Index Insights

Sustainable Investment | Product Engineering

FTSE Russell

How to build a climate-adjusted government bond index

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AUTHORS

Douglas Bourne
Analyst
+44 0 207 797 3946
dbourne@lseg.com

Lee Clements
Head of Sustainable Investment Solutions
+44 0 207 797 3812
lclements@ftserussell.com

Guillaume Emin
Senior Sustainable Investment Manager
+33 0 1 87 44 88 92
gemin@lseg.com

Thomas Lorans
Sustainable Investment Macro Analyst
+33 0 1 70 37 65 00
tlorans@lseg.com

Overview

- Climate change is a substantial challenge, which is expected to have a significant impact on global economies, both in terms of its physical effects and mitigating efforts.
- There exist multiple, distinct design and methodological challenges associated with incorporating climate risks into government bond indexes. We characterize these risks into three distinct types: **Physical, Transition** and **Resilience**.
- To date, investors have focused mostly on climate risk at the corporate or asset level (particularly listed equities). Consequently, government bond investors risk overlooking the impact of climate change on their portfolios.
- As climate risks accelerate, they are increasingly gaining attention from government bond investors, However, there remains a lack of climate-based investment products in fixed income, particularly in sovereigns.
- We introduce the Advanced Climate Index Series in this paper, which builds on the pioneering launch of the Climate WGBI in 2019; it has been designed for index-users with a focus on improving the climate performance of their government bonds investments.

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Executive summary

Why is climate change an issue for government bond investors?

- Climate change is a substantial challenge, which is expected to have a significant impact on global economies, both through its physical effects and mitigating efforts.
- Climate change impacts can be characterized into three distinct risk types: (1) **Physical** (idiosyncratic geographical exposure to the adverse impacts of climate change); (2) **Transition** (the level of future carbon emission reduction needed to meet the Paris conference target of less than 2 degrees of global warming and the recent trend of historical carbon emission); (3) **Resilience** (the degree to which an individual economy is prepared for climate change). The costs associated with these risks are becoming increasingly material, already exceeding hundreds of billions of dollars.
- Climate risks are accelerating and increasingly entering the investment horizon of government bond investors. 30% of the FTSE World Government Bond Index market value has maturities beyond 2030, where the risks of climate change become more acute.

Why does the government bond market lack climate products?

- To date, investors have focused mostly on climate risk at the corporate or asset level (particularly listed equities).
- Consequently, government bond investors risk overlooking the impact of climate change at the national level and the unique climate exposure of sovereign bonds.
- The lack of climate-based investment products in fixed income, particularly in sovereigns, has affected investors’ ability to address climate risk in their government bond portfolios.
- Our research shows evidence that the impact of climate change on government bond valuations are not fully priced in.
- There exists multiple, distinct design and methodological challenges associated with incorporating climate risks into government bond indexes. The clustering of major bond markets that exhibit similar environment performance and the desire for index-users not to diverge materially away from the market-value-weighted equivalent benchmark characteristics are some examples.

Introducing the FTSE Advanced Climate Index Series

- Building on the pioneering launch of the Climate WGBI in 2019, we introduce the Advanced Climate Index Series, which has been designed for index-users with an increased focus on improving the climate performance of their government bonds investments.
- The Advanced Climate Index Series uses a tilting methodology to finesse market value weights according to the physical risk, transition risk and resilience at the national level (i.e., their three-pillar climate, country scores).
- Each of these three pillars is considered equally, as they reflect various complementary dimensions of climate risks.

Section 1: Climate change and government bonds

Introduction to climate change and government bonds

Climate change poses a significant dilemma for investors, where short and long-term risks and benefits may not always be aligned. It is particularly tempting to trade off some aspects of long-term climate resilience for immediate economic gains. Most economic indicators are of high frequency, but have a low to moderate impact, therefore medium-term trends, risks and opportunities, such as climate change, are not well priced into markets, despite the magnitude of potential risks for investors.

The economic transitions and non-linear risks associated with climate change call for a massive reallocation of capital. If climate resilience is to be adequately developed, private and public investors have an important role to play.

While potential climate scenarios remain uncertain and climate risk analysis for sovereign bond markets is still in its infancy, we believe it is a material topic for this asset class, given its exposure to global macroeconomic risks and events.

The purpose of this report is to outline ways in which government bond investors can take into account climate risks in their investment approaches. The paper presents and articulates in detail the climate methodology, which underpins the FTSE Advanced Climate World Government Bond Index (Advanced Climate WGBI), emphasizing the rationale behind each climate pillar, and also qualifying the chosen calibration.

In a recent report, the Bank of International Settlements and the Banque de France highlighted that: “Climate change could […] lead to “green swan” events […] and be the cause of the next systemic financial crisis.” In the United Kingdom, the Bank of England recently initiated a process for a Biennial Exploratory Scenario (BES) exercise on climate risk[1], while ACPR (Banque de France) presented in July the scenarios and main assumptions of its pilot climate exercise[2]. It can also be noted that, in 2018, the central bank of the Netherlands had already conducted a stress test to investigate “the potential financial stability impact of a disruptive energy transition for the financial sector of the Netherlands.” This illustrates well the increasing integration of climate risks into financial assessments, as climate challenges represent growing risks, and are calling for strengthened action. We hope this paper and the solutions we present here can bring useful thoughts and contributions to this historic challenge.

How could climate change impact government bonds?

The impact of climate change on sovereign risk

First and foremost, what are climate risks and how do they affect sovereign investors? As outlined in our previous research paper in this series (“How could climate change impact sovereign risk?”[3]), climate risks can be defined across two main pillars: (1) transition risks − the risk of economic dislocation and financial losses associated with the process of transitioning toward a low-carbon economy; (2) and physical risks − the potential economic and financial losses caused by climate-related hazards. To consider the overall sovereign climate risk, these must be offset by resilience – the preparedness and adaptive capacity of countries, as well as their level of political commitment, to manage the risks and challenges posed by the transition and physical risks. It is considered that transition risks and physical risks can be mitigated or

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[1] Bank of England, Bank of England consults on its proposals for stress testing the financial stability implications of climate change, December 2019.

[2] ACPR, Scenarios and main assumptions of the ACPR pilot climate exercise, July 2020.

[3] FTSE Russell Research, How could climate change impact sovereign risk? November 2019.

exacerbated depending on countries’ engagement and their position on various climate change issues.

In this context, climate risk can be considered a function of:

Transition risks **Physical risks** **Resilience**

The next section details each of these pillars and their effect on sovereign finances.

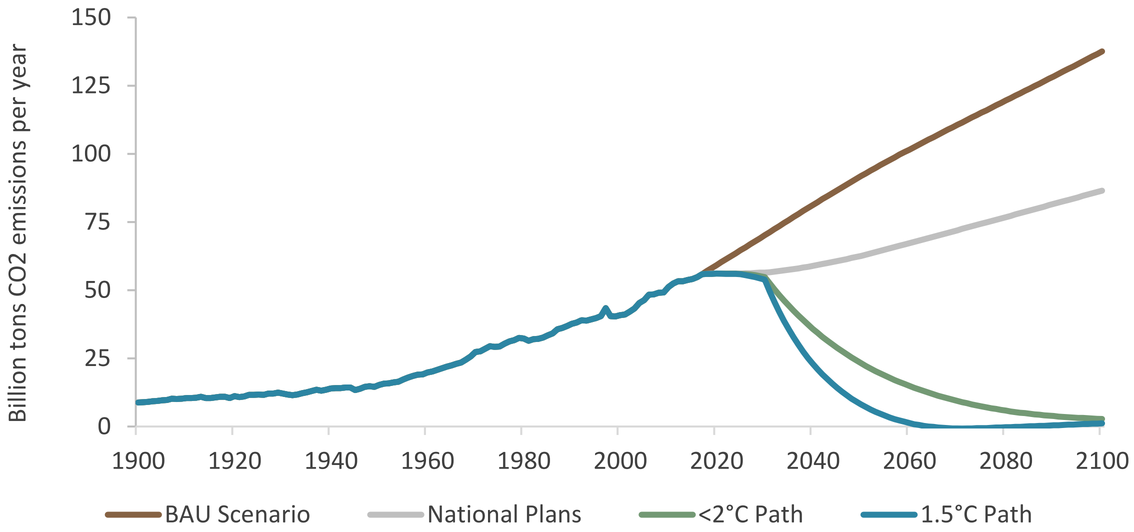
Transition risk

Transition risks are the risk of economic dislocation and financial losses associated with the process of transitioning toward a low-carbon economy. While the climate transition represents a significant opportunity, required efforts to reduce carbon emissions are particularly high for some countries, which may represent a higher risk if the transition at stake is not, or poorly, implemented. In addition, carbon trends vary across countries, with carbon intensities decreasing faster in some countries than in others. In this regard, below-average trends can also reflect higher risks.

a. Overview

Sovereigns are uniquely exposed to transition risks. The limitation of climate change implies massive global action, and countries are not all in the same position in this context. Whether it is because they structurally emit more greenhouse gases (GHG), have more exposure to fossil fuels production and consumption, have limited flexibility to develop low-carbon energy sources, or are under more pressure to reduce their GHG emissions, some countries are more exposed to transition risks than others. For example, some countries have to undertake significant efforts to become aligned in the future with a realistic sharing of a global carbon budget that would keep the world within a 2°C level of warming. This can also be illustrated by historical trends and the fact that some countries have reduced their emissions at a much slower pace than others in the past decades or in recent years, suggesting a less positive transition positioning.

Figure 1: The current climate trajectory suggests an undershoot of a 2°C target



BAU: Business as Usual. The BAU scenario described on this graph is based on the C-ROADS climate simulator that was built by Climate Interactive, Ventana Systems, and the MIT Sloan School of Management. This scenario combines the UN's medium fertility population projections, historical GDP per capita rates (converging over time), and GHG per capita projections for each gas (consistent with the last decade's trends for CO2, and following the IPCC's RCP 8.5 scenario for non-CO2 greenhouse gases)[4].

Sources: FTSE Russell & Beyond Ratings, Climate Interactive.

No country can really be immune to climate change, particularly in our interconnected world. In the future, it is also possible to expect further integration of climate issues in international negotiations and foreign policies, as well as into domestic litigation risks. Nonetheless, while some countries present higher risks, other countries may benefit from relative advantages and strengths, whether in terms of greenhouse gas emissions levels, structure of the energy mix or political commitments. As the awareness of climate risks increases, the positive transition positioning of countries may also hopefully significantly develop.

Lastly, *transition risks* are very significant given the key role of energy in the economy. As research has shown, there is a strong correlation between energy use and GDP worldwide[5]. In addition, some economists have shed some light on the causal relationship between energy and GDP by highlighting the critical role of energy in economic development[6]. However, 80% of global energy today depends on fossil fuels. This percentage has only seen a limited reduction over the long term, and only in relative terms[7]. Therefore, energy remains a huge climate-related challenge accounting for 75% of global greenhouse gas emissions[8]. As such, climate *transition risks* are interconnected with the need for an energy transition.

b. Examples of transition risks for sovereigns

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[4] Climate Interactive, Scoreboard Science and Data, Consulted on September 4, 2020.

[5] PRI, Beyond Ratings, The impact of energy and climate on sovereign risk, 2015.

[6] Gaël Giraud, Zeynep Kahraman, How Dependent is Growth from Primary Energy ? Output Energy Elasticity in 50 Countries (1970-2011), April 2014.

[7] IEA, Key World Energy Statistics 2020, August 2020.

[8] Gütschow, J.; Jeffery, L.; Gieseke, R., Günther, A. (2019): The PRIMAP-hist national historical emissions time series (1850-2017). v2.1. GFZ Data Services. https://doi.org/10.5880/pik.2019.018.

To illustrate climate change transition risks on sovereigns, we can draw on examples, some of which are described below. They point to the fact that climate risks are not only expected to be material for investors in the long term, but they already matter in current investment decisions.

Policy and litigation risks

While countries with ambitious climate commitments can become more resilient with regards to energy and climate risks, countries with limited commitments tend to be more exposed. For example, the President of the European Commission, Ursula von der Leyen, had announced in her 2019 agenda for Europe that she would introduce a Carbon Border Tax[9]. A similar policy has also been proposed in the US by more than 3,500 economists in 2019[10]. It can also be noted that, at the end of 2019, the Dutch Supreme Court upheld a ruling requiring the government to take bigger action to cut greenhouse gas emissions[11]. A few months later, a UK court of appeal considered illegal the plans for a third runway at Heathrow airport due to climate reasons[12].

Energy transition implementation challenges

Implementing the climate transition can also be challenging, even when there are national commitments. Between 1990 and 2019, energy-related CO2 emissions have increased or remained flat every year, except in 2009 (due to the economic crisis) and 2015[13]. In Germany, in June 2019, the government-appointed expert commission monitoring the energy transition noted that the country was still lagging behind important targets[14]. In France, various attempts to set or increase carbon taxes have faced socio-political opposition. At the same time, the energy transition can reduce exposure to climate risks, but also to energy risks, seen for example during oil price fluctuations (for exporters and importers) and growing resource constraints (peak oil risks[15]).

Impact on government revenues and expenditures

Transitioning to a low carbon economy also involves potential impacts on public revenues and expenditures. For example, the European Union plus Norway generated more than €400 billion of net, government fiscal revenue from the energy sector in 2015, predominantly from fossil fuels[16], which could be negatively impacted by the climate transition. Jobs linked to the energy sector may also be affected, which will impact both tax income and welfare costs[17].

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[9] Ursula von der Leyen, A Union that strives for more - My agenda for Europe, 2019.

[10] Including 27 Nobel laureates, 4 former Chairs of the Federal Reserve, and 2 former Treasury Secretaries. In: Beyond Ratings, The material scenario of potential carbon border taxes, July 2019.

[11] The Guardian, Dutch supreme court upholds landmark ruling demanding climate action, December 2019.

[12] The Guardian, Heathrow third runway ruled illegal over climate change, February 2020.

[13] IEA, Energy related CO2 emissions, 1990-2019, February 2020.

[14] Clean Energy Wire, Government advisors give low marks for German energy transition progress, June 2019.

[15] IEA, Oil production with no new investment from 2018 and demand by scenario, 2010-2040, December 2019.

[16] IOGP, Update on Energy Taxation and Subsidies in Europe, May 2018.

[17] U.S. Energy and Employment Report (USEER).

Physical risk

Physical risks are the potential economic and financial losses caused by climate-related hazards. Recent events suggest physical risks are already intensifying, with multiple potential impacts from extreme events (e.g. wild fires, floods, etc.) and more progressive, but potentially damaging shifts (e.g. increased population and territorial exposure to dangerous combinations of hot and humid weather, increased poverty due to lower agricultural yields, etc.). In this context, physical risk assessments aim to consider country exposures to the various potential physical impacts of climate change, based on both their potential (direct and indirect) social and economic consequences.

a. Overview

The *physical risks* posed by climate change are well documented and significant. We list a few examples here:

- **Disaster-related damages:** In 2016, the World Bank estimated the annual cost of disaster-related damages for the global economy already represented USD 520 billion annually[18].
- **Health:** The World Bank highlighted that climate change is one of the elements that could contribute to fast-spreading, catastrophic pandemics or other health issues[19]. Or, according to the WHO, climate change could be the cause of 250,000 additional deaths per year between 2030 and 2050, based on specific risks only (heat, coastal flooding, diarrheal diseases, malaria, dengue and undernutrition), without taking into account major other dimensions such as economic damages, river flooding and human security risks[20].
- **Migration flows:** A 2015 UN study highlighted that there could be millions of environmental migrants globally by 2050, with 200 million as the most broadly cited estimate[21].
- **Conflicts:** It can also be noted that climate change is increasingly recognized as a “threat multiplier” that can increase conflict risks[22].

Such risks entail significant economic and socio-political consequences, with unavoidable implications for sovereign risks. As reflected in key damage functions, this is all the more important given the risks of tipping points at stake. As illustrated below, except in the Nordhaus function, notable non-linear effects should be expected from climate change[23]. Indeed, physical changes are bound to be profound if countries follow business-as-usual trends, according to which they would undershoot international climate targets. One of the scenarios is a global warming of +5°C, which is of a similar magnitude to the global temperature difference since the last ice age[24].

This situation means that preparation must be anticipated well in advance of material impacts in order to achieve effective mitigation. In addition, the non-linear dimension illustrates why, by definition, information on future climate risks cannot be fully reflected by current and historical data, or backward-looking extrapolation methods.

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[18] The World Bank, Breaking the Link Between Extreme Weather and Extreme Poverty, November 2016.

[19] The World Bank, Pandemic preparedness and Covid-19 (coronavirus), Consulted on September 4, 2020.

[20] WHO, Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s, 2014.

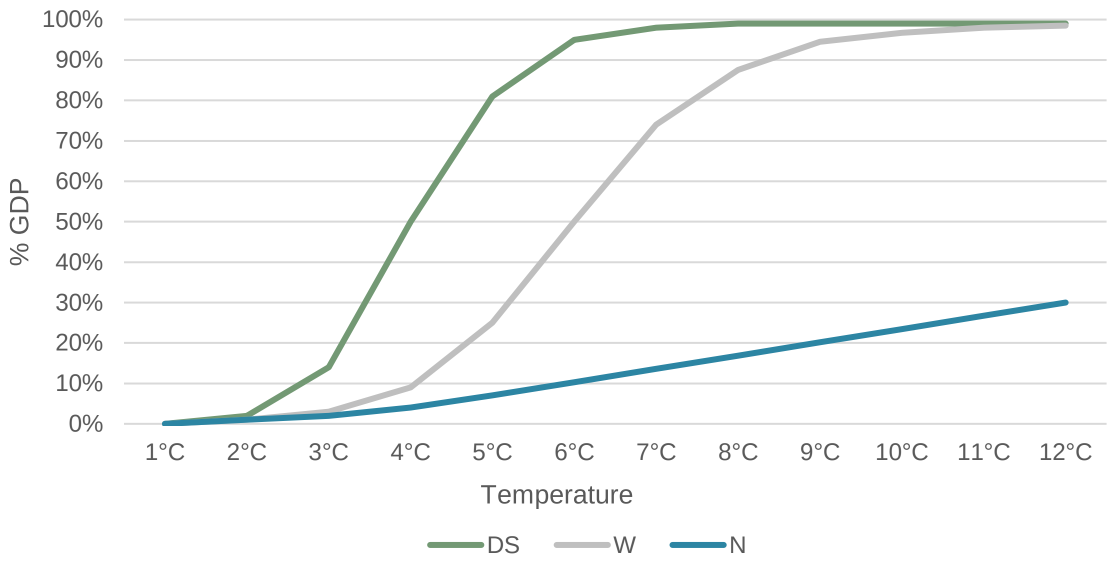
[21] United Nations University, Climate Migrants Might Reach One Billion by 2050, 2017.

[22] UN News, Climate change recognized as ‘threat multiplier’, UN Security Council debates its impact on peace, January 2019.

[23] Regarding the Nordhaus function, it should however be noted that it does not consider disruptive threshold effects even based on very high and theoretical levels of global warming.

[24] Live Science, How Would Just 2 Degrees of Warming Change the Planet? 2017.

Figure 2: Climate Change Damage Functions



Note: DS: Dietz and Stern; W: Weitzmann; N: Nordhaus.

Sources: FTSE Russell & Beyond Ratings, Covington and Thamotheram (2015)[25]

b. Examples of physical risks for sovereigns

There are unavoidable uncertainties on how physical risks will precisely materialize in terms of time horizon, location, magnitude or frequency. However, the expected impact and increase of these risks in business-as-usual scenarios are clear. The following examples can be mentioned regarding potential implications.

Temperature change

Exposure to physical risks can first be reflected by the significant rise in global temperature, with a warming of +1°C already observed since the pre-industrial era. Many progressive evolutions suggest climate change is already triggering material physical impacts, as with the notable reduction of the Arctic Sea Ice Minimum[26].

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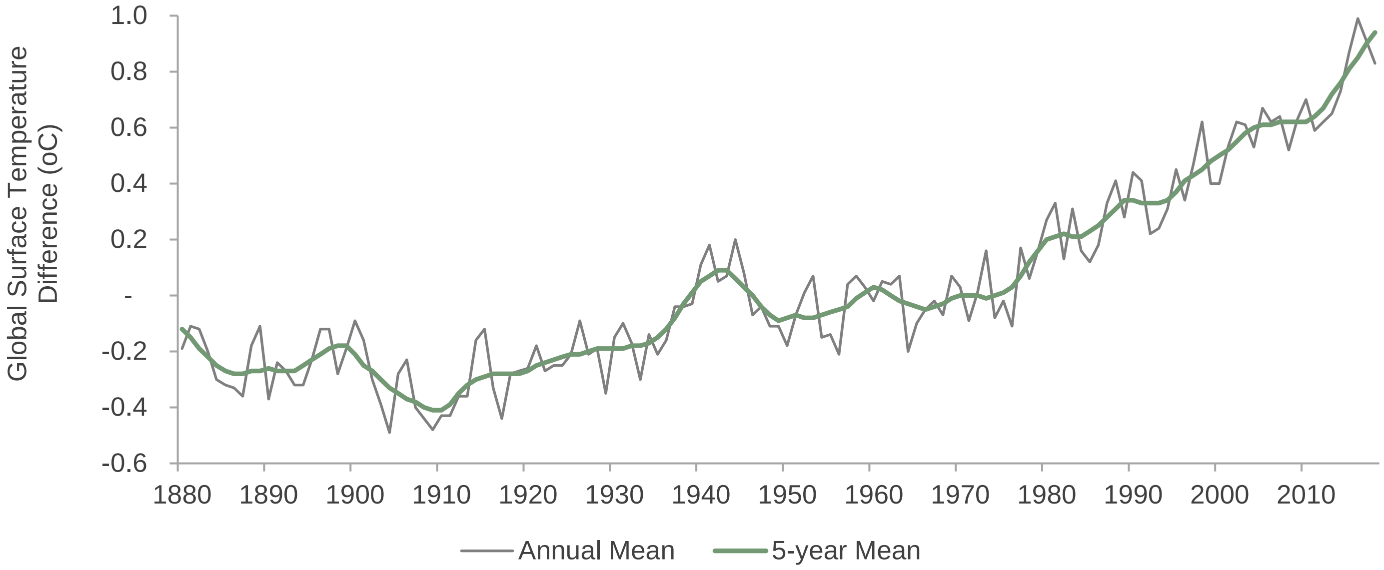
[25] Covington. H and Thamotheram. R (2015), "The Case for Forceful Stewardship (Part 1): The Financial Risk from Global Warming", Available at SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2551478.

[26] NASA, Arctic Sea Ice Minimum, Consulted on September 4, 2020.

Figure 3: Global Surface Temperature Evolution



Sources: FTSE Russell & Beyond Ratings, NASA.

Climate-related natural disasters

It is not possible to strongly attribute individual natural disasters to climate change. However, the increase in the frequency and magnitude of extreme events such as wildfires, or floods, is also consistent with the anticipated impacts of climate change. For example, highly destructive wildfires have been observed in recent years in several areas worldwide (Brazil, Australia and the US). This even resulted in some direct and concrete financial losses for the shareholders of the bankrupt utility company, PG&E, in California that agreed to pay USD 11 billion due to its track record of sparking wildfires[27]. As such, natural disaster risks can turn into significant financial or economic issues risks.

Impact on government revenues and expenditures

Climate risks can directly and indirectly translate into substantial government expenditures, as a result of rising costs due to extreme weather damage and infrastructure adaptation investments, particularly in scenarios of higher global warming levels. Governments have a notable role to play to adapt and protect national infrastructure, reduce socio-economic vulnerability, or ensure sufficient emergency expenditure capacities.

Resilience

Resilience is the ability of social-ecological systems to prepare for, absorb and recover from climatic shocks and stresses and positively adapt and transform their structures in the face of long-term change and uncertainty. It can be seen as the degree to which a country is prepared to meet the challenges of climate change and is actively addressing the risks highlighted in the previous two sections.

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[27] The Guardian, Bankrupt California utility blamed for deadly wildfires agrees to $11bn payout, September 2019.

a. Overview

Resilience is the most complex element of assessing climate risk. There are many ways in which a country can be resilient, and it is often difficult to disaggregate the resilience from the underlying risk. The resilience can be broadly about the level of development of a country − a wealthy country, with strong institutions and a healthy, diverse economy, will be more resilient to the broader climate transition challenges. Therefore, some indicators, which tend to represent more traditional measures of social and governance, are also very important here. In addition, there are more specific elements of resilience, where countries are directly dealing with climate changes (e.g., investing to change their energy industry or adapt their infrastructure and maintaining ecological elements such as forests, which can act as an important carbon sink).

In this context, resilience can be seen to align with the main dimensions of the socio-ecological system (SES):

Institutional

- Effective governance and institutions.
- Participation on various levels.
- Process of building climate resilience, harmonization of perceptions and objectives.

Social

- Characteristics such as health, education and food security.
- Prevalence of social networks as well as similar system-wide aspects, due to their importance in dealing with climate shocks and stresses.

Economic

- Economic activities within a SES.
- Availability and distribution of financial assets (savings to repair productive goods damaged by a climatic hazard, funds to finance adjustments in planting behavior).

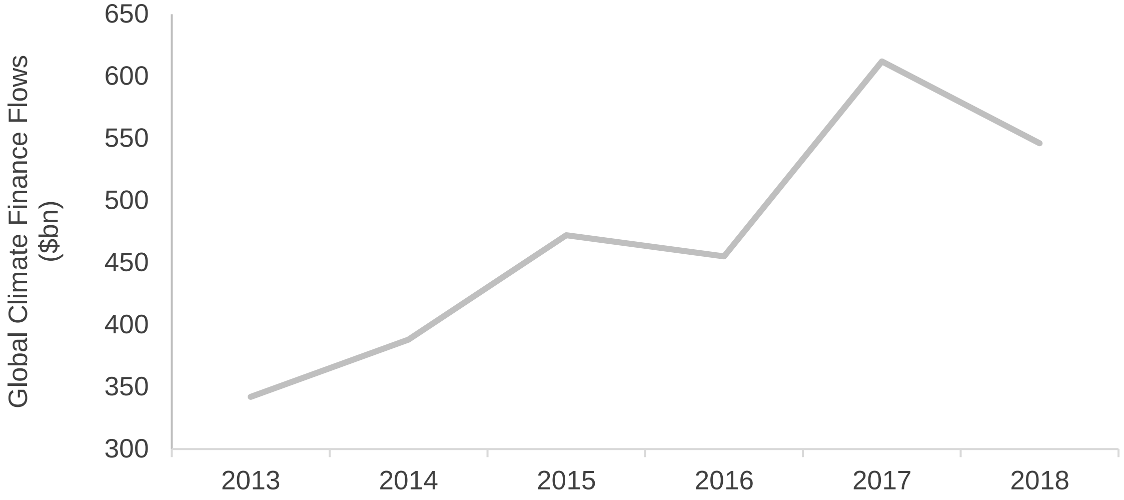
Ecological

- Diversity and state of the natural environment.
- Ecosystem’s own ability to adapt to a changing climate (e.g. biodiversity, deforestation rate).
- Functioning of critical ecosystem services (e.g. drinking water, fresh air).

Note: Adapted from GIZ and UNU-EHS (2014).

Many countries are actively investing to boost resilience, mitigating climate change, adapting their infrastructure and transforming their energy systems and economies. Approximately half of this investment is currently coming from state-based institutions, and countries are actively encouraging industry and the financial sector to invest. However, an acceleration of investment is needed to meet the 2-degree goal and not all countries are equally active.

Figure 4: Global Climate Finance Flows



Sources: FTSE Russell & Beyond Ratings, Climate Policy Initiative.

b. Examples of types of resilience for sovereigns

Resilience covers a relatively broad range of issues. Without trying to be exhaustive, the following examples highlight areas of significant impact on sovereign climate analyses. The full range of resilience indicators used in the FTSE Russell sovereign climate risks analysis can also be found in the appendix.

Institutional resilience

Institutional performance is an important part of climate resilience. For example, the combination of countries' climate policy commitments, disaster preparedness and government effectiveness can influence their ability to both manage and adapt to risks. Climate resilience calls for strong capacities in disaster response planning, risk monitoring, improvement of the national energy efficiency, or transformation of the energy mix. The March 2011 Fukushima Daiichi nuclear accident illustrated the ability of a country, like Japan, to leverage energy efficiency during an energy supply shock[28]. At the same time, however, the high structural dependence on fossil fuels illustrates the challenges at stake globally and in most countries.

Social resilience

Low levels of social resilience can increase vulnerability to climate risks, for example when social weaknesses and inequalities weigh on capacities to implement transition measures. In France, rising fuel prices and the planned increase in carbon taxation represented one of the causes of the "yellow vests" protest movement that began in October 2018. In 2019, significant protests led Ecuador to repeal a law that aimed to end fuel subsidies. Such cases illustrate the need for social considerations in implementing the energy transition, and they emphasize at the same time the social vulnerabilities that call for such transition.

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[28] IEA, Energy Policies of IEA Countries: Japan 2016 Review, September 2016.

Economic resilience

Countries with an above-average culture of research & development, or corporate monitoring of their environmental impacts, could be better positioned to proactively manage future changes. For example, certain countries have been effective in leading development in various energy transition technologies, such as Japan in hybrid electric and fuel cell vehicles, or Denmark in wind power generation, creating economic opportunities.

Ecological resilience

Ecological resilience highlights the broad scope of the environmental aspects that can impact countries' capacities to prepare for, absorb and recover from climate shocks. For example, climate change can increase water stress, which can result in notable socio-economic risks in the case of significant water withdrawals compared with available resources. For example, climate change is often considered to be one of the factors, (in addition to overuse) that led Lake Chad to shrink to 10% of its size since the 1960s, contributing to social tensions in the region[29]. The evolution of forest areas can also help to assess resilience, as increasing the forest cover can allow to capture carbon from the atmosphere and, thus, support adaptation.

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[29] Africa Renewal, Drying Lake Chad Basin gives rise to crisis, December 2019.

Section 2: Are sovereign climate risks “priced in” today?

Do investors pay enough attention to climate risks?

Given the climate-related risks already mentioned, international financial institutions and central banks have become concerned that the financial system may be underprepared to cope with these risks.

As an illustration, in the fifth chapter of its last Global Financial Stability Report (April 2020)[30], the International Monetary Fund (IMF) alerts to climate change risks undervaluation by financial markets. According to the IMF, investors should pay more attention to these risks as *“a sudden shift in investors’ perception of this future risk could lead to a drop in asset values, generating a ripple effect on investor portfolios”.*

Physical and transition risks pricing seem to be both a major concern. Regarding climate physical risk, the IMF conducted a study to examine the physical risk on assets value from climate change and finds that investors might not be pricing these risks adequately, with physical risk from climate change not appearing to be reflected in global equity valuations. The international institution explains the potential mispricing of physical climate risk by investors as follows: *“Standard asset pricing theory suggests that investors should demand a premium for holding assets exposed to a future increase in physical risk induced by climate change […]. However, because the nature of the risk is long term, and depends on complex interactions between climate variables and socioeconomic developments that are difficult to model, markets may not price future physical risk correctly”.*

Regarding transition risk, The Network for Greening the Financial System (NGFS, 2019), a group of central banks and financial supervisors, has expressed concern that financial risks related to abrupt transition toward a low-carbon economy are not fully reflected in asset valuations, and has called for integrating this risk into financial stability monitoring[31]. An explanation of the potential mispricing of transition risk by investors could be government delays in introducing or strengthening policies toward a low-carbon economy, which means that investors cannot fully anticipate policy developments and price them in (Battiston and Monasterolo, 2019[32]).

What about investors in sovereign bonds?

Most existing studies have been conducted on equity markets, seen by the IMF as a *“key segment of the global financial system, [providing] a data-rich environment, and sensitive to long-term risks, making them fertile ground for investigating how projected future physical risk affects financial markets and institutions”.*

Fewer studies have been conducted on sovereign bonds. Furthermore, the literature on sovereign bonds has focused on broad environmental risks rather than specifically on climate change. For example, a 2018 empirical analysis of OECD countries found a positive relationship between good ESG performance and lower default risk, as well as sovereign bond yields spreads, based on 20 OECD countries between 1996-2012. However, this paper also highlighted that: *“the social and governance dimensions have a significant negative association with sovereign bond yield spreads, whereas the environmental dimension does not”*[33].

Based on the findings of this study, the pricing-in of environmental risks in sovereign investing would appear to remain limited. This can be partly illustrated by a number of tests that Beyond Ratings has conducted on its Sovereign Risk Monitor ESG scores. Our assessments have shown, for example, that countries with the highest ESG scores, by ESG quintile, had the lowest

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[30] IMF, Global Financial Stability Report: Markets in the Time of COVID-19, Chapter 5, April 2020.

[31] Network for Greening the Financial System (NGFS), A call for action - Climate change as a source of financial risk, April 2019.

[32] Stefano Battiston, Irene Monasterolo, A climate risk assessment of sovereign bonds’ portfolio, 2019.

[33] Gunther Capelle-Blancard, Patricia Crifo, Marc-Arthur Diaye, Rim Oueghlissi, Bert Scholtens.

average CDS spreads on the 2009-2018 period, while those with the lowest ESG scores, had the highest average CDS spreads. However, this relationship between scores and CDS spreads varies across ESG pillars and is more limited when considering the E score only[34].

As shown in the figure below, we have analyzed the average CDS spreads by ESG quintile for each pillar: Environment (E), Social (S) and Governance (G). On all individual dimensions, countries with the highest scores (quintiles five) have the lowest average CDS spreads, and an almost linear relationship can be observed between governance scores and CDS spread quintiles. However, the relationship of the environmental dimension with CDS spreads is the least significant. A potential explanation is that environmental issues are not yet fully priced in and reflected in sovereign risk ratings and CDS levels, in part due to quantification or time-horizon challenges.

Figure 5: Average sovereign CDS spreads by individual environmental, social and governance quintiles 2009-2018

Sources: Hermes and Beyond Ratings. Data as of April 2019.

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[34] Hermes Investment Management and Beyond Ratings, Pricing ESG Risk in Sovereign Credit, Q3 2019.

Climate change and sovereign bonds pricing

Although our previously mentioned analysis focused on environmental performance overall, these issues also apply to climate change risks more specifically.

In order to test the existence, or not, of a risk premium related to climate risks in sovereign CDS spreads, we applied an econometric approach[35]. We specified an econometric regression (simple OLS panel) using credit ratings as a control variable and conducted an analysis on 45 countries[36] (the list of countries is available in the appendix). We used numerically transformed credit ratings from Standard & Poor's in our model (see conversion rule and econometric specification in the appendix). Credit ratings were used as a proxy for the probability of default, while climate risks scores (Transition and Physical Risks indexes from the Climate WGBI[37] index methodology) were used as a measurement for climate risks.

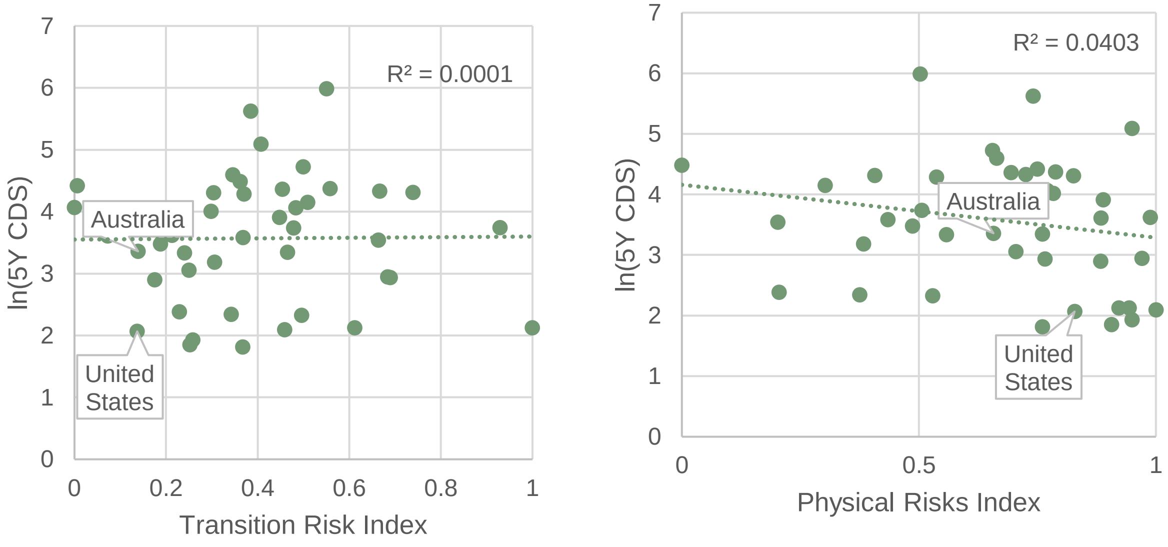
The relationship between credit ratings and sovereign CDS spreads is strong and statistically significant (results are available in the appendix, with R-squared and p-values), in line with the literature. However, as regards climate risks, both Transition and Physical Risks indexes are uncorrelated with sovereign CDS spreads.

As a result, this assessment rules out the existence of a climate risk premium in the case of historical sovereign CDS spreads.

To provide more details on this lack of relationship between sovereign CDS spreads and climate risks, we show below the correlation between sovereign CDS spreads and Climate WGBI Transition and Physical Risks indexes scores. As highlighted by these graphs, the relationship is close to zero (R-squared at 0.00 for the Transition Risk index and at 0.04 for the Physical Risks index).

Figure 6: Relationship between sovereign CDS spreads and CWGBI Transition and Physical Risks Indexes, 45 countries, Q1 2020

Figure 6: Relationship between sovereign CDS spreads and CWGBI Transition and Physical Risks Indexes, 45 countries, Q1 2020



Source: Beyond Ratings.

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[35] Hermes Investment Management and Beyond Ratings, Pricing ESG Risk in Sovereign Credit, Q3 2019.

[36] Based on an assessment cohort of 50 countries and the countries for which 5-year CDS spread data were available

[37] Climate World Government Bond Index.

To illustrate these findings, the specific cases of Australia and the United States are interesting: both countries benefit from a low CDS spread, although they perform poorly in terms of transition risk, based on the Transition Risk Index. In addition, Australia appears to have more exposure to physical risks than many other considered countries, which does not seem to be reflected in its relatively moderate level of CDS spread.

The risks associated with climate change pose a new challenge to the financial sphere. As we have seen, these risks do not seem to be fully taken into account by investors at the moment.

Due to the unprecedented nature of the current rapid rise in temperature in the history of humanity (physical risks), the structural shifts required in our economies toward a decarbonated economy (transition risks), and the limits of historical data to assess these changes, evolutions in traditional approaches seem to be needed to better integrate climate issues into financial risk assessments.

Section 3: Quantifying Sovereign Climate Risk

The challenges of measurement

As we have described, the lack of pricing-in of climate risks in sovereign investing today can be at least partly explained by the challenges of measurement. Even if there are more efforts to measure these risks, we must keep in mind that such appraisals call for innovative approaches at various levels.

The challenges at stake relate in part to the time horizon of climate change. In a famous 2015 speech on "Breaking the Tragedy of the Horizon – climate change and financial stability", Mark Carney highlighted that "the catastrophic impacts of climate change will be felt beyond the traditional horizons of most actors"[38]. As climate risks can be beyond the business cycle, the political cycle, and even the horizon of technocratic authorities like central banks (bound by their mandates), the measurement and discounting of climate risks remain challenging.

Another reason for this pricing and measurement challenge is the specific nature of climate risks. By the high magnitude of their business-as-usual expected impacts, climate risks are profoundly non-linear. In addition, the causal relationships of climate risks involve other elements and dynamics than those that can be analyzed based on back-testing. Financial risk measurements usually heavily rely on historical data, but historical data currently cannot reflect the impacts of climate change, which represents an intrinsically new risk. Again, this dimension also leads to measurement uncertainty.

In this context, climate change should be regarded as a specific type of non-linear risk posing systemic macro risks. Tipping points can be reached in the absence of ambitious action, which could lead to "catastrophic and irreversible impacts that would make quantifying financial damages impossible."[39] **Nonetheless, the uncertainties and the new nature of the dynamics at stake mean that these risks cannot be merely assessed based on back-testing. As the BIS puts it: "the problem is that extrapolating historical trends can only lead to mispricing of climate-related risks, as these risks have barely started to materialize"[40]. The situation then requires a change of paradigm: "traditional backward-looking risk assessment models that merely extrapolate historical trends prevent the full appreciation of the future systemic risk posed by climate change. An "epistemological break" (Bachelard (1938)) is beginning to take place in the financial community, with the development of forward-looking approaches grounded in scenario-based analyses."[41]**

An innovative approach

As described above, measuring and pricing-in climate risks unavoidably carries uncertainties, although these risks also do matter given their expected magnitude. There is strong scientific evidence that climate risk must be taken very seriously, but unavoidable uncertainties remain as to how climate risks will materialize in time, space, and based on what precise causes and sequences. Uncertainties exist at the physical risk level (directly addressed by climate models), but they also characterize the socio-economic aspects of climate change. This is all the truer given that, for example, several political scenarios can exist with potentially different types of impacts (positive or negative) on financial assets risks over time.

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[38] Mark Carney, Bank of England, Breaking the Tragedy of the Horizon - climate change and financial stability, September 2015.

[39] BIS, Banque de France, Patrick Bolton, Morgan Després, Luiz Awazu Pereira da Silva, Frédéric Samama, Romain Svartzman, The green swan - Central banking and financial stability in the age of climate change, January 2020.

[40] BIS, Banque de France, Patrick Bolton, Morgan Després, Luiz Awazu Pereira da Silva, Frédéric Samama, Romain Svartzman, The green swan - Central banking and financial stability in the age of climate change, January 2020.

[41] BIS, Banque de France, Patrick Bolton, Morgan Després, Luiz Awazu Pereira da Silva, Frédéric Samama, Romain Svartzman, The green swan - Central banking and financial stability in the age of climate change, January 2020.

These aspects clearly do not mean that no measurement or no analysis is possible. It is true that the uncertainty at stake illustrates well the fact that not everything can be measured, or that quantitative measurement is not sufficient in the present case. However, measurement can usefully support the development of new and innovative approaches. For example, it can be relevant to assess climate risks based on forward-looking scenarios to go beyond the back-testing of statistical relationships, but scenarios also require quantitative data beyond their qualitative dimensions.

As an illustration, several examples of scenarios can be considered here, for which our analytics can bring added value. Such scenarios are generally characterized by “What if?” questions. Under each scenario, it is appropriate to wonder what the main negative or positive impacts could be for sovereign risk, and what conclusions can be derived from assessing various potential pathways. For example, to illustrate this point:

- What if we follow a business-as-usual scenario leading to the strong intensification of global warming impacts?
- What if the energy transition is implemented at massive scale?
- What if carbon border tax adjustments are implemented in some regions?
- What if the current reduction in economic growth dynamics takes root under energy and climate constraints?

Such scenarios partly depend on political and socio-economic dynamics that are themselves characterized by uncertainties. However, the divergence in the pathways to which they correspond can significantly affect sovereign risks.

In the Advanced Climate WGBI and EGBI Series, several potential future pathways are thus indirectly considered through the quantitative indicators that are assessed. For example, we measure distance to target metrics to assess the level of future effort in reducing GHG emissions required from countries. For these metrics, we quantitatively assess realistic potential carbon budgets by country that would be consistent with a 2°C alignment pathway at a global level, based on a statistical approach and available world budgets. This applies forward-looking assessments of transition risks. Even such indicators unavoidably leverage historical data, but they are not developed and calibrated on back-tested historical data, but rather on the future possibilities that appear the most realistic, based on available information and climate risk dynamics. For example, Beyond Ratings’ distance to target KPIs aim to model, by country, the most realistic expected future carbon budgets aligned with a 2°C target, based on a quantitative and statistical approach. Similarly, our selection of physical risk indicators aims to reflect key dimensions of such risks to assess exposure to future impacts.

As a result, assessing climate risk clearly calls for innovative approaches, for reasons that are partly related to the measurement challenges. However, solutions also exist and continue to be developed to meet these challenges, as those presented in our Advanced Climate WGBI and EGBI framework for sovereign assets.

The key objectives of the methodology

In the context that we have described, the methodology of the Advanced Climate Government Bond Index Series can bring several notable solutions to investors. The methodology we have developed provides an appropriate solution to the measurement challenges discussed above, allowing investors to measure and incorporate climate risks in their portfolio construction and investment processes. It follows that this integration of climate risk also allows investors to reduce their climate risk as well as achieve positive climate impacts.

Section 4: FTSE climate risk methodology

Three pillars of climate risk

The FTSE climate risk methodology is built on three pillars, as described below, that provide a quantitative assessment of the key dimensions of climate risks. Our analytical framework defines two main categories of risks being *transition risk* and *physical risk*. Resilience dimensions are considered in addition to these two elements.

- Transition risk represents the level of climate related risk exposure of the country's economy as measured by the distance to reach the modelled emissions needed to meet a 2-degree alignment.
- Physical risk represents the level of climate related risk exposure to the country and its economy from the physical effects of climate change.
- Resilience represents a country's preparedness and actions to cope with its level of climate related risk exposure.

The following sections outline the measurement of climate risk. Further details can be found in the FTSE Advanced Climate Risk Adjusted Government Bond Index Methodology and the FTSE Fixed Income Index Guide.

Transition risk

The implementation of the climate and energy transition involves notable challenges. These challenges may relate to transition costs, but they also reflect the risks for countries of not shifting to low-carbon economies. As a result, overall transition risks can be considered higher for countries from which higher reduction of their GHG emissions should be required, and whose trends are not well aligned with relevant transition goals applicable to them.

Key performance indicators

We assess transition risk using our CLAIM methodology (Climate Liabilities Assessment Integrated Methodology). This statistical methodology allows us to estimate the breakdown of any carbon budget related to any type of global warming temperature at a horizon of 2100. It allows assessing the 2°C carbon budget of any country or its carbon budget for any temperature. To do this, it proposes to determine the most likely GHG emissions allocation based on a stochastic process using 15 variables, almost entirely from the Kaya-derived economic and carbon equation. The CLAIM methodology is presented in more detail in the Appendix.

In this context, our assessment of transition risk is based on the two following indicators, which allows a forward-looking analysis beyond the use of historical data:

- Territorial distance to target (%):

Annual reduction rate (expressed as CAGR) of total territorial GHG emissions required to reach 2°C-compliant territorial GHG budgets in 2050. Budgets are estimated using the FTSE Climate Liabilities Assessment Integrated Methodology (CLAIM). 2050 is selected as the reference year, as it offers a relatively long-term time horizon, allowing some stability in the results.

This indicator assesses the scale of transition challenges for the country.

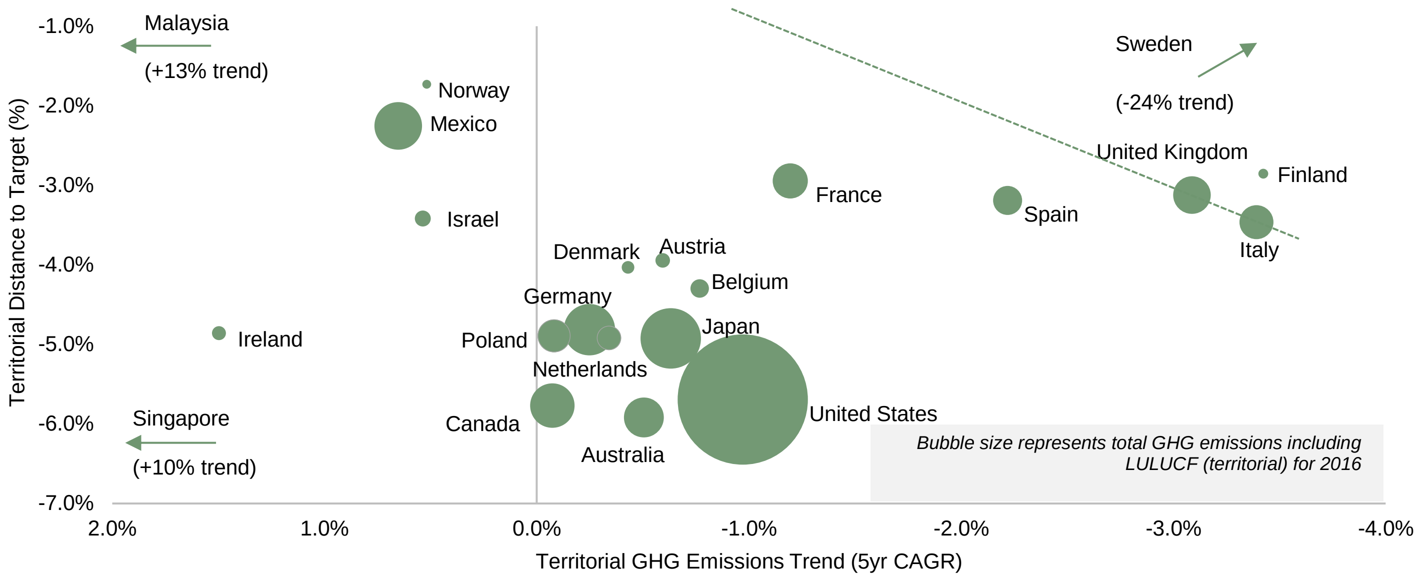
It is based on 15 national variables around GDP per capita, energy intensity of GDP and carbon intensity of energy production.

- GHG emissions gap between trend and distance to target (% gap):

Gap between the required annual reduction of total territorial GHG emissions to reach the 2°C-compliant territorial GHG budgets in 2050 (expressed as CAGRs) minus the five-year historical trend of these total territorial GHG emissions (expressed as CAGR).

This indicator measures how well countries are currently managing emissions.

Figure 7: 2019/2020 Transition Risk Assessment for WGBI countries



Source: Beyond Ratings, FTSE Russell. Data as of 2016.

Figure 8 shows the 2019/2020 Transition risk assessment for the WGBI countries (as of May 2020). On the y-axis, we plot each country's Territorial Distance to Target – the required annual reduction in GHG emissions to meet a 2-degree aligned 2050 scenario, and on the x-axis, we plot each country's 5-year trend in GHG emissions. The size of the bubbles represents the latest total GHG emissions, and the dotted line signifies "2-degree alignment". A country on the line would be reducing GHG emissions at the same rate as the annual rate needed to meet a 2-degree 2050 scenario. As can be seen, according to our assessment, few countries in the WGBI cohort are currently 2-degree aligned.

Physical risk

Assessing the physical dimension of climate risks at country-level unavoidably involves a range of uncertainties, given the lack of track-record on how climate physical risk can manifest. In addition, physical risk can involve progressive difficulties and non-linear shocks as well as tipping points, and its deployment will depend on the efforts provided or not to drastically reduce greenhouse gas emissions.

Key performance indicators

The three indicators retained to assess physical risk are described below. They are based on raw data and, in some cases, internal calculation to improve the relevance of results.

- Sea level exposure (%): Percentage of population living in areas where elevation is below five meters.

- Agricultural exposure (index/CV): Coefficient of variation of agricultural production (in kilocalories) weighted by the share of agriculture in GDP.
- Climate-related natural disaster exposure: 95th percentile of the distribution of the share of population killed by climate-related natural disasters in a given year.

Resilience

Resilience represents a country's preparedness and actions to cope with climate change. It usefully allows the adjustment of risk assessments, as some elements of country profiles can indeed help to mitigate risks and improve country capacity to absorb shocks and adapt to new patterns. The dimensions of our Resilience pillar thus cover the measurement of various capacities in terms of anticipation, absorption, adaptation and transformation, from a low to a high degree of implied structural changes. Our methodology applies those assessments at the level of four socio-ecological dimensions: Institutional, Social, Economic and Ecological.

Key performance indicators

23 indicators are computed in our Resilience assessment, categorized in four equally weighted sub-pillars. This approach aims to reflect both the diversity of capacities at stake and the different aspects involved at a socio-ecological, socio-political or socio-economic level. The full list of sub-pillars and indicators is as follows:

Figure 8: Resilience sub-pillars and indicators

Institutional	Social	Economic	Ecological
NDC Temperature	Fuel subsidies	CDP performance ratio	Freshwater withdrawals
Government effectiveness	GINI Index	Insurance penetration	Share of protected areas
Disaster preparedness	Human development index	R&D expenses	Share of biodiversity threatened
External debt % of GDP	Voice & accountability	Logistics performance	Biodiversity stock
	Use of sanitation services	Doing business	Afforestation rate
	Access to electricity	Green bonds performance ratio	
		Water productivity	
		Agricultural adaptive capacity	

Full details of each KPI including data sources, available history and time lag are provided in the Appendix.

Sovereign climate risk scores

To derive country climate risk scores, we need to perform a series of data transformation and aggregation steps:

First, we convert the raw indicator values, in their various forms, into z-scores that have been mapped to s-scores that range from 0 to 1, using a cumulative normal distribution function[42]. To do so, underlying indicator values are evaluated relative to an index assessment cohort. The countries assessed for the Climate WGBI universe are in line with the universe of local currency sovereign bond markets tracked by the standard version of these indexes. For the EGBI, the subset of EGBI eligible countries are used to compute Z-scores.

Second, we aggregate indicator scores to derive climate risk pillar scores. Each indicator, within each sub-pillar, within each climate pillar is equally weighted in this aggregation.

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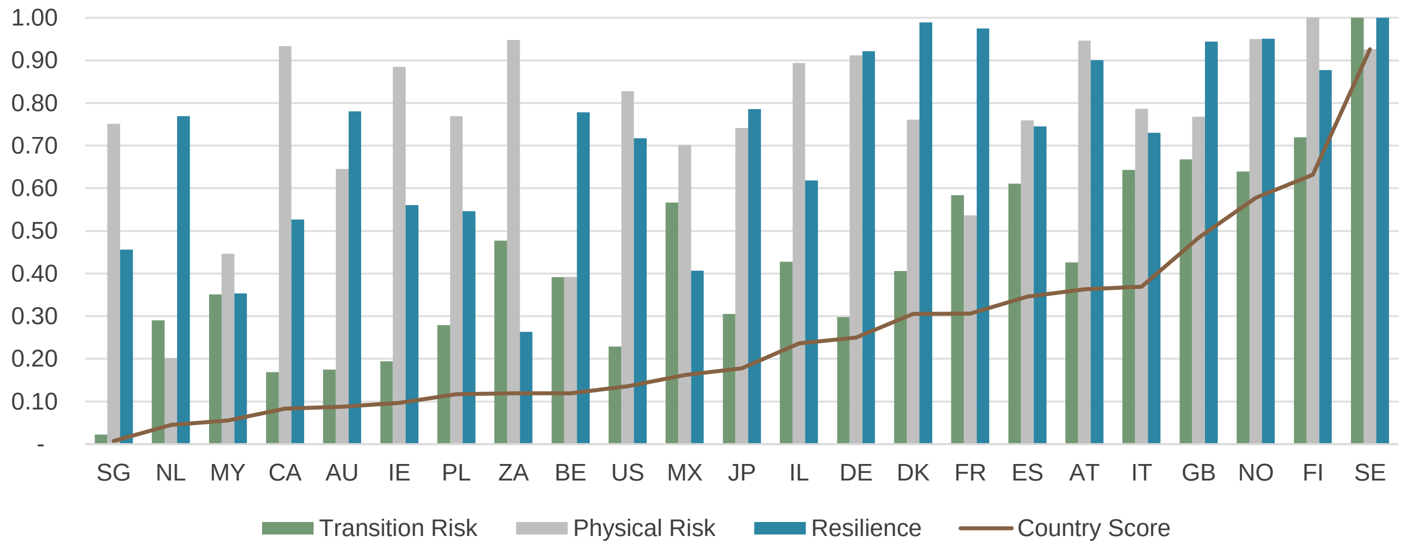
[42] Some sub-indicators, where there are significant outlier country scores, have been windsorised before normalization with values above the 95th percentile and below the 5th percentile set to the 95th percentile and the 5th percentile, respectively.

Finally, we combine climate risk pillar scores to derive country climate risk scores. This can be done in several ways, as we will discuss later in this paper.

To give a sense of the output of this assessment process, in (Figure 10), we show 2019/2020 climate pillar scores and country scores for the WGBI countries. These scores are computed across a cohort of 50 countries and three climate pillar scores are multiplied together to give overall climate country scores.

Figure 9: 2019/2020 Climate Pillar and Country Scores for WGBI countries



Source: Beyond Ratings, FTSE Russell. Data as of May 2020 Review

Section 5: Implementation into a climate risk-adjusted government bond index

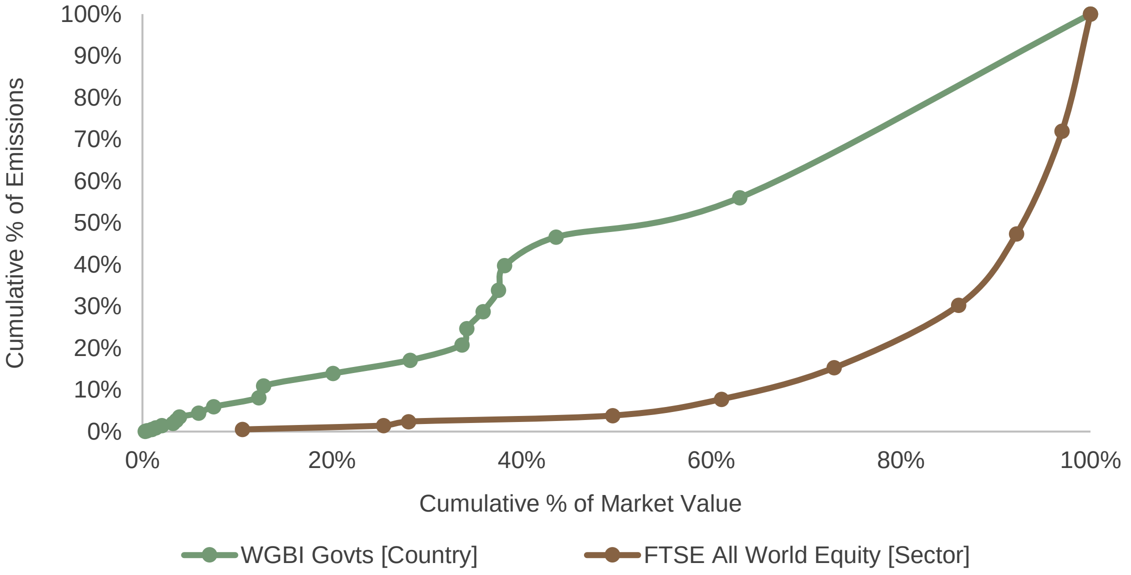
Introduction

The ability to incorporate climate risk considerations, reduce climate risk exposure and achieve meaningful benefits in environmental performance in a sovereign bond index is a very different proposition to that of an equity index. The profile of each index, and the relative environmental performance of its constituents, mean that an inclusion/exclusion approach drastically changes the index profile and characteristics.

From a territorial emissions perspective, the emissions concentration of a Government Bond Index is much more evenly distributed across constituents than a Global Equity Index, where certain sectors (oil & gas) contribute a large proportion of emissions for only a small amount of market value.

Given this, an inclusion/exclusion approach is not possible without compromising the overall investment objective (i.e. global government bond market exposure). As a result, we opt for a tilting approach. This requires adjusting market value weights to provide higher exposures to countries less exposed to climate change risks and lower the exposures to countries that are more exposed to climate change risks.

Figure 10: Cumulative % of emissions and of MV



Source: FTSE Russell & Beyond Ratings. Carbon data as of 2016, Market value as of Dec 2018

Adjusting index weights using climate scores

As noted in Section 3, a single climate score can be calculated for each sovereign by combining climate pillar scores. To do so, we draw upon the way in which factors can be combined in a multi-tilting approach to maintain the power of the tilt[43] as follows:

$$CS \quad = TRI^{\alpha} \times PRI^{\beta} \times RI^{\gamma}$$

where,

TRI, *is the county's Transition Risk Pillar score*	α, *is the TRI tilt power*
PRI, *is the county's Physical Risk Pillar score*	β, *is the PRI tilt power*
RI, *is the county's Resilience Pillar score*	γ, *is the RI tilt power*
CS, *is the final Country Climate score*	

Tilt powers are configurable and can be calibrated according to the investment and environmental performance objectives. Final computed climate scores can then be applied to each country's market value weight in the underlying index to derive the adjusted weights:

$$\theta_i = \frac{\omega_i CS_i}{\sum_{i=0}^{n}(\omega_i CS_i)}$$

where,
ω, *is the county's market value weight in the underlying index*
θ, *is the county's weight in the Climate Adjusted Index*

The power of the tilt

Having calculated climate pillar scores for a given assessment cohort of countries, we can then analyze the impact and sensitivity of adjusting the tilt strengths applied to each climate risk pillar on key financial and environmental performance metrics. Here, we select the WGBI universe and an assessment cohort of 50 countries, whose local currency sovereign bond markets are actively tracked by FTSE Russell. Taking each pillar in isolation (i.e. with the other climate pillar tilts set to 0), we adjust the tilt strength in increments from 0 to 5 and extract key performance metrics calculated over a back-tested period from January 2002 to March 2020. Key performance metrics selected are (1) *annual tracking error vs. WGBI and (2) improvement in 2°C alignment (as measured by the improvement in the GAP between GHG emissions trend).*

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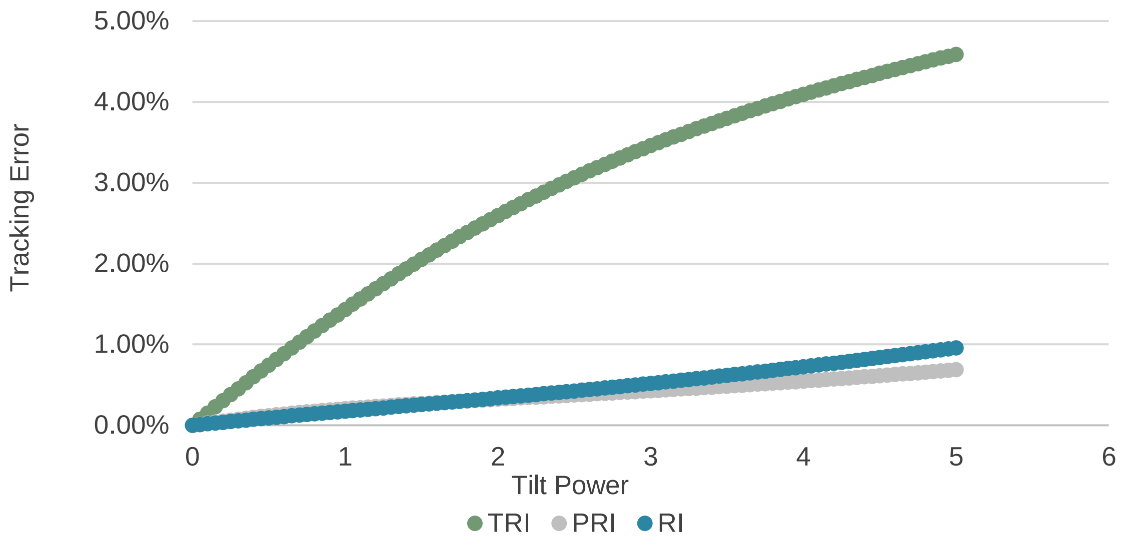
[43] FTSE Russell Research, Multi-factor indexes: The power of tilting, August 2017.

Figure 11: Analysis of Tilt Strength on TE to WGBI (in USD terms)



X axis represent the tilt power of the applied the risk pillar, while the two other risk pillars are held constant at a value of 1.

Source: FTSE Russell & Beyond Ratings.

As can be seen in Figure 11 tilts applied to the transition risk scores have the most significant impact on tracking error. Index weight changes are more sensitive to these scores than physical risk or resilience scores. This is explained by the fact that transition risk scores are negatively correlated to bond market size (used to calculate the weights of the standard market value weighted WGBI), whereas physical risk and resilience scores are positively correlated with bond market size.

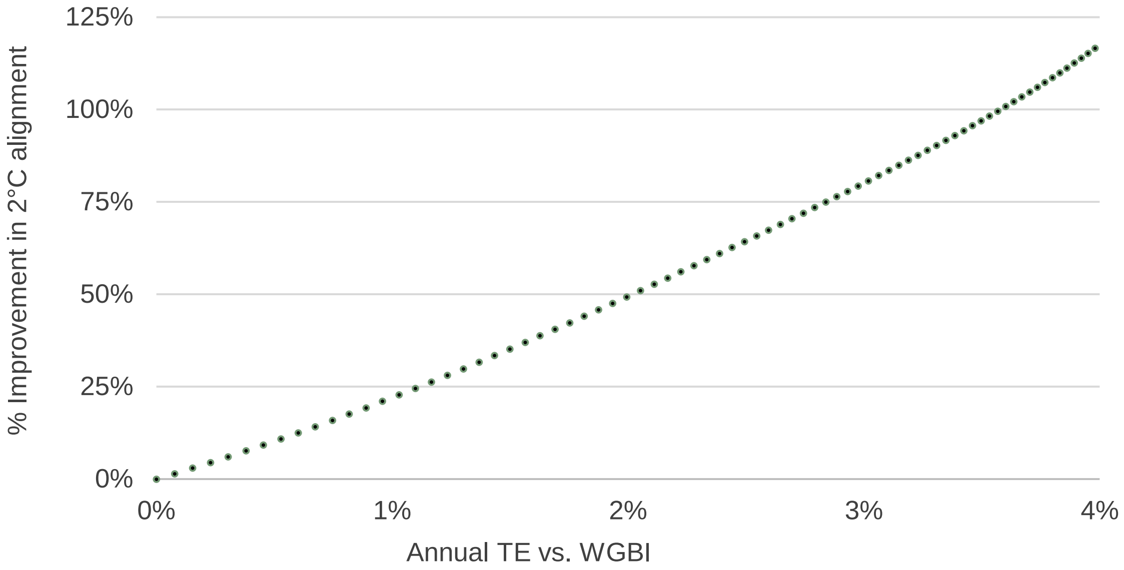
Figure 12: Analysis of climate pillar scores

Measure	Transition	Physical	Resilience
Correlation with market value weights (WGBI)	-16.7%	1.6%	11.5%
Standard deviation of scores	22%	20%	21%

Source: FTSE Russell & Beyond Ratings.

We have used annual tracking error as our measure of financial performance and not absolute performance. The reason for this is it allows us to better understand the extent to which the portfolio deviates from the market value index as the various tilts are applied. Clearly, there is a trade-off between environmental performance and deviations from the portfolio characteristics of the equivalent market-value weighted index. This can be seen in Figure 14 where the percentage improvement to 2°C alignment is plotted against the tracking error as the tilt power to transition risk is increased (with physical risk and resilience held constant at 1).

Figure 13: Environmental performance versus tracking error



Source: FTSE Russell & Beyond Ratings.

To illustrate this point, we can assess the weight deviations required to build a 2°C index. Given only four of the WGBI countries (as of the end of March 2020) have a 2100 temperature equivalent of below 2°C, significant deviations in index weights would be needed. In fact, two of these countries, Sweden and Norway, have a relatively small amount of government bonds in the market, and therefore have a low market value weights in the index (<1%). Boosting their weights to such an extent would be challenging, not least due to the fact that the assets tracking the WGBI would far exceed the debt outstanding in these small and peripheral global bond markets. In addition, the US (the largest country by weight) has an estimated temperature of 5.5°C (i.e. the implicit 2100 global warming if all countries positioned themselves like the US). Even if we reduce the weight of the US to 0%, the index temperature would only decrease from 4.0°C to 3.0°C − still far from a 2°C target. Moreover, such a reduction of the US share in a global universe would represent a major investment shift.

As of the beginning of May 2020, the WGBI’s temperature stood at 3.9°C (global warming on a 2100 horizon), in comparison with 3.3°C for the Advanced Climate WGBI (-16%). EGBI had a temperature of 2.5°C but this was 2.3°C for its Advanced Climate version (-9%).

Advanced Climate Risk Adjusted WGBI and EGBI

The FTSE Advanced Climate Risk Adjusted Government Bond Index Series offers investors a compromise between a 2-degree pathway alignment and deviations in market-value weighted portfolio characteristics, while at the same time effectively positioning investors to benefit from the potential mispricing of government bonds. The series comprises the FTSE Advanced Climate World Government Bond Index (“Advanced Climate WGBI”) and the FTSE Advanced Climate European Monetary Union (EMU) Government Bond Index (“Advanced Climate EGBI”). Crucially, the series applies a tilt strength of 1 to each climate risk pillar.

Figure 14: Cimate Index Design Criteria

	FTSE Climate WGBI	FTSE Climate EGBI
Country Climate Scores	Updated annually and applied each May month-end rebalance. The cut-off for input data is May 1 of each year.	Updated annually and applied each May month-end rebalance. The cut-off for input data is May 1 of each year.
Country Climate Score Assessment Cohort	Local currency sovereign bond markets eligible for the WGBI.	Local currency sovereign bond markets eligible for the EGBI.
Climate Pillars and tilt calibration	Geometric tilt: • Transition risk: 1 • Physical risk: 1 • Resilience: 1	Geometric tilt: • Transition risk: 1 • Physical risk: 1 • Resilience: 1
Rebalancing	Once a month at the end of the month	Once a month at the end of the month
Base date	December 31, 2001	December 31, 2001

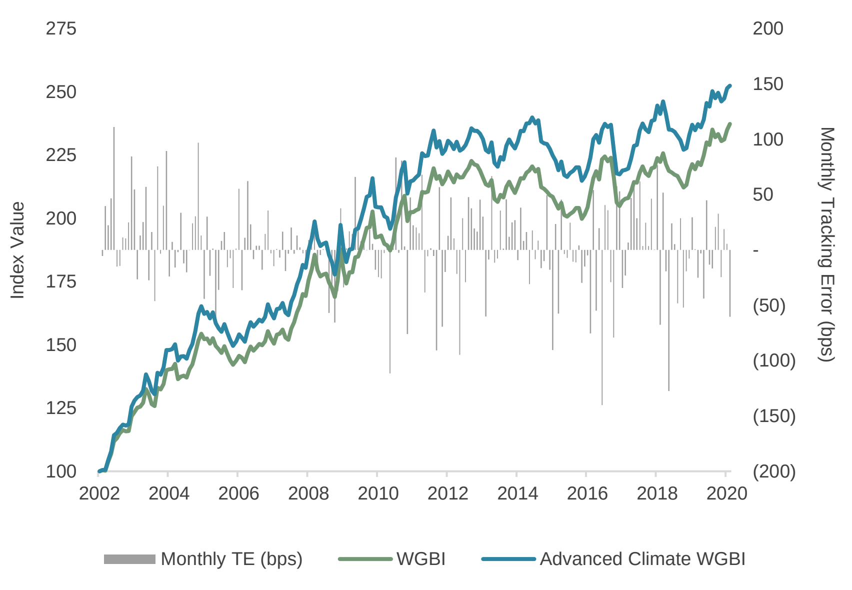
Source: FTSE Russell & Beyond Ratings.

Advanced Climate WGBI (ACWGBI)

Figure 15 presents the back-tested historical performance of the ACWGBI vs the WGBI. As can be seen, the ACWGBI is closely correlated with the WGBI, with annualized tracking error of just 1.48%. Over the period the ACWGBI outperforms the WGBI at the expense of a slightly higher volatility and an increase in average monthly turnover. However, the portfolio is on average 28% more aligned to a 2-degree pathway (100% would be 2-degree aligned) and provides an average annual GHG reduction of 2,717 MtCO2, more than the combined GHG emissions of Japan (1,249) and Germany (901) – the two largest GHG emitters in the WGBI after the US, based on the most recent emissions data.

Figure 15: Advanced Climate WGBI (ACWGBI) Performance

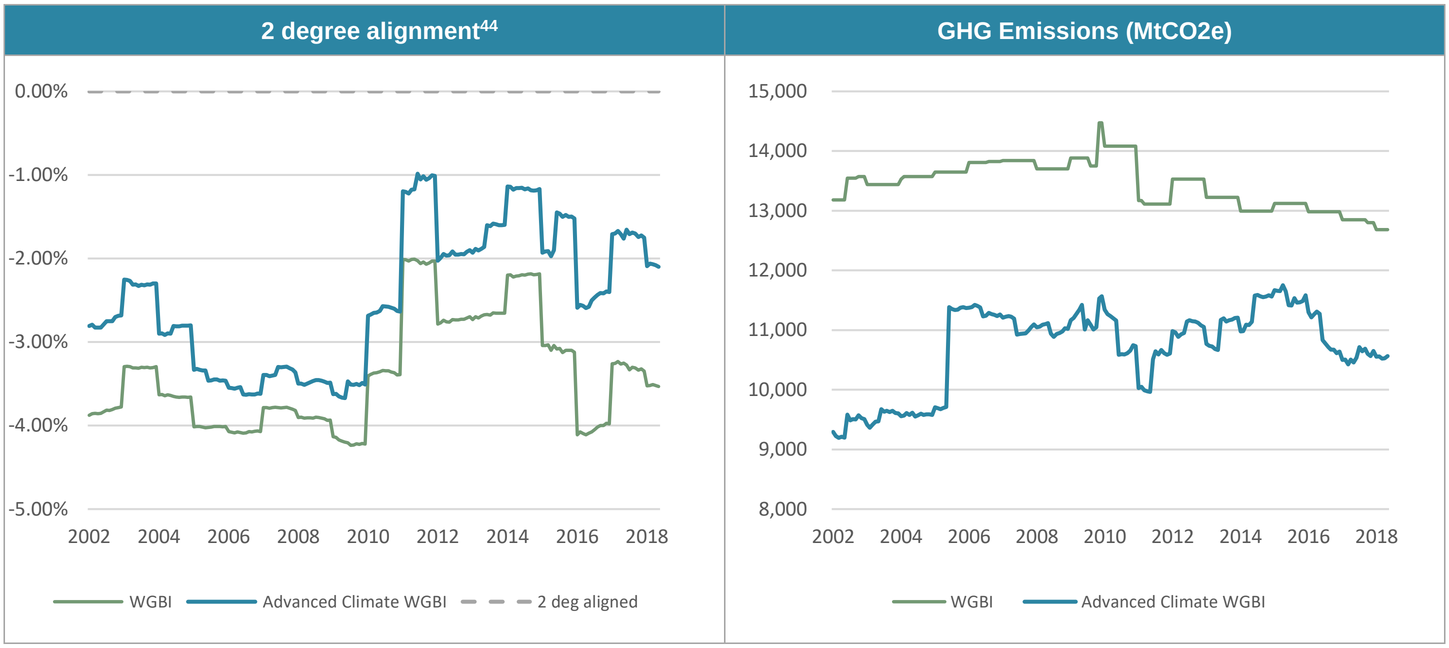
Advanced Climate WGBI vs WGBI (USD unhedged, rebased Jan 2002)



Metric	WGBI	ACWGBI
Annualized Return	4.81%	5.13%
Annualized Volatility	6.52%	7.20%
Risk-Adjusted Returns	0.738	0.713
Tracking error		1.48%
Return Correlation		98.5%
Av. Monthly Turnover	1.83%	2.60%
Max Drawdown (End Date)	-10.26% (Nov-2015)	-10.54% (Oct-2008)
GHG emissions GAP between trend and target	3.20%	2.33%
Av. Improvement in 2-degree alignment		+28%
Av. Total GHG Emissions	13,434	10,717
Av. Total GHG Emissions reduction		2,717 (20%)

Source: FTSE Russell & Beyond Ratings. June 2020 Past performance is no guarantee of future results. Returns shown represent hypothetical, historical performance. Please see the end for important legal disclosures.

Figure 16: Advanced Climate WGBI (ACWGBI) Environmental Performance


2 degree alignment[44]

GHG Emissions (MtCO2e)

Source: FTSE Russell & Beyond Ratings. June 2020 Past performance is no guarantee of future results. Returns shown represent hypothetical, historical performance. Please see the end for important legal disclosures

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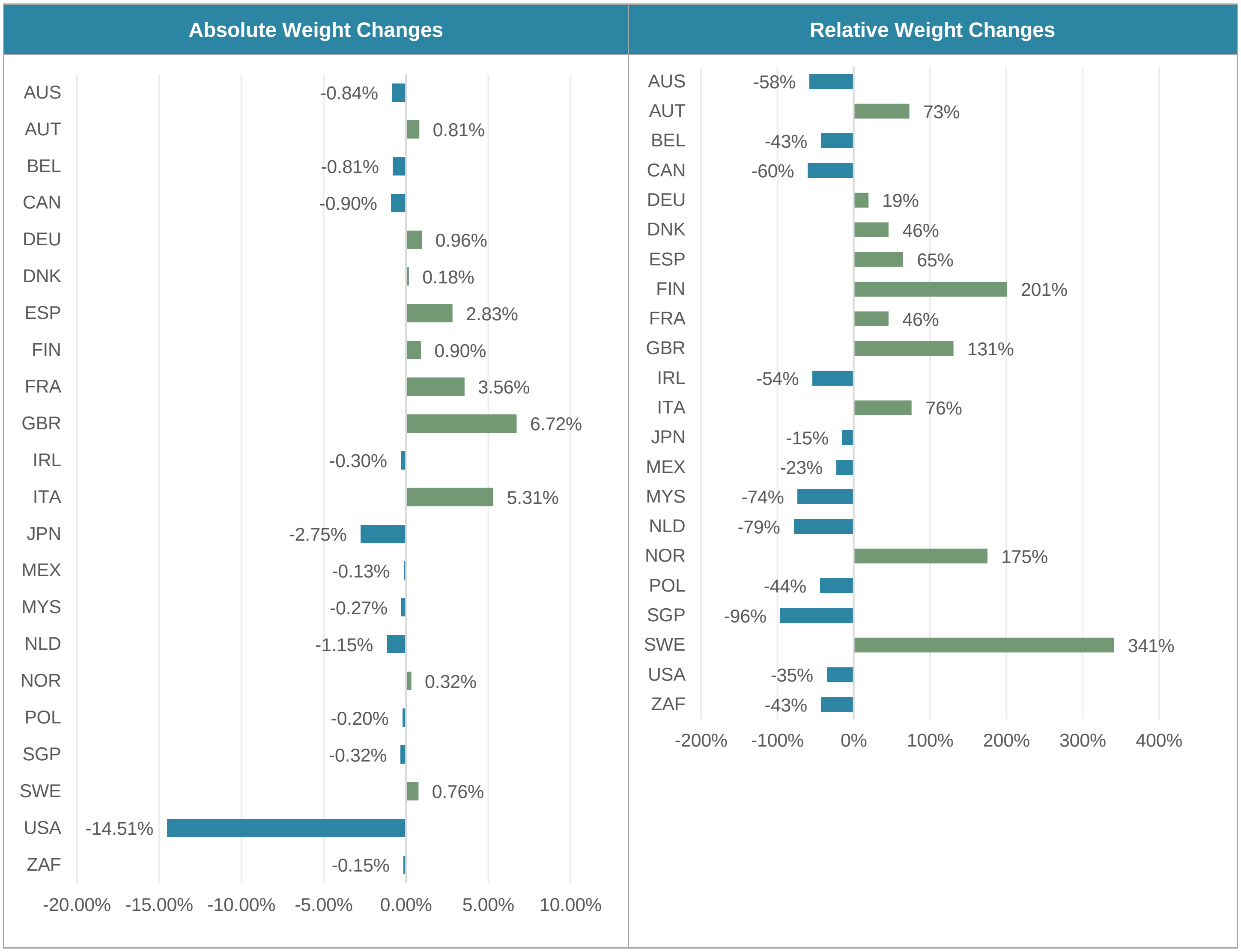
[44] Measured by annualized GHG emissions cuts GAP between trend and distance to target compliant with a 2 degree aligned 2050 scenario.

Figure 17: Advanced Climate WGBI (ACWGBI) Weight Adjustments (April 2020)



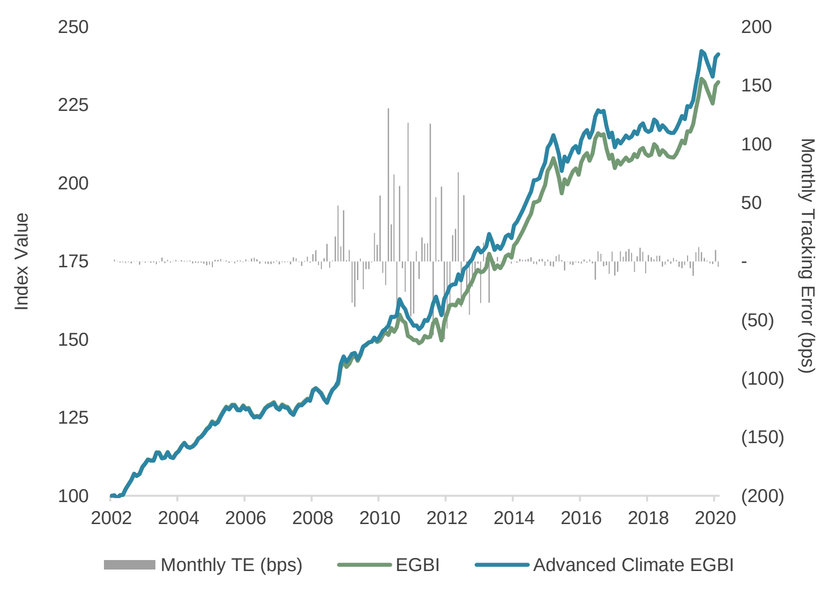
Source: FTSE Russell. June 2020

Advanced Climate EGBI (ACEGBI)

Figure 18 presents the back-tested historical performance of the ACEGBI vs the EGBI. The ACEGBI is even closer correlated with the EGBI than the ACWGBI vs WGBI, with annualized tracking error of just 0.77%. Over the period the ACEGBI outperforms the EGBI with slightly lower volatility but increased average monthly turnover. **The portfolio is on average 26% more aligned to a 2-degree pathway (100% would be 2-degree aligned) and provides an average annual GHG reduction of 204 MtCO2.** The improvement in 2-degree alignment is close to that achieved by the ACWGBI and the lower absolute GHG reduction is to be expected given the lower starting emissions (due to the smaller pool of countries in the EGBI) and the relatively better starting position in terms of emissions performance.

Figure 18: Advanced Climate EGBI (ACEGBI) Performance

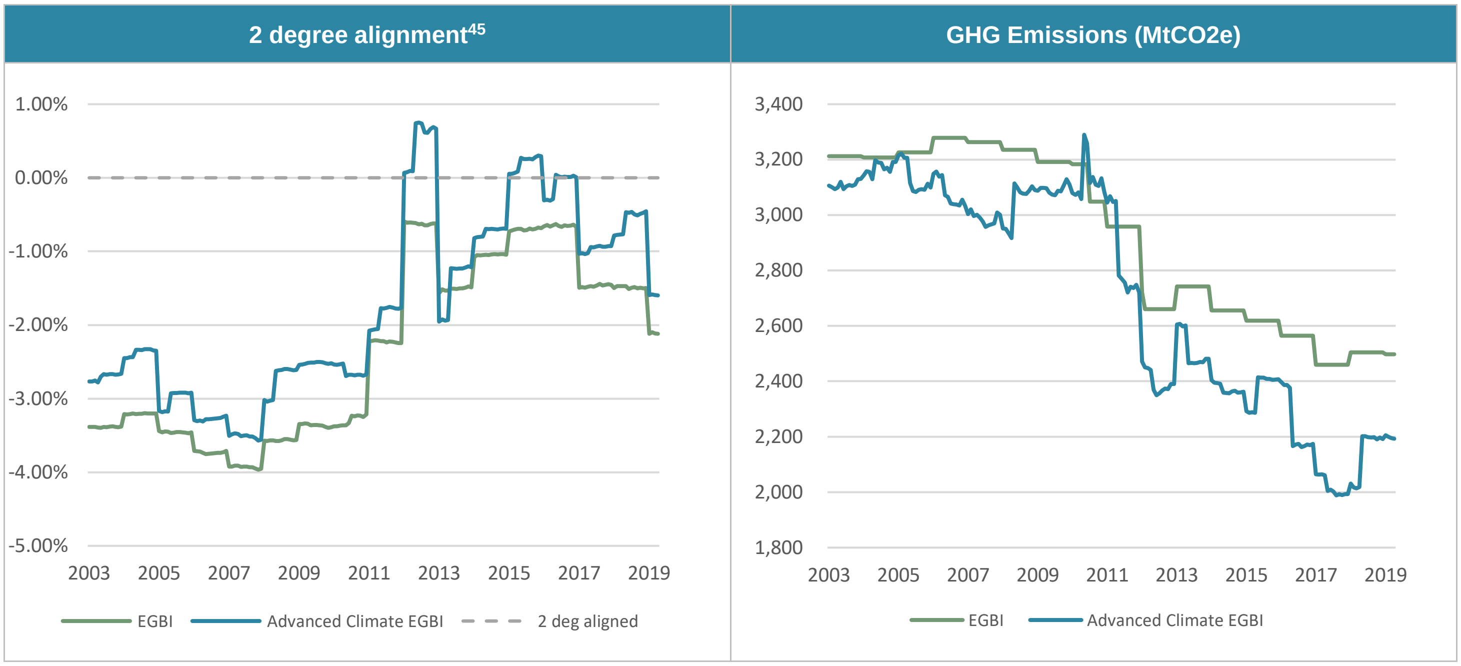
Advanced Climate EGBI vs EGBI (EUR, re-based Jan 2002)



Metric	EGBI	ACEGBI
Annualized return	4.57%	4.78%
Annualized volatility	4.02%	3.97%
Risk-adjusted returns	1.138	1.203
Tracking error		0.77%
Return correlation		98.0%
Av. monthly turnover	1.40%	2.58%
Max drawdown (End date)	-5.78% (Mar-2011)	-5.87% (Mar-2011)
GHG emissions GAP between trend and target	2.35%	1.73%
Av. Improvement in 2-degree alignment		+26%
Av. total GHG Emissions	2,921	2,717
Av. Total GHG Emissions reduction		204 (7%)

Source: FTSE Russell & Beyond Ratings. June 2020 Past performance is no guarantee of future results. Returns shown represent hypothetical, historical performance. Please see the end for important legal disclosures.

Figure 19: Advanced Climate EGBI (ACEGBI) Environmental Performance


2 degree alignment[45]

GHG Emissions (MtCO2e)

Source: FTSE Russell, as of June 2020.

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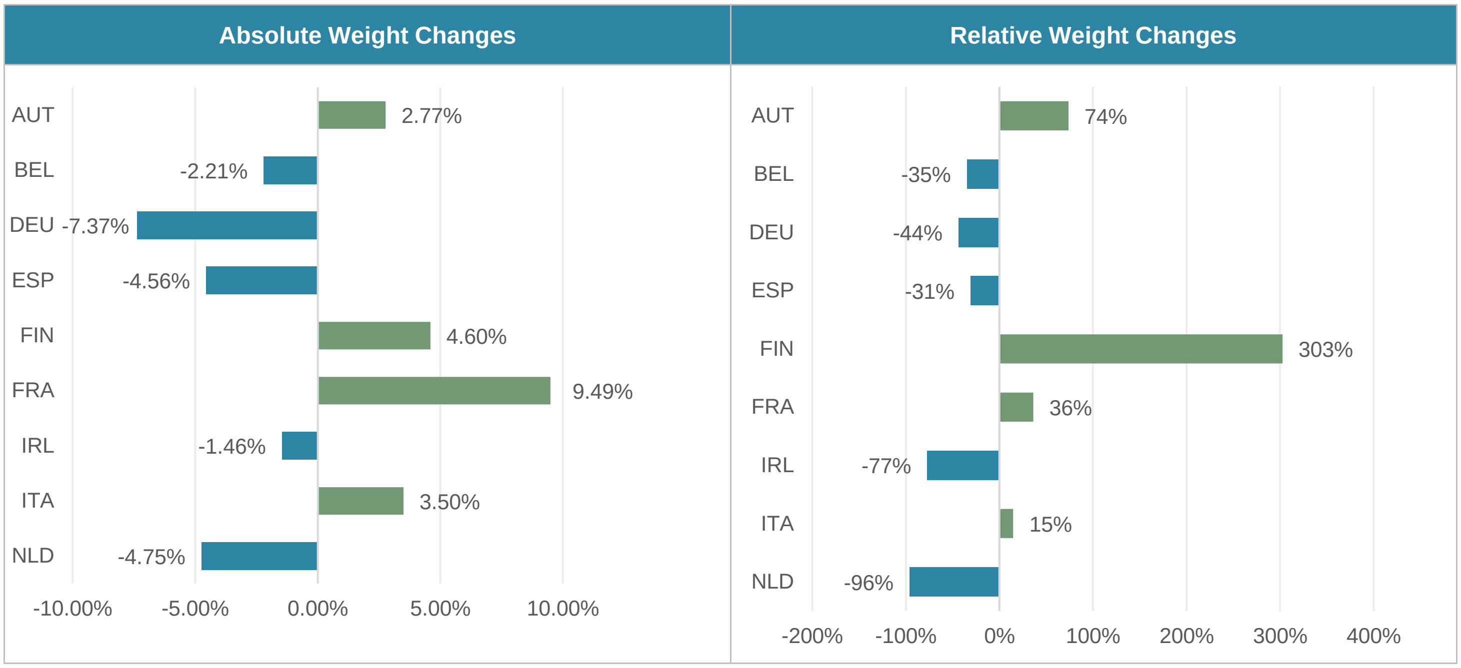
[45] Measured by annualized GHG emissions cut GAP between trend and distance to target compliant with a 2-degree aligned 2050 scenario.

Figure 20: Advanced Climate EGBI (ACEGBI) Weight Adjustments (April 2020)



Source: FTSE Russell, as of June 2020.

Measuring environmental benefits

There are multiple ways in which the environmental benefits of a climate tilted index can be measured against the market valued weighted. The most common measures are focused on transition risk, particularly on carbon emissions. Some are focused on the current situation such as total current carbon emissions, or weighted average carbon intensity (by GDP or per capita). Others are more forward looking such as the degree of improvement in the trend in reducing carbon emissions vs the distance to target (annual cuts needed to limit warming to 2o). A broader measure can be to measure the improvements in the weighted-average climate scores for the index as in figure 21.

Figure 21: Improvements in climate scores

Improvements of weighted-average overall climate country score between advanced climate risk-adjusted and market-value weighted index

Source: FTSE Russell & Beyond Ratings, June 2020.

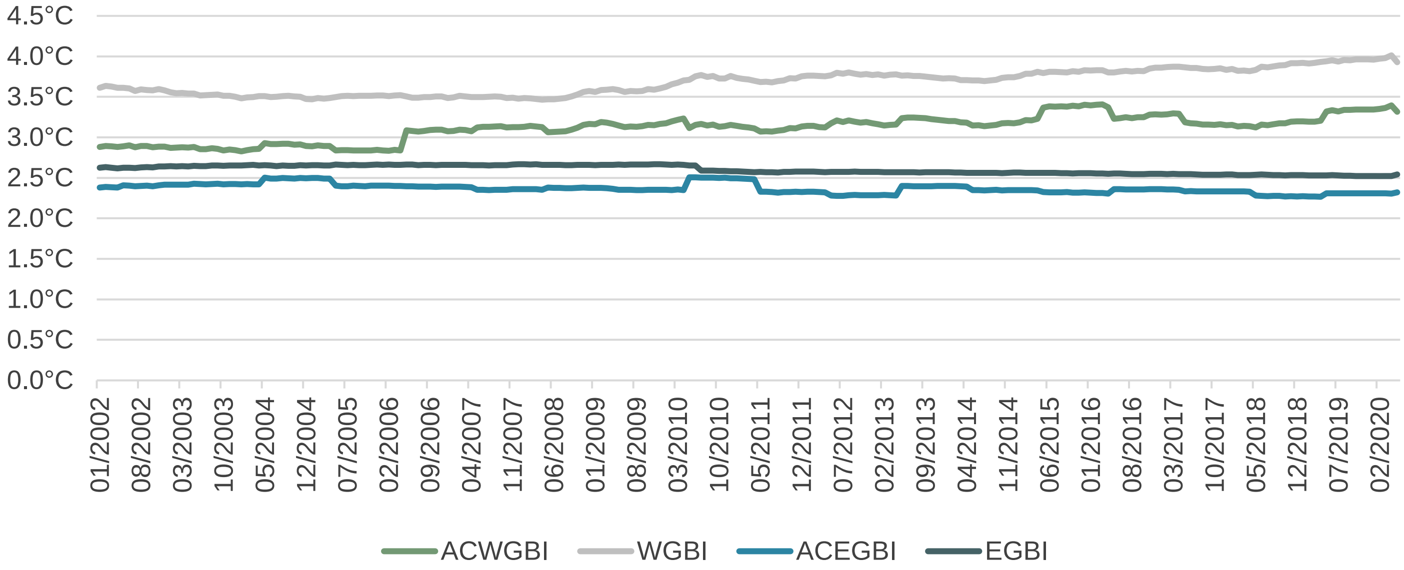
More advanced measures can look at the changes in the implied temperature of portfolio, however, these rely on a number of modelling assumptions and are no guarantee of the future. We have back-tested the impact of country weight changes on the temperature of the WGBI and the EGBI, based on latest available country assessments. Several key findings can be highlighted as described below:

The temperature of the WGBI is structurally above that of the EGBI, which is consistent with the high U.S. temperature in comparison with lower temperatures in European countries overall.

In addition, this figure shows notable positive gaps in favor of the advanced climate version of each index. As of the beginning of May 2020, the WGBI's temperature stood at 3.9°C (global warming on a 2100 horizon), in comparison with 3.3°C for the Advanced Climate WGBI (-16%). EGBI had a temperature of 2.5°C but this was 2.3°C for its Advanced Climate version (-9%).

Lastly, evolution trends diverge between the WGBI and the EGBI. While EGBI and ACEGBI present a relatively stable trend on the period from January 2002 to May 2020, both the ACWGBI and WGBI see an increase of their average temperature on this period (respectively from 3.6°C to 3.9°C and from 2.9°C to 3.3°C). This reflects for example the high increase of the US weight in the index on the period, from 25% to 38% in the standard WGBI.

Figure 22: Evolution of the average temperature of WGBI and EGBI based on standard and advanced climate versions (averages weighted by index weights)



Notes: temperatures are based on the latest data available, so that only effects from weight changes are reflected by this figure. Applied weights are start of the month index profile weights. As Nationally Determined Contributions (NDCs) are taken into account, the graph implies a back-testing of index temperatures based on current temperature estimates.

Source: FTSE Russell & Beyond Ratings.

It can thus be noted that both Advanced Climate WGBI and EGBI lead to improved temperature levels in comparison with their reference universes, although they remain above a 2°C threshold in the context of current country commitments.

Section 6: Conclusion

Climate change is a key global risk, which in recent years has rapidly become a public, investor and government priority. Countries are at the forefront of facing the physical impact of climate change, transitioning their economies for mitigation and adapting the nation to become more resilient. The costs of climate change are already in the multiple hundred billion dollars. Financial impacts can manifest itself in a number of ways: reducing government revenues associated with fossil fuels and increasing costs of climate financing or costs of climate natural disasters. Economies are likely to change significantly as they transition to a lower carbon future, with both winners and losers. The topic has risen significantly up the political agenda with widely varying impacts such as changing immigration patterns, tax protests or wildfires. Given the numerous types of risks and potential impacts combined with uncertainty around which climate path the world will take, it can be a complex subject for investors to consider. However, by dividing the risk into Transition, Physical and Resilience, it is possible to both quantify the relative risks different countries face and develop systemic ways to include them in the sovereign bond investment process.

Climate change has been a growing topic for equity investors for a number of years, but it has had little impact in the sovereign bond asset class. The forward-looking nature of the risk means it is often considered ‘over the investment horizon’. However, with accelerating climate impact today and 30% of the weight of the WGBI over 10 years of maturity, where the impacts will become more acute, the materiality of climate risk for sovereign investors should not be underestimated. Various studies have shown that the market has not been pricing in climate risk, meaning there has been no historical imperative to manage the risk. However, this may change going forward and become a critical blind spot for investors. Despite the rapid growth in the sustainable investment market, the sovereign bond market remains very underserved. Where sovereign ESG issues are considered, they tend to be around social and governance issues rather than climate and environment. Growing investor interest in climate risk is increasing demand for sovereign bond climate solution and this is likely to be accelerated by regulatory measures such as climate risk reporting, and bank climate stress tests.

FTSE Russell have taken the three-pillar climate risk framework, the forward looking ‘CLAIM, climate carbon budget model and multiple national level climate related performance indicators to develop relative national climate scores. These are then used with a customizable tilting methodology to adjust the market value weights of the World and European Government Bond Indexes in a systematic, quantitative fashion. The resulting indexes transfer weighting towards strong climate performers (e.g. Finland) and away from poor climate performers (e.g. Australia). This improves the current climate performance of the indexes (e.g. lower associated weighted average carbon emissions) and reduces potential future climate risk (e.g. improved long-term alignment with transition targets).

The first Climate Risk Adjusted WGBI product was launched in 2019, followed by the Advanced Climate Risked Adjusted WGBI and EGBI, the next step forward in the climate risk adjusted index family. These latter indexes have stronger tilts towards the climate risk scores of the associated sovereign bond issuers leading to indexes that exhibit better climate performance metrics. These give investors more tools to integrate climate risk considerations into their sovereign bond investments and increase their climate ambitions.

Appendix:

Climate pillars and underlying indicators

Country climate scores are derived from assessments across three climate pillars. Each pillar contains multiple underlying indicators. Raw data inputs are typically normalized to ensure countries are scored between 0 and 1 for each indicator. Within each climate pillar, the underlying indicators are equally weighted.

FTSE Climate Pillars and Indicators: Sovereign Assessment

Climate Pillar	Indicator	Indicator description	Source(s)	Lag[46]	History[47]	Ref
Transition Risk	Territorial distance to target	Required annual reduction of total territorial GHG emissions including LULUCF in order to reach 2°C-compliant territorial GHG budgets in 2050 (expressed as CAGR). Budgets are estimated using the FTSE Climate Liabilities Assessment Integrated Methodology[48] (CLAIM).	Various[49]	2-3 years	2000	TRI.01
	GHG emissions gap between trend and distance to target	Gap between the 5-year historical trend of total territorial GHG emissions including LULUCF and the required annual reduction of these emissions to reach 2°C-compliant territorial GHG budgets in 2050 (based on CAGRs).	Various[3]	2-3 years	2005	TRI.02
Physical Risk	Sea level exposure	Percentage of total population living in areas where elevation is below 5 meters.	World Bank	0-5 years	1990	PRI.01
	Agricultural exposure	Agricultural production coefficient of variation (standard deviation / mean) weighted by share of agriculture in GDP.	FAO	0-5 years	1961	PRI.02
	Climate-related natural disaster exposure	95th percentile of the distribution of the proportion of population killed by climate related natural disasters in a given year.	EM-DAT	0-1 year	1990	PRI.03
Resilience	Institutional resilience	*NDC temperature equivalent:* intended country C02 emissions in 2030 as explicitly or implicitly targeted in the country National Determined Contribution (NDC) is translated into an equivalent climate trajectory (temperature increase) using the FTSE Climate Liabilities Assessment Integrated Methodology (CLAIM).	Beyond Ratings	Not relevant[50]	2016	RI.01
		Government effectiveness: captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.	World Bank WDI	1-2 years	2000	RI.02
		External debt percentage of GDP: outstanding amount of debt owed to non-residents expressed as a share of GDP.	Oxford Economics	0-1 year	2000	RI.03
		Disaster preparedness: an indication of a country's capacity to deal with climate-related nature disasters.	ND-GAIN	2-3 years	2000	RI.04

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[46] Time period between indicator measurement and indicator publication.

[47] First available publication date for each indicator.

[48] Powered by Beyond Ratings, a London Stock Exchange Group company. Further details on the CLAIM model can be provided by Beyond Ratings on request.

[49] Various underlying data sources including: PRIMAP-hist; UNFCC; CAIT; National data; United Nations; CDIAC; World Bank; OECD; Enerdata.

[50] Because the NDC temperature equivalent reflects a country's target, it does not change each year.

Climate Pillar	Indicator	Indicator description	Source(s)	Lag[46]	History[47]	Ref
	Social resilience	*Fuel subsidies:* ratio of subsidies vs. taxes on fuels. This indicator compares actual fuel prices to international prices to determine the level of subsidies/taxes.	Enerdata / EIA	1-2 years	2000	RI.05
		GINI index: measures the extent to which the distribution of income among individuals or households within an economy deviates from a perfectly equal distribution.	World Bank WDI	0-5 years	2000	RI.06
		Human development index: measures three key dimensions of human development: • a long and healthy life – life expectancy at birth • being knowledgeable – expected years of schooling and mean years of schooling, and • standard of living – Gross National Income per capita.	UNDP	1-2 years	2000	RI.07
		Voice and accountability: captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.	World Bank WDI	1-2 years	2000	RI.08
		Use of sanitation services: percentage of population with access to improved sanitation facilities.	World Bank WDI	3-4 years	2000	RI.09
		Access to electricity: percentage of population with access to electricity.	World Bank WDI	2-3 years	2000	RI.10
	Economic resilience	*CDP performance ratio:* percentage (based on market capitalization) of companies in a country that communicate on their impact on the environment.	CDP and Factset	0-1 year	2017	RI.11
		Insurance penetration: the ratio of premium underwritten in a given year to the GDP. Includes life-insurance and non-life insurance.	OECD	1-2 years	2007	RI.12
		R&D expenses: gross domestic expenditures on R&D, expressed as a percentage of GDP. Includes both capital and current expenditures in the four main sectors: business enterprise, government, higher education and private non-profit.	World Bank WDI	2-3 years	2000	RI.13
		Logistics performance: reflects perceptions of a country's logistics based on: efficiency of customs clearance process, quality of trade- and transport-related infrastructure, ease of arranging competitively priced shipments, quality of logistics services, ability to track and trace consignments, and frequency with which shipments reach the consignee within the scheduled time.	World Bank WDI	0-1 year	2007	RI.14
		Ease of doing business: the distance of an economy to the "frontier," which measures the gap between an economy's performance and a measure of best practice across the entire sample of 41 indicators for 10 Doing Business topics.	World Bank Doing Business	0-1 year	2009	RI.15
		Green bonds performance ratio: 3 year moving average of green bond new issuance as a percentage of GDP.	World Bank	0-1 year	2016	RI.16
		Water productivity: indicates the efficiency by which each country uses its water resources. Water productivity is calculated as GDP in constant prices divided by annual total water withdrawal.	World Bank WDI	0-5 years	2000	RI.17
		Agricultural adaptive capacity: composite index that reflects each country's capacity to adapt their agricultural system to environmental issues, especially climate change. The indicator corresponds to the average score on seven sub-indicators: (i) Agricultural capital stock (in USD) relative to agricultural production (in USD) (ii) Agriculture Orientation Index, reflects public support to agricultural sector (iii) Agrobiodiversity, reflects the variety of crops cultivated in the country (iv) The share of organic agriculture (as a % of agricultural land)	FAO	2-3 years	2016	RI.18

Climate Pillar	Indicator	Indicator description	Source(s)	Lag[46]	History[47]	Ref
		(v) The long-term cereals yield trend (calculated as the second derivative) (vi) The share of irrigated agriculture (as a % of land), and (vii) The share of conservation agriculture (as a % of land).				
	Ecological resilience	*Freshwater withdrawals:* percentage of total annual freshwater withdrawals on internal resources. Annual freshwater withdrawals refer to total water withdrawals, not counting evaporation losses from storage basins. Withdrawals also include water from desalination plants in countries where they are a significant source of freshwater. Withdrawals can exceed 100 percent of total renewable resources where extraction from nonrenewable aquifers or desalination plants is considerable or where there is significant water reuse.	World Bank Indicators	1-3 years	2002	RI.19
		Share of protected areas: percentage of protected areas (terrestrial and marine) of total territorial area. • Terrestrial protected areas are totally or partially protected areas of at least 1,000 hectares that are designated by national authorities as scientific reserves with limited public access, national parks, natural monuments, nature reserves or wildlife sanctuaries, protected landscapes, and areas managed mainly for sustainable use. • Marine protected areas are areas of intertidal or subtidal terrain - and overlying water and associated flora and fauna and historical and cultural features - that have been reserved by law or other effective means to protect part or all of the enclosed environment. Sites protected under local or provincial law are excluded.	UNEP / IBAT	2-3 years	2016	RI.20
		Share of biodiversity threatened: percentage of the total number of species in the country (Biodiversity Stock), both animal and vegetal, that are threatened according to International Union for Conservation of Nature - IUCN categories. Species referred as 'Threatened' include 'Critically endangered', 'Endangered' and 'Vulnerable' species, corresponding to different levels of extinction risk.	IUCN	0-1 year	2017	RI.21
		Biodiversity stock: total number of species in the country as reported by the International Union for Conservation of Nature - IUCN, including both animal and vegetal.	IUCN	0-1 year	2017	RI.22
		Afforestation rate: previous 5-year variation of forest cover based on FAO forestry data. All types of forest are considered, including primary, planted and naturally regenerated forests.	FAO	2-3 years	2000	RI.23

CLAIM methodology

The CLAIM methodology allows to conduct forward-looking assessments of countries alignment with long-term climate goals. In particular, it allows assessing country GHG emissions budgets consistent with a global 1.5°C or 2°C target (or any other target), and to do so at country level. In addition, it also allows to combine these budgets with an assessment of the political commitments of countries (as in NDCs or nationally determined contributions), and to assess temperatures by country on this basis.

Context

The Paris Agreement 1.5-2.0°C targets require net zero emissions by 2100. In this basis, both current trajectories and national plans (based on NDCs or nationally determined contributions) appear to be insufficient to remain below 2°C global warming globally. For example, current NDCs would result in global warming that can be assessed above 3°C.

A scientific consensus has been reached to aim for a much below global 2° climate target. However, as for now international climate negotiations have failed to precisely determine how to allocate GHG emissions reductions among countries on this basis. In this context, Beyond Ratings has developed the unique and proprietary CLAIM methodology to address these issues and offer a consistent analytical framework at macro country level.

Key principles

The CLAIM methodology is based on several key principles. Its general philosophy is to assess national carbon budgets based on a statistical quantitative approach to aim for a neutral and objective approach. The process to assess carbon budgets per country can be described as follows:

- The starting point of the methodology was to use the Kaya equation as described below. The Kaya identity describes the key factors determining carbon emissions.

$$\frac{GHG\ Emissions}{Population} = \frac{GDP}{Population} * \frac{Energy}{GDP} * \frac{GHG\ Emissions}{Energy}$$

- The Kaya identity factors are then broken down into 14 variables, to which we add total CO2 emissions since 1950, given the weight of historical emissions in international climate negotiations. This allows to identify all the “responsibility” and “capacity” factors that mathematically determine GHG emissions, on a granular basis.
- Based on these 15 criteria, a probabilistic approach of allocations is then applied. It consists in 2 million simulations testing different ways to combine criteria with each other.
- These tests then allow to assess many potential carbon budgets for each country, taking into account the potential ways in which criteria can be combined. This provides a distribution of potential budgets by country, allowing to assess the probability of the various potential budgets.
- The calculated distribution then allows assessing the most realistic carbon budget for each country. The mode of the distribution thus allows assessing a national budget allocation for each country. The mode describes the broadest scope of potential negotiation outcomes.
- As a result, many national budgets are assessed, covering all the countries included in the analysis. The total of these budgets may not be as such compatible with a 2°C or 1.5°C target, but the combination of these budgets provides an allocation of either a 2°C or 1.5°C global budget between countries (or any other allocation corresponding to any other assessed global temperature). For this last step, we rely on IPCC global carbon budgets corresponding to global warming levels, as assessed on a 2100 time horizon.

To conclude, the above steps allow to assess an allocation of national carbon budgets for countries, and to apply such an allocation in relation with various global budgets corresponding to various global warming assessments.

List of simulated factors

15 factors are tests in the statistical simulations to assess national carbon budgets, as described below:

Variables included in CLAIM simulation tests

Variables
GDP/capita in constant US$ (Last Available Data: LAD)
GDP/capita evolution since 2000
Energy intensity of GDP at US$ constant (without biomass) (LAD)
Energy intensity of GDP at US$ constant (without biomass) evolution since 2000
CO2 intensity of energy (kg per kg of oil equivalent energy use) (LAD)
CO2 intensity (kg per kg of oil equivalent energy use) evolution since 2000
GHG including LULUCF per capita (LAD)
GHG including LULUCF per capita evolution since 2000
CO2 emissions from the energy sector (LAD)
CO2 emissions from the energy sector evolution since 2000
GHG emissions excluding CO2 from the energy sector (LAD)
GHG emissions excluding CO2 from the energy sector evolution since 2000
Primary energy consumption per capita (LAD)
Primary energy consumption per capita evolution since 2000
Total CO2 emissions since 1950

Source: FTSE Russell & Beyond Ratings.

Translation into temperature assessments

The NDC equivalent temperature represents what the global temperature would be in 2100 if all countries had the same level of ambition as the analyzed country. Country ambition is characterized by the difference between a 2°C (or other) compatible GHG emissions budget and its NDC objective. Applying the spread of this gap to all countries at a global level, and translating this in terms of emissions, then makes it possible to determine a level of global temperature warming in 2100.

Key output and indicators

The CLAIM methodology thus allows assessing several criteria, including the indicators below:

- **Territorial distance to target**: Required annual reduction of total territorial GHG emissions including LULUCF in order to reach 2°C-compliant territorial GHG budgets in 2050 (expressed as CAGR).

- **GHG emissions gap between trend and distance to target:** Gap between the 5-year historical trend of total territorial GHG emissions including LULUCF and the required annual reduction of these emissions to reach 2°C-compliant territorial GHG budgets in 2050 (based on CAGRs).
- **NDC temperature equivalent:** Intended country CO2 emissions in 2030, as explicitly or implicitly targeted in the country National Determined Contribution (NDC), are translated into an equivalent climate trajectory (temperature increase) by comparing them with carbon budgets.

The Climate Technology Compass

The CLAIM model opens to further methodological developments. On this basis, we have also developed the Climate Technology Compass available online: https://compass.transitionmonitor.org/

This tool combines our national climate alignment assessments with sector analyses. It enables investors, financial institutions, corporates and governments to map the technology transition and investments necessary to achieve the 2°C target for 101 countries and eight climate relevant sectors. Outputs include a range of sector specific metrics (such as production, capacity, emissions or investment needs data) under 2°C or NDC scenarios, and based on relevant technologies in analyzed sectors. It has been supported by Climate-KIC which is supported by the EIT, a European Union body.

Climate risks pricing in sovereign CDS spread

To support what we say in this paper about the fact that climate change risks seem to be only partially priced by the market at present, we propose an empirical approach, following on from the Beyond Ratings / Hermes Investment study.

Methodology

In order to determine a potential pricing of climate change-related risks incorporated in historical sovereign CDS spread, we used an econometric approach addressed in previous publications (Beyond Ratings and Hermes Investment, 2019, 2020). We specify our econometric regression (simple OLS panel) such as:

$$\ln(CDS)_i = \alpha_0 + \beta_1 CR_i + \beta_2 Physical\_Risks\_Index_i + \beta_3 Transition\_Risk\_Index_i + \varepsilon_i$$

Where $\ln(CDS)$ is the natural logarithm of CDS spread, α_0 is a constant, CR_i the credit rating transformed in numeral scale (see Data section) of country i, $Physical\_Risks\_Index_i$ is the score associated with climate physical risks, $Transition\_Risk\_Index_i$ the score associated with transition risk and ε_i the error-term.

Credit ratings are used to control for perceived likelihood for government to reimburse its debt. Scores for physical and transition risks are taken from Climate-adjusted World Government Bond Index methodology.

We take the last available data only (2020) for this study and take into account 45 countries (see Table 1).

This first approach is for descriptive purposes only, as a robust econometric specification requires a much larger number of observations. We've excluded outliers such as Argentina.

Table 1. Countries included in the study

Countries				
Australia	Czech Republic	Ireland	Peru	Spain
Austria	Denmark	Israel	Philippines	Sri Lanka
Belgium	Finland	Italy	Poland	Sweden
Brazil	France	Japan	Portugal	Switzerland
Canada	Germany	Malaysia	Romania	Thailand
Chile	Greece	Mexico	Russia	Turkey
China	Hungary	Netherlands	Saudi Arabia	United Kingdom
Colombia	India	New Zealand	Singapore	United States
Croatia	Indonesia	Norway	South Africa	Vietnam

Source: Beyond Ratings

In this study, we choose to use S&P's credit ratings only. Table 2 present our conversion rule to obtain numerical transformation of credit ratings. We take into account the combination between credit rating and associated outlook.

Table 2. Conversion rule between ratings combined with outlook and credit rating

Rating combined with outlook	Numerical Scale
AAA/stable	62
AAA/negative	61
AA+/positive	60
AA+/stable	59
AA+/negative	58
AA/positive	57
AA/stable	56
AA/negative	55
AA-/positive	54
AA-/stable	53
AA-/negative	52
A+/positive	51
A+/stable	50
A+/negative	49
A/positive	48
A/stable	47
A/negative	46
A-/positive	45
A-/stable	44
A-/negative	43
BBB+/positive	42
BBB+/stable	41
BBB+/negative	40
BBB/positive	39
BBB/stable	38
BBB/negative	37
BBB-/positive	36
BBB-/stable	35
BBB-/negative	34
BB+/positive	33
BB+/stable	32
BB+/negative	31
BB/positive	30
BB/stable	29
BB/negative	28
BB-/positive	27
BB-/stable	26
BB-/negative	25
B+/positive	24
B+/stable	23
B+/negative	22
B/positive	21
B/stable	20
B/negative	19
B-/positive	18
B-/stable	17
B-/negative	16
CCC+/positive	15
CCC+/stable	14
CCC+/negative	13
CCC/positive	12
CCC/stable	11
CCC/negative	10
CCC-/positive	9
CCC-/stable	8
CCC-/negative	7
CC/positive	6
CC/stable	5
CC/negative	4
C/positive	3
C/stable	2
C/negative	1
D	0

Source: Beyond Ratings

Conducting the study on last available data, we take the current (2020) ratings numerically transformed.

Results

Table 4 shows the results of the study. Credit ratings used as exogenous variable are statistically significant. This means that a large part of sovereign CDS heterogeneity can be explained by credit ratings. The coefficient sign is also in line with our expectations: higher is the government's creditworthiness, lower is the sovereign CDS spread.

Regarding climate risks, results are mixed. Indeed, if the coefficient sign for Transition Risk Index is in line with our expectations, the relationship is statistically insignificant. Considering Physical Risks, coefficient sign is positive, which would that higher is the exposure to physical risks, lower is the sovereign CDS spread. This result is inconclusive, as neither the coefficient sign or statistical significance for transition risk.

Table 3. Results

Variable	Coeff	P> |t |
Const	6.7162	0.000***
Numerically transformed rating	-0.0704	0.000***
Transition Risk Index	-0.5108	0.180
Physical Risks Index	0.4491	0.243
R-squared		0.726

Source: Beyond Ratings, Note: *** significant at 1% level

Climate resilience capacities

As discussed, climate resilience is the ability of social-ecological systems to prepare for, absorb and recover from climatic shocks and stresses, while positively adapting and transforming their structures and means for living in the face of long-term change and uncertainty.

In this context and for more details, climate resilience can be considered to depend on the combination of the following capacities.

Climate resilience capacities by degree of structural change

ANTICIPATION

- The anticipative capacity is the ability of a system to **plan and prepare** for negative events through the implementation of predetermined responses.
- It includes early warning systems, disaster response planning, dyke systems in flood-prone areas, etc.

Low degree of structural change

▼

ABSORPTION

- The absorptive capacity is the ability of a system to recover from the impacts of negative events using predetermined coping responses.
- It includes insurance schemes, disaster risk reduction capacities, etc.

Low degree of structural change

▼

ADAPTION

- The adaptive capacity refers to the ability of a system to adjust or modify its characteristics and actions to respond to existing and anticipated future climatic shocks and stresses.
- It includes adjusted planting behaviour, improved resource efficiency, reduced local pollution, etc.

Moderate degree of structural change

▼

TRANSFORMATION

- The transformative capacity is the ability of a system to fundamentally change its characteristics and actions when the existing system is untenable in the face of future climatic shocks and stresses.
- It includes livelihood transformation, displacement of population, change from fossil energies to renewables, etc.

High degree of structural change

Note: Definitions adapted from Dixon and Stringer (2015); GIZ and UNU-EHS (2014); IPCC (2012); Béné et al. (2012); Brooks (2003).

Source: FTSE Russell & Beyond Ratings.

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EMEA
+44 (0) 20 7866 1810

North America
+1 877 503 6437

Asia-Pacific
Hong Kong +852 2164 3333
Tokyo +81 3 4563 6346
Sydney +61 (0) 2 8823 3521

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