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The Exposure of Institutional Investors to Environmental Risks: A Study Focused on the Management of International Reserves by Central Banks.

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Abstract

Through literature review and analysis of specialized reports from praxis, this study addressed how to consider environmental risks in the strategic asset allocation of the International Reserves (IRs) managed by Central Banks (CBs). For that, it was also proposed a multicriteria analytical model for the evaluation of the environmental risk exposure of an investment portfolio, compatible with the investor profile of the CBs. Environmental physical and transition risks are resulting in a range of financial risks. Despite proper risk management being essential for efficient investment management, environmental risk analysis is still incipient in the financial investment sphere, especially among CBs. The theoretical and practical gaps in this subject were reinforced in the first comprehensive report of the newly created group of CBs, the Network for Green Financial System (NGFS). CBs, notwithstanding their regulatory, supervisory and other relevant functions, are among the largest global investors, managing IRs totaling trillions of dollars. The study has the potential to impact the construction of the IR investment portfolios due to the different angles that must be considered in the selection of currencies and asset classes. This study may also support CBs decision making from a managerial perspective, in addition to helping them with the construction of a related framework.

Keywords: Responsible Investment; Impact Investment; Sustainable Finance; Green Finance; Central Banks; International Reserves; Institutional Investors.

1. Introduction

Effective risk management, including risk identification, measurement and control, is essential for efficient operation of financial markets. In the worldwide discussion about financial risk management, analyses of environmental externalities, trends and events are becoming recurrent and gradually more relevant (TCFD, 2017; Bank of England, UNEP and CISL, 2017; Andreeva and Voysey, 2016; Caldecott, 2014a).

The evidence indicates that environmental physical and transition factors are resulting in a range of financial risks, which are expected to increase in the future (TCFD, 2017). According to G20 GFSG (2016), these environmental factors are tied to business, market, credit, and legal risks, all of which have financial implications. The environmental physical risks include climatic, geologic and ecosystemic factors, while the transition risks include political, technological, and sentimental influences (Bank of England, UNEP and CISL, 2017).

Despite the fact that proper risk management is essential for efficient investment management, environmental risk analysis is incipient in the financial investment sphere, especially among Central Banks (CBs). The theoretical and practical gaps in this subject were reinforced in the first reports of the newly created group of CBs, the Network for Green Financial System (NGFS, 2018 and 2019).

CBs, in addition to carrying out regulatory, supervisory and other relevant functions, are among the largest global investors, managing the International Reserves (IRs). According to The World Bank (2019), the IRs totaled US$11.966 trillion in 2017, which places the BCs among the largest global investors. For comparison purposes, total assets in pension funds amounted to US$ 28.389 trillion among members of the Organization for Economic Co-operation and Development-OECD in the same period (OECD, 2018).

The management of environmental risks has not been a primary objective of the IRs management (NFGS, 2018 and 2019). Possibly for this reason, CBs are not significantly addressing environmentally sustainable management and the Green Finance market from the perspective of IR managers (Sevillano and Romo, 2018). However, the physical and transition environmental risks are beginning to be understood as types of financial risks, which may affect the investments performance (Bank of England, UNEP and CISL, 2017; Andreeva and Voysey, 2016). As a result, the management of environmental risk exposure of the IRs is important for CBs.

The IRs are investments held by CBs in foreign currency, for the purpose of managing exchange rates and carrying out monetary policies. They allow for the capacity to meet liquidity needs in crises and mitigate of exchange rate volatility, among other purposes related to monetary and foreign exchange policy (Silva Jr, 2011; Hawkins, Rangarajan, 1970; Kohlscheen, O'Connell, 2004; Detragiache, 1996; AIzenman, Marion, 2002; Allen et al, 2002). Thus, the management of the IRs consists of the investment in asset classes available within the international financial market.

The management of the IRs by CBs is beginning to be included in discussions of environmental sustainability. In December 2017, the Network for Green Financial System (NGFS) was established by eight central banks. The network's purpose was to define and promote the implementation of best practices inside and outside NGFS Members (34 members in Apr2019), and to develop analytical work on green finance. In its first report, the group reinforced the existence of the theoretical and practical gaps in which this research focuses:

> NGFS Members acknowledge that climate-related risks are a source of financial risk ... some NGFS members have extended this analysis to broader environmental risks finding that these are a source of financial risk as well ... 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 ... there is a need to build intellectual capacity in translating the science into decision-useful financial risk assessment information ... 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)

On April 2019, the NGFS already included 34 members and approached the CBs' investments as follows:

> Acknowledging the different institutional arrangements in each jurisdiction, the NGFS encourages central banks to lead by example in their own operations. Without prejudice to their mandates and status, this includes integrating sustainability factors into the management of some of the portfolios at hand (own funds, pension funds and reserves to the extent possible). (NGFS, 2019, p.28)

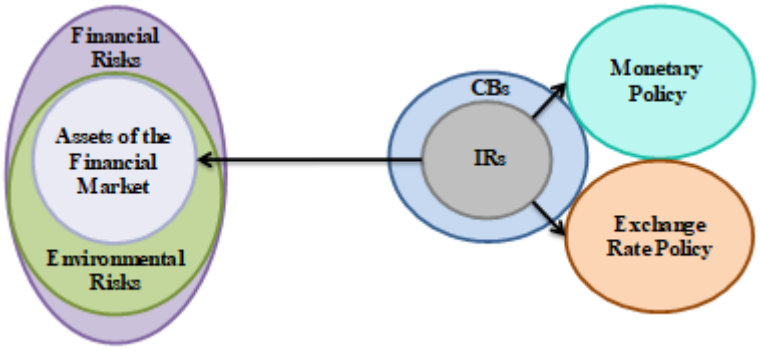
CBs are long-term public investors seeking safe and liquid investment opportunities while ensuring a return on investment compatible with the risk tolerance set out in their investment policy. Because CBs are long-term public investors, they have a greater degree of risk aversion. Considering the three pillars of investment (security, liquidity and profitability), CBs are more likely to accept lower profitability in favor of safety and liquidity, seeking lower risk (Bindseil; Gonzalez; Tabakis, 2009). Fixed-income securities investors generally prefer liquidity, and CBs are usually positioned within the fixed-income securities category.

The set of investment possibilities for these investors has widened, which favors the optimization of the investment portfolio through the diversification of its assets. Many long-term investment opportunities are emerging as a result of the need to seek alternatives for sustainable development. In this context, it is important that CBs are attentive to these opportunities, seeking to assess the compatibility of the risks of these investments with the nature of their operations. **The question that this research seeks to address is how to consider environmental risk in the Strategic Asset Allocation (SAA) of international reserves.**

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

The problem situation can be better understood through the figure 1, as follows:

Figure 1- Problem situation.



Source: prepared by the authors.

In order to answer this research question, the study built upon previous theoretical analyses of environmental risk and international reserves management. Other studies, which addressed the environmentally sustainable performance of CBs, had different objectives than those proposed in this study. They focused on the environmental sustainability of CBs as financial market regulators and as oversight agents, but not as IR managers (e.g.: Campliglio et al, 2018). On the other hand, the studies that focused on Green Finance from the perspective of investors mostly did not address the IRs managed

by CBs or the role of CBs as investors. The theoretical studies of environmental risk analysis, detailed in the following section, were generally focused on other investors.

2. The Environmental Risk Analysis

Effective risk management is essential for wise investment allocation by portfolio managers and for the smooth operation of the financial markets. Without proper risk analysis, assets may be mispriced, leading to failures in capital allocation. This in turn may affect investments profitability and financial stability. The global 2008 financial crisis is an example of the consequences of problems in the risk analysis process. One of the essential functions of investment managers is to adequately account for risks to support these portfolio management decisions.

In addition to the usual risks already considered by financial market managers, the environmental risk sources are being associated with a range of financial risks. Evidence indicates that environmental physical and transition factors are resulting in business, market, credit, and legal risks. All of these risks have financial implications that can be non-linear and disruptive (TCFD, 2017; Bank of England, UNEP and CISL 2017; G20 GFSG, 2016).

The dimensions of the environmental physical risks are climatic, geologic and ecosystemic (Bank of England, UNEP and CISL 2017). Physical risks include shock events and changes in trends. According to *The Global Risks Report 2017*, prepared by the World Economic Forum, four of the five top risks in terms of impact are environmentally related. Three of them are physical (extreme weather events, water crises and major natural disasters) and one is transitional (failure of climate change mitigation and adaptation).

Among the climatic physical risks, global warming is by far the most discussed one, strongly associated with carbon emissions. The devastating consequences of global warming are widely acknowledged, such as rising sea levels due to polar melting, drought fires destroying huge areas of forests on different continents, and numerous other effects (IPCC, 2013). 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 time and severity of global warming physical effects are difficult to estimate. The large-scale and long-term nature of the problem makes it exceptionally challenging, especially in the context of economic decision-making. However, the effects of global warming are not just long term. The worldwide effort to achieve a low-carbon economy affects virtually all industries and sectors, significantly and even disruptively (TCFD, 2017). Cap-and-trade regimes and Results-Based Financing (RBF) are already stimulating the alignment of the energy market with public policies aimed at sustainable energy production and reduction of carbon emissions. The change in the energy matrix, incorporating clean technologies, already exemplifies potential medium-term 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 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, Huizen and Jung, 2017).

The dimensions of the environmental transition risks can be categorized as political, technological, and sentimental (Bank of England, UNEP and CISL, 2017). The first dimension includes policy actions to mitigate, or adapt to, climate change. In the regulatory field, it includes the establishment of cap-and-trade regimes and government regulatory programs designed to reduce the total level of emissions of certain chemicals, particularly carbon dioxide, as a result of industrial activity. By contrast, the second dimension of transition risks include clean technologies, as the renewable energy sources. Finally, the third dimension is related to the sentiment of investors and public opinion, which influences the governmental approach to the transition to an economy with positive environmental externalities.

Along these lines, a study conducted by CISL (2015) "quantified the potential financial impact of a shift in market sentiment driven by significant changes in investor and consumer beliefs about the future effects of climate change, modelling the impact of three market sentiment scenarios on four portfolios with different asset allocations" (p.6). The study was motivated by the understanding that "while the most significant physical impacts of climate change will probably be seen in the second half of this century, financial markets could be affected much sooner, driven by the projections of likely future impacts, changing regulations and shifting market sentiment" (p.5). The research demonstrated that changing asset allocations among different asset classes and regions, combined with investing in low climate risk sectors, could offset only half of the negative financial impacts in the short term. Climate change sentiment risk would then represent an "unhedgeable risk" for investment portfolios.

The potential vulnerability to environmental risks is under analysis for new classes of assets, as sovereign bonds. Central banks and financial regulators, especially at the EU level, have undertaken assessments of the implications of environmental risks for the stability of sectors and the financial system as a whole.

Dietz, Bowen, Dixon and Grandwell (2016) estimated the impact of twenty-first-century climate change on the present market value of global financial assets. According to their estimates, it would constitute a substantial write-down in the fundamental value of 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. Hence, measures to avoid climate warming make financial sense to investors, while represent transition risks that also need to be considered.

Benedetti et al (2019) also studied the climate change transition risk for investors and developed a model to capture the potential impact of carbon pricing on fossil fuel 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 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. For the authors, there is an increasing likelihood that governments of major economies will act within the next decade to reduce greenhouse gas emissions, probably by intervening in the fossil fuel markets through taxation or cap and trade mechanisms (collectively "carbon pricing").

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. In addition, the transition to a low-carbon economy impacts the value generation of high-carbon sectors, affecting financial assets. 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, UNEP Enquiry and CISL, 2017).

Meanwhile, the concept of Environmental Risk Analysis (ERA) contemplates tools and methodologies to integrate environmental data into the risk management and asset allocation processes. According to G20 GFSG (2017), ERA contemplates risk identification (financial analysis of environmental factors), analysis (pricing and implications to investment portfolio) and management (actions to mitigate or transfer risks). Failures in the ERA could lead to mispricing of assets, mistakes in capital allocation and exposure to "stranded asset". According to Caldecott, Tilbury and Carey (2014, p.2):

> "Stranded assets" are assets that have suffered from unanticipated or premature write-downs, devaluations or conversion to liabilities. They can be caused by a range of environment-related risks and these risks are poorly understood and regularly mispriced, which has resulted in a significant over-exposure to environmentally unsustainable assets throughout our financial and economic systems. Current and emerging risks related to the environment represent a major discontinuity, able to profoundly alter asset values across a wide range of sectors. Some of these risk factors include: environmental challenges (e.g. climate change, water constraints); changing resource landscapes (e.g. shale gas, phosphate); new government regulations (e.g. carbon pricing, air pollution regulation); falling clean technology costs (e.g. solar PV, onshore wind); evolving social

norms (e.g. fossil fuel divestment campaign) and consumer behaviour (e.g. certification schemes); litigation and changing statutory interpretations (e.g. changes in the application of existing laws and legislation).

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.

Currently, to perform the ERA is still a big challenge. The analysis involves the identification of environmental factors and the evaluation of the related direct or indirect risk exposure to 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. As an example, transition scenarios may consider large 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 as follows:

Figure 2- Summary of Case Studies on Environmental Risk Analysis.

Environmental Risk Factor	Country	Scenario Analysis	Financial Risk Tool	Results
Transition (impact of environmental regulation and carbon price)	Germany	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)	UK	Analysis of impacts of transition risks on German electricity utilities (UK investment focus)	SOTP valuation methodology (DCF + EV/EBITDA)	Total and per share firm valuation
Transition (climate scenarios linked to various risk factors)	International	Examining the effect of transitions risks on strategic asset allocation	Integrated assessment model incorporated in asset allocation investment model	Median additional annual returns to 2050
Physical (Climate Change)	International	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, UNEP and CISL 2017.

Robins and McDaniels (2016) found that the spread of ERA 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 receive more attention, including in rating decisions. Examples of ERA at individual asset, portfolio and systemic levels are summarized as follows:

Figure 3- Examples of ERA at individual asset, portfolio and systemic levels.

	Market risk		Credit risk		Financial system	Economy Wide
Analysis level	Asset	Portfolio	Asset	Portfolio	Systemic	Systemic
Organization example	Allianz Global Investors	Mercer	S&P/ SwissRe	ICBC	DNB	UBS
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, UNEP and CISL (2017).

The sovereign credit risk is particularly relevant for the management of international reserves due to the composition of Central Banks investment portfolios, as detailed in the next section. The Moody's Investor Service 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 debt 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 shift.

In the Moody's methodology, sovereign susceptibility to climate change is a function of exposure and resilience. The economic diversification and the geographic location will impact the exposure. On the other side, resilience will be built based on the local development level, fiscal flexibility and government policies. Less developed countries, mostly situated in the Southern Hemisphere, would be the most susceptible to physical climate change.

Back to ERA analysis, there is still a deficit in regard to the availability of information about environmental risks (Pierschel, 2018). The following organizations provide information to measure the portfolio's carbon footprint (specifically to assess exposure to carbon emissions risks): yourSRI.com (Online Portfolio Carbon Footprint); South Pole Carbon (Bespoke Investment Carbon Footprints and Investment Climate Impact Assessments); Trucost (Portfolio Carbon Footprint); Bloomberg (Carbon Emissions Data Integrated into Comprehensive Portfolio Analytics); MSCI ESG Research (Tools for understanding portfolio exposure to carbon asset risk and implementing fossil fuel free and low carbon investment strategies); EIRIS (Climate Change Toolkit); ET Index (Carbon Footprint Analysis); INRATE (Carbon Footprint Analysis); Ecofys (Carbon Footprint Analysis); Sustainalytics (Carbon Footprint Analysis), (MontrealPledge, 2017).

Based on the concepts presented so far, the ERA synthesis is comprised of the following stages:

Figure 4- Framework from Theory and Praxis.

1)Scenarios analysis:	Caldecott, Tilbury and Carey (2014); CISL (2015); TCFD (2017) and Scott, Huizen and Jung (2017);
2)Environmental risk factors:	IPCC (2013 and 2014); Moody´s (2016); Scott, Huizen and Jung (2017) and Bank of England, UNEP and CISL (2017);
3) Environmental risk tools in each impact dimension of the financial portfolio:	CISL (2015); GFSG (2016); Dietz, Bowen, Dixon and Grandwell et al (2016); Moody´s (2016); Bank of England, UNEP and CISL (2017) and Benedetti et al (2019).

Source: prepared by the authors.

To better apply this model to IR management, the specific theoretical studies are reviewed and presented in the next section.

3. The International Reserves Management

The objectives of IR management vary among CBs and among portfolios below the same investment manager. For some of them, the main objective is to hedge liabilities. For others, it is capital preservation for future generations. 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 IRs managers, the primary investment objectives of IR management is capital preservation (74% of the answers), liquidity (52%), and return maximization (42%) and supporting monetary policy (6%). According to the researcher, "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).

It follows that security is so important to IRs managers that even when inquired about asset types used to enhance the portfolio rate of return, 73% of the answers indicated preference for long-term government bonds and 61% indicated credit related securities (i.e. Supranationals, Agency and Corporate Bonds), which indicates the clear preference for low credit risk. For comparison purposes, Equities were selected by only 14% and Asset-Backed Securities with 19% (Morahan and Mulder, 2013). On the liquidity side, 71% of the answers in the UBS survey indicated that CBs should not invest in illiquid asset classes such as real estate and infrastructure (UBS, 2018).

When asked about the investment instruments approved for IRs 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%). What is common among IR managers is that reserves investments are oriented toward safe and liquid securities or other assets with low storage costs (i.e. precious metals). Most IRs are invested in long-term fixed income securities from supranational issuers or highly-rated governmental or government-related ones (Vecchio, 2009; McCauley and Rigaudy, 2011; UBS, 2018;

Jones, 2018). Indeed, most of the international reserves are primarily composed by US government debt, i.e. US Treasury securities (McCauley, 2019 and Jeanne, 2012).

In crises, IRs are fundamental to quickly mobilize funds in liquidity portfolios, or even investment ones, to meet foreign currency needs of domestic banks or firms and to support the foreign exchange value of the domestic currency (McCauley and Rigaudy, 2011). The financial stability objectives are a very important constraint to IR management, as well as to short-term liquidity needs and reputational concerns. However, the peer benchmarking possibilities are low (Jones, 2018).

Morahan and Mulder (2013), basing their research on a survey circulated to reserve managing central banks of IMF member countries in April 2012, identified the main concerns/difficulties experienced in IRs management during the crisis episodes of the 2008-2012 period. The credit risk of the reserves was clearly the main concern (80.6%), as detailed:

Figure 5: Concerns/difficulties experienced in IR management during recent crises

#	Concerns/difficulties experienced in IR management during recent crises	Total	Advanced Countries	Middle Income Countries	Low Inc. Countries
1	Credit risk of reserves	80.6%	82.6%	76.0%	84.2%
2	Liquidity of reserves	50.7%	56.5%	48.0%	47.4%
3	Other issues relating to the composition of reserves (e.g. concerns related to specific asset classes)	37.3%	34.8%	52.0%	21.1%
4	Level of reserves	31.3%	26.1%	24.0%	47.4%
5	Currency composition (e.g., increased needs for certain currencies)	29.9%	34.8%	20.0%	36.8%
6	Other	14.9%	21.7%	8.0%	15.8%
7	Did not experience any difficulties	9.0%	0.0%	16.0%	10.5%
Number of respondents		67	23	25	19

Source: adapted by the authors based on Morahan and Mulder (2013)

The analysis of the triggers to asset reallocation indicates that after credit risk (1st and 2nd positions), the reputational risks were relevant, appointed by 45% of the answers, as demonstrated in the next figure:

Figure 6: Triggers to asset reallocation

#	Triggers to asset reallocation	Total	Advanced Countries	Middle Income Countries	Low Income Countries
1	Rating downgrades	80.0%	85.7%	75.0%	80.0%
2	Other sources of awareness of increased credit risk	60.0%	66.7%	50.0%	66.7%
3	Reputational risk	45.0%	47.6%	50.0%	33.3%
4	Worsening CDS Spreads	41.7%	42.9%	50.0%	26.7%
5	Increased volatility	36.7%	42.9%	25.0%	46.7%
6	Balance sheet risk management considerations	25.0%	28.6%	16.7%	33.3%
7	Other	10.0%	4.8%	12.5%	13.3%
Number of respondents		60	21	24	15

Source: adapted by the authors based on Morahan and Mulder (2013)

Jones (2018) documented evidences which indicate procyclical IRs portfolio behavior during the crisis. For the author, the evolution of related vulnerabilities justifies “cautious optimism and lingering concern” (p.2). Special caution is necessary to synchronized

investment practices of reserve managers with one another and other private sector investors. In this context, measures to avoid the IRs procyclicality in future international financial crises are proposed.

IR managers measure their profile of risk relative to a benchmark. Research indicates the usage of VaR to measure risk in the IRs portfolio (78% of the answers), followed by tracking error (48%), CVaR (43%) and Max Drawdown (35%) (UBS, 2018).

On the currency side, the US dollar has the status of a reserve currency. The US dollar is the main currency in IR portfolios, representing around 60% of total 2018 IRs (IMF, 2018). Under the terms of the Bretton Woods Agreement, after World War II (1944), the United States agreed to exchange US dollars for gold and the currencies of the signatory nations were indexed to the US dollar within a 1% deviation limit. To keep their currency within the permissible range, central banks would buy or sell US dollars. Hence, the US dollar has become the official reserve currency of the world (Vecchio, 2009). The IRs currency composition is guaranteed through the Government Bonds Market, where the US Treasury Bond is the main asset. According to Vecchio (2009), it is expected that a transition away from the dollar will occur gradually until 2030, with a limited impact on the dollar's value and the level of domestic US interest rates. The RMB is expected to become a leading reserve currency, on the level of USD and EUR today, according with 38% of over 30 CBs 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 and euro, baskets of currencies called the Special Drawing Rights (SDR) are also present in IR 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 IRs 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 and Mulder, 2013).

Finally, specifically regarding Environmental, Social and Governance (ESG) Investment, 36% of IR managers answered that they do not consider sustainable and responsible investment aspects in the IR 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. When asked about which approach to sustainable investing they were considering, almost 80% answered "integration" which refers to incorporating ESG considerations into portfolios. On the other side, 73% answered that they do not invest in Green Bonds. However, the oil price development appeared as the 6th most prominent concern when IRs managers were asked about the main risks the global economy is currently facing (UBS, 2018). Oil price is one important variable to consider in the discussion of the environmental transition risk to clean energy.

Jones (2018) understood that the ESG concerns are not applicable for IRs managers. This information was presented in a taxonomy proposal of constraints to IR 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 financial risks with medium- and long-term impact, thus applicable to IR management.

Building off of the concepts presented so far, the model of analysis for this study was constructed as follows:

Figure 7: Model of analysis

<table>
<tr><th>Concept</th><th>Hypothesis</th><th>Dimensions</th><th colspan="2">Observable components</th><th>Indicators</th></tr>
<tr><td rowspan="6">ERA and IRs</td><td rowspan="2">IRs, managed by CBs, are exposed to environmental risks.</td><td>Physical</td><td rowspan="2">Financial risks (business, credit, market and legal) due to:</td><td>Climatic, Geologic and Ecosystem factors:
global temperature;
global precipitation;
ice level and snow cover;
ocean temperature, level and ph;
CO2 levels;
radiative forcing;
biodiversity, systemic services, resource usage;</td><td rowspan="5">Variation in the price of the assets (or class of assets) in IRs portfolios as a function of the observable components.</td></tr>
<tr><td>Transition (mitigation/ adaptation)</td><td>Policy;
Technology;
Sentiment.</td></tr>
<tr><td rowspan="3">Environmental risks can be considered in the SAA of the IRs.</td><td>Asset Level</td><td colspan="2">Business, legal, market and credit risks.</td></tr>
<tr><td>Portfolio Level</td><td colspan="2">Market and credit risks.</td></tr>
<tr><td>Systemic Level</td><td colspan="2">Financial system and economy-wide.</td></tr>
</table>

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

The next section discusses the methodological procedures executed in this analysis to determine how to consider environmental risk in the SAA of the IRs.

4. Methodology

The objectives of this study was to address how to consider environmental risk in the Strategic Asset Allocation (SAA) of international reserves. For that, this study also discussed environmental physical and transition risks to which CBs are exposed as managers of IRs, and proposed a multicriteria analytical model for the evaluation of the environmental risk exposure of an investment portfolio that is compatible with the investor profile of CBs. This was performed through literature review and analysis of specialized reports from praxis.

First, the authors analyzed the historical evolution of the environmental sustainability and green finance areas to select the appropriate studies for review. This analysis allowed for the identification of the main global initiatives to be considered, whose reports were studied and included in this research (see Appendix A for further details). Some important references were the reports of the IPCC- Intergovernmental Panel on Climate Change,

PRI- Principles for Responsible Investment, TCFD- Task Force on Climate Related Financial Disclosure, G20 Green/Sustainable Finance Study Group, NGFS- Network for Greening the Financial System and PRB- Principles for Responsible Banking.

Additionally, the literature review included the publications of the 22 universities that are members of the Global Research Alliance for Sustainable Finance and Investment (GRASFIa, 2019). The publications were identified through the webpages of the sustainable finance centers and programs of the GRASFI universities, as well as through the resumes of the Research Leaders of these initiatives. Still other publications were gathered through the internet, using the search terms "sustainable finance", "publication" and the name of each university or its research leaders. Additionally, the analysis covered the publications of the 25 professors who were involved with the GRASFI 2nd Annual Conference Committee (GRASFIb, 2019). The assumption here adopted was that they would include studies related to sustainable finance.

Finally, additional research was conducted in Scopus using the keywords "central bank," "international reserves" and "foreign currency reserves," associated with the words "environmental risk" and "climate risk".

The publications were analyzed focusing on the common points that addressed the research question. Namely, identifying arguments that discussed how the IRs are exposed to environmental physical and transition risks, and how this exposure can be evaluated and integrated in a strategic asset allocation compatible with the investor profile of the CBs. The results are detailed as follows.

5. Results and Discussions

The environmental risks to which the investment portfolios of central banks are exposed (section 2) need to be assessed and quantified to enable their management (section 3). For this purpose, a multicriteria analytical model for the evaluation of these environmental risks was developed. The model, which is compatible with the investor profile of the CBs, is outlined in Figure 8, and its output is an input to the Strategic Asset Allocation Model, outlined in Figure 9, and to the Strategic Green Asset Allocation Model, outlined in figure 10:

Figure 8: Multicriteria analytical model for ERA on IRs management

1) Assessment of env.risk in time (events and trends), based on scenario analysis.		3) Environmental risk tools in each dimension for the analysis of IRs managers						
		Financial Risks				Reputa-cional Risk	Systemic Risks	
		Business	Legal	Market	Credit		Financial System	Economy-wide
2) Environ-mental factors	Physical Climatic Geologic Ecosystem	Asset level: OpVaR.	Legal risk analysis, considering legal risk management measures as ISDAs and (G)MRAs.	Asset level: Discounted Cash Flow (DCF) valuation; relative performance. Portfolio level: market at risk; 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.	Reputa-cional risk analysis.	Financial firm´s exposure, size and concentration; system-wide losses on different scenarios.	Impact on GDP, consumption, financial conditions (scenarios, macro models and model based).
	Transition Policy Technology Sentiment							

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

Figure 9: IRs Strategic Asset Allocation Model

IRs Focus (main exposure)	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)
IR concern for crises mitigation	Countercyclicality	
Three pillars of investment	Security	Liquidity / Profitability

Figure 10: Strategic Green* Asset Allocation Model

Currency
USD, EUR and others

Maturity (years)
< 5
05-10
10-20
> 20

Sustainability (ESG)
Environmental (Green)
Social
Governance

Asset Region	
Global	
Europe	France
	Germany
	UK
	Others
Asia	China
	India
	Russia
	South Corea
	Others
North America	Canada
	USA
Latin America	Brazil
	Mexico
	Others
Oceania	Australia
	Others
Africa	
Others	BRICS
	Others

Issuers
BIS
Others

Investment Driver
Diversification
Superior returns
Institutional reputation
Support to Green* market growth
Green* (e.g.: climate) risk mitigation

Green* Strategy
Best in class
Impact investing
Norms-based screening
Sustainability themed
Engagement and voting
Green* integration
Exclusions

Green Asset Classes
Green Bonds
Climate-aligned Bonds
Green Mutual Investment Funds
Green Investment Trusts
Green Equities
Green Index
Green Exchange Traded Funds-ETFs

Green* Area Focus
Clean Energy
Low-carbon transportation
Low-carbon building
Sustainable use of land and marine resources
Water management
Waste management
Industry
TIC- Technology, info and communication
Biodiversity and environmental conservancy

Liquidity
Turnover
Bid-ask spread

Green*/Total IR Amount
% of IR amount

Green* Second Opin.
Climate Bonds Initiative
DNVGL
Sustainalytics
Cicero
Oekom
Vigeo

Green* Data Sources and External Revisors
MSCI
CDP
Roberco Sam
Auditors (PWC, etc)
Rating Agencies (E.g.: Moody's Green Bonds Assessment)

Financial Data
Bloomberg
Thomson Reuters EIKON
FTSE Russell Green Revenues
Company websites

Control
Use of Proceeds
Process to evaluate and select projects
Management of Proceeds
Report

Market depth
Outstanding

*Green or ESG, if in a broader scope.

Source: prepared by the authors based on Climate Bonds Initiative, 2018; European Commission, 2016; Eurosif, 2018; Green Bonds Principle, 2018 and other references detailed in this study.

The proposed multicriteria analytical model for ERA on IRs management (figure 8) 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, and changes in the public's and investors' sentiment towards a sustainable future.

Based on the analysis of environmental risk factors, the multicriteria analytical model takes into account the subsequent analysis of the impacts on financial portfolios, considering the financial risks, reputational risks and systemic risks. The financial risks are considered in the following dimensions: business, legal, market and credit. The systemic risks include the financial system and the economy-wide risks.

Environmental risk analysis tools are demonstrated for each risk dimension in the asset and portfolio levels. The tools employed include Operational Value-at-Risk (OpVar); Discounted Cash Flow (DCF) valuation; relative performance; market at risk; 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). On the legal side, the model includes the Global Master Repurchase Agreement (GMRA) and the International Swaps and Derivatives Association (ISDA) Master Agreement.

The model also takes into account the IRs preferences on assets (mainly Treasury Bonds, Supranationals, Sovereign Eurobonds, US Agencies, Inflation Protected Bonds, Corporates, MBS/ABS, Covered Bonds and Banks Debt), currencies (mainly American dollar-USD, Euro-EUR, Chinese Yuan-CNY, Japanese Yen-JPY and Pound sterling-GBP) and the concerns for crisis mitigation (countercyclicality).

Finally, the three investment pillars are included: security, liquidity and profitability. The relevance of each of the investment pillars (profitability in relation to liquidity or security) depends on the strategic objectives of each IR manager, which ultimately reflect the reasons for which the reserves are being maintained. For example, Sovereign Wealth Funds (SWFs) can prioritize profitability in 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 output of the ERA model (figure 9) is the IR investment guidelines based on ERA on the top of the main concerns of the IRs managers. Environmental risk management is not the primary concern of the IRs managers, which is to adequately address the reasons which motivate the IRs existence (which may vary from country to country). Hence, the ERA model output addresses environmental risk exposure jointly with the concerns on currency, asset type, countercyclicality and relevance of each of the three investment pillars.

The input to the Strategic Green Asset Allocation Model (figure 10) is the output of the ERA model (figure 8) and of the IRs Strategic Asset Allocation (figure 9). These investment guidelines direct the partial allocation of the IRs in green assets. The guidelines contemplate the specification of asset classes, currencies, issuers and regions/countries, maturity, liquidity (bid-ask spread, turnover), market depth (outstanding) and other specific ESG variables to achieve an efficient investment portfolio, which may require a multi-objective optimization.

One of the ESG variables is the definition among the three sustainable factors: environmental, social and governance. This indicates if the IR management concentrate the analysis only in green assets or in sustainable ones, more broadly speaking.

Also, another important variable is the percentage of the total IR amount to be invested based on the Green* criteria. Depending on the size of the total IR amount and the volume to be invested, the market depth may be a constraint.

The investment drive is a key variable to indicate the motivations of the Green* investments: diversification; superior returns; institutional reputation; support to Green* market growth or Green* (e.g.: climate) risk mitigation. This may lead to partial reallocation of IRs portfolio to green investment alternatives that suit the investor profile of Central Banks and mitigate their exposure to environmental risks. Also, CBs may decide 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). In the other hand, CBs may be concerned about green washing associated with the green assets available in the market, or even be concerned about the lack of standardization of the green assets available in the market.

The Green* strategy is another variable to be considered. According to Eurosif (2018), they may vary between “best in class”; “impact investing”; “norms-based screening”; “sustainability themed”; “engagement and voting”; “Green* integration” and “Exclusions”.

The Green* area focus indicates any specific area of the Green Economy. It is related to the United Nations Sustainable Development Goals (SDGs).

The Green* second opinion providers may minimize the risks associated with the Green* investments, as well as the Green* data sources, the Green* external revisors, the

financial data providers and the control procedures stated by the Green Bonds Principles (2018).

The multicriteria analytical model for ERA on IRs management (figure 8) allows the identification of the main concepts, relationships and tools to be considered by the CBs. On the top of it, the model supports the inclusion of the ERA outputs in the Strategic Asset Allocation (SAA) analysis of the IRs by the CBs, jointly with the Strategic Green Asset Allocation Model (figures 9 and 10).

6. Conclusions

This study discussed the environmental risk exposure of IRs and developed a multicriteria analytical framework to consider environmental risk in the Strategic Asset Allocation (SAA) by CBs. The study is relevant to the construction of the investment portfolio of the IRs because of the different angles that must be considered in the selection of countries and instruments.

The main argument is that environmental risk analysis should be included in the traditional approach for SAA in central banks. 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 IR objectives, like hedging liabilities and evaluating countercyclicality to market movements, the central banks should also take environment risk into account.

The framework outlined in this research opens many possibilities for further studies. The major challenges are scenarios analysis and the evaluation of their impacts on portfolio management. The link between portfolio evaluation and the multicriteria problem for decision making presents an additional challenge.

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Appendix A- Evolution of Environmental Sustainability and Green Finance

Figure 11- Key milestones in the Evolution of Environmental Sustainability and Green Finance

Year	Milestones			
1972	UN Conf. Human Environ. (Stockholm)	UN Environment Programme (UNEP)	26 principles on environment and dvlpment	
1988	Intrgv. Panel Climate Change (IPCC)			
1987	Our Common Future-Brundtland Report			
1989	UNGA Resolution 44/228			
1990	INC Framework Convention Clim. Change			
1992	ECO-92 Earth Summit	UNEP-FI	Agenda 21	Convention on Biological Diversity
1995	1ª UN COP Climate Change			
1996	ISO 14000 Envir. Management			
1997	Kyoto Protocol (entered into force on 2005)	Global Reporting Initiative (GRI)		
1999	UN Global Compact	Dow Jones Sustain. Index (DISI)		
2000	Millennium Declaration	Millennium Development Goals	Earth Charter	Carbon Disclosure Program (CDP)
2001	FTSE4Good Index Series			
2003	Marrakesh Process	Collevecchio Declaration and BankTrack	Equator Principles	
2005	Kyoto Protocol entered into force			
2006	PRI - Principles for Responsible Invest.	IFC Sustainability Framework		
2007	First Green Bond issuance			
2009	Sustainable Stock Exch. Initiative -SSE			
2010	IIRC- Council Fin.Nfin			
2012	Natural Capital Declaration			
2014	IPCC Climate Change 2014: Synthesis Report	Portfolio Decarbonization Coalition (PDC)	EUA EPA 30% less carbon up to 2030	EUA-China join announc. on climate change
	ICMA Green Bonds Principles	Montreal Pledge		

Year	Milestones			
2015	COP21 and Paris Agreement	2030 Agenda Sustainable Develop.	TCFD- TaskForce Climate-related Fin.Discl.	UNEP INQUIRY The Financ.SystemWeNeed
2016	G20 GFSG/SFSG First meeting	Green Finance Synthesis Report	Paris Agreement entered into force	
2017	China National Emissions Scheme	NGFS	First TCFD Report	GRASFI
2018	NGFS First Report	PRB- Principles for Responsible Banking		
2019	EU Taxonomy for sustainable activities			

Source: Prepared by the author, based on Chesney, Gheyssens e Taschini (2013), Souza (2018) and other public information