BANK FOR INTERNATIONAL SETTLEMENTS

BIS Working Papers
No 849

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March 2020

JEL classification: E58, F31, G11, G17.

Keywords: Central banks, green bonds, reserve management, sustainability.

This publication is available on the BIS website (www.bis.org).

ISSN 1020-0959 (print)
ISSN 1682-7678 (online)

Reserve management and sustainability: the case for green bonds?

Ingo Fender, Mike McMorrow, Vahe Sahakyan and Omar Zulaica[1]

Abstract

Central banks' frameworks for managing foreign reserves have traditionally balanced a triad of objectives: liquidity, safety and return. Pursuing these objectives involves explicit trade-offs. More of an emphasis on returns, for instance, may require central banks to sacrifice some of the safety and liquidity of their overall holdings. Most recently, central banks have shown significant interest in incorporating environmental sustainability considerations into their policy frameworks, including their reserve management. This paper first explores whether sustainability considerations would support a tetrad of reserve management objectives, by drawing on the results of a recent BIS Survey on Reserve Management and Sustainability. It then illustrates how central banks might analyse (and weigh) all four objectives in allocating part of their foreign exchange reserves to green bonds using currently available market data.

JEL classification: E58, F31, G11, G17.

[1] This paper is an extended and revised version of the same authors' September 2019 BIS Quarterly Review article, which updates earlier results and reports previously unpublished findings from a survey of reserve managers. The authors are all members of Reserve Management Advisory Services (RMAS), a Unit within the BIS Banking Department. The views expressed are those of the authors and do not necessarily reflect those of the BIS. We are grateful to Pierre Cardon, Torsten Ehlers, Ulrike Elsenhuber, Kumar Jegarasasingam, Frank Packer, and Philip Wooldridge as well as participants at the Central Banking Climate Risk Summit and various BIS Banking Department seminars for comments, and to Nicolas Lemercier and Matias Puig for excellent research assistance.

1. Introduction

Central banks are playing an increasingly active role in promoting the move towards a sustainable global economy (Carney (2015), ECB (2019)). A pertinent example is the recently established *Network for Greening the Financial System (NGFS)*, which brings together around 40 central banks, supervisory agencies and international financial institutions to develop a coordinated response to climate-related risks in the global financial system (NGFS (2019), Pereira da Silva (2019), Bolton et al (2020)).[2]

There are various tools that central banks can use to support the greening of the financial system. These range from disclosure requirements and the provision of data to the integration of climate-related risks into financial stability assessments (Volz (2017)). In addition, central banks can help mobilise funds to contribute to the large-scale public sector investment required to reach the goals of the Paris Agreement (UN (2018)). In key tool in this context is the portfolios of assets that central banks have been entrusted to manage as part of their country's exchange rate policies: foreign exchange (FX) reserves.[3]

In this paper, we explore how environmental sustainability objectives might fit within central banks' reserve management frameworks. This requires expanding the usual *triad* of reserve management objectives – liquidity, safety and return – into a *tetrad*. Using the example of green bonds, we find that sustainable investments can be included in reserve portfolios without foregoing safety and return, although their accessibility and liquidity currently pose some constraints. The results of an illustrative portfolio construction exercise 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.

The remainder of this paper is organised as follows. The next chapter summarises the reserve management process in a systematic manner and explores how sustainability considerations can be integrated into it. The third chapter examines green bonds' liquidity, safety and return and their diversification benefits. The final chapter concludes. Throughout the paper, we draw on a BIS survey on reserve management and sustainability, which was conducted in H2-2019 with respondents from a total of 102 institutions, expanding earlier results in Fender, McMorrow, Sahakyan and Zulaica (2019).

2. Reserve management and sustainability

2.1 Reserve management process

Any debate about whether FX reserves can be employed to pursue sustainability purposes traces back to a discussion of the objectives for holding reserves. For any country, these uses of reserves will be the key drivers of how reserves are invested, translating into more concrete investment objectives at the reserve manager level.

Historically, reserve assets have been accumulated primarily for precautionary purposes and according to various metrics of reserve adequacy (eg IMF (2016)). The objective has been to assure markets that the country authorities can meet their external financial obligations and, more generally, to instil

2 The NGFS is a voluntary, consensus-based forum collaborating to develop climate- and environment-related risk management practices in the financial sector and to mobilise mainstream finance to support the transition towards a sustainable economy.

3 Another possibility is central banks' pension fund portfolios, where portfolio managers tend to enjoy some flexibility regarding asset allocation (Elsenhuber and Skenderasi (2019)). Other portfolios (eg those accumulated in the context of unconventional monetary policies), in contrast, would tend to be dedicated solely to fulfilling monetary policy objectives, limiting the scope for active portfolio allocation decisions (NGFS (2019)).

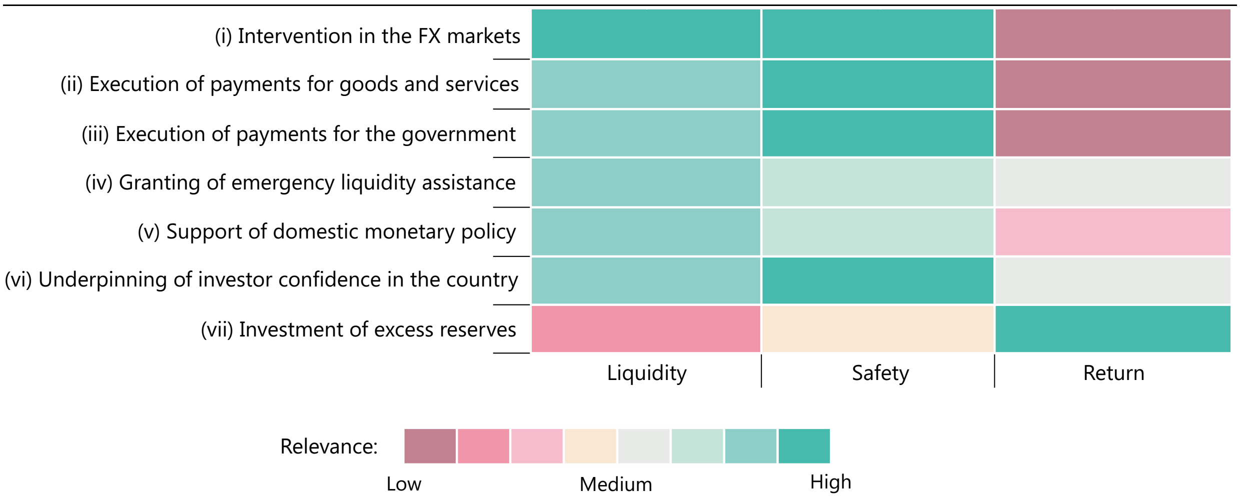
confidence in the domestic economy. On this basis, reserves have typically been accumulated, and measured, against benchmarks such as import coverage, short-term external borrowing, broad money or combinations thereof. Reserve managers, in turn, have traditionally emphasised their ability to mobilise reserves (eg for FX intervention purposes), prioritising the liquidity and safety (or capital preservation) of reserve assets in their asset allocation decisions.

More recently, however, reserves have become widely perceived as exceeding the levels indicated by standard adequacy metrics, at least for some countries (IMF (2016)). According to IMF data, total reserves increased by almost 10% annually over the 2000-19 period, reaching about USD 11.44 trillion at end-2019. This recent growth was mostly a by-product of central banks' monetary and exchange rate policies rather than for explicit adequacy purposes. Anecdotal evidence suggests that the resulting "excess" levels of reserves have led reserve managers to place more emphasis on achieving adequate returns, for example by diversifying the asset and currency composition of their portfolios.

This suggests a direct link (or "mapping") between the seven economic uses of reserves that are usually identified in the literature (Borio et al (2008)) and the *triad* of objectives (ie liquidity, safety and return) commonly pursued by reserve managers. We express the relevant trade-offs by way of a 7x3 matrix (Graph 1), with different colour codings used to illustrate possible weights that reserve managers are likely to give to their various objectives, given alternative economic uses for their reserves.

Mapping between economic uses of reserves (rows) and reserve management objectives (columns)[1]

Graph 1



[1] For illustrative purposes.

Source: Authors' elaboration.

Graph 1 suggests that different economic uses are likely to lead to different portfolio allocations. For example, a reserve manager who needs to regularly smooth liquidity conditions in the FX market vis-à-vis the euro (Graph 1, row (i)) will tend to favour assets providing sufficient liquidity and safety (in terms of both credit and market risk; green shading). This suggests large allocations to short-dated, high credit quality, euro-denominated securities, even for low- or negative-yielding returns on those funds (red shading). Yet, when investing the portion of the reserves considered "excess" from an adequacy perspective (row (vii)), the same reserve manager will tend to more strongly emphasise return (green shading), probably yielding more risky and diversified portfolios. This would entail some costs in terms of liquidity (red shading) and, to a some extent, safety (beige shading).[4]

[4] A key aspect of these decisions is the choice of the appropriate unit of account (numeraire) for the reserves portfolio. See McCauley (2008) for details.

Of course, the trade-offs between the various objectives are not one-to-one, and the economic uses of reserves are not mutually exclusive. In practice, therefore, central banks will look across several objectives, as specified in their mandates, to set liquidity, safety and return requirements accordingly.

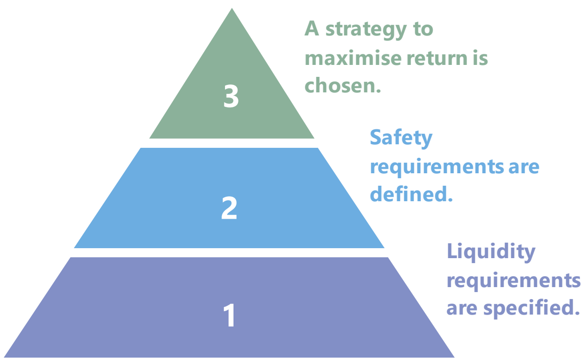
In the portfolio construction exercise, this typically translates into one of two hierarchical approaches to portfolio construction, which divides the reserve portfolio into sub-portfolios: a liquidity and/or working capital tranche and a separate investment tranche:

a) Under the first model (Graph 2, left-hand panel), parts of the portfolio are reserved exclusively for assets that meet a specific threshold requirement for liquidity, limiting the extent to which FX reserves may be invested in assets considered "less liquid". Then, safety requirements are set, which may be reflected in market and credit risk investment targets or guidelines (eg, a volatility objective or asset class and currency exposure limits) – this limits the extent to which FX reserves may be invested in assets considered "less safe". Finally, the reserve manager would find the portfolio that maximises return subject to these constraints. At this stage, the "excess" reserves not needed for liquidity or working capital purposes would be allocated more freely as part of the investment tranche.

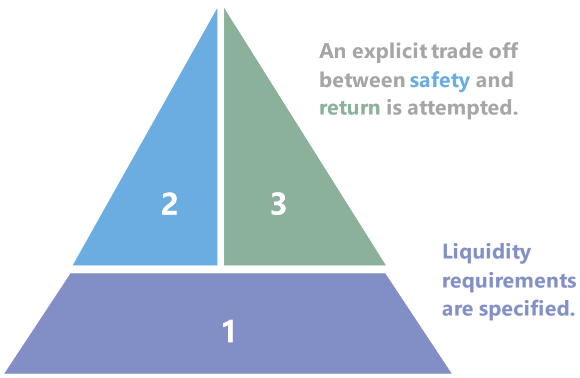
b) Under an alternative approach (Graph 2, right-hand panel), the manager first sets liquidity requirements, but then trades off safety and return jointly in the portfolio optimisation process. In the mean-variance approach, for example, this could mean finding the portfolio with the highest risk-adjusted return, regardless of the absolute level of volatility.

Hierarchical approaches to portfolio construction for reserve managers — Graph 2

Hierarchical approach: model 1



Hierarchical approach: model 2



Source: Authors' elaboration.

Given central banks' rising interest in green finance, is there a way to integrate sustainability considerations into this reserve management process? And, if so, how? Answering these questions involves: first, consideration of the relevant objectives and tools; and, second, an assessment of the selected tools against the primary objectives of liquidity, safety or return. We look at both of these considerations in turn.

2.2 Sustainability as a reserve management objective

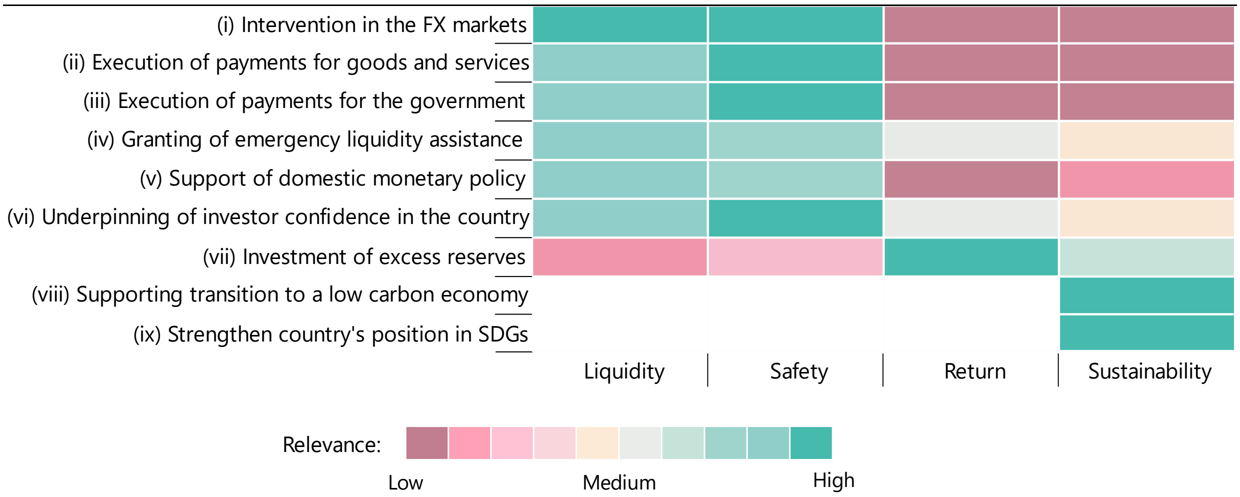
There are two – not mutually exclusive – ways for central banks to include sustainability into their reserve management process: explicit and implicit integration. The application of any of these two approaches mainly depends on governance considerations and, in particular, central bank mandates.

Explicit integration can be achieved by central banks that are able to specify sustainability as one of the policy purposes for holding reserves. In Graph 1, this would entail adding one or more rows, representing new economic uses of reserves (eg supporting the transition to a low-carbon economy) to guide portfolio choice. In practice, this would imply changing the central bank's statutes or other key governance documents, which may face legal or political constraints.[5] To the best of our knowledge, no central bank has yet taken this step, even though some already aim for sustainability as part of their current, general statutory mandate.[6]

Implicit integration involves introducing sustainability into the pursuit of the traditional economic uses of reserves. This requires recognising the indirect ways in which sustainability (or the lack thereof) affects central banks' existing policy objectives. One key factor is risk management. Central banks using their FX reserves as a means to underpin investor confidence in the country (Graph 1, row (vi)), for example, may decide to tilt their reserve portfolios towards assets deemed less exposed to possible long-term financial losses arising from climate risks.[7] Some central banks may also choose to "lead by example" in setting responsible investment standards and integrating climate-related criteria into their operations; they may also seek to mitigate reputational risk in the event that climate risks materialise in the future.

Mapping between economic uses of reserves (rows) and reserve management objectives (columns)[1]

Graph 3



[1] For illustrative purposes.

Source: Authors' elaboration.

Irrespective of the chosen approach, including sustainability in the reserve management process introduces additional trade-offs. In the context of Graph 1, this would involve expanding the triad of liquidity, safety and return to a *tetrad*, with sustainability as the fourth reserve management objective

[5] There are also questions about the appropriate assignment of explicit sustainability objectives in the broader policymaking context, which could also be vested with sovereign wealth funds.

[6] In an analysis of central bank mandates, Dikau and Volz (2019) find that the goal of supporting sustainable growth is directly included in at least a dozen central banks' mandates, and indirectly in the mandates of many others.

[7] An example for this type of analysis, applied to central bank bond purchases, is Monnin (2018).

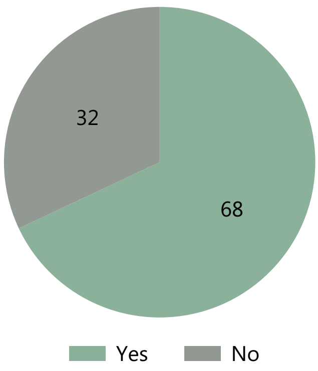
(see Graph 3). In practice, this would then be reflected in changes to the central bank's investment and/or risk management guidelines.[8]

Sustainability and central bank policy objectives

Percentage of respondents[1] Graph 4

Does your central bank include sustainability considerations in the pursuit of its policy objectives?

Do you think there is scope to include sustainability as a reserve management objective?



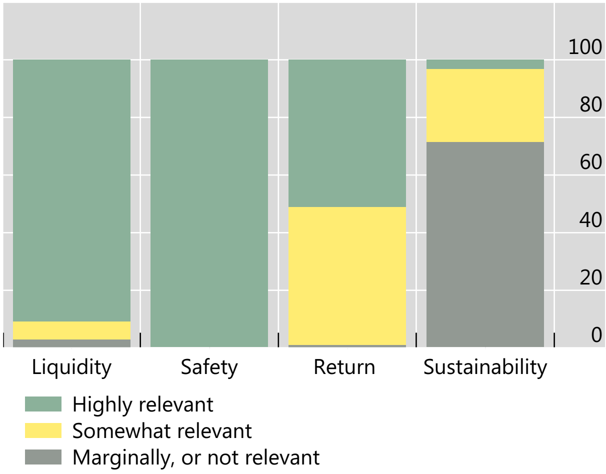
[1] Number of respondents = 102.

Sources: Authors' survey of reserve managers and official institutions; authors' calculations.

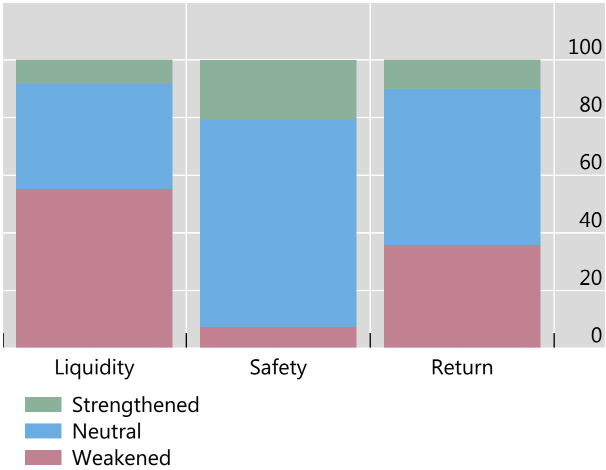
Sustainability in asset allocation: tipping the balance

Percentage of respondents[1] Graph 5

What is the relevance of each of the following four objectives in determining the asset allocation of your foreign reserves?



What would be the impact of including sustainability as a reserve management objective in a reserve portfolio?



[1] Number of respondents = 102.

Sources: Authors' survey of reserve managers and official institutions; authors' calculations.

[8] Examples include the Bank of France and the Netherlands Bank, which recently took the pioneering step of adopting responsible investment charters for their own funds and, in the latter case, also for their FX reserves. See Bank of France (2018) and Netherlands Bank (2019).

Survey results suggest that most central banks do not currently include sustainability considerations in the pursuit of their policy objectives (Graph 4, left-hand panel). And those who do, don't necessarily aim to satisfy a general statutory or legal obligation. At the same time, however, over half of the institutions in the sample consider there to be scope for including sustainability as a fourth reserve management objective, in addition to liquidity, safety and return (ie without necessarily adjusting their mandates and, hence, the stated uses of their reserves (Graph 4, right-hand panel)).

In fact, with regards to the inclusion of sustainability as part of the asset allocation process, roughly 28% are considering sustainability as being somewhat or highly relevant for their institutions at this time (Graph 5 left-hand panel). In addition, most believe that the impact of integrating sustainability considerations into reserve portfolios may weaken liquidity (55% believe so) and return (36%), but many see a neutral (72%) to strengthening (21%) effect in terms of safety (Graph 5, right-hand panel). The latter speaks to how important climate-related risks may be for monetary authorities and stewards of financial stability. A final point to highlight is that some reserve managers in fact believe liquidity and return may be strengthened (8% and 10%, respectively) by introducing sustainability into their objectives.

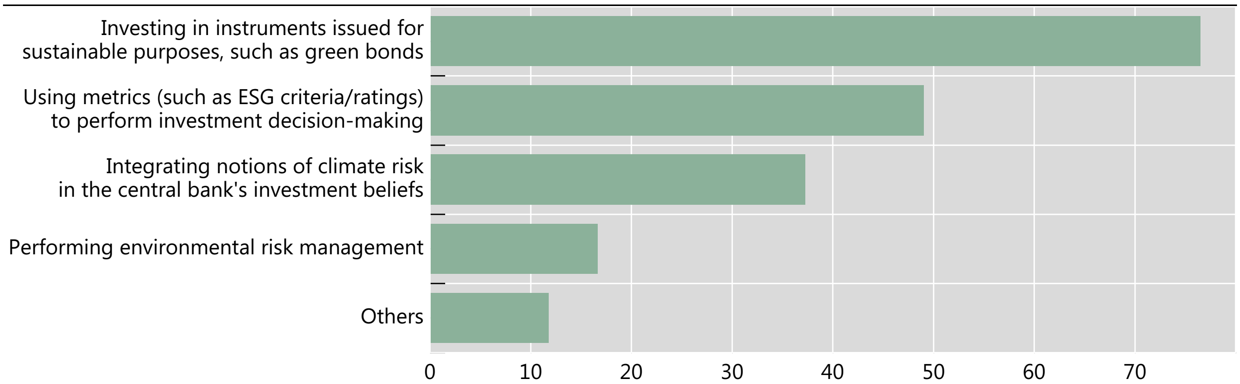
2.3 Tools for implementing sustainability

We have also surveyed central banks regarding their choice of tools for integrating sustainability into their reserve management process. Their preference seems to be for green bond investments (Graph 6). This answer does not come as a surprise, as it fits within the asset class that is core to reserve portfolios – fixed income– and conforms to the strict investment guidelines to which central banks are typically subject.

Anecdotal evidence suggests that this was not always the case, and that green bond purchases may have been driven by conjunctural considerations. Similar to other asset managers, some central banks viewed green bonds as a relative value addition to their pool of conventional bonds. But now that sustainability has become a more central motivation, central banks' contribution to the development of standards and practices (eg in the context of the certification of green bonds according to their likely environmental or climate-related effects) would tend to provide additional benefits to the market as a vehicle for intregrating sustainability as an investment objective.

Tools considered to integrate sustainability into reserve management

Percentage of respondents[1] Graph 6



[1] Number of respondents = 102.

Sources: Authors' survey of reserve managers and official institutions; authors' calculations.

Purchasing instruments issued for sustainable purposes is not, however, the only means for integrating sustainability into reserve management activities. Other ways include:

a) The management of investments using environmental, social and governance (ESG) criteria. ESG investing is based on the notion that ESG factors are drivers of a company's long-term value, risk and return, and serve as a signal of how sustainable the company is over the long term. Including ESG factors in the analysis of a company extends the assessment beyond traditional financial risk metrics. ESG metrics may be applied in the form of an overlay strategy, or they may be included in all aspects of the investment process.[9] An example of a central bank that introduced this tool is the Banque de France, which in its responsible investment charter committed to deepening the analysis of ESG factors for its investment decisions.[10]

b) Integrating notions of climate risk in reserve managers' investment beliefs. Usually accompanied by the introduction of other tools, this entails forming a hypothesis about whether the price of an asset reflects any environmental risks. This means is more challenging to implement, as investors would require a framework for understanding the value of an asset in different environmental scenarios. As highlighted by Ehlers and Packer (2017), an outstanding question continues to be whether a green bond can provide investors with a hedge against environmental risks. This relies greatly on the extent to which the issuers' income stream is dependent on changes in carbon regulations, or physical climate risks. An example of a central bank using this tool is De Nederlandsche Bank, who in its responsible investment charter, highlighted the *belief* that environmental criteria (along with social and governance factors) enhance the understanding of long-term risks and opportunities.[11]

c) Performing environmental risk management. More generally than managing portfolio-level volatility or asset-specific climate-related risks, central banks could consider integrating climate risks into their enterprise risk models or their reserve management framework. An important first question would be, for example, whether there are any exposures to high-carbon assets which may result in potentially damaging financial losses. At a bank-wide level, Basel III already requires banks to assess the impact of specific environmental risks on the bank's credit and operational risk exposures.[12]

Central banks use a variety of other methods to integrate sustainability. These include exclusionary screening, openly supporting international initiatives on sustainable development (such as the Paris Agreement and the United Nations Principles for Responsible Investment), and incorporating sustainable development into their institution's strategic plans. Overall, however, Graph 6 renders green bonds an interesting case study. In what follows, we take the perspective of a reserve manager looking to integrate sustainability through the purchase of these assets, and seek to analyse the characteristics of the market in terms of liquidity, safety, and return.

3. Green bonds: liquidity, safety and return

Green bonds are fixed income securities whose proceeds are used to finance new or existing eligible green projects, eg projects to combat pollution, climate change or the depletion of biodiversity and natural resources (Ehlers and Packer (2017); BIS (2019a)). They are either asset-backed or asset-linked, and issuers must declare the types of green projects eligible to receive funds at issuance. Green bonds

9 Elsenhuber and Skenderasi (2019).

10 Banque de France (2018).

11 In addition, some empirical studies have shown that financial instruments of companies with better environmental, social and governance practices tend to outperform those that do not (see for example: Kempt and Osthoff (2007) for the equity market, and Hoepner and Nilsson (2017a) for the fixed income market – and references therein). This continues to be a point of discussion.

12 See University of Cambridge Institute for Sustainability Leadership (2014).

are the biggest part of the broader universe of socially responsible investments, which include bonds and equities from issuers identified by ESG standards.

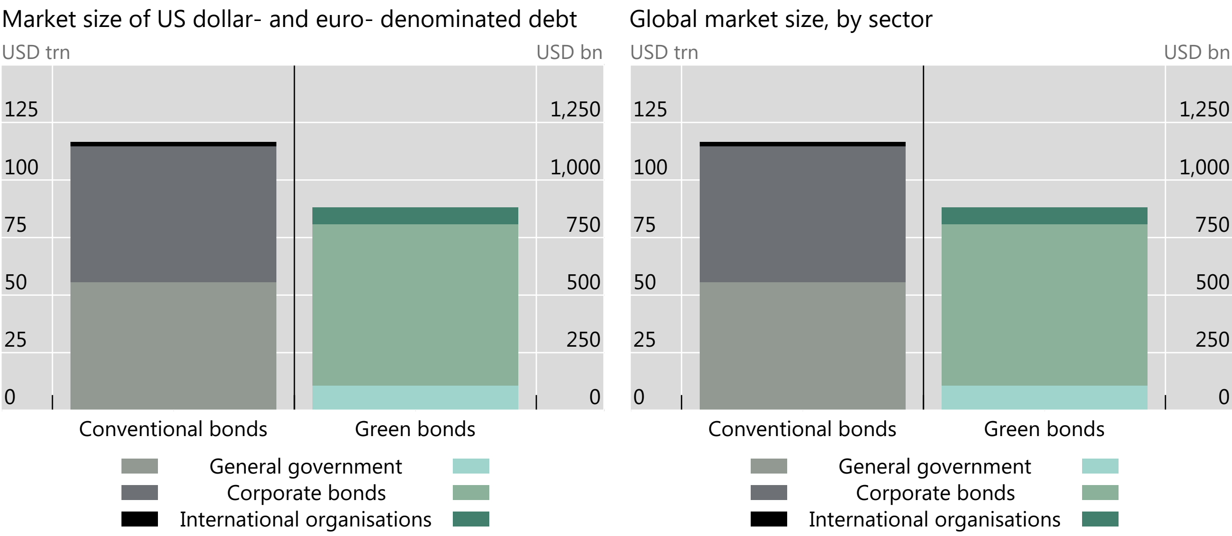
The green bond market has evolved into a diverse array of issuers across geographies and currencies. This has expanded the investment opportunity set of official sector institutions, and many now consider green bonds as their own *asset class*. This section is dedicated to analysing the asset class from a liquidity, safety and return perspective, with each being measured versus their conventional comparators (which normally appear in reserve portfolios). According to data from the International Monetary Fund, more than three quarters of world reserve assets continue to be concentrated in at least two reserve currencies: 61.78% in US dollars, and 20.07% in euros.[13] We choose to focus our discussion on these two currencies, allowing us to make more detailed comparisons.

3.1 Green bond liquidity

An instrument is said to be liquid if transactions in it can take place rapidly and with little impact on price (Borio et al (2008)). On this basis, eligibility will depend on at least two considerations.

The first concerns the stock of instruments available for investment. Both the size and diversity of the green bond market have grown considerably over time. Issuance has increased rapidly in recent years, rising from less than $50 billion in 2014 to close to $230 billion in 2018. A key catalyst for market development was the 2014 introduction by the International Capital Market Association (ICMA) of the Green Bond Principles (GBPs).

Fixed income market size by type of issuer and currency Graph 7



Sources: IMF; Climate Bond Initiative; Dealogic; Environmental Finance Bond Database; Euroclear; Thomson Reuters; Xtrakter Ltd; national data; BIS debt securities statistics; BIS calculations.

However, at current levels, the US dollar and euro segments represent only about 7.4% of global FX reserves (excluding gold), respectively, limiting the scope for investments. Outstanding amounts also continue to be small relative to their conventional comparators. This is true both at the overall market level and for key market segments relevant for reserve managers, such as government bonds and those issued by international organisations (Graph 7). Given large oversubscriptions in primary markets (CBI (2018)) and low secondary market turnover, accessibility of green bonds will tend to be limited, especially

[13] IMF Currency Composition of Official Foreign Exchange reserves (COFER), data as of the third quarter of 2019.

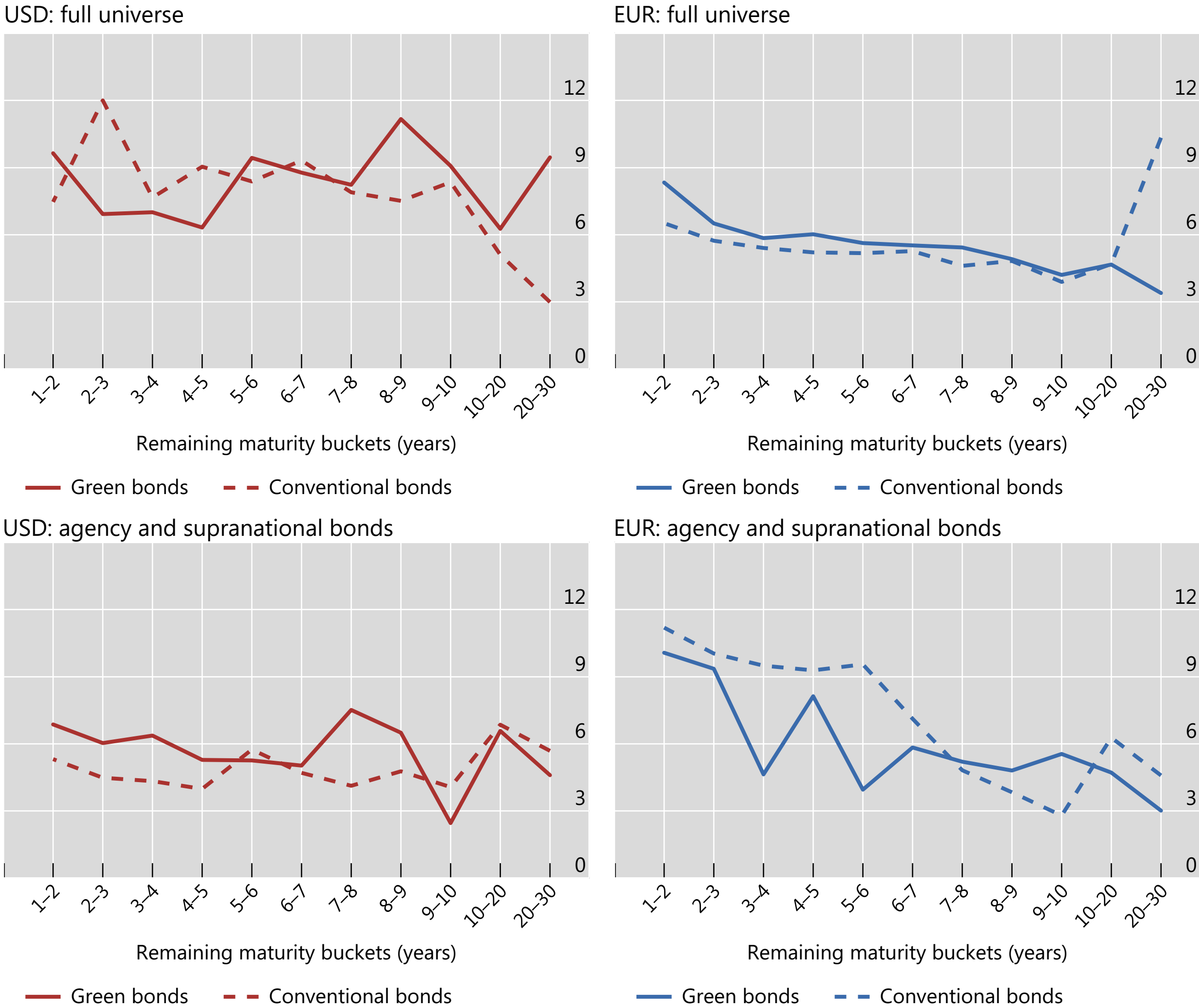
if investors hold these bonds to maturity. The flipside, however, is that, if strong demand persists, investors should be able to liquidate their holdings easily, if required.

The second consideration concerns the cost of trading, which is inherently difficult to measure. One proxy is bid-ask spreads. Graph 8 reports median bid-ask spreads for US dollar- and euro-denominated green bonds and their conventional counterparts for a universe of supranational, corporate and government bonds (upper two panels) and for the sub-universe of supranational and agency issues (bottom two panels). The resulting bid-ask term structures suggest that green bonds may be slighty less costly to buy and sell for short-term maturities, and more expensive to trade in medium to long term buckets. In general, however, the costs of trading are not markedly different and these figures are more encouraging than those found in earlier analyses (eg Fender, McMorrow, Sahakyan, Zulaica (2019)).

Term structure of bid-ask spreads for green and conventional bonds[1]

In basis points

Graph 8



[1] Median daily bid–ask spread in February 2020, by remaining maturity bucket. Full universe is comprised of supranational, corporate, government and municipal bonds labelled green.

Sources: Bloomberg; BIS calculations.

These conclusions hold when seen from the perspective of a specific sector; for example, the euro-denominated supranational and agency green bond bid-ask term structure is more jagged, but on average, still above that of conventional bonds by 2 basis points (Graph 8, bottom panel).

As a result, green bonds may not be eligible for the liquidity or working capital tranches of central banks' reserve portfolios. Inclusion into investment tranches, in turn, is constrained by the market's still-limited size. Central banks may thus have to limit the size of their allocations.

3.2 Green bond safety

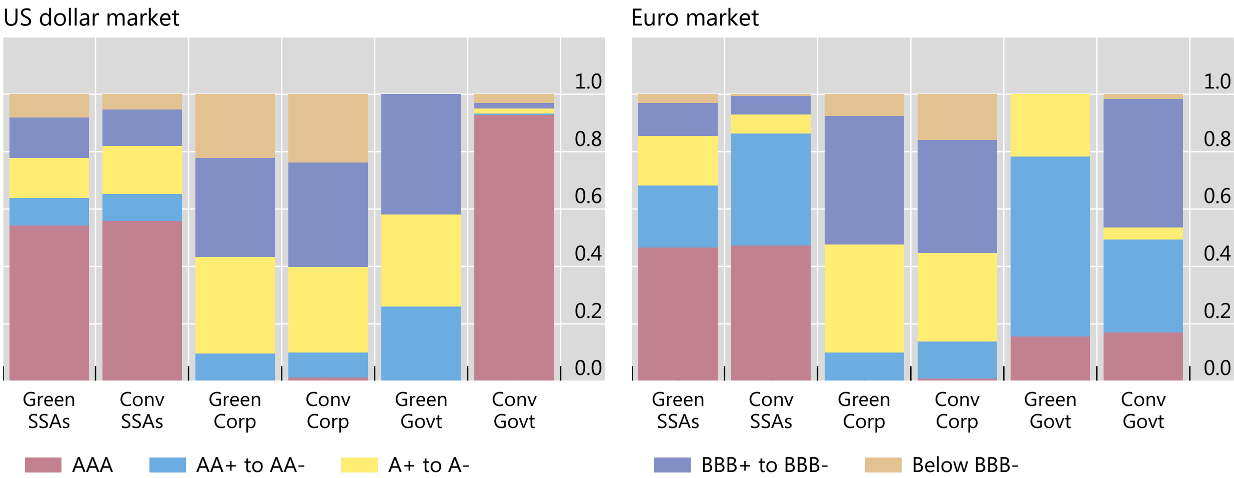
In the reserve management community, safety is typically understood as the ability to preserve the value of the central bank's portfolios, which is a function of the absence of certain types of risk. We start by assessing the eligibility of green bonds from a *credit* risk perspective, by investigating the credit ratings of newly issued green bonds by issuance year and contrasting them with those in conventional bond markets. While the concept of safety goes well beyond credit ratings, central banks typically constrain the credit quality of their reserve portfolios by imposing credit rating guidelines on their investments. A common requirement is to exclude bonds with ratings of BBB+ and below.

How do green bonds measure up against this metric? We find that the ratings composition of green and conventional bond markets has broadly converged, supporting eligibility. Although green bond at-issuance ratings in 2014 were more concentrated, the array of available credit ratings has expanded. This puts high-graded green bonds at shares similar to their conventional comparator market. Recent data for total amounts outstanding at the sectoral level appear to confirm this observation (Graph 9). The main exception is government bonds, where credit quality in green-labelled instruments tends to be lower, particularly in the US dollar market, in part because only a few countries have so far issued in this space. In the conventional space, the share is dominated by the US Treasury market.

Green and conventional bond market rating distribution by type of issuer[1]

In percent of amount outstanding

Graph 9



Conv Corp = conventional corporate bonds; Conv Govt = conventional government bonds; Conv SSAs = green supranational & agency bonds; Green Corp = green corporate bonds; Green Govt = green government bonds; Green SSAs = green supranational & agency bonds.

[1] Amount outstanding included in green and conventional bond market benchmarks. Only includes rated securities; end–February 2020 data.

Sources: Bloomberg; ICE BofAML indices; BIS calculations.

An important point to highlight in this context is that, given two bonds from the same issuer, choosing the green bond should make no difference in terms of default risk. This reflects the fact that green bonds are usually backed by the full balance sheet of the issuer, and not only by the cash flows related to the climate-friendly project that was financed from the proceeds. As a result, the coupon and principal of green bonds have usually the same likelihood of being serviced as those of conventional bonds. Of course, this does not mean they are free of any environmental risk (see Ehlers and Packer (2017)).

A reserve manager may also be concerned about the exposure to currency risk. Given the current state of the market, investors with a USD or EUR numeraire can easily participate in the green bond market without facing FX rate volatility. For other investors, currency hedging may be a solution to contain FX risk, provided that markets for the relevant hedging instruments vis-à-vis the domestic or numeraire currency are liquid enough.

Finally, safety may also be understood from the perspective of price volatility, tail-risk or probability of facing a loss. We defer this discussion for later, where an asset-class level analysis is performed. But we preview for the reader the conclusion that green bonds would likely not be considered less safe than the standard conventional instrument.

3.3 Green bond return

The third aspect of eligibility is return. Evidence from both primary and secondary markets points to a small and negative yield premium ("greenium").[14] However, much of this evidence is at the *security* level, which restricts the analysis to a relatively small sample of matched bonds. The more relevant question for reserve managers is how a *portfolio* of green bonds is likely to behave vis-à-vis one composed of conventional bonds with similar characteristics. We thus take the analysis to the asset class level and focus on relative returns for fixed income indices.

To control for differences in index composition, we compare two "matched" indices: one for green and the other for conventional bonds. Given limited availability of green bonds, we select an available green bond index as our reference portfolio. We then build a portfolio of conventional bonds that matches its characteristics in terms of sectors, rating composition and duration.[15]

To do this, we dissect the green bond index (in USD or EUR) into each issuer sector i and credit rating bucket j. Then, we construct a synthetic conventional portfolio that matches this breakdown, by applying the green index's sector and rating weights to individual conventional bond indices for each combination of sector i and credit rating bucket j.[16] We also ensure that the conventional indices closely track the green portfolio's duration.[17] We then compare index performance, assuming rebalancing costs to be zero for both portfolios. Of course, the issuer and rating composition of the two portfolios will change over time, which must be taken into account when the indices are rebalanced.

On this basis, the yield to maturity of the portfolio of the conventional index (in either USD or EUR) at every month-end t is:

$$y_t^{Conv.} = \sum_i w_{i,t}^{Green} * (\sum_j w_{j,t}^{Green} y_{(i,j),t}^{Conv.})$$

where $w_{i,t}^{Green}$ and $w_{j,t}^{Green}$ are the weights that sector i and rating bucket j have at month t in the green benchmark, $y_{(i,j),t}^{Grey}$ is the yield to maturity of the conventional index of sector i and rating bracket j, and

[14] Zerbib (2019) provides a comprehensive literature review. He finds, controlling for liquidity, an average green bond premium of -2 basis points. This suggests that, on average, holding such bonds to maturity yields a lower return.

[15] Bloomberg Barclays MSCI indices are used as a basis for the green bond universe and ICE BofAML indices for the conventional bond market. The underlying sectors used are: agencies, corporates, governments, municipals and covered bonds; the underlying credit rating brackets are: AAA, AA+ to AA-, A+ to A-, BBB+ to BBB-.

[16] In practice, conventional bond indices also include green bond issues. However, their size as a fraction of the overall conventional index is negligible and thereby has no impact on our analysis. For illustration, in the US dollar agency total conventional bond index, green bonds represent 3% of issues; in the corporate case the share is 0.5%.

[17] Our duration tracking error is 0.18 years on average.

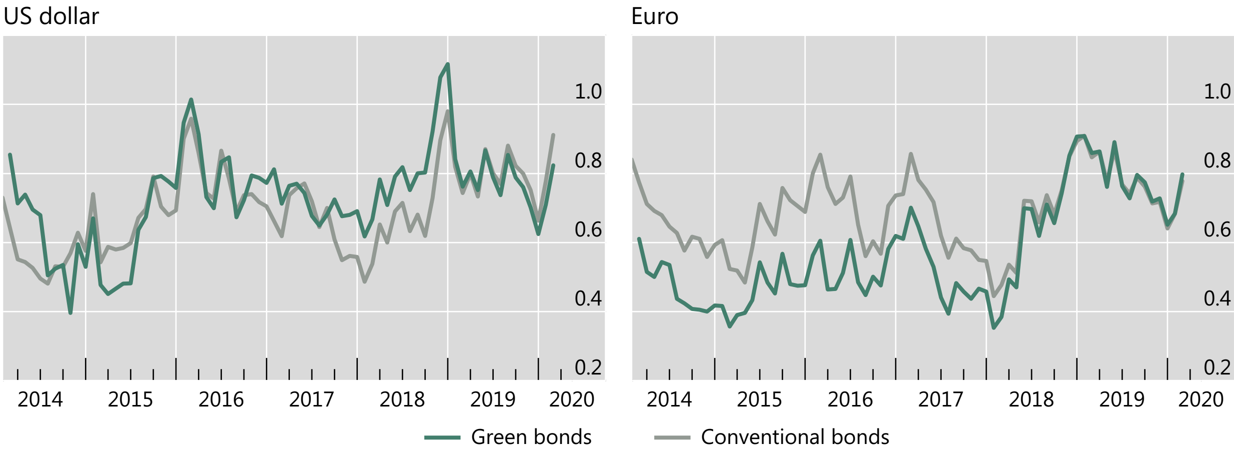
$y_t^{Conv.}$ is the yield to maturity of the complete conventional bond portfolio. This can then be contrasted with the yield of the green portfolio.

In line with established practice, in order to isolate the compensation of green and conventional bonds relative to their risk-free benchmark, we remove the risk-free component of the yields to maturity by subtracting the zero-coupon yield of the government instrument with equivalent duration.[18]

Green and conventional bond spreads to the reference curve[1]

In percentage points

Graph 10



[1] Yield curve factor model for the reference curve uses monthly data since 1953 for US Treasuries from the Board of Governors of the Federal Reserve System and monthly data since 1974 for German bunds from the Bundesbank (see Annex for details).

Sources: Board of Governors of the Federal Reserve System; Deutsche Bundesbank; Bloomberg; ICE BofAML indices; authors' calculations.

Our results (Graph 10) suggest that green bonds compare reasonably well with their conventional peers. Based on our approach, a USD investor tracking the green index would have enjoyed a spread 3.5 bp above that of the conventional benchmark (ie the difference in spreads is a positive *portfolio greenium*), while the EUR-based investor would have earned 11.2 bp less than the comparator market (negative *portfolio greenium*).

However, this greenium estimate has varied considerably over time, due in part to differences in issuer composition across benchmarks, even when credit rating and sector breakdowns are set equal. It also appears that the portfolio greenium has narrowed over time as the green bond market developed, with the spread between conventional and green returns closing as of 2019. In fact, for both currencies, we fail to reject the null hypothesis that the average spreads of green and conventional bond benchmarks are equal over the last two calendar years.[19]

Absolute returns paint a similar picture. Table 1 reports summary statistics comparing the risk-return properties of green and conventional bonds. These are based on our two aforementioned model portfolios and a generic zero-coupon bond of equal maturity. A couple of points stand out. First, both types of portfolios possess broadly comparable historical returns. For example, between 2014 and the beginning of 2020, US dollar green bonds had an average monthly return of 0.31%, while the conventional benchmark returned 0.29% over the same period. Second, we observe that, in both the

[18] The reference curve for this purpose is obtained by applying the shadow short rate approach for modelling the term structure of interest rates (Bjorheim et al (2018) and Annex).

[19] Two-tailed t-test with a 95% confidence interval.

US dollar and euro cases, the volatility and tail risk of the conventional and green instruments are broadly similar, sometimes favouring green bonds.

This confirms the point that, from a safety perspective, investment in green bonds would not seem to subject reserve managers to higher risk than their conventional alternative. This holds regardless of whether safety is defined in terms of price volatility, performance in extreme scenarios[20] or the probability of facing a negative return – all of these measures are oftentimes used by reserve managers to express risk tolerance.

Asset class summary statistics[1]

In per cent

Table 1

	US dollar assets			Euro assets		
	Government bonds	Green bonds	Conventional bonds	Government bonds	Green bonds	Conventional bonds
Average return	0.25	0.31	0.29	0.32	0.34	0.37
Volatility	0.94	0.79	0.71	1.34	1.18	1.18
VaR return (97.5%)	–1.36	–0.97	–0.78	–2.17	–2.23	–2.17
Expected shortfall (97.5%)	–1.82	–1.55	–1.44	–2.37	–2.68	–2.69
Probability of negative return	51.39	33.33	37.50	40.28	33.33	31.94
Duration (years)	5	5	5	9	9	9

[1] Historical statistics using monthly returns from January 2014 to February 2020.

Sources: Board of Governors of the Federal Reserve System; Deutsche Bundesbank; Bloomberg; ICE BofAML indices; authors' calculations.

Having established eligibility – at least outside reserve managers' liquidity tranches – does it make sense to add green bond allocations from a risk-return perspective? Answering this question involves trading off green bond safety and return in a portfolio context, after taking the reserve manager's liquidity requirements into account.

3.4 Asset allocation

To analyse whether green bonds may improve the risk-return profile of a traditional reserve manager's portfolio, we perform several illustrative asset allocation exercises. The eligible assets for these exercises are government bonds and our two previously defined green and conventional bond portfolios. We explore potential diversification benefits by running optimisations for both USD and EUR numeraires.

3.4.1 Methodology

Portfolio construction is a forward looking exercise by nature. It is thus ill-advised to rely on historical returns for this purpose. In line with practice among reserve managers, we thus apply a statistical factor-based approach[21] to price our illustrative reserve portfolios in a forward-looking manner.

To do this, we proceed as follows: First, we decompose the historical fixed income portfolio yields (both green and conventional) into a set of factors: level, slope, curvature, spread, and a residual. Second, we estimate the empirical distributions of the idiosyncratic shocks; and third, we project these distributions forward. The expected path for the total return of each portfolio is then dependent on two drivers:

[20] It is important to note that there may be a small-sample bias when estimating tail-risk measures. This arises from the relatively short history of the green bond market.

[21] See Bjorheim et al (2018) and Diebold and Li (2006) for details; additional information is available on request.

sovereign yield curves and how they evolve over time, and the spread that is paid above these *risk-free* yields.[22] To model the uncertainty around these expected paths, we use the historical, empirical distributions of the various risk factors, which allow us to project the risk characteristics of the portfolios. These projections of the risk factors are then used to price the sovereign bonds as well as the conventional and green bond portfolios in the future, and estimate forward-looking summary statistics of their returns. We do this separately for USD and EUR-denominated portfolios. Further detail is presented in the Annex.

We make two sets of simplifying assumptions to keep our analysis tractable.[23] To project the sovereign yield curve factors (level, slope and curvature), we rely on a simple autoregressive model.[24] And, for the spreads, we impose restrictions such that the expected paths of both USD and EUR green and conventional credit spreads are, on average, equal and constant over time and close to their current levels. This reflects the empirical evidence of small and possibly vanishing "greenium" effects (Graph 8) as well as results from our informal survey, where a majority of reserve managers saw no meaningful difference between green and conventional bond returns.[25]

3.4.2 Results: prospective risk return properties

Our findings are documented in Table 2. A couple of points stand out. First, as assumed, green and conventional portfolios possess the same expected return.[26] Second, we can explore their prospective risk properties, which are backed out from the empirical distributions of their underlying risk factors.

Asset class summary statistics, based on prospective returns[1]

In percent | Table 2

	US dollar assets			Euro assets		
	Government bonds	Green bonds	Conventional bonds	Government bonds	Green bonds	Conventional bonds
Expected return	0.45	1.33	1.33	–2.63	–1.80	–1.81
Volatility	3.21	3.30	3.40	4.72	4.96	5.04
VaR return (97.5%)	–5.56	–4.84	–5.13	–12.03	–11.54	–11.94
Expected shortfall (97.5%)	–6.59	–5.9	–6.11	–13.79	–13.46	–13.71
Probability of negative return	46.06	35.68	36.06	73.10	65.72	65.26
Duration (years)	5	5	5	9	9	9

[1] Prospective statistics using monthly annualised returns over the next 5 years, based on monthly data from 1953 to 2020, as available.
Sources: Deutsche Bundesbank; US Federal Reserve Board; Bloomberg; ICE BofAML indices; BIS calculations.

[22] The yield of each portfolio $P = \{Green, Conv.\}$, k months in the future is given by: $y_{t+k}^{P}(\tau) = y_{t+k}^{Gov}(\tau) + s_{t+k}^{P} + \varepsilon_{t+k}$, where $y_{t+k}^{Gov}(\tau)$ is the yield of the government security, determined by the three yield curve factors; s_{t+k}^{P} is the spread paid above this yield by portfolio P; and ε_{t+k} a residual term that captures uncertainty around the forecast.

[23] This is for illustrative purposes. In practice, reserve managers would choose their own model to link what they believe are the drivers of future returns to their underlying risk factors. For example, in a macroeconomic-based approach, variables such as real GDP growth and year-on-year inflation may be used to predict the yield curve.

[24] Their expected path is that implied by the recursive estimation of the AR(1) process on observations of the monthly factors over the next 5 years.

[25] In the survey, 57% of reserve managers responded that there is no meaningful return difference between green and conventional bonds, while 34% and 9% think they provide investors with lower and higher returns, respectively.

[26] Absolute return levels depend in part on the specification of interest rate forecasts. Given the autoregressive process chosen in our illustrative example, interest rates are projected to rise on average. As a consequence, part of the projected total bond return reflects capital losses. The choice of a more adequate model specification to forecast interest rates is out of the scope of this Working Paper.

Here, we observe that, in both the USD and EUR cases, the volatility, tail-risk and probability of loss of the conventional and green instruments are broadly similar, just like in the historical case (Table 1).

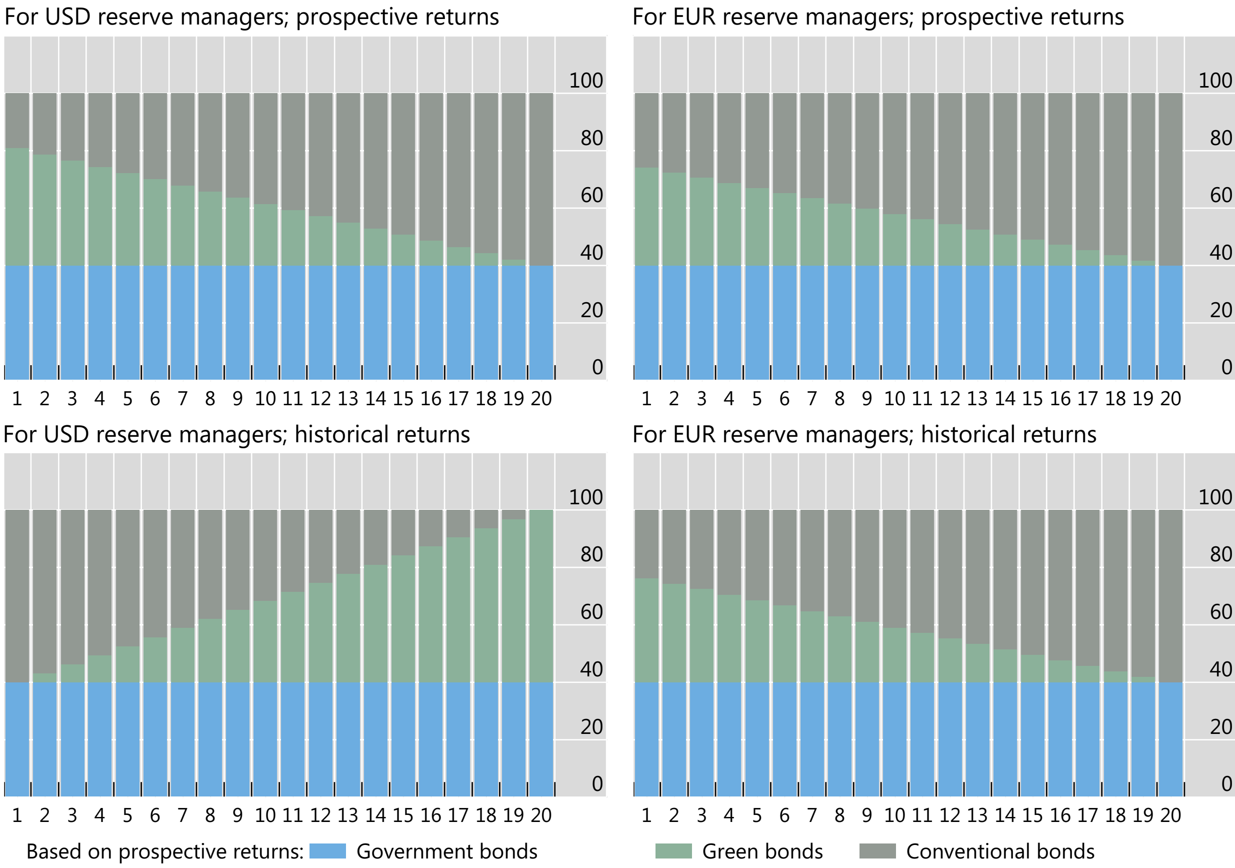
3.4.3 Results: portfolio optimisation exercise

Using a hierarchical approach to portfolio construction – mimicking model 2 from Graph 2 above – we begin by setting *liquidity* requirements by means of a constraint of 40% to be invested in sovereign bonds.[27] Then, we use a standard mean-variance optimisation algorithm to trade-off *safety* and *return*, combining conventional and green bonds to obtain the best possible pairs of expected return and volatility. Our results are documented in the blue, green and grey bars of Graph 11 (two upper panels), with portfolios further along the frontier (denoted by increasing portfolio numbers) implying higher volatility. Given that, in our prospective exercise, conventional bonds are envisioned to have slightly higher volatility than green bonds (see Table 2 in both the USD and EUR cases), these are found further into the efficient frontier.

Composition of the portfolios on the efficient frontier[1]

In percent of each portfolio

Graph 11



[1] Efficient frontiers for illustrative reserve portfolios, based on prospective and historical returns, respectively. Prospective returns calculated based on 5-year-ahead projections as described in the Annex. Historical returns are calculated from a sample from Jan-2014 to Feb-2020. Sovereign bond investment imposed at 40% for all exercises. Portfolios on the frontier are sorted from lower to higher volatility. Minimum risk portfolios are labelled 1; maximum risk portfolios are labelled 20.

Sources: Bundesbank; US Federal Reserve Board; Bloomberg; ICE BofAML indices; BIS calculations.

[27] For illustrative purposes, we assume an investment tranche size of 60%, which leaves 40% as the size of the liquidity and working capital tranches.

Regardless of the fact that green and conventional assets are assumed to have equal prospective returns, including both types of bonds in the illustrative reserve portfolio helps improve risk-adjusted returns. For example, in the minimum risk portfolios (labelled "1" in both panels), we find that green and conventional bonds are both present, illustrating mutual diversification benefits. The same applies to the maximum risk portfolio (labelled "20").

Results based on historical, rather than prospective, returns are qualitatively similar (Graph 11, two bottom panels). This is despite the history of greenium effects (Graph 10), particularly in the euro-denominated market, which reduces green bond allocations relative to the prospective return case. Nevertheless, for both currencies, green bonds are present in nearly all portfolios along the efficient frontier. Allocations in the minimum risk portfolios, in turn, are anchored by the relative size of historical return volatilities observed for both green and conventional bonds.

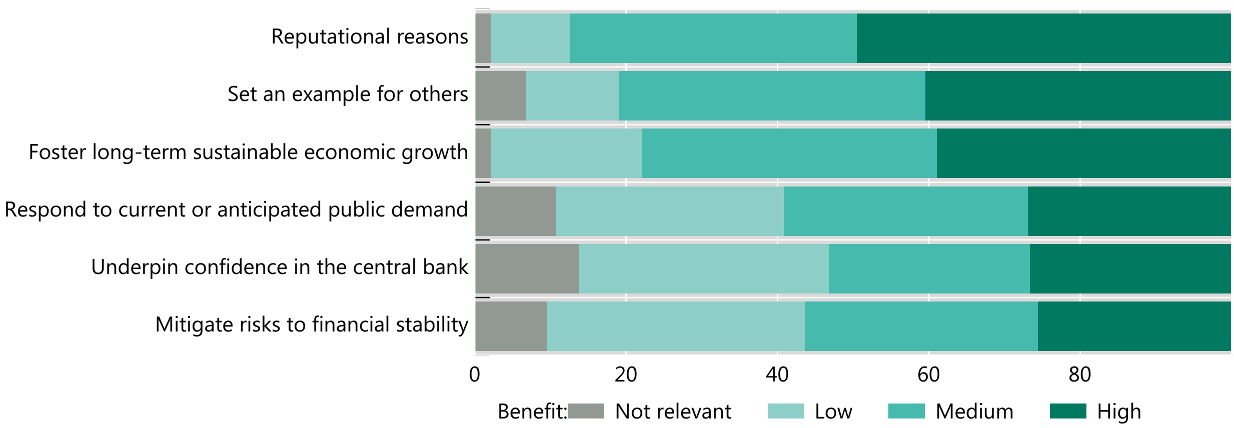
Of course, real world asset allocation exercises would tend to involve a wider range of eligible assets as well as additional constraints. This will change the resulting portfolio weights for the overall FX reserve portfolio. Nonetheless, our illustrative exercise suggests that, when deciding their portfolio allocations, reserve managers can reap diversification benefits even from subtle differences in risk-return properties between green and conventional bonds.

4. Concluding remarks

While central banks are playing an increasingly active role in promoting green finance, comparatively less attention has been paid to how they might integrate sustainability into their policy frameworks – specifically for their FX reserves.

Benefits of including sustainability in the pursuit of policy objectives

Percentage of respondents[1] Graph 12



[1] Number of respondents = 102.

Sources: Authors' survey of reserve managers and official institutions; authors' calculations.

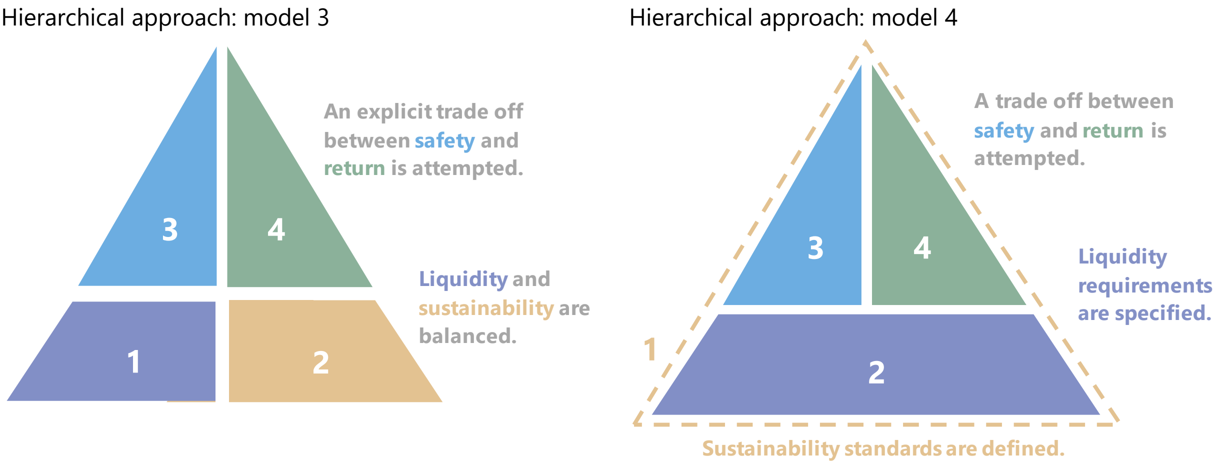
In this paper, we explored how sustainability might be integrated into the reserve management process – either by *explicitly* articulating sustainability as a defined purpose for holding reserves, or *implicitly* as a supporting aspect of existing policy purposes. Central banks' choice between either of these two approaches will depend primarily on their legal and governance frameworks. Regardless, central banks apparently see many benefits from its integration, the most prominent ones among survey respondents being reputational reasons, setting an example for others, and fostering long-term sustainable economic growth (Graph 12).

As portrayed in this paper, integrating sustainability through the purchase of green bonds will involve additional trade-offs, turning the classical *triad* of liquidity, safety and return into a *tetrad* of reserve management objectives. Indeed, by analysing the asset class properties of green bonds, we found that their accessibility and liquidity currently pose some constraints. This is one reason why reserve managers may wish to limit the total volume of green bonds held, particularly in light of the relatively small (but rapidly growing) size of the market. In practice, the extent of this limit will depend on the priority reserve managers give to sustainability in their reserve management objectives.

Overall, however, we found that sustainability objectives can be integrated into reserve management frameworks without forgoing safety and return. Indeed, the results of an illustrative portfolio construction exercise suggest that adding both green and conventional bonds can help generate diversification benefits and, hence, improve the risk-adjusted returns of traditional sovereign bond portfolios. To the extent that central bank involvement helps to establish minimum standards and practices in a still-developing market (BIS (2019b)), this would tend to confer additional benefits (eg by guarding against so-called "greenwashing").

In this context, a *new* hierarchical approach to portfolio construction could work as follows. First, trade off liquidity and sustainability; then, trade off safety and return (Graph 13, left-hand panel). Alternatively, for institutions where sustainability is deemed a first-order consideration, it could precede the whole process. For example, by setting liquidity, safety and return requirements only using instruments whose environmental impact or footprint has been assessed beforehand (Graph 13, right-hand panel). To perform this analysis, however, investors may require more and better quality information, such as standardised green labels and climate-risk related disclosures. These are still some way off.[28]

Hierarchical approaches to portfolio construction including sustainability[1] Graph 13



[1]Continued from Graph 2.

Source: Authors' elaboration.

Of course, instruments such as green bonds are only one tool for implementing sustainability objectives. Some central banks – particularly those with abundant FX reserves, which are more likely to hold less traditional reserve assets – may have more options for doing so. For example, by making sustainable investment choices in the corporate bond or equity parts of their portfolios, or by adding new asset classes (such as green infrastructure). After all, there is more than one way to go green.

28 The Task Force on Climate-related Financial Disclosures (TCFD) is developing voluntary, consistent climate-related financial risk disclosures for use by companies in providing information to investors, lenders, insurers, and other stakeholders.

References

Bank for International Settlements (2019a): "The BIS's support of green finance", Annual Report 2018/19, June, pp 33.

———— (2019b): "BIS launches green bond fund for central banks", press release, 26 September.

Banque de France (2018): "Responsible Investment Charter", March.

Bjorheim, J, J Coche, A Joia and V Sahakyan (2018): "A Macro-Based Process for Actively Managing Sovereign Bond Exposures". In: *Advances in the Practice of Public Investment Management*, Springer, pp 103–29.

Bolton, P, M Despres, L Pereira da Silva, F Samama and R Svartzman (2020): "The green swan", January.

Borio, C, J Ebbesen, G Galati and A Heath (2008): "FX reserve management: elements of a framework", *BIS Papers*, no 38, March.

Carney, M (2015): "Breaking the tragedy of the horizon – climate change and financial stability", *speech given at Lloyd's of London*, 29 September

Climate Bond Initiative (CBI, 2018): "Green bond pricing in the primary market", December.

De Nederlandsche Bank (2019): "Responsible Investment Charter", March.

Diebold, F X and C Li (2006): "Forecasting the term structure of government bond yields", *Journal of Econometrics*, 130(1), pp 337–64.

Dikau, S and U Volz (2019): "Central Bank Mandates, Sustainability Objectives and the Promotion of Green Finance", *Working Paper 222*, University of London.

Ehlers, T and F Packer (2017): "Green bond finance and certification", *BIS Quarterly Review*, September, pp 89–104.

Elsenhuber, U and A Skenderasi (2019): "ESG Investing: How public investors can implement sustainable investing", *mimeo*. Forthcoming in: *Evolving Practices in Public Investment Management: Proceedings of the Seventh Public Investors Conference*.

European Central Bank (2019): "Climate change and financial stability", *Financial Stability Review*, May.

Fender, I, M McMorrow, V Sahakyan and O Zulaica (2019): "Green bonds: the reserve management perspective", BIS Quarterly Review, September, pp 49–63.

International Monetary Fund (2016): "Guidance note on the assessment of reserve adequacy and related considerations", June.

McCauley, R (2008): "Choosing the currency numeraire in managing official foreign exchange reserves", In: Pringle, R and Carver, N (Eds), *RBS reserve management trends 2008*, London, pp 25–46.

Monnin, P (2018): "Integrating Climate Risks into Credit Risk Assessment, Current Methodologies and the Case of Central Banks Corporate Bond Purchases", *Discussion Note 18/4*, Council on Economic Policies, December.

Network for Greening the Financial System (NGFS, 2019): "A call for action: climate change as a source for financial risk", April.

Pereira da Silva, L (2019): "Research on climate-related risks and financial stability: An "epistemological break"?", *BIS management speeches*, May.

United Nations (UN, 2018): "Financing for SDGs: Breaking the bottlenecks of investment", *concept note*, New York.

Volz, U (2017): "On the role of central banks in enhancing green finance", *UNEP Inquiry Working Paper 17/01*, February.

Zerbib, O D (2019): "The effect of pro-environmental preferences on bond prices: Evidence from green bonds", *Journal of Banking and Finance*, vol 98, pp 39–60.

Annex: Factor-based approach to portfolio construction[29]

To derive prospective risk and return measures of bonds of different maturities, we employ a forward-looking, factor-based approach to asset allocation performed in three steps: (1) factor identification and projection, (2) return projection, and (3) portfolio optimisation.

1. Factor identification and projection

First, we identify and estimate the underlying statistical factors of government bond yield curves. To achieve this, we use a dynamic Nelson-Siegel term structure model, modified slightly from the version proposed by Diebold and Li (2006). The model decomposes historical yields into three factors: the short rate, slope and curvature, which are then projected forward.[30] For the purposes of this study, we rely on a simple autoregressive model that generates projected paths for all three factors over the next 5 years.[31] For securities belonging to other fixed-income asset classes (ie green bonds and their conventional counterparts), additional spread factors, representing compensation for any risks beyond those embedded in the government yield curve, are estimated and projected using the same autoregressive approach.

To keep the analysis simple, we restrict the expected paths of both USD and EUR green and conventional bond spreads to be, on average, equal and constant over time and close to their current levels. This reflects the empirical evidence of small and possibly vanishing "greenium" effects (Graph 10) as well as results from our survey, in which a majority of reserve managers saw no meaningful difference between green and conventional bond returns.

2. Return projection (asset pricing)

Second, we use our yield curve factor projections to project the zero-coupon term structure of interest rates for each period in our projection horizon. For the green spreads and their conventional counterparts, we add the relevant spread factor projections to identify the prospective yields of each asset. Armed with these simulated yield distributions, we can then estimate a prospective return distribution for each generic asset class, from which forward-looking summary statistics – such as the expected return (mean), volatility (standard deviation) and other risk metrics – are derived. As implementation considerations typically come at a later stage of the FX reserve management process, the derived prospective return distributions do not include transaction costs.

3. Portfolio optimisation

Finally, we estimate an expected return vector and a variance-covariance matrix from the prospective asset return distributions. On this basis, a standard (Markowitz) mean-variance algorithm is applied to derive a frontier of efficient portfolios, including the global minimum variance portfolio.

29 For more details on the factor-based approach, contact BAAM@bis.org.

30 Departures from the original Nelson-Siegel model and the methodology for factor projection are described in more detail in Bjorheim et al (2019)).

31 This is for illustrative purposes. In practice, reserve managers would choose their own model to link what they believe are the drivers of future returns to their underlying factors. For example, in a macroeconomic-based approach, variables such as real GDP growth and year-on-year inflation may be used to predict the yield curve.

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