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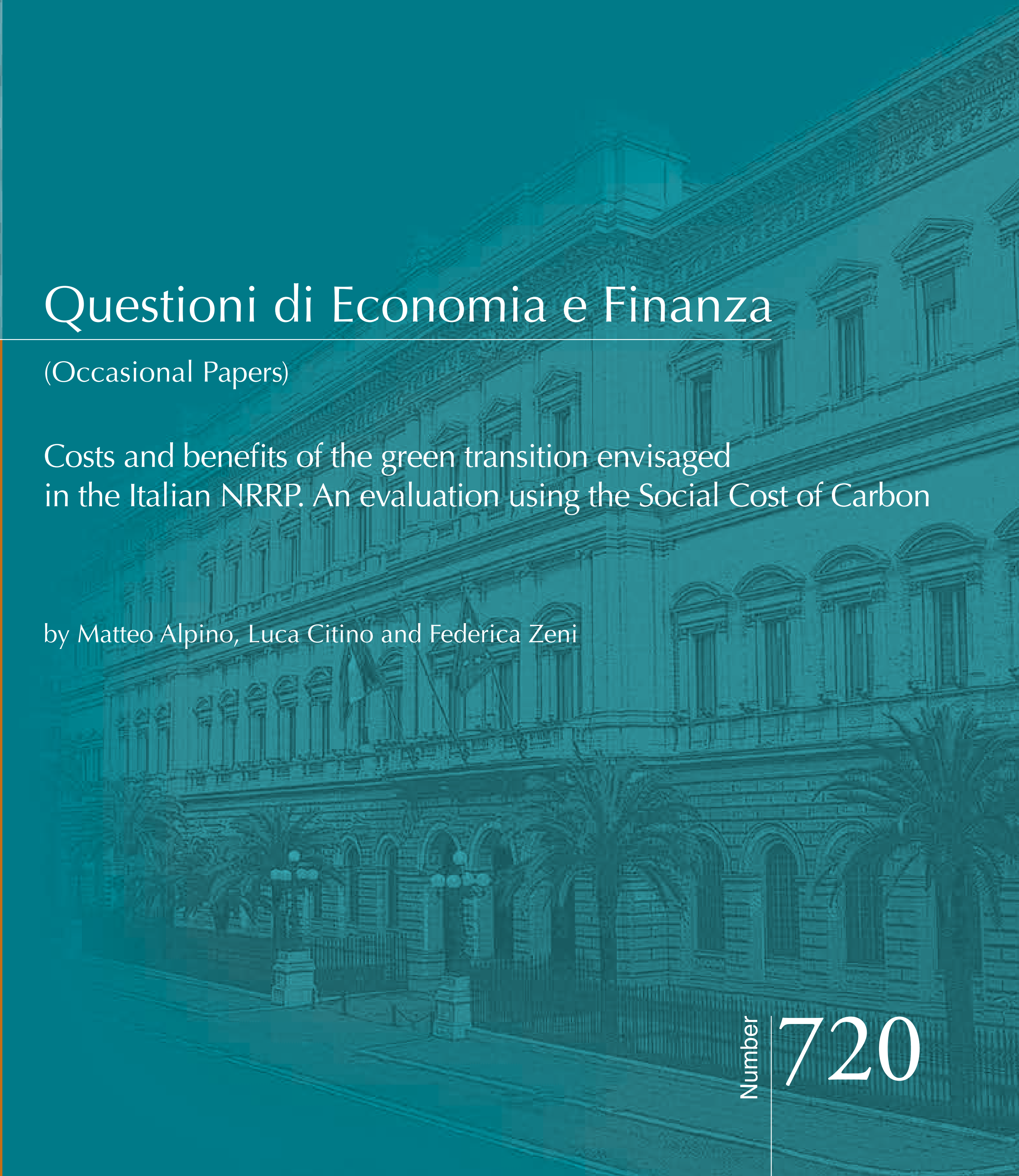

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(Occasional Papers)

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# COSTS AND BENEFITS OF THE GREEN TRANSITION ENVISAGED IN THE ITALIAN NRRP. AN EVALUATION USING THE SOCIAL COST OF CARBON

by Matteo Alpino*, Luca Citino* and Federica Zeni*°

## Abstract

We perform a cost-benefit analysis of the green investments contained in the Italian National Recovery and Resilience Plan (NRRP). We compute the future discounted benefits in terms of expected emission reductions using various estimates of the Social Cost of Carbon, and compare them with the investment cost. Our results suggest that several projects would not have a positive net present value, unless policymakers are willing to use relatively low discount rates and give higher weight to benefits accruing to developing countries. The fact that investments under the NRRP are financed via long-term debt helps in bridging the gap between costs and benefits. Investments in renewable energy are an exception, as their benefits outweigh the cost within a short time-frame.

**JEL Classification**: D61, P18.
**Keywords**: social cost of carbon, national recovery and resilience plan, cost-benefit analysis.
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## Contents

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* Bank of Italy, Structural Economic Analysis Directorate.

° World Bank Research.

## 1. Introduction[1]

Economists often frame climate change policy as a cost-benefit analysis problem: the optimal abatement path balances the benefits of avoiding future greenhouse gas (GHG) emissions and the costs of investing in particular abatement technologies or policies (see Becker et al., 2011). The actual implementation of this simple principle is rather complex, as it requires the measurement of quantities that are not directly observable. First, cost measures should take into account behavioural responses by economic agents as well as equilibrium effects. Second, the benefits from preserving the current climate will materialize many decades into the future and are highly uncertain. Finally, future benefits must be converted in monetary amounts, so that they are comparable with abatement costs.

In this respect, the most common approach is to employ estimates of the social cost of carbon (SCC): the present discounted value of future *global* damages from releasing one unit of GHGs into the atmosphere. The SCC represents the shadow price of marginal emission reductions, and is calculated by combining several components: a mapping from GHG emission flows to the GHG stock; a mapping from the GHG stock to the climate; a mapping from the climate to economic damages; and a discount rate that allows us to compute the present value of future damages.

This approach is very flexible in that it can be applied to evaluate the benefits of different environmental policies and green investment projects. In this short paper, we evaluate the set of green investments contained in the Italian National Recovery and Resilience Plan (NRRP),[2] which total €71.7 billion (37.5 per cent of all the funds dedicated to the plan). Thanks to quantitative information about the actual investments contained in the NRRP and state-of-the-art estimates of the SCC, we compute the benefits and costs of expected emission reductions from all green investments for which the Plan reports expected GHG abatement estimates[3] (61 per cent of total green spending) every year from today until 2100.

Overall, our analyses suggest that several sizable investment projects included in the Italian NRRP would not have a positive net present value, unless policymakers are willing to:

a) use relatively low discount rates (2 per cent at most);

b) give more weight to damages occurring in poor regions of the world than to those occuring in advanced countries.

On point a), our reading of the most recent literature is that, in the context of climate change mitigation, appropriate discount rates range between 1 and 3 per cent, both according to the normative approach (Ramsey, 1928) and the positive one (e.g. Bauer and Rudebush, 2021). Our results reflect the fact that several interventions are very costly, but deliver only a *gradual* reduction in emissions. As such, since sizable abatements are reached only after a long period of time, the present value of the damages avoided is small, unless the discount rate is low enough. Investment in renewable energy is a notable exception to this rule, as it produces benefits within a short time-frame and therefore appears socially valuable also when adopting higher discount rates. The fact that investment costs in the NRRP are not paid up front, but rather financed via long-term debt, helps in bridging the gap between costs and benefits.

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[1] We would like to thank Fabrizio Balassone, Guido De Blasio, Andrea Linarello, Francesca Lotti and Enrico Sette for their useful comments.

[2] We take Italy as a case study, but this methodology readily applies to other policies in other countries as well.

[3] The abatement estimate corresponds to the quantity of emissions abated thanks to the intervention.

Of course, all of these public investments could also yield other *non-environmental* benefits, both private and social. For example, an intervention aimed at increasing the energy efficiency of residential buildings to abate GHG emissions may also generate private gains for the beneficiaries in terms of lower energy expenditures or create jobs in the construction sector. These gains should be accounted for in the evaluation. A precise measurement of these gains is outside the scope of our analysis. Nevertheless, our exercise still benchmarks how large these gains ought to be in order for the intervention to justify its cost.

## 2. Comparison with alternative approaches

The SCC-based cost-benefit analysis implemented in this note is not the only approach used by economists to evaluate and select climate policies. The main alternative is the so-called *"cost-effectiveness analysis"*, whereby policies are chosen as to minimize economic costs subject to a given target of emissions reduction. While a lively academic debate[4] about the appropriateness of the two approaches in actual policymaking is still ongoing, we think that they are not mutually exclusive and that there are things to be learned from both.

In the context of our empirical exercise it must be stressed that: a) the Italian NRRP fits into the broader European climate action plan that imposes quantity emission reduction targets to reach carbon neutrality by 2050; b) all NRRPs must satisfy a set of rules and constraints in order to receive funding by the European Commission. As such, the Italian NRRP is therefore subject to several constraints that have made the SCC-based approach not applicable in isolation. In fact, the policy maker cannot rely solely on cost-benefit analysis if she must comply with quantity constraints.

Nonetheless, we believe that a cost-benefit analysis based on the SCC can complement the "*cost-effectiveness approach"* because it converts environmental benefits in a money metric, thus allowing for a wide range of comparisons within and outside the environmental domain. One example of combining both approaches in policymaking is provided by the current US administration, which has committed to reduce GHG emissions by 50 per cent before 2050, but has also reinstated the Interagency Working Group tasked with updating the SCC estimates used by federal agencies.

Furthermore, our approach would be even more relevant in an institutional context where quantity targets are not assigned exogenously, but rather traded-off against the social net present value of available investments. As European governments are ready to spend billions of euros to combat climate change, finding out which measures deliver the highest "bang for the buck" and what policies (if any) are a waste of resources is crucial. In fact, climate change does not constitute the only challenge that societies face, as highlighted by the recent pandemic. Our analysis could therefore tell whether a reallocation of resources across policies (both environmental or in different domains such as healthcare and education) for the *same* total expenditure could be welfare improving, even though such reallocation may not necessarily be feasible under the existing policy constraints.[5]

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[4] The debate features Nobel laureates on both sides: William Nordhaus favours the cost-benefit approach while Joseph Stiglitz the cost-effectiveness one. Two recent contributions to the debate are Stern and Stiglitz (2021) and Aldy et al. (2021).

[5] Note also that our framework is best suited for small re-adjustments from one policy to another. We are less equipped to deal with large changes in policy, which would require more data to estimate the cost and benefit functions.

## 3. Institutional framework

European regulations prescribe that the NRRP must devote at least 37 per cent of their resources to the green transition. According to the evaluation conducted by the European Commission, the Italian plan devotes 37.5 per cent (71.7 billion euros) to climate policies (*climate contribution* in the technical jargon by the European Commission).[6] The *climate contributions* of the different missions and components are detailed in Table 1. The biggest shares of green spending come from renewable energy and sustainable mobility (mission M2C2) and investments in the rail network (M3C1), on which 21.9 and 20.6 billion euros are spent, respectively. Energy efficiency (M2C3) is also an important element, with 12.6 billion euros contributing to the green transition.

*Table 1 – Official green tagging in the Italian NRRP*

| | **Cost** | **Climate *contribution*** | |
|---|---|---|---|
| | ***(billion euros)*** | | ***(percentage)*** |
| M2C1. Circular economy and sustainable agriculture | 5.26 | 2.29 | 1.2 |
| M2C2. Renewable energy, hydrogen, grid and sustainable mobility | 23.77 | 21.87 | 11.4 |
| M2C3. Energy efficiency and renovation of buildings | 15.36 | 12.61 | 6.6 |
| M2C4. Protection of land and water resources | 15.05 | 9.4 | 4.9 |
| M3C1. Investments in the rail network | 24.76 | 20.56 | 10.7 |
| M4C2. From research to business | 11.44 | 1.97 | 1.0 |
| Others | 95.85 | 3.02 | 1.7 |
| **Total** | **191.49** | **71.72** | **37.5** |

Source: European Commission analysis of the Italian NRRP (https://ec.europa.eu/info/system/files/com-2021-344_swd_en.pdf).

## 4. Methodology

Our aim is to calculate the social value of the reductions in GHG emissions that are expected from the green investments in the Italian NRRP and contrast this with their direct investment cost, in order to assess whether they are convenient from an economic standpoint. To this end, we rely on the concept of social cost of carbon (SCC).

The SCC is defined as the present discounted monetary value of current and future global social damages from an additional unit of GHG emissions released in the atmosphere. Conversely, it corresponds to the marginal benefit of emission reductions and thus the maximum price that a benevolent social planner would be willing to pay to avoid such damages. The latter definition is particularly useful: it allow us to express costs and benefits of emission reductions in a common money metric.

It is important to stress that the SCC is a time-varying measure: the abatement of a ton of GHGs can have a different social value depending on the year when it occurs. In particular, most Integrated Assessment Models (IAMs)[7] derive an optimal SCC that is increasing over time. This result is due to three channels: 1) discounting, as future damages are valued less than current ones; 2) functioning of

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[6] For each component, the European Commission indicates the percentage that is considered "green" (*climate contribution*). Overall, the *climate contribution* must be at least 37 per cent. For other details on the Plan see https://ec.europa.eu/commission/presscorner/detail/en/ip_21_3126.

[7] IAM are large-scale models that incorporate the climate and the carbon cycle into an otherwise standard DSGE framework. They play a prominent role in today's evaluation of climate policies: they have featured extensively in IPCC reports and the 2018 Sveriges Riksbank Prize in Economic Sciences was awarded to William Nordhaus for the development of such models. The most prominent IAMs include: the DICE (Dynamic Integrated Climate and Economy) model by William Nordhaus, the PAGE (Policy Analysis of greenhouse Effect) model by Chris Hope, and the FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) by Richard Tol. For a review see Weyant (2017).

the natural system, as changes in temperature and precipitation depend on the stock rather than on the flow of GHG emissions; 3) convexity of the damage function, as negative effects become generally more severe as the climate changes even more.

For a given SSC sequence, we compute the social value of a green investment as follows: we multiply year by year the flow of expected emission reductions by the SCC, and discount the overall sum back to the year when the investment cost is incurred. To fix ideas, let us consider an investment whose cost $I$ is paid upfront in year $t = 0$, and that lowers emissions by $E_t$ in every year $t$ starting from year $t = e \geq 0$, up to year $T$. The net present value of the social benefits from avoided emissions $V_T$ can be written as:

$$V_T = \sum_{t=e}^{T} \frac{SCC_t \times E_t}{(1+\delta)^t},$$

where abated emissions $E_t$ in every year *t* are priced at the corresponding $SCC_t$ and discounted to the present at the rate $\delta$. Following the recommendation by the US Interagency Working Group (IWG), we pick the same discount rate used to compute the $SSC_t$ in order to ensure internal consistency. Equipped with this formula and the investment cost $I$, we can also compute how many years are needed in order for the green investment to pay out, that is how many years are needed for $V_T$ to equate $I$. This framework allows us to present results as graphs: for each investment, we plot its cumulated social value $V_T$ over time calculated according to six different SCCs, and the investment cost as a horizontal dotted line. The breakeven year, if it ever occurs, corresponds to the intersection between the horizontal line representing the investment cost and the cumulated social value line.[8] Furthermore, our framework assumes that emission reductions generated by a project do not affect the SCC value in subsequent years. The assumption is reasonable in our analysis because each single project in the Italian NRRP has a negligible impact on the *global* stock of carbon emissions over time.

One limitation of the simple methodology sketched above is that in reality the initial investment cost is not paid upfront: the NRRPs are financed by public debt issuances either by the European Commission or by the national governments. Since in our calculations the costs are borne immediately, our analysis might deliver excessively pessimistic results. To account for this in a simple way, we conduct a sensitivity test for those investments that display benefits that are much lower than the cost. In particular, we assume that the investment is financed by a 30-year zero-coupon bond with initial price equal to the face value $I$ (so that the financial return for the investor is 0). In this case, the discounted cost for the government is equal to $I/(1+\delta)^{30}$, where the discount rate is the same as the one used to compute $V_T$. Of course this assumption is a simplification, since the borrowing cost is probably not so low in reality, but it provides a stark juxtaposition to our previous assumption. This comparison allows us to assess whether any result that points to an inefficient use of resources can be reverted when accounting for a more realistic financial structure of the project.

There are three additional caveats to our analysis, all of which are driven by lack of ideal data.

First, we do not verify whether the expected abatement estimates reported in the NRRP are realistic or not. Rather, we take the Plan's numbers off the shelf and assume these constitute a reasonable

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[8] Note that the NRRP presents the estimated annual abatement, but does not specify for how long this effect will last. Our framework implicitly assumes that the policies will keep on abating emission at the same rate reported in the NRRP until 2100, even though this may not always be the case; for example, the improvements in energy efficiency in buildings (e.g. a special rooftop) will not necessarily deliver the same energy savings forever without further renovations after some years.

estimate.[9] By remaining agnostic about how these figures were calculated, our approach allows to recover the implicit value that policymakers must be assigning to the benefits of these investments, given the costs and expected emissions abatement levels.

Second, our approach does not take into account that green interventions may generate additional positive or negative *fiscal* externalities, which should be added or removed from the investment cost borne by the government, depending on their sign (Hendren and Sprung-Keyser, 2020). For example if incentives for weatherization programs increase revenues in the construction sector, which are taxed, the additional fiscal revenues should be subtracted from the investment cost borne by the government.[10] In this work, we do not estimate these fiscal externalities, but it is important to keep their potential existence in mind when interpreting the results.

Third, in this work we consider the current unitary abatement cost as static, while some studies suggest that early investments in one technology might have positive spillover effects that will eventually bring down the unitary cost (Gillingham and Stock, 2018). This may be particularly relevant for some nascent technologies such as hydrogen, while may be less relevant for more "traditional" types of interventions, such as weatherization programs or investment in photovoltaic panels.

## 5. Data

*Social cost of carbon* - We rely on two sources to retrieve SSC schedules: the US Interagency Working Group (IWG) and the German Environmental Agency (UBA). These agencies provide the official estimates used in federal policymaking by the respective authorities in the two countries. Both agencies use global damages in their calculations, making it possible to adopt their estimates to evaluate policies in other countries.[11] We choose to rely on figures from government agencies rather than from the academic literature for two reasons. First, the latter often reports SCC estimates for one year only, thus making it difficult to evaluate investments that abate emissions over a long period of time; instead, both the IWG and the UBA provide schedules until 2050, and instructions on how to extrapolate SSC values further in time. Second, estimates by the IWG and the UBA are themselves based on models developed in academic work, in particular on Integrated Assessment Models.[12]

As of 2021, the IWG recommends the use of four estimates, obtained with discount rates that range from 2.5 to 5 per cent; however, the IWG also states that whenever the investment horizon spans the lifetime of several generations, the appropriate discount rate is probably lower, a point on which we elaborate below. The four values for 2020 are reported in Table 2. Three of these four estimates are computed as the average across many model simulations using discount rates of 2.5, 3 and 5 per cent;

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[9] It would be important to know how the Plan's estimates were computed. For example, previous evidence has shown that ex-ante estimates of emission reductions are often biased upward when obtained from engineering models that typically do not incorporate behavioural responses (Fowlie et al., 2018).

[10] When incorporating fiscal externalities one should also take into account that the green investment under consideration potentially crowds out alternative investments, which in turn might have generated revenues for the government. The fiscal externality to add or subtract is thus the *net* effect on government revenues. On this, see also Finkelstein and Hendren (2020).

[11] Accounting for global damages is the standard approach for calculating the SCC due to the fact that climate change is a global externality: damages do not depend on where emissions are produced.

[12] In particular the IWG uses an average of DICE, FUND and PAGE, and UBA uses the FUND model.

the fourth estimate corresponds to the 95th percentile across the model simulations with a 3 per cent discount rate and should be used for sensitivity analysis.[13]

On the other hand, the UBA provides two SSC estimates, also reported in Table 2, both characterized by discount rates that decline over time. In one case, the discount rate starts at 3 per cent and declines to 2 per cent in 2250; in the other one, it starts at 2 per cent and declines to 1 per cent in 2250.[14] The corresponding German estimates of the SSC are higher than those used by the IWG for at least two reasons: a) the discount rates are lower; b) the UBA framework assigns a higher weight to damages in poorer countries, which on average are also more exposed to climate change.

As it is visible from Table 2, the six SCCs considered in our work display considerable variation and broadly cover the range of recommendations provided by different authors in the academic literature. Much of the variability is due to the use of different discount rates, ranging from 2 per cent (decreasing) to 5 per cent. For transparency, we report our findings for all SCCs described thus far, in order to show the sensitivity of the results to this parameter and to accommodate different views on this matter. However, based on our reading of the most recent academic articles on the topic, we think that discount rates below 3 per cent are probably appropriate in the context of climate change mitigation, both from a normative and from a positive perspective.

Consider first the normative approach derived from the Ramsey (1928) model, where the discount rate $\delta$ is a function of the pure rate of time preferences $\rho$, the consumption elasticity of marginal utility $\omega$ and the growth rate of per capita consumption $g$:

$$\delta = \rho + \omega \cdot g.$$

Given a value of $\rho$ close to zero – consistent with equal welfare weights for current and future unborn generations – it is hard to come up with discount rates above 3 per cent without assuming very large values of $\omega$ and $g$.[15] To give some perspective, consider that in a recent survey of environmental economists (Drupp et al., 2018) the median values for $\rho, \omega, g$ are respectively 0.5, 1 and 1.6 per cent, and the median value for $\delta$ is 2 (that is approximately consistent with the Ramsey rule).

Let us consider now the market-based positive approach, where the discount rate $\delta$ should be equal to the long-term real return on savings. While traditionally this approach yielded large discount rates, recent empirical evidence from the bond market (Bauer and Rudebush, 2021) and from the real estate market (Giglio et al., 2015, 2021) combined with asset pricing models suggest that the discount rate should be around 2 per cent, consistent with the normative perspective. Finally, even in a world with uncertainty about the appropriate rate, the discounting of future damages at all possible discount rates

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[13] The estimates by the IWG were supposed to be updated in February 2022, but the release of the new figures have been delayed by a court order that barred the US administration from using the SCC in federal policymaking. The ban was later lifted by the Supreme Court, but the updated SCC figures have not been released yet. The new SSCs will most likely be revised upwards due to the incorporation of recent advances in the literatures on the effects of climate change (whose damages seem larger than what had been found in previous studies) and on intergenerational discounting (which points towards lower discount rates).

[14] The two estimates are characterized by a pure rate of time preference equal respectively to 1 and 0 per cent. A pure rate of time preference equal to zero implies that the social planner weighs the welfare of current and future generation equally.

[15] In the literature $\omega$ is in the range 0.5-4 whereas estimates of the growth rate $g$ are concentrated between 1 and 2 per cent. Note, on the other hand, that it is also hard to come up with discount rates close to zero unless one assumes negative o negligible growth rates $g$ in the future.

will result in a certainty-equivalent rate that decreases over time and converges to the lowest one (Weitzman, 1998).[16]

Table 2 – Social cost of CO2 for emissions released in 2021

| Country | United States | | | | Germany | |
|---|---|---|---|---|---|---|
| Discount rate (%) | 5 | 3 | | 2.5 | ≤3 | ≤2 |
| Distribution moment from model simulations | Average | Average | 95th pct. | Average | Average | Average |
| SCC (euro) | 13 | 46 | 133 | 68 | 197 | 682 |

*Abatement effects and investment costs* – The source for the investment costs and for the expected GHG reductions is the version of the NRRP approved by the European Commission. For each policy or investment, the plan reports its cost in euros in detailed tables. However, the Plan reports the path of expected abatement effects for some policies only.[17] In particular, the Plan reports abatement effects for policies whose total combined cost equals 44.1 billion euros, that is 61 per cent of total NRRP spending devoted to the green transition. Table 3 details the list of policies for which the Plan reports the abatement cost, and that we can thus evaluate in this work.

Table 3 – Cost and expected CO2 abatement for investments devoted to the green transition

| | **Cost** | **Expected CO2 abatement** |
|---|---|---|
| | ***(billion euros)*** | ***(million tons per year)*** |
| M2C1. Circular economy and sustainable agriculture | 5.27 | - |
| M2C2. Renewable energy, hydrogen, grid and sustainable mobility | 23.78 | - |
| ----- *Development of agri-voltaic systems* | *1.1* | *0.8* |
| ----- *RES promotion for energy communities* | *2.2* | *1.5* |
| ----- *Promotion of innovative systems (including off-shore)* | *0.68* | *0.286* |
| M2C3. Energy efficiency and renovation of buildings | 15.36 | 0.718 |
| ----- *Superbonus* | *13.95* | *0.667* |
| ----- *Energy efficiency in public buildings* | *1.21* | *0.0108* |
| ----- *District heating* | *0.2* | *0.04* |
| M2C4. Protection of land and water resources | 15.05 | - |
| M3C1. Investments in the rail network | 24.77 | 2.3 |
| M4C2. From research to business | 11.44 | - |

Source: Italian NRRP.

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[16] This is a consequence of Jensen's inequality.

[17] For example, at page 144: "*Il risparmio energetico atteso dal superbonus è di circa 191 Ktep/anno con una riduzione delle emissioni di gas serra di circa 667 KtonCO2/anno.*"

## 6. Results

Table 4 summarizes our results: for each investment, we report the breakeven year, if it occurs before 2100, according to the different SCCs under consideration. In the following, we provide details on estimates concerning individual investment programmes.

*Table 4 – The table reports breakeven years for all policies under consideration according to different SCCs. A star denotes a breakeven year occurring later than 2100 or the absence of a breakeven year.*

| *Country (agency)* | *United States (IWG)* | | | | *Germany (UBA)* | |
|---|---|---|---|---|---|---|
| *Discount rate (%)* | *5* | *3* | | *2.5* | *≤3* | *≤2* |
| *Distribution moment from model simulations* | *Average* | *Average* | *95th pct.* | *Average* | *Average* | *Average* |
| Development of agri-voltaic systems | * | 2067 | 2049 | 2037 | 2034 | 2028 |
| RES promotion for energy communities and jointly acting renewables self-consumers | * | 2071 | 2051 | 2037 | 2034 | 2028 |
| Promotion of innovative systems (including off-shore) | * | * | 2072 | 2046 | 2041 | 2029 |
| *Superbonus* | * | * | * | * | * | 2067 |
| Energy efficiency in public buildings | * | * | * | * | * | * |
| Promotion of efficient district heating | * | * | * | 2079 | 2066 | 2034 |
| Rail network (upper bound) | * | * | * | * | * | 2039 |

### 6.1 M2C3. Energy efficiency and renovation of buildings

This set of measures aims at reducing emissions by increasing energy efficiency in private and public buildings. The main policy is the *superbonus*, which accounts for 90 per cent of the total spending on this Mission.

*Superbonus* – The policy provides a tax credit up to 110 per cent for expenses aimed at increasing the energy efficiency of private residential buildings. This type of intervention is popular in government and consulting circles because energy efficiency is depicted as a “win-win” option, which allows to save money and reduce environmental externalities at the same time. Economists are usually less optimistic about the cost-benefit ratio of this policy, as they ask why rational individuals would not pursue building renovations independently of public support, if these were privately beneficial.

Indeed, from a purely economic point of view, this type of policy is justified only if there are investment inefficiencies e.g. lack of information, inattention or liquidity constraints, and these cannot be addressed *directly* (Allcott and Greenstone, 2012).[18] On the contrary, if there are no investment inefficiencies and private investment decisions are socially suboptimal just because energy savings are not valued at their social cost, then a tax on energy consumption is preferable. This is because the climate change externality is linked to energy *consumption* and not to energy efficiency *investments*. Paradoxically, energy efficiency programs could even increase emissions if they stimulate additional energy demand (“rebound effect”).

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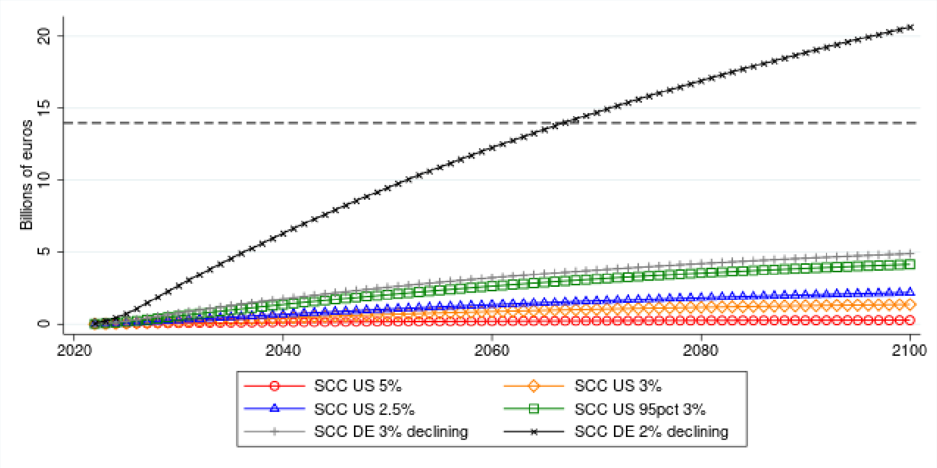
[18] A large literature has investigated under what circumstances economic agents fail to make privately optimal choices in the energy domain. Recent work has unveiled substantial heterogeneity in the degree of such inefficiencies across different strata of the population, which calls for targeted policies.

The *superbonus* costs 13.95 billion euros and is expected to abate emissions by 0.677 million tons of CO2 starting from 2027; for our purposes, we assume that between 2021 and 2027 the emissions reduction will grow linearly. Notably, not only is the policy explicitly aimed at reducing GHG emissions; it also aims at stimulating economic activity in the construction sector, which has performed poorly in recent years and likely has large fiscal multipliers. According to EU guidelines, 100 per cent of the cost of the *superbonus* can be considered climate-related, so it fully contributes to the target imposing at least 37 per cent of the total plan to be devoted to the green transition.

As shown in Figure 1, our methodology indicates that the *superbonus* is not a cost effective way to contrast climate change. The policy reaches the breakeven point before 2100 only when using the SCC from UBA with a 2 per cent discount rate. Even in this case, the initial investment is completely repaid only in 2067. In all other cases, the present discounted value of emission reductions until 2100 coming from the *superbonus* varies between 0.27 and 4.9 billion euros, that is between 1.9 and 35.1 per cent of the initial investment.

*Figure 1 - Superbonus*



As stressed above, our exercise only captures the climate-related benefits of this policy. Even in this case, our exercise is useful because it quantifies how much other benefits must be worth in order for the investment to be socially valuable. Considering emission abatement until 2100, and excluding the use of the highest SCC, the present discounted value of the economic stimulus provided by the *superbonus* (plus any other potential benefits) must be at least 9.1 billion euros if we consider the UBA SCC that discounts the future starting at 3 per cent, and at least 11.76 billion euros if we consider the IWG SCC discounting the future at 2.5 per cent. In other words, the investment multiplier must be between 0.65 and 0.8 for the combined effect of economic stimulus and climate benefits to equal to the investment cost.

In short, our analysis suggests that the *superbonus* might be worth pursuing in its current form only if we account for substantial non-climate benefits stemming from the policy or if we adopt a low discount rate and we give a higher weight to damages in poor countries. The result stems from the fact that this policy is both very expensive and does not induce large abatements.

In our view, an important unaddressed question is whether it would be possible to achieve the same emissions reductions with a deduction rate lower than 110 per cent, a feature which makes the *superbonus* very expensive. Suppose for example that a 40 per cent deduction would be sufficient to trigger the same amount of renovations among homeowners, and thus achieve the same degree of energy savings and emission reductions currently reported in the Plan.[19] In this case, for a total cost of around 5 billion euros, our calculations would point to a much more optimistic assessment (i.e. a breakeven is in fact reached a little later than 2100 with the lower SCC by UBA – grey line) because the remaining 60 per cent of the cost would be borne by homeowners.

*Energy efficiency in public buildings* – The component includes the construction of new schools and the renovation of some courts of justice for a total cost of 1.21 billion euros. According to the Italian plan, this investment is expected to abate emissions by 0.0108 million tons of CO2 starting from 2026. According to EU guidelines, 40 per cent of the cost of the component is labelled as climate-related. Irrespective of the choice of SCC, the investment appears to be very inefficient in environmental terms (Figure 2); even adopting the highest SCC, the component does not repay its initial cost by 2100. Even considering just 40 per cent of the initial investment (the share labelled as climate related), the breakeven does not occur within the considered time horizon.

*Figure 2 – Energy Efficiency in Public Buildings*

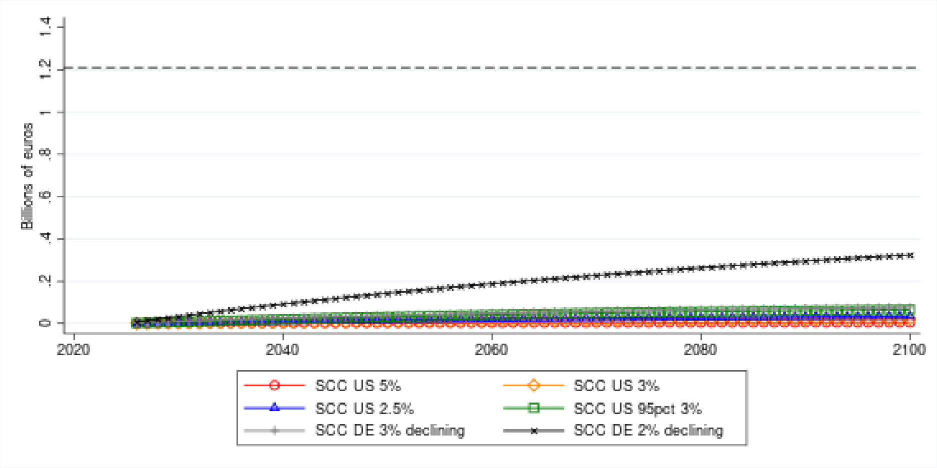
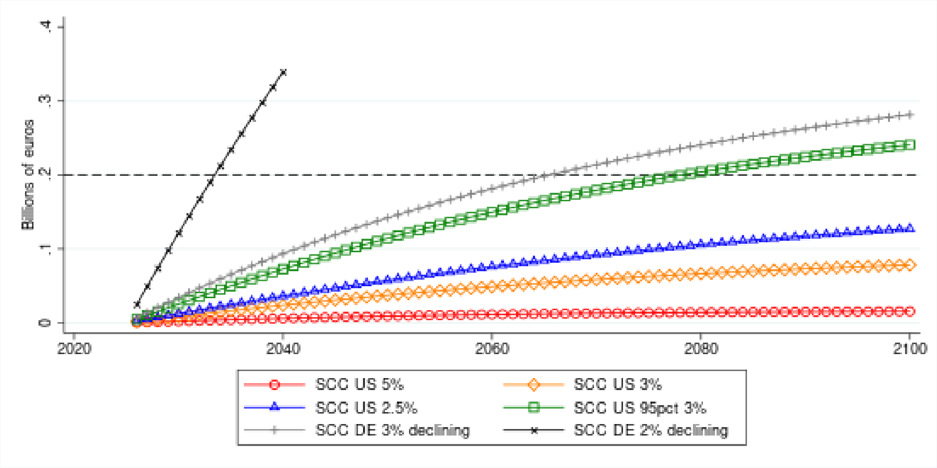


*Figure 3 – Promotion of Efficient District Heating*



*Promotion of efficient district heating* – The component includes different measures to develop district heating for a total cost of 0.2 billion euros. According to the Italian plan, this investment is expected to abate emissions by 0.04 million tons of CO2 starting in 2026; it is labelled as 100 per

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[19] On inframarginal participation in energy-efficiency programs see Boomhower and Davis (2014).

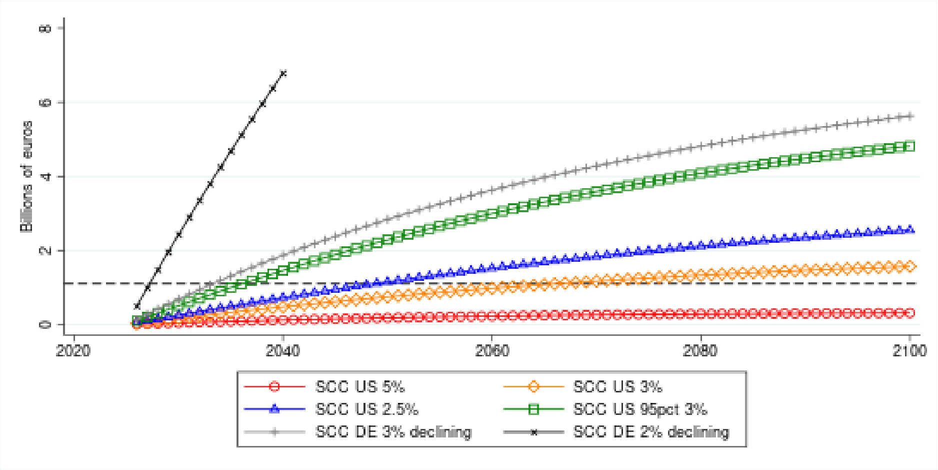
cent devoted to the green transition according to the EU guidelines. When using the average SCCs from the IWG, the investment does not repay its costs over the time horizon until 2100 even if we apply a 2.5 per cent discount rate (Figure 3). When considering the 95th percentile version of the SCC with a 3 per cent discount rate, the breakeven is reached in 2079. The estimates from UBA suggest a more optimistic cost-benefit ratio: the breakeven is reached in 2034 with a 2 per cent declining discount rate and in 2066 with a 3 per cent declining discount rate.

### 6.2 M2C2. Renewable energy, hydrogen, grid and sustainable mobility

Policies in this category of the plan are very heterogeneous. The plan reports the expected abatement only for three measures out of four in the renewable energy domain, while it does not report it for hydrogen, grid and sustainable mobility. The former three measures in the renewables domain account for 16 per cent of the total funding of the M2C2 category. We will focus on these interventions.

*Development of agri-voltaic systems* – The policy aims at installing solar panels in agricultural fields without subtracting land from farming. It is tagged as 100 per cent devoted to the green transition according to EU guidelines, with a cost of 1.1 billion euros. According to the Plan, this investment will abate emissions by 0.8 million tons of CO2 per year once realized, which we assume will happen in 2026 (the expected end of the plan).

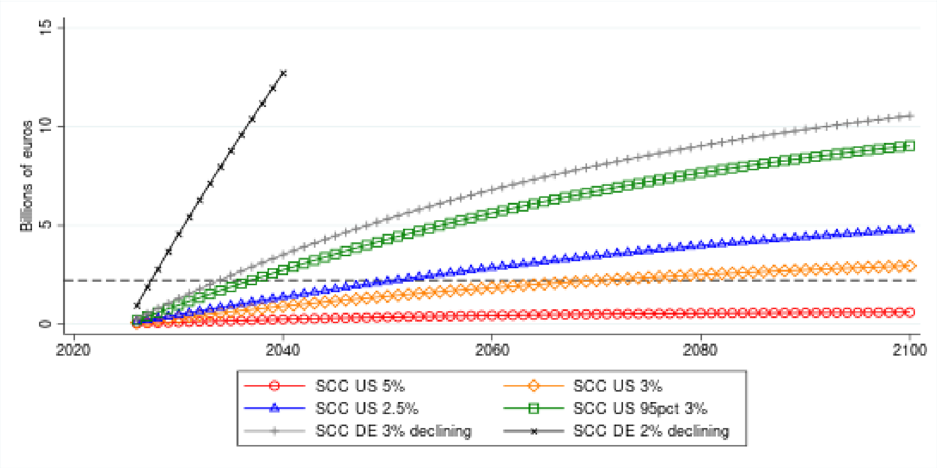
*Figure 4 - Agri-voltaic Systems*



When adopting the highest SCC (UBA with 2 per cent declining discount rate), the investment is repaid in full already in 2028. At the other end of the spectrum, the SCC from the IWG with a 5 per cent discount rate assigns to this investment a value well below the initial cost, even if one considers benefits from emission reductions until 2100. The other SCCs suggest that the initial cost will be fully compensated by the benefits in terms of emission reductions by, respectively, 2034, 2037, 2049 and 2067 (see Figure 4). Overall, this policy stands out as very cost-effective.

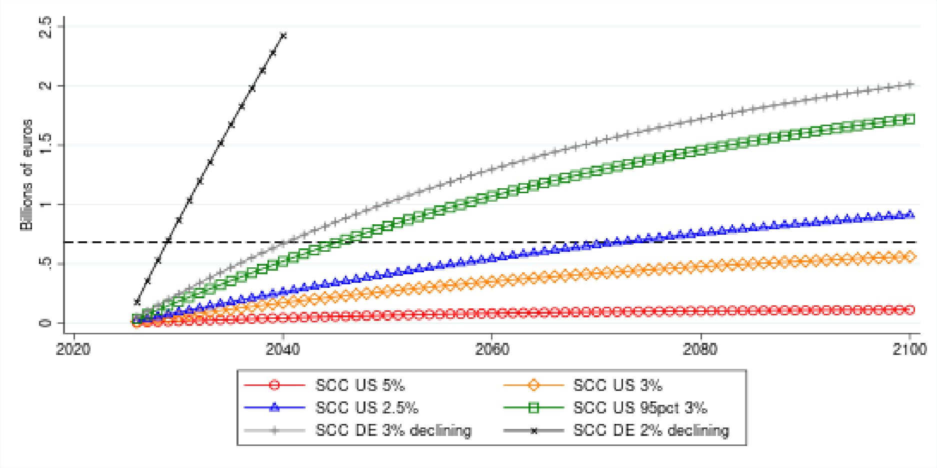
*RES promotion for energy communities and jointly acting renewables self-consumers* – The policy devotes 2.2 billion euros to encourage the production of renewable energy among consumers, firms and public administrations located in small towns. It is tagged as 100 per cent devoted to the green transition according to EU guidelines. According to the Plan it will abate emissions by 1.5 million tons of CO2 per year once realized. We assume the investment will be completed by 2026. This measure is very efficient: results are quite similar to the development of agri-voltaic systems discussed above as the cost-benefit ratio is almost the same (Figure 5).

*Figure 5 – RES promotion among self-consumers*



*Promotion of innovative renewable energy systems (including off-shore)* – The measure aims at supporting innovative renewable energy plants (e.g. those that exploit sea waves) for a total cost of 0.68 billion euros. It is tagged as 100 per cent devoted to the green transition according to EU guidelines. The NPRR expects that this investment will abate emissions by 0.286 million tons of CO2 per year once realized, which we assume will happen in 2026.

*Figure 6 - Innovative RES (including off-shore)*



Our findings suggest that this policy is only slightly less efficient than the two other interventions on renewable energy sources, but still almost reaches a breakeven by 2100 even when adopting a 3 per cent discount rate (Figure 6).

### 6.3 M3C1. Investments in the rail network

Investments in the rail network include the expansion and renovation of several rail lines for a total cost of 24.77 billion euros. These interventions are expected to shift both passenger and freight traffic from road to rail. According to the plan, the ambitious policy goal is to raise the share of passengers travelling by train from 6 to 10 per cent; this would result in emission reductions of 2.3 million tons of CO2 per year. Unfortunately, the NRRP does not make the freight traffic explicit, making it impossible to compute the corresponding emission abatement. We therefore conduct two exercises: one in which we consider only an increase in the use of the rail for passenger transport, which can be seen as a lower bound, and one in which we make some assumptions to also include the expected increase in the freight traffic. In particular, we assume that the investment might have an analogous effect on goods transport, and thus result in a total drop in emission of 3.3 million tons of CO2 per year. In both scenarios, we assume that the shift from road to rail would occur in 2026, the year by which the investments must be completed.

As in the case of the *superbonus*, this component is not only aimed at reducing emissions: the government believes that improved rail networks can also increase the accessibility of remote areas, in particular in the South, and foster economic convergence between low- and high-income regions. Existing evidence suggests that cutting transport costs might actually increase economic divergence, if not coupled with other policies that make laggard regions more attractive. In this context, our estimates of the benefits of the policy may thus represent a lower bound.

Figures 7 and 8 report the results for the lower and upper bound scenarios detailed in the previous paragraph. In both cases, accounting for benefits from emissions reduction until 2100 is not enough for the investment to recover its initial cost when using the average SCCs from the IWG. Results obtained with the SCCs from the UBA are more favourable, but the breakeven is reached well before 2100 only using the SCC estimate that discounts the future with a 2 per cent declining rate. With higher discount rates the desirability of the policy necessarily hinges upon its potential benefits in terms of improving economic convergence of laggard areas or from fiscal externalities, as large infrastructure investments may increase GDP and thus tax revenues.

*Figure 7 - Rail network (lower bound)*

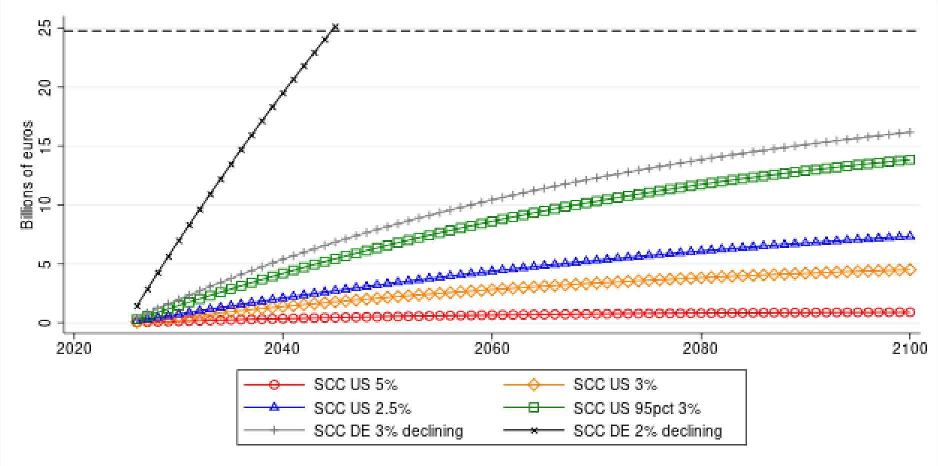
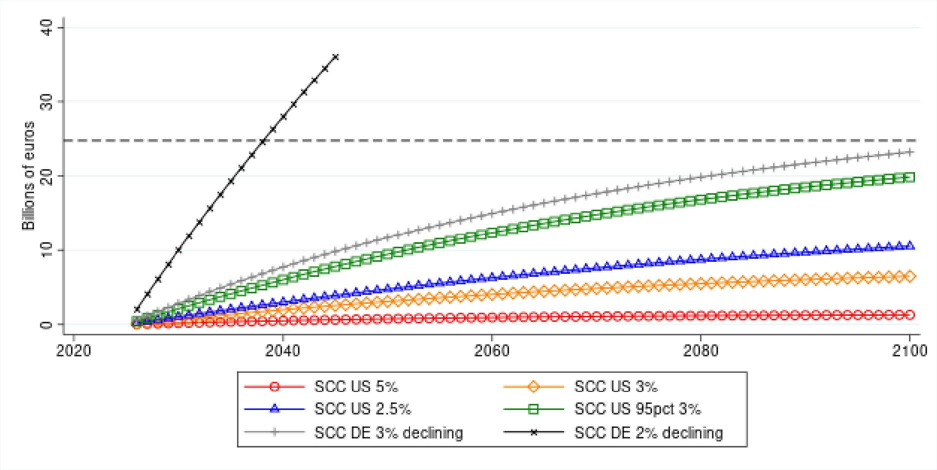


Figure 8 - Rail network (upper bound)



## 6.4 Financing investments via debt

Our previous analysis showed that both the *superbonus* and the investments in the rail network do not display a favourable cost-benefit ratio, unless we consider non-environmental benefits. Since these two investments are very sizable, we conduct an additional sensitivity test. In this section we assess the extent to which the results derived above depend on the assumption that the investment cost is paid upfront, and we check whether accounting for the fact that the NRRP is financed via public debt can significantly affect our findings. In particular, here we assume that the investment is financed via a 30-year zero-coupon bond with initial price equal to the face value $I$ (so that the financial return for the investor is 0). The investment cost for the government is thus equal to $I/(1+\delta)^{30}$ , which can be sensibly lower than $I$ depending on the discount rate (see Figure 9).

Figure 9 - Discount factor at 30-year horizon as a function of the discount rate

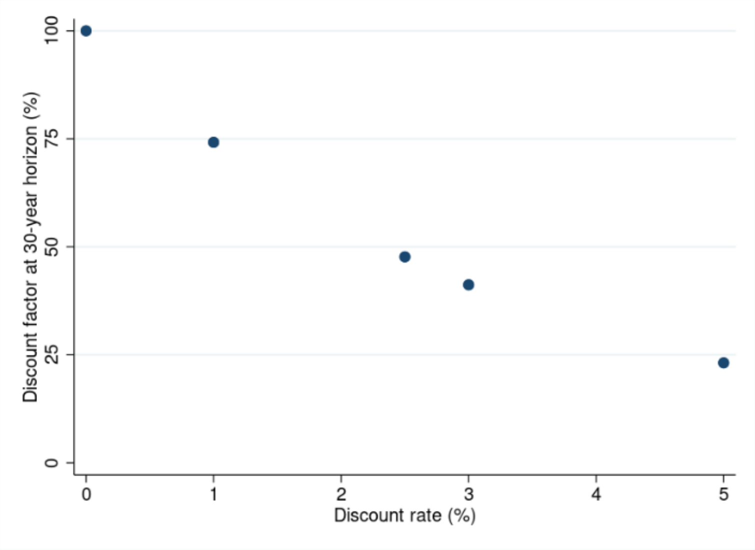


Figure 10 reports results for the *superbonus*: each panel shows the cumulative value of the project $V_t$ as a coloured connected line, and its cost $I/(1+\delta)^{30}$ as a horizontal dashed line. When using the mean SCCs provided by the IWG with discount rates of 5, 3 and 2.5 per cent (upper panels), the value of the investment is still well below its cost, after accounting for emission reductions until 2100. On the contrary, when using the high-impact SCC by the IWG with a 3 per cent discount rate or the SCC by UBA with a 3 per cent declining discount rate, financing the investment via debt is enough to almost match costs and benefits in 2100.

Figure 11 reports results for the investments in the rail network (upper bound scenario). In this case, financing the project via debt goes a long way in aligning costs and benefits. In particular, the breakeven is almost reached before 2100 when using the mean SCC by the IWG with a 2.5 per cent discount rate, while it occurs around mid-century using the high-impact SCC by the IWG with a 3 per cent discount rate or the SCC by UBA with a 3 per cent declining discount rate. Only when using discount rates above 3 per cent, the value remains well below the cost even when accounting for emissions reductions until 2100.

*Figure 10 – Superbonus financed via debt*

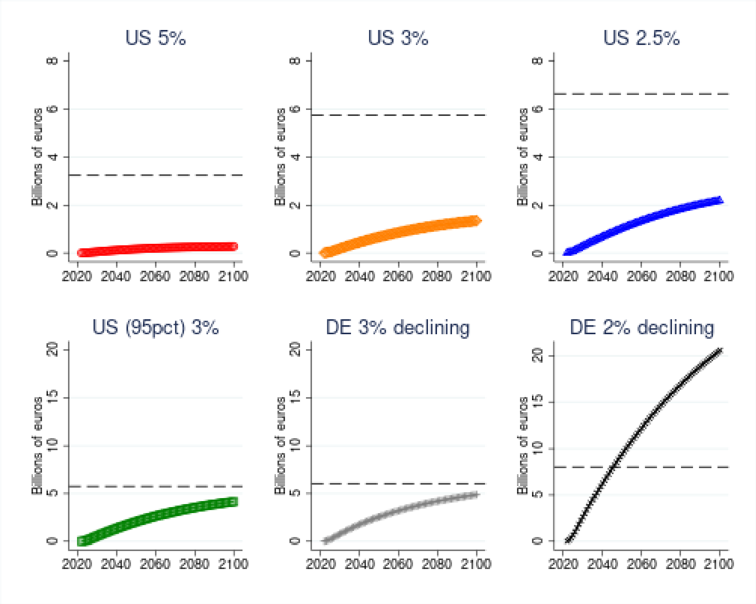
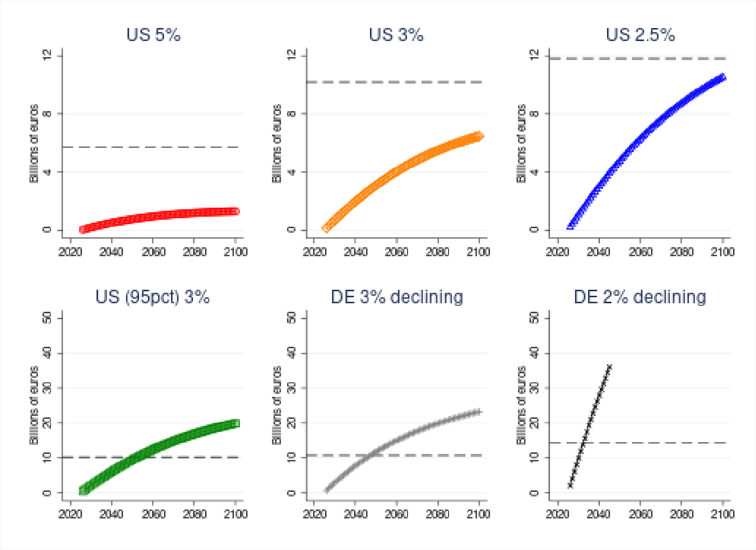


*Figure 11 - Rail network (upper bound scenario) financed via debt*



## 7. Conclusion

In this short paper, we provide a baseline quantitative assessment of the green projects included in the Italian NRRP, using state-of-the-art estimates of the SCC. For those projects where investment costs and expected GHG emission reductions are provided (61 per cent of the NRRP funding dedicated to green investments), we estimate the breakeven year after which the monetary present value of cumulative environmental benefits will exceed the costs.

This simple exercise reveals that several projects included in the Italian NRRP would have a positive net present value if the policymakers adopted relatively low social discount rates (around 2 per cent) and gave more weight to damages that occur in developing countries rather than in advanced ones. When using higher discount rates and equal weighting, several projects might still be worth pursuing if policymakers envisage substantial non-environmental benefits from the investments. A discount rate of 2 per cent (declining over time) is the lowest that we consider in the present study, since we use the SCC computed by the US and German agencies. Our reading of the most recent literature is that values below 3 per cent are probably appropriate in the context of climate change mitigation, although there is some disagreement about this (Drupp et al., 2018). The sensitivity of our results to the chosen discount rate stems from the fact that several interventions are very costly, but deliver only a slow reduction in GHG emissions over time.

When we take into account the fact that the investments are financed via debt issued under very favourable conditions, the outcome of the evaluation becomes more positive also for higher discount rates (in particular this is the case for the investments in the rail network). The investments aimed at increasing the penetration of renewable energy sources stand out as those for which the benefits outweigh the cost even using high discount rates and without considering non-environmental benefits in the calculation.

Finally, we caution against rushing to draw conclusions about the Italian plan based only on our analysis. As mentioned above, the NRRPs are subject to several constraints meant to reach a compromise between different policy goals (e.g. digitalization, decarbonization, etc.). Moreover, these plans are embedded in the general European climate policy, which is currently based on quantity emission targets to achieve carbon neutrality by 2050.

## References

Aldy, J. E., Kotchen J. M., Stavins R. N. and Stock, J. H. (2021). Keep climate policy focused on the social cost of carbon. *Science, 373(6557),* 850-852.

Allcott, H., & Greenstone, M. (2012). Is there an energy efficiency gap?. *Journal of Economic perspectives*, *26*(1), 3-28.

Bauer, D. M., & Rudebusch, G. D. (2021). The Rising Cost of Climate Change: Evidence from the Bond Market. *Review of Economics and Statistics*.

Becker, G. S., Murphy, K. M., & Topel, R. H. (2011). On the economics of climate policy. *The BE Journal of Economic Analysis & Policy*, *10*(2).

Boomhower, J., & Davis, L. W. (2014). A credible approach for measuring inframarginal participation in energy efficiency programs. *Journal of Public Economics*, *113*, 67-79.

Drupp, M. A., Freeman, M. C., Groom, B., & Nesje, F. (2018). Discounting disentangled. *American Economic Journal: Economic Policy*, 10(4), 109–34.

Finkelstein, A., & Hendren, N. (2020). Welfare analysis meets causal inference. *Journal of Economic Perspectives*, 34(4), 146-67.

Fowlie, M., Greenstone, M., & Wolfram, C. (2018). Do energy efficiency investments deliver? Evidence from the weatherization assistance program. *The Quarterly Journal of Economics*, 133(3), 1597-1644.

Giglio, S., Maggiori, M., & Stroebel, J. (2015). Very long-run discount rates. *The Quarterly Journal of Economics*, 130(1), 1-53.

Giglio, S., Maggiori, M., Rao, K., Stroebel, J., & Weber, A. (2021). Climate change and long-run discount rates: Evidence from real estate. *The Review of Financial Studies*, 34(8), 3527-3571.

Gillingham, K., & Stock, J. H. (2018). The cost of reducing greenhouse gas emissions. *Journal of Economic Perspectives*, 32(4), 53-72.

I. W. G. on Social Cost of Carbon (2021). *Technical support document: Social cost of carbon for regulatory impact analysis under executive order 13990.* (Tech. Rep.). United States Government.

Hendren, N., & Sprung-Keyser, B. (2020). A unified welfare analysis of government policies. *The Quarterly Journal of Economics*, 135(3), 1209-1318.

Ramsey, F. P. (1928). A mathematical theory of saving. *The Economic Journal*, *38*(152), 543-559.

Stern, N., & Stiglitz, J. E. (2021). *The social cost of carbon, risk, distribution, market failures: An alternative approach* (No. w28472). National Bureau of Economic Research.

Weitzman, M. L. (1998). Why the far-distant future should be discounted at its lowest possible rate. *Journal of environmental economics and management*, 36(3), 201–208.

Weyant, J. (2017). Some contributions of integrated assessment models of global climate change. *Review of Environmental Economics and Policy*.