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Within-country inequality and the shaping of a just global climate policy

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Abstract

Climate change and global inequality are intertwined. First, from a cross-country perspective, poorer countries have less financial capacity to abate emissions and are more vulnerable to climate impacts. Second, within countries, climate damages and mitigation costs tend to fall disproportionately on poorer households, which has implications for the political feasibility of mitigation. Integrated Assessment Models used for global climate policy evaluation have so far typically not considered inequality effects within countries. To fill this gap, we develop a global Integrated Assessment Model representing national economies and sub-national income distribution, and assess a range of climate policy schemes with varying levels of effort sharing across countries and households. The schemes are consistent with limiting temperature increases to 2°C, and account for the possibility to use revenues from carbon pricing to address distributional effects within and between countries. Among these, we explore a "Loss and Damage" scheme, aiming to compensate vulnerable countries for unavoidable damages from climate change. A key finding is that relatively low levels of international transfers can result in sizable improvements in inequality and welfare, due to the impacts on the most vulnerable households within countries. If international transfers are not feasible, our results show that the greatest inequality reductions can be achieved through sub-national transfers and reallocation of abatement efforts across time and countries.

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Climate change is one of the most pressing issues that societies are facing. Research on climate policy often highlights the trade-off between taking action to efficiently address climate change and ensuring fairness. Poorer nations have contributed less to total emissions, and are less able to afford mitigation and adaptation policies (Dellink et al., 2009). Additionally, the burden of climate impacts tends to fall disproportionately on the poorest households within countries (Hallegatte and Rozenberg, 2017). Ramping up mitigation policies to reach Paris agreement targets may also disproportionately affect the most vulnerable households, for example through its effects on prices (Ohlendorf et al., 2021).

Examining impacts beyond average regional effects can help inform decision-makers about the political feasibility of climate policies (Fabre et al., 2023), and their interaction with other sustainable development goals. Sub-national climate policy impacts depend on the international allocation of the climate burden, the relative vulnerability of populations within countries, and domestic policies. However, Integrated Assessment Models used for global climate policy evaluation have so far typically not considered inequality effects within countries.

Here, we develop a global climate policy model with income inequality, climate damages and mitigation costs at the sub-national levels. Our approach examines how revenues from mitigation policy can be used to address distributional effects arising from mitigation costs and unavoidable climate impacts, both between and within countries. To this end, we focus on a scenario limiting temperature increases to 2°C, and analyze the global inequality and welfare impacts of a range of carbon taxation and transfer schemes, with varying levels of effort sharing across countries and households.

A number of studies have shown that recycling a carbon tax at the domestic or global level has potential to generate poverty reductions and welfare gains (Davies et al., 2014; Soergel et al., 2021; Budolfson et al., 2021; Fujimori et al., 2020; Emmerling et al., 2024a), improve distributional outcomes (e.g., Vogt-Schilb et al., 2019; Feindt et al., 2021) and foster political acceptance (Klenert et al., 2018; Carattini et al., 2019). Closest to our approach, Emmerling et al. (2024b) studies carbon taxation and recycling in a global climate policy model with sub-national impacts, but covers only a subset of countries, thereby missing impacts on some of the world's most vulnerable populations[1]. Our results show that even modest (international) transfers can lead to substantial improvements in global inequality and welfare, due to their impact on the most vulnerable households within countries.

One proposal to improve fairness in facing the burden of climate change is to compensate the most vulnerable countries for the "Loss and Damage" they experience. The Warsaw International Mechanism for Loss and Damage, set up at COP19, proposes a fund financed by developed countries[2]. In this paper, we examine whether revenues from carbon taxation could be sufficient to compensate vulnerable low-income countries for unavoidable climate damages, and the resulting welfare and inequality effects. We contribute to the scarce literature providing quantitative estimates of Loss and Damage using Integrated Assessment Models (Markandya and González-Eguino, 2019; Tavoni et al., 2024), and further account for within-country effects of transfers.

[1]In particular, Emmerling et al. (2024b) includes Sub-Saharan African countries as a single region. In addition, we analyze a different set of policies, including differentiated taxes and international transfers.

[2]The idea that more developed countries should help developing ones to ensure their transition and adaptation to climate change is widely accepted in international negotiations. Notably, the Paris Agreement envisions financial transfers in the form of assistance (Paris Agreement, Article 9 UNFCCC, 2015).

However, international transfers may also face feasibility constraints. To make climate policy more equitable while upholding ambition, an alternative is to delay mitigation efforts in developing countries, and compensate that delay with stronger mitigation in developed countries. In the context of carbon taxation, this amounts to favoring carbon taxes that are differentiated across countries over uniform taxes– which are considered more cost-efficient but less fair. Bauer et al. (2020) analyses uniform versus differentiated taxes with the ReMIND model, but focuses on the level of necessary transfers to achieve "equitable effort sharing" across twelve regions, and does not include sub-regional inequality. Here, we disentangle the different channels of impact on global inequality and welfare: overall mitigation costs, between- and within-country inequality, and timing of mitigation efforts and carbon tax revenue use.

1 Approach

We develop a global climate policy model in the vein of the Nested Inequalities Climate Economy model (NICE, Dennig et al., 2015), which features within-region inequality for twelve world regions. We build on the latest version of the model, which allowed for carbon tax revenue recycling (Budolfson et al., 2021). To investigate carbon tax and revenue recycling scenarios at the global, country and within-country levels, we augment the granularity of the model to 179 countries[3]. We downscale mitigation costs, carbon tax burdens and climate damages to the country-level and distribute them across deciles within countries. Details can be found in Methods (M1-3).

We compare the effects of different policy designs consistent with a 2°C temperature increase target: optimally differentiated taxes versus a global carbon tax; and in the case of the global carbon tax, different redistribution schemes – at the country level, at the global level, or somewhere in-between to reflect a Loss and Damage policy (see Methods M.5 for descriptions). The comparison is based on average consumption, on inequality indices (Gini and Atkinson indices), and on a more comprehensive welfare measure based on Atkinson (1970).

To rank scenarios in terms of welfare, we employ equally distributed equivalent consumption (EDEC). This is an inequality-adjusted per capita consumption measure. The methodology is similar to the one used for the Inequality-adjusted Human Development index (IHDI, see UNDP, 2024): average consumption is "discounted" according to the level of consumption inequality. EDEC is equal to the average consumption value when there is no inequality across people but falls below average consumption as inequality rises. In this sense, EDEC measures the level of consumption, "discounted" by the level of inequality. The key parameter is inequality aversion η. For a given level of inequality, the larger η the larger the loss (or "discount") applied to the average consumption (see SI.7 for details).

[3] This set of countries corresponds to the set represented in the Shared Socioeconomic Pathways, with Somalia, Venezuela, New Caledonia and Trinidad and Tobago removed due to data limitations.

2 Results

2.1 Cost-effectiveness and inequality impacts of 2°C scenarios

Introducing a global carbon tax or differentiated carbon taxes at the country level implies very different burden sharing of emission reductions. A global uniform carbon tax addresses heterogeneity in emitters by equalizing the marginal cost of abatement in all countries, thus ensuring cost-effectiveness (see, e.g., Chichilnisky and Heal, 1994). On the other hand, the burden sharing in the differentiated tax case is not based on efficiency but on fairness considerations. The sharing rule reflects the notion that an additional dollar or consumption unit is more valuable in a poorer country, by taking into account differences in the marginal welfare derived from consumption (details can be found in SI.3).

Consistent with environmental economics theory, we find that differentiating carbon taxes implies higher total abatement costs at the global level, indicated by a larger percentage reduction in consumption per capita compared to business-as-usual (BAU) than with a global uniform tax (Figure 1a). The magnitude of the cost-efficiency loss is determined by countries' abatement costs and by the magnitude and distribution of deviations in tax levels from the uniform tax case. The latter is driven by the strength of the fairness motive, parameterized by the inequality aversion, η.[4] In addition, we find that all tax and recycle schemes in the 2°C scenario result in increases in global consumption per capita with respect to the BAU towards the end of the century, as climate damages associated with stronger climate change are avoided. In the BAU, the increase in global average temperature reaches close to 3°C by the end of the century (see SI.F.3).

Next, Figure 1b displays the change (in percentage) in our welfare measure, equally distributed equivalent consumption (EDEC), compared to BAU. While the 2°C scenario only increases global consumption per capita with respect to BAU at the end of the century, all carbon tax schemes result in welfare increases compared to the BAU within the first decades of implementation. This is because EDEC accounts for changes in average consumption and inequality. As shown in Figure 1c, all schemes in the 2°C scenario result in a decrease in global inequality, as measured by the Gini index (based on the population-weighted decile per capita consumption level in all countries). Further decomposing[5] changes in global inequality, we find that the decrease in global inequality can be explained by decreases in between- and within-country inequality (Figure 1d).

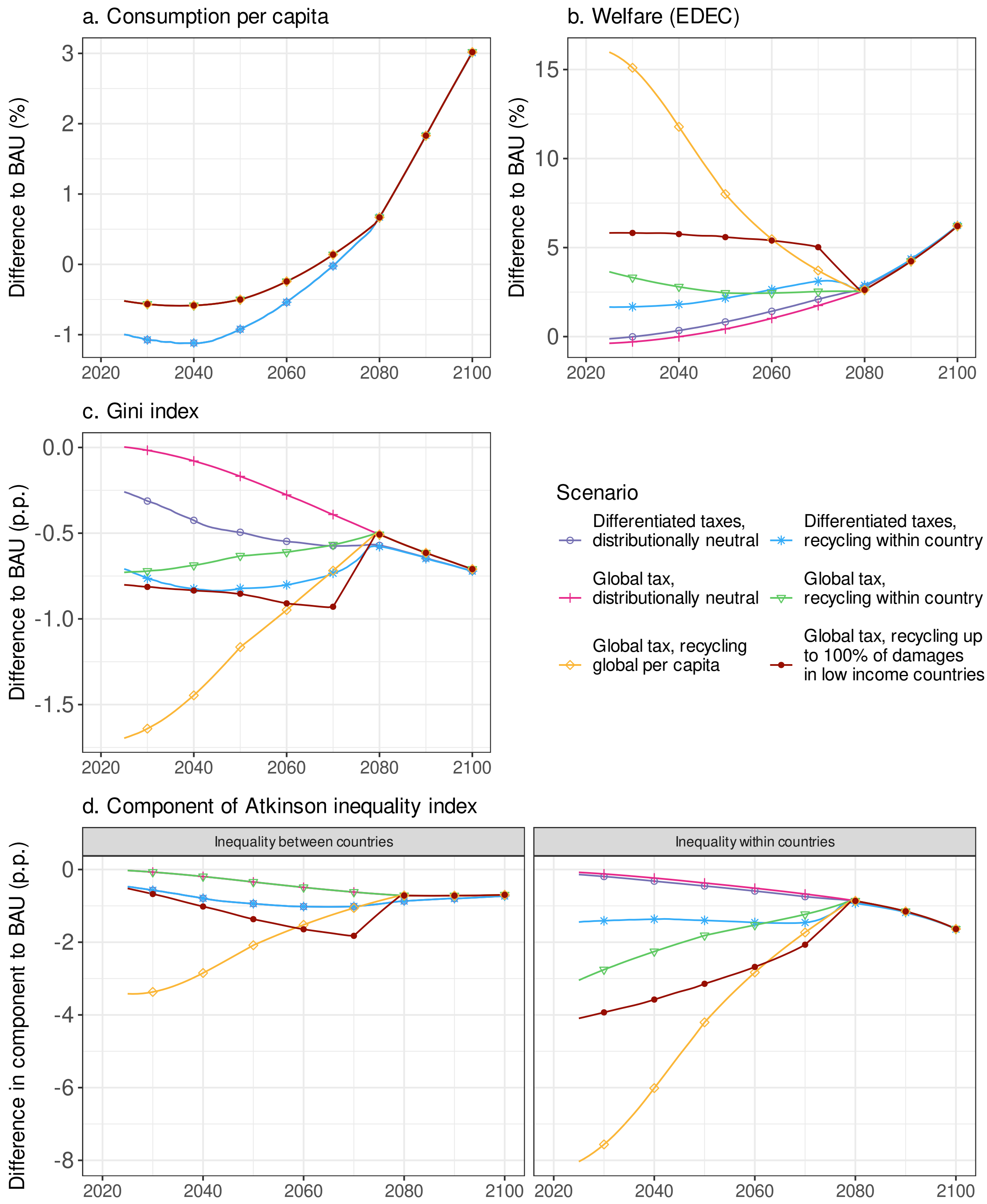
Between-country inequality decreases in all 2°C scenarios compared to the BAU because keeping global temperature increases under 2°C reduces climate damages, which benefits poorer countries disproportionately. Differentiated taxes schemes further decrease between-country inequality because they shift part of the mitigation costs from poorer to richer countries. Schemes with international transfers also decrease inequality across countries, as they feature transfers from richer to poorer countries.

Within-country inequality also decreases with every scheme because climate damages are avoided, and damages fall disproportionately on the poorest within countries (following the evidence in Gilli et al. (2024), see Methods M.1 for details). Furthermore, in

[4] As can be seen in the sensitivity analysis in SI.11, a higher level of inequality aversion produces larger spread of differentiated taxes, as more weight is put on costs in relatively poorer countries.

[5] The inequality components are computed from per capita consumption of deciles in all countries, using the Atkinson index and setting $\eta = 1.5$. The Atkinson index is used for this decomposition instead of the Gini, because it is decomposable by subgroups (meaning that total inequality is a function of inequality in each subgroup), which is, in general, not the case for the Gini. Formal details on the decomposition can be found in SI.7.

Figure 1: Difference compared to the business-as-usual scenario of a. consumption per capita (%), b. welfare (equally distributed equivalent consumption, %), c. Gini index (p.p.), and d. component of Atkinson inequality index (p.p.), in the 2°C scenario and for the six carbon tax and revenue recycling scheme alternatives.



schemes with revenue recycling, the revenue is distributed across households on an equal per capita (EPC) basis, which improves the progressivity of these schemes. EPC recycling corresponds to an income elasticity of 0, which is more progressive than recycling proportionally to damages (with an income elasticity larger than 0 in our calibration)[6]. The effects of revenue recycling occur until carbon tax revenues fall to zero when world decarbonization is achieved.

The welfare gains in the 2°C scenario compared to the BAU also depend on the assumed inequality aversion. We use a value of $\eta = 1.5$, in line both with expert surveys and meta-analyses on inequality aversion in the context of climate policy (Nesje et al., 2023; Del Campo et al., 2024), and with Barrage and Nordhaus (2024). Our sensitivity analysis (SI.11) shows that increasing or decreasing the inequality aversion does not change the ranking of policies in terms of welfare. As expected, the size of the overall welfare gain compared to BAU decreases under lower inequality aversion in all scenarios with redistribution.

2.2 Which policy for improved global welfare and equity ?

Next, we analyze the ranking of carbon tax and transfer schemes, in terms of their global welfare effects (using EDEC), compared to the BAU. The most welfare-enhancing policies are the two which feature global uniform taxation with international transfers (Figure 1b). Under the global equal per capita recycling scheme, global welfare increases up to 15% compared to the BAU. This scheme combines the cost-effectiveness of uniform taxation with the strongest decline in the global Gini compared to the BAU (up to 1.5 p.p., Figure 1c), explained by the strongest reductions in both between- and within-country inequality (respectively, declining up to 3.5 p.p. and 8 p.p., Figure 1d). The strong inequality improvement results from the flows of international transfers that the scheme entails (up to 2.25% of global GDP, see Figure SI.F.6).

However, revenue sharing at such a scale might not be feasible. We study next a "Loss and Damage" scheme, in which the global revenues from uniform carbon taxation are used to compensate vulnerable countries for the climate damages they incur. The global revenue not used for Loss and Damage compensation is kept and recycled equal per capita within countries. The policy results in an increase in welfare by up to 5% compared to BAU (Figure 1b), and is the second best policy in terms of Gini index reductions (Figure 1c). A small number of countries receives Loss and Damage transfers, but these are low income and relatively unequal countries. So the scheme reduces between- and within-country inequality more than uniform carbon taxation without international transfers. We assess the Loss and Damage policy in more detail in section 2.4.

The following most welfare-enhancing policies are the two with revenue recycling within-country, under uniform and differentiated carbon taxation. The differentiated tax scheme results in larger reductions in the global Gini index (Figure 1c), due to its effect on between-country inequality, but is less cost-effective (see above). Under differentiated taxes, carbon taxes in relatively poorer countries ramp up later in the century[7], which implies that transferrable carbon tax revenue is available later in these countries. As a result, the uniform scheme is more welfare-enhancing than the differentiated taxes scheme

[6]Within countries, the richest households incur more damages and carbon tax costs in absolute terms (reflected by income-elasticities above zero), but receive the same absolute transfers from equal per capita recycling as poorer households.

[7]See SI.5 for illustration of the trajectories of uniform and differentiated taxes.

until mid-century.

Finally, we find that if international transfers are not feasible, and if recycling of revenue is distributionally neutral (i.e., revenues are refunded to exactly offset tax payments), then differentiated taxes are more welfare improving that uniform taxes (Figure 1b). Our results show that differentiated taxes are less cost-effective (Figure 1a), but that this is counter-balanced by larger global inequality reductions under differentiated taxes. These larger global inequality reductions are driven by larger between-country inequality reductions (Figure 1d), as taxes are differentiated across countries with a rule that accounts for equity concerns (see SI.3). Our results confirm that, in the absence of domestic and international transfers, a differentiated tax scheme that shifts abatement costs onto richer countries can lead to global welfare gains compared to a uniform tax (Bauer et al., 2020).

2.3 National-level outcomes

To investigate the heterogeneous effects of differentiated and uniform carbon taxes and recycling scheme across countries, we map the global distribution of welfare changes[8] compared to the BAU (in terms of percentage change in equally distributed equivalent consumption) for four policy alternatives in 2030 and 2050 (Figure 2). We also select a subset of countries of different income levels for which we analyze the timing of welfare gains and losses over the whole century (Figure SI.F.7).

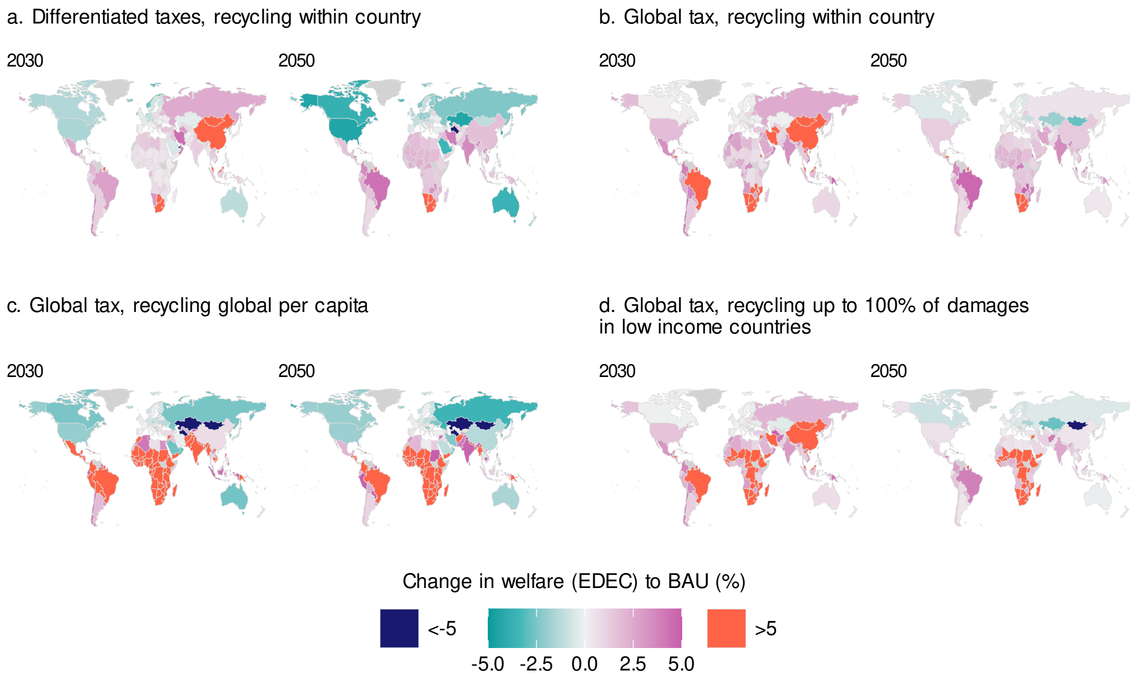
High-income countries experience welfare losses under the differentiated taxes and the global equal per capita recycling schemes (Figure 2a and c). On the contrary, poorer countries experience gains, whatever the scenario. This is because they tend to be more vulnerable to climate change damages, and thus benefit relatively more from the 2°C policies. Welfare in lower income countries is additionally increased due to the inequality-improving effect of within-country revenue recycling, and in cases with international transfers. Generally, welfare impacts at the country level depend on baseline income and inequality, magnitude of avoided climate damages, and emission level and abatement costs (see SI.10).

The global per capita recycling policy results in the most widespread and large gains in relatively lower income countries (Figure 2), with a low-income country like Guinea experiencing an increase in welfare compared to the BAU of up to 30% (Figure SI.F.7). The Loss and Damage scenario, in which revenues from uniform carbon taxation are used to compensate low-income countries for the damages they incur and remaining revenues are recycled in originating countries, results in welfare increases for the targeted low-income countries, with little impact for non-targeted countries (Figure 2 b and d). For instance, Guinea experiences a welfare increase of over 10% with respect to BAU up to 2070 under the Loss and Damage scheme, while middle- and high-income countries experience similar welfare changes under the Loss and Damage and the global tax with within-country recycling scheme (Figure SI.F.7). However, for middle- and high-income countries, welfare later in the century is relatively lower in the Loss and Damage scheme, because a larger share of global revenues needs to be transferred to low-income countries, as shown in the next section.

Note also that, in the case of per capita recycling within a country, some relatively richer countries can benefit more from the differentiated tax scheme than poorer countries. This is for instance the case of Brazil, having more welfare gains than many lower

[8] In complement, country-level effects on consumption per capita, avoided climate damages, Gini index and abatement costs are displayed in section SI.10.

Figure 2: Difference in welfare (equally distributed equivalent consumption, EDEC) in the 2°C scenario compared to the business-as-usual scenario (%) for four carbon tax and revenue recycling scheme alternatives in 2030 and 2050.



Note: $\eta = 1.5$. The scale is truncated at -5% and +5% to enable visual comparison across policies, and across gains versus losses. Figure SI.F.7 displays the untruncated results for the whole time horizon, for a selection of countries of various income levels.

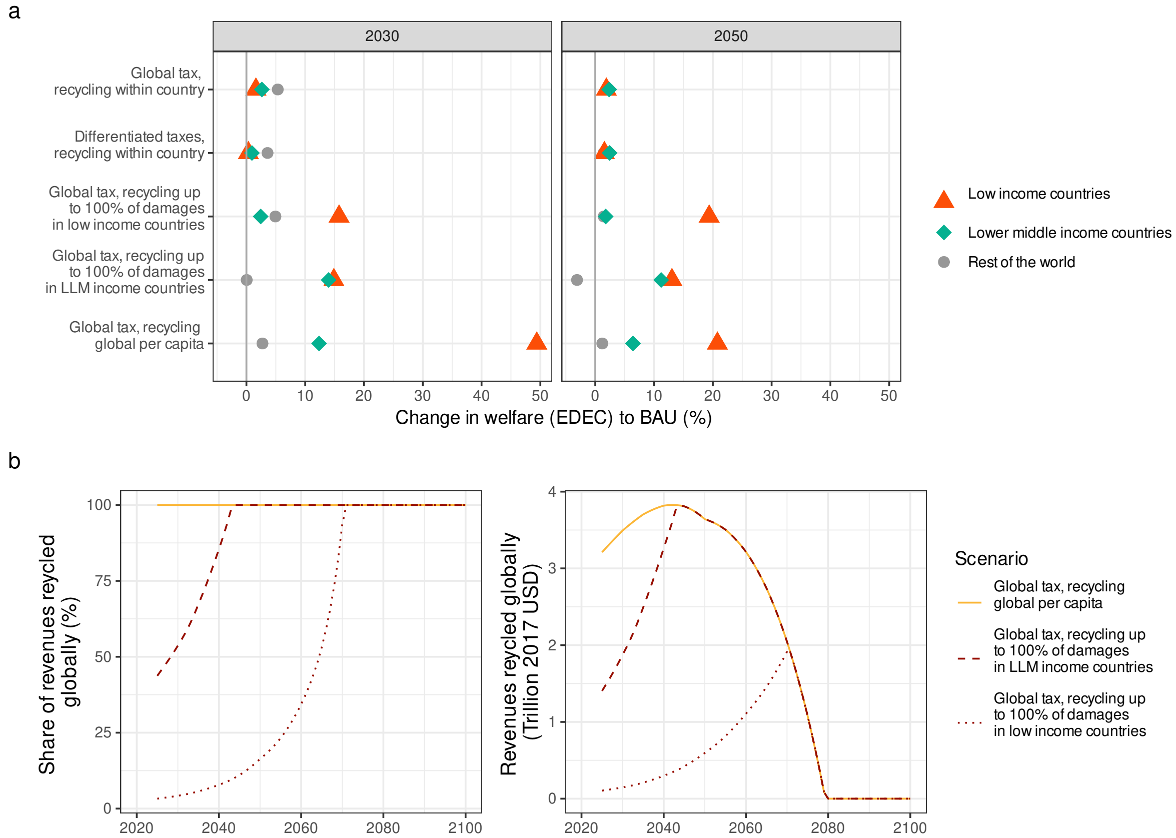
income countries (Figure 2a). This may seem counter-intuitive as differentiated taxes are usually thought to be a better solution to mitigate transition costs in developing countries compared to a globally uniform tax when unlimited intergovernmental transfers are impossible (Chichilnisky and Heal, 1994; Hourcade and Gilotte, 2000). But this seemingly paradoxical conclusion can be explained by the fact that our scenarios include revenue recycling, which is not usually considered in other works. Recycling tax revenues can bring welfare benefits, especially in more unequal countries.

2.4 Funding needs and welfare effects of Loss and Damage policies

Finally, we focus on two "Loss and Damage" schemes in which revenues from uniform taxation are transferred to cover up to 100% of damages in selected countries. This represents an intermediary scenario between recycling revenues on a global scale, which requires large international transfers, and recycling revenues only within-countries. In a first variant, transfers are directed only to low-income countries, while in a second variant, both low-income and low-middle income countries are targeted (the list of low and low-middle income countries can be found in SI.6). We evaluate the magnitude of international transfers of carbon tax revenues in the two scenarios (Figure 3b) and compare their welfare effects to those of other scenarios (Figure 3a).

We find that covering all damages in low and low-middle income countries would re-

Figure 3: Welfare impact in low and lower-middle income versus the rest of the world and global revenue needs in the 2°C scenario for different carbon tax and revenue recycling scheme alternatives.



Note: $\eta = 1.5$. a. Difference compared to the business-as-usual scenario of equally distributed equivalent consumption (%); b. share (%) and amount (trillion 2017 dollars) of revenues recycled globally, in 2030 and 2050. Low-income and low-middle-income countries as defined by the World Bank, see SI.6.

quire around 1.8 trillion USD2017 in 2030 (50% of global carbon tax revenues) and over 3.5 trillion USD2017 in 2050 (over 100% of revenues). Focusing only on low-income countries, we find funding needs of 100 billion USD2017 in 2030 (5% of revenues) and 500 billion USD2017 in 2050 (15% of revenues). Our estimates for Loss and damage compensation in low and low-middle income countries are in the same order of magnitude but larger than the (scarce) previous published estimates[9]. The differences can be explained by different damage functions, target countries, and definitions of unavoided losses and damages from climate change[10].

Turning to welfare impacts (Figure 3a), covering 100% of damages in low-income countries results in larger welfare improvements (more than 10 percentage points) than scenarios with only recycling within countries, with little effect on welfare in non-targeted countries. In 2050, the welfare gains for low income countries in the loss and damage

[9] Markandya and González-Eguino (2019) estimate needs of 20 to 80 billion USD2005 in 2030 and 1.1–1.7 trillion USD2005 in 2050. In a commentary, Tavoni et al. (2024) estimate total Loss and Damage funding needs to be between 128 and 937 billion USD for the year 2025.

[10] Here we take the extreme position that all damages in poor countries are unavoided losses and damages.

scenario are similar to those in the global equal per capita recycling scenario, while requiring only about 20% of the global revenues to be international transferred. Countries that are not low or low-middle income can still experience welfare gains in the Loss and Damage scenarios, because the share of carbon tax revenues that is not transferred as Loss and Damage funding is recycled within countries on an equal per capita basis; and because any 2°C scenario results in avoided climate damages with respect to the BAU. In 2050, the welfare gains for low-income countries in the loss and damage scenario are similar to those in the global equal per capita recycling scenario, while requiring only 20% of the global revenues to be transferred. Finally, covering up to 100% of damages in both low-income and low-middle income countries also brings welfare improvements for targeted countries but implies channeling 100% of carbon tax revenues after 2040, which results in welfare losses compared to the BAU for the group of non-targeted countries.

3 Discussion

We build a global climate policy integrated assessment model which captures the distribution of income, mitigation costs and climate damages at the sub-national level, and examine the global inequality and welfare impacts of both country-level and global climate policies, including transfers. We find that impacts on within-country inequality play an important role in global inequality outcomes, and that relatively small transfers (domestic or international) can improve global inequality and welfare as they benefit the most vulnerable households within countries.

Our results show that a uniform global carbon tax with global per capita recycling would be most inequality-improving, but would entail collecting and redistributing globally up to 2.25% of global GDP. In contrast, a "Loss and Damage" policy, in which revenues from global carbon taxation are used to compensate vulnerable countries for climate damages, could improve global welfare while requiring lower international transfers. We find that, by 2050, around 15% of global carbon tax revenues would be needed to compensate low income countries, but that global revenues would be insufficient to compensate for damages in both low- and low-middle-income countries. Compensating low income countries could bring strong inequality reduction and significant welfare increases for these countries, while also improving welfare in the rest of the world, under the assumption that the revenues that are not transferred are kept and recycled domestically.

However, governments may be hesitant to participate in revenue sharing on such a large scale. If international transfers are limited, our results suggest that a good alternative policy could be to implement differentiated taxes with domestic revenue recycling. In addition, we find that the timing of the benefits from differentiated and global taxes with domestic recycling of tax revenues differs. A uniform tax yields larger benefits in the first decades in most countries, while differentiated taxes yield benefits later in the century for poorer countries.

Our results remain conditional on a number of assumptions, and could be extended. We assume that revenue can be redistributed effectively and at a negligible cost, either at the domestic or global levels. While this assumption might be a good approximation at the country level in developed countries because states already operate fiscal and distributive systems, distributing revenue to the poorest households in the least developed countries might be more challenging (Slater, 2011). Collecting and distributing funds at a global level would lead to additional bureaucratic costs. Taking those into account could reduce the magnitude of the benefits of implementing the climate policies we consider. We also abstract from modeling negative emissions. Using a substantial share of tax revenues to finance negative emissions could reduce the magnitude of our welfare results, but would likely not qualitatively change them. Including negative emissions could also lead to dampen the inequality improvements from mitigation, if the returns from net emissions technologies accrue disproportionately to rich investors (Andreoni et al., 2024). Last, our analysis does not feature trade and economic feedback effects of transfers.

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Author contributions

A.M. M.Y.B. and S.Z designed the research. All authors developed the model (code writing and/or data preparation). M.Y.B. performed the model runs and prepared the figures. A.M., M.Y.B. and S.Z. wrote the manuscript, and edited it with S.F..

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M Methods

M.1 Within country inequality and distributional impacts

While the previous versions of the NICE model featured consumption quintiles (Dennig et al., 2015; Budolfson et al., 2021), we here introduce consumption deciles. We calibrate baseline deciles using country income gini projections until 2100 in the SSP2 scenario, as provided by Rao et al. (2018). SSP2 is the "Middle of the road" Shared Socio-economic Pathway (SSP), and corresponds to a scenario where socio-economic and technical projections are in the continuation of historical trends. Importantly, the SSPs do not account for the likelihood of different socioeconomic and emissions futures and thus neglect an important source of model uncertainty. We note, however, that the results from prior work using NICE remain largely unchanged when using alternative SSP scenarios that assume either low (SSP1) or high (SSP3) levels of global inequality (Budolfson et al., 2021).

We assume that for each country i, income is distributed across deciles according to a lognormal distribution $LN(\mu_i, \sigma_i)$. We can deduce standard deviations σ_i from country Gini indices.[11] From the standard deviations σ_i, we can deduce a Lorenz curve for each country and each time step, from which we obtain country income deciles over time. We use a transformation vector to derive consumption deciles from income deciles, following the approach proposed by Pinkovskiy and Sala-i Martin (2009).

Climate damages, mitigation costs and carbon tax burdens are distributed across deciles using consumption elasticities (see Dennig et al., 2015, for the use of elasticities in the modelling of distributional impacts in NICE). The initial burden of a carbon tax is the distribution of mitigation costs and carbon tax payments before tax revenues are recycled and redistributed. Within each country, mitigation costs and carbon tax payments are assumed to be distributed across deciles using the same consumption elasticity of the initial burden for a given country at a given time. Consumption elasticity of the initial burden is calibrated using the estimation provided in Budolfson et al. (2021), which they derive from a review of the literature on the initial burden of carbon taxation across countries before the redistribution of tax revenues. The consumption elasticity of the initial burden $w_{i,t}$ of country i at time t is thus given by: $w_{i,t} = \hat{\alpha} + \hat{\beta} \cdot \log y_{i,t}$, with y the GDP per capita. This elasticity is thus endogenous, as it depends on GDP per capita computed by the model at each time step. We use the values estimated in Budolfson et al. (2021), which are $\hat{\alpha} = 3.22$ and $\hat{\beta} = -0.22$.

The distribution of climate damages across deciles could range from being inversely proportional to consumption (damage elasticity of consumption $\xi = -1$), to being proportional to consumption ($\xi = 1$) or more than proportional to consumption ($\xi > 1$). In absolute value, the richest tend to suffer more from climate change than the poorest, simply because they have more to lose. Therefore, we can assume that the distribution of damages across deciles will not be flat, i.e., $\xi > 0$. Damages are also likely to fall disproportionately on the poorest deciles, i.e. be less than proportional to income or consumption, i.e., $\xi < 1$. Gilli et al. (2024) are the first to provide an estimate of the global

[11] Cowell (2011) indeed shows that, in the case of a lognormal distribution, we have the following relation:

$$\sigma_i = \sqrt{2} \cdot \Phi^{-1}\left(\frac{Gini_i + 1}{2}\right),$$

where Φ^{-1} is the inverse of the cumulative distribution function of a standard normal distribution.

within-country income-elasticity of damages[12]. We use the mean of their estimates for the SSP2-based projections, resulting in an income-elasticity of 0.6.

M.2 Country level output, emissions and abatement

Future output (GDP) levels for each country are calibrated with initial data from the Penn World Tables 10.0 and the GDP per capita growth rates from the SSP2 scenario (Dellink et al., 2017) (see section above for a description of the SSP2 scenario). Following Dennig et al. (2015), we assume national saving rates start at their empirical value from the Penn World Tables 10.0 (taking the average from 2010 to 2020) and converge to a fixed long term saving rate of 27% at a rate of 3% per year.

Country level emissions intensities of output are computed until 2100 from projected GDP streams based on the SSP2 trajectory, and from emission trajectories based on the ReMIND model in a business-as-usual scenario. The initial country-level emission intensity of output is computed by dividing observed emissions (from the Global Carbon Project database) by observed GDP (from the Penn World Tables). To project emission intensity in the BAU scenario, we use SSP2 data on BAU emissions, provided by the ReMIND model. Only regional level data is available for projected emissions (12 world regions). We derive regional growth rates of the emission intensity of output based on GDP and emissions growth rates from the SSP2 BAU scenario. Then, we estimate a linear, region-specific OLS model of emission intensity growth over time. The growth rates of emission intensity are negative in all regions and become more negative over time in most regions. In the few regions in which growth rates of emission intensity increase, we bound the growth rate of the emission intensity to zero. Finally, we use the estimated time- and region-specific growth rates of emission intensity of output to project the country-level emission intensities of output, starting from the initial values estimated for each country.

Next, we model country level mitigation trajectories. We use the same abatement cost function as in Barrage and Nordhaus (2024), but differentiate the multiplicative parameter by country. As a result, the cost of abatement as a share of gross output in country i for a mitigation rate of μ_i is

$$\Lambda_{it}(\mu_{it}) = \theta_{1,it}\mu_{it}^{\theta_2},$$

with $\theta_2 = 2.6$ (taken from Barrage and Nordhaus (2024)). We calibrate the multiplicative parameter $\theta_{1,it}$ using the global backstop price from Barrage and Nordhaus (2024) and the assumption that the marginal cost of abatement at a 100% mitigation rate per unit of emission (in USD per unit of emissions) is equal to the global backstop price in every country.

As a result, the mitigation rate μ_{it} is a function of θ_2 and of the ratio between the carbon tax and the backstop price. Because the backstop price and θ_2 are set at the global level, a given level of carbon tax in t results in the same mitigation rate in every country. However, the abatement cost in terms of share of gross output is heterogeneous across countries for a same level of mitigation, due to the heterogeneity in θ_1. Details can be found in Appendix SI.1.

Finally, we follow Budolfson et al. (2021) and rule out negative emissions, because the distributional effect of revenues would still be pronounced even if a large share of revenues was used for negative emission technologies. The Loss and Damage scenario targeting low-income countries shows that the welfare-enhancing effect of redistributing

[12] They estimate several damage functions using within-country inequality data and compute an elasticity for projected distributional impacts, based either on SSP2 or SSP3.

revenues holds for these countries even though only a small share of global revenues is redistributed in the first decades.

M.3 Country level climate damages

The global temperature change caused by greenhouse gas emissions is modeled using mimiFaIRv2 (Errickson et al., 2022), a Julia implementation of the Finite Amplitude Impulse Response model (FaIR). FaIR is a climate model designed to reproduce the global climate system's response to greenhouse gas emissions with good accuracy, and to capture non-linearities in the carbon cycle, while keeping complexity level and run-time low (Leach et al., 2021). The global temperature anomaly is downscaled to a country level temperature anomaly with pattern scale coefficients taken from the Coupled Model Intercomparison Project Phase 6 (CMIP6, O'Neill et al., 2016).

Following the usual practice in the literature, we assume that climate damages as a share of GDP are a function of the temperature anomaly. But contrary to most existing approaches (in particular models derived from the RICE model by Nordhaus and Yang, 1996), the country damage function depends on the local temperature anomaly that we obtain through our downscaling methodology. More specifically, the country-level damage function has the generic form:

$$\delta_i(\Delta_i T) = \beta_{i1} \cdot \Delta_i T + \beta_{i2} \cdot (\Delta_i T)^2,$$

where $\Delta_i T$ is the local temperature anomaly and $\delta_i(\Delta_i T)$ is the damage loss measured as a share of GDP lost for a given temperature anomaly. Parameters β_{i1} and β_{i2} are country-specific parameters that are calibrated to represent a general relationship between temperature increase and climate damages, as predicted in the econometric analysis by Kalkuhl and Wenz (2020). More details, as well as plots of the damage function calibration process, can be found in Supplementary Information SI.2.

M.4 Globally uniform and nationally-differentiated carbon tax trajectories, and resulting emissions

We implement 2°C scenarios with either a global uniform tax or differentiated taxes by country. For the global uniform tax, we select the welfare optimizing carbon tax trajectory among the exponentially increasing carbon tax pathways that keep temperature under 2°C until 2100. For the differentiated tax by country, we use a rule that gives the optimal ratio of carbon taxes between each country and a chosen reference country. The rule is derived from maximisation of the sum of utilities from consumption for each country, under an emission budget constraint (the detailed method is presented in Appendix SI.3). We choose the United States as the reference country. We find the tax trajectory for the United States (implying a tax trajectory for every other country through the rule) that enables the same global emissions reductions in each period until 2100 compared to the global uniform tax.

Figure SI.F.5 in the Appendix presents a few examples of implemented tax trajectories in the differentiated and uniform tax alternative of the 2°C scenario for countries with a variety of income levels and geographical locations. By construction, the global uniform carbon tax is always lower than the differentiated taxes in high income countries (e.g., USA, Germany and the Republic of Korea).

The resulting emissions are presented in Figure SI.F.2 in the Appendix. The emission trajectories of the differentiated and uniform tax scenarios are very close. Total carbon budgets over the 2020-2100 period are approximately 850 $GtCO_2$ and differ only by 5 $GtCO_2$ (less than 1%). This results in a likelihood of keeping the global temperature increase below 2°C of over 83 % (IPCC, 2021). With the 2°C scenario with a uniform carbon tax, CO_2 emissions fall to zero in 2080, while some residual CO_2 emissions persist until 2090 under the differentiated taxes 2°C scenario.

M.5 Alternative revenue recycling options

Our two carbon tax scenarios compatible with 2°C result in global tax revenues of up to 4 trillion dollars (up to 2% of global GDP) for the uniform global tax, and up to 2.5 trillion dollars (up to 1.7% of global GDP) for the differentiated taxes (Figure SI.F.6)[13]. We consider six alternatives regarding the distribution of carbon tax revenues.

In the case of differentiated taxes by country, we explore two options: one where the recycling of revenues is neutral, i.e., carbon tax revenues are refunded within each country to exactly offset the carbon tax payment; the other where carbon tax revenues are redistributed as equal per capita payments within countries.

In the case of a global uniform carbon tax, we consider four alternatives. The first two options mirror the previously described scenarios for differentiated taxes: the first one assumes a redistribution of the revenues of the global carbon tax which neutralizes the distributional effect of the carbon tax within countries, the second assumes that the revenues of the global tax are redistributed on an equal per capita basis within each country.

Two additional alternatives are considered. The first one assumes that all tax revenues are collected globally and redistributed equally per capita at the global level. This scheme thus induces international transfers between countries, i.e., revenues raised in a given country are not necessarily redistributed within that country.

The last option attempts to represent a possible Loss and Damage policy. It assumes that the revenue from a uniform global carbon tax is used to compensate low income and low-middle income countries[14] for the climate damages they face. To do this, we create a climate fund, and countries contribute to the fund with their carbon tax revenues. In terms of recipient countries, we analyze two schemes, one where only low income countries are targeted, and another where both low income and low-middle income countries receive compensation. Finally there are two cases depending on the relative size of funding needs and available revenue.

If there is enough carbon tax revenue to cover all the climate damages of poor countries, each country contributes a share (the same for all countries) of its carbon tax revenue so that the total amount in the fund equals the total amount of climate damages of poor countries. The revenue in the fund is then distributed to each poor country to cover its national damages and redistributed equally per capita within the country.[15] The

[13]The finding that differentiated carbon taxes yield a lower total revenue (Fig. SI.F.6a) implies that higher taxes in wealthy countries fail to compensate for the lost revenue from low-income countries.

[14]World Bank classification, see Appendix SI.6 for the list.

[15]We could imagine that the distribution is made according to how much damages individuals face, and use the income elasticity of carbon damage ξ to do that. We are considering a scheme that is simple to implement, especially in poor countries, so that the equal per capita approach is relevant. Remark also that given that the distribution of damages across deciles will not be flat ($\xi > 0$), the equal per capita approach actually maximizes redistribution by giving more to poor household that the damages

remaining portion of the carbon tax revenue is kept in each country and redistributed equally per capita within the country.

If there is not enough carbon tax revenue to cover the climate damages of poor countries, the total amount of carbon tax revenue will be transferred to the climate fund to compensate poor countries as much as possible. The revenue in the fund is distributed to each poor country in proportion to its national damages and redistributed equally per capita within the country.

they actually face.

Supplementary Information

SI.1 Abatement cost

For country i at time t, the cost of abatement in terms of share of gross output is

$$\Lambda_{it}(\mu_{it}) = \theta_{1,it}\mu_{it}^{\theta_2} \tag{SI.1.1}$$

with μ_{it} abatement rate, $\theta_{1,it}$ country-specific parameters and $\theta_2 = 2.6$. It follows that the cost of abatement in dollars per unit of emission is

$$C_{it}(\mu_{it}) = \frac{\Lambda_{it}(\mu_{it})Y_{it}}{E_{it}} \tag{SI.1.2}$$

$$= \frac{\theta_{1,it}\mu_{it}^{\theta_2}}{\sigma_{it}} \tag{SI.1.3}$$

with $\sigma_{it} = \frac{E_{it}}{Y_{it}}$ the emissions intensity of country i in t, an exogenous parameter calibrated on emissions projections of the REMIND model (Baumstark et al., 2021) .

We compute $\theta_{1,it}$ for each country by equating the marginal cost of abatement in dollars per unit of emission $C_{it}(\mu_{it})$ at full decarbonization ($\mu_{it} = 1$), to the backstop price (i.e. the global price per tCO2 that enables full decarbonization):

$$\frac{\partial C_{it}(1)}{\partial \mu_{it}} = \frac{\theta_{1,it}\theta_2}{\sigma_{it}} = p_t^{backstop}, \tag{SI.1.4}$$

which results in

$$\theta_{1,it} = p_t^{backstop}\frac{\sigma_{it}}{\theta_2}. \tag{SI.1.5}$$

We use the trajectory of the price for full decarbonization from Barrage and Nordhaus (2024), who perform a statistical analysis on the ENGAGE study (Riahi et al., 2021). Converted into 2017US$ per tCO2, this implies a backstop price of 495 2017US$ per tCO2 in 2050. As in Barrage and Nordhaus (2024), the backstop price decreases by 1% by year betwen 2020 and 2050, and by 0.01% after 2050. This results in a price for full decarbonization in 2020 of 670 2017US$.

SI.2 Damage functions

Assume that net output Y^{net} is a function of gross output Y and *absolute temperature* levels T in a country, such that

$$Y^{net} = (1 - \delta(T))Y, \tag{SI.2.1}$$

with $\delta(T)$ given by

$$\delta(T) = 1 - e^{-\beta_1 T - \beta_2 T^2}. \tag{SI.2.2}$$

Given this specification, the change in net output resulting from an increase in 1°C in a country's average annual temperature, from an initial temperature T, is

$$\Delta Y^{net} = \frac{(1 - \delta(T+1))Y - (1 - \delta(T))Y}{(1 - \delta(T))Y}. \tag{SI.2.3}$$

Substituting $\delta(T)$ for its expression and after some algebra, the change in net output resulting from an increase in 1°C in a country's average annual temperature T can be rewritten as

$$\Delta Y^{net} = e^{-\beta_1 - \beta_2(2T+1)} - 1 \approx -\beta_1 - \beta_2(2T+1) \tag{SI.2.4}$$

To calibrate parameters β_1 and β_2, we use the results by Kalkuhl and Wenz (2020) on the reduction of economic output from a 1°C increase in temperature. Kalkuhl and Wenz (2020, Table 9) obtain that, in their preferred econometric specification, a 1°C increase in annual mean temperature implies a 0.8% decrease in output when the initial temperature is 10°C. And they obtain that 1°C increase in annual mean temperature implies a 3.5% decrease in output when the initial temperature is 25°C. Plugging these numbers into equation SI.2.4, we obtain $\beta_1 = -0.0109$ and $\beta_2 = 0.0009$. The results of this calibration are shown in Figure SI.F.1a. (net output as a share of gross output, i.e. $1 - \delta(T)$, as a function of average annual temperature) and Figure SI.F.1b. (change in net output from a 1°C average annual temperature increase, i.e. ΔY^{net}, as a function of average annual temperature).

Next, we want to compute country-specific damage functions that depend on the climate change driven *temperature anomalies* from pre-industrial temperature in that region, that we denote $\bar{T}_i$, where i is the index for the country. Remark that we have:

$$\big(1 - \delta(T)\big) = \tfrac{1-(\delta(T)-\delta(\bar{T}_i))-\delta(\bar{T}_i)}{1-\delta(\bar{T}_i)}\big(1 - \delta(\bar{T}_i)\big) \tag{SI.2.5}$$

The share $\delta(\bar{T}_i)$ would be lost anyway in the absence of climate change (when the climate anomaly is nil), so the share of gross output lost in country i due to climate change is simply:

$$\delta_i(T) = 1 - \tfrac{1-\delta(T)}{1-\delta(\bar{T}_i)} = 1 - e^{-\beta_1(T-\bar{T}_i)-\beta_2(T^2-(\bar{T}_i)^2)}. \tag{SI.2.6}$$

This can be written as a function of the local temperature anomaly, $\Delta_i T = T - \bar{T}_i$:

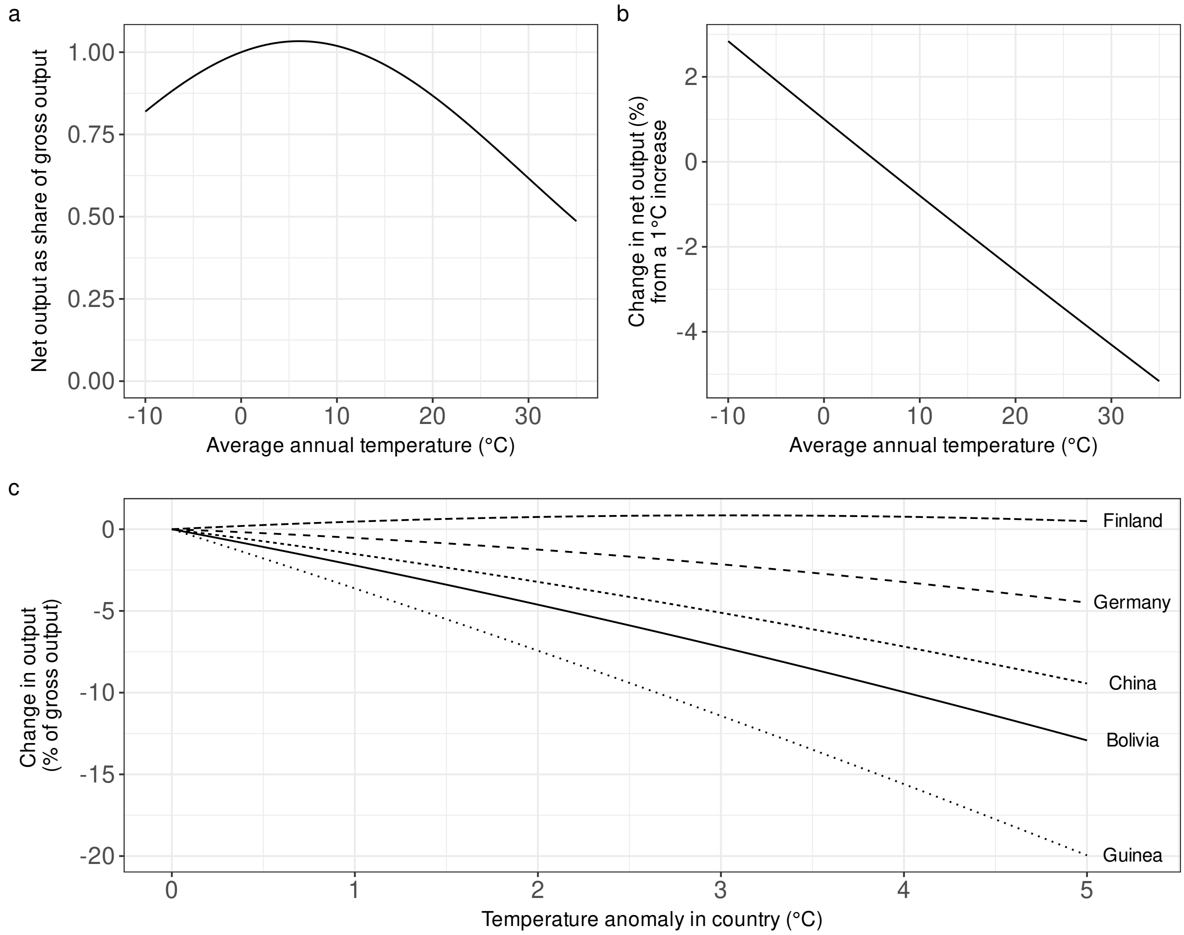
$$\delta_i(\Delta_i T) = 1 - e^{-\beta_1\Delta_i T - \beta_2(\Delta_i T)^2 - 2\beta_2\bar{T}_i\Delta_i T} \approx (\beta_1 + 2\beta_2\bar{T}_i)\Delta_i T + \beta_2(\Delta_i T)^2. \tag{SI.2.7}$$

We thus obtain the country-specific damage function $\delta_i(\Delta_i T) = \beta_{i1}\cdot\Delta_i T + \beta_{i2}\cdot(\Delta_i T)^2$, with $\beta_{i1} = \beta_1 + \beta_2\bar{T}_i$ and $\beta_{i2} = \beta_2$. To calibrate parameters β_{i1} and β_{i2}, we only need to know parameters β_1 and β_2 (already calibrated above) and the local pre-industrial temperature.

For the local pre-industrial temperature, we use the average annual temperature in the country for the period 1900-1909, based on the population weighted temperature in Dell et al. (2012). The temperature in period 1900-1909 is not significantly different from the pre-industrial temperature at the global level, hence the choice of the period.

Figure SI.F.1c plots the resulting country-level damage function for a selection of countries.

Figure SI.F.1: Calibrated impact of average annual temperature on output and resulting damage functions for a selection of countries.



Note: a. Net output as a share of gross output as function of the average annual temperature (°C) within a country; b. Change in net output from a 1°C average annual temperature increases as function of the average annual temperature (°C) within a country; and c. Resulting damage function (% change in gross output as a function of a country's temperature anomaly in °C) for a selection of countries.

SI.3 A simple model of optimally differentiated carbon tax

Assume that there is a set of countries $I = \{1, \cdots, n\}$, with i the index of the country and consider a specific period t. Assume that we have the objective to emit at most E_t at the global level. How should emissions be shared between the different countries?

To answer the question, let Y_{it} be the gross production and σ_{it} the emissions intensity in country i at period t. For an abatement effort μ_{it}, the emissions in the country will be $(1 - \mu_{it})E_{it}$, with $E_{it} = \sigma_{it} Y_{it}$.

The abatement cost (as a share of gross production) is given by the function $\Lambda_{it}(\mu_{it})$ that depends on the abatement effort μ_{it}. Given the population N_{it} in the region, per capita consumption is given by:

$$c_{it} = (1 - s_{it})\big(1 - \Lambda_{it}(\mu_{it})\big)\frac{Y_{it}}{N_{it}}, \tag{SI.3.1}$$

with s_{it} the savings rate in the country.

We assume that we want to fix optimal abatement efforts that maximize the sum of utilities from consumption. The objective is thus to maximize

$$\sum_i N_{it} u(c_{it})$$

with the constraint that the sum of emissions is less than E_t: $\sum_i (1 - \mu_{it}) E_{it} \leq E_t$.

Using the equations above, we obtain the following maximization problem:

$$\begin{array}{cc} \max\limits_{(\mu_{it})_i} & \sum_i N_{it} u \left((1 - s_{it}) \Big(1 - \Lambda_{it}(\mu_{it}) \Big) \frac{Y_{it}}{N_{it}} \right) \\ s.t. & \sum_i (1 - \mu_{it}) \sigma_{it} Y_{it} \leq E_t \end{array}$$

The first order condition with respect to each μ_{it} yields:

$$(1 - s_{it}) \frac{\partial \Lambda_{it} / \partial \mu_{it}}{\sigma_{it}} u'(c_{it}) = \lambda,$$

with λ the multiplier associated with the constraint.

Denote τ_{it} the carbon tax in country i. The abatement cost per emission in the model is $C_{it}(\mu_{it}) = \frac{\Lambda_{it}(\mu_{it}) Y_{it}}{E_{it}} = \frac{\Lambda_{it}(\mu_{it})}{\sigma_{it}}$. In equilibrium, the carbon tax should be equal to the marginal abatement cost per emission, so we should have $\tau_{it} = C'_{it}(\mu_{it}) = \frac{\partial \Lambda_{it} / \partial \mu_{it}}{\sigma_{it}}$. We obtain a formula for the optimal level of the carbon tax in country i at period t:

$$\tau_{it} = \frac{(1 - s_{it})}{(1 - s_{1t})} \frac{u'(c_{1t})}{u'(c_{it})} \tau_{1t}. \tag{SI.3.2}$$

Thus, we have a relation between the tax rate in any country and the tax rate in the first country that we take as a reference.

To close the model, we do not use c_{it} as defined above but the approximation by:

$$\tilde{c}_{it} = (1 - s_{it}) \frac{Y_{it}}{N_{it}}.$$

SI.4 Emissions and temperature trajectory

Figure SI.F.2: CO_2 emissions ($GtCO_2$) for the business-as-usual scenario SSP2 (black), and for the 2°C scenarios implemented via a global uniform tax (red) and via differentiated taxes across countries (blue).

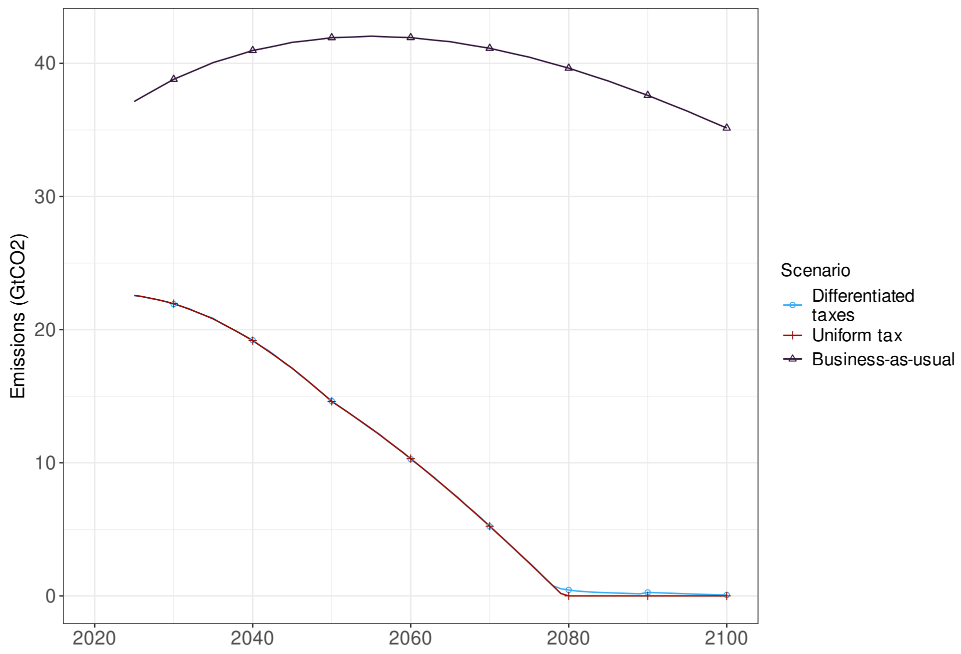
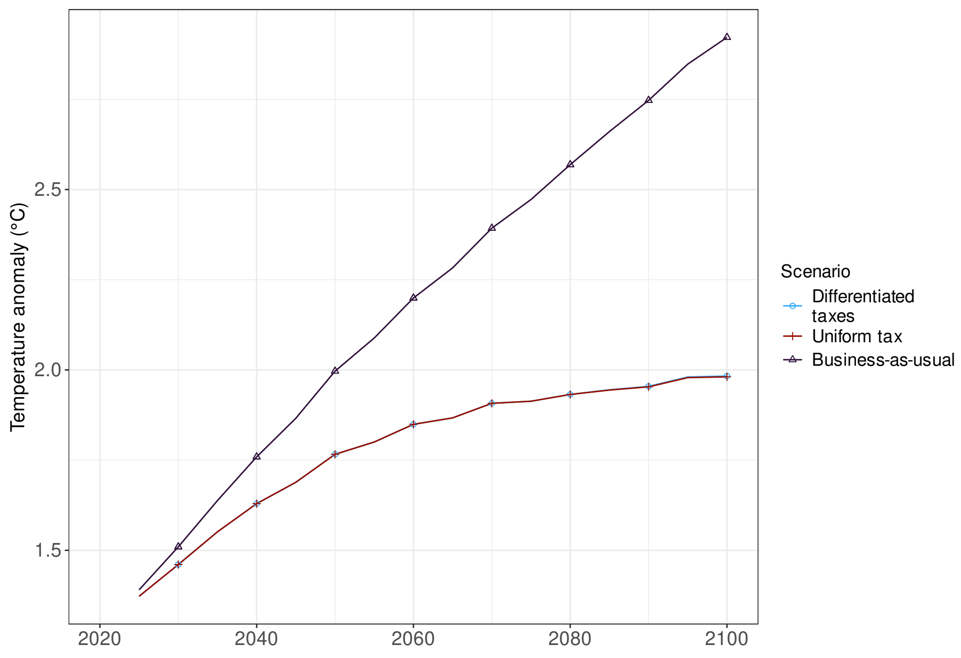


Figure SI.F.3: Temperature anomaly (°C) for the business-as-usual scenario SSP2 (black), and for the 2°C scenarios implemented via a global uniform tax (red) and via differentiated taxes across countries (blue).



SI.5 Country carbon tax for 2030 and 2050, and trajectories for selected countries

Figure SI.F.4: Carbon taxes (USD/tCO_2) in 2030 and 2050, for the 2°C scenarios implemented via a global uniform tax and via differentiated taxes across countries.

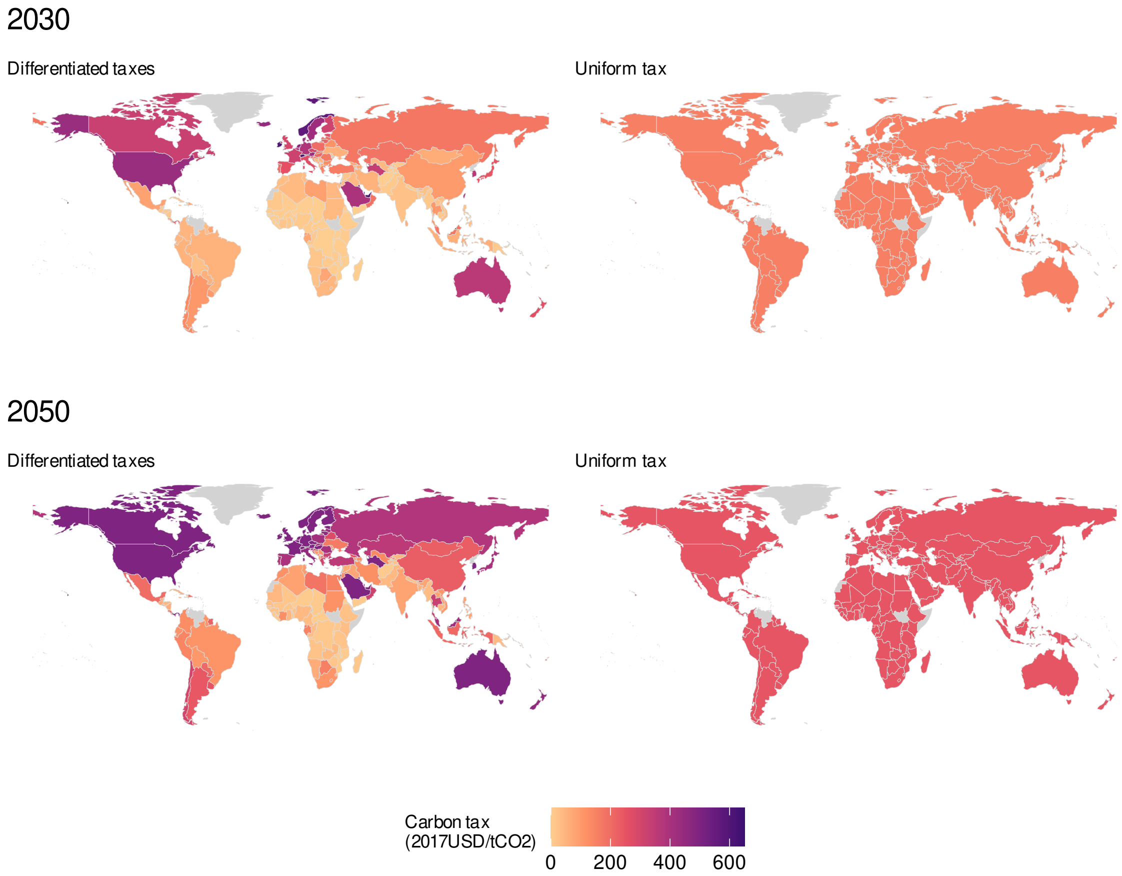
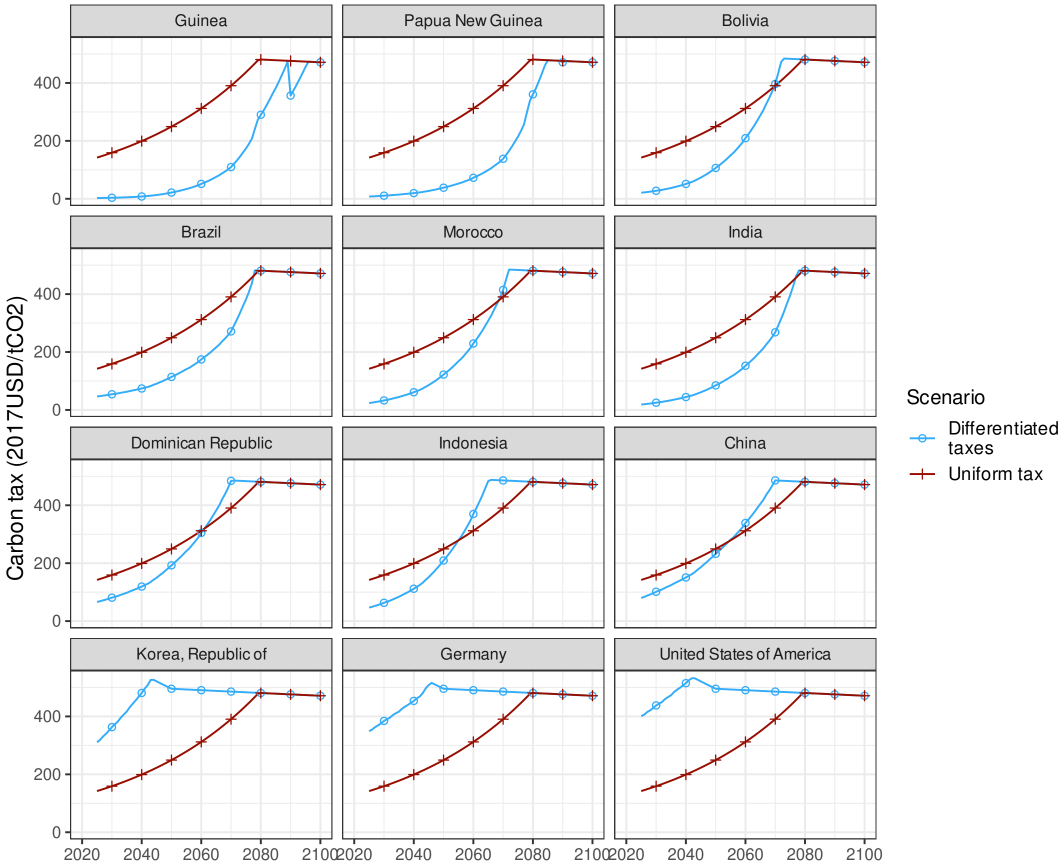


Figure SI.F.5: Carbon taxes (USD/tCO_2) for a selection of countries, for the 2°C scenarios implemented via a global uniform tax and via differentiated taxes across countries.



SI.6 List of low- and low-middle-income countries

Low-income countries: Afghanistan, Burundi, Burkina Faso, Central African Republic, Democratic Republic of the Congo, Eritrea, Ethiopia, Guinea, The Gambia, Guinea-Bissau, Liberia, Madagascar, Mali, Mozambique, Malawi, Niger, The Democratic People's Republic of Korea, Rwanda, Sudan, Sierra Leone, Somalia, South Sudan, Syrian Arab Republic, Chad, Togo, Uganda, Yemen, Republic of Zambia.

Low-middle-income countries: Angola, Benin, Bangladesh, Bolivia, Bhutan, Côte d'Ivoire, Cameroon, Republic of the Congo, Comoros, Cabo Verde, Djibouti, Algeria, Arab Republic of Egypt, Federal States of Micronesia, Ghana, Honduras, Haiti, Indonesia, India, Islamic Republic of Iran, Kenya, Kyrgyz Republic, Cambodia, Kiribati, Lao People's Democratic Republic, Lebanon, Sri Lanka, Lesotho, Morocco, Myanmar, Mongolia, Mauritania, Nigeria, Nicaragua, Nepal, Pakistan, Philippines, Papua New Guinea, West Bank and Gaza, Senegal, Solomon Islands, El Salvador, São Tomé and Príncipe, Eswatini, Tajikistan, Timor-Leste, Tunisia, Tanzania, Ukraine, Uzbekistan, Vietnam, Vanuatu, Samoa, Zimbabwe.

SI.7 Welfare measurement via equally distributed equivalent consumption

Instantaneous welfare in country i and period t is measured with a utilitarian social welfare function

$$\frac{P_{it}}{N_q}\sum_q \frac{c_{iqt}^{1-\eta}}{1-\eta} \tag{SI.7.1}$$

with c_{iqt} consumption in quantile q country i and period t, P_{it} the population in country i and period t, N_q the number of quantiles and η inequality aversion.

Instantaneous equally distributed equivalent consumption (Atkinson, 1970) in country i is defined as the level $c_{EDE,it}$ such that if given to each quantile q, yields the same level of welfare as the actual distribution of quantile consumption c_{iqt}

$$\frac{P_{it}}{N_q}\sum_q \frac{c_{EDE,t}^{1-\eta}}{1-\eta} = \frac{P_{it}}{N_q}\sum_q \frac{c_{iqt}^{1-\eta}}{1-\eta}. \tag{SI.7.2}$$

Hence,

$$c_{EDE,it} = \left(\frac{1}{N_q}\sum_q c_{iqt}^{1-\eta}\right)^{\frac{1}{1-\eta}} \tag{SI.7.3}$$

Denote $\bar{c}_{it}$ the average consumption in country i and period t, remark that we have the following decomposition:

$$c_{EDE,it} = \bar{c}_{it} \times \left(\frac{1}{N_q}\sum_q \left(\frac{c_{iqt}}{\bar{c}_{it}}\right)^{1-\eta}\right)^{\frac{1}{1-\eta}} = \bar{c}_{it} \times (1 - A_t(\eta)),$$

where $A_t(\eta)$ is the so-called Atkinson inequality index for consumption in country i and period t. So, we can decompose the welfare effect into an effect on average consumption and an effect on inequality (Atkinson, 1970).

We can also compute welfare at the global level. The global equally distributed equivalent consumption is defined as $c_{EDE,t}$ such that

$$\sum_i \frac{P_{it}}{N_q}\sum_q \frac{c_{EDE,t}^{1-\eta}}{1-\eta} = \sum_i \frac{P_{it}}{N_q}\sum_q \frac{c_{iqt}^{1-\eta}}{1-\eta}. \tag{SI.7.4}$$

Resulting in

$$\begin{aligned} c_{EDE,t} &= \left(\frac{\sum_i \frac{P_{it}}{N_q}\sum_q c_{iqt}^{1-\eta}}{\sum_i P_{it}}\right)^{\frac{1}{1-\eta}} && \text{(SI.7.5)} \\ &= \left(\frac{\sum_i P_{it}(c_{EDE,it})^{1-\eta}}{\sum_i P_{it}}\right)^{\frac{1}{1-\eta}} && \text{(SI.7.6)} \end{aligned}$$

Denoting $\bar{c}_t$ the average consumption at the global level in period t, we again obtain the Atkinson decomposition:

$$c_{EDE,t} = \bar{c}_t \times \left(\frac{\sum_i \frac{P_{it}}{N_q}\sum_q \left(\frac{c_{iqt}}{\bar{c}_t}\right)^{1-\eta}}{\sum_i P_{it}}\right)^{\frac{1}{1-\eta}} = \bar{c}_t \times (1 - A_t(\eta)),$$

where $A_t(\eta)$ is the Atkinson inequality index for global consumption in period t.

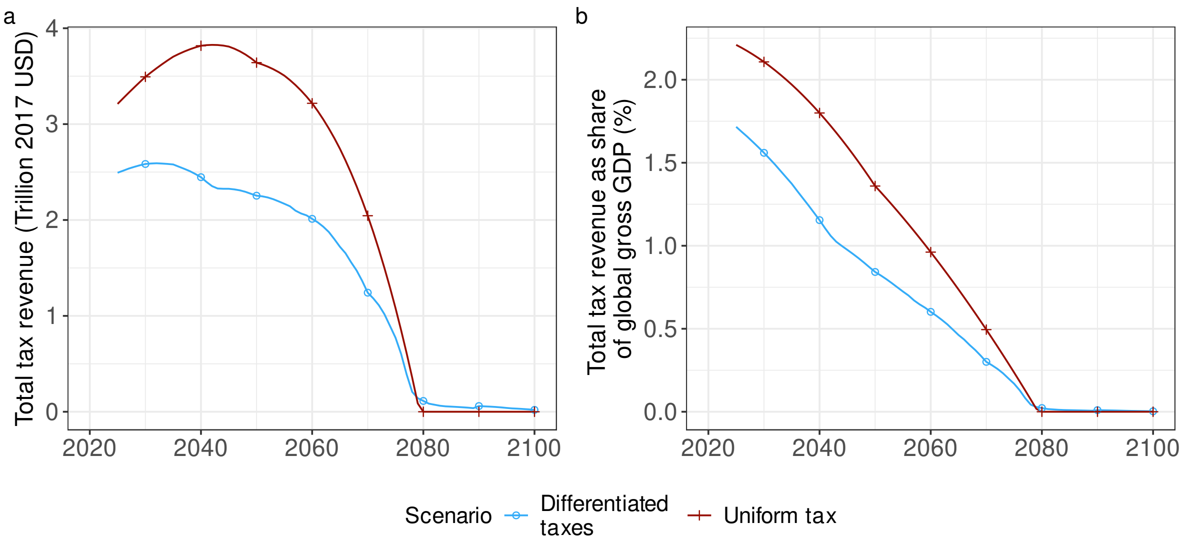
The Atkinson inequality index $A_t(\eta)$ can be further decomposed into a between and a within country component:

$$(1 - A_t(\eta)) = \left([1 - A_t^b(\eta)]^{1-\eta} + [1 - A_t^w(\eta)]^{1-\eta} - 1\right)^{\frac{1}{1-\eta}},$$

where A_t^b is the between country component of the Atkinson inequality index and $A_t^w(\eta)$ is the within country component

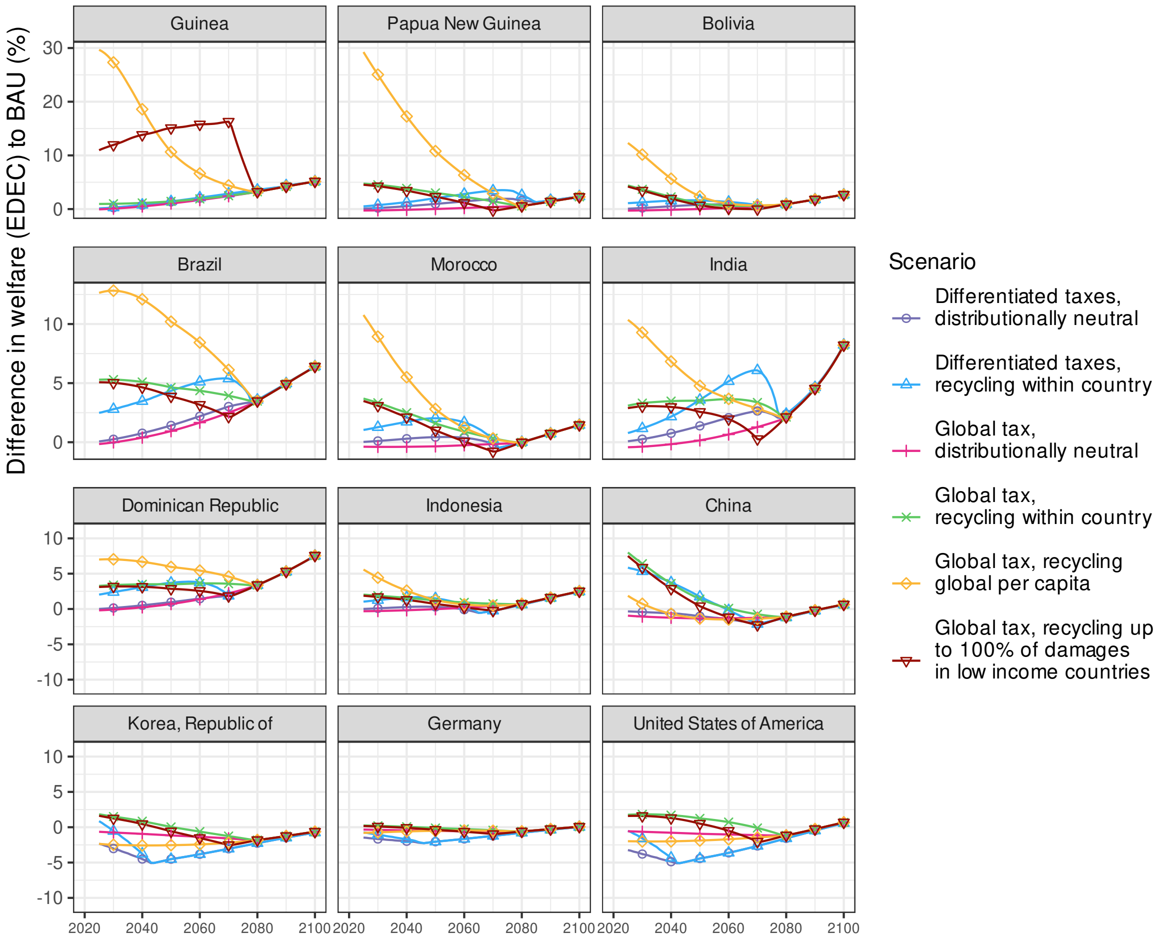
SI.8 Global revenues from the carbon tax

Figure SI.F.6: Global carbon tax revenues in the 2°C scenario, in a. trillion 2017USD, and b. share of global gross output (%).



SI.9 Welfare trajectories for selected countries

Figure SI.F.7: Difference in welfare (equally distributed equivalent consumption, EDEC) for a selection of countries in the 2°C scenario compared to the business-as-usual scenario (%) for the six carbon tax and revenue recycling scheme alternatives



SI.10 Country level effects on consumption per capita, damages, Gini index, and abatement costs in 2030 and 2050

Figure SI.F.8: Difference (%) in consumption per capita in the 2°C scenario compared to the business-as-usual scenario for four carbon tax and revenue recycling scheme alternatives in 2030 and 2050.

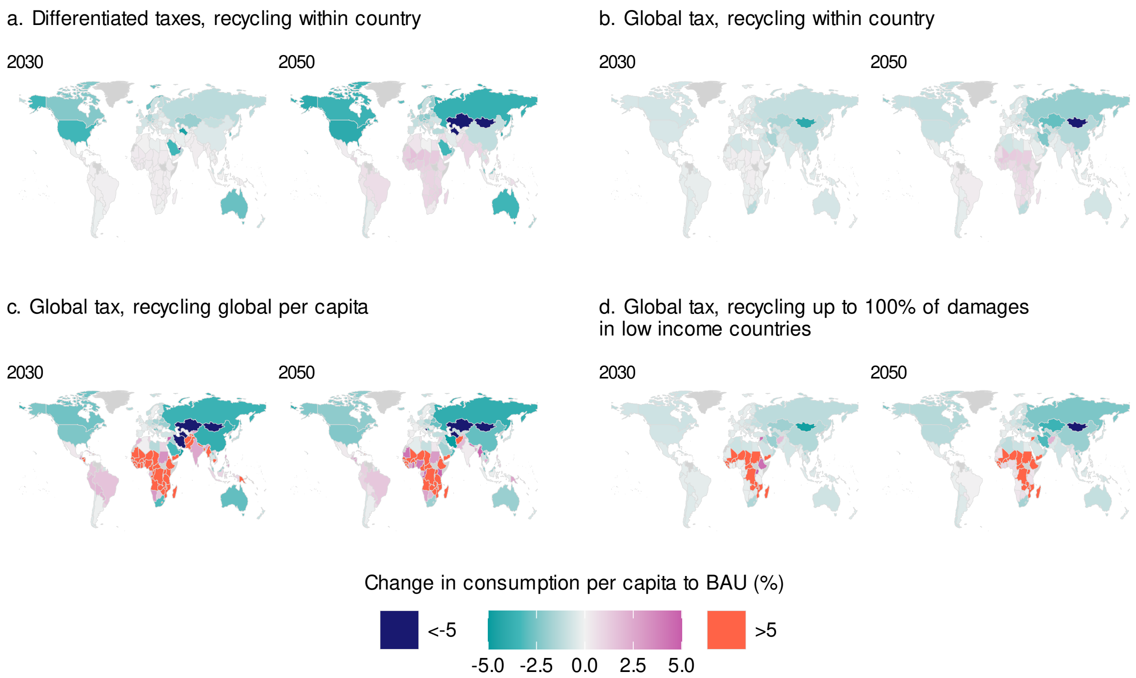


Figure SI.F.9: Change (p.p.) in the damage share in gross output in 2°C scenario compared to the business-as-usual scenario, in 2030 and 2050.

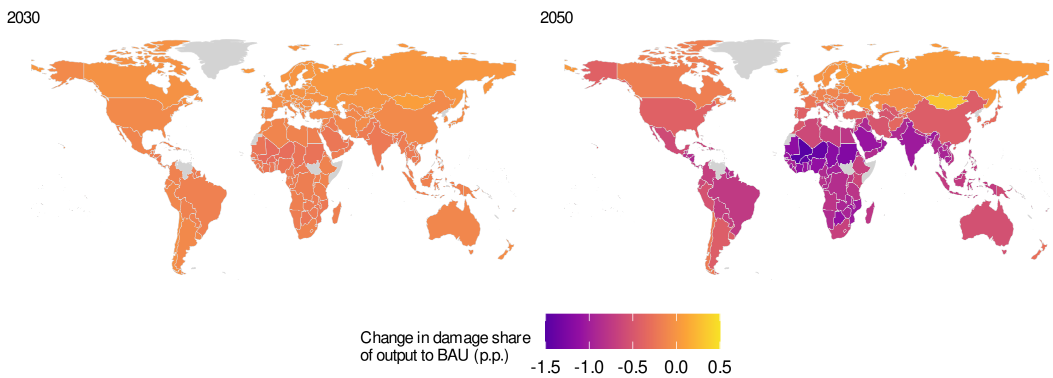


Figure SI.F.10: Difference (p.p.) in the Gini index in the 2°C scenario compared to the business-as-usual scenario for four carbon tax and revenue recycling scheme alternatives in 2030 and 2050.

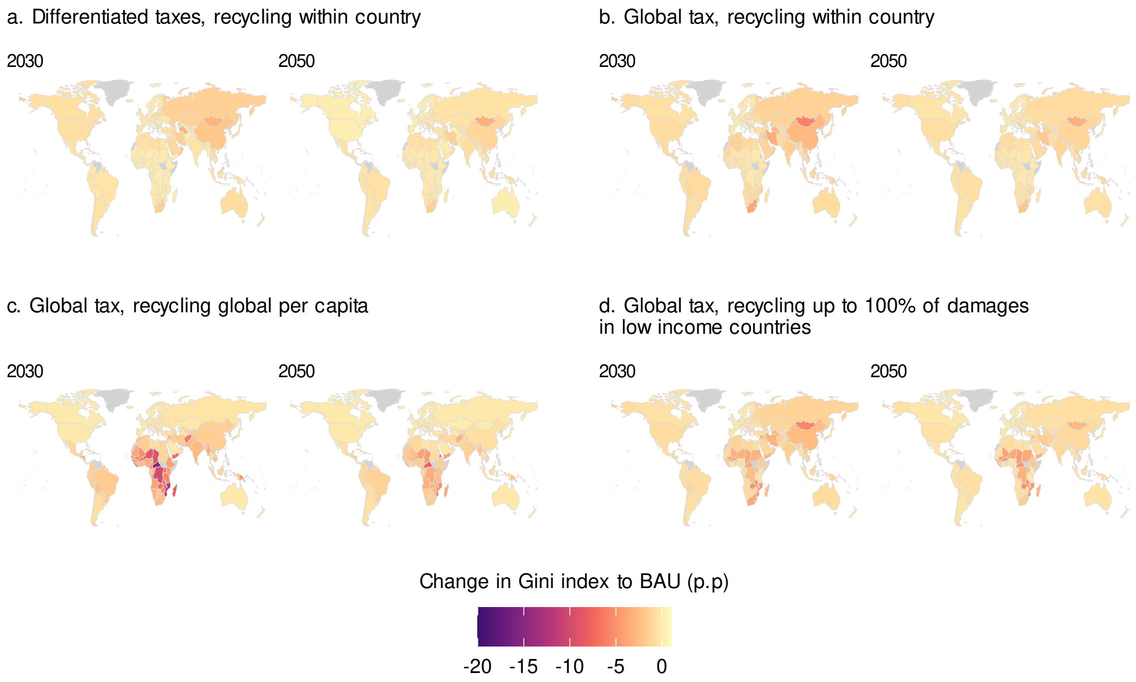
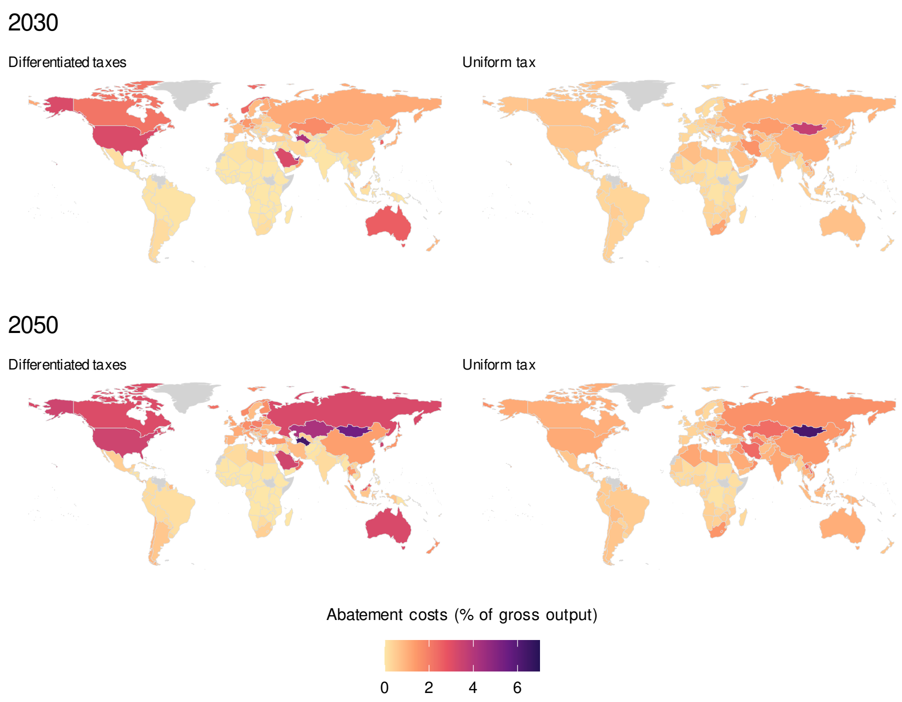
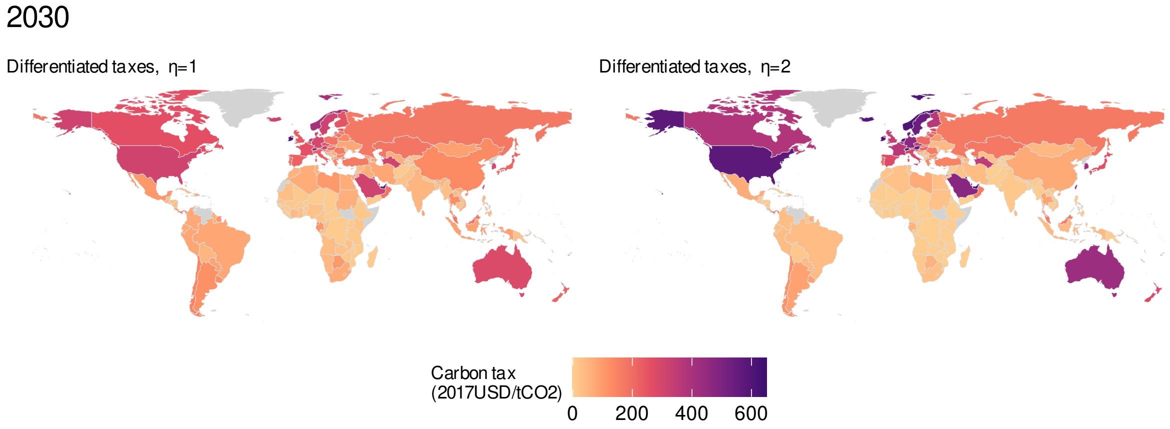


Figure SI.F.11: Abatement costs share in gross output (%) in the 2°C scenario, for differentiated and uniform taxes in 2030 and 2050.



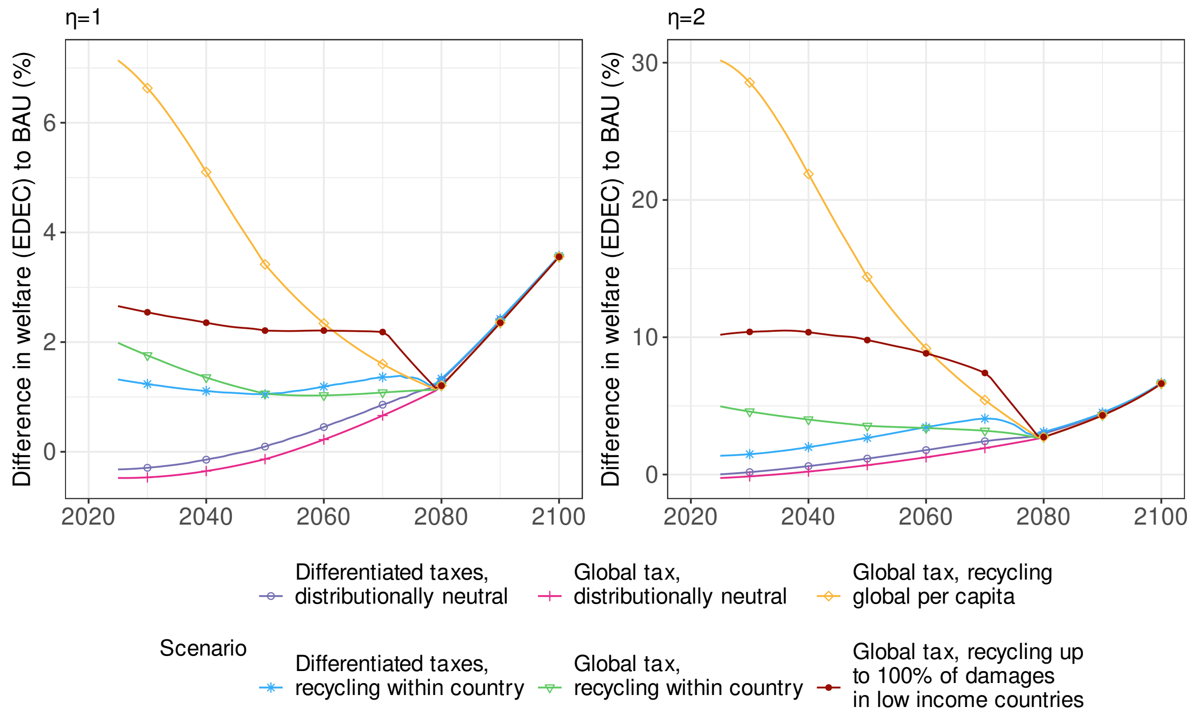
SI.11 Sensitivity analysis: inequality aversion

Figure SI.F.12: Carbon taxes (USD/tCO_2) in 2030, for the 2°C scenarios implemented via differentiated taxes across countries, for $\eta = 1$ and $\eta = 2$.



Note: the global emissions pathway is the same as in the main analysis, but the differentiated taxes are recalculated for each value of η.

Figure SI.F.13: Difference in welfare (equally distributed equivalent consumption, EDEC) in the 2°C scenario compared to the business-as-usual scenario (%) for the six carbon tax and revenue recycling scheme alternatives, for $\eta = 1$ and $\eta = 2$.



Note: the global emissions pathway is the same as in the main analysis, but the differentiated taxes are recalculated for each value of η.