Index Insights

Sustainable Investment | Climate Risks

FTSE Russell

Anticipating the climate change risks for sovereign bonds

Part 3: Insights on the physical risks

January 2022

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Overview

In this paper, we illustrate the possible effects of climate change depending on the level of mitigation efforts within the next years, and decades. We focus on two specific climate hazards: (i) the average temperature and (ii) the frequency of very hot days. Then, building on the methodologies developed in the first two parts of the series, "Anticipating the climate change risks for sovereign bonds," we continue our exploration of quantifying financial risk from climate change for sovereign issuers.

Compared to our previous studies, this analysis provides more detailed results, in terms of time horizons, countries and climate scenarios. We highlight our three main findings:

- Almost all countries might experience adverse effects from climate change. Emerging markets are the most highly vulnerable to climate change, with a high default risk due particularly to their lower fiscal capacities;
- The first evidence of financial instability in the sovereign market from unmitigated climate change could be seen as early as 2030;
- Contrary to common belief, our results show that even a Paris-aligned scenario will lead to significant physical risks for many countries, especially in Latin America, Africa and Southeast Asia.

Contents

1. Introduction

Physical climate risks are induced by potential impacts on assets, livelihoods and activities from climate change. These impacts can result from extreme meteorological or climate events (e.g., a change in the frequency and/or intensity of storms, droughts or floods), or to a chronic change in climate conditions (e.g., increased temperatures).

Physical climate risks result from the combination of three main components:

(i) The climate hazard itself − the occurrence of distinct, impactful events or the chronic changes caused by climate change;

(ii) The exposure of an asset to climate hazards − this depends mainly on the location of the asset;

(iii) The vulnerability of the asset to climate hazards − this depends on the asset's sensitivity to a given hazard (i.e., the level of impact if that climate hazard occurs) and the adaptive capacity (i.e., the capacity of the asset to adjust to new climate conditions or to minimize damages).

These physical impacts from climate change have real financial consequences *(*e.g., loss of revenues, increasing insurance/maintenance costs, loss of value) that can jeopardize the financial stability of a financial counterparty (e.g., decreased yields for a corporate, increased probability of default for a sovereign).

In this paper, we first illustrate how climate change could materialize, in a situation where no further mitigation efforts would be implemented. The following section provides the projections based on two specific climate hazards: (i) higher average temperatures and (ii) the frequency of very hot days.

Then, building on the methodologies developed in the first two parts of the series "Anticipating the climate change risks for sovereign bonds"[1], we continue our exploration to quantify financial risk from climate change for sovereign issuers, following various anticipated scenarios.

2. Two illustrative climate hazards

2.1. Climate change, models and scenarios

Before diving into physical risks of climate change, it is important to understand what we mean by climate conditions. Climate can be defined by the statistical state (average, variability) of weather conditions during long periods (typically 20-30 years), at a given location. On the other hand, climate change represents the modification of this statistical state over time (e.g., frequency of extreme events, average temperature, etc.). This means that projected climate information will provide a statistical description of future potential conditions. Climate models are increasingly able to generate reliable information on anticipated climate hazards, but no climate model can predict a storm in a few years or compare specific years in the future. This observation is important to keep in mind when referring to the climate projections.

Raw climate data are issued from observations (for past events) and climate models (for projections). Climate models simulate possible future climates, based on scenarios of future GHG emissions, to explore different potential paths. Because emissions are mostly caused by human

[1] FTSE Russell, 2021, Anticipating the climate change risks for sovereign bonds. See Anticipating Climate Risks (Condensed Version) of Part 1 and Part 2 in the series | FTSE Russell.

activities, these climate scenarios are called SSP − Shared Socioeconomic Pathways − in the latest generation of models. (They were called RCP − Representative Concentration Pathways − in the previous generation.) Both terms are used in this paper, depending on the climate model used for the assessment.

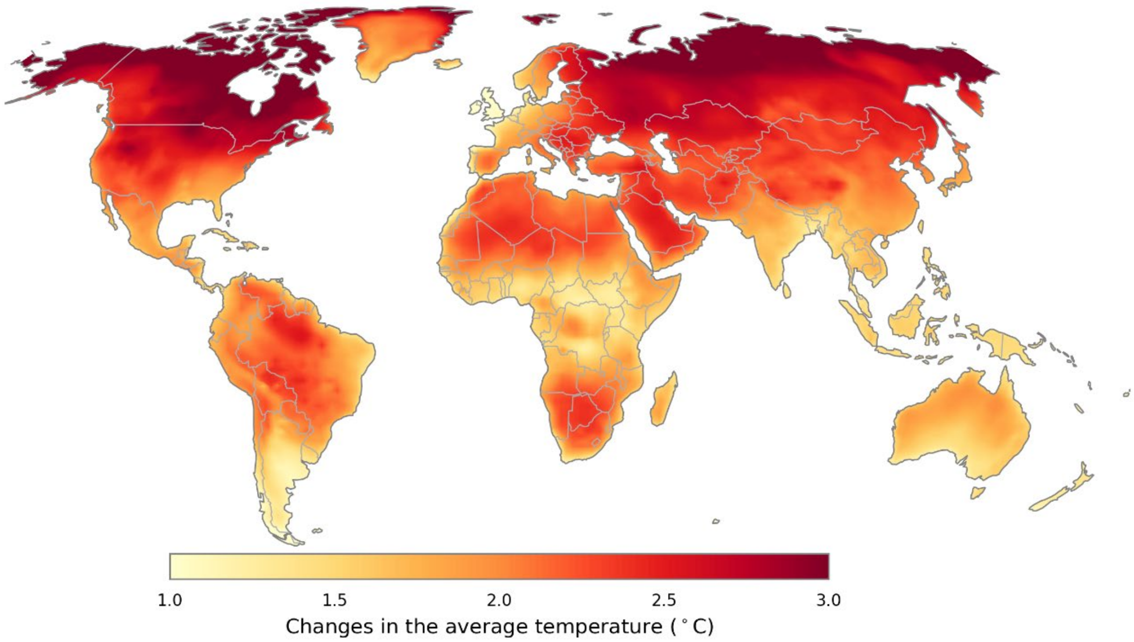
The evolutions presented in Figure 1 and Figure 2 in sections 2.2 and 2.3 correspond to the SSP585 climate scenario, i.e., a scenario with no mitigation effort, which would lead to an average temperature increase of 4-6°C by the end of the century. It is important to note that only two hazards are presented for illustrative purposes and do not represent the full range of climate hazards that can impact the economy (e.g., droughts, sea level rise, floods and wildfires).

2.2. Most countries could have exceeded a 1.5°C warming by 2050

Average temperature varies around the world. While the global yearly average temperature is around 15°C (already more than 1°C warmer than in the pre-industrial era), the yearly average temperature at the surface spreads from less than 5°C in Canada or Russia, to more than 30°C in the tropics. However, the projected, climate change-induced increase in temperature is not uniform across regions, with high-latitude areas (i.e., currently cold areas) experiencing a larger increase than tropical regions (see Figure 1). In the scenario studied, the average temperature in Canada, Russia or Scandinavia is expected to increase by 2-3°C between 2000-2050 (i.e., a 3-4°C increase since the pre-industrial era and well above the Paris agreement global objective). In the tropics, the temperature increase is expected to be around 0.5 to 1°C from 2000 to 2050 (i.e., a 1-2°C increase since the pre-industrial era).

It is important to highlight that the 1.5°C objective is a global average objective and includes both the continental and oceanic areas of the world. Warming being slower for the ocean than for the emerged lands, reaching a global warming of 1.5°C or 2°C would actually mean higher values for most continental areas, as early as the 2050 horizon. Low-latitude countries, already experiencing a higher average temperature, will see their temperature increase significantly, whereas high-latitude, colder countries will be impacted by a much more dramatic climate change. The transmission of these physical impacts to the economic system would materialize in several ways: change in labor productivity, energy consumption, agricultural yields, etc.

Figure 1. Changes in the Average Temperature in 2050, SSP585 Climate Scenario



Notes: The impact of climate change on average temperature will significantly vary around the world. The average temperature is expected to increase by 2 to 3°C globally by 2050 (compared to the end of the 20th century), but by less than 1°C in the tropical regions. This means that by 2050, the temperature in many countries will be 3-4°C higher than during the pre-industrial era, well above the Paris Agreement global objective.

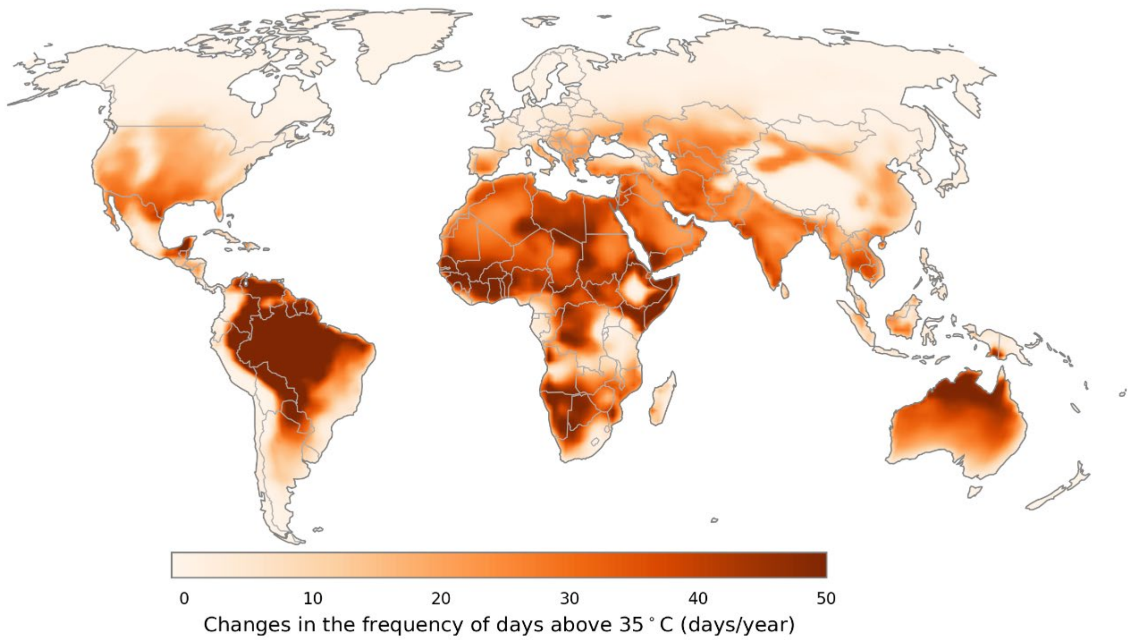
2.3. Very hot days: the new normal even beyond the tropical regions?

We also consider the evolution of the frequency of very hot days − defined here as days of the year with a maximum temperature above **35°C**. This threshold was selected for illustrative purposes, but the same analysis could be carried out for any temperature threshold that is deemed impactful for a given asset, activity or group of people.

As for average temperatures, exposure to very hot days is highly heterogeneous, the tropical countries being exposed to a few weeks up to a few months of very high temperature. Europe and the United States are exposed to a few days to a few weeks (e.g., in the south of Spain or the Midwest in the United States). However, the evolution of the frequency of very hot days in the first half of the century is dramatic in many areas, with a doubling of very hot days in South America, Southern Europe, Central Australia or Southern Africa, for example. These very hot conditions can impact livelihoods and cause severe health issues, especially for outdoor workers and can trigger large business impacts (e.g., disruptions in the production processes, reorganization of work organization, health issues for workers, etc.).

Transportation can be impacted too, for instance the airborne sector with difficulties for take-off and landing, or damages to concrete buildings and runways. Summer heatwaves will become the norm in countries that have been experiencing few such events in the past. Finally, extreme heat events can boost drought periods and increase the pressure on water resources.

Figure 2. Changes in the Frequency of Very Hot Days in 2050, SSP585 Climate Scenario



Notes: By 2050, the frequency of heatwaves increases everywhere in the world and the tropical, warm countries will experience significant heatwaves periods every year. A doubling of the number of very hot days is projected in South America, Southern Europe, Central Australia or Southern Africa, potentially impacting a large part of the economy, especially for sectors relying on an outdoor workforce or for sectors dependent on stable and suitable climate conditions.

The evolutions described on figures 1 and figure 2 highlight the effect of climate change for both the average climate conditions (i.e., chronic changes) and the frequency, or intensity, of extreme events. However, climate analysis is only the first step of a physical risks assessment. The specific climate indicators (e.g., the frequency of exceeding an impactful threshold) need to be translated into physical and financial impacts to fully understand the impacts of climate change on assets, activities and livelihoods. Such a quantified approach is explored in the next section, focusing on the average temperature indicator.

3. Unmitigated climate change would be challenging for sovereign financial stability

The two climate hazards highlighted in the previous section are good illustrations of the heterogeneous impacts of physical risks from climate change. However, when it comes to studying the economic and financial impacts of such hazards, it is important to consider the economic and financial resilience of sovereigns. All economies do not have the same financial capacity to adapt to unmitigated climate change.

3.1. Context and methodology

In the first two parts of the series, "Anticipating the climate change risks for sovereign bonds", we have reached a milestone toward the wider project of investigating the use of forward-looking analyses to assess climate change risks, as recommended by regulating international institutions. Building on the Network for Greening the Financial System[2] (NGFS) approach, we explore different scenarios in terms of climate evolution and transition towards a low carbon economy. The methodological framework allows a country-level assessment of climate change risks[3] from economic and financial standpoints.

This study focuses on physical risks only. Like in the two initial papers of the series, the country assessment methodology relies on Burke and Tanutama (2019)[4], who establish a relationship between productivity (i.e., GDP) loss and temperature increase[5], allowing the calibration of a damage function.

The GDP shock implied by the temperature increase is then reflected in the debt dynamic of sovereigns. We assume that physical damage would increase the debt-to-GDP ratio since it lowers fiscal revenues as damages affecting infrastructures, employment, manufactured products and services should reduce the tax base. We then build default probabilities, using a proprietary model that is based on an empirical calibration of default threshold[6].

Compared to our previous studies on the impact of temperature increase in 2050 for 26 countries constituents of the World Government Bond Index (WGBI) in the RCP 8.5 scenario[7], we provide a more in-depth impact assessment in this study:

- Include 113 countries[8], allowing a more detailed analysis for emerging markets and developing economies;
- For three different time horizons: 2030, 2040 and 2050;
- In the context of three different climate scenarios[9]: RCP 2.6 (corresponding to about 1.6°C warming), RCP 4.5 (about 2.5°C warming) and RCP 8.5 (about 4°C warming).

[2] The NGFS is a network of 87 central banks (ECB, BoJ, BoE, Fed, etc.) and 13 supervisors (IMF, WBG, BIS, etc.), launched at the One Planet Summit in 2017 in Paris, aiming at strengthening the global response required to meet the goals of the Paris agreement and to enhance the role of the financial system to manage climate change-related risks.

[3] In the paper "Anticipating the climate change risks for sovereign bonds", both transition and physical risks are assessed, although only physical risk is considered in the report.

[4] Burke, M., & Tanutama, V. (2019). Climatic constraints on aggregate economic output (No. w25779). National Bureau of Economic Research.

[5] This study does not directly capture the impact of extreme weather events and the rise in sea levels on GDP.

[6] Collard, F. Habib M. & Rochet J.-C. (2015). Sovereign debt sustainability in advanced economies. Journal of the European economic association, 13(3), 381-420 and Collard, F. Habib M. & Rochet J.-C. (2016) The reluctant defaulter: a tale of high government debt. Swiss Finance Institute Research Paper Series 17-39.

[7] Corresponding to the "Hot House World" scenario in the NGFS framework

[8] Albania, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Bangladesh, Belarus, Belgium, Benin, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Burkina Faso, Cambodia, Cameroon, Canada, Chile, China, Colombia, Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Ethiopia, Finland, France, Gabon, Georgia, Germany, Ghana, Greece, Guatemala, Honduras, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Kazakhstan, Kenya, Kuwait, Latvia, Lebanon, Lithuania, Luxembourg, Macedonia, Malaysia, Mali, Mauritius, Mexico, Moldova, Mongolia, Morocco, Mozambique, Namibia, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Russia, Rwanda, Saudi Arabia, Senegal, Slovakia, Slovenia, South Africa, Spain, Sri Lanka, Suriname, Sweden, Switzerland, Tajikistan, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Ukraine, United Arab Emirates, United Kingdom,United States, Uruguay, Uzbekistan, Venezuela, Vietnam and Zambia. These 113 economies have long-term foreign-currency credit ratings from Standard & Poor's, which are useful for computing each country's default probability.

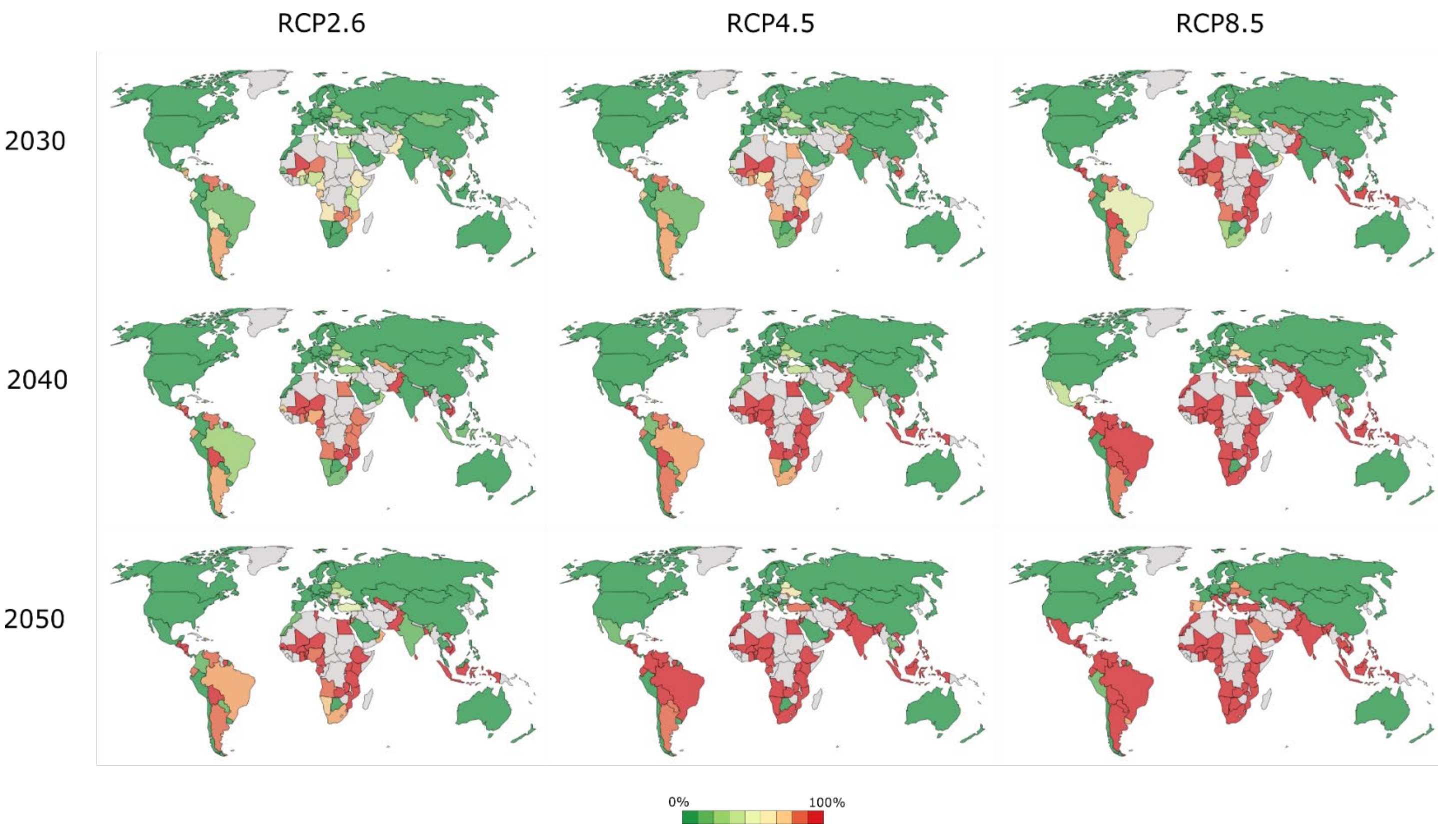
[9] In the 5th Assessment Report of the IPCC (the next, AR6, will be published in 2022), ranges of global warming (in 2100 compared to 1850-1900) are given for each RCP:

- RCP8.5 : 3.2 - 5.4°C
- RCP4.5 : 1.7 - 3.2°C
- RCP2.6: 0.9 - 2.3°C

3.2. Impact on default probability

The deepening of our previous assessment allows us to have better visibility of the physical risks from climate change for sovereign assets across time, countries, and possible climate evolutions. Then, Figure 3 shows our estimated default probabilities for the 113 sovereign issuers, three time horizons and three climate scenarios mentioned above. Green shades represent low probabilities of defaults and red shades represent high probabilities.

Figure 3. Default Probability for RCPs 2.6, 4.5 and 8.5, from 2030 to 2050



First, it is quite logical to see that the most pessimistic scenario (i.e., RCP 8.5) returns the highest number of sovereigns affected by important creditworthiness imbalances. This translates into a very high average default probability at a global scale. Turning to the most optimistic scenario (i.e., RCP 2.6, which corresponds to a global temperature rise below 2°C by 2100, reaching the Paris Agreement target), the physical risks associated with such a scenario are usually assumed to be relatively low. However, our results show that a significant number of sovereign issuers are also vulnerable under this scenario and would experience severe episodes of financial instability.

Second, it is also rational to see that the further the horizon, the higher the average default probability at a global scale. For all scenarios, average temperature is expected to rise until at least 2050, leading to increasing damages in the first half of the century.

Third, from a geographical point of view, and keeping in mind the previous validated intuitions, it appears that the most financially affected sovereigns (in terms of default probability rise) are first the least creditworthy sovereigns currently, as defined by the rating agencies (e.g., countries mostly located in Africa and Latin America), and second those with the lowest fiscal capacity[10] (e.g., South and Southeast Asia, South and Eastern Europe and obviously more sovereigns in Africa and Latin America).

Most advanced economies, although much more indebted than the emerging or developing ones, seem to be relatively spared by these creditworthiness risks related to climate change financing.

These results do not mean that every sovereign issuer in Latin America, South & South-East Asia, Africa and the Mediterranean area would default. Our model, like any other model, is not able to predict political interventions that would prevent countries from defaulting. However, given the large number of sovereign issuers that would experience severe financial stress, it is likely that global financial stability would be threatened in an unmitigated climate change scenario.

According to our estimates, a stylized fact appears in Figure 3: the three maps on the diagonal starting at the bottom left (i.e., RCP 2.6 in 2050, RCP 4.5 in 2040 and RCP 8.5 in 2030) are obviously very similar due to the almost linear increase in temperatures from a scenario to another. In this context, it seems critical to implement radical actions quickly, not only to reduce GHG emissions but also to adapt to climate change. That implies reorienting financial flows accordingly, in priority towards the most vulnerable countries.

Conclusion

This paper focuses on some of the physical impacts of climate change and the consequences for sovereign assets. It provides more detailed results in terms of time horizons, countries and climate scenarios than our previous studies. Three main findings can be highlighted:

- Emerging countries are the most widely and highly vulnerable of all to climate change, with a high default risk particularly due to lower fiscal capacities;
- Unmitigated climate change could result in the first signs of financial instability in the sovereign market by no later than 2030,
- Contrary to common belief, our analysis shows that even a Paris-aligned scenario will heighten the vulnerability to physical risks in many countries in Latin America, Africa and Southeast Asia.

Urgent actions to reduce GHG emissions and adapt to climate change seem critical in this context to mitigate the risks of financial instability. It is also important to note that international trade and financial relations across countries are not considered in our evaluation. The much higher impacts in emerging markets and developing economies would have negative feedback effects in the advanced economies through international transmission channels, which cannot be accounted for in our assessment framework at this stage. Our next research will aim to address this issue.

[10] The fiscal capacity or “fiscal space” is an established and agreed term in public policy economics. It is commonly defined as the budgetary capacity that allows a government to provide resources for public purposes without undermining its fiscal sustainability.

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