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Abstract

Europe faces a large climate investment gap. To fill it, we propose the joint issuance of climate bonds by the European Stability Mechanism. These bonds would be funded by selling greenhouse gas emission allowances via the Emissions Trading System, extended to cover all sectors. Access to the resulting funds would be conditional on countries' performance on the implementation of climate projects. European climate bonds would meet the demand for a safe, liquid and green asset, while accelerating climate investment, and increasing its resilience to sovereign crises, as well as the greening of both investors' portfolios and monetary policy.

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1 Introduction

Most scientists agree that the trend increase in greenhouse gas (GHG) emissions stemming from human activities is responsible for global warming (IPCC, 2022a; EC, 2022a).[1] This has triggered awareness of the urgency to limit GHG emissions, so as to avoid the potentially catastrophic effects of global warming. To this aim, in 2015, the United Nations (UN) approved the Paris Agreement, which set the target to limit global temperature increase to "well below 2°C above pre-industrial levels", and has been so far ratified by most UN countries (UNFCCC, 2015). However, recent analyses show that countries are not on track to deliver on this target, as most of them have not introduced yet stringent limits on GHG emissions (Conference of the Parties, 2021). Indeed, with the exception of the COVID-19 period, CO_2 emissions from fossil fuel combustion and related activities have increased so rapidly as to put the world on course for a temperature rise of 2.9°C by the end of this century (Burton and Muttitt, 2023). 2023 has been the hottest year on record, with a 1.46°C rise in the average world temperature relative to the pre-industrial level (Copernicus Climate Change Services, 2023), and the European Union (EU) already reaching 2°C on average in 2021 (Euractiv, 2022).

Failing to deliver on the Paris Agreement temperature target is expected to entail large economic and social costs, due to increasingly frequent and severe disasters (climate physical risks), and to the structural adjustments of the economy required for fast decarbonization (climate transition risk).[2] Climate-related losses have already risen from \$895 billion (bn) in the 1978-1997 period to \$2,250bn in 1998-2017 – a 150% increase (UNDRR, 2018). Even under conservative estimates of future damages from climate change, and limiting the analysis to the euro area, delaying the low-carbon transition after 2030 would lead to over 12% real GDP loss by 2050 compared to an orderly low-carbon

[1] While in the pre-industrial age (i.e., before 1900) the CO_2 concentration was on average 278 ppm (parts per million), it has steadily increased thereafter, especially since 1960 (320 ppm), reaching 424 ppm in May 2023. Over the same interval, the global temperature has feature a similar long-run accelerating increase: it rose by an average 0.08° C per decade from 1880 to 1981, and by an average 0.18° C per decade from 1981 to 2022 (NOAA, 2022).

[2] See also NGFS (2019); ECB (2020) and BIS (2021).

transition (Gourdel et al., 2022).[3] From 2014 to 2022, Europe has already experienced a substantial increase in a range of adverse effects of climate change, including heat waves, changing precipitation patterns, sea-level rise, and increased frequency and intensity of extreme weather events (IPCC, 2022a). The economic costs are likely to be even larger in developing countries, which can invest fewer resources in climate action.

However, mitigating climate change and adapting to it requires large investments and coherent policies (IPCC, 2022b). Recent estimates by the Climate Policy Initiative (Buchner et al., 2021) place the funding needs in the range of 4.5 to 5 trillion (tn) dollars per year at the global level, mostly for investments in transport, energy systems and efficiency.[4] In the EU, climate investment needs range between €550bn and €912bn per year.[5] Nevertheless, such estimates mostly cover climate mitigation investments, which are aimed at reducing GHG emissions. Instead, the financing of climate adaptation investments, which are meant to build resilience to climate change, is still largely neglected and imprecisely estimated.

Current plans by the European Commission (EC) go partly towards filling these investment needs, with ambitious programs such as the Green Deal and the Next Generation EU (EC, 2019, 2022d).[6] Nevertheless, the resources currently budgeted for climate investment programs by the EU and its Member States (MS) cover less than half of the investment needs in this area, resulting in a large investment gap (see Section 2 below). Moreover, these programs mostly focus on mitigation, and fail to address the large and growing need for adaptation investment, which have the nature of public goods and therefore require public funding. Furthermore, EU climate investment programs are threatened by policy uncertainty (Battiston et al., 2021), including changing green standards, the

[3] An orderly transition is defined by the Network for Greening the Financial System (NGFS) as a situation in which climate policies, e.g. a carbon tax, are introduced before 2030 and in a predictable way, thus limiting adjustment costs (NGFS, 2019).

[4] These investment needs greatly exceed those currently undertaken. Global mitigation investments amounted to approximately \$1.3tn in 2021-22 (IPCC, 2022b). Adaptation investments have reached \$63bn worldwide (Buchner et al., 2023).

[5] For details, see EC (2022b, 2021b, 2022c)

[6] The EC has also undertaken relevant actions regarding climate disclosure (e.g. EC (2020)) and climate risk assessment, including climate scenario analysis and climate stress-test (ECB, 2022; EIOPA, 2022).

potential weakening of green regulation by populist politicians, and the reallocation of climate funding to other priorities.[7] Finally, the implementation of climate programs is hindered by the lack of a common and coherent fiscal framework, and by differences in fiscal and implementation capacity across MS. In this regard, the new EU fiscal rules will tighten fiscal space of MS, implying likely reductions in their ability to invest in climate mitigation and adaptation.[8]

Filling the European climate investment gap is crucial to limit the effects of climate change on the economic performance and the financial stability of EU MS (Battiston et al., 2017; NGFS, 2019; ECB, 2020). To address this gap, we propose to introduce a joint climate debt financing scheme. Our proposal consists of three complementary policy reforms: (i) the introduction of a uniform EU carbon pricing scheme for all sectors, (ii) the joint issuance of European climate bonds, to be serviced by the revenues of the common carbon pricing scheme, and (iii) the implementation of a European climate policy plan funded by the issuance of these bonds.

The EU carbon pricing scheme is to be based on the sale of carbon emission allowances that polluting firms and households are required to purchase to be compliant with EU regulation. To this purpose, we propose an extension of the EU Emission Trading System (ETS) to all sectors, in line with current plans by the EC.[9] This scheme would substitute for a EU-wide carbon tax, as it would face all European firms and households with a common carbon price, equal to the ETS permit price. By fine-tuning its sales of ETS permits, the EC would be able to calibrate this EU-wide carbon price at a level consistent with a science-based target. The ETS permit sales would enable the EC to directly appropriate the resulting revenue: compared to a system of national carbon

[7]See for instance Taylor (2021) and Gavin et al. (2023).

[8]The agreement includes benchmark thresholds for all countries for annual average reduction of one percentage point in the debt ratio for countries with debt above 90% (e.g. Italy, France and Spain) and 0.5% for those between 60% and 90%, and a structural deficit margin of 1.5% of GDP, see EC (1997).

[9]The ETS issues pollution permits and auctions them several times per year. Moreover, it enables participants to trade these emission permits on the secondary market at any time. Currently, the ETS does not yet cover all industrial sectors and households: it only applies to EU firms belonging to the sectors listed in Annex 1 of the Directive 87/2003/EC (EC, 2003). However, the EC already envisages the extension of ETS emission allowances (so-called ETS 2) to fuel combustion in buildings, road transport and small firms, which are not covered by the existing ETS (EC, 2023a).

taxes, this scheme would not be at the mercy of MS' choices regarding carbon tax rates and their transfers of the resulting tax revenue to the EC. As such, ETS permit sales would effectively create the first form of EU common fiscal capacity. This would prevent the weakening of mitigation targets driven by political instability at national level and by the capture of MS governments by pressure groups.

To identify the potential fiscal capacity created by the sale of ETS permits, we compute the present discounted value (PDV) of the revenues that these sales will generate under alternative scenarios for the future path of carbon prices, based on the climate scenarios developed by the Network for Greening the Financial System (NGFS).[10] Even in the scenario associated with the lowest possible value of the PDV (equal to €2.2tn), the resulting fiscal capacity would be of the same order of magnitude as the funding already budgeted for EU climate policies (EC, 2021a). In contrast, in the scenario where climate policies will remain fragmented across the world's regions, the fiscal capacity resulting from the proposed scheme would be much larger (€11.5tn), and could fill the EU climate financing gap for many years.

The sale of ETS allowances will enable the EC to service European climate bonds, i.e., pay their coupons and their principal at maturity. Since the revenues from these sales are inevitably uncertain, the servicing of these bonds will require resources to buffer potential temporary shortfalls of revenues relative to debt repayments. Hence, the issuance and servicing of European climate bonds must be managed by an agency featuring both appropriate debt management expertise and sufficient equity capital to reassure investors about the safety of these bonds. Among EU institutions, the European Stability Mechanism (ESM) fulfills both of these requirements: first, it already manages the issuance and servicing of the bonds funding the €800bn NextGenEU program; second, it currently has a lending capacity of €422bn.[11] We expect the servicing of these bonds to be cheaper than that of bonds issued via the NextGenEU program, due to their regular issuance,

[10]See Menon et al. (2022)

[11]To place this number in perspective, the European Investment Bank (EIB) issues €60bn a year. See "Celebrate that European safe assets have joined the €1tn club", *Financial Times* (2024).

greater scale, and exclusive objective of financing "green" investments.

Access to the bonds' revenues will contribute to avoid the postponement of urgent climate investments in all EU MS. European climate bonds will also contribute to meet the current demand for a EU safe asset, which would form the backbone of an integrated European capital market, and thus contribute to the accomplishment of the long-awaited Capital Market Union (CMU) in Europe. At the same time, the issuance of such bonds would help global investors to green their portfolios. Finally, these bonds may prove a valuable addition to the portfolio of assets held and traded by the European Central Bank (ECB) in the conduct of its monetary policy.

A novel feature of our proposal is the coordination between EU-level fiscal and climate policies. Beside creating a federal fiscal capacity to jointly fund climate investments in Europe, it would entrust the EC with the design of European climate policies and bring discipline to their implementation, by tying countries to a system of check and balances on the use of the funds raised by issuing European climate bonds. Indeed, in our proposal, access to these funds will be conditional on countries' performance regarding the implementation of planned climate investments. Project delivery will be evaluated against the achievement of a set of Key Performance Indicators (KPIs), to be supervised by the European Investment Bank (EIB).

The paper is organized as follows. Section 2 quantifies the EU climate finance investment gap, considering both mitigation and adaptation policies. Section 3 discusses why it is more efficient to design and fund climate policies at the EU level rather than at the national level. Section 4 presents our policy proposal, and estimates the European climate bond's issuance capacity based on the climate scenarios generated by the NGFS for the EU. Section 5 discusses the macroeconomic and financial benefits from the issuance of European climate bonds. Section 6 presents concluding remarks.

2 The European climate investment gap

Climate investments have two distinct but interconnected objectives, i.e. mitigation and adaptation. Mitigation investments aim at preventing or decreasing the release of pollutants that contribute to climate change, for instance replacing fossil-fueled energy production with nuclear, solar, wind and geothermal energy plants, and connecting these to power-hungry, densely populated areas by suitably extending the power grid. In contrast, adaptation investments aim to increase the resilience of the economy to the effects of climate change, e.g. by protecting coastal areas against sea-level rise and areas exposed to the risk of floods, wildfires and landslides. Mitigation and adaptation investments are complementary: reducing emissions via earlier and more effective mitigation results in lower global temperature increase, and therefore in lower incidence and costs of climate-related natural disasters. Hence, both types of investments are needed to increase societal resilience to climate change.

Climate investments are usually funded by general taxation or by carbon taxes, as well as the revenues from the sale of emission allowances such as the ETS in the EU. They are also funded via the sale of green bonds, whose proceeds are earmarked to finance investments in renewable energy, transportation and construction industries.[12]

Europe's mitigation investment needs over the period 2020-30 include €58.4 bn per year to be invested in the electric grid and €336 bn per year for energy system investments, excluding transport (EC, 2021b, 2022c), while estimates of adaptation needs vary widely, ranging from €158 to 518 bn/year (EC, 2022b). Based on available estimates, the sum of EU mitigation and adaptation needs ranges between €550bn/year and €912bn/year (EC, 2022b, 2021b, 2022c). The official EU estimate is in the middle of this range: the EU-27 MS and the EC must invest over €700 bn per year to achieve the Green Deal target of Net Zero emissions by 2050 (EC, 2023d).

The resources currently budgeted by the EU and its MS for their climate policies in 2021-27 fall short of these investment needs. The EC long-term budget of €2tn at

[12] See EC (2023b).

current prices (30% of EU budget) implies spending about €330 bn/year for mitigation, adaptation and cost of natural disasters (EC, 2021a). In addition, within the Recovery and Resilience Facility Programs, EU MS were required to allocate at least 37% of spending to climate investments (EC, 2021c). This leaves a sizeable gap between EU climate investments needs and budgeted expenses. Based on the EU official estimates of its investment needs (€700 bn/year), this "climate investment gap" amounts to

$$\text{investment gap} = \underbrace{\text{investment needs}}_{\text{€700bn/y}} - \underbrace{\text{budgeted expenses}}_{\text{€330bn/y}} = \text{€370bn/y}$$

Based on the €912bn/year upper bound of climate investment needs, the gap would rise to €582bn/year. In fact the gap may be even larger, considering that these estimates may still omit mitigation and adaptation needs that we are unaware of, given the uncertainty associated to climate impacts.

3 Designing and funding European climate policies

In principle, the EU climate investment gap may be partly covered by national MS budgets. However, in 2019 EU MS only spent €90bn on climate investments (OECD, 2022), namely, less than one quarter of the investment gap. This highlights the challenges of financing climate investments at the national level.

Moreover, recent experiences of financing climate investments by individual MS are quite heterogeneous, with some countries being more active, and others being unable to allocate adequate resources to climate policies out of their national budgets and to implement climate investment projects, such as those envisaged by the NextGenEU program (EC, 2021a).

Hence, designing and enforcing climate policies at the supra-national level could not only contribute to increase overall spending on climate actions in Europe, but also reduce inefficiencies due to their cross-country heterogeneity, as described in Section 3.1. European institutions are obvious candidates to be entrusted with the design and enforcement of joint climate policies. But such enforcement would be more effective if the raising and allocation of the funding required for such policies were done at the supranational level, as discussed in Section 3.2.

3.1 Why climate policies should be designed at the EU level

Designing climate policies at the national level can generate inefficiencies for several reasons, namely, (i) spatial spillovers, (ii) regulatory externalities and (iii) regulatory capture.

First, carbon emission spillovers across national borders imply that individual MS may opt for too lenient environmental targets, because the resulting harm would be partly borne by neighboring countries.

Second, polluting firms can choose across different jurisdictions by relocating their activities across national borders ("emissions offshoring"), i.e., they may engage in regulatory arbitrage. For instance, increases in domestic fossil fuel prices resulting from national carbon taxes, or more stringent emissions targets, may lead to the re-allocation of production to countries with less stringent mitigation rules–a phenomenon known as "carbon leakage" (Ambec et al., 2024; Benincasa et al., 2022; Laeven and Popov, 2022). In turn, this may induce governments to set inefficiently low national climate standards. Indeed, each government has little incentive to introduce ambitious climate policies and regulations, fearing that they would induce domestic producers to relocate to more lenient jurisdictions and/or provide an advantage to foreign producers located there (Hoel, 1991; Felder and Rutherford, 1993). As a result, regulatory arbitrage also tends to lead to a "run to the bottom" in national environmental standards. [13]

Third, even if climate policy standards are designed at the supra-national level, a

[13] The EC is currently planning the introduction of the "carbon border adjustment mechanism" (CBAM) to avoid carbon leakage and distortions in international trade. The CBAM consists of imposing tariffs on imports so as to create a level playing field between domestic and foreign producers in the carbon price that they face. The EU is planning to introduce the CBAM in 2026 within the ETS. Initially, the CBAM will apply to imports of select industries (aluminum, cement, fertilizers, iron and steel, electricity and hydrogen), by charging importers of these goods a carbon tax equal to the average price of permits traded in the ETS (EC, 2023c).

similar "run to the bottom" may arise in the enforcement of the common standards if it is left to national governments. Insofar as national authorities are captured by domestic pressure groups and lobbies, they will tend to water down the enforcement of climate policies and regulations within their respective jurisdictions. Here a fitting parallel can be drawn with prudential bank supervision in the euro area: the design of common rules in banking supervision for euro-area banks has been supplemented by common enforcement by the Single Supervisory Mechanism (SSM), recognizing that national central banks might otherwise be too lenient in their supervisory role. Entrusting climate policy standards to a supra-national authority would also shield these standards from the vagaries of national politics in countries featuring high government instability, thus increasing their credibility over time.

Designing climate policies at the supra-national level can address these inefficiencies, by settings the standards and objectives of climate policies exclusively on the basis of their contribution to decarbonization, while leaving their implementation to MS, as done under the current EU climate strategy in connection with the NextGenEU, consistently with the subsidiarity principle. The EU would however monitor the implementation of climate policies and projects by MS, by setting KPIs and entrusting their enforcement to the EIB, so as to overcome possible inefficiencies and moral hazard issues. To ensure incentive compatibility of this scheme, the EU can threaten to withhold further funding of non-compliant MS, again in line with the NextGenEU program.

3.2 Why climate policies should be funded at the EU level

As already noted, limited fiscal space may constrain public financing of climate policies. This already currently applies to EU MS featuring high public debt and elevated cost of debt service, but the fiscal constraint on their climate policies is likely to become even more stringent after 2024, once the Stability and Growth Pact is reinstated. This will require large fiscal adjustments by several MS, and currently does not yet contain any exemption for green investment (i.e. "green golden rules"), as highlighted by Zettelmeyer

(2023).

The resulting under-investment in climate policies in some EU MS is likely to have negative spillover effects on other EU MS. First, there may be climate risk spillovers via greater cross-border emissions, as already noted in Section 3.1. Second, under-investment in climate policies by high-debt countries would increase their exposure to natural disasters, weakening not only their own economic performance, but also that of other EU MS via demand and supply chains. For instance, more fragile countries would tend to import less from the rest of the EU, and would contribute fewer exports of intermediate goods to foreign production. These spillover effects could be amplified by financial market reactions: investors may respond to increased climate risk in the affected countries by repricing their sovereign debt and cutting back on lending. This may generate a sovereign debt crisis, with potentially destabilising effects for other EU countries.

Therefore, allocating resources across EU MS so as to enable also the more vulnerable MS to fund climate policies is not only in the interest of high-debt EU countries but in that of the EU as a whole. Moreover, relaxing the fiscal constraint on climate investment is all the more important considering that most climate investments will be frontloaded, as earlier spending on climate policies is expected to achieve larger co-benefits and imply fewer GDP losses from natural disasters (Gourdel et al., 2022; Emambakhsh et al., 2023).

Thus, efficiency requires joint EU-level climate financing. This is in line with the growing consensus for the creation of an EU fiscal union to fund EU spending on common goods. In this regard, the former ECB President Mario Draghi recently stated that

> "Europe must now confront a host of supranational challenges that will require vast investments in a short time frame, including defence as well as the green transition and digitisation. As it stands, however, Europe neither has a federal strategy to finance them, nor can national policies take up the mantle [...] Without action, there is a serious risk that Europe underdelivers on its climate goals" (The Economist, October 2023).

Relatedly, over 100 EU economists signed the 2023 Manifesto for Europe (Joaquin et al., 2023), which calls for a fundamental reform of the EU budget built on a permanent or, at least, recurrent central fiscal capacity to supply European Public Goods in the triple green, digital and social transition. Recently, the President of the ECB, Christine Lagarde, also highlighted that joint EU-level climate financing may have important distributional benefits, as she stressed the importance of "sharing the burden fairly" so as to mitigate the short-term costs and related backlashes of frontloading green investments (Lagarde, 2023).

4 The policy proposal

Our policy proposal consists of three complementary reforms: the introduction of a uniform EU-level carbon pricing scheme, the joint issuance of European climate bonds to be serviced by the revenues of this scheme, and the design and implementation of a EU climate policy plan funded by the issuance of these bonds. Section 4.1 presents our proposed carbon pricing scheme, explaining how it differs from existing carbon pricing regimes in Europe. Section 4.2 explains how joint issuance of European climate bonds would enable the EU to tap the additional fiscal capacity created by the EU carbon pricing scheme, and compares it to the issuance of NextGenEU bonds currently implemented by the EC. Finally, Section 4.3 presents estimates of the federal fiscal capacity created by our policy proposal, and thus of the potential issuance of European climate bonds, under different scenarios for the future path of carbon prices and revenues. These are in turn based on the climate scenarios generated by the Network for Greening the Financial System (NGFS), using the REMIND-MagPie process-based Integrated Assessment Model.

4.1 A EU-wide carbon price

The EU already has the most advanced carbon pricing regime in the world (World Bank, 2023). In particular, the EU ETS is the first and largest cap-and-trade system allowing firms to trade CO_2 equivalent emission permits. The market is formed by two segments:

a primary market with auctions, where permits are sold by the EC to firms, and a secondary market where firms and financial intermediaries continuously trade outstanding allowances. This market generates a single carbon price for the whole of the EU at each point in time. Since firms in all the EU-27 MS are subject to the EU ETS directive (EC, 2003), they must all pay the carbon permit price determined by the ETS, which in 2023 amounted to €88 per ton. Currently, the revenues from the sale of ETS allowances (around €20-25bn per year) are rebated to the respective MS and to the European Environmental Agency (EEA) and are mainly used to support climated policies (European Enviroment Agency, 2023).

On top of this market-based system for carbon allowances, various EU countries also feature national carbon taxes, whose rates vary greatly across them and generally differ from the common ETS rate, as shown by Figure 1: in most countries, carbon taxes are levied at a considerably lower rate than the ETS carbon price, with Sweden being an exception. Moreover, the emission tax rate can differ across pollutants, with some countries featuring two different rates, shown in the figure as carbon tax (1) and carbon tax (2). For instance, Denmark features a carbon tax on fossil fuels at approximately €25 per ton, alongside with a carbon tax on fluorinated gases at approximately €20 per ton. Similarly, Finland has a dual-tiered carbon tax system, encompassing a tax of €78 per ton on transport fuels and around €53 per ton for other fossil fuels. Estonia, France, Latvia, Spain and Sweden, instead, feature a single carbon tax rate. Finally, Germany and Italy charge no carbon tax, although Germany has an additional ETS on heating and transport fuels since 2021.

Both carbon taxes and ETS carbon allowances are policy instruments aimed at deterring GHG emissions. However, they differ in their characteristics and mechanisms. First, the allowances traded on the ETS set an upper bound on total carbon emissions and can be bought by firms depending on their needs, while carbon taxes place a price tag on emissions. Second, the ETS determines a single carbon price for the whole EU and applies to CO_2 emissions by all firms in a given sector (e.g., steel production), irrespective of the

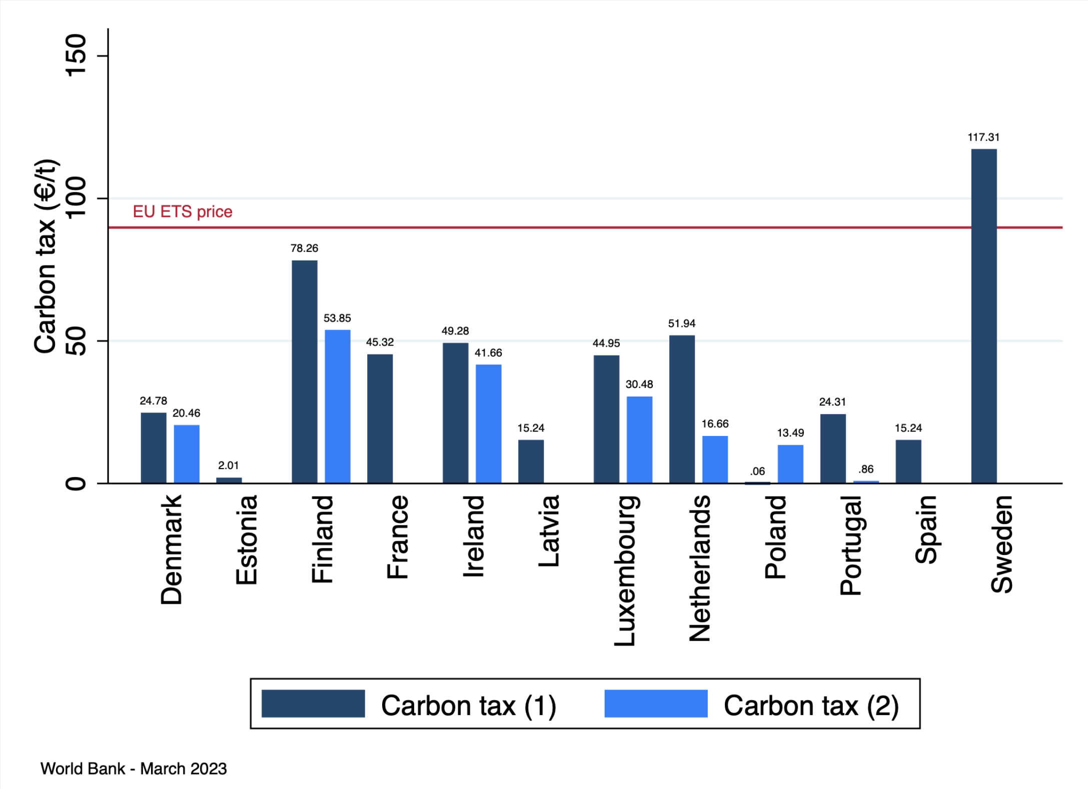


Figure 1: EU carbon tax rates

Source: World Bank (2023). See the Appendix (Table 2) for definition of carbon tax rates.

energy sources being used; in contrast, carbon taxes are set at potentially different levels by national member states and apply to specific sources of energy, such as fossil fuels, irrespective of the sectors in which they are used. However, firms in sectors required to buy ETS allowances face no carbon taxes. For instance, in France and Sweden there is no overlap between the two carbon pricing schemes, as firms in sectors required to buy ETS allowances (e.g., manufacturing firms) are exempted from the respective national carbon taxes (Government of Sweden, 2023). In France, where the ETS price exceeds the carbon tax rate, firms in industries required to comply with ETS allowances effectively pay a higher carbon price than firms in other sectors, while in Sweden the opposite occurs.

Our proposal aims at strengthening the current EU framework of carbon pricing by extending the requirement of ETS allowances to all sectors, so as to face all EU firms with a uniform and predictable carbon price. At each date, the EC can manage the supply of allowances available to firms so as to target a pre-announced, science-based path for ETS carbon prices, taking into account and smoothing temporary fluctuations in the demand for emission allowances. In principle, the EC can manage the supply of allowances both by changing the amounts sold in the primary market via auctions and by operating on the secondary market in the same way as central banks manage the money supply via open-market operations to target interest rates.[14]

A key aspect of our proposal is that the EC would retain the revenue resulting from the sale of ETS allowances within the EU budget (rather than rebating it to MS as currently done), effectively reallocating fiscal revenue from the state to the EC level and creating a source of federal tax revenue at the supranational level. However, this fiscal capacity would be deployed to fund climate policies designed and agreed at the EU level in the various MS according to climate risk priorities. Note that MS that generate more carbon emissions would contribute more to EU climate policies, as their firms and households would purchase a greater amount of ETS allowances; however, these MS would also benefit proportionately from spending on mitigation policies aimed at reducing future carbon emissions. This should ensure a rough long-term proportionality between the fiscal revenue contributed by each MS to this scheme and the funding it receives for its mitigation policies. However, some deviations from such proportionality between contributions and spending across MS may be required to face adaptation investment needs (e.g., protection against sea-level rise or floods and hydro-geological erosion), which are likely to be disproportionately concentrated in some MS.

The proposed amendment to the current ETS would have three important implications. First, the new design of the EU ETS would be efficient, as it would face all emitters with a uniform carbon price, irrespective of their sector and national jurisdiction. Second, it would reduce transition risk in the EU, as firms and households would be able to base

[14]Currently, the Market Stability Reserve (MSR), implemented since 2019, represents a long-term solution to address issues related to the supply of EU ETS allowances and their price (European Parliament, 2015). The surplus of allowances allocated during the initial two phases of the EU ETS and the consequent drop of the permit price required the creation of measures to regulate allowance supply. The MSR, designed to rectify over-allocation and to improve the system's resilience to major shocks, operates within the auction market to achieve its aims. However, it could be reasonable to extend the MSR's operations to the secondary market, so as to fulfill the role outlined in this proposal.

their investment decisions on a pre-announced target path for carbon prices. Third, since it would enable the EC to appropriate all the revenue stemming from carbon pricing in the EU via sales of ETS allowances, it will make national carbon taxes redundant. These revenues will provide the federal fiscal capacity needed to fund the issuance of European climate bonds, as explained in the next section.

4.2 Issuance of European climate bonds

European climate bonds are to be jointly issued by a EU-level institution on behalf of all MS, and to be serviced them with the revenues from sales of ETS carbon allowances, as described above. Such a bond will appeal to investors for two main reasons.

First, European climate bonds will enable investors with a sustainability mandate (e.g. Environmental Social Governance institutional investors, Net Zero alliance signatories, etc) to "green" their portfolios, because our proposal restricts the use of the revenue raised via their issuance to the exclusive funding of climate policies. This is envisaged to occur via conditionality clauses mandating precise criteria for the quality of the projects and via monitoring of their implementation through KPIs by the EIB. This should enable European climate bonds to command a "greenium", i.e., a lower yield on account of them being exclusively and credibly earmarked to support climate policies.[15]

Second, the bond will be regarded by investors as a EU safe asset, on a par with national sovereign bonds, being directly backed by the revenue that the EC would obtain from sales of ETS allowances. As such, it would support a favorable treatment by prudential regulation of banks' and insurance companies' exposures, and would be used by

[15] Currently there is no universal agreement in the literature regarding the existence of the greenium in the sovereign bonds market. Grzegorczyk and Wolff (2022) and Baker et al. (2022) document a systematically lower yield for green sovereign bonds compared to traditional bonds, indicating a positive greenium. In contrast, according to Bolton et al. (2022), the evidence is consistent with a negative greenium, i.e., with the yield of green bonds exceeding that of comparable conventional bonds. They argue that this result hinges on the lack of credible, legally binding commitments from sovereign issuers to earmark funds for green projects, leading to investor distrust. However, as mentioned above, our proposal restricts the funds raised through the issuance of European climate bonds to the funding of climate policies and envisages a mechanism to monitor their implementation. Hence, they should be able to command a greenium.

the ECB as collateral in its monetary policy operations. If the issuance of these bonds is entrusted to the European Stability Mechanism (ESM), their repayment could also be guaranteed by unused ESM resources, so that the cost of servicing the bond would benefit from ESM's rating. Entrusting issuance of European climate bonds to the ESM would also capitalize on the expertise and proved track record of an existing supranational institution in issuing bonds on behalf of the EU.

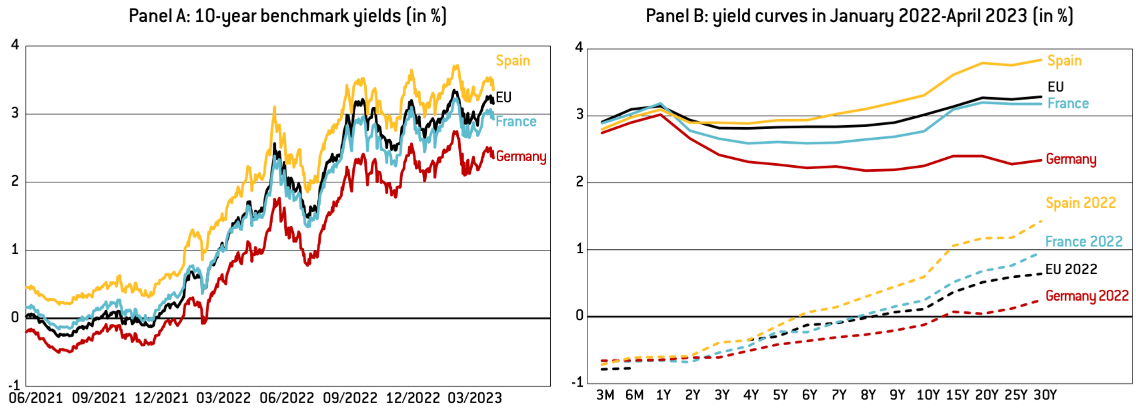
These characteristics would enable the issuance of European climate bonds to overcome some of the limitations of the current issuance of European bonds within the NextGenEU program in terms of borrowing costs and liquidity. This program allowed the EC to borrow up to €750bn by 2026, issuing bonds with maturities ranging from 3 to 30 years, based on a pre-agreed issuance volume, and placed mainly via bank-syndicated transactions. Moreover, no debt rollover was foreseen: bonds are to be repaid starting from 2028 up to 2058 (Claeys et al., 2023).[16]

Some weaknesses of the NextGenEU bonds emerge considering their funding cost: in 2023, their yields exceeded German ones by about 80 basis points (bp), and also French ones by about 20 bp, even though they were below their level in 2021 (Figure 2). This yield differential may reflect the comparatively low market liquidity of EU bonds: the bid-ask spread for 10-year NextGenEU bonds greatly exceeds that of the French and German bond with the same maturity, and recently also that of Spanish bonds, while their trading volume is way lower than that of these countries (Figure 3).

However, European climate bonds are envisaged to differ from NextGenEU bonds in several important respects, making them far more appealing to investors and thus able to command lower yields (see Table 1):

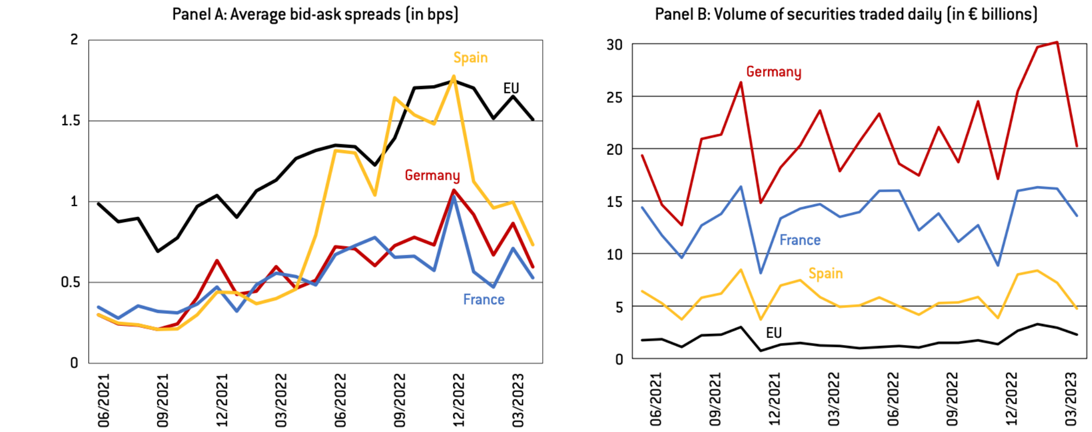
1. Being serviced by the predictable cash flow of sales of ETS carbon allowances for several decades, even long-maturity European climate bonds could be rolled over several times and thus could be frequently issued according to a pre-announced

[16]EU MS recently agreed to increase the EU's debt guarantees by adding 0.6% and might introduce new own EU resources in the future (European Parliament, 2021; Claeys et al., 2023).



Source: Bruegel based on Bloomberg. Notes: dashed lines represent data as of 3 January 2022 while unbroken lines represent data as of 11 April 2023. For January 2022, the EU yield curve was incomplete so the values for the 1- and 3-year maturity yields are extrapolated.

Figure 2: NextGenEU bond performance. Panel A shows the 10-year benchmark yield (in %), Panel B shows the yield curves between January 2022 - April 2023 (in %).



Source: Bruegel based on Bloomberg. Notes: Panel A: Monthly average of bid-ask spreads for 10-year bonds for selected issuers in basis points. Panel B: Monthly average of daily volume of security trades by issuer in € billions.

Figure 3: NextGenEU bond bid-ask spread and volumes. Panel A shows the average bid-ask spreads (bp), Panel B shows the volume of securities traded daily (bn€).

regular calendar. This would guarantee a steady flow of freshly issued bonds, which are typically the most actively traded and liquid ones.[17] .

2. The scale of their total issuance would be from 3 to 15 times larger than that of the NextGenEU bond issuance (see Section 4.3 below). This should also contribute to making them more liquid than the NextGenEU bond, as larger asset issuance is well known to be associated with lower bid-ask spreads and higher turnover rates

[17] Krishnamurthy (2002), Goldreich et al. (2005) and Goldstein and Hotchkiss (2020) document not only that "on-the-run" bonds are more liquid than "off-the-run" ones with the same residual maturity, but that investors require a lower yield on them, reflecting a lower liquidity premium.

(Foucault et al., 2023).

3. While NextGenEU bonds are backed by MS via off-balance sheet items in their national budgets, European climate bonds would be backed by ETS sales revenues directly appropriated by the EC via the sale of EU ETS. As such, it should be considered by investors as a European-issued sovereign asset, rather than as a quasi-sovereign asset backed by national MS. This should enhance its perceived safety from investors' standpoint.[18]

4. While NextGenEU bonds are issued to fund a variety of investment programs in MS, including climate policies, European climate bonds will be *solely* issued to fund climate investments. This will appeal to investors with a sustainability mandate, and should make it more likely that European climate bonds will command a greenium.

5. Finally, while NextGenEU bonds are issued mainly via syndication procedures entrusted to a select group of large EU banks, the frequency and magnitude of European climate bond issuance would warrant them being sold via regular auctions, which typically feature lower issuance costs than a syndication mechanism.

Table 1: Differences between NextGenEU bond and European climate bonds

Next Generation EU bond	**European climate bond**
fixed issuance → no rollover	regular issuance → debt rollover
low volume → low liquidity	high volume → high liquidity
backed by MS, off-balance sheet → quasi-sovereign asset → not fully safe asset	backed by ETS sales, in-balance sheet → sovereign asset → safe asset
funding various programs → no "greenium"	only funding climate policy → "greenium"
mainly placed via syndication → high issuance cost	placed via auction → low issuance cost

[18]Since currently the EMS is restricted to receive funding only from MS, EU regulations should be modified so as to enable the EMS to receive direct from the EC as well.

4.3 European climate bond issuance capacity

The potential issuance of European climate bonds will be determined by the fiscal capacity created by the EU-level carbon pricing scheme described in Section 4.1. To assess the magnitude of this fiscal capacity, we consider the carbon price and the Kyoto GHG emissions trajectories estimated for the EU27 by the NGFS conditioned to climate scenarios characterised by different mitigation targets, building on those reviewed by the IPCC (Menon et al., 2022).

The carbon price trajectories and the corresponding adjustments in production by sector and technology in the EU, consistent with a given temperature target, e.g, below 2°C (Kriegler et al., 2013), are provided by the REMIND-MAgPIE process-based Integrated Assessment Model (IAM).[19] This model provides such trajectories for several scenarios, characterised by different mitigation ambition (coherent with a temperature target, e.g. 2° C), different level and timing of the carbon tax introduction (i.e. before or after 2030), and different levels of associated physical and transition risk. Here we use the estimated trajectories for four NGFS scenarios (described below).[20]

The structure of the REMIND-MagPie model is presented in Figure 4. It includes a macroeconomic module connected to a land use module (MagPie), informed by a vegetation module and energy system module, which is in turn connected to a climate system module (MAGICC). The model translates climate scenarios into adjustments to production levels, considering their energy technology and impact on climate. The

[19] This model belongs to the family of process-based IAM that integrate and connect via physical processes the different sectors that affect the production of emissions (e.g., agriculture, transport, energy, etc). The characteristics of each sector are captured at a high level of disaggregation by specific modules. The level of detail of sectors' representation and modelling solutions vary across process-based IAMs. For instance, in most of them the economic modules are based on partial equilibrium models and a simple Ramsey module, but some IAMs rely on computable general equilibrium models. However, all process-based IAM rely on a carbon budget approach (also called target emission approach): an optimal path of emissions (i.e., that featuring the least-cost and the maximum intertemporal utility of agents in the corresponding sector) is determined to reach a given target in terms of cumulative emissions. This approach requires estimates of technology-specific cost of energy and emission factors, and thus a high level of disaggregation in terms of technology and process. In a carbon budget approach, for each temperature in 2100 there is a corresponding amount of emissions which lead to reaching that temperature with a given probability. The carbon budget thus implies a certain carbon price.

[20] As the REMIND-MAgPIE model produces estimates for EU28 (Richters et al., 2022), EU27 Kyoto GHG emissions are obtained by subtracting the UK emissions from the EU28.

macroeconomic model establishes energy demand (considering variables such as population growth), while the energy model calculates energy supply and associated input costs based on a specified emission level and corresponding carbon price. The projected emissions pathways are used to estimate global temperature outcomes using the MAGICC model (Meinshausen et al., 2011).[21]

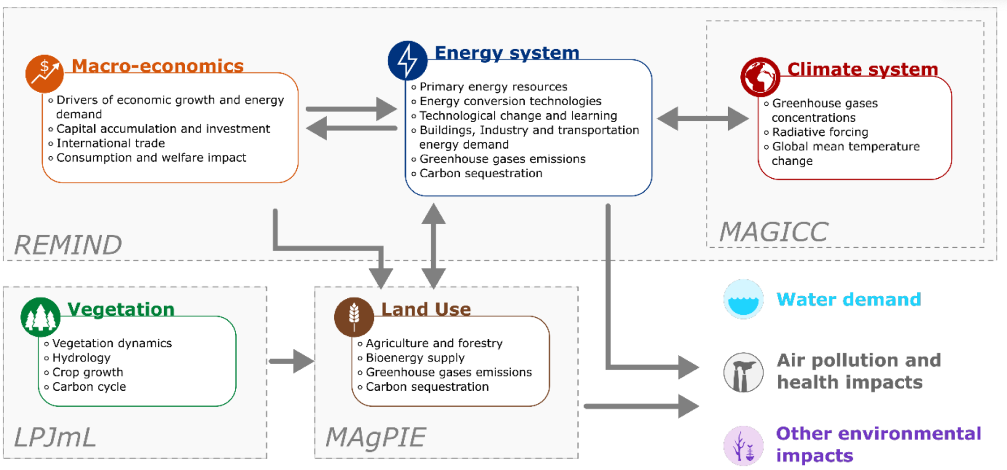


Figure 4: REMIND-MagPie framework
Source: NGFS (2022). Technical Documentation V3.1.

The four NGFS scenarios that we consider in our analysis run until 2100 and differ in terms of temperature target, timing and characteristics of climate action.[22] These distinctions translate in different levels of climate physical risk and transition risk, as illustrated in Figure 5:

1. The "delayed transition" scenario assumes a late and sudden introduction of climate policies, so that annual emissions do not decrease until 2030. The scenario features high transition risks due to delayed and hence costlier climate policies. These policies however limit physical risk by keeping temperatures below 2°C by the end of the century.

[21]The climate scenarios developed by process-based IAMs have been used for climate financial risk assessment since the climate stress test by Battiston et al. (2017). Investors in several jurisdictions (e.g. Euro-area banks and insurance companies) are required by their supervisory authorities to run climate stress tests using these scenarios (see e.g. ECB (2022)).

[22]For further details, see Allen et al. (2020); Richters et al. (2022); Menon and Stracca (2023).

2. The "fragmented world" scenario assumes a delayed and divergent climate policy response among countries globally, leading to an increase in global temperatures around 2.3°C by the end of the century, and therefore to high physical and transition risks.

3. The "below 2°C" scenario considers an early introduction of climate policies that gradually increase in stringency implying a 67% chance of reaching the 2°C target. Thus, it is associated with both low transition and physical risk.

4. The "current policies" scenario assumes that climate policies are held at the currently implemented level, leading to low transition risk due to the absence of stringent climate policies, but high physical risk due to inadequate mitigation and adaptation policies.

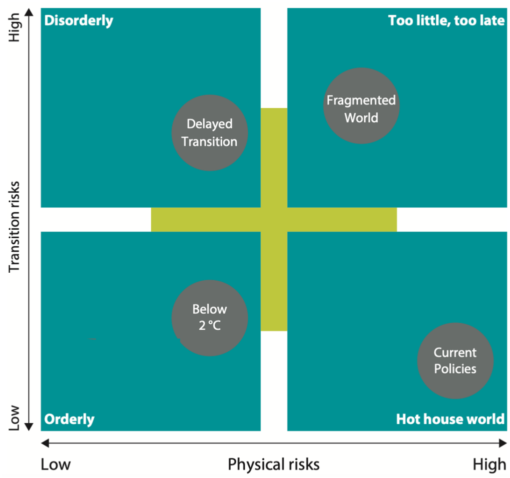


Figure 5: Selected NGFS Scenarios
Source: NGFS (2023). Scenarios for central banks and supervisors.

For each of these scenarios, Figure 6 shows the estimates of the carbon price (in 2010 US dollars/ton), i.e., the shadow price of the cost-minimisation procedure necessary to reach the relevant target emission level (Gourdel et al., 2022), and the CO_2 equivalent Kyoto GHG (CO_2, CH_4, N_2O and F-Gases) emissions in Megatons (Mt).

The "delayed transition" scenario features the highest carbon price path and, consequently, the lowest level of GHG emissions by 2050. In contrast, in the "current policies"

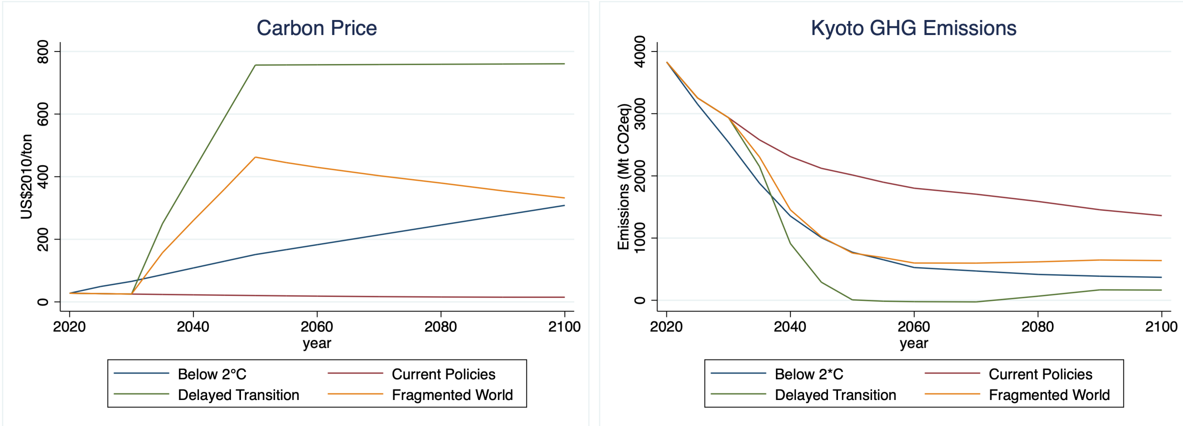


Figure 6: NGFS Scenarios Trajectories. Source: NGFS. Carbon price in 2010 US \$/ton (left), Kyoto GHG in CO_2eq Mt (right) for each scenario from 2020 to 2100.

scenario the carbon price trajectory is flat, and as a result GHG emissions are the highest and most persistent. In the "below 2°C" and "fragmented world" scenarios the path of GHG emissions is comprised between these two extremes, but in the latter the carbon price and emission paths are more unstable than in former, as the carbon price stays too low in the first decade and must therefore rise sharply in the subsequent two decades.

Assuming that the EC manages the supply of ETS carbon allowances by targeting the carbon price estimated for each of the four scenarios, the revenues accruing to the EC will equal the product of the respective carbon price (in 2010 US dollars) and the corresponding Kyoto GHG emissions, upon converting them from megaton (Mt) to ton (t):

$$\text{estimated revenues} \;=\; \text{carbon price} \times \; CO_2\text{eq Kyoto GHG emissions.}$$

Figure 7 plots the resulting revenue trajectories for each of the four NGFS scenarios. In all four scenarios, revenues from the sales of ETS allowances are estimated to stay quite sustained and stable until the end of the century, as the change in quantities (emissions) is foreseen to be compensated by the change in carbon prices in the opposite direction. In most decades, revenues are projected to be highest in the "fragmented world" scenario and lowest in the "current policies" scenario. The path of carbon revenues is foreseen to be at an intermediate and stable level in the "below 2°C" scenario, while it is unstable with a "delayed transition".

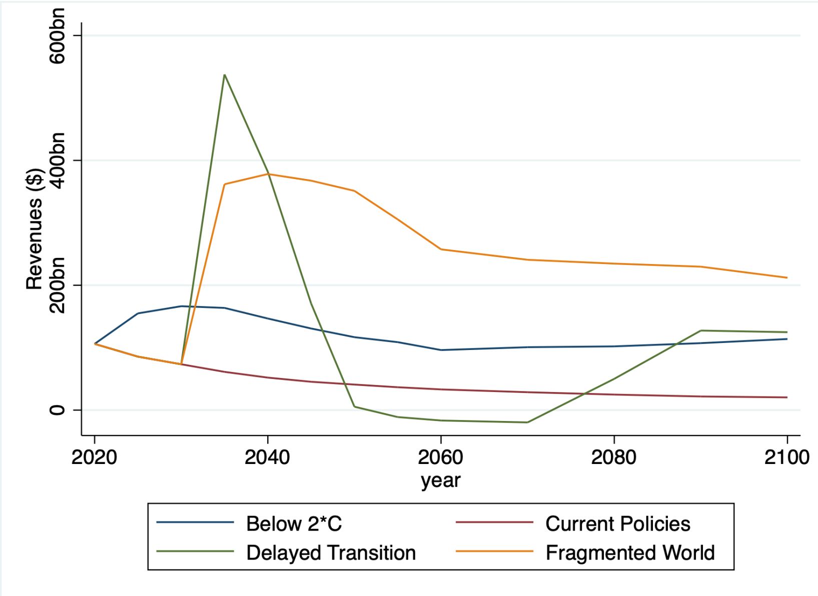


Figure 7: Carbon Revenues for EU27.
Source: NGFS. Revenues in 2010 $bn for each scenario, from 2020 to 2100.

In order to determine the resulting European climate bond issuance capacity, we estimate the present discounted value (PDV) of the revenue starting from 2024. To this aim, we convert the revenues in 2023 US dollars.[23] Next, since NGFS projections are at a five (or ten) years' frequency, we interpolate them to obtain yearly revenues, and discount these real cash flows with the real spot interest rates for the corresponding maturities, as measured by US Treasury Inflation-Protected Securities (TIPS) rates.[24] This enables us to compute the PDV of constant-dollar revenues for each scenario, as of 2024:

$$PDV = \sum_{t=0}^{76} \frac{\text{revenue}_{2024+t}}{(1 + r_t)^t}$$

where the estimation horizon ranges from 2024 to 2100 (76 years) and r_t is the maturity-t real spot rate as of 2024.[25] Finally, we convert this constant-dollar PDV into constant-

[23]To this purpose, we use the US GDP deflator drawn from the Federal Reserve Economic Data (FRED) by St. Louis Fed.

[24]We draw these data from the Wall Street Journal website for 1-year maturity and from the Federal Reserve's website for longer maturities.

[25]Using this rate, which reflects the currently negligible default risk of US government bonds, is justified if one assumes the probability of default of the EU on these bonds to be equally negligible and the future

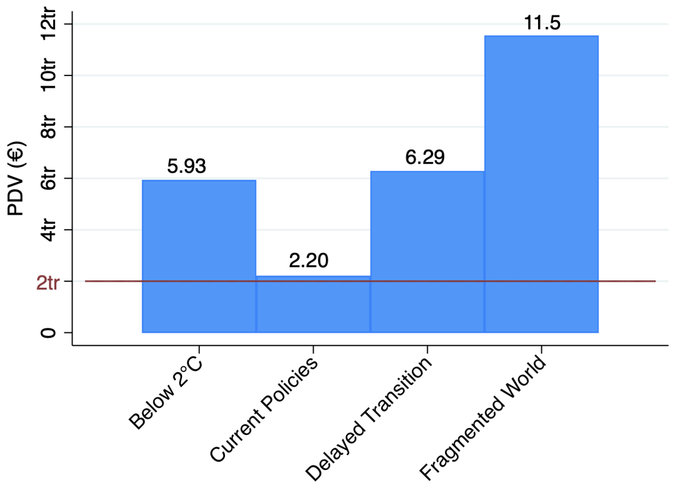


Figure 8: PDV of Estimated Revenues.
PDV in €tn for each NGFS scenario. €2tn (red line) is the EC's long-term budget (6y).

euro PDV amounts, using the euro/dollar exchange rate in 2024 ($1/€0.9167). Figure 8 displays the resulting European climate bond issuance capacity estimates conditional on the four NGFS scenarios.

Figure 8 shows that the issuance capacity varies from a lower bound of €2.20tn in the "current policies" scenario to an upper bound of €11.5tn in the "fragmented world" scenario, taking intermediate values close to €6tn in the other two scenarios. However, in all of these cases the issuance capacity of European climate bonds exceeds the European Commission's long-term budget (6 years) for climate actions (€2tn). It also exceeds the corresponding 6 years climate investment gap, estimated to equal €2.22tn.[26]

path of interest rates to be invariant across scenarios. However, the path of default-free interest rates may differ across scenarios. If so, the ETS revenues in each scenario should be discounted by the relevant sequence of interest rates and the PDV should be computed by weighting the discounted revenues in each scenario by the respective probabilities. However, the developers of process-based IAMs explicitly state that probabilities cannot be meaningfully assigned to the climate scenarios they consider: see Dessai and Hulme (2004) and IPCC (2007).

[26]The estimated 6 years climate investment gap is obtained multiplying by 6 the yearly gap resulting from Section 2.

5 Benefits of the European climate bond

The estimates presented in the previous section suggest that implementing our proposal would provide the EU with large financial resources to support its climate policies, enabling it to foster the low-carbon transition more swiftly and effectively than with the currently allocated resources. In addition, the proposed reform would have other important benefits in terms of both macroeconomic performance and of capital market development for the EU, which we discuss in this section.

5.1 Macroeconomic performance

As already mentioned in Section 2, mitigation and adaptation finance initiatives are complementary to tackle climate change. As they both contribute to shield the economy from climate-related losses (e.g. from natural disasters), they also protect countries' fiscal capacity, and enable them to fund climate policies without sacrificing other important policy priorities.

Specifically, spending on climate policies may generate a positive "real feedback loop" via its positive effect on economic growth and fiscal capacity, as illustrated by Figure 9. Starting from the top of the figure, faster and larger spending on mitigation and adaptation contributes to increase a country's resilience to climate disasters. Higher resilience, in turn, helps the country to maintain high GDP growth, which strengthens its fiscal capacity, and thus its ability to invest in climate mitigation and adaptation. As a result, spending on climate policies tends to be self-reinforcing and correlate with better macroeconomic performance and higher fiscal capacity.

Figure 9 shows that the macroeconomic effects triggered by public climate investments may also generate a "financial feedback loop". By sustaining a country's fiscal capacity, climate policies can contribute to improve investors' expectations about a country's climate risk exposure, lowering its perceived solvency risk. This, in turn, should translate into lower yields on the country's sovereign debt. The resulting lower cost to finance

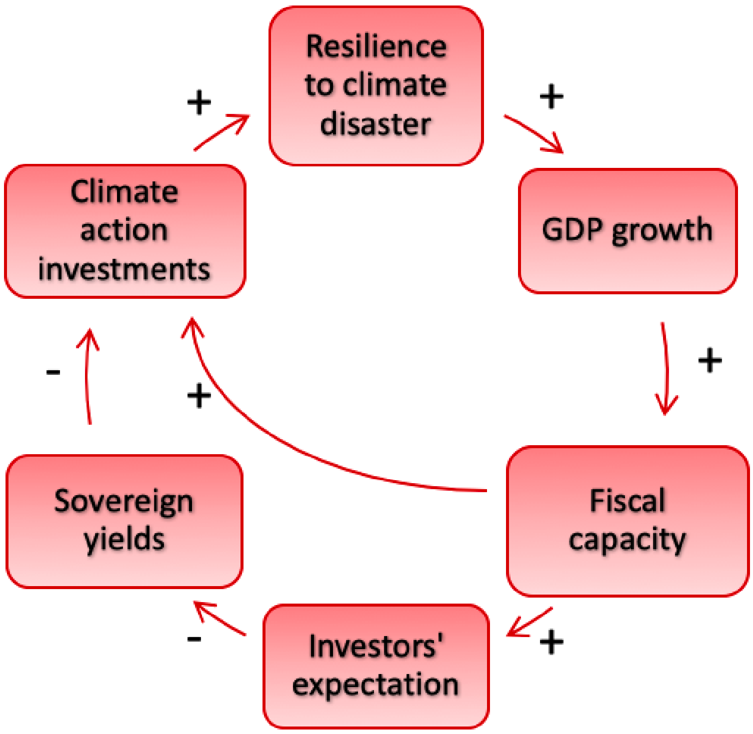


Figure 9: The real and financial climate feedback loops. The arrows indicate causal relationships, while the signs indicate the direction of the corresponding effects, either reinforcing (+), or balancing (-).

public climate investments would reinforce the positive effect of greater fiscal capacity on climate investing, and thus contribute to increase the country's climate resilience, closing the loop. Thus, the financial loop would reinforce the real feedback loop set in motion by climate policies.

The climate feedback loops illustrated by Figure 9 implicitly highlight the potential for multiple equilibria, with climate investment, macroeconomic performance and financial stability correlating across equilibria. If so, the economy may be trapped in an inefficient equilibrium featuring low climate investment and resilience, anaemic growth and high sovereign risk. If inadequate resources are spent on mitigation and adaptation policies, the economy is exposed to severe and frequent natural disasters, which sap its growth and reduce its fiscal capacity. This, in turn, prevents the government from funding climate investments and policies. The reduction in fiscal capacity increases the likelihood of a sovereign debt crisis, and investors' negative expectations regarding sovereign solvency further hinder the government's ability to fund climate policies.

Mobilizing timely and sufficiently large resources for climate action investments, the issuance of European climate bonds can avoid such inefficient outcomes, by adding to the resources available to fund climate investments. As illustrated by Figure 9, this can set in motion virtuous, self-reinforcing macroeconomic effects, consisting not only of higher and more stable GDP growth, but also of lower risk of sovereign debt crises.

The issuance of European climate bonds can have an additional, and no less important, benefit in terms of international competitiveness of the European industries catering to the decarbonization process. The funding raised by issuing these bonds can be the financial backbone of the EU response to the ongoing competition from US and China to attract investments instrumental to the low-carbon transition. In particular, it can help Europe fend off the challenge arising from the US Inflation Reduction Act (The White House, 2023), allowing EU MS to attract and support firms that contribute to the decarbonization of the economy.

5.2 Safe asset supply and financial stability

The issuance of European climate bonds can also play a key role in the development and in the stability of European capital markets, by providing a large supply of a safe euro-area asset issued at different maturities.

As already highlighted in Section 4.2, European climate bonds can be expected to be highly liquid, being issued regularly and in large amounts. Investors will also perceive them as a safe sovereign asset, being issued by a supranational financial authority with high credit rating and with the direct backing of the revenue from sales of ETS allowances.

As such, these bonds will be ideally positioned to fill the current demand for a EU safe asset, and address the scarcity in the global supply of safe debt securities.[27] Currently, the euro area does not supply a safe asset to the same extent as the US, although its economy

[27] This scarcity is witnessed by the fact that the most widely held safe asset, US Treasury bills and bonds, earns a "safe haven" premium of 0.7% per year on average (Krishnamurthy and Vissing-Jorgensen, 2012).

is similar in size and its financial markets are at the same stage of development. Only a few euro-area countries (Germany, the Netherlands and Luxembourg) issue sovereign debt with a triple-A rating by either Moody's or S&P, but their supply of public debt is far smaller than that of the US: in the last quarter of 2022, the face value of central government debt securities issued by these countries amounted to €201bn (i.e. about 1.5% of euro area GDP), while that issued in the US was $1.6tn (6.15% of US GDP).

The scarcity and asymmetric supply of euro-denominated safe assets creates two problems (see Brunnermeier et al. (2017)). First, it exposes the European economy to a potential "diabolic loop" between bank risk and sovereign risk, by encouraging banks to be overly exposed to domestic sovereign risk. Second, the asymmetry across countries in the supply of safe assets creates the potential for sudden, self-fulfilling capital flights from high-risk to low-risk countries in search of safety at times of crisis.

However, the financial benefits of the European climate bonds would not only rest on their safety. By being credibly tied to climate investments, these bonds will represent a new, plentiful supply of a *green* safe asset. Namely, they will be a form of safe sovereign debt that global investors could use to satisfy their growing appetite for environmentally sustainable portfolios. The "greenness" of these bonds would be guaranteed by a system of checks and balances to avoid greenwashing as well as EU MS' moral hazard. To this aim, the use of the revenues obtained from the sale of European climate bonds would be conditional on their use to fund climate projects in the EU, whose implementation will be monitored via KPIs by the EIB.[28] EU MS that fail to deliver on their KPIs will face a penalty, in the form of reduced allocation of subsequent funding. As such, these bonds are likely to command a greenium relative to comparably safe sovereign assets, such as US treasuries.

[28]EIB checking on the implementation of EU-funded projects is not a novelty, being already in place in the context of EU Structural and Cohesion Funds, and of the Recovery and Resilience Facility.

5.3 Monetary policy conduct

European climate bonds may also become a key policy instrument for the conduct of monetary policy in the euro area, being a EU-wide safe and green asset. The ECB could employ them to carry out its two main types of monetary policy operations. On the one hand, it could accept European climate bonds as high-quality collateral in lending to euro-area financial institutions. The haircut rate at which the ECB would accept them as collateral would reflect their safety, sending a strong signal to markets. On the other hand, the ECB could use European climate bonds as the main asset for open market operations or asset purchase programs. Of course, reliance on these bonds will depend on the extent to which the ECB will maintain a structural portfolio of assets, which is currently under debate within its operational framework review.

Employing European climate bonds in its operations would have two main advantages for the ECB. First, it would simplify the implementation of its monetary policy programs. When necessary, the ECB could simply decide the size of the programs, without having to discuss the cross-country composition of the assets to be purchased, as well as the distribution of any gains/losses on these assets: the availability of this supranational bond would overcome all concerns about monetary policy giving preferential treatment to any national issuer.

Second, European climate bonds would represent a simple vehicle for "greening" monetary policy. This would not be a completely new policy: already with its corporate sector purchase program (CSPP), the ECB has tilted its corporate bond purchases towards issuers with better climate performance, measured on the basis of lower GHG emissions, more ambitious carbon reduction targets and better climate-related disclosures. But the availability of European climate bonds would enable the ECB to scale up considerably its "green" asset portfolio, while taking lower default risk than it would by purchasing corporate debt issued by low-carbon companies. The"greening" of monetary policy has a firm legal basis in the ECB statute: while its primary mandate is to maintain price stability, its secondary mandate is to support the general economic policies in the EU.[29] This includes helping an orderly transition to a carbon-neutral economy, including the promotion of sustainable finance and the creation of incentives for a greener financial system. The availability of European climate bonds would provide a way for the ECB to fulfill this aspect of its secondary mandate without jeopardising the price stability objective.

6 Conclusion

Europe faces a large climate investment gap. To fill it, in this paper we propose the joint issuance of a European climate bond, to be serviced by the revenues from the sales of ETS allowances. The proposal envisages the extension of the ETS to all sectors (in line with current plans for an ETS 2) and the calibration of ETS allowances supplied by the EC so as to target a science-based carbon price path. This scheme would not only commit EU policy makers to a future path of carbon prices (contributing to reduce transition risk), but would also enable the EC to tap and manage a federal source of fiscal capacity. The revenues should be used to fund climate investing initiatives designed and enforced at the EU level. We show that this scheme could provide a substantial amount of additional funding to EU climate policies: even in the scenario associated with the lowest possible PDV of future revenues, the fiscal capacity generated by this scheme would be of the same order of magnitude as the funding already budgeted for EU climate policies.

Our proposal would contribute to improve the climate resilience of the EU. On one hand, the supra-national design of EU climate policies proposed would avoid the inefficiencies stemming from potential cross-border externalities and spillover effects of state-level climate policies. Their joint funding and enforcement would avoid potential moral

[29] Article 127 (1) of the Treaty on the Functioning of the European Union mandates that, "without prejudice to the objective of price stability, the ESCB shall also support the general economic policies in the EU with a view to contributing to the achievement of the Union's objectives as laid down in Article 3 of the Treaty on European Union". These objectives include balanced economic growth, a highly competitive social market economy aiming at full employment and social progress, and a high level of protection and improvement of the quality of the environment.

hazard issues in the national implementation of climate policies, as the funds raised by the issuance of European climate bonds would be made available to MS conditional on their performance on the implementation of climate investments. At the same time, the issuance of European climate bonds would increase the speed and efficiency of EU climate investing, by relieving the fiscal constraints that might otherwise deter it in more vulnerable MS.

The proposed scheme can also be expected to have macroeconomic and financial benefits. It would protect economic growth and stability of the EU from the threats posed by natural disasters, and increase its resilience to sovereign crises. Additionally, the joint issuance of such bonds may benefit the international competitiveness of European industries catering to the decarbonization process, by supporting the European response to the ongoing competition from US and China to attract investments for the low-carbon transition.

Finally, the joint issuance of the European climate bond would provide a large supply of European safe, liquid and green assets, which would both not only meet investors' demand for these assets and provide the backbone for an integrated European capital market, but also enable the ECB to green its monetary policy operations.

Appendix

Table 2: EU-27 carbon taxes

Description of the carbon taxes over different EU countries.

Country	Carbon tax (1)	Carbon tax (2)
Denmark	Fossil Fuels	F-gases
Estonia	CO_2eq	
Finland	Transport fuels	Other fossil fuels
France	CO_2eq	
Ireland	Diesel & petrol	Other fossil fuels
Latvia	CO_2eq	
Luxembourg	Diesel	Other fossil fuels
Netherlands	CO_2eq	Electricity & industry
Poland	CO_2eq	F-gasses
Portugal	CO_2eq	
Spain	CO_2eq	
Sweden	CO_2eq	

Source: World Bank

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