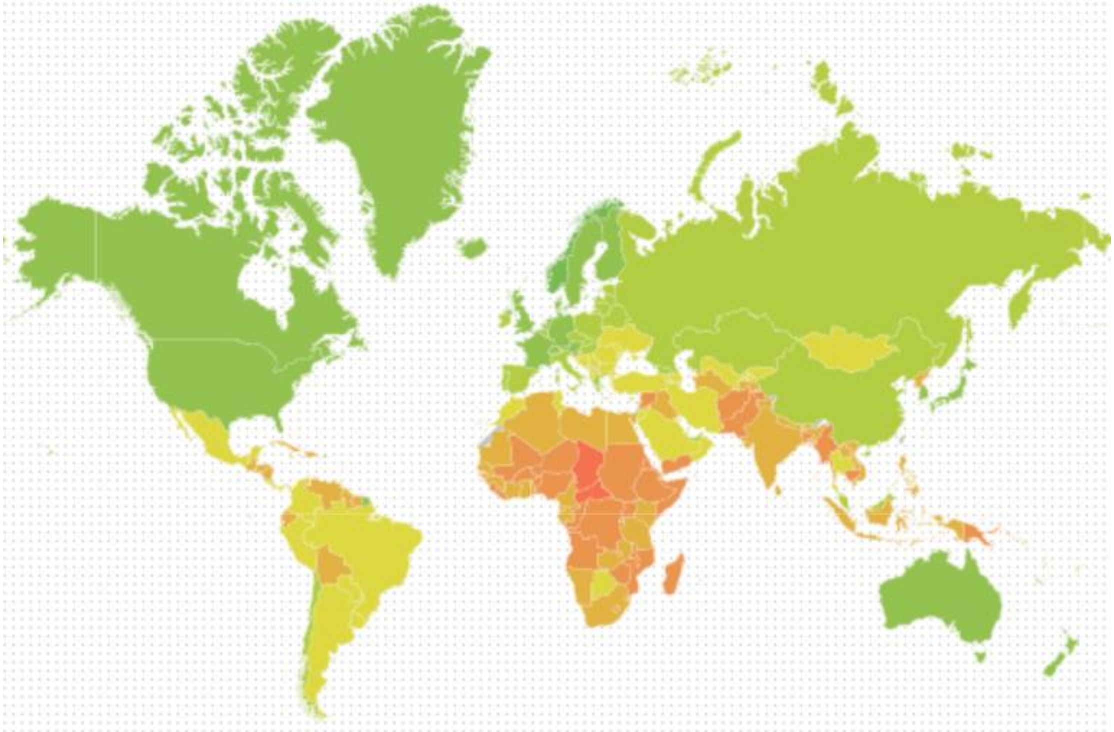
World Map of the Global Climate Risk Index 2000 – 2019



Source: Germanwatch, Eckstein et al. (2021).

Figure 5

Countries of the world by their position on the ND-GAIN Country Index



Source: ND-GAIN (2021).

Different methodologies justified the different assessments among the three sources above, highlighting the results for Australia and Canada, for instance. The EIB (Ferrazzi et al., 2021), in its scoring model to assess climate change at a country level, provides two sets of scores for physical and transition risks, with aggregate exposures to various risk factors, considering the adaptation and mitigation capacity of each country. In the other hand, the Notre Dame Global Adaptation Initiative Index (ND-GAIN, 2021) was developed by the University of Notre Dame and is built on a set of equally weighted variables to assess climate physical risk, including sovereign readiness to improve resilience, but without taking the transition risk into account. Germanwatch (Eckstein et al., 2021) in its Global Climate Risk Index exclusively considers extreme weather events. Other six less extensive indicators exist and may complement the analysis, as detailed by EIB (Ferrazzi et al., 2021): Fragile Planet from HSBC and the ones from Moody´s, The World Energy Council, Yale University, Robeco SAM and The World Economic Forum.

To sum up, the strategic asset allocation of the international reserves could focus on hedge to asset price movements related to environmental and climate risk analysis, as detailed in the bottom of Table 1. This hedge could take into consideration sovereign exposures and consider also other relevant data for the traditional strategic asset allocation (e.g.: international reserves economic objectives; investment guidelines and investment pillars).

4.4 The Methodology

The methodology of this study is summarized in Figure 6:

Figure 6

Methodological summary

Methodological Steps:	Variables:
1) Real Status IRs 2019	1) Sovereign bonds returns
2) Definition of Constraints: Min & Max allocation	2) Foreign exchange rates
2.1 Base: based on real status of IRs	3) Commodities Prices
2.2 SIM1 up to SIM8, considering:	4) WACI
2.2.1 Financial objectives	
2.2.2 Economic objectives	
2.2.3 Sustainability objectives, including the enviromental and climate risk management	
3) Portfolio Optimization in Software R	
4) Portfolio Analysis in MSExcel	
4.1 Risk/return	
4.2 Correlation with the commodities and currencies	
4.3 WACI	

Source: prepared by the authors of this study.

To evaluate the impacts of the proposed framework, this research focused on investment portfolio simulation and optimization in R, with synthesized data of bond returns, data from foreign exchange rates, and data from commodities' prices. Several optimal mean-variance portfolios are calculated based on constraints that guarantee similarity to real international reserves portfolios from the selected countries. These constraints are chosen based on countries' international reserves data available on the internet (see Banco Central de Chile, 2019; Banco Central de Reserva del Perú, 2020; Banco Central do Brasil, 2020; Banco do México, 2019; Bank of Jamaica, 2021; IMF, 2021a).

The financial risk and return of the investment portfolios were analyzed, considering the standard deviation of returns as a measurement of risk, and the average of historical monthly returns, annualized, as a measurement of return. The return/risk ratio was calculated by dividing return by risk, in a proxy of the Sharpe Ratio (risk free rate was considered zero).

Besides risk and return analysis, the correlation matrix was discussed, as well as the indicator Weighted-Average Carbon Intensity (WACI), to test the application of the framework for the management of the international reserves by central banks. The analysis was performed with support of MS Excel. This discussion supports the inclusion of the ESG dimension on the strategic asset allocation of the international reserves.

Five central banks were selected out of the ten central banks covered in the second study (see Table 1), according to the following criteria: top three central banks in volume of international reserves (see Table 1), resulting in Brazil, Mexico and Peru, complemented by the one with the highest international reserves/GDP (22% for Jamaica) and the one with the indication of the highest percentage for hedge (4,5% for ores & metals/international reserves for Chile), both excluding the central banks previously selected. Thus, final sample also included Jamaica and Chile.

The portfolio exercise was based on the following data, for the 5 years period from Jan2015 up to Dec2020, gathered on BR Investing (2021):

- interest rate for the sovereign bonds from Australia (AUD), Canada (CAD), China (CHI), France (FRA), Germany (GER), Japan (JAP), Switzerland (CHF), United Kingdom (UK) and United States (USA), for 2, 3 and 5-year bonds;
- exchange rate variance for the respective national currencies (AUD, CAD, CNY, EUR, JPY, CHF, GPB and USD) plus selected currencies from Latin America and the Caribbean (BRL, CLP, CRC, JMD, MXN, PEN); and

- commodity price variances for Aluminum (ALU), Copper (COB), Petroleum (PET), Soy (SOJ) and Gold (GOL).

The currencies and investment alternatives were selected considering what are the typical assets used by central banks. Even the restrictions used were chosen to have portfolios similar to what the central banks of each country have, maintaining the central banks investment pattern. Thus, for each analyzed country, the portfolio restrictions changed.

Up to eight simulations were performed for each country, selected according to the particularities of each central bank in the management of the international reserves:

1. base status (Base), with 3% variance on real international reserves allocation per currency in Dec2019 (around 3% more or less on cap and bottom constraint), plus reallocation of other currencies on cap based on the proportion of the currencies under review;
2. simulation 2 (SIM2), which is base status plus allowance to new currencies (e.g.: CNY, JPY, CHF, GPB for Chile) and gold;
3. simulation 3 (SIM3), which is SIM2 plus the adjustments made after analysis based on the proposed framework. For SIM3, the investment portfolio was rebalanced according with the hedge percentage indicated in Table 1 and observing the correlation of the investment alternatives with the critical commodities for each country. Rebalance was performed to assets more negatively correlated to them, proportionally;
4. simulation 4 (SIM4) considered the same hedge percentage of SIM3, but observing the correlation of the investment alternatives with the national currency;
5. simulation 5 (SIM5) is based on SIM 3, but reducing maximum allocation constraint for sovereigns with high WACI and higher climate risk, with increment in the ones with lower WACI and climate risk (Eckstein et al., 2021; Ferrazzi et al., 2021; ND-GAIN, 2021);

6. simulation 6 (SIM6) considered the adjustments of SIM3 applied on the minimum allocation constraint (bottom), not on the maximum allocation constraint (cap), except in the circumstances when minimum would be higher than maximum; in these circumstances, the adjustment was made in both maximum and minimum constraint (Brazil with Gold and JPY; Mexico with Gold, EUR, JPY, CHF and GPB);
7. simulation 7 (SIM7) considered zero authorization for the top two currencies with higher correlation with the commodity and zero authorization for the top two currencies with higher WACI. Also, SIM7 used the minimum and maximum allocation from SIM2, thus allowing new currencies, but the hedge percentage is included in maximum allocation and distributed alongside all the other currencies according with their correlation with the commodity, in a countercyclical strategy. Minimum allocation remains equals Base, which in turn is equals SIM2 up to SIM5.
8. simulation 8 (SIM8), as SIM7, considered zero authorization for the top two currencies with higher correlation with the commodity and zero authorization for the top two currencies with higher WACI. However, SIM8 used the minimum and maximum allocation from Base, instead of SIM2 (adopted in SIM7). Another difference is that SIM8 included the hedge percentage as an addition in the maximum allocation only for the top two investment alternatives with highest countercyclicality to the commodity, and as a reduction in the minimum allocation for the currency with higher correlation with the commodity and higher WACI, after previous exclusions.

Portfolios were tested with bonds of 2, 3 and 5 years of maturity. Thus, 3 interest profiles were tested to access the effects of changes in duration.

Also, for TCFD (2017) alignment, the indicator WACI was also considered in the portfolio exercise to support decision of rebalance among existing sub asset classes and regions/countries, as detailed in the attached Tables 4 (Chile), 10 (Peru), 16 (Brazil), 22

(Jamaica) and 28 (Mexico). WACI was valued based on tons of CO2 emissions per millions of GDP in USD, with data from the International Energy Agency (IEA) and International Monetary Fund (IMF) for AUD, CAD, CHI, FRA, GER, JAP, CHF, UK and USA. For WACI purposes, allocation in Gold was rebalanced to the other asset alternatives proportionally.

Finally, in the correlation analysis, the portfolio results were compared with different commodities and currencies for countercyclicality purposes. In a countercyclical strategy for the local currency, the objective is to obtain positive returns for the international reserves when the local currency is losing value, when more units of local currency are necessary to buy one USD. Thus, the objective of this countercyclical strategy is to have a more positive correlation between local currency and international reserves portfolio. For commodities, it is the opposite: the negative correlations are the objectives, searching for better returns in the international reserves when the commodity in focus is facing lower values.

The analysis included the short-term impact of the environmental variable (WACI), the exposure to the commodities and to variances in the valuation of the national currency. Those two were included to accommodate the economic objectives of the international reserves. All three variables were assessed to evaluate the manager's problem of short-term risk-return analysis versus long-term climate risk perception. This assessment was based on historical data, in-sample and out-of-sample testing. Risk, return, WACI and correlation with commodities and national currency were assessed for traditional portfolio versus environmental risk analysis portfolio.

4.5 Results and discussion

A multi-objective analysis was performed, considering the risk/return perspective, alongside the evaluation of environmental and climate exposures, hedge strategies to address the economic objectives of the international reserves, and the implications to the WACI of the portfolios.

Up to eight simulations were performed for each country to evaluate the risk, return and WACI impacts of an environmental and climate risk management performed through the strategic asset allocation of the international reserves, with the overall findings presented in the following sections, consolidated in Section 4.6 and detailed in attached Tables:

4.5.1 Chile

Based on the assumptions of six simulations (Base, SIM2, SIM3, SIM4, SIM5 and SIM6), the investment portfolios for Chile were optimized according with the cap and bottom criteria, resulting in the allocation for currencies and tickers of sovereign bonds detailed in table 1 (see tables in the attachment).

The optimization resulted in less AUD, CAD and EUR with more CNY, CHF, GPB, USD and Gold when comparing Base with all other simulations (see table 1). **Changes in the maturity of the bonds implied in no variances for allocation in CNY and Gold**, but with changes in all other investment alternatives, **including USD below the maximum allocation constraint for bonds with 5Y** (see Table 4). There were no major variances in the allocation among SIM2 up to SIM6, but **all of them resulted in a better risk-adjusted return when compared to Base** (see Table 5). Simulations resulted in **WACI close to 0.67% higher or 3.37% lower than Base when considering GDP or population in the metric**, respectively (see Table 6). SIM6 returned portfolios with WACI lower than Base in both methods, using GDP or population in the metric. SIM2 up to SIM6, for **hedge with the economic objective in focus** (see Table 7), led to **less procyclical portfolios** (see Table 8).

Base to SIM2-2Y bonds (with 3% on Base, plus reallocation of Others and allowance for new currencies) led to more CNY, JPY, CHF, GPB, USD and Gold and less AUD, CAD and EUR (table 1). This portfolio resulted in a risk-adjusted return of 0.61 against 0.57 in Base (Table 5). Also, SIM2-2Y portfolio was 8.18% lower in positive correlation with Copper and with reduction of 6.78% in the negative correlation with CLP (Table 8), thus leading to a more countercyclical portfolio. Further, the new portfolio presented a 0.11% lower WACI, despite of considering GDP or population in the metric (Table 6). Although, SIM2 with 3Y and 5Y bonds returned portfolios with higher WACI than Base, using GDP.

SIM2 to SIM3-2Y bonds (with hedge for Copper) led to more CNY, JPY, GPB, USD and Gold. This portfolio resulted in better overall performance, with a risk-adjusted return higher in 265 basis points, 1.22% lower in positive correlation with Copper and with reduction of 1.82% in the negative correlation with CLP, then also leading to a more countercyclical portfolio, but 0.409% higher and 0.15% lower in WACI related to SIM2 when considering GDP or population in the metric, respectively.

SIM2 to SIM4-2Y bonds (changing Copper per CLP in the correlation analysis for hedge purposes) resulted mainly in less gold and more GPB, with a risk-adjusted return higher in 264 basis points, 1.07% lower in positive correlation with Copper and with reduction of 1.82% in the negative correlation with CLP, leading to a more countercyclical portfolio, but 0.38% higher and 0.21% lower in WACI related to SIM2 when considering GDP or population in the metric, respectively..

SIM2 to SIM5-2Y bonds (hedge for Copper, SIM3, but reducing maximum allocation constraint for sovereigns with high WACI and higher climate risk) resulted in a portfolio with risk-adjusted return higher in 229 basis points, 0.88% lower in positive correlation with Copper and with reduction of 1.82% in the negative correlation with CLP (more countercyclical portfolio), but 0.15% higher and 0.22% lower in WACI related to SIM2 when considering GDP or population in the metric, respectively.

Lastly, SIM2 to SIM6-2Y bonds (hedge for Copper on bottom constraint) resulted in a portfolio with risk-adjusted return lower in 8 basis points, 0.61% lower in positive correlation with Copper and with no variance in the correlation with CLP. For WACI purposes, SIM6 returned portfolios lower than Base in both methods, using GDP (0.50%) or population (2.04%) in the metric.

Since the methodology of this study intends to maintain the same investment pattern of the analyzed central banks, SIM7 and SIM8 were not performed for Chile since they would highly differ from the currencies and investment alternatives selected by this central bank in real international reserves portfolios. SIM7 and SIM8 would consider zero allocation in AUD and CAD, when real status in was 8.03% and 7.69% each (IMF, 2021a; Banco Central de Chile, 2019, see Table 1).

Overall, the financial risk and return of the investment portfolios were analyzed, considering the standard deviation of returns as a measurement of risk, and the average of historical monthly returns, annualized, as a measurement of return. As detailed in Table 5, the highest risk-adjusted return was obtained in SIM3 and SIM4, with hedge against Copper and CLP, followed by SIM5 (which is SIM3 rebalanced by WACI and climate risk).

Longer maturity of the bonds resulted in positive impacts in the risk-adjusted return of the portfolios, as detailed in Table 11. **As expected, higher duration leads to portfolios with higher risks and returns. For profitability purposes, lengthening the yield curve (with longer duration) may be positive, but safety and liquidity pillars may lead to different decisions. In the safety side, the longer the duration, the higher the exposure to market risk**.

Most of the simulations, as detailed in Table 6, led to an increased WACI if CO2 emissions from fuel combustion is considered against GDP, but a lower WACI if the analysis is performed against population, except by SIM2-2Y and SIM6 with negative impact on WACI when considering both GDP and population in the metric. **Thus, investment portfolios of the simulations performed may be an alternative to be considered in the intention to decrease financial risk in a higher proportion than reducing return, with a lower WACI if the**

analysis is considered against population, but most of them with higher WACI when taking into consideration the GDP. SIM6 would be an alternative to reduce WACI in all durations (2Y, 3Y and 5Y), using both GDP or population in the metric.

Now considering the economic objective of the reserves, ores and metals (mainly Copper) were responsible for 53% of total export of Chile in 2019 as detailed in Table 1. In the simulation 3 (SIM3), hedge for Copper was performed with the percentages and allocations indicated in Table 7, which in turn were stablished based on the correlation matrix between Copper and the investment alternatives. The 4.51% of total hedge was based on the ARA/IMF metric and detailed in the Table 1.

According with the Table 8, different simulations and changes in the maturity of the bonds (2Y, 3Y or 5Y) cause significant impact in the correlation with Copper and Chilean pesos (CLP). The longer the maturity, the less procyclical are the portfolios to CLP and Copper. SIM3 to SIM5 with **5Y bonds led to the portfolios less positively correlated with Copper and CLP, in a less procyclical strategy**, relevant to hedge for physical and transition risks related to this commodity and the national currency.

To sum up the analysis for Chile, investment portfolio of SIM3 and SIM4 with 5Y bonds may be an alternative to be considered in the intention to better risk-adjusted return and less procyclicality to Copper and CLP, with lower WACI when considering population in the metric, but higher WACI based on GDP. Thus, for profitability and countercyclicality purposes for Copper and CLP, lengthening the yield curve may be positive, but safety and liquidity pillars may lead to different decisions. This longer duration is aligned with the longer-term perspective of the typical ESG investments, however WACI could be negatively impacted in this strategy for Chile, depending on the how this metric will be calculated (if based on GDP or population). No countercyclical portfolio was obtained for the CLP and Copper, only less procyclical ones. For WACI purposes, SIM6 returned portfolios lower than Base in both methods, using GDP or population in the metric, with risk-adjusted returns higher than Base and less procyclical portfolios for Cooper and CLP, in all durations.

4.5.2 Peru

The optimized investment portfolios for Peru resulted in less USD and more of all other investment alternatives when comparing Base with all other simulations (Table 9). Changes in the maturity of the bonds implied in variances for all currencies and simulations (see Table 10). Mainly, the higher the maturity, the lower the allocation in USD, and the higher the allocation in GPB, CHF, EUR, CAD, AUD, and Gold. There were no major variances in the allocation among SIM2 up to SIM7, but **all of them resulted in a better risk-adjusted return when compared to Base, except by SIM7-5Y** (see Table 11). Simulations resulted in **WACI up to 2.59% higher than base when considering GDP in the metric, but up to 6.7% lower than base when considering population instead of GDP** (see Table 12), but SIM7 offered lower WACI in both methods and in all durations. SIM3 up to SIM7, for **hedge with the economic objective in focus** (see Table 13), led to less countercyclical portfolios, but still negatively correlated with the commodity, thus aligned with a countercyclical strategy (see Table 14).

Base to SIM2-2Y bonds (with 3% on Base, plus reallocation of Others and allowance for new currencies) led to less USD and more of all other investment alternatives (Table 9). This resulted in a portfolio with a risk-adjusted return higher in 611 basis points (Table 11), but 2,04% higher in WACI considering GDP and 0.99% lower when considering population in the metric (Table 12), 18.88% less negatively correlated with Copper and 200% more negatively correlated with PEN (Table 14), thus leading to a less countercyclical portfolio, but its carbon intensity depends on the chosen method for calculating the WACI.

SIM2 to SIM3-2Y bonds (with hedge for Copper) led to less USD and CHF and more of all other investment alternatives. This portfolio resulted in better overall performance, with a risk-adjusted return higher in 8.2 basis points, 0.26% higher and 0.11% lower in WACI related to SIM2 when considering GDP or population in the metric, respectively. Nevertheless, the outcome of this investment simulation was 1.63% less negatively correlated with Copper and with no variance in the correlation with PEN, then also leading to a less countercyclical and possibly more carbon intensive portfolio.

SIM2 to SIM4-2Y bonds (changing Copper per PEN in the correlation analysis for hedge purposes) resulted mainly in less USD and CHF and more of all other investment alternatives. The risk-adjusted return of the new portfolio was higher in 11.9 basis points, 0.238% higher and 0.10% lower in WACI related to SIM2 when considering GDP or population in the metric, respectively. Again, the new portfolio was 2.01% less negatively correlated with Copper, but with no variance in the correlation with PEN, leading again to a less countercyclical and possibly more carbon intensive portfolio.

SIM2 to SIM5-2Y bonds (hedge for Copper, SIM3, but reducing maximum allocation constraint for sovereigns with high WACI and higher climate risk) resulted in a portfolio with WACI 0.17% higher and0.13% lower related to SIM2 when considering GDP or population in the metric, respectively. Notwithstanding, the risk-adjusted return of this new portfolio was lower in 9.31 basis points, but 602 basis points higher than Base. Also, this investment portfolio alternative was 0.92% less negatively correlated with Copper and with no variance in the correlation with PEN. Again, a less countercyclical and possibly more carbon intensive portfolio was obtained.

SIM2 to SIM6-2Y bonds (hedge for Copper on bottom constraint) resulted in a portfolio with risk-adjusted return lower in 88 basis points, but 523 basis points higher than Base. This new portfolio was 1.96% less negatively correlated with Copper and with no variance in the correlation with PEN. The WACI was 0.15% lower related to SIM2, but 1.88% higher related to Base, when considering GDP. The WACI with population in the metric totaled 0.26% lower than SIM2. Thus, another less countercyclical and possibly more carbon intensive portfolio was obtained.

At last, SIM2 to SIM7-2Y bonds (with zero authorization for top two in WACI and in correlation with Copper) resulted in the first portfolio with WACI lower than Base both by GDP (0.19%) or population (0.77%). The risk-adjusted return was 509 basis points lower than SIM2-2Y, but 110 basis points higher than Base-2Y. This portfolio was finally 14.80% more negatively correlated with Copper, but still 6.87% less negatively correlated than Base. The correlation with the local currency, PEN, was zero. Hence, a less carbon intensive portfolio was obtained, with higher risk-adjusted return in comparison with Base, still negatively correlated with Copper, but with no correlation with PEN.

In the financial risk-return analysis, as detailed in Table 11, the highest risk-adjusted return was obtained in SIM3 and SIM4, with hedge against Copper and PEN, but with small variance to SIM5 (which is SIM3 rebalanced by WACI and climate risk).

Longer maturity of the bonds resulted in negative impacts in the risk-adjusted return of the portfolios, as detailed in Table 11. Thus, **for profitability purposes, shorter the yield curve (with lower duration) may be positive, but safety and liquidity pillars may lead to different decisions.**

The simulations, as detailed in Table 12, led to an increased WACI if CO2 emissions is considered against GDP, but a lower WACI if the analysis is performed against population, except by SIM7 with lower WACI in both methods. **Thus, SIM7 investment portfolios (2Y, 3Y and 5Y) may be an alternative to be considered with the intention to decrease financial risk in a higher proportion than reducing return, with a lower WACI in both methods. Other simulations performed offer a lower WACI if the analysis is considered against population, but higher WACI when taking into consideration the GDP**.

Now considering the economic objective of the reserves, ores and metals (mainly Copper) were responsible for 46% of total export of Peru in 2019 as detailed in Table 1. In the simulation 3 (SIM3), hedge for Copper was performed with the percentages and allocations indicated in Table 13, which in turn were stablished based on the correlation matrix between Copper and the investment alternatives. The 1.60% of total hedge was based on the ARA/IMF metric and detailed in the Table 1.

Table 14 shows that different simulations and changes in the maturity of the bonds (2Y, 3Y or 5Y) little impacted the correlation with Copper, which remained around 0.30 and 0.39 negatively correlated in all cases. Copper. This is aligned with a countercyclical strategy to the commodity, but all simulations led to portfolios less negatively correlated than Base.

With the purpose of countercyclicality to the local currency, the correlation with Soles (PEN) was also analyzed. Different simulations and changes in the maturity of the bonds did not cause significant impact in the correlation with the national currency, as detailed in Table 14, except by SIM7, with no correlation with PEN. Base is the most countercyclical strategy (0.04 positive correlation).

To sum up the analysis for Peru, investment portfolio of Base is the only portfolio countercyclical to the local currency, while SIM7 is the only one not correlated with PEN and with WACI lower than BASE in both methods (GDP or population). Base and SIM7 are the most countercyclical portfolios to Copper and the ones with the lowest WACI using GDP in the metric, but with the highest WACI when changing GDP by population. Base and SIM7 present the lowest risk-adjusted return but shorter maturities may increment the results significantly (e.g.: 63,9% SIM7-5Y up to 103.3% SIM7-2Y). SIM3 and SIM4 are alternatives for better risk-adjusted returns but would lead to worse WACI with GDP but better WACI with population. Both would remain negatively correlated with Copper, but less than Base. Both would be procyclical to PEN. Thus, the balance by the board of the central bank among financial, economic and sustainability objectives may lead to different decisions, which may include Base, SIM7, SIM3, SIM4 or other simulations to be performed.

4.5.3 Brazil

The optimized investment portfolios for Brazil resulted in no major variances in the allocation among the simulations (see Table 15), but **most of them (16 out of 21, or 76%) resulted in a better risk-adjusted return when compared to Base**, except by SIM6-2Y, SIM7 and SIM8-5Y (see Table 17). Simulations resulted in **WACI up to 3.17% higher or 0.80% lower than Base when considering GDP or population in the metric**, respectively, **except by SIM7 with WACI lower with both GDP and population, and SIM8 with opposite results: WACI around 0.2% lower or higher than Base, considering GDP or population** (see Table 18). SIM3 up to SIM6, for **hedge with the economic objective in focus** (see Table 19), led to **more procyclical portfolios, but portfolios with 3Y and 5Y bonds remained negatively correlated with Soy, in alignment with a countercyclical strategy. SIM7 and SIM8 led to more countercyclical portfolios for Soy and BRL, in all maturities** (see Table 20).

In Table 15, the optimization resulted in less USD and more AUD, CAD, CNY and Gold when comparing Base with other simulations, besides SIM2 with no variance for Gold and except by SIM7 and SIM8 with more USD and Gold. No variance occurred for JPY and CHF, besides an increment in SIM6. The simulations resulted in less EUR or no variance, despite more EUR in SIM6. Less EUR was a consequence in simulations with 5Y bonds, except by SIM7. In turn, less GPB was a consequence only in SIM2-3Y, with increment or maintenance in all other simulations.

Changes in the maturity of the bonds implied in no variances for allocation in JPY, CHF and Gold, except by SIM7 and SIM8-2Y, but with changes in all other investment alternatives, highlighting more EUR in 5Y bonds (see Table 16).

Base to SIM2-2Y bonds (with 3% on Base, plus reallocation of Others and allowance for new currencies) led to more AUD, CAD and CNY and less USD, with no variance for the others (Table 15). This portfolio resulted in a risk-adjusted return higher in 38 basis points (Table 17), 6,38% higher in positive correlation with Soy and no variance in the correlation with BRL, but less positively correlated for 3Y and 5Y bonds (Table 20), thus leading to a more procyclical portfolio. WACI was 0.95% higher when considering GDP, but 0.25% lower when considering population (Table 18).

SIM2 to SIM3-2Y bonds (with hedge for Soy) led to more CAD, CNY, GPB and Gold. This portfolio resulted in 0.06% lower risk-adjusted return (but 0,32% higher than Base), 0,43% higher in positive correlation with Soy and no variance in the correlation with BRL, then also leading to a more procyclical portfolio. WACI was 0.10% higher when considering GDP, but 0.04% lower when considering population.

SIM2 to SIM4-2Y bonds (changing Soy per BRL in the correlation analysis for hedge purposes) resulted mainly in more CAD, CNY, Gold and GPB and USD, with a risk-adjusted return lower in 5 basis points (but 33 basis points higher than Base), 0.56% higher in positive correlation with Soy and no variance in the correlation with BRL, leading again to a more procyclical portfolio. WACI was 0.12% higher when considering GDP, but 0.05% lower when considering population.

SIM2 to SIM5-2Y bonds (hedge for Soy, SIM3, but reducing maximum allocation constraint for sovereigns with high WACI and higher climate risk) resulted in almost no change in the risk-adjusted return (one basis point), 1.44% higher in positive correlation with Soy (more procyclical portfolio) and no change in correlation with BRL. WACI was 0.31% higher when considering GDP, but 0.11% lower when considering population.

SIM2 to SIM6-2Y bonds (hedge for Soy on bottom constraint) resulted in a portfolio with risk-adjusted return lower in 218 basis points, 10.89% higher in positive correlation with

Soy and 40% more negatively correlated with BRL, in another procyclical portfolio. WACI was 0.102% and 0.28% lower when considering GDP and population, respectively, but still 0.93% higher than Base, with GDP.

SIM2 to SIM7-2Y bonds (with zero authorization for top two in WACI and in correlation with Soy) resulted in a portfolio **with WACI lower with both GDP and population**, with no AUD, CAD and CNY, less USD and more Gold and GPB. Risk-adjusted return was lower in 92 basis points. Positive correlation with Soy was lower in 7.87% (2% to Base) in a less procyclical portfolio in relation to the commodity. With 3Y and 5Y bonds the portfolios were negatively correlated to Soy, aligned with a countercyclical strategy. Correlation with BRL was 40% less negative with 2Y bonds, and positive for 3Y and 5Y bonds.

SIM2 to SIM8-2Y bonds (SIM7, with hedge changes in both minimum and maximum allocation constraint) resulted in a portfolio with no AUD, CAD and CNY, less EUR and more Gold and USD, with the best overall performance. Risk-adjusted return was higher in 261 basis points (and 299 when related to Base). Positive correlation with Soy was lower in 16.44% (21.45% to Base) in a less procyclical portfolio in relation to the commodity. As occurred with SIM7, SIM8 with 3Y and 5Y bonds also led to portfolios negatively correlated to Soy, thus aligned with a countercyclical strategy. In SIM8 the correlation with BRL became positive for all different durations (2Y, 3Y and 5Y), with portfolios countercyclical to the local currency. WACI was lower than SIM2 up to 2.51% when considering GDP in all durations for SIM8 (and up to 0.21% lower than Base), but up to 0.66% higher when considering population (up to 0.19% higher than Base).

In the financial risk-return analysis, as detailed in Table 17, the highest risk-adjusted return was obtained in SIM8. Also, shorter durations led to portfolios with higher risk-adjusted returns, thus portfolios with 2Y bonds performed better than the ones with 5Y bonds.

SIM8 led to WACI lower than Base if CO2 Emissions from Fuel Combustion is considered against GDP, but higher than Base if the analysis is performed using population data, as detailed in Table 18. **Thus, investment portfolios of SIM8 may be an alternative to be considered in the intention to decrease financial risk in a higher proportion than reducing return, with a lower WACI if the analysis is considered against GDP, but higher WACI when taking into consideration the population. SIM7 is an alternative to lower WACI with both GDP and population, but risk-adjusted return was also lower than Base**.

Now considering the economic objective of the reserves, food and agriculture was responsible for 40% of total export of Brazil in 2019 as detailed in Table 15, with Soybeans on top, totaling USD26,1 billion (OEC, 2020). In the simulation 3 (SIM3), hedge for Soy was performed with the percentages and allocations indicated in Table 19, which in turn were stablished based on the correlation matrix between Soy and the investment alternatives. The 1.24% of total hedge was based on Table 17.

According to the Table 20, correlation with Soy was positive with 2Y bonds portfolios and negative with 3Y and 5Y bonds. Simulations with 3Y and 5Y bonds **led to portfolios negatively correlated with Soy, in a countercyclical strategy**, relevant to hedge for physical and transition risks related to this commodity.

With the purpose of countercyclicality to the local currency, the correlation with Real (BRL) was also analyzed. SIM8 and all simulations with 3Y and 5Y bonds led to portfolios positively correlated to the local currency, as detailed in Table 20. **Thus, 3Y and 5Y bonds increase countercyclicality with BRL when compared to 2Y bonds**.

To sum up the analysis for Brazil, Base and SIM8 are the portfolios with lowest WACI taking into consideration the GDP, but the ones with highest WACI when considering population in the metric. SIM7 leads to lower WACI with both GDP and population. All simulations with 3Y and 5Y bonds are countercyclical for Soy and BRL, but 2Y bonds must be avoided in this strategy. Also, risk-adjusted returns were higher with shorter duration for all simulations, what indicates to 3Y bonds portfolios as the optimal choice to conciliate countercyclicality to Soy, BRL and obtain better risk-adjusted returns.

4.5.4 Jamaica

The portfolio optimization for Jamaica resulted in less USD and more AUD, CAD, Gold and JPY, this last one only in 2Y and 3Y bonds (Table 21). Longer duration of the bonds led to less USD and JPY and more of all other currencies (see Table 22). There were no major variances in the allocation among SIM2 up to SIM6, but **all of them resulted in a better risk-adjusted return when compared to Base** (see Table 23). Simulations for Jamaica led to investment portfolios with WACI up to 1.22% lower than Base when considering population in the metric and using 5Y bonds (see Table 24). In all other circumstances, WACI was higher than Base up to 0.48%. SIM3 up to SIM6, for **hedge with the economic objective in focus** (see Table 25), led countercyclical portfolios for both commodity and currency, thus aligned with a countercyclical strategy (see Table 26).

Base to SIM2-2Y bonds (with 3% on Base, plus reallocation of Others and allowance for new currencies) led to less USD and GPB and JPY, Gold, AUD and CAD (Table 21). This resulted in a portfolio with a risk-adjusted return higher in 24 basis points (Table 23), but higher in WACI considering GDP (0.24%) and population (0.03%) in the metric (Table 24). The new portfolio was 5.29% more negatively correlated with Alumina and with no variance in the correlation with JMD (Table 26), thus leading to a more countercyclical and more carbon intensive portfolio.

SIM2 to SIM3-2Y bonds (with hedge for Alumina) led to less USD and more GPB, CNY and Gold. This portfolio resulted in better financial performance, with a risk-adjusted return higher in 3 basis points. Although, WACI was higher considering GDP (0.03%) and lower considering population (0.02%) in the metric, but still higher than Base in both methods

(Table 24). The new portfolio was again more negatively correlated with Alumina (0.03%) and with no variance in the correlation with JMD (Table 26), resulting in another countercyclical but more carbon intensive portfolio.

SIM2 to SIM4-2Y bonds (changing Alumina per JMD in the correlation analysis for hedge purposes) resulted mainly in less USD and more GPB, JPY and Gold. The risk-adjusted return of the new portfolio was lower by 5 basis points related to SIM2, but still higher than Base in 20 basis points. Portfolio showed same WACI considering GDP and lower WACI with population (0.01%) in the metric, but again higher than Base in both methods (Table 24). Once more, the new portfolio was 0.55% more negatively correlated with Alumina, but with no variance in the correlation with JMD, leading one more time to a countercyclical and more carbon intensive portfolio.

SIM2 to SIM5-2Y bonds (hedge for Alumina, SIM3, but reducing maximum allocation constraint for sovereigns with high WACI and higher climate risk) resulted in a portfolio higher in WACI considering GDP (0.02%) and lower in WACI when using population (0.02%) in the metric, but still higher than Base in both methods (Table 24). On top of that, the risk-adjusted return of this new portfolio was higher in 2 basis points. Also, this investment portfolio alternative was 0.14% more negatively correlated with Alumina and with no variance in the correlation with JMD. Again, it was obtained a more countercyclical and carbon intensive portfolio.

At last, SIM2 to SIM6-2Y bonds (hedge for Alumina on bottom constraint) resulted in a portfolio with risk-adjusted return lower than SIM2 in 3 basis points, but 21 basis points higher than Base. This new portfolio was 0.42% less negatively correlated with Alumina than SIM2 but 4.85% more negatively correlated than Base, with no variance in the correlation with JMD. The WACI was lower than SIM2 (up to 0.02%), but still higher than Base (up to 0.23%)

when considering GDP or population in the metric (Table 24). Thus, another countercyclical and more carbon intensive portfolio was obtained.

In the financial risk-return analysis, as detailed in Table 23, **all simulations resulted in a better risk-adjusted return when compared to Base**. The highest risk-adjusted return was obtained in SIM3 (with hedge against Alumina) and SIM5 (which is SIM3 rebalanced by WACI and climate risk).

Longer maturity of the bonds resulted in negative impacts in the risk-adjusted return of the portfolios, as detailed in Table 23. Thus, **for profitability and safety purposes, shorter the yield curve (with lower duration) may be positive, but the liquidity pillar may lead to different decisions**.

All simulations, as detailed in Table 24, led to an increased WACI if CO2 emissions is considered against GDP and population, except by the simulations with 5Y bonds using population in the WACI method. **Thus, investment portfolios of the simulations performed may be an alternative to be considered in the intention to decrease financial risk in a higher proportion than reducing return, but a lower WACI would only be obtained with 5Y bonds and using population instead of GDP**.

Now considering the economic objective of the reserves, ores and metals (mainly Alumina) were responsible for 55% of total export of Jamaica in 2019 as detailed in Table 1. In the simulation 3 (SIM3), hedge for Alumina was performed with the percentages and allocations indicated in Table 25, which in turn were stablished based on the correlation matrix between Alumina and the investment alternatives. The 0.12% of total hedge was based on the ARA/IMF metric and detailed in the Table 1.

Table 26 shows that longer duration leads to portfolios less negatively correlated to Alumina, so 2Y bonds are more countercyclical to the commodity than 3Y and 5Y bonds.

However, all simulations in all different maturities led to portfolios negatively correlated to Alumina. This is aligned with a countercyclical strategy to the commodity.

With the purpose of countercyclicality to the local currency, the correlation with Jamaican Dolar (JMD) was also analyzed. Different simulations and changes in the maturity of the bonds did not cause significant impact in the correlation with the national currency, as detailed in Table 26.

To sum up the analysis for Jamaica, all simulations returned investment portfolios which are countercyclical to the commodity and the local currency, with small variances among them within the same duration. In general, shorter maturities lead to portfolios which are more countercyclical to the commodity Alumina, with lower WACI (e.g.: Base-2Y) and with higher risk-adjusted results (e.g.: 70.21% SIM3-5Y up to 122.01% SIM3-2Y). SIM3 and SIM5 lead to best risk-adjusted returns. Base with 2Y bonds leads to the portfolio with lowest WACI using GDP, but SIM6-5Y presents the lowest WACI when considering population. SIM4-2Y is the portfolio with the highest negative correlation with the commodity. Thus, the balance by the board of the central bank among financial, economic and sustainability objectives may lead to different decisions, including portfolios with shorter durations using the simulations above, or others.

4.5.5 Mexico

The optimized investment portfolios for Mexico resulted in less USD and more EUR when comparing Base with all other simulations (Table 27). Changes in the maturity of the bonds implied in changes for all simulations and mostly all currencies (see Table 28). Mainly, the higher the maturity, the lower the allocation in USD and JPY, and the higher the allocation in the other investment alternatives. There were no major changes in the allocation among SIM2 up to SIM5, but **five of them resulted in a better risk-adjusted return when compared to Base** (see Table 29). Simulations resulted in **WACI up to 2.04% higher than Base when considering GDP in the metric, but up to 1.89% lower than base when considering population instead of GDP** (see Table 30). SIM4 and SIM5, for **hedge with the economic objective in focus** (see Table 31), led to portfolios with lower positive correlation with MXN, but still positive correlated, thus aligned with a countercyclical strategy (see Table 32).

Base to SIM2-2Y bonds (with 3% on Base, plus reallocation of Others and allowance for new currencies) led to less USD and more EUR (Table 27). This resulted in a portfolio with a risk-adjusted return lower by 11 basis points (Table 29). WACI was 0.05% higher when considering GDP in the metric, but 0.06% lower when considering population (Table 30). Correlation with MXN was 3.85% lower than Base, but still positive (Table 32), thus still leading to a countercyclical portfolio but possibly more carbon intensive, depending on the chosen method for calculating the WACI.

SIM2 to SIM4-2Y bonds (changing Copper per MXN in the correlation analysis for hedge purposes) resulted mainly in less USD and EUR and more GPB, JPY, Gold, CNY, CAD and AUD. The risk-adjusted return of the new portfolio was higher than SIM2 in 46 basis points, and 34 more than Base. WACI was 1.22% higher when considering GDP in the metric, but 0.64% lower when considering population (Table 30). Correlation with MXN was equal

SIM2, thus 3.85% lower than Base, but still positive (Table 32), thus still leading to another countercyclical portfolio but possibly a more carbon intensive one.

SIM2 to SIM5-2Y bonds (hedge for MXN but reducing maximum allocation constraint for sovereigns with high WACI and higher climate risk), similar to SIM4-2Y, resulted in a portfolio with less USD and EUR and more of the other investment alternatives, but in different percentages. WACI was 0.95% higher and 0.80% lower to SIM2 when considering GDP or population in the metric, respectively. Notwithstanding, the risk-adjusted return of this new portfolio was higher than SIM2 by 0.10 basis points, but 2 basis points lower than Base. Correlation with MXN was again equal SIM2, thus 3.85% lower than Base, but still positive (Table 32), thus still leading to another countercyclical portfolio but possibly a more carbon intensive alternative.

In the financial risk-return analysis, five portfolios resulted in a better risk-adjusted return when compared to Base, which are SIM4-2Y, SIM5-3Y, SIM2-5Y, SIM4-5Y and SIM5-5Y, as detailed in Table 29. The highest risk-adjusted return was obtained in SIM4-2Y, with hedge for MXN, but with small variance to Base and SIM5 (which is SIM4 rebalanced by WACI and climate risk).

Longer maturity of the bonds resulted in negative impacts in the risk-adjusted return of the portfolios, as detailed in Table 29. Thus, **for profitability and safety purposes, shorter the yield curve (with lower duration) may be positive, but the liquidity pillar may lead to different decisions**.

All simulations, as detailed in Table 30, led to an increased WACI if CO2 emissions is considered against GDP, but a lower WACI if the analysis is performed against population. **Thus, five investment portfolios related to the simulations performed may be an alternative to be considered in the intention to decrease financial risk in a higher**

proportion than reducing return, with a lower WACI if the analysis is considered against population, but higher WACI when taking into consideration the GDP.

Now considering the economic objective of the reserves, manufacturing exports were responsible for 77% of total export of Mexico in 2019 as detailed in Table 1. Commodities were not relevant for the national exports, thus SIM3 and SIM6 were not performed to Mexico, but the other simulations were performed to evaluate alternatives to countercyclical portfolios for MXN alongside lower WACI and better risk-adjusted returns. In the simulation 4 (SIM4), hedge for MXN was performed with the percentages and allocations indicated in Table 31, which in turn were stablished based on the correlation matrix between MXN and the investment alternatives. The 9.69% of total hedge was based on the ARA/IMF metric and detailed in the Table 1.

The Table 32 shows that different simulations and changes in the maturity of the bonds (2Y, 3Y or 5Y) little impacted the correlation with MXN, which remained between 0.19 and 0.26, positively correlated in all cases. This is aligned with a countercyclical strategy to the local currency, but all simulations led to portfolios less positively correlated than Base.

To sum up the analysis for Mexico, all simulations returned investment portfolios which are countercyclical to the local currency. In general, shorter maturities lead to portfolios which are more countercyclical to MXN, with better risk-adjusted returns and with lower WACI when considering GDP, but higher WACI when considering population in the method. SIM4-2Y led to the best risk-adjusted return. SIM5-5Y is related to the lowest WACI considering population but, using GDP in the method, the lowest WACI comes from Base-2Y. This last one is also the portfolio with the highest countercyclicality to MXN. Thus, the balance by the board of the central bank among financial, economic and sustainability objectives may lead to different decisions, including portfolios with shorter durations using the simulations above, or others.

4.5.6 Consolidated results

Based on the above results, the balance of profitability, safety, liquidity, and sustainability pillars may lead to different decisions to be taken by the board of the central bank in the management of international reserves, which may be supported by the highlights presented in Table 2 and by the information as follow:

Table 2

Panel with the highlights of the multi-objective analysis

Central Bank	Simulation	Risk-adjusted return	WACI		Correlation		Comments
			GDP	Population	Commodity	Currency	
Chile	SIM4-5Y	69,11%	253,97	0,014128	0,03	-0,26	Highest risk-adjusted return, lowest WACI per population, best correlation with commodity and with currency.
	SIM6-2Y	60,66%	251,28	0,014323	0,40	-0,55	Lowest WACI per GDP
Peru	SIM4-2Y	108,43%	239,23	0,014591	-0,30	-0,04	Highest risk-adjusted return
	SIM7-2Y	103,30%	233,47	0,014638	-0,35	0,00	Third best correl. w/ commodity and currency, with lower WACI and higher return
	Base-2Y	102,20%	233,91	0,014751	-0,38	0,04	Best correlation with currency
	SIM7-5Y	63,90%	232,03	0,013974	-0,37	0,02	Lowest WACI per GDP
	SIM3-5Y	66,53%	239,48	0,013763	-0,34	-0,01	Lowest WACI per population
	Base-5Y	64,04%	233,91	0,014751	-0,39	0,04	Best correlation with commodity and currency
Brazil	SIM2-2Y	103,30%	236,20	0,014237	0,09	-0,05	Highest risk-adjusted return
	SIM8-5Y	67,75%	233,80	0,014259	-0,12	0,12	Best correlation with commodity and currency
	SIM7-3Y	84,29%	233,74	0,014251	-0,02	0,06	Second lowest WACI per GDP and WACI per population lower than SIM8
	SIM8-3Y	85,44%	233,39	0,014290	-0,04	0,09	Lowest WACI per GDP
	SIM5-5Y	69,87%	241,37	0,014139	-0,09	0,08	Lowest WACI per population
Jamaica	SIM3/5-2Y	122,01%	236,52	0,014636	-0,17	0,20	Highest risk-adjusted return
	SIM4-2Y	121,94%	236,46	0,014637	-0,17	0,20	Best correlation with commodity and currency
	Base-2Y	121,75%	235,90	0,014635	-0,16	0,20	Lowest WACI per GDP
	SIM6-5Y	70,18%	236,69	0,014451	N/A	0,20	Lowest WACI per population
Mexico	SIM4-2Y	122,45%	241,14	0,014547	N/A	0,25	Highest risk-adjusted return
	Base-2Y	122,11%	238,12	0,014648	N/A	0,26	Lowest WACI p/ GDP & best correl. w/ currency
	SIM5-5Y	70,25%	241,50	0,014370	N/A	0,20	Lowest WACI per population

Source: prepared by the authors of this study

For Chile, longer durations led to better risk-adjusted returns and less procyclicality to both Copper and CLP, with lower WACI when considering population in the metric, but higher WACI based on GDP. Thus, for profitability and countercyclicality purposes, lengthen the yield curve may be positive, but WACI could be negatively impacted in this strategy for Chile, depending on the how this metric will be calculated. No countercyclical portfolio was obtained for the local currency and main commodity, only less procyclical ones. SIM6 returned portfolios with lower WACI than Base in both methods, using GDP or population in the metric.

For Peru, only Base portfolio was countercyclical to the local currency PEN. All portfolios led to countercyclical portfolios to the commodity Copper. Simulations returned lower WACI when considering population in the metric but higher WACI when changing to GDP, but SIM7 offered lower WACI in both methods and in all durations. Risk-adjusted returns were better in shorter maturities.

For Brazil, Base and SIM8 were the portfolios with lowest WACI taking into consideration the GDP, but the ones with highest WACI when considering population in the metric. SIM7 leads to lower WACI than Base with both GDP and population. All simulations with 3Y and 5Y bonds were countercyclical for Soy and BRL, but 2Y bonds must be avoided in this strategy. Also, risk-adjusted returns were higher with shorter duration in all simulations, what indicates to 3Y bonds portfolios as the optimal choice to conciliate countercyclicality to Soy, BRL and obtain better risk-adjusted returns.

For Jamaica, all simulations returned investment portfolios which are countercyclical to the commodity and the local currency, with small variances among them within the same duration. In general, shorter maturities lead to portfolios which are more countercyclical to the commodity Alumina, with lower WACI (e.g.: Base-2Y) and with higher risk-adjusted returns (e.g.: 70.21% SIM3-5Y up to 122.01% SIM3-2Y).

For Mexico, all simulations returned investment portfolios which are countercyclical to the local currency. In general, shorter maturities lead to portfolios which are more countercyclical to MXN, with better risk-adjusted returns and with lower WACI when considering GDP, but higher WACI when considering population in the method. SIM4-2Y led to the best risk-adjusted return. SIM5-5Y is related to the lowest WACI considering population but, using GDP in the method, the lowest WACI comes from Base-2Y. This last one is also the portfolio with the highest countercyclicality to MXN.

As identified, longer maturity of the bonds resulted in positive or negative impacts in the risk-adjusted return of the portfolios, depending on the central bank and its typical portfolio allocation. Thus, for profitability purposes, lengthening the yield curve (with longer duration) may be positive or negative, but safety and liquidity pillars may lead to different decisions. In the safety side, the longer the duration, the higher the exposure to market risk. In the other hand, if central banks include new asset classes as Green Bonds, liquidity may be in check and must be further analyzed. On top of it, the acceptance level for each pillar may change among central banks.

To sum up, the results indicate the possibility to manage the exposure to environmental and climate risks of international reserves, without prejudice to the economic and financial objectives of central bank.

4.6 Conclusion

This study discussed the risk, return, correlation with relevant commodities and local currencies, as well as WACI impacts of environmental and climate risk management performed through the strategic asset allocation of the international reserves. Portfolio optimizations were customized for a sample of central banks. A multi-objective analysis was performed, considering the risk/return perspective, alongside the evaluation of environmental and climate exposures, hedge strategies to address the economic objectives of the international reserves, and the implications to the WACI of the portfolios.

After up to eight different simulations performed for five different central banks, with the particularities of each respective countries, it was identified that a multi-objective analysis may support changes in allocation of the international reserves portfolios, within different durations, assets, or currencies, which could lead to better performance in the sustainability dimension, including environmental and climate risk management, on top of the traditional financial and economic dimensions.

In a nutshell, the balance by the board of each central banks among financial, economic and sustainability objectives may lead to different decisions, which can be supported by the information provided in this study and may include many other simulations and analysis to be performed. On top of that, the management of environmental and climate risks and the positive impact management, based for instance on WACI of investment portfolios, may be balanced to avoid decisions with sovereign implications leading to climate negative impacts and respective cyclical effects (with special attention to SIM5).

As limitations of this study, gold was not included in the WACI analysis and specific green investment alternatives were not tested. Also, the study was performed based on historical data, not in scenario analysis. For further studies, ex-ante scenarios could be considered, as 1) nothing happens; 2) climate crisis; and 3) 2 degrees. Also, social and governance factors could also be in scope.

4.7 References

Banco Central de Chile. (2019). *Gestión de Reservas Internacionales del Banco Central de Chile*. https://www.bcentral.cl/documents/33528/133286/GestionReservasInternacionales2019.pdf/7f296fee-2706-d6ca-dbc0-7dd596c5e496?t=1577374755637

Banco Central de Reserva del Perú. (2020). GESTIÓN DE LAS RESERVAS INTERNACIONALES: DICIEMBRE 2020. *NOTAS DE ESTUDIOS DEL BCRP*, *February*(15), 1–33. https://www.bcrp.gob.pe/docs/Publicaciones/Notas-Estudios/2021/nota-de-estudios-15-2021.pdf

Banco Central do Brasil. (2020). *Relatório de Gestão das Reservas Internacionais Relatório de Gestão das Reservas Internacionais* (Vol. 12, Issue Março). https://www.bcb.gov.br/content/estabilidadefinanceira/relgestaoreservas/GESTAORESERVAS202003-relatorio_anual_reservas_internacionais_2020.pdf

Banco do México. (2019). *Financial Statements: Vol. December*. https://www.bcb.gov.br/content/estabilidadefinanceira/relgestaoreservas/GESTAORESERVAS202003-relatorio_anual_reservas_internacionais_2020.pdf

Bank for International Settlements. (2021a). *Climate-related financial risks – measurement methodologies* (Issue April). https://www.bis.org/bcbs/publ/d518.htm

Bank for International Settlements. (2021b). *Climate-related risk drivers and their transmission channels* (Issue April). https://www.bis.org/bcbs/publ/d517.htm

Bank for International Settlements. (2021c). *Consultative Document - Principles for the effective management and supervision of climate-related financial risks* (Issue November). https://www.bis.org/bcbs/publ/d530.pdf

Bank of Jamaica. (2021). *Annual Report 2020*. https://boj.org.jm/wp-content/uploads/2021/03/2020_boj_annual_report.pdf

BR Investing. (2021). *No Title*. https://br.investing.com/

Bruno, G., Esakia, M., & Goltz, F. (2021). "Honey, I Shrunk the ESG Alpha": Risk-Adjusting ESG Portfolio Returns. *Working Paper, April*. https://cdn.ihsmarkit.com/www/pdf/0521/Honey-I-Shrunk-the-ESG-Alpha.pdf

Calvo, G. A., Izquierdo, A., & Loo-kung, R. (2012). Optimal Holdings of International Reserves: Self-Insurance Against Sudden Stop. *NBER WORKING PAPER SERIES*, *July*(No. 18219), 1–35. https://doi.org/10.3386/W18219

Clark, G. L., Feiner, A., & Viehs, M. (2015). *From the Stockholder to the Stakeholder: How Sustainability Can Drive Financial Outperformanc* (Issue March). https://doi.org/10.2139/ssrn.2508281

Eckstein, D., Künzel, V., & Schäfer, L. (2021). Global climate risk index 2021. In *Germanwatch*. https://www.germanwatch.org/sites/default/files/Global Climate Risk Index 2021_2.pdf

European Commission. (2020). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability*. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0474&from=EN

Fender, I., McMorrow, M., Sahakyan, V., & Zulaica, O. (2019). Green Bonds: The Reserve Management Perspective. *BIS Quarterly Review*, *September*, 49–63.

Ferrazzi, M., Zwart, S., & Kalantzis, F. (2021). *EIB Working Paper 2021/03 - Assessing climate change risks at the country level : the EIB scoring model*. https://library.oapen.org/bitstream/id/64cd9e28-bb92-4cfb-9365-c974cdcb2f9d/9789286150340.pdf

Feuer, W. (2021). *Here's More Evidence That ESG Funds Outperformed During the*

Pandemic. Institutional Investor. https://www.institutionalinvestor.com/article/b1r9gb5p9k10b4/Here-s-More-Evidence-That-ESG-Funds-Outperformed-During-the-Pandemic

Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance and Investment*, *5*(4), 210–233. https://doi.org/10.1080/20430795.2015.1118917

IEA. (2021). *CO2 emissions from fuel combustion - Highlights (million tons of CO2).* International Energy Agency. https://www.iea.org/data-and-statistics/data-product/greenhouse-gas-emissions-from-energy#ghg-emissions-from-fuel-combustion

IMF. (2020). Assessing Reserve Adequacy (ARA). In *Research*. https://www.imf.org/external/np/spr/ara/

IMF. (2021a). Data Template on International Reserves and Foreign Currency Liquidity (IRFCL). In *IMF Data*. https://data.imf.org/?sk=2DFB3380-3603-4D2C-90BE-A04D8BBCE237&sId=1390030341854

IMF. (2021b). GDP, current prices (Billions of U.S. dollars). In *IMF Data*. https://www.imf.org/external/datamapper//export/excel.php?indicator=NGDPD

Johnson, S. (2021). *ESG outperformance narrative 'is flawed', new research shows*. Financial Times. https://www.ft.com/content/be140b1b-2249-4dd9-859c-3f8f12ce6036

Kaminsky, G., Lizondo, S., & Reinhart, C. M. (1998). Leading Indicators of Currency Crises. In *IMF Staff Papers* (Vol. 45, Issue 1, pp. 1–48). https://doi.org/10.2307/3867328

Kemp, D., Lebre, E., Owen, J., & Valenta, R. K. (2021). *Clean energy? The world's demand for copper could be catastrophic for communities and environments*. The Conversation. https://theconversation.com/clean-energy-the-worlds-demand-for-copper-could-be-catastrophic-for-communities-and-environments-157872

Mellman, J., Ovenden, S., & Evans, J. (2021). *The EU Taxonomy for sustainable investments*

– *mining, metals & minerals*. Watson Farley & Williams. https://www.wfw.com/articles/the-eu-taxonomy-for-sustainable-investments-mining-metals-minerals/

ND-GAIN. (2021). *ND-GAIN Country Index*. Notre Dame Global Adaptation Initiative. https://gain.nd.edu/our-work/country-index/

NGFS. (2018). First Progress Report. *Network for Greening the Financial System, October*, 1–12. https://www.ngfs.net/sites/default/files/medias/documents/818366-ngfs-first-progress-report-20181011.pdf

NGFS. (2019). A sustainable and responsible investment guide for central banks' portfolio management. *Network for Greening the Financial System Technical Document, October*. https://www.ngfs.net/sites/default/files/medias/documents/ngfs-a-sustainable-and-responsible-investment-guide.pdf

NGFS. (2020a). Case studies of Environmental Risk Analysis Methodologies. *NGFS Occasional Paper, September*, 1–603. https://www.ngfs.net/sites/default/files/medias/documents/case_studies_of_environmental_risk_analysis_methodologies.pdf

NGFS. (2020b). Overview of Environmental Risk Analysis by Financial Institutions. *Network for Greening the Financial System, September*.

NGFS. (2020c). Progress report on the implementation of sustainable and responsible investment practices in central banks' portfolio management. In *NGFS Technical document* (Issue December). https://www.ngfs.net/sites/default/files/medias/documents/sri_progress_report_2020.pdf

NGFS. (2021). Guide on climate-related disclosure for central banks. *NGFS Technical Document, December*. https://www.ngfs.net/sites/default/files/medias/documents/guide_on_climate-related_disclosure_for_central_banks.pdf

OEC. (2020). *Soybeans in Brazil*. Product in Country. https://oec.world/en/profile/bilateral-product/soybeans/reporter/bra

Pedersen, L. H., Fitzgibbons, S., & Pomorski, L. (2021). Responsible investing: The ESG-efficient frontier. *Journal of Financial Economics*, *142*(2), 572–597. https://doi.org/10.1016/j.jfineco.2020.11.001

Platform on Sustainable Finance. (2021). *Platform on sustainable finance: technical working group - Taxonomy pack for feedback* (Issue August). https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/210803-sustainable-finance-platform-report-technical-screening-criteria-taxonomy_en.pdf

PRI. (2019). *Embedding ESG issues into strategic asset allocation frameworks - A discussion paper*. https://www.unpri.org/embedding-esg-issues-into-strategic-asset-allocation-frameworks-discussion-paper/4815.article

Pucker, K. P. (2021). *The Trillion-Dollar Fantasy*. Institutional Investor. https://www.institutionalinvestor.com/article/b1tkr826880fy2/The-Trillion-Dollar-Fantasy

Silva Jr., A. F. A. (2011). The Self-Insurance Role of International Reserves and the 2008-2010 Crisis. *Central Bank of Brazil Working Paper*, *256*, 1–26. https://doi.org/10.2139/ssrn.1956702

Taparia, H. (2021). *The World May Be Better Off Without ESG Investing*. Stanford Social Innovation Review. https://ssir.org/articles/entry/the_world_may_be_better_off_without_esg_investing#

TCFD. (2017). Recommendations of the Task Force on Climate-related Financial Disclosures. *Task Force on Climate-Related Fiancial Disclosures*, *June*, 1–74.

https://assets.bbhub.io/company/sites/60/2020/10/FINAL-TCFD-Annex-Amended-121517.pdf

The World Bank. (2021a). *Total reserves (includes gold, current US$)*. https://data.worldbank.org/indicator/fi.res.totl.cd?view=chart

The World Bank. (2021b). *World Development Indicators - Population*. https://api.worldbank.org/v2/en/indicator/SP.POP.TOTL?downloadformat=excel

Torinelli, Viviane H., Silva Jr., A. F. A., Andrade, J. C. S., & Martinez-Jaramillo, S. (2021). Latin America (LatAm) Central Banks (CBs) environmental risk management of the international reserves: an applied framework discussion. In *XXIII ENGEMA* (pp. 1–20). http://engemausp.submissao.com.br/23/anais/arquivos/58.pdf?v=1643301635

Torinelli, Viviane Helena, & Silva Júnior, A. F. de A. da. (2021). Environmental risk analysis (ERA) in the strategic asset allocation (SAA) of the international reserves (IRs) managed by central banks (CBs). *Latin American Journal of Central Banking*, *2*(1), 100021. https://doi.org/10.1016/j.latcb.2021.100021

UNEP FI. (2019). *Changing course: UNEP FI and twenty institutional investors launch new guidance to implement TCFD Recommendations*. Industries - Investment. https://www.unepfi.org/news/industries/investment/changing-course-unep-fi-and-twenty-institutional-investors-launch-new-guidance-for-implementing-tcfd/

Whelan, T., Atz, U., Clark, C., & CFA. (2021). *ESG and financial performance: Uncovering the Relationship by Aggregating Evidence from 1,000 Plus Studies Published between 2015 – 2020*. https://www.stern.nyu.edu/sites/default/files/assets/documents/NYU-RAM_ESG-Paper_2021.pdf

Whieldon, E., & Clark, R. (2021). *Most ESG funds outperformed S&P 500 in early 2021 as studies debate why*. S&P Global Market Intelligence. https://www.spglobal.com/marketintelligence/en/news-insights/latest-newsheadlines/most-esg-funds-outperformed-s-p-500-in-early-2021-as-studies-debate-why-64811634

Wursthorn, M. (2021). *Tidal Wave of ESG Funds Brings Profit to Wall Street*. The Wall Street Journal. https://www.wsj.com/articles/tidal-wave-of-esg-funds-brings-profit-to-wall-street-11615887004

Zerbib, O. D. (2020). A Sustainable Capital Asset Pricing Model (S-CAPM): Evidence from Green Investing and Sin Stock Exclusion. *SSRN Electronic Journal*, *April 2019*. https://doi.org/10.2139/ssrn.3455090

4.8 Attachment A - Tables with the results

A.1 Chile

Table 3

Strategic Asset Allocation of the Investment Portfolio (Chile)

Currency & Gold		AUD	CAD	CNY	EUR		GOLD	JPY	CHF	GPB	USD	OTHERS
Real Status 2019		8,03%	7,69%	0,00%	9,86%		0,00%	0,00%	0,00%	0,00%	51,78%	22,65%
Max. alloc. constraint		AUD	CAD	CHI3	FRA3	GER3	GOL	JAP3	CHF	UK3	USA3	
	Base	10,00%	10,00%	0,00%	6,00%	6,00%	0,00%	0,00%	0,00%	0,00%	68,00%	
	SIM2	10,69%	10,24%	1,00%	6,56%	6,56%	1,00%	1,00%	1,00%	1,00%	68,95%	
	SIM3	10,95%	10,49%	1,42%	6,98%	6,98%	1,49%	1,59%	1,48%	1,42%	69,71%	
	SIM4	10,94%	10,55%	1,44%	6,95%	6,95%	1,38%	1,54%	1,44%	1,55%	69,76%	
	SIM5	10,75%	10,30%	1,34%	6,88%	6,88%	1,49%	1,59%	1,81%	1,76%	69,71%	
	SIM6	10,69%	10,24%	1,00%	6,56%	6,56%	1,00%	1,00%	1,00%	1,00%	68,95%	
Min allocation const.		8,00%	7,00%	0,00%	5,00%	5,00%	0,00%	0,00%	0,00%	0,00%	50,00%	
	SIM6	8,25%	7,26%	0,42%	5,42%	5,42%	0,49%	0,59%	0,48%	0,42%	50,77%	
Optimization												
2Y	Base	10,00%	10,00%	0,00%	6,00%	6,00%	0,00%	0,00%	0,00%	0,00%	68,00%	
	SIM2	8,01%	7,87%	1,00%	5,45%	5,73%	1,00%	0,73%	0,28%	0,98%	68,95%	
	SIM3	8,00%	7,12%	1,42%	5,03%	5,11%	1,49%	0,89%	0,06%	1,18%	69,71%	
	SIM4	8,00%	7,11%	1,44%	5,03%	5,09%	1,38%	0,84%	0,05%	1,29%	69,76%	
	SIM5	8,00%	7,09%	1,34%	5,01%	5,08%	1,49%	0,82%	0,05%	1,40%	69,71%	
	SIM6	8,30%	7,42%	1,00%	5,44%	5,49%	1,00%	0,86%	0,56%	0,97%	68,95%	
3Y	Base	10,00%	10,00%	0,00%	6,00%	6,00%	0,00%	0,00%	0,00%	0,00%	68,00%	
	SIM2	8,06%	8,43%	1,00%	5,57%	5,61%	1,00%	0,27%	0,13%	0,99%	68,95%	
	SIM3	8,00%	7,40%	1,42%	5,16%	5,13%	1,49%	0,25%	0,03%	1,40%	69,71%	
	SIM4	8,00%	7,36%	1,44%	5,15%	5,11%	1,38%	0,23%	0,03%	1,53%	69,76%	
	SIM5	8,00%	7,29%	1,34%	5,11%	5,09%	1,49%	0,21%	0,02%	1,73%	69,71%	
	SIM6	8,30%	7,56%	1,00%	5,52%	5,47%	1,00%	0,68%	0,52%	0,99%	68,95%	
5Y	Base	10,00%	10,00%	0,00%	6,00%	6,00%	0,00%	0,00%	0,00%	0,00%	68,00%	
	SIM2	8,11%	9,35%	1,00%	5,23%	5,35%	1,00%	0,00%	0,02%	1,00%	68,94%	
	SIM3	8,05%	7,90%	1,42%	5,03%	5,15%	1,49%	0,00%	0,02%	1,42%	69,52%	
	SIM4	8,05%	7,84%	1,44%	5,03%	5,13%	1,38%	0,00%	0,02%	1,55%	69,57%	
	SIM5	8,04%	7,72%	1,34%	5,02%	5,10%	1,49%	0,00%	0,01%	1,76%	69,51%	
	SIM6	8,32%	7,86%	1,00%	5,42%	5,49%	1,00%	0,60%	0,51%	1,00%	68,80%	

Source: prepared by the authors based on Banco Central de Chile (2019) and IMF (2021a).

Table 4

Changes in the Maturity of the Bonds (Chile)

Currency - Optimization		AUD	CAD	CNY	EUR	GOLD	JPY	CHF	GPB	USD	OTHERS
SIM3	2Y	8,00%	7,12%	1,42%	10,14%	1,49%	0,89%	0,06%	1,18%	69,71%	0,00%
	3Y	8,00%	7,40%	1,42%	10,29%	1,49%	0,25%	0,03%	1,40%	69,71%	0,00%
	5Y	8,05%	7,90%	1,42%	10,18%	1,49%	0,00%	0,02%	1,42%	69,52%	0,00%
SIM4	2Y	8,00%	7,11%	1,44%	10,13%	1,38%	0,84%	0,05%	1,29%	69,76%	0,00%
	3Y	8,00%	7,36%	1,44%	10,27%	1,38%	0,23%	0,03%	1,53%	69,76%	0,00%
	5Y	8,05%	7,84%	1,44%	10,16%	1,38%	0,00%	0,02%	1,55%	69,57%	0,00%
SIM5	2Y	8,00%	7,09%	1,34%	10,10%	1,49%	0,82%	0,05%	1,40%	69,71%	0,00%
	3Y	8,00%	7,29%	1,34%	10,20%	1,49%	0,21%	0,02%	1,73%	69,71%	0,00%
	5Y	8,04%	7,72%	1,34%	10,12%	1,49%	0,00%	0,01%	1,76%	69,51%	0,00%
SIM6	2Y	8,30%	7,42%	1,00%	10,94%	1,00%	0,86%	0,56%	0,97%	68,95%	0,00%
	3Y	8,30%	7,56%	1,00%	10,99%	1,00%	0,68%	0,52%	0,99%	68,95%	0,00%
	5Y	8,32%	7,86%	1,00%	10,91%	1,00%	0,60%	0,51%	1,00%	68,80%	0,00%

Source: prepared by the authors based on this study.

Table 5

Risk-adjusted return[4] (Chile)

Simulation		Return*	Variance to				Risk**	Variance to				Risk-
			Base:	SIM2:	3Y:	SIM3:		Base:	SIM2:	3Y:	SIM3:	adjusted
2Y	Base	1,28%			-16,92%		2,25%			-7,83%		56,74%
	SIM2	1,19%	-6,58%		-17,65%		1,97%	-12,73%		-10,20%		60,74%
	SIM3	1,17%	-8,49%	-2,04%	-17,53%		1,85%	-18,09%	-6,14%	-11,04%		63,39%
	SIM4	1,18%	-8,06%	-1,58%	-17,48%	0,47%	1,85%	-17,68%	-5,67%	-10,95%	0,50%	63,37%
	SIM5	1,16%	-9,01%	-2,60%	-17,51%	-0,57%	1,85%	-18,09%	-6,14%	-10,84%	0,00%	63,03%
	SIM6	1,19%	-6,55%	0,03%	-17,71%	2,12%	1,97%	-12,59%	0,16%	-10,25%	6,71%	60,66%
3Y	Base	1,54%					2,44%					62,95%
	SIM2	1,45%	-5,77%				2,19%	-10,44%				66,23%
	SIM3	1,42%	-7,82%	-2,18%			2,07%	-15,14%	-5,26%			68,38%
	SIM4	1,42%	-7,44%	-1,78%		0,41%	2,08%	-14,80%	-4,87%		0,40%	68,38%
	SIM5	1,41%	-8,36%	-2,76%		-0,59%	2,07%	-15,33%	-5,46%		-0,22%	68,13%
	SIM6	1,45%	-5,67%	0,11%		2,34%	2,19%	-10,24%	0,22%		5,77%	66,16%
5Y	Base	2,12%			37,54%		3,17%			29,56%		66,82%
	SIM2	2,02%	-4,55%		39,31%		2,96%	-6,52%		35,23%		68,23%
	SIM3	1,99%	-6,03%	-1,55%	40,20%		2,88%	-9,10%	-2,76%	38,79%		69,08%
	SIM4	2,00%	-5,71%	-1,21%	8,14%	0,35%	2,89%	-8,83%	-2,47%	38,65%	0,30%	69,11%
	SIM5	1,98%	-6,36%	-1,89%	6,86%	-0,35%	2,87%	-9,27%	-2,94%	38,83%	-0,19%	68,97%
	SIM6	2,02%	-4,45%	1,69%	9,59%	1,34%	2,98%	-5,78%	0,80%	36,01%	3,65%	67,77%

*average of historical monthly returns, annualized
**standard deviation of returns

Source: prepared by the authors.

[4] Sharp Index: return less risk free rate (zero), obtained by dividing return by risk

Table 6

WACI analysis (Chile)

WACI- Actual GDP		AUD	CAD	CNY	EUR	JPY	CHF	GPB	USD	TOTAL	Variance to			
t CO2e/$MM USD GDP		271,04	336,62	691,44	272,63	211,60	48,52	121,50	233,91		Base:	SIM2:	SIM3:	2Y:
2Y	Base	27,10	33,66	- 0,00	32,72	0,00	0,00	- 0,00	159,06	252,54				
	SIM2	21,92	26,74	6,98	30,80	1,57	0,14	1,21	162,91	252,27	-0,11%			
	SIM3	22,01	24,32	9,97	28,06	1,91	0,03	1,45	165,52	253,28	0,29%	0,40%		
	SIM4	21,99	24,28	10,10	27,99	1,80	0,03	1,59	165,46	253,23	0,27%	0,38%	-0,02%	
	SIM5	22,01	24,24	9,41	27,94	1,76	0,02	1,73	165,52	252,64	0,04%	0,15%	-0,25%	
	SIM6	22,73	25,24	6,98	30,12	1,84	0,27	1,20	162,91	251,28	-0,50%	-0,39%	-0,77%	
3Y	Base	27,10	33,66	0,00	32,72	0,00	0,00	- 0,00	159,06	252,54				
	SIM2	22,06	28,65	6,98	30,79	0,57	0,06	1,21	162,91	253,24	0,28%			0,39%
	SIM3	22,01	25,29	9,97	28,49	0,54	0,02	1,73	165,52	253,57	0,41%	0,13%		0,11%
	SIM4	21,99	25,14	10,10	28,38	0,50	0,01	1,88	165,46	253,45	0,36%	0,08%	-0,04%	0,09%
	SIM5	22,01	24,91	9,41	28,24	0,45	0,01	2,13	165,52	252,69	0,06%	-0,22%	-0,34%	0,02%
	SIM6	22,73	25,72	6,98	30,27	1,46	0,25	1,22	162,91	251,54	-0,40%	-0,67%	-0,76%	0,10%
5Y	Base	27,10	33,66	0,00	32,72	0,00	0,00	0,00	159,06	252,54				0,00%
	SIM2	22,20	31,80	6,98	29,14	0,00	0,01	1,23	162,88	254,24	0,67%			0,78%
	SIM3	22,15	27,00	9,97	28,16	- 0,00	0,01	1,75	165,08	254,12	0,63%	-0,05%		0,33%
	SIM4	22,11	26,76	10,09	28,09	- 0,00	0,01	1,91	165,00	253,97	0,57%	-0,11%	-0,06%	0,29%
	SIM5	22,12	26,38	9,40	28,02	0,00	0,01	2,17	165,06	253,16	0,24%	-0,43%	-0,38%	0,21%
	SIM6	22,79	26,74	6,98	30,04	1,28	0,25	1,23	162,55	251,85	-0,27%	-0,94%	-0,84%	0,23%
WACI- Actual Pop											Variance to			
t CO2e/$MM Pop		0,015	0,016	0,007	0,012	0,008	0,004	0,005	0,015		Base:	SIM2:	SIM3:	2Y:
2Y	Base	0,002	0,002	- 0,000	0,001	0,000	0,000	- 0,000	0,010	0,01462				
	SIM2	0,001	0,001	0,000	0,001	0,000	0,000	0,000	0,010	0,01436	-1,81%			
	SIM3	0,001	0,001	0,000	0,001	0,000	0,000	0,000	0,010	0,01433	-1,96%	-0,15%		
	SIM4	0,001	0,001	0,000	0,001	0,000	0,000	0,000	0,010	0,01433	-2,02%	-0,21%	-0,06%	
	SIM5	0,001	0,001	0,000	0,001	0,000	0,000	0,000	0,010	0,01432	-2,03%	-0,22%	-0,06%	
	SIM6	0,001	0,001	0,000	0,001	0,000	0,000	0,000	0,010	0,01432	-2,04%	-0,23%	-0,02%	
3Y	Base	0,002	0,002	0,000	0,001	0,000	0,000	- 0,000	0,010	0,01462				
	SIM2	0,001	0,001	0,000	0,001	0,000	0,000	0,000	0,010	0,01441	-1,47%			0,35%
	SIM3	0,001	0,001	0,000	0,001	0,000	0,000	0,000	0,010	0,01435	-1,82%	-0,36%		0,14%
	SIM4	0,001	0,001	0,000	0,001	0,000	0,000	0,000	0,010	0,01434	-1,90%	-0,44%	-0,08%	0,12%
	SIM5	0,001	0,001	0,000	0,001	0,000	0,000	0,000	0,010	0,01433	-1,96%	-0,50%	-0,14%	0,06%
	SIM6	0,001	0,001	0,000	0,001	0,000	0,000	0,000	0,010	0,01434	-1,94%	-0,49%	-0,05%	0,09%
5Y	Base	0,002	0,002	0,000	0,001	0,000	0,000	0,000	0,010	0,01462				0,00%
	SIM2	0,001	0,001	0,000	0,001	0,000	0,000	0,000	0,010	0,01446	-1,12%			0,70%
	SIM3	0,001	0,001	0,000	0,001	- 0,000	0,000	0,000	0,010	0,01416	-3,13%	-2,03%		-1,19%
	SIM4	0,001	0,001	0,000	0,001	- 0,000	0,000	0,000	0,010	0,01413	-3,37%	-2,28%	-0,25%	-1,38%
	SIM5	0,001	0,001	0,000	0,001	0,000	0,000	0,000	0,010	0,01415	-3,25%	-2,16%	-0,13%	-1,25%
	SIM6	0,001	0,001	0,000	0,001	0,000	0,000	0,000	0,010	0,01417	-3,11%	-2,01%	0,27%	-1,10%

Source: prepared by the authors based on IEA (2021), IMF (2021b) and The World Bank (2021b).

Table 7

Percentages and indication for reallocation or rebalance- international reserves economic objective in focus (Chile)

Commodity:	Ore&Me	Agro	Manuf	Fuel						
Hedge:	4,51%	2,78%	1,21%	0,08%						
Percentages and indication for reallocation or rebalance - IR economic objective in focus:										
	AUD	CAD	CHI3	FRA3	GER3	GOL	JAP3	CHF	UK3	USA3
SIM3; SIM(	0,25%	0,26%	0,42%	0,42%	0,42%	0,49%	0,59%	0,48%	0,42%	0,77%
SIM4	0,25%	0,31%	0,44%	0,39%	0,39%	0,38%	0,54%	0,44%	0,55%	0,81%
Percentages and indication for reallocation or rebalance- WACI in focus:										
SIM5	0,06%	0,06%	0,34%	0,32%	0,32%	0,49%	0,59%	0,81%	0,76%	0,77%

Source: prepared by the authors based on Torinelli et al. (2021).

Table 8

Correlation analysis with commodity and currency (Chile)

Commodity / Currency		Copper	Variance to Base:	Variance to SIM2:	Variance to 2Y:	CLP	Variance to Base:	Variance to SIM2:	Variance to 2Y:
2Y	Base	0,44				-0,59			
	SIM2	0,40	-8,18%			-0,55	-6,78%		
	SIM3	0,40	-9,30%	-1,22%		-0,54	-8,47%	-1,82%	
	SIM4	0,40	-9,17%	-1,07%		-0,54	-8,47%	-1,82%	
	SIM5	0,40	-8,99%	-0,88%		-0,54	-8,47%	-1,82%	
	SIM6	0,40	-8,74%	-0,61%		-0,55	-6,78%	0,00%	
3Y	Base	0,32				-0,50			
	SIM2	0,27	-12,84%		-31,57%	-0,46	-8,00%		-16,36%
	SIM3	0,26	-17,30%	-5,12%	-34,27%	-0,44	-12,00%	-4,35%	-18,52%
	SIM4	0,26	-17,12%	-4,91%	-34,22%	-0,45	-10,00%	-2,17%	-16,67%
	SIM5	0,26	-17,04%	-4,81%	-34,28%	-0,44	-12,00%	-4,35%	-18,52%
	SIM6	0,27	-15,82%	-3,41%	-33,50%	-0,46	-8,00%	0,00%	-16,36%
5Y	Base	0,09				-0,33			
	SIM2	0,05	-45,76%		-87,57%	-0,28	-15,15%		-49,09%
	SIM3	0,03	-69,50%	-43,78%	-92,93%	-0,26	-21,21%	-7,14%	-51,85%
	SIM4	0,03	-68,82%	-42,51%	-92,78%	-0,26	-21,21%	-7,14%	-51,85%
	SIM5	0,03	-70,16%	-44,98%	-93,10%	-0,26	-21,21%	-7,14%	-51,85%
	SIM6	0,04	-57,52%	-21,69%	-90,21%	-0,28	-15,15%	0,00%	-49,09%

Source: prepared by the authors.

A.2 Peru

Table 9

Strategic Asset Allocation of the Investment Portfolio (Peru)

Currency & Gold		AUD	CAD	CNY	EUR		GOLD	JPY	CHF	GPB	USD	OTHERS
Real Status 2019		0,00%	0,00%	0,00%	0,00%		4,00%	0,00%	0,00%	0,00%	87,00%	9,00%
Max alloc. constraint		AUD	CAD	CHI3	FRA3	GER3	GOL	JAP3	CHF	UK3	USA3	
	Base	0,00%	0,00%	0,00%	0,00%	0,00%	4,53%	0,00%	0,00%	0,00%	98,47%	
	SIM2	1,00%	1,00%	1,00%	1,00%	1,00%	4,53%	1,00%	1,00%	1,00%	98,47%	
	SIM3	1,09%	1,09%	1,15%	1,15%	1,15%	4,70%	1,21%	1,17%	1,15%	98,75%	
	SIM4	1,13%	1,13%	1,13%	1,15%	1,15%	4,70%	1,19%	1,16%	1,17%	98,69%	
	SIM5	1,02%	1,02%	1,12%	1,11%	1,11%	4,70%	1,21%	1,29%	1,27%	98,75%	
	SIM6	1,00%	1,00%	1,00%	1,00%	1,00%	4,53%	1,00%	1,00%	1,00%	98,47%	
	SIM7	0,00%	0,00%	0,00%	1,19%	1,19%	4,75%	1,26%	1,21%	1,19%	98,82%	
Min allocation const.		0,00%	0,00%	0,00%	0,00%	0,00%	3,88%	0,00%	0,00%	0,00%	84,39%	
	SIM6	0,09%	0,09%	0,15%	0,15%	0,15%	4,05%	0,21%	0,17%	0,15%	84,66%	
Optimization												
	Base	0,00%	0,00%	0,00%	0,00%	0,00%	4,09%	0,00%	0,00%	0,00%	95,91%	
	SIM2	0,45%	0,63%	0,89%	0,38%	0,31%	4,14%	0,30%	0,01%	0,44%	92,44%	
	SIM3	0,48%	0,67%	1,01%	0,40%	0,33%	4,20%	0,33%	0,01%	0,48%	92,09%	
2Y	SIM4	0,49%	0,69%	1,00%	0,40%	0,32%	4,20%	0,33%	0,01%	0,48%	92,08%	
	SIM5	0,46%	0,63%	0,99%	0,39%	0,32%	4,19%	0,34%	0,01%	0,52%	92,15%	
	SIM6	0,48%	0,62%	0,89%	0,42%	0,38%	4,25%	0,44%	0,18%	0,50%	91,83%	
	SIM7	0,00%	0,00%	0,00%	0,57%	0,45%	4,16%	0,39%	0,03%	0,59%	93,80%	
	Base	0,00%	0,00%	0,00%	0,00%	0,00%	4,47%	0,00%	0,00%	0,00%	95,53%	
	SIM2	0,79%	0,92%	1,00%	0,57%	0,57%	4,48%	0,07%	0,03%	0,96%	90,60%	
	SIM3	0,84%	0,99%	1,15%	0,64%	0,60%	4,64%	0,08%	0,02%	1,09%	89,94%	
3Y	SIM4	0,87%	1,02%	1,13%	0,64%	0,60%	4,64%	0,08%	0,02%	1,10%	89,90%	
	SIM5	0,79%	0,93%	1,12%	0,62%	0,59%	4,64%	0,09%	0,03%	1,20%	90,00%	
	SIM6	0,79%	0,91%	1,00%	0,62%	0,59%	4,50%	0,26%	0,20%	0,96%	90,18%	
	SIM7	0,00%	0,00%	0,00%	0,82%	0,80%	4,68%	0,12%	0,07%	1,16%	92,35%	
	Base	0,00%	0,00%	0,00%	0,00%	0,00%	4,53%	0,00%	0,00%	0,00%	95,47%	
	SIM2	0,98%	1,00%	1,00%	0,92%	0,95%	4,53%	0,07%	0,49%	1,00%	89,06%	
	SIM3	1,07%	1,09%	1,15%	1,06%	1,09%	4,70%	0,07%	0,53%	1,15%	88,09%	
5Y	SIM4	1,11%	1,13%	1,13%	1,06%	1,09%	4,70%	0,07%	0,52%	1,17%	88,02%	
	SIM5	1,00%	1,02%	1,12%	1,02%	1,05%	4,70%	0,07%	0,59%	1,27%	88,15%	
	SIM6	0,98%	1,00%	1,00%	0,93%	0,96%	4,53%	0,26%	0,56%	1,00%	88,78%	
	SIM7	0,00%	0,00%	0,00%	1,13%	1,15%	4,75%	0,13%	0,71%	1,19%	90,94%	

Source: prepared by the authors based on Banco Central de Reserva del Perú (2020) and IMF (2021a).

Table 10

Changes in the Maturity of the Bonds (Peru)

Currency - Optimization		AUD	CAD	CNY	EUR	GOLD	JPY	CHF	GPB	USD
SIM3	2Y	0,48%	0,67%	1,01%	0,73%	4,20%	0,33%	0,01%	0,48%	92,09%
	3Y	0,84%	0,99%	1,15%	1,24%	4,64%	0,08%	0,02%	1,09%	89,94%
	5Y	1,07%	1,09%	1,15%	2,15%	4,70%	0,07%	0,53%	1,15%	88,09%
SIM4	2Y	0,49%	0,69%	1,00%	0,72%	4,20%	0,33%	0,01%	0,48%	92,08%
	3Y	0,87%	1,02%	1,13%	1,23%	4,64%	0,08%	0,02%	1,10%	89,90%
	5Y	1,11%	1,13%	1,13%	2,15%	4,70%	0,07%	0,52%	1,17%	88,02%
SIM5	2Y	0,46%	0,63%	0,99%	0,71%	4,19%	0,34%	0,01%	0,52%	92,15%
	3Y	0,79%	0,93%	1,12%	1,21%	4,64%	0,09%	0,03%	1,20%	90,00%
	5Y	1,00%	1,02%	1,12%	2,07%	4,70%	0,07%	0,59%	1,27%	88,15%
SIM6	2Y	0,48%	0,62%	0,89%	0,81%	4,25%	0,44%	0,18%	0,50%	91,83%
	3Y	0,79%	0,91%	1,00%	1,21%	4,50%	0,26%	0,20%	0,96%	90,18%
	5Y	0,98%	1,00%	1,00%	1,89%	4,53%	0,26%	0,56%	1,00%	88,78%
SIM7	2Y	0,00%	0,00%	0,00%	1,02%	4,16%	0,39%	0,03%	0,59%	93,80%
	3Y	0,00%	0,00%	0,00%	1,62%	4,68%	0,12%	0,07%	1,16%	92,35%
	5Y	0,00%	0,00%	0,00%	2,28%	4,75%	0,13%	0,71%	1,19%	90,94%

Source: prepared by the authors based on this study.

Table 11

Risk-adjusted return[5] (Peru)

Simulation		Return*	Variance to				Risk**	Variance to				Risk-adjusted
			Base:	SIM2:	3Y:	SIM3:		Base:	SIM2:	3Y:	SIM3:	
2Y	Base	1,09%			-18,86%		1,07%			-35,88%		102,20%
	SIM2	1,08%	-1,61%		-17,66%		0,99%	-7,16%		-35,07%		108,31%
	SIM3	1,07%	-2,03%	-0,42%	-16,97%		0,99%	-7,63%	-0,50%	-34,68%		108,40%
	SIM4	1,07%	-2,06%	-0,46%	-16,95%	-0,03%	0,99%	-7,69%	-0,57%	-34,65%	-0,07%	108,43%
	SIM5	1,07%	-2,11%	-0,51%	-16,87%	-0,08%	0,99%	-7,55%	-0,42%	-34,62%	0,08%	108,22%
	SIM6	1,06%	-2,82%	-1,23%	-18,39%	-0,81%	0,99%	-7,55%	-0,42%	-35,35%	0,08%	107,43%
	SIM7	1,07%	-2,62%	-1,02%	-16,99%	-0,60%	1,03%	-3,66%	3,78%	-34,97%	4,30%	103,30%
3Y	Base	1,35%					1,67%					80,76%
	SIM2	1,31%	-3,04%				1,53%	-8,31%				85,41%
	SIM3	1,29%	-4,25%	-1,25%			1,51%	-9,33%	-1,11%			85,28%
	SIM4	1,29%	-4,31%	-1,31%		-0,06%	1,51%	-9,43%	-1,22%		-0,11%	85,33%
	SIM5	1,29%	-4,45%	-1,46%		-0,21%	1,51%	-9,33%	-1,11%		0,00%	85,11%
	SIM6	1,30%	-3,37%	-0,34%		0,92%	1,53%	-8,30%	0,01%		1,13%	85,11%
	SIM7	1,28%	-4,81%	-1,83%		-0,59%	1,59%	-4,99%	3,62%		4,78%	80,92%
5Y	Base	1,94%			43,83%		3,03%			81,39%		64,04%
	SIM2	1,87%	-3,41%		43,28%		2,82%	-7,01%		83,96%		66,52%
	SIM3	1,85%	-4,61%	-1,24%	43,29%		2,78%	-8,18%	-1,26%	83,67%		66,53%
	SIM4	1,85%	-4,65%	-1,28%	86,99%	-0,04%	2,78%	-8,28%	-1,36%	83,69%	-0,10%	66,57%
	SIM5	1,85%	-4,79%	-1,43%	86,85%	-0,19%	2,78%	-8,15%	-1,23%	83,74%	0,03%	66,39%
	SIM6	1,87%	-3,54%	1,11%	89,01%	1,16%	2,82%	-7,02%	-0,01%	83,92%	1,26%	66,44%
	SIM7	1,85%	-4,72%	-0,08%	86,70%	0,07%	2,89%	-4,52%	2,68%	82,29%	3,99%	63,90%

*average of historical monthly returns, annualized

**standard deviation of returns

Source: prepared by the authors.

[5] Sharp Index: return less risk free rate (zero), obtained by dividing return by risk

Table 12

WACI analysis (Peru)

WACI- Actual GDP		AUD	CAD	CNY	EUR	JPY	CHF	GPB	USD	TOTAL	Variance to			
t CO2e/$MM USD GDP		271,04	336,62	691,44	272,63	211,60	48,52	121,50	233,91		Base:	SIM2:	SIM3:	2Y:
	Base	-	-	-	-	-	-	-	233,91	233,91				
	SIM2	1,28	2,21	6,41	1,98	0,66	0,01	0,55	225,57	238,68	2,04%			
	SIM3	1,36	2,35	7,32	2,07	0,74	0,00	0,60	224,86	239,30	2,31%	0,26%		
2Y	SIM4	1,40	2,42	7,19	2,05	0,73	0,00	0,61	224,83	239,23	2,28%	0,23%	-0,03%	
	SIM5	1,29	2,23	7,16	2,02	0,74	0,00	0,66	224,98	239,08	2,21%	0,17%	-0,09%	
	SIM6	1,37	2,18	6,45	2,30	0,97	0,09	0,64	224,32	238,31	1,88%	-0,15%	-0,38%	
	SIM7	-	-	-	2,91	0,86	0,02	0,75	228,93	233,47	-0,19%	-2,18%	-2,35%	
	Base	-	-	-	-	-	-	-	233,91	233,91				
	SIM2	2,24	3,24	7,24	3,27	0,15	0,02	1,22	221,87	239,24	2,28%			0,24%
	SIM3	2,39	3,50	8,33	3,56	0,19	0,01	1,39	220,61	239,97	2,59%	0,30%		0,28%
3Y	SIM4	2,47	3,61	8,18	3,53	0,18	0,01	1,41	220,50	239,90	2,56%	0,27%	-0,03%	0,28%
	SIM5	2,26	3,28	8,11	3,46	0,19	0,01	1,53	220,74	239,59	2,43%	0,14%	-0,16%	0,21%
	SIM6	2,23	3,21	7,23	3,46	0,58	0,10	1,22	220,87	238,90	2,13%	-0,14%	-0,42%	0,24%
	SIM7	-	-	-	4,64	0,27	0,03	1,48	226,62	233,05	-0,37%	-2,59%	-2,73%	-0,18%
	Base	-	-	-	-	-	-	-	233,91	233,91				0,00%
	SIM2	2,78	3,53	7,24	5,34	0,15	0,25	1,27	218,20	238,77	2,08%			0,04%
	SIM3	3,04	3,85	8,34	6,15	0,15	0,27	1,47	216,22	239,48	2,38%	0,30%		0,08%
5Y	SIM4	3,15	3,99	8,20	6,15	0,15	0,27	1,49	216,05	239,44	2,37%	0,28%	-0,02%	0,09%
	SIM5	2,84	3,60	8,13	5,93	0,16	0,30	1,62	216,36	238,95	2,15%	0,07%	-0,22%	-0,06%
	SIM6	2,79	3,53	7,24	5,39	0,57	0,28	1,27	217,52	238,60	2,01%	-0,07%	-0,35%	0,12%
	SIM7	-	-	-	6,53	0,29	0,36	1,52	223,33	232,03	-0,80%	-2,82%	-2,90%	-0,62%
WACI- Actual Pop											Variance to			
t CO2(	CO2/POP	0,015	0,016	0,007	0,012	0,008	0,004	0,005	0,015		Base:	SIM2:	SIM3:	2Y:
	Base	-	-	-	-	-	-	-	0,015	0,01475				
	SIM2	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01461	-0,99%			
	SIM3	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01459	-1,10%	-0,11%		
2Y	SIM4	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01459	-1,09%	-0,10%	0,01%	
	SIM5	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01459	-1,12%	-0,13%	-0,02%	
	SIM6	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01457	-1,24%	-0,26%	-0,16%	
	SIM7	-	-	-	0,000	0,000	0,000	0,000	0,014	0,01464	-0,77%	0,22%	0,35%	
	Base	-	-	-	-	-	-	-	0,015	0,01475				
	SIM2	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01455	-1,36%			-0,38%
	SIM3	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01452	-1,54%	-0,18%		-0,45%
3Y	SIM4	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01452	-1,54%	-0,17%	0,01%	-0,45%
	SIM5	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01451	-1,61%	-0,25%	-0,06%	-0,49%
	SIM6	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01452	-1,58%	-0,22%	-0,05%	-0,34%
	SIM7	-	-	-	0,000	0,000	0,000	0,000	0,014	0,01458	-1,16%	0,20%	0,45%	-0,40%
	Base	-	-	-	-	-	-	-	0,015	0,01475				0,00%
	SIM2	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01448	-1,84%			-0,86%
	SIM3	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01376	-6,70%	-4,95%		-5,66%
5Y	SIM4	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01398	-5,24%	-3,46%	1,57%	-4,20%
	SIM5	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01385	-6,10%	-4,34%	0,64%	-5,04%
	SIM6	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01376	-6,69%	-4,94%	-1,53%	-5,52%
	SIM7	-	-	-	0,000	0,000	0,000	0,000	0,014	0,01397	-5,27%	-3,49%	0,89%	-4,53%

Source: prepared by the authors based on IEA (2021), IMF (2021b) and The World Bank (2021b).

Table 13

Percentages and indication for reallocation or rebalance- international reserves economic objective in focus (Peru)

Commodity:	Ore&Me	Agro	Manuf	Fuel						
Hedge:	1,60%	0,83%	0,34%	0,24%						
Percentages and indication for reallocation or rebalance- IR economic objective in focus:										
	AUD	CAD	CHI3	FRA3	GER3	GOL	JAP3	CHF	UK3	USA3
SIM3; SIM6	0,09%	0,09%	0,15%	0,15%	0,15%	0,17%	0,21%	0,17%	0,15%	0,27%
SIM4	0,13%	0,13%	0,13%	0,15%	0,15%	0,17%	0,19%	0,16%	0,17%	0,22%
SIM7	0,00%	0,00%	0,00%	0,19%	0,19%	0,22%	0,26%	0,21%	0,19%	0,34%
Percentages and indication for reallocation or rebalance- WACI in focus:										
SIM5	0,02%	0,02%	0,12%	0,11%	0,11%	0,17%	0,21%	0,29%	0,27%	0,27%

Source: prepared by the authors based on Torinelli et al. (2021).

Table 14

Correlation analysis with commodity and currency (Peru)

Commodity / Currency		Copper	Variance to			PEN	Variance to		
			Base:	SIM2:	2Y:		Base:	SIM2:	2Y:
2Y	Base	-0,380				0,04			
	SIM2	-0,309	-18,88%			-0,04	-200,00%		
	SIM3	-0,304	-20,20%	-1,63%		-0,04	-200,00%	0,00%	
	SIM4	-0,302	-20,51%	-2,01%		-0,04	-200,00%	0,00%	
	SIM5	-0,306	-19,63%	-0,92%		-0,04	-200,00%	0,00%	
	SIM6	-0,303	-20,47%	-1,96%		-0,04	-200,00%	0,00%	
	SIM7	-0,354	-6,87%	14,80%		0,00	-100,00%	-100,00%	
3Y	Base	-0,385				0,04			
	SIM2	-0,312	-19,04%		1,10%	-0,04	-200,00%		0,00%
	SIM3	-0,307	-20,37%	-1,65%	1,09%	-0,04	-200,00%	0,00%	0,00%
	SIM4	-0,305	-20,78%	-2,15%	0,96%	-0,05	-225,00%	25,00%	25,00%
	SIM5	-0,309	-19,76%	-0,89%	1,14%	-0,04	-200,00%	0,00%	0,00%
	SIM6	-0,309	-19,90%	-1,07%	2,03%	-0,04	-200,00%	0,00%	0,00%
	SIM7	-0,359	-6,85%	15,05%	1,32%	0,00	-100,00%	-100,00%	
5Y	Base	-0,394				0,04			
	SIM2	-0,34	-13,00%		10,96%	-0,01	-125,00%		-75,00%
	SIM3	-0,34	-14,18%	-1,35%	11,28%	-0,01	-125,00%	0,00%	-75,00%
	SIM4	-0,34	-14,48%	-1,70%	11,32%	-0,01	-125,00%	0,00%	-75,00%
	SIM5	-0,34	-13,74%	-0,85%	11,05%	-0,01	-125,00%	0,00%	-75,00%
	SIM6	-0,34	-13,37%	-0,43%	12,70%	-0,01	-125,00%	0,00%	-75,00%
	SIM7	-0,37	-5,70%	8,39%	4,76%	0,02	-50,00%	-300,00%	

Source: prepared by the authors.

A.3 Brazil

Table 15

Strategic Asset Allocation of the Investment Portfolio (Brazil)

Currency & Gold		AUD	CAD	CNY	EUR		GOLD	JPY	CHF	GPB	USD	OTHERS
Real Status 2019		0,00%	0,00%	0,00%	7,35%		0,94%	1,73%	0,00%	2,11%	86,77%	1,10%
Max. alloc. constraint		AUD	CAD	CHI3	FRA3	GER3	GOL	JAP3	CHF	UK3	USA3	
	Base	0,00%	0,00%	0,00%	3,83%	3,83%	0,98%	1,80%	0,00%	2,20%	90,37%	
	SIM2	1,00%	1,00%	1,00%	3,83%	3,83%	0,98%	1,80%	1,00%	2,20%	90,37%	
	SIM3	1,10%	1,10%	1,12%	3,95%	3,95%	1,12%	1,93%	1,13%	2,32%	90,53%	
	SIM4	1,08%	1,09%	1,14%	3,93%	3,93%	1,10%	1,93%	1,12%	2,34%	90,59%	
	SIM5	1,02%	1,02%	1,14%	3,94%	3,94%	1,12%	1,83%	1,27%	2,45%	90,53%	
	SIM6	1,00%	1,00%	1,00%	3,83%	3,83%	1,12%	1,93%	1,00%	2,20%	90,37%	
	SIM7	0,00%	0,00%	0,00%	3,99%	3,99%	1,16%	1,97%	1,17%	2,36%	90,59%	
	SIM8	0,00%	0,00%	0,00%	3,83%	3,83%	1,16%	1,80%	0,00%	2,20%	90,59%	
Min allocation const.		0,00%	0,00%	0,00%	3,56%	3,56%	0,91%	1,68%	0,00%	2,05%	84,17%	
	SIM6	0,10%	0,10%	0,12%	3,69%	3,69%	1,05%	1,81%	0,13%	2,17%	84,33%	
	SIM8	0,00%	0,00%	0,00%	2,94%	2,94%	0,91%	1,68%	0,00%	2,05%	84,17%	
Optimization												
2Y	Base	0,00%	0,00%	0,00%	3,56%	3,56%	0,98%	1,68%	0,00%	2,07%	88,15%	
	SIM2	0,02%	0,05%	0,47%	3,56%	3,56%	0,98%	1,68%	0,00%	2,07%	87,61%	
	SIM3	0,02%	0,06%	0,52%	3,56%	3,56%	1,12%	1,68%	0,00%	2,08%	87,40%	
	SIM4	0,02%	0,06%	0,53%	3,56%	3,56%	1,10%	1,68%	0,00%	2,08%	87,41%	
	SIM5	0,02%	0,06%	0,63%	3,56%	3,56%	1,12%	1,68%	0,00%	2,09%	87,28%	
	SIM6	0,11%	0,15%	0,49%	3,69%	3,69%	1,12%	1,81%	0,13%	2,17%	86,64%	
	SIM7	0,00%	0,00%	0,00%	3,56%	3,56%	1,59%	1,68%	0,00%	2,08%	87,52%	
	SIM8	0,00%	0,00%	0,00%	2,94%	2,94%	1,58%	1,68%	0,00%	2,07%	88,79%	
3Y	Base	0,00%	0,00%	0,00%	3,56%	3,56%	0,98%	1,68%	0,00%	2,16%	88,06%	
	SIM2	0,27%	0,22%	0,91%	3,56%	3,56%	0,98%	1,68%	0,00%	2,15%	86,66%	
	SIM3	0,28%	0,23%	1,02%	3,56%	3,56%	1,12%	1,68%	0,00%	2,23%	86,32%	
	SIM4	0,28%	0,23%	1,04%	3,56%	3,56%	1,10%	1,68%	0,00%	2,24%	86,31%	
	SIM5	0,25%	0,21%	1,27%	3,56%	3,56%	1,12%	1,68%	0,00%	2,31%	86,04%	
	SIM6	0,31%	0,28%	0,91%	3,69%	3,69%	1,12%	1,81%	0,13%	2,19%	85,88%	
	SIM7	0,00%	0,00%	0,00%	3,56%	3,56%	1,60%	1,68%	0,00%	2,27%	87,33%	
	SIM8	0,00%	0,00%	0,00%	2,96%	2,97%	1,60%	1,68%	0,00%	2,17%	88,63%	
5Y	Base	0,00%	0,00%	0,00%	3,72%	3,74%	0,98%	1,68%	0,00%	2,20%	87,68%	
	SIM2	0,84%	0,98%	1,00%	3,68%	3,69%	0,98%	1,68%	0,03%	2,20%	84,92%	
	SIM3	0,92%	1,07%	1,12%	3,60%	3,67%	1,12%	1,68%	0,00%	2,32%	84,50%	
	SIM4	0,90%	1,06%	1,14%	3,60%	3,67%	1,10%	1,68%	0,00%	2,34%	84,50%	
	SIM5	0,85%	0,99%	1,40%	3,57%	3,58%	1,12%	1,68%	0,00%	2,45%	84,36%	
	SIM6	0,85%	0,98%	1,00%	3,70%	3,71%	1,12%	1,81%	0,13%	2,20%	84,52%	
	SIM7	0,00%	0,00%	0,00%	3,81%	3,84%	1,60%	1,68%	0,14%	2,36%	86,57%	
	SIM8	0,00%	0,00%	0,00%	3,51%	3,56%	1,60%	1,68%	0,00%	2,20%	87,45%	

Source: prepared by the authors based on Banco Central do Brasil (2020) and IMF (2021a).

Table 16

Changes in the Maturity of the Bonds (Brazil)

Currency - Optimization		AUD	CAD	CNY	EUR	GOLD	JPY	CHF	GPB	USD
SIM3	2Y	0,02%	0,06%	0,52%	7,12%	1,12%	1,68%	0,00%	2,08%	87,40%
	3Y	0,28%	0,23%	1,02%	7,12%	1,12%	1,68%	0,00%	2,23%	86,32%
	5Y	0,92%	1,07%	1,12%	7,27%	1,12%	1,68%	0,00%	2,32%	84,50%
SIM4	2Y	0,02%	0,06%	0,53%	7,12%	1,10%	1,68%	0,00%	2,08%	87,41%
	3Y	0,28%	0,23%	1,04%	7,12%	1,10%	1,68%	0,00%	2,24%	86,31%
	5Y	0,90%	1,06%	1,14%	7,27%	1,10%	1,68%	0,00%	2,34%	84,50%
SIM5	2Y	0,02%	0,06%	0,63%	7,12%	1,12%	1,68%	0,00%	2,09%	87,28%
	3Y	0,25%	0,21%	1,27%	7,12%	1,12%	1,68%	0,00%	2,31%	86,04%
	5Y	0,85%	0,99%	1,40%	7,15%	1,12%	1,68%	0,00%	2,45%	84,36%
SIM6	2Y	0,11%	0,15%	0,49%	7,38%	1,12%	1,81%	0,13%	2,17%	86,64%
	3Y	0,31%	0,28%	0,91%	7,38%	1,12%	1,81%	0,13%	2,19%	85,88%
	5Y	0,85%	0,98%	1,00%	7,40%	1,12%	1,81%	0,13%	2,20%	84,52%
SIM7	2Y	0,00%	0,00%	0,00%	7,12%	1,59%	1,68%	0,00%	2,08%	87,52%
	3Y	0,00%	0,00%	0,00%	7,13%	1,60%	1,68%	0,00%	2,27%	87,33%
	5Y	0,00%	0,00%	0,00%	7,65%	1,60%	1,68%	0,14%	2,36%	86,57%
SIM8	2Y	0,00%	0,00%	0,00%	5,88%	1,58%	1,68%	0,00%	2,07%	88,79%
	3Y	0,00%	0,00%	0,00%	5,93%	1,60%	1,68%	0,00%	2,17%	88,63%
	5Y	0,00%	0,00%	0,00%	7,07%	1,60%	1,68%	0,00%	2,20%	87,45%

Source: prepared by the authors based on this study

Table 17

Risk-adjusted return[6] (Brazil)

Simulation		Return*	Variance to				Risk**	Variance to				Risk-
			Base:	SIM2:	3Y:	SIM3:		Base:	SIM2:	3Y:	SIM3:	adjusted
2Y	Base	1,23%			-18,37%		1,20%			-32,61%		102,92%
	SIM2	1,24%	0,26%		-18,35%		1,20%	-0,11%		-32,05%		103,30%
	SIM3	1,23%	-0,62%	-0,87%	-18,36%		1,19%	-0,93%	-0,82%	-32,07%		103,24%
	SIM4	1,23%	-0,49%	-0,75%	-18,33%	0,13%	1,19%	-0,82%	-0,71%	-32,04%	0,11%	103,25%
	SIM5	1,23%	-0,58%	-0,83%	-18,28%	0,04%	1,19%	-0,96%	-0,85%	-31,93%	-0,03%	103,31%
	SIM6	1,22%	-1,18%	-1,44%	-18,59%	-0,57%	1,21%	0,57%	0,68%	-31,50%	1,51%	101,12%
	SIM7	1,19%	-3,85%	-4,10%	-18,65%	-3,26%	1,16%	-3,35%	-3,24%	-33,03%	-2,44%	102,38%
	SIM8	1,20%	-3,11%	-3,36%	-18,71%	-2,51%	1,13%	-5,85%	-5,75%	-34,42%	-4,97%	105,91%
3Y	Base	1,51%					1,78%					84,96%
	SIM2	1,51%	0,24%				1,76%	-0,94%				85,96%
	SIM3	1,50%	-0,63%	-0,86%			1,75%	-1,72%	-0,79%			85,90%
	SIM4	1,50%	-0,54%	-0,77%		0,09%	1,75%	-1,65%	-0,72%		0,07%	85,92%
	SIM5	1,50%	-0,68%	-0,91%		-0,05%	1,74%	-1,95%	-1,03%		-0,24%	86,06%
	SIM6	1,50%	-0,91%	-1,15%		-0,29%	1,76%	-1,06%	-0,13%		0,67%	85,09%
	SIM7	1,46%	-3,51%	-3,74%		-2,90%	1,73%	-2,75%	-1,83%		-1,05%	84,29%
	SIM8	1,47%	-2,69%	-2,92%		-2,08%	1,72%	-3,25%	-2,34%		-1,56%	85,44%
5Y	Base	2,11%			39,66%		3,09%			73,89%		68,23%
	SIM2	2,10%	-0,39%		38,79%		3,02%	-2,39%		71,34%		69,63%
	SIM3	2,09%	-1,09%	-0,71%	39,00%		3,00%	-3,17%	-0,80%	71,33%		69,70%
	SIM4	2,09%	-1,03%	-0,65%	38,96%	0,06%	3,00%	-3,13%	-0,76%	71,28%	0,04%	69,71%
	SIM5	2,09%	-1,14%	-0,76%	39,01%	-0,05%	2,99%	-3,46%	-1,10%	71,22%	-0,30%	69,87%
	SIM6	2,09%	-1,12%	-0,03%	39,37%	-0,03%	3,01%	-2,75%	-0,37%	70,93%	0,44%	69,37%
	SIM7	2,05%	-3,02%	-2,01%	40,37%	-1,95%	3,03%	-2,06%	0,34%	75,14%	1,15%	67,56%
	SIM8	2,06%	-2,39%	-1,27%	40,09%	-1,31%	3,04%	-1,70%	0,71%	76,69%	1,52%	67,75%

*average of historical monthly returns, annualized
**standard deviation of returns

Source: prepared by the authors

[6] Sharp Index: return less risk free rate (zero), obtained by dividing return by risk

Table 18

WACI analysis (Brazil)

WACI- Actual GDP		AUD	CAD	CNY	EUR	JPY	CHF	GPB	USD	TOTAL	Variance to			
t CO2e/$MM USD GDP		271,04	336,62	691,44	272,63	211,60	48,52	121,50	233,91		Base:	SIM2:	SIM3:	2Y:
2Y	Base	-	-	-	19,60	3,59	-	2,54	208,24	233,97				
	SIM2	0,06	0,18	3,27	19,60	3,59	-	2,53	206,96	236,20	0,95%			
	SIM3	0,07	0,20	3,65	19,63	3,60	-	2,55	206,75	236,44	1,06%	0,10%		
	SIM4	0,06	0,20	3,69	19,63	3,59	-	2,55	206,73	236,47	1,07%	0,12%	0,01%	
	SIM5	0,06	0,19	4,41	19,63	3,60	-	2,57	206,48	236,93	1,26%	0,31%	0,21%	
	SIM6	0,31	0,50	3,44	20,35	3,87	0,06	2,67	204,94	236,15	0,93%	-0,02%	-0,14%	
	SIM7	-	-	-	19,72	3,62	-	2,57	208,03	233,95	-0,01%	-0,95%	-1,26%	
	SIM8	-	-	-	16,29	3,61	-	2,56	211,02	233,48	-0,21%	-1,15%	-1,13%	
3Y	Base	-	-	-	19,62	3,59	-	2,65	208,01	233,87				
	SIM2	0,74	0,74	6,37	19,60	3,59	-	2,64	204,72	238,41	1,94%			0,94%
	SIM3	0,77	0,79	7,12	19,63	3,60	-	2,74	204,19	238,84	2,13%	0,18%		1,02%
	SIM4	0,76	0,78	7,25	19,63	3,59	-	2,76	204,14	238,90	2,15%	0,21%	0,03%	1,03%
	SIM5	0,69	0,72	8,87	19,63	3,60	-	2,83	203,54	239,88	2,57%	0,62%	0,43%	1,25%
	SIM6	0,84	0,95	6,36	20,35	3,87	0,06	2,69	203,14	238,27	1,88%	-0,06%	-0,27%	0,90%
	SIM7	-	-	-	19,74	3,61	-	2,80	207,59	233,74	-0,05%	-1,96%	-2,56%	-0,09%
	SIM8	-	-	-	16,43	3,61	-	2,67	210,67	233,39	-0,21%	-2,11%	-2,05%	-0,04%
5Y	Base	-	-	-	20,53	3,59	-	2,70	207,13	233,95				-0,01%
	SIM2	2,30	3,32	6,98	20,29	3,59	0,01	2,70	200,61	239,81	2,51%			1,53%
	SIM3	2,52	3,65	7,83	20,04	3,60	-	2,85	199,89	240,37	2,75%	0,24%		1,66%
	SIM4	2,47	3,62	7,97	20,05	3,59	-	2,87	199,85	240,43	2,77%	0,26%	0,02%	1,67%
	SIM5	2,32	3,38	9,79	19,72	3,60	-	3,01	199,55	241,37	3,17%	0,65%	0,42%	1,88%
	SIM6	2,32	3,32	6,99	20,41	3,87	0,06	2,70	199,93	239,61	2,42%	-0,08%	-0,34%	1,47%
	SIM7	-	-	-	21,19	3,61	0,07	2,91	205,78	233,57	-0,16%	-2,60%	-3,23%	-0,16%
	SIM8	-	-	-	19,58	3,61	-	2,72	207,89	233,80	-0,07%	-2,51%	-2,43%	0,14%
WACI- Actual Pop											Variance to			
t CO2e/ CO2/POP		0,015	0,016	0,007	0,012	0,008	0,004	0,005	0,015		Base:	SIM2:	SIM3:	2Y:
2Y	Base	-	-	-	0,001	0,000	-	0,000	0,013	0,01427				
	SIM2	0,000	0,000	0,000	0,001	0,000	-	0,000	0,013	0,01424	-0,25%			
	SIM3	0,000	0,000	0,000	0,001	0,000	-	0,000	0,013	0,01423	-0,30%	-0,04%		
	SIM4	0,000	0,000	0,000	0,001	0,000	-	0,000	0,013	0,01423	-0,30%	-0,05%	0,00%	
	SIM5	0,000	0,000	0,000	0,001	0,000	-	0,000	0,013	0,01422	-0,37%	-0,11%	-0,07%	
	SIM6	0,000	0,000	0,000	0,001	0,000	0,000	0,000	0,013	0,01420	-0,54%	-0,28%	-0,23%	
	SIM7	-	-	-	0,001	0,000	-	0,000	0,013	0,01427	-0,03%	0,22%	0,33%	
	SIM8	-	-	-	0,001	0,000	-	0,000	0,013	0,01430	0,19%	0,44%	0,73%	
3Y	Base	-	-	-	0,001	0,000	-	0,000	0,013	0,01427				
	SIM2	0,000	0,000	0,000	0,001	0,000	-	0,000	0,013	0,01420	-0,48%			-0,29%
	SIM3	0,000	0,000	0,000	0,001	0,000	-	0,000	0,013	0,01418	-0,59%	-0,12%		-0,36%
	SIM4	0,000	0,000	0,000	0,001	0,000	-	0,000	0,013	0,01418	-0,61%	-0,13%	-0,02%	-0,37%
	SIM5	0,000	0,000	0,000	0,001	0,000	-	0,000	0,013	0,01415	-0,79%	-0,31%	-0,19%	-0,49%
	SIM6	0,000	0,000	0,000	0,001	0,000	0,000	0,000	0,013	0,01417	-0,70%	-0,22%	-0,09%	-0,23%
	SIM7	-	-	-	0,001	0,000	-	0,000	0,013	0,01425	-0,10%	0,38%	0,70%	-0,12%
	SIM8	-	-	-	0,001	0,000	-	0,000	0,013	0,01429	0,18%	0,66%	0,88%	-0,07%
5Y	Base	-	-	-	0,001	0,000	-	0,000	0,013	0,01425				-0,15%
	SIM2	0,000	0,000	0,000	0,001	0,000	0,000	0,000	0,013	0,01419	-0,46%			-0,36%
	SIM3	0,000	0,000	0,000	0,001	0,000	-	0,000	0,013	0,01417	-0,57%	-0,11%		-0,42%
	SIM4	0,000	0,000	0,000	0,001	0,000	-	0,000	0,013	0,01417	-0,60%	-0,13%	-0,03%	-0,44%
	SIM5	0,000	0,000	0,000	0,001	0,000	-	0,000	0,013	0,01414	-0,80%	-0,34%	-0,23%	-0,58%
	SIM6	0,000	0,000	0,000	0,001	0,000	0,000	0,000	0,013	0,01417	-0,61%	-0,15%	-0,01%	-0,22%
	SIM7	-	-	-	0,001	0,000	0,000	0,000	0,013	0,01421	-0,27%	0,19%	0,54%	-0,38%
	SIM8	-	-	-	0,001	0,000	-	0,000	0,013	0,01426	0,04%	0,51%	0,66%	-0,29%

Source: prepared by the authors based on IEA (2021), IMF (2021b) and The World Bank (2021b).

Table 19

Percentages and indication for reallocation or rebalance- international reserves economic objective in focus (Brazil)

Commodity:	Ore&Met	Agro	Manuf	Fuel						
Hedge:	0,04%	1,24%	1,04%	0,43%						
Percentages and indication for reallocation or rebalance- IR economic objective in focus:										
	AUD	CAD	CHI3	FRA3	GER3	GOL	JAP3	CHF	UK3	USA3
SIM3; SIM6	0,10%	0,10%	0,12%	0,12%	0,12%	0,14%	0,13%	0,13%	0,12%	0,16%
SIM4	0,08%	0,09%	0,14%	0,10%	0,10%	0,12%	0,13%	0,12%	0,14%	0,22%
SIM7	0,00%	0,00%	0,00%	0,17%	0,17%	0,19%	0,17%	0,17%	0,16%	0,22%
Percentages and indication for reallocation or rebalance- WACI in focus:										
SIM5	0,02%	0,02%	0,14%	0,11%	0,11%	0,14%	0,03%	0,27%	0,25%	0,16%
SIM8	0,00%	0,00%	0,00%	0,62%	0,62%	0,00%	0,00%	0,00%	0,00%	0,00%

Source: prepared by the authors based on Torinelli et al. (2021).

Table 20

Correlation analysis with commodity and currency (Brazil)

Commodity / Currency		Soy	Variance to			BRL	Variance to		
			Base:	SIM2:	2Y:		Base:	SIM2:	2Y:
2Y	Base	0,08				-0,05			
	SIM2	0,09	6,38%			-0,05	0,00%		
	SIM3	0,09	6,83%	0,43%		-0,05	0,00%	0,00%	
	SIM4	0,09	6,97%	0,56%		-0,05	0,00%	0,00%	
	SIM5	0,09	7,90%	1,44%		-0,05	0,00%	0,00%	
	SIM6	0,10	17,97%	10,89%		-0,07	40,00%	40,00%	
	SIM7	0,08	-2,00%	-7,87%		-0,03	-40,00%	-40,00%	
	SIM8	0,07	-16,44%	-21,45%		0,01	-120,00%	-120,00%	
3Y	Base	-0,02				0,04			
	SIM2	-0,01	-59,95%		-110,35%	0,02	-50,00%		-140,00%
	SIM3	-0,01	-64,96%	-12,51%	-109,02%	0,03	-25,00%	50,00%	-160,00%
	SIM4	-0,01	-65,75%	-14,48%	-108,80%	0,03	-25,00%	50,00%	-160,00%
	SIM5	-0,01	-71,37%	-28,51%	-107,30%	0,02	-50,00%	0,00%	-140,00%
	SIM6	0,00	-82,13%	-55,38%	-104,17%	0,02	-50,00%	0,00%	-128,57%
	SIM7	-0,02	10,02%	174,69%	-130,86%	0,06	50,00%	200,00%	-300,00%
	SIM8	-0,04	56,04%	289,59%	-151,34%	0,09	125,00%	350,00%	800,00%
5Y	Base	-0,11				0,11			
	SIM2	-0,09	-16,59%		-208,40%	0,08	-27,27%		-260,00%
	SIM3	-0,09	-17,75%	-1,40%	-206,43%	0,07	-36,36%	-12,50%	-240,00%
	SIM4	-0,09	-17,77%	-1,42%	-206,27%	0,07	-36,36%	-12,50%	-240,00%
	SIM5	-0,09	-17,56%	-1,16%	-205,62%	0,08	-27,27%	0,00%	-260,00%
	SIM6	-0,09	-17,32%	-0,88%	-196,89%	0,07	-36,36%	-12,50%	-200,00%
	SIM7	-0,11	0,71%	20,73%	-242,06%	0,11	0,00%	37,50%	-466,67%
	SIM8	-0,12	4,18%	24,89%	-272,34%	0,12	9,09%	50,00%	1100,00%

Source: prepared by the authors.

A.4 Jamaica

Table 21

Strategic Asset Allocation of the Investment Portfolio (Jamaica)

Currency & Gold		AUD	CAD	CNY	EUR		GOLD	JPY	CHF	GPB	USD	OTHERS
Real Status 2019		0,00%	0,00%	0,50%	0,60%		0,00%	0,00%	0,00%	0,60%	91,50%	6,80%
Max allocation constraint		AUD	CAD	CHI3	FRA3	GER3	GOL	JAP3	CHF	UK3	USA3	
	Base	0,00%	0,00%	0,55%	0,33%	0,33%	0,00%	0,00%	0,00%	0,66%	100,00%	
	SIM2	1,00%	1,00%	0,55%	0,33%	0,33%	1,00%	1,00%	1,00%	0,66%	100,00%	
	SIM3	1,01%	1,01%	0,57%	0,34%	0,34%	1,01%	1,01%	1,01%	0,68%	100,00%	
	SIM4	1,01%	1,01%	0,55%	0,34%	0,34%	1,04%	1,02%	1,01%	0,68%	100,00%	
	SIM5	1,00%	1,00%	0,57%	0,34%	0,34%	1,01%	1,01%	1,02%	0,69%	100,00%	
	SIM6	1,00%	1,00%	0,55%	0,33%	0,33%	1,00%	1,00%	1,00%	0,66%	100,00%	
Min allocation constraint		0,00%	0,00%	0,49%	0,29%	0,29%	0,00%	0,00%	0,00%	0,58%	88,76%	
	SIM6	0,01%	0,01%	0,50%	0,30%	0,30%	0,01%	0,01%	0,01%	0,60%	88,77%	
Optimization												
2Y	Base	0,00%	0,00%	0,54%	0,30%	0,30%	0,00%	0,00%	0,00%	0,63%	98,23%	
	SIM2	0,35%	0,40%	0,54%	0,30%	0,30%	0,94%	0,02%	0,00%	0,62%	96,52%	
	SIM3	0,35%	0,40%	0,55%	0,30%	0,30%	0,95%	0,02%	0,00%	0,64%	96,48%	
	SIM4	0,36%	0,40%	0,54%	0,30%	0,30%	0,98%	0,03%	0,00%	0,64%	96,46%	
	SIM5	0,35%	0,40%	0,55%	0,30%	0,30%	0,95%	0,02%	0,00%	0,64%	96,48%	
	SIM6	0,36%	0,40%	0,54%	0,31%	0,31%	0,94%	0,03%	0,01%	0,63%	96,47%	
3Y	Base	0,00%	0,00%	0,55%	0,31%	0,31%	0,00%	0,00%	0,00%	0,66%	98,17%	
	SIM2	0,66%	0,78%	0,55%	0,31%	0,31%	1,00%	0,01%	0,01%	0,66%	95,71%	
	SIM3	0,67%	0,79%	0,57%	0,31%	0,31%	1,01%	0,01%	0,01%	0,68%	95,64%	
	SIM4	0,67%	0,79%	0,55%	0,31%	0,31%	1,04%	0,01%	0,01%	0,68%	95,63%	
	SIM5	0,66%	0,78%	0,57%	0,31%	0,31%	1,01%	0,01%	0,01%	0,69%	95,65%	
	SIM6	0,66%	0,78%	0,55%	0,31%	0,31%	1,00%	0,01%	0,02%	0,66%	95,68%	
5Y	Base	0,00%	0,00%	0,55%	0,33%	0,33%	0,00%	0,00%	0,00%	0,66%	98,14%	
	SIM2	0,98%	1,00%	0,55%	0,33%	0,33%	1,00%	0,00%	0,35%	0,66%	94,80%	
	SIM3	0,99%	1,01%	0,57%	0,34%	0,34%	1,01%	0,00%	0,35%	0,68%	94,71%	
	SIM4	0,99%	1,01%	0,55%	0,34%	0,34%	1,04%	0,00%	0,36%	0,68%	94,70%	
	SIM5	0,98%	1,00%	0,57%	0,34%	0,34%	1,01%	0,00%	0,36%	0,69%	94,72%	
	SIM6	0,98%	1,00%	0,55%	0,33%	0,33%	1,00%	0,01%	0,36%	0,66%	94,78%	

Source: prepared by the authors based on Bank of Jamaica (2021) and IMF (2021a).

Table 22

Changes in the Maturity of the Bonds (Jamaica)

Currency - Optimization		AUD	CAD	CNY	EUR	GOLD	JPY	CHF	GPB	USD
SIM3	2Y	0,35%	0,40%	0,55%	0,60%	0,95%	0,02%	0,00%	0,64%	96,48%
	3Y	0,67%	0,79%	0,57%	0,62%	1,01%	0,01%	0,01%	0,68%	95,64%
	5Y	0,99%	1,01%	0,57%	0,67%	1,01%	0,00%	0,35%	0,68%	94,71%
SIM4	2Y	0,36%	0,40%	0,54%	0,60%	0,98%	0,03%	0,00%	0,64%	96,46%
	3Y	0,67%	0,79%	0,55%	0,63%	1,04%	0,01%	0,01%	0,68%	95,63%
	5Y	0,99%	1,01%	0,55%	0,67%	1,04%	0,00%	0,36%	0,68%	94,70%
SIM5	2Y	0,35%	0,40%	0,55%	0,60%	0,95%	0,02%	0,00%	0,64%	96,48%
	3Y	0,66%	0,78%	0,57%	0,62%	1,01%	0,01%	0,01%	0,69%	95,65%
	5Y	0,98%	1,00%	0,57%	0,67%	1,01%	0,00%	0,36%	0,69%	94,72%
SIM6	2Y	0,36%	0,40%	0,54%	0,61%	0,94%	0,03%	0,01%	0,63%	96,47%
	3Y	0,66%	0,78%	0,55%	0,63%	1,00%	0,01%	0,02%	0,66%	95,68%
	5Y	0,98%	1,00%	0,55%	0,66%	1,00%	0,01%	0,36%	0,66%	94,78%

Source: prepared by the authors based on this study

Table 23

Risk-adjusted return[7] (Jamaica)

Simulation		Return*	Variance to				Risk**	Variance to				Risk-
			Base:	SIM2:	3Y:	SIM3:		Base:	SIM2:	3Y:	SIM3:	adjusted
2Y	Base	1,39%			-17,47%		1,14%			-37,69%		121,75%
	SIM2	1,32%	-5,38%		-17,68%		1,08%	-5,56%		-37,79%		121,99%
	SIM3	1,32%	-5,44%	-0,07%	-17,66%		1,08%	-5,65%	-0,09%	-37,77%		122,01%
	SIM4	1,31%	-5,60%	-0,24%	-17,67%	-0,17%	1,08%	-5,76%	-0,20%	-37,78%	-0,11%	121,94%
	SIM5	1,32%	-5,45%	-0,08%	-17,66%	-0,01%	1,08%	-5,66%	-0,10%	-37,77%	0,00%	122,01%
	SIM6	1,32%	-5,42%	-0,04%	-17,70%	0,03%	1,08%	-5,58%	-0,02%	-37,80%	0,08%	121,95%
3Y	Base	1,69%					1,84%					91,92%
	SIM2	1,60%	-5,14%				1,74%	-5,42%				92,19%
	SIM3	1,60%	-5,22%	-0,09%			1,73%	-5,53%	-0,12%			92,22%
	SIM4	1,60%	-5,38%	-0,25%		-0,16%	1,73%	-5,62%	-0,21%		-0,09%	92,16%
	SIM5	1,60%	-5,24%	-0,10%		-0,01%	1,73%	-5,54%	-0,12%		0,00%	92,21%
	SIM6	1,60%	-5,16%	-0,02%		0,07%	1,74%	-5,42%	0,01%		0,13%	92,17%
5Y	Base	2,31%			37,02%		3,30%			79,58%		70,14%
	SIM2	2,20%	-4,61%		37,79%		3,14%	-4,68%		80,99%		70,18%
	SIM3	2,20%	-4,68%	-0,08%	37,81%		3,14%	-4,78%	-0,11%	81,01%		70,21%
	SIM4	2,20%	-4,80%	-0,20%	103,96%	-0,12%	3,14%	-4,84%	-0,17%	81,07%	-0,06%	70,16%
	SIM5	2,20%	-4,70%	-0,09%	104,41%	-0,01%	3,14%	-4,78%	-0,10%	81,03%	0,00%	70,19%
	SIM6	2,20%					3,14%	-4,68%	0,00%	80,98%	0,11%	70,18%

*average of historical monthly returns, annualized

**standard deviation of returns

Source: prepared by the authors

[7] Sharp Index: return less risk free rate (zero), obtained by dividing return by risk

Table 24

WACI analysis (Jamaica)

WACI- Actual GDP		AUD	CAD	CNY	EUR	JPY	CHF	GPB	USD	TOTAL	Variance to			
t CO2e/$	CO2/GDP	271,04	336,62	691,44	272,63	211,60	48,52	121,50	233,91		Base:	SIM2:	SIM3:	2Y:
2Y	Base	-	-	3,73	1,63	-	-	0,76	229,78	235,90				
	SIM2	0,97	1,35	3,76	1,64	0,05	-	0,77	227,92	236,46	0,24%			
	SIM3	0,97	1,36	3,87	1,65	0,05	-	0,78	227,84	236,53	0,26%	0,03%		
	SIM4	0,98	1,37	3,76	1,65	0,05	-	0,78	227,86	236,46	0,23%	0,00%	-0,03%	
	SIM5	0,96	1,35	3,87	1,65	0,05	-	0,79	227,84	236,52	0,26%	0,02%	0,00%	
	SIM6	0,98	1,36	3,77	1,69	0,07	0,00	0,78	227,80	236,45	0,23%	-0,01%	0,00%	
3Y	Base	-	-	3,80	1,69	-	-	0,80	229,64	235,92				
	SIM2	1,81	2,66	3,84	1,70	0,01	0,01	0,81	226,14	236,98	0,45%			0,22%
	SIM3	1,83	2,68	3,98	1,72	0,01	0,01	0,83	226,00	237,06	0,48%	0,03%		0,22%
	SIM4	1,83	2,68	3,84	1,72	0,01	0,01	0,83	226,04	236,97	0,44%	0,00%	-0,04%	0,22%
	SIM5	1,81	2,65	3,98	1,72	0,01	0,01	0,84	226,01	237,04	0,47%	0,03%	-0,01%	0,22%
	SIM6	1,82	2,65	3,84	1,73	0,03	0,01	0,81	226,07	236,96	0,44%	-0,01%	0,00%	0,22%
5Y	Base	-	-	3,80	1,79	-	-	0,80	229,55	235,94				0,01%
	SIM2	2,68	3,40	3,84	1,80	-	0,17	0,81	223,99	236,70	0,32%			0,10%
	SIM3	2,71	3,43	3,98	1,85	-	0,17	0,83	223,80	236,79	0,36%	0,04%		0,11%
	SIM4	2,71	3,44	3,84	1,85	-	0,17	0,83	223,84	236,69	0,32%	0,00%	-0,04%	0,10%
	SIM5	2,68	3,40	3,98	1,85	-	0,17	0,85	223,81	236,75	0,35%	0,02%	-0,01%	0,10%
	SIM6	2,68	3,40	3,84	1,81	0,03	0,18	0,81	223,95	236,69	0,32%	0,00%	0,00%	0,10%
WACI- Actual Pop											Variance to			
t CO2e/$MM Pop		0,015	0,016	0,007	0,012	0,008	0,004	0,005	0,015		Base:	SIM2:	SIM3:	2Y:
2Y	Base	-	-	0,000	0,000	-	-	0,000	0,014	0,01463				
	SIM2	0,000	0,000	0,000	0,000	0,000	-	0,000	0,014	0,01464	0,03%			
	SIM3	0,000	0,000	0,000	0,000	0,000	-	0,000	0,014	0,01464	0,01%	-0,02%		
	SIM4	0,000	0,000	0,000	0,000	0,000	-	0,000	0,014	0,01464	0,02%	-0,01%	0,01%	
	SIM5	0,000	0,000	0,000	0,000	0,000	-	0,000	0,014	0,01464	0,01%	-0,02%	0,00%	
	SIM6	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01464	0,01%	-0,02%	-0,01%	
3Y	Base	-	-	0,000	0,000	-	-	0,000	0,014	0,01463				
	SIM2	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01464	0,06%			0,00%
	SIM3	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01464	0,03%	-0,02%		0,00%
	SIM4	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01464	0,04%	-0,01%	0,01%	0,00%
	SIM5	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01463	0,03%	-0,03%	-0,01%	-0,01%
	SIM6	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01464	0,04%	-0,01%	0,00%	0,01%
5Y	Base	-	-	0,000	0,000	-	-	0,000	0,014	0,01463				-0,04%
	SIM2	0,000	0,000	0,000	0,000	-	0,000	0,000	0,014	0,01461	-0,16%			-0,22%
	SIM3	0,000	0,000	0,000	0,000	-	0,000	0,000	0,014	0,01445	-1,20%	-1,04%		-1,24%
	SIM4	0,000	0,000	0,000	0,000	-	0,000	0,000	0,014	0,01449	-0,93%	-0,77%	0,27%	-0,98%
	SIM5	0,000	0,000	0,000	0,000	-	0,000	0,000	0,014	0,01448	-0,99%	-0,83%	0,21%	-1,03%
	SIM6	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,014	0,01445	-1,22%	-1,06%	-0,29%	-1,26%

Source: prepared by the authors based on IEA (2021), IMF (2021b) and The World Bank (2021b).

Table 25

Percentages and indication for reallocation or rebalance- international reserves economic objective in focus (Jamaica)

Commodity:	Ore&Met	Agro	Manuf	Fuel						
Hedge:	0,12%	0,05%	0,007%	0,04%						
Percentages and indication for reallocation or rebalance- IR economic objective in focus:										
	AUD	CAD	CHI3	FRA3	GER3	GOL	JAP3	CHF	UK3	USA3
SIM3; SIM	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,02%	0,02%
SIM4	0,01%	0,01%	0,00%	0,01%	0,01%	0,04%	0,02%	0,01%	0,01%	0,00%
Percentages and indication for reallocation or rebalance- WACI in focus:										
SIM5	0,00%	0,00%	0,01%	0,01%	0,01%	0,01%	0,01%	0,02%	0,03%	0,01%

Source: prepared by the authors based on Torinelli et al. (2021).

Table 26

Correlation analysis with commodity and currency (Jamaica)

Commodity / Currency		ALU	Variance to			JMD	Variance to		
			Base:	SIM2:	2Y:		Base:	SIM2:	2Y:
2Y	Base	-0,1609				0,20			
	SIM2	-0,1694	5,29%			0,20	0,00%		
	SIM3	-0,1695	5,32%	0,03%		0,20	0,00%	0,00%	
	SIM4	-0,1704	5,86%	0,55%		0,20	0,00%	0,00%	
	SIM5	-0,1697	5,43%	0,14%		0,20	0,00%	0,00%	
	SIM6	-0,1687	4,85%	-0,42%		0,20	0,00%	0,00%	
3Y	Base	-0,1335				0,20			
	SIM2	-0,128	-4,46%		-24,74%	0,20	0,00%		0,00%
	SIM3	-0,127	-4,55%	-0,09%	-24,84%	0,20	0,00%	0,00%	0,00%
	SIM4	-0,128	-4,09%	0,39%	-24,86%	0,20	0,00%	0,00%	0,00%
	SIM5	-0,128	-4,35%	0,12%	-24,76%	0,20	0,00%	0,00%	0,00%
	SIM6	-0,127	-4,73%	-0,28%	-24,64%	0,20	0,00%	0,00%	0,00%
5Y	Base	-0,10				0,20			
	SIM2	-0,09	-10,40%		-47,78%	0,20	0,00%		0,00%
	SIM3	-0,09	-10,62%	-0,24%	-47,92%	0,20	0,00%	0,00%	0,00%
	SIM4	-0,09	-10,26%	0,16%	-47,98%	0,20	0,00%	0,00%	0,00%
	SIM5	-0,09	-10,43%	-0,04%	-47,87%	0,20	0,00%	0,00%	0,00%
	SIM6	-0,09	-10,51%	-0,13%	-47,63%	0,20	0,00%	0,00%	0,00%

Source: prepared by the authors.

A.5 Mexico

Table 27

Strategic Asset Allocation of the Investment Portfolio (Mexico)

Currency & Gold		AUD	CAD	CNY	EUR		GOLD	JPY	CHF	GPB	USD	OTHERS
Real Status 2019		0,49%	0,80%	0,72%	0,00%		0,67%	0,65%	0,01%	0,12%	92,86%	3,67%
Max alloc. constraint		AUD	CAD	CHI3	FRA3	GER3	GOL	JAP3	CHF	UK3	USA3	
	Base	0,52%	0,86%	0,77%	0,00%	0,00%	0,71%	0,69%	0,01%	0,13%	99,29%	
	SIM2	0,52%	0,86%	0,77%	1,00%	1,00%	0,71%	0,69%	0,01%	0,13%	99,29%	
	SIM4	1,23%	1,59%	1,66%	1,83%	1,86%	1,81%	1,78%	0,96%	1,04%	100,00%	
	SIM5	0,69%	1,03%	1,63%	1,69%	1,69%	1,81%	1,83%	1,69%	1,71%	100,00%	
Min allocation const.		0,47%	0,78%	0,70%	0,00%	0,00%	0,65%	0,63%	0,01%	0,12%	90,07%	
Optimization												
2Y	Base	0,49%	0,81%	0,76%	0,00%	0,00%	0,71%	0,63%	0,01%	0,13%	96,47%	
	SIM2	0,49%	0,81%	0,76%	0,22%	0,12%	0,71%	0,63%	0,01%	0,13%	96,13%	
	SIM4	0,65%	0,98%	1,42%	0,24%	0,09%	1,73%	0,65%	0,01%	0,54%	93,69%	
	SIM5	0,54%	0,85%	1,39%	0,23%	0,09%	1,72%	0,65%	0,01%	0,80%	93,71%	
3Y	Base	0,50%	0,84%	0,77%	0,00%	0,00%	0,71%	0,63%	0,01%	0,13%	96,41%	
	SIM2	0,50%	0,84%	0,77%	0,46%	0,37%	0,71%	0,63%	0,01%	0,13%	95,58%	
	SIM4	1,15%	1,57%	1,66%	0,62%	1,25%	1,81%	0,63%	0,03%	1,04%	90,25%	
	SIM5	0,59%	0,94%	1,60%	0,52%	0,25%	1,81%	0,63%	0,01%	1,64%	92,00%	
5Y	Base	0,52%	0,86%	0,77%	0,00%	0,00%	0,71%	0,63%	0,01%	0,13%	96,37%	
	SIM2	0,52%	0,86%	0,77%	0,92%	0,94%	0,71%	0,63%	0,01%	0,13%	94,52%	
	SIM4	1,15%	1,57%	1,66%	0,62%	1,25%	1,81%	0,63%	0,03%	1,04%	90,25%	
	SIM5	0,67%	1,02%	1,63%	0,88%	1,30%	1,81%	0,63%	0,04%	1,71%	90,31%	

Source: prepared by the authors based on Banco do Mexico (2019) and IMF (2021a).

Table 28

Changes in the Maturity of the Bonds (Mexico)

Currency - Optimization		AUD	CAD	CNY	EUR	GOLD	JPY	CHF	GPB	USD
SIM4	2Y	0,65%	0,98%	1,42%	0,33%	1,73%	0,65%	0,01%	0,54%	93,69%
	3Y	1,15%	1,57%	1,66%	1,87%	1,81%	0,63%	0,03%	1,04%	90,25%
	5Y	1,15%	1,57%	1,66%	1,87%	1,81%	0,63%	0,03%	1,04%	90,25%
SIM5	2Y	0,54%	0,85%	1,39%	0,32%	1,72%	0,65%	0,01%	0,80%	93,71%
	3Y	0,59%	0,94%	1,60%	0,77%	1,81%	0,63%	0,01%	1,64%	92,00%
	5Y	0,67%	1,02%	1,63%	2,18%	1,81%	0,63%	0,04%	1,71%	90,31%

Source: prepared by the authors based on this study

Table 29

Risk-adjusted return[8] (Mexico)

Simulation		Return*	Variance to			Risk**	Variance to			Risk-
			Base:	SIM2:	3Y:		Base:	SIM2:	3Y:	adjusted
2Y	Base	1,36%			-17,63%	1,11%			-38,01%	122,11%
	SIM2	1,35%	-0,16%		-17,44%	1,11%	-0,07%		-37,83%	121,99%
	SIM4	1,27%	-6,57%	-6,42%	-40,06%	1,03%	-6,84%	-6,77%	-65,38%	122,45%
	SIM5	1,26%	-7,05%	-6,90%	-16,57%	1,03%	-7,03%	-6,97%	-37,05%	122,09%
3Y	Base	1,65%				1,79%				91,89%
	SIM2	1,64%	-0,39%			1,78%	-0,36%			91,86%
	SIM4	2,11%	28,40%	28,90%		2,99%	66,81%	67,40%		70,73%
	SIM5	1,51%	-8,23%	-7,87%		1,64%	-8,45%	-8,13%		92,11%
5Y	Base	2,26%			37,26%	3,22%			80,12%	70,03%
	SIM2	2,24%	-0,75%		36,76%	3,19%	-0,99%		78,97%	70,20%
	SIM4	2,11%	-6,46%	-5,75%	0,00%	2,99%	-7,39%	-6,46%	0,00%	70,73%
	SIM5	2,10%	-7,17%	-6,47%	38,84%	2,98%	-7,47%	-6,54%	82,06%	70,25%

*average of historical monthly returns, annualized
**standard deviation of returns

Source: prepared by the authors

Table 30

WACI analysis (Mexico)

WACI- t CO2e/	Actual Pop CO2/POP									Variance to		
		0,015	0,016	0,007	0,012	0,008	0,004	0,005	0,015		Base:	SIM2:	2Y:
2Y	Base	0,0001	0,0001	0,0001	-	0,0001	0,0000	0,0000	0,0143	0,01465			
	SIM2	0,0001	0,0001	0,0001	0,0000	0,0001	0,0000	0,0000	0,0143	0,01464	-0,06%		
	SIM4	0,0001	0,0002	0,0001	0,0000	0,0001	0,0000	0,0000	0,0141	0,01455	-0,69%	-0,64%	
	SIM5	0,0001	0,0001	0,0001	0,0000	0,0001	0,0000	0,0000	0,0141	0,01452	-0,86%	-0,80%	
3Y	Base	0,0001	0,0001	0,0001	-	0,0001	0,0000	0,0000	0,0143	0,01465			
	SIM2	0,0001	0,0001	0,0001	0,0001	0,0001	0,0000	0,0000	0,0142	0,01463	-0,14%		-0,09%
	SIM4	0,0002	0,0002	0,0001	0,0002	0,0001	0,0000	0,0001	0,0136	0,01445	-1,35%	-1,21%	-0,66%
	SIM5	0,0001	0,0001	0,0001	0,0001	0,0001	0,0000	0,0001	0,0138	0,01442	-1,58%	-1,45%	-0,74%
5Y	Base	0,0001	0,0001	0,0001	-	0,0001	0,0000	0,0000	0,0143	0,01465			0,00%
	SIM2	0,0001	0,0001	0,0001	0,0002	0,0001	0,0000	0,0000	0,0140	0,01460	-0,30%		-0,25%
	SIM4	0,0002	0,0002	0,0001	0,0002	0,0001	0,0000	0,0001	0,0136	0,01445	-1,35%	-1,05%	-0,66%
	SIM5	0,0001	0,0002	0,0001	0,0003	0,0001	0,0000	0,0001	0,0136	0,01437	-1,89%	-1,59%	-1,05%

Source: prepared by the authors based on IEA (2021), IMF (2021b) and The World Bank (2021b).

[8] Sharp Index: return less risk free rate (zero), obtained by dividing return by risk

Table 31

Percentages and indication for reallocation or rebalance- international reserves economic objective in focus (Mexico)

Commodity:	Ore&Met	Agro	Manuf	Fuel						
Hedge:	0,23%	0,97%	9,69%	0,67%						
Percentages and indication for reallocation or rebalance- IR economic objective in focus:										
	AUD	CAD	CHI3	FRA3	GER3	GOL	JAP3	CHF	UK3	USA3
SIM4	0,71%	0,73%	0,89%	0,83%	0,86%	1,10%	1,09%	0,94%	0,91%	1,64%
Percentages and indication for reallocation or rebalance- WACI in focus:										
SIM5	0,17%	0,17%	0,85%	0,69%	0,69%	1,10%	1,14%	1,67%	1,58%	1,64%

Source: prepared by the authors based on Torinelli et al. (2021).

Table 32

Correlation analysis with currency (Mexico)

Currency		MXN	Variance to		
			Base:	SIM2:	2Y:
2Y	Base	0,26			
	SIM2	0,25	-3,85%		
	SIM4	0,25	-3,85%	0,00%	
	SIM5	0,25	-3,85%	0,00%	
3Y	Base	0,24			
	SIM2	0,22	-8,33%		-12,00%
	SIM4	0,19	-20,83%	-13,64%	-24,00%
	SIM5	0,21	-12,50%	-4,55%	-16,00%
5Y	Base	0,22			
	SIM2	0,21	-4,55%		-16,00%
	SIM4	0,19	-13,64%	-9,52%	-24,00%
	SIM5	0,20	-9,09%	-4,76%	-20,00%

Source: prepared by the authors.

5 Policy Brief:

Walk the talk: the management of environmental and climate risk exposure of the international reserves by central banks

Viviane H. Torinelli[1,2], Antônio F. A. Silva Júnior[1,2] and José Célio Silveira Andrade[1,2]

[1] Business School, Universidade Federal da Bahia, Salvador, Bahia, Brazil (UFBA),

[2] Brazilian Research Alliance for Sustainable Finance and Investment (BRASFI),

Author Note

Viviane H. Torinelli https://orcid.org/0000-0002-1330-6370

Antônio F. A. Silva Júnior https://orcid.org/0000-0002-4417-5991

José Célio Silveira Andrade https://orcid.org/0000-0002-6794-8686

Correspondence email: vivitorinelli@gmail.com

5.1 Policy brief in a nutshell

The exposure of the international reserves to environmental and climate risks must de managed at least due to the associated financial risks. In fact, the strategic asset allocation of international reserves is a multi-objective problem that must consider safety, liquidity and profitability issues. Environmental and climate risk management adds a new economic/financial objective to the problem. Therefore, we argue that incorporating environmental and climate risks to the strategic asset allocation can be done without prejudice to the economic and financial objectives of the central banks and may eventually compose a strategy of positive impact management. Central banks are among the largest global investors, managing international reserves totaling around 13 trillion of dollars. This action is politically relevant to safeguard the execution of the monetary and foreign exchange policies through the use of international reserves and for the possible real-world effect of the reallocation of those assets.

5.2 Context or scope of problem

Human actions and the modern economy are significantly aggravating physical climate risks and living conditions on earth (IPCC, 2021). Also, climate and environmental risks are the main risks to the world economy in the next 10 years (WEF, 2022).

There is growing pressure and action from governments, regulatory bodies, society and the investor community for sustainable initiatives. For example, the G20 is mobilized through the Sustainable Finance Working Group (G20 SFWG, 2022) to support the strategic objective of sustainable and balanced growth. Also in this sense, 105 central banks and monetary authorities are mobilized in a Network for Greening the Financial System, to enhance risk management and to mobilize capital for sustainable development, aligned with the goals from the Paris Agreement (NGFS, 2021c). Besides, the responsible investor community totaled US$121 trillion of assets under management in 2021 (PRI, 2021). On top of that, with European leadership, efforts are being made to make a just transition towards a climate-neutral economy. The objective is mobilize around €55 billion over the period 2021-2027 in the most affected regions, to alleviate the socio-economic impact of the transition (European Commission, 2022). The aim is to build a new economy with positive socio-environmental externalities, a green economy that generates income and employment through public and private investments focused on maintaining biodiversity and systemic services, reducing pollution and carbon emissions and increasing energy efficiency and resource use (GIZ, 2011).

The transition to this new economy generates risks to be managed, in addition to the possible physical impacts associated with environmental and climatic factors. Therefore, the risks of transition to a new economic logic are also presented as relevant (OECD, 2021). Hence, we are achieving a more common understanding that environmental and climate factors result in physical and transition risks, which in turn are relevant sources of financial risks (NGFS, 2020d).

The financial risks linked to environmental and climate factors may undermine the resiliency of the investment portfolios, including the ones from the international reserves. The international reserves managed by central banks total around US$13 trillion (IMF, 2021a) and are specially critical to safeguard economies in crisis and to execute the national monetary and foreign exchange policies (Aizenman & Marion, 2002; Allen et al., 2002; Detragiache, 1996; Hawkins & Rangarajan, 1970; Kohlscheen & O'Connell, 2004; Silva Jr., 2011). Thus, the management of international reserves consists of their application in asset classes available in the international financial market, and to consider environmental and climate risks is not among its primary objectives. Possibly for this reason, central banks are not significantly addressing the sustainable and responsible investment management and the green finance market as managers of the international reserves (Dafe & Volz, 2015; NGFS, 2018, 2020e; Sheng, 2015; Volz, 2017).

The challenge to be faced is how to manage the exposure of international reserves to environmental and climate risks, without prejudice to the economic and financial objectives of central banks. As known, environmental and climate risks are sources of relevant financial risk and must be managed (Andersson et al., 2016; WRI & UNEP-FI, 2015), at least due to the associated financial risks, but maybe also to compose a strategy of positive impact in the real-world (PRI, 2019).

5.3 Policy alternatives

Three policy alternatives are listed to address the problem just detailed: 1) Traditional management; 2) Environmental and climate risk management; 3) Positive impact management.

1) Traditional management

Central banks continue to manage the international reserves according with the traditional framework, which contemplates the economic and financial objectives of the central banks, alongside with the three pillars of investment, and aligned with the investment mandate of each central bank (Aizenman & Marion, 2002; Allen et al., 2002; Detragiache, 1996; Fender et al., 2019; Hawkins & Rangarajan, 1970; IMF, 2018, 2019; Jeanne, 2012; Jones, 2018; Kohlscheen & O'Connell, 2004; McCauley, 2019; McCauley & Rigaudy, 2011; Morahan & Mulder, 2013; NGFS, 2019, 2020e; Silva Jr., 2011; UBS, 2018, 2019; Vecchio, 2009).

2) Environmental and climate risk management

Central banks understand that the exposure of the international reserves to environmental and climate risks must be managed at least due to the associated financial risks. In addition to the physical risks associated with the depredation of the environment and the climate change, transition risks arising from political, technological and investor perception changes can also cause significant financial risks, which need to be managed and, as far as possible, mitigated (Bank for International Settlements, 2019; Bank of England, 2020; Bank of England et al., 2017; Banque de France, 2020; Battiston & Monasterolo, 2019; Benedetti et al., 2019; Bolton et al., 2020; Bose et al., 2019; Cahen-Fourot et al., 2021; Caldecott et al., 2014; Cambridge Centre for Sustainable Finance, 2016; Campbell & Viceira, 2003; Campiglio et al., 2018; CISL, 2015; Dafe & Volz, 2015; Dietz et al., 2016; Fender et al., 2019; G20 Green Finance Study Group, 2016, 2017; IPCC, 2014; Jones, 2018; Lamperti et al., 2019; Lydenberg, 2016; McKinsey Global Institute, 2020; Mercer, 2011, 2015; Moody's Investor Service, 2016; NGFS, 2019, 2020a, 2020b, 2020c, 2020d, 2020e; Ortec Finance, 2020; PRI, 2019; Scott et al., 2017; TCFD, 2017; Torinelli et al., 2021; Torinelli & Silva Júnior, 2021; UBS, 2018; UNEP FI, 2019; Volz, 2017; Volz et al., 2020; WRI & UNEP-FI, 2015; WWF et al., 2017).

3) Positive impact management

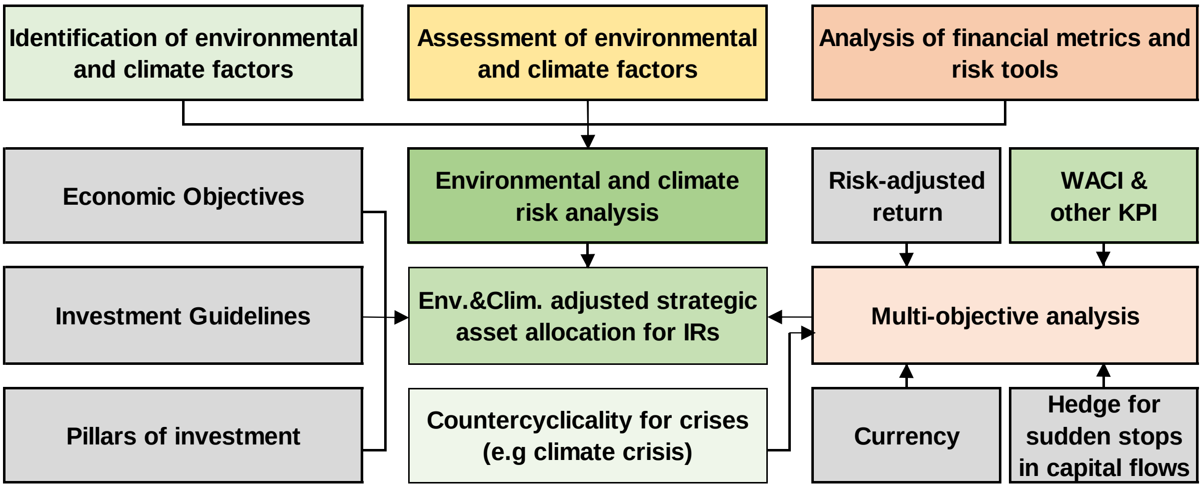
Central banks understand they may go beyond environmental and climate risk management, by implementing a positive impact management through the management of the international reserves (Bose et al., 2019; NGFS, 2020e, 2020b; PRI, 2019; Scott et al., 2017; Sveriges Riksbank, 2019). To get a measure of the amounts involved, the International Energy Agency estimates that to reach net zero emissions by 2050, annual clean energy investment worldwide must more than triple by 2030 to around US$4 trillion annually (IEA, 2022). In order to achieve this objective of environmentally sustainable development agreed between nations, joint action by all economic actors, government and the private sector is necessary (UN, 2022). The participation of central banks would be relevant given that they are among the major global investors (IMF, 2021).

5.4 Policy recommendations

As concrete steps to be taken to address the policy issue, environmental and climate risk analysis should be included in the traditional approach to strategic asset allocation by central banks at least due to the relevance of the environmental and climate risks to which international reserves are exposed. This exposure can be managed by central banks based on a multi-objective analytical framework to consider environmental and climate risks in the strategic asset allocation of the investment portfolios, considering the different angles needed in the selection of countries and instruments. A hedging strategy is also applicable to asset price movements related to environmental and climate risk analysis, considering other relevant and traditional data of strategic asset allocation. The proposed framework is detailed in Figure 1:

Figure 1

Multi-objective framework for the management of international reserves



Source: prepared by the authors of this study, based on Study 3 (Chapter 4), Torinelli et al. (2021) and Torinelli & Silva Júnior (2021).

Also, besides the environmental and climate risk management of the international reserves, this may eventually compose a strategy of positive impact in the real-world. Either way, the adoption of carbon intensity indicators in the management of investment portfolios (e.g.: WACI, the weighted average carbon intensity) may be balanced to avoid decisions with sovereign implications that lead to negative impacts on the climate and respective cyclical effects.

5.5 Conclusion

As a result of the applied framework, with multi-objective analysis, the management of the international reserves can become more resilient to environmental and climate risks without undermining the financial and economic objectives of the central banks. Also, this management may eventually compose a strategy of positive impact management.

This action is politically relevant to safeguard the execution of the monetary and foreign exchange policies using international reserves and for the possible real-world effect of the reallocation of those assets.

5.6 References

Aizenman, J., & Marion, N. (2002). International Reserve Holdings with Sovereign Risk and Costly Tax Collection. NBER WORKING PAPER SERIES INTERNATIONAL, Setember(Working Paper 9154). https://www.nber.org/system/files/working_papers/w9154/w9154.pdf

Allen, M., Rosenberg, C., Keller, C., Setser, B., & Roubini, N. (2002). A Balance Sheet Approach to Financial Crisis. A Balance Sheet Approach to Financial Crisis, 02(210), 1–63. https://doi.org/10.5089/9781451957150.001.a001

Andersson, M., Bolton, P., & Samama, F. (2016). Hedging climate risk. Financial Analysts Journal, 72(3), 13–32. https://doi.org/10.2469/faj.v72.n3.4

Bank for International Settlements. (2019). BIS launches green bond fund for central banks. https://www.bis.org/press/p190926.htm

Bank of England. (2020). The Bank of England's climate-related financial disclosure 2020. In Climate Change. https://www.bankofengland.co.uk/prudential-regulation/publication/2020/climate-related-financial-disclosure-2019-20

Bank of England, UNEP Enquiry, & CISL. (2017). Enhancing Environmental Risk Assessment in Financial Decision-Making (Issue July). https://www.tcfdhub.org/resource/enhancing-environmental-risk-assessment-into-financial-decision-making/

Banque de France. (2020). Responsible Investment Report 2019. https://www.banque-france.fr/en/banque-de-france/corporate-social-responsibility/economic-and-civic-commitment/contributing-responsible-investment

Battiston, S., & Monasterolo, I. (2019). A Climate Risk Assessment of Sovereign Bonds' Portfolio. SSRN Electronic Journal, 1–27. https://doi.org/10.2139/ssrn.3376218

Benedetti, D., Biffis, E., Chatzimichalakis, F., Fedele, L. L., & Simm, I. (2019). Climate change investment risk: optimal portfolio construction ahead of the transition to a lower-carbon economy. Annals of Operations Research (2021), 299(1–2), 847–871. https://doi.org/10.1007/s10479-019-03458-x

Bolton, P., Despres, M., Pereira da Silva, L. A., Svartzman, R., & Samama, F. . (2020). The green swan - Central banking and financial stability in the age of climate change (Issue January). Bank for International Settlements (BIS). https://www.bis.org/publ/othp31.pdf

Bolton, P.; Kacperczyk, M.; Samama, F. (2022). Net-Zero Carbon Portfolio Alignment. Financial Analysts Journal, Forthcoming.

Bose, S., Dong, G., & Simpson, A. (2019). Sustainable Investing and Asset Allocation at Global Scale. In Palgrave Studies in Impact Finance, in: The Financial Ecosystem (pp. 225–251). Palgrave Macmillan. https://doi.org/10.1007/978-3-030-05624-7

Cahen-Fourot, L., Campiglio, E., Godin, A., Kemp-Benedict, E., & Trsek, S. (2021). Capital stranding cascades: The impact of decarbonisation on productive asset utilisation. Energy Economics, 103, 105581. https://doi.org/10.1016/j.eneco.2021.105581

Caldecott, B., Tilbury, J., & Carey, C. (2014). Stranded Assets and Scenarios. In Discussion Paper (Issue January). https://www.smithschool.ox.ac.uk/research/sustainable-finance/publications/Stranded-Assets-and-Scenarios-Discussion-Paper.pdf

Cambridge Centre for Sustainable Finance. (2016). Environmental risk analysis by financial institutions – a review of global practice (Issue September). https://www.cisl.cam.ac.uk/system/files/documents/environmental-risk-analysis.pdf

Campbell, J. Y., & Viceira, L. M. (2003). Strategic Asset Allocation: Portfolio Choice for Long-Term Investors. The Economic Journal, 113(488), F408–F409. https://doi.org/10.1093/0198296940.001.0001

Campiglio, E., Dafermos, Y., Monnin, P., Ryan-Collins, J., Schotten, G., & Tanaka, M. (2018). Climate change challenges for central banks and financial regulators. Nature

Climate Change, 8(6), 462–468. https://doi.org/10.1038/s41558-018-0175-0

CISL. (2015). Unhedgeable risk: How climate change sentiment impacts investment. https://www.cisl.cam.ac.uk/resources/sustainable-finance-publications/unhedgeable-risk

Dafe, F., & Volz, U. (2015). Financing Global Development: The Role of Central Banks. In SSRN Electronic Journal (Vol. 8). https://doi.org/10.2139/ssrn.2797226

Detragiache, E. (1996). Fiscal Adjustment and Official Reserves in Sovereign Debt Negotiations. Economica, 63(249), 81–95. https://doi.org/10.2307/2554635

Dietz, S., Bowen, A., Dixon, C., & Gradwell, P. (2016). Climate value at risk' of global financial assets. Nature Climate Change, 6(7), 676–679. https://doi.org/10.1038/nclimate2972

European Commission. (2022). The Just Transition Mechanism: making sure no one is left behind. Finance and the Green Deal. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/finance-and-green-deal/just-transition-mechanism_en

Faiella et al (2021). Climate and environmental risks: measuring the exposure of investments. Mercati, infrastrutture, sistemi di pagamento- Approfondimenti. Banca D'Italia, number 15.

Fender, I., McMorrow, M., Sahakyan, V., & Zulaica, O. (2019). Green Bonds: The Reserve Management Perspective. BIS Quarterly Review, September, 49–63.

G20 Green Finance Study Group. (2016). G20 Green Finance Synthesis Report 2016. UN Environment, July. http://www.g20.utoronto.ca/2016/green-finance-synthesis.pdf

G20 Green Finance Study Group. (2017). G20 Green Finance Synthesis Report 2017. UN Environment, July. https://www.bundesfinanzministerium.de/Content/EN/Standardartikel/Topics/world/G7-G20/G20-Documents/Hamburg_reports-mentioned/G20-Green-Finance-Synthesis-Report.pdf

G20 SFWG. (2022). Document Repository. https://g20sfwg.org/

GIZ. (2011). Green Finance: An Innovative Approach to Fostering Sustainable Economic Development and Adaptation to Climate Change. www.giz.de

Hawkins, R. G., & Rangarajan, C. (1970). On the Distribution of New International Reserves. The Journal of Finance, 25(4), 881–891. https://doi.org/10.2307/2325423

IEA. (2022). The IEA at COP26. Commentary. https://www.iea.org/commentaries/the-iea-at-cop26

IMF. (2018). World Currency Composition of Official Foreign Exchange Reserves. http://data.imf.org/regular.aspx?key=41175

IMF. (2019). Special Drawing Right (SDR). https://www.imf.org/en/About/Factsheets/Sheets/2016/08/01/14/51/Special-Drawing-Right-SDR

IMF. (2021). Currency Composition of Official Foreign Exchange Reserves. https://data.imf.org/?sk=E6A5F467-C14B-4AA8-9F6D-5A09EC4E62A4

IPCC. (2014). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. In Climate Change 2014 Mitigation of Climate Change. https://doi.org/10.1017/cbo9781107415416

IPCC. (2021). Climate Change 2021 - The Physical Science Basis - Summary for Policemakers. In Climate Change 2021: The Physical Science Basis. Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

Jeanne, O. (2012). The Dollar and Its Discontents: Vol. Working Pa (Issues 12–10). https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact

=8&ved=2ahUKEwjwkqj-i8z1AhVnGbkGHSkUB2cQFnoECAQQAQ&url=http%3A%2F%2Fciteseerx.ist.psu.edu%2Fviewdoc%2Fdownload%3Fdoi%3D10.1.1.638.146%26rep%3Drep1%26type%3Dpdf&usg=AOvVaw3ymkLL7PtP

Jones, B. (2018). Central Bank Reserve Management and International Financial Stability-Some Post-Crisis Reflections. IMF Working Papers, 18(31), 1. https://doi.org/10.5089/9781484342008.001

Kohlscheen, E., & O’Connell, S. A. (2004). A Sovereign Debt Model with Trade Credit and Reserves. Mimeo, 743. https://doi.org/10.2139/ssrn.941107

Lamperti, F., Bosetti, V., Roventini, A., & Tavoni, M. (2019). The public costs of climate-induced financial instability. Nature Climate Change, 9(11), 829–833. https://doi.org/10.1038/s41558-019-0607-5

Lydenberg, S. (2016). Integrating Systemic Risk into Modern Portfolio Theory and Practice. Journal of Applied Corporate Finance, 28(2 Sustainability and Shareholder Value), 56–61. https://doi.org/10.1111/jacf.12175

McCauley, R. N. (2019). Safe Assets: Made, Not Just Born. Ssrn, 769. https://www.bis.org/publ/work769.htm

McCauley, R. N., & Rigaudy, J.-F. (2011). Managing foreign exchange reserves in the crisis and after. BIS Working Papers No. 58, 58, 19–47. http://papers.ssrnhttps//www.bis.org/publ/bppdf/bispap58b.pdf

McKinsey Global Institute. (2020). Climate risk and response Physical hazards and socioeconomic impacts. McKinsey Global Institute, January, 164. https://www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts

Mercer. (2011). Climate Change Scenarios – Implications for Strategic Asset Allocation.

Public Report. https://doi.org/10.2139/ssrn.1911824

Mercer. (2015). Investing in a time of climate change. http://www.mercer.com/services/investments/investment-opportunities/responsible-investment/investing-in-a-time-of-climate-change-report-2015.html

Moody's Investor Service. (2016). Climate Change & Sovereign Credit Risk. 1. https://www.moodys.com/sites/products/ProductAttachments/Climate_trends_infographic_moodys.pdf

Morahan, A., & Mulder, C. B. (2013). Survey of Reserve Managers: Lessons from the Crisis. IMF Working Papers, 13(99), 1. https://doi.org/10.5089/9781484308486.001

NGFS. (2018). First Progress Report. Network for Greening the Financial System, October, 1–12. https://www.ngfs.net/sites/default/files/medias/documents/818366-ngfs-first-progress-report-20181011.pdf

NGFS. (2019). A sustainable and responsible investment guide for central banks' portfolio management. Network for Greening the Financial System Technical Document, October. https://www.ngfs.net/sites/default/files/medias/documents/ngfs-a-sustainable-and-responsible-investment-guide.pdf

NGFS. (2020a). Case studies of Environmental Risk Analysis Methodologies. NGFS Occasional Paper, September, 1–603. https://www.ngfs.net/sites/default/files/medias/documents/case_studies_of_environmental_risk_analysis_methodologies.pdf

NGFS. (2020b). Guide to climate scenario analysis for central banks and supervisors. Network for Greening the Financial System, June. https://www.ngfs.net/sites/default/files/medias/documents/ngfs_guide_scenario_analysis_final.pdf

NGFS. (2020c). NGFS Climate Scenarios for central banks and supervisors. Network for

Greening the Financial System, June. https://www.ngfs.net/sites/default/files/media/2021/08/27/ngfs_climate_scenarios_phase2_june2021.pdf

NGFS. (2020d). Overview of Environmental Risk Analysis by Financial Institutions. Network for Greening the Financial System, September.

NGFS. (2020e). Progress report on the implementation of sustainable and responsible investment practices in central banks' portfolio management. In NGFS Technical document (Issue December). https://www.ngfs.net/sites/default/files/medias/documents/sri_progress_report_2020.pdf

NGFS. (2021). Membership as of December 15th 2021. https://www.ngfs.net/en/about-us/membership

OECD. (2021). Financial Markets and Climate Transition: Opportunities, Challenges and Policy Implications. In OECD Business and Finance Outlook. https://www.oecd.org/finance/Financial-Markets-and-Climate-Transition-Opportunities-Challenges-and-Policy-Implications.pdf

Ortec Finance. (2020). Scenario Analysis for Systemic Climate Risk. In Case Studies of Environmental Risk Analysis Methodologies. NGFS. https://eprints.soas.ac.uk/33510/1/case_studies_of_environmental_risk_analysis_methodologies.pdf

PRI. (2019). Embedding ESG issues into strategic asset allocation frameworks - A discussion paper. https://www.unpri.org/embedding-esg-issues-into-strategic-asset-allocation-frameworks-discussion-paper/4815.article

PRI. (2021). Principles for Responsible Investment - Annual Report 2021 (Issue December). https://dwtyzx6upklss.cloudfront.net/Uploads/y/o/i/pri_annualreport_2021_web_346706.pdf

Scott, M., Huizen, J. van, & Jung, C. (2017). The Bank of England's response to climate change. Bank of England Quarterly Bulletin, 98–109. https://www.unepfi.org/psi/wp-content/uploads/2017/06/BANKOFENGLAND_response_climatechange.pdf

Sheng, A. (2015). Central banks can and should do their part in funding sustainability. Centre for International Governance Innovation - FIXING CLIMATE GOVERNANCE SERIES, 1, 1–20. https://wedocs.unep.org/bitstream/handle/20.500.11822/34564/FCP.pdf?sequence=1&isAllowed=y

Silva Jr., A. F. A. (2011). The Self-Insurance Role of International Reserves and the 2008-2010 Crisis. Central Bank of Brazil Working Paper, 256, 1–26. https://doi.org/10.2139/ssrn.1956702

Sveriges Riksbank. (2019). Flodén: Riksbank selling bonds for climate reasons. Speeches and Presentations. https://www.riksbank.se/en-gb/press-and-published/speeches-and-presentations/2019/floden-riksbank-selling-bonds-for-climate-reasons/

TCFD. (2017). Recommendations of the Task Force on Climate-related Financial Disclosures. Task Force on Climate-Related Fiancial Disclosures, June, 1–74. https://assets.bbhub.io/company/sites/60/2020/10/FINAL-TCFD-Annex-Amended-121517.pdf

Torinelli, V. H., Silva Jr., A. F. A., Andrade, J. C. S., & Martinez-Jaramillo, S. (2021). Latin America (LatAm) Central Banks (CBs) environmental risk management of the international reserves: an applied framework discussion. In XXIII ENGEMA (pp. 1–20). http://engemausp.submissao.com.br/23/anais/arquivos/58.pdf?v=1643301635

Torinelli, V. H., & Silva Júnior, A. F. de A. da. (2021). Environmental risk analysis (ERA) in the strategic asset allocation (SAA) of the international reserves (IRs) managed by central banks (CBs). Latin American Journal of Central Banking, 2(1), 100021.

https://doi.org/10.1016/j.latcb.2021.100021

UBS. (2018). UBS Annual Reserve Manager Survey 2018. 24th Reserve Management Seminar. https://swfi-cdn.sfo2.cdn.digitaloceanspaces.com/partnerContent/ubs-annual-reserve-manager-survey.pdf

UBS. (2019). UBS Annual Reserve Manager Survey 2019. 25th Reserve Management Seminar, June. https://swfi-cdn.sfo2.cdn.digitaloceanspaces.com/partnerContent/UBS Reserve Management Seminar June 2019.pdf

UN. (2022). Sustainable Development Goal 17: Revitalize the global partnership for sustainable development. https://www.un.org/sustainabledevelopment/globalpartnerships/

UNEP FI. (2019). Changing course: UNEP FI and twenty institutional investors launch new guidance to implement TCFD Recommendations. Industries - Investment. https://www.unepfi.org/news/industries/investment/changing-course-unep-fi-and-twenty-institutional-investors-launch-new-guidance-for-implementing-tcfd/

Vecchio, F. (2009). Questioning the U.S. Dollar’s Status as a Reserve Currency. https://www.jpmorgan.com/jpmpdf/1158630192140.pdf

Volz, U. (2017). On the role of Central Banks in enhancing green finance. United Nations Environment Programme, Inquiry Wo(February), 1–27. http://unepinquiry.org/wp-content/uploads/2017/02/On_the_Role_of_Central_Banks_in_Enhancing_Green_Finance.pdf

Volz, U., Beirne, J., Preudhomme, N. A., Fenton, A., Mazzacurati, E., Renzhi, N., & Stampe, J. (2020). Climate Change and Sovereign Risk. In SOAS Centre for Sustainable Finance (Issue October). https://doi.org/10.25501/SOAS.00033524

WEF. (2022). The Global Risks Report 2022 17th Edition. World Economic Forum.

WRI, & UNEP-FI. (2015). Carbon Asset Risk: Discusssion Framework. 13(2), 255–270.

http://www.unepfi.org/fileadmin/documents/carbon_asset_risk.pdf%5Cnhttp://www.wri.org/sites/default/files/carbon-asset-risk-discussion-framework-ghgp_0.pdf

WWF, Godinot, S., & Vandermosten, J. (2017). WWF Climate Guide To Asset Owners: Aligning Investment Portfolios With the Paris Agreement. WWF Report EU 2017, 72.

6 Conclusion

This thesis discussed the environmental and climate risk exposure of international reserves and developed a multicriteria analytical framework to consider environmental and climate risks in the strategic asset allocation by central banks. The study is relevant to the construction of the investment portfolios of the international reserves considering the different angles needed in the selection of countries and instruments.

A hedging strategy is applicable to asset price movements related to environmental and climate risk analysis, considering other relevant and traditional data of strategic asset allocation. In addition, carbon intensity indicators can be considered in the allocation review to mitigate climate transition risks and eventually in a strategy of positive impact management.

On top of it, the balance of the board of each central bank between the financial, economic and sustainability objectives can lead to different decisions, which can be supported by the information provided in this thesis and can include many other simulations and analyzes to be carried out.

The results, conclusion, future studies, limitations, and products, per study, are summarized as follows:

Chapter 2 - Study 1: Framework proposal.

As results, the study one discussed the exposure to environmental and climate risk of international reserves and developed a multi-criteria analytical framework to consider environmental risk in the strategic allocation of assets by central banks.

The conclusion is that environmental risk analysis should be included in the traditional approach to strategic asset allocation by central banks due to the relevance of the environmental and climate risks to which international reserves are exposed.

Future studies could focus on Social and Governance factors, complementing ESG analysis, as well as non-financial investment objectives from an international reserve management perspective.

As limitations, the study one only addresses the environmental aspects of ESG factors, and focus on environmental and financial risk management rather than non-financial investment objectives such as “creating a positive impact on the environment and society along with financial returns” (NGFS, 2019).

The main product of the study one was the article published in LAJCB, with scientific contribution (Torinelli & Silva Júnior, 2021).

<u>Chapter 3 - Study 2:</u> Discussion of the framework with a sample of central banks and initial test of the quantification of effects.

As results, the study two discussed the specific environmental risk exposures of ten central banks from Latin America and the Caribbean, and their respective international reserves, including hedging alternatives, with proposals for specific percentages to be considered. The analysis considered national exposure, the economic objectives of the international reserves and the various angles that should be considered when allocating investment portfolios between countries and instruments. In this sample, commodities were in focus due to the economic objectives of the international reserves. Exposures to environmental risks from food and agriculture, fuels and minerals and metals sectors were identified, as well as relevant exposures to physical climatic risks in both countries located in the Caribbean.

The conclusion is that a hedging strategy is applicable to asset price movements related to environmental risk analysis, considering other relevant and traditional data of strategic asset allocation. An alternative for some central banks from Latin America and the Caribbean sample could be to migrate to assets less correlated with commodities and currencies to mitigate relevant scenarios. In addition, carbon intensity indicators can be considered in the allocation review to mitigate climate transition risks.

Future studies may focus on social and governance factors from the perspective of managing international reserves. Furthermore, although we held initial meetings with the representatives from the sample of central banks from Latin America and the Caribbean, only one of them answered the questionnaire, which limits the applicable discussion of the framework. Alternatively, study three focuses on the risk-return analysis of the applied framework using different assets and specific portfolios, to validate the framework.

As limitations, the study two only addresses the environmental aspects of Environmental, Social and Governance (ESG) factors.

The main product was paper awarded with the honorable mention in the XXVI Award of the Brazilian National Treasury (DOU, 2021), and accepted to be published in 2022 in the publication of the National Treasury, "Cadernos do Tesouro Nacional" (in Portuguese and in English). Also, the second study was awarded as best paper on the thematic of Sustainable Finance in the XXIII Engema Congress (Torinelli et al., 2021).

Chapter 4 - Study 3: Application of the framework for central banks.

As results, after up to eight different simulations carried out for five different central banks from Latin America and the Caribbean, with the particularities of each respective country, it was identified that a multi-objective analysis can identify changes in the allocation of international reserve portfolios, with different durations, assets or currencies, which could lead to a better performance in the sustainability dimension, including environmental and climate risk management, without prejudice to traditional financial and economic dimensions.

The conclusion is that the balance of the board of each central bank between the financial, economic and sustainability objectives can lead to different decisions, which can be supported by the information provided in this study and can include many other simulations and analyzes to be carried out. Furthermore, the adoption of the indicator Weighted Average Carbon Intensity (WACI) in the management of investment portfolios may be balanced to avoid decisions with sovereign implications that lead to negative impacts on the climate and respective cyclical effects.

Future studies could consider ex-ante scenarios for the analysis. In addition, social and governance factors may also be in scope. As limitations, Gold was not included in WACI analysis, specific green investment alternatives have not been tested and the study was based on historical data, not scenario analysis. The third study (chapter 4), as well as the adjusted framework covered in the policy brief (chapter 5), will be submitted for publication in 2022.

This thesis concludes that environmental and climate risk analysis should be included in the traditional approach to strategic asset allocation by central banks at least due to the relevance of the environmental and climate risks to which international reserves are exposed. As a result of the applied framework, with multi-objective analysis, the management of the international reserves can become more resilient to environmental and climate risks without undermining the financial and economic objectives of the central banks. This action is relevant to the investment management perspective of the international reserves, to safeguard the execution of the monetary and foreign exchange policies through the use of those reserves and for the possible real-world effect of the reallocation of those assets.

As limitations, this study only addresses the environmental aspects of ESG factors. Also, gold was not included in WACI analysis, specific green investment alternatives have not been tested and the study was based on historical data. Furthermore, the focus of this research is on environmental and financial risk management rather than non-financial investment objectives such as positive impact management. Future studies could address these limitations.

7 Appendix A: Questionnaire

Framework validation questionnaire: Environmental Risk Analysis (ERA) in the Strategic Asset Allocation (SAA) of the International Reserves (IRs) managed by CBs (CBs).

Link w/ Torinelli&SilvaJr Framework

For questions of group 1 (environemntal factors) and 4 (SAA), please consider the scale 1 to 7, where 1 means lower and 7 means higher. Please use 8 if you do not feel confortable to express an opinion. Please also sign de direction of the impact, if Positive (P) or Negative (N). Probability of ocurrence will reflet exposure in time (e.g.: one incident in 10 years). Impact of the ocurrence will reflect the size of the expected event.

1 Environmental factors
1,1 Environmental physical factors
1.1.1 Environmental physical climatic factors

1.1.1 Figure 9 (Chapter 2)

In your personal understanding, how exposed to the following physical climatic factors is/are

	the economy of your country?			the exports and imports of your country?			the IRs of your country?		
	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact
1.1.1.1 CO2 levels;									
1.1.1.2 Global temperature;									
1.1.1.3 Global precipitation;									
1.1.1.4 Ice level and snow cover;									
1.1.1.5 Ocean temperature, level and ph.									

1.1.2 Environmental physical geologic factors

In your personal understanding, how exposed to the radiative forcing, which is the difference between the sunlight aborved by the Earth and the energy radiated back to space (the scientific basis for the greenhouse effect), is/are

	the economy of your country?			the exports of your country?			the IRs of your country?		
	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact
1.1.2.1 Radiative forcing;									

1.1.3 Environmental physical ecosystemic factors

In your personal understanding, how exposed to the following physical ecosystemic factors is/are

	the economy of your country?			the exports of your country?			the IRs of your country?		
	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact
1.1.3.1 Biodiversity;									
1.1.3.2 Resource usage;									
1.1.3.3 Ecosystem services.									

1,2 Environmental transition factors

In your personal understanding, how exposed to the following enviromental transition factors is/are

	the economy of your country?			the exports of your country?			the IRs of your country?		
	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact
1.2.1 Policy and legal;									
1.2.2 Technology;									
1.2.3 Sentiment/Reputation;									

1,3 Environmental physical and transition factors

1.3.1 In your personal understanding, how exposed to the environmental physical and transition factors is the economy of your country? What are the main sectors at risk?

1.3.2 In your personal understanding, how exposed to the environmental physical and transition factors are the exports of your country? What are the main sectors at risk?

1.3.3 In your personal understanding, how exposed to the environmental physical and transition factors is the IR portfolio of your country? What is the main exposure: currency, country, instrument?

1.3.4 In your opinion, is the IR of your country exposed to the environmental risks or to the global actions taken in order to mitigate and to adapt to the environmental risks (e.g.: changes in the energy matrix with impact in the national economies)? Why/How?

1.3.5 In your opinion, which instruments and measures may mitigate the exposure of the IRs management to the environmental risks?

2 Assessment of environmental risk in time

2.1 In the context of the IR management, does the CB you represent feed, monitor or query any historical database of environmentally related events with financial impacts? If yes, could you detail it? Thank you!

Yes	No

1.1.2
Figure 9
(Chapter 2)

	Yes	No
2.2 In the context of the IR management, does the CB you represent assess environmental risk exposure in time?		

	Scenario Analysis	Stress Test
2.2.1 If Yes was the answer to question 2.2, how do you assess the environmental risk exposure of the IRs portfolios in time? If "scenario analysis" or "stress test" are used, please detail which scenarios are considered. If "other technique" is used, please detail it.		

2.2.2 If Yes was the answer to question 2.2, which risk metrics do you consider in your analysis (e.g.: Weighted Average Carbon Intensity; Total Carbon Emissions; Carbon Footprint; Carbon Intensity; Exposure to Carbon Related Assets; Decline in revenues; Increase in costs; Impact on exports etc)?

3 Translation of environmental exposures into measured financial risks — 1.1.3 Figure 9 (Chapter 2)

3.1 Business Risk

In the management of IRs, do you translate enviromental fators into business risk? If yes, how?

3.2 Market Risk

In the management of IRs, do you translate enviromental fators into market risk? If yes, how?

3.3 Credit Risk

In the management of IRs, do you translate enviromental fators into credit risk? If yes, how?

3.4 Systemic Risk

In the management of IRs, do you translate enviromental fators into systemic risk? If yes, how?

3.5 ERA methodology - Investment Portfolio

3.5.1 Do you consider any methodology for evaluating environmental risk exposure in an investment portfolio? If so, which one? If not, why?

3.5.2 Do you use or know any methodology for contemplating environmental risk in choosing an efficient investment portfolio (eg: multi-objective optimization)? What methodology?

4 International Reserves (IRs) & Strategic Asset Allocation (SAA) — 1,2 Figure 10 (Chapter 2)

4.1 What are the economic objectives of the IRs managed by the CB you represent?

4.2 What are the investment guidelines of the IRs managed by the CB you represent?

4.3 What is the character of the IRs management in the CB you represent? E.g: priorities among the three pillars of investment (profitability, liquidity,safety); countercicliclality and market neutrality concerns etc.

4.4 What are the top 5 asset classes of the IRs portfolios in the CB you represent, and which is the percentage allocated in each of them?

4.5 What are the top 5 currencies of the IRs portfolios in the CB you represent, and which is the percentage allocated in each of them?

4.6 What are the SAA model approaches used for IR management by the CB you represent?

5 Environmental Risk Analysis (ERA) & SAA — 2 & 3 Figure 11 and 12 (Chapter 2)

5.1 Economic objectives

In your perspective, how exposed to environmental risks are the following typical IR economic objectives?	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact
5.1.1 Intervention in the FX markets;			
5.1.2 Execution of payments for goods and services;			

	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact
5.1.3 Execution of payments for the government;			
5.1.4 Granting of emergency liquidity assistance;			
5.1.5 Support of domestic monetary policy;			
5.1.6 Underpinning of investor confidence in the country;			
5.1.7 Investment of excess reserves.			

5.2 Assets

In your perspective, how exposed to environmental risks are your IRs portfolios due to the following asset classes?

	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact
5.2.1 Treasury Bonds;			
5.2.2 Supranationals;			
5.2.3 Sovereign Eurobonds;			
5.2.4 US Agencies;			
5.2.5 Inflation Protected Bonds;			
5.2.6 Corporate and covered bonds;			
5.2.7 MBS/ABS			
5.2.8 Equities;			
5.2.9 Banks Debt;			
5.2.10 Green Bonds;			
5.2.11 Other- which?______________________________			

5.3 Currencies

In your perspective, how exposed to environmental risks are your IRs portfolios due to the following currencies?

	Probability of ocurrence	Impact of ocurrence	(P) or (N) impact
5.3.1 USD;			
5.3.2 EUR;			
5.3.3 CNY			
5.3.4 JPY;			
5.3.5 GBP;			
5.3.6 Other- which?____________________			

5.4 How do you understand that the Environmental Risk Management may impact the IR Economic Objectives and the IR Investment Guidelines?

5.5 How do you understand that the Environmental Risk Management may impact the IR Strategic Asset Allocation?

5.6 In your opinion, what would be the effect on the short term and long term financial returns of the IRs due to a partial reallocation of its portfolio to green investment alternatives that suit the investor profile of CBs and mitigate their exposure to environmental risks (and/or their exposure to global actions taken in order to mitigate and to adapt to the environmental risks)? For example: would it be most probably negative in the short term and positive in the long term? Why?

5.7 In your opinion, how an incremental performance of the International Reserves, managed by the Central Banks, in the Green Finance market would impact this market segment, as well as the Green Economy? Do you believe it would significantly modify the depth and liquidity of the Green Finance market, impacting the Green Economy*? Why/How?

6 ESG Investment Strategy

2 & 3
Figure 11 and 12
(Chapter 2)

6.1 Does the CB you represent has any ESG investment strategy? If yes, how would you define it? Reference: http://www.eurosif.org/responsible-investment-strategies/

Best-in-class		Engagement & Voting	
Impact Investing		ESG Integration	
Norms-based screening		Exclusions	
Sustainability-themed		Other - Please specify: ____________	
No ESG investment strategy.			

6.2 What are (or would be) your drivers for considering alternatives of ESG investments?

Management based on ERA	☐	Support the Green Market Growth	☐
Diversification	☐	Climate risk mitigation	☐
Institutional reputation	☐	Other - Please specify: ________________	☐
Superior returns	☐	No driver for ESG investments.	☐

6.3 Which of the following green asset classes does the CB you represent consider for investments with the IR:

Green Bonds	☐	Green Index	☐
Green Investment Funds	☐	Green Exchange Traded Funds-ETFs	☐
Green Investment Trusts	☐	Unlabeled Green Assets	☐
Green Equities	☐	Other - Please specify: ________________	☐

6.4 Which currencies you think may better support a strategy of mitigating climate risks in IR management?

USD	☐	GBP	☐
EUR	☐	JPY	☐
Other - Please specify: ________________	☐		

6.5 Does the CB you represent has investments allocated in any Green Asset? If Yes, please select in which assets you actually invest (if No, please jump to question 6.11):

Green Bonds	☐	Green Index	☐
Green Investment Funds	☐	Green Exchange Traded Funds-ETFs	☐
Green Investment Trusts	☐	Unlabeled Green Assets	☐
None Green investments	☐	Other - Please specify: ________________	☐

6.6 If Yes was the answer to question 6.7, please indicate which is your average percentage of investments in green assets, considering the total amount of investments of the CB (0% up to 100%):____

6.7 Please indicate which categories of green bond issuers is the CB you represent interested in?

Sovereign	☐	Supranational	☐
Corporate	☐	Agencies	☐
Financial Institutions	☐	Municipals	☐

6.8 Does the CB you represent has any plan to adopt the analysis of ESG (Environmental, Social and Governance) factors in its balance sheet management, besides the management of the IRs (or is already doing so)?

Yes - Please specify how: _________________	☐
No	☐
I cannot inform	☐

6.9 Please indicate the most probable proportion that the Green Assets will represent in the total investment portfolio of the CB you represent, in ten years from now (2030) (0% up to 100%):

For the purpose of the management of the investment portfolio, for questions 6.13 to 6.24 please consider the scale 1 to 7, where 1 means less probable and 7 means more probable:

6.10' Does the CB you represent would avoid investing in Green Assets due to low liquidity (high Bid-Ask Spread, low Turnover)?

1-No	2	3	4	5	6	7-Yes
☐	☐	☐	☐	☐	☐	☐

6.11 Does the CB you represent would take into consideration to invest in Green Assets with an objective to explore the higher Yeld due to lower liquidity (with higher liquidy risk, in case of assets been sold previously to the due date)?

1-No	2	3	4	5	6	7-Yes
☐	☐	☐	☐	☐	☐	☐

6.12 Does the CB you represent see Green Assets as a market with low depth (Outstanding)?

1-No	2	3	4	5	6	7-Yes
☐	☐	☐	☐	☐	☐	☐

6.13 Does the CB you represent would take into consideration to invest in Green Assets despite of a low depth (Outstanding)?

1-No	2	3	4	5	6	7-Yes

6.14 Does the CB you represent would take into consideration to invest in Green Assets as protection strategy (e.g.: not losing money)?

1-No	2	3	4	5	6	7-Yes

6.15 Does the CB you represent would avoid investing in Green Assets due to safety issues, as increased default risk?

1-No	2	3	4	5	6	7-Yes

6.16 Does the CB you represent would avoid investing in Green Assets due to reputational risk?

1-No	2	3	4	5	6	7-Yes

6.17 Does the CB you represent would take into consideration to invest in Green Assets as a strategy to support the Green Finance and the Green Economy?

1-No	2	3	4	5	6	7-Yes

6.18 Does the CB you represent would take into consideration to invest in Green Assets as a strategy to mitigate the potential economic risks due to global actions taken in order to mitigate and to adapt to environmental risks (e.g.: changes in the energy matrix with impact in the national economies)?

1-No	2	3	4	5	6	7-Yes

6.19 Does the CB you represent is concerned about green washing associated with the green assets available in the market?

1-No	2	3	4	5	6	7-Yes

6.20' Does the CB you represent is concerned about lack of standardization of the the green assets available in the market?

1-No	2	3	4	5	6	7-Yes