Climate Inequality: Carbon Capture for Redistribution

Elisa Belfiori* Manuel Macera†

Abstract

We study optimal climate policy in a global economy where regions differ in wealth and climate vulnerability. Carbon emissions from production lead to output losses, and there is a technology for carbon capture. We provide an aggregation result: the model with heterogeneity can be cast into a representative region economy with a different discount factor and damage function. This result offers a simple rule to account for inequality in the design of climate policy. We show that wealthier regions should bear more responsibility for carbon capture to reduce atmospheric carbon and that inequality *per se* does not entail a compromise on the global emissions target. It is only if regions must contribute uniformly to carbon capture that the optimal climate policy dictates higher global net emissions relative to the first best. Carbon capture serves as a natural redistribution mechanism precisely because lump-sum transfers are unavailable.

Keywords: Heterogeneous Regions; Negative Emissions; Inequality; Carbon Capture.

*Corresponding author. Business School, Universidad Torcuato Di Tella. Av. Figueroa Alcorta 7350, Buenos Aires, C1428BCW, Argentina. ebelfiori@utdt.edu.

†Department of Economics, Universidad Torcuato Di Tella. Av. Figueroa Alcorta 7350, Buenos Aires, C1428BCW, Argentina. mmacera@utdt.edu.

1 Introduction

That countries share a common but differentiated responsibility in addressing global climate change has long been acknowledged and was first stated formally at the 1992 United Nations Conference on Environment and Development. While this principle is grounded in climate justice, its implementation has been elusive. Solutions like the Green Climate Fund, established within the United Nations Framework Convention on Climate Change to assist developing countries with climate policies, have yet to channel sufficient funds. Reaching net zero by 2050, the global target agreed upon in the 2015 United Nations Climate Change Conference in Paris, is compatible with the view of common but differentiated responsibilities only if substantial funds flow into low-income developing countries to assist them with their climate goals. In this paper, we explore the role of carbon capture and sequestration in addressing countries' differentiated responsibilities regarding climate action.

Negative emissions technologies play a significant role in most feasible pathways consistent with the Paris Agreement, and deployment is already underway in several countries, including Iceland (Climeworks' Mammoth direct air capture facility), the United States (Occidental's Stratos plant in Texas), and Sweden (Stockholm Exergi's bioenergy carbon capture project in Stockholm). Carbon capture is thus a particularly natural instrument for addressing these responsibilities for three reasons. First, accountability in international climate agreements operates at the national level: Nationally Determined Contributions are national pledges, making the country the natural unit for assigning differentiated responsibilities. Second, since contributions are assigned at the country level, they can be directly conditioned on observable country characteristics: rich countries can be assigned larger burdens, while poor countries can be assigned smaller or none, without recourse to explicit monetary transfers. The redistribution is embedded in the public-good structure of carbon capture itself: all countries benefit from reduced atmospheric carbon regardless of their individual contribution. Third, the remaining alternatives (redistributing productive capital directly, or using mitigation to address inequality) both come at the cost of productive efficiency. Competitive factor markets already channel capital to its highest-value use globally; concentrating investment in poorer or more climate-exposed regions would divert it from higher-productivity destinations. Mitigation imposes the same distortion from the other direction: reducing emissions by scaling back production also requires pulling resources away from efficient uses. Carbon capture avoids both costs: differentiated contributions do not affect how capital is allocated across regions or how production is organized, leaving productive efficiency undisturbed.

To develop this argument, we lay out a neoclassical model with heterogeneous regions and incomplete markets. Carbon emissions from production generate output losses, a negative climate externality, and a technology to absorb these emissions through carbon capture is available to all regions. Carbon capture entails positive global effects at the cost of using up productive resources. In the model, regions differ in their initial wealth and their climate-related output losses. We characterize climate policies by solving the problem of a utilitarian planner that assigns equal weights to all regions and avoids direct transfers of resources across them, much in the spirit of the constrained-efficiency literature proposed in Diamond (1967) and Dávila et al. (2012).

In our model, however, there is still some room for redistribution embedded in the choice of each region's contribution to carbon capture. To limit this redistribution, we impose an additional constraint on the planner's problem consisting of a minimum contribution that she can ask from each region. When this minimum is set to zero, contributions are required to be non-negative, precluding direct transfers of resources across regions. As the minimum increases, the planner is forced to ask for positive contributions from all regions and, thus, the scope for redistribution is reduced. The optimal climate policy specifies a global target for net carbon emissions and a schedule of net emissions across regions.

The main result of the paper is an aggregation result. In particular, we show that the solution to the planner's problem in an economy with heterogeneous regions coincides with the planner's solution in a representative region economy in which two key parameters are redefined to summarize the underlying heterogeneity: the discount factor and the elasticity of the damage function with respect to carbon emissions. This result provides a simple way to account for wealth and climate differences across regions in the choice of global emissions and carbon capture. We use it extensively to understand how the planner's solution depends on prevailing inequality and how the burden of cleaning up the atmosphere through carbon capture is distributed across regions.

Our analysis provides several important lessons. First, we show that the constrained efficient outcome requires wealthier regions to bear a larger responsibility for cleaning the atmosphere through carbon capture. Since we explicitly rule out lump-sum transfers, this implies a substantial redistribution of global resources through carbon capture financing. By taking responsibility for capturing carbon, high-income countries indirectly transfer room in the atmosphere to low-income countries to use during their slower transition to a carbon-free economy. The fact that carbon capture can be a mechanism for addressing differential climate responsibilities is a novel insight of this paper.

We also show that when wealth differences across regions are small, global climate policy coincides with the first best Pareto optimal policy, indicating a complete separation between climate and redistribution motives. As wealth inequality increases, however, a potential tension between these two motives emerges. In the case in which all regions must contribute uniformly to carbon capture, we show that efficiency calls for a more lenient climate policy as wealth differences increase. However, if it is feasible to assign differentiated carbon capture responsibilities, efficiency dictates a more stringent climate policy as inequality increases, with fewer emissions and more carbon capture relative to the Pareto optimal policy. These results highlight that inequality per se does not entail a compromise on global climate goals.

Finally, we study the effect of differences in climate vulnerability, distinguishing between predetermined differences in climate exposure and uncertain climate shocks. Climate heterogeneity calls for a more stringent policy relative to the first best: unable to condition contributions on regional climate exposure, the planner adjusts aggregate capital to redistribute through factor returns, reducing emissions and expanding carbon capture. Climate uncertainty, by contrast, does not distort the optimal target when differentiated contributions are feasible: precautionary savings channel additional resources into both capital and carbon capture in first-best proportions, leaving the optimal policy undisturbed.

This paper belongs to the literature that studies optimal climate policy in a multi-country setting, especially Krusell and Smith (2022), Chichilnisky and Heal (1994), and Hillebrand and Hillebrand (2019). Without lump-sum transfers, Chichilnisky and Heal (1994) shows that abatement efforts are heterogeneous, with high-income countries bearing a higher burden on abatement efforts. Similar to Chichilnisky and Heal (1994), wealthier regions should bear more responsibility for carbon capture in our setup. We differ in our focus on carbon capture and characterize the global climate policy for a broad array of limits to redistribution, from no redistribution (homogeneous carbon capture) to complete redistribution (Pareto optimal benchmark with transfers).

This paper relates to Hillebrand and Hillebrand (2019), who study the optimal climate policy of a global economy with multiple regions. Their focus is on characterizing an optimal climate policy, composed of taxes and transfers, that implements the optimal regional emissions and is also incentive-compatible with the laissez-faire equilibrium. In contrast, this paper studies how alternative sources of inequality (stemming from economic and climate factors) across regions affect the optimal allocation and the stance of global climate policy, defined as a global net emissions target. Importantly, we rule out transfers across countries as those characterized by Hillebrand and Hillebrand (2019) and also Chichilnisky and Heal (1994) and introduce a carbon capture technology as a redistribution mechanism across countries.

Krusell and Smith (2022) study the distribution of climate impacts around the world, accounting for heterogeneity in income and temperature increases across regions. We share with that paper that we build upon a standard neoclassical growth model augmented with a climate module and feature regional heterogeneity in economic and climate outcomes. We differ from them in that we study the optimal climate policy of such an unequal world, while the focus in Krusell and Smith (2022) is to quantify the climate impacts. The paper relates to Jacobs and van der Ploeg (2019) for its contribution to optimal climate policy in heterogeneous agents economies. Jacobs and van der Ploeg (2019) studies when the optimal carbon tax differs from the Pigouvian formula to incorporate re-distributive motives. In contrast, this paper studies heterogeneity across regions, not individuals, and characterizes the optimal policy in terms of allocations (i.e., a net emissions target). Also, this paper analyzes how alternative sources of inequality affect the optimal outcome.

While considering existing inequality across regions, the paper focuses on efficiency rather than equity, as we adopt a utilitarian planner and rule out direct transfers of resources across regions. In this regard, the paper differs from the literature that performs welfare analysis on a multi-country economy like Anthoff and Emmerling (2019), Anthoff and Tol (2010) and Budolfson et al. (2021).

For its focus on optimal policy, this paper differs from existing literature that works with heterogeneous agents climate-economy models aiming to quantify climate change's consequences. Significant contributions to this literature are Fried et al. (2018) and Fried

(2021), with whom we share the neoclassical growth model with heterogeneous agents framework, and Cruz and Rossi-Hansberg (2023) and Conte et al. (2022) add climate heterogeneity into spatial economies. These papers consider the impacts of given carbon taxes while, in contrast, we look for the optimal climate policy. In addition, Fried et al. (2018) and Conte et al. (2022) more broadly belong to a rich literature that studies how the incidence of taxes depends on the government's use of carbon taxation revenue, with recent contributions by Goulder et al. (2019) and van der Ploeg et al. (2022) to this line of research.

The literature on carbon capture studies this instrument primarily as an aggregate deployment problem, along two lines: integrated assessment approaches compare it against other abatement options and identify the policy instruments that implement a given target (Gerlagh and van der Zwaan, 2006; Kalkuhl et al., 2015), while analytical optimal control models characterize the optimal path of sequestration alongside fossil fuel extraction (Moreaux and Withagen, 2015; Amigues et al., 2016; Grimaud and Rougé, 2014). This paper complements the literature by exploiting the public-good nature of carbon capture to characterize the optimal structure of contribution obligations across countries that differ in wealth and climate exposure.

Two recent contributions are particularly closely related to the issues addressed here. Banerjee and Barbieri (2025) study how global income uncertainty shapes countries' contributions to emissions reduction under alternative national commitment structures. Their setting is non-cooperative, considers only emissions reduction as an instrument, and focuses on aggregate income shocks common to all countries. We study instead constrained-efficient allocations, introduce carbon capture as the central redistribution instrument, and feature idiosyncratic climate uncertainty alongside wealth heterogeneity across regions. Despite these differences, both papers share a common message: the form of national climate commitments is decisive. Their finding that whether countries commit to an absolute abatement cap or a share of income matters for total abatement and welfare resonates directly with our paper: the form of the carbon capture constraint, whether contributions are wealth-differentiated or imposed uniformly, is decisive for the stance of global climate policy and its redistributive content.

Exbrayat et al. (2025) analyze a global carbon tax in a setting with mobile firms and imperfect competition across asymmetrically-sized countries, showing that firm mobility generates spatial non-neutrality in the distribution of emission reductions. Their results speak directly to a modeling choice in this paper. If carbon capture were a firm-level duty, redistribution across countries would require differential treatment, namely a carbon price that varies by country of origin. In a world with mobile firms, however, such differential pricing generates private incentives to relocate: firms migrate toward lower-obligation countries, and Exbrayat et al.'s findings suggest these relocation effects would erode the redistributive intent. Country-level contribution schedules, as in our paper, condition redistribution directly on national characteristics and are not subject to this arbitrage. We therefore follow the institutional architecture of international climate agreements, in which countries rather than firms are the accountable units, and focus on how wealth heterogeneity shapes the optimal structure of such responsibilities.

The rest of the paper is structured as follows. We present the model in Section 2, the laissez-faire equilibrium in Section 3, study the first best allocation in Section 4, and present the main analytical results in Section 5. Section 6 contains a numerical exercise and Section 7 offers some final remarks.

2 The Model Economy

The world consists of a unit measure of regions, each inhabited by a representative household and a representative firm. There is a final good produced using capital and labor, which can be used for consumption or as capital. Households live for two periods, and all production occurs in the last period.

The use of capital in the production of the final good releases carbon to the atmosphere. It is feasible, however, to capture and sequester atmospheric carbon using a technology that uses capital in a linear fashion. Investment in this technology occurs in the first period and it is financed through the contribution of all regions. We use $\mathbf{K}$ and $\mathbf{M}$ to denote the global aggregates of capital used in the production of the final good and in carbon capture and sequestration, respectively. The amount of carbon in the atmosphere is determined by global net carbon emissions, $\mathbf{S} = \Pi(\mathbf{K}, \mathbf{M})$, where

$$\Pi(\mathbf{K}, \mathbf{M}) = \xi_d \mathbf{K} - \xi_g \mathbf{M}, \tag{1}$$

for positive constants ξ_d and ξ_g.

Carbon in the atmosphere creates a negative externality that results in an output loss in the final goods sector, which is specific to each region. More precisely, the total output of the regional-representative firm that uses K units of capital and L units of labor is $F(K, L) = (1 - D(\mathbf{S}, \epsilon))\tilde{F}(K, L)$, where $\tilde{F}(K, L) = K^{\alpha} L^{1-\alpha}$ is a Cobb-Douglas production technology with capital share $\alpha \in (0, 1)$, and

$$D(\mathbf{S}, \epsilon) = 1 - \exp\left(-\gamma(\mathbf{S} + \epsilon)\right), \tag{2}$$

with $\gamma > 0$, is the damage function. The output loss due to the climate externality is determined by the value of ϵ, which we refer to as *climate vulnerability*, and is the sum of two components. The first component, z, captures predetermined differences across regions regarding these losses and we refer to it as *climate inequality*. The second component, ν, represents region-specific climate shocks that occur in the second period, and we refer to it as *climate uncertainty*. We assume z and ν are mutually independent and normally distributed in the cross section of regions, with standard deviations σ_z and σ_ν and means

μ_z and μ_ν, respectively. As both shocks are idiosyncratic at the regional level, the model features no aggregate uncertainty.

Households are endowed with y units of the final good in the first period, and one unit of labor in the second period. We interpret y as wealth and assume it is log-normally distributed in the cross-section of regions, with mean equal to one, (normal) standard deviation given by σ_y, and independent from ϵ. In the first period, households decide how much to consume, to save, and to contribute to finance investment in carbon capture and sequestration. In the second period, they simply consume all their income.

Labor markets operate at a regional level - i.e., no migration -, and there is an international asset market for a non-contingent risk-free bond. This implies that households face labor income uncertainty due to the presence of climate shocks, but the return to their savings is deterministic, as there is no aggregate uncertainty. The budget constraints are

$$c_0 + a \leq y - m, \tag{3}$$

$$c_1 \leq w(\epsilon) + Ra, \tag{4}$$

where m denotes the contribution to carbon capture and sequestration. Households' preferences over consumption are given by the utility function:

$$u(c_0) + \beta\mathbb{E}\left[u(c_1)\right], \tag{5}$$

where the expectation is taken with respect to the region-specific climate shock ν. The instantaneous utility function is logarithmic, e.g. $u(c) = \ln(c)$. The problem of each household is to maximize (5), subject to (3) and (4).

In each region, the representative firm solves

$$\max_{K,L}(1 - D(\mathbf{S}, \epsilon))F(K, L) - w(\epsilon)L - RK, \tag{6}$$

taking factor prices and the amount of carbon in the atmosphere as given. Firms' optimal behavior requires:

$$\begin{aligned} (1 - D(\mathbf{S}, \epsilon))\tilde{F}_L(K(\epsilon), L(\epsilon)) &= w(\epsilon), \qquad (7) \\ (1 - D(\mathbf{S}, \epsilon))\tilde{F}_K(K(\epsilon), L(\epsilon)) &= R, \qquad (8) \end{aligned}$$

for all ϵ.

2.1 Competitive Equilibrium

We use G to denote the cross-sectional wealth distribution, with density $g(y)$; and H to denote the cross-sectional distribution of exposure across regions, with density $h(\epsilon)$. The function H is generated by the cross-sectional distributions of z and v, which we denote Φ and Ψ, respectively, with corresponding densities $\phi(z)$ and $\psi(v)$.

The asset market requires consistency between first-period savings decisions and second-period capital choices:

$$\int \int a(y,z)g(y)\phi(z)\,\mathrm{d}y\,\mathrm{d}z = \int K(\epsilon)h(\epsilon)\,\mathrm{d}\epsilon. \tag{9}$$

In the second period, labor markets clear if

$$L(\epsilon) = 1, \tag{10}$$

for all ϵ. The global amount of carbon capture is

$$\mathbf{M} = \int \int m(y,z)g(y)\phi(z)\,\mathrm{d}y\,\mathrm{d}z, \tag{11}$$

which corresponds to the sum of all contributions across regions.

Walras' Law implies that if (9), (10), and (11) are satisfied, then final good market also clears in both periods. For completeness we list here the final good market clearing conditions:

$$\int\int c_0(y,z)g(y)\phi(z)\,\mathrm{d}y\,\mathrm{d}z \;=\; \int yg(y)\,\mathrm{d}y - \int K(\epsilon)h(\epsilon)\,\mathrm{d}\epsilon - \mathbf{M}, \tag{12}$$

$$\int\int c_1(y,\epsilon)g(y)h(\epsilon)\,\mathrm{d}y\,\mathrm{d}\epsilon \;=\; \int (1 - D(\mathbf{S},\epsilon))F(K(\epsilon),1)h(\epsilon)\,\mathrm{d}\epsilon. \tag{13}$$

A *Competitive Equilibrium* consists of households' decision rules $c_0(y,z)$, $a(y,z)$, $c_1(y,\epsilon)$, and $m(y,z)$; firms' production plan $K(\epsilon)$, and $L(\epsilon)$, global aggregates $\mathbf{K}$, $\mathbf{M}$ and $\mathbf{S}$; and prices $w(\epsilon)$ and R such that policies solve individual agents' problems taking prices and global emissions as given, global aggregates are consistent with individual decisions, and all markets clear.

3 The Laissez-faire Equilibrium

In a laissez-faire equilibrium, no carbon capture occurs and thus $\mathbf{M}$ is zero. It will prove convenient to reduce the equilibrium to the following three objects: the amount of productive capital $\mathbf{K}$, the distribution of assets holdings across households η, and the distribution of productive capital across regions χ. We must require $\chi(\epsilon) \geq 0$ for all ϵ, and

$$\int \chi(\epsilon)h(\epsilon)\,\mathrm{d}\epsilon = 1, \tag{14}$$

$$\int \eta(y,z)g(y)\phi(z)\,\mathrm{d}y\,\mathrm{d}z = 1. \tag{15}$$

Productive capital in each region is then recovered as $K(\epsilon) = \chi(\epsilon)\mathbf{K}$, household assets as $a(y,z) = \eta(y,z)\mathbf{K}$, and consumption plans from individual budget constraints. We characterize the laissez-faire equilibrium using this notation. The following lemma characterizes the distribution of capital and asset holdings. The proof is in Appendix A.

Lemma 1 *In a laissez-faire equilibrium, the distribution of capital across regions is given by*

$$\chi(\epsilon) = \exp\left\{-\frac{\gamma}{1-\alpha}\left(\epsilon - \mu_\epsilon + \frac{\gamma}{1-\alpha}\frac{\sigma_\epsilon^2}{2}\right)\right\} \tag{16}$$

for all ϵ, and the distribution of asset holdings across households satisfies

$$\beta\alpha\mathbb{E}\left[\frac{y - \eta(y,z)\mathbf{K}}{(1-\alpha)\chi(\epsilon)\mathbf{K} + \alpha\eta(y,z)\mathbf{K}}\right] = 1, \tag{17}$$

for all y and ϵ, where the expectation is taken with respect to the climate shock ν.

Notice that the distribution of capital depends only on the stochastic properties of ϵ, and thus, it will be the same in any equilibrium. Since capital is freely mobile internationally, it always flows to its most productive use, so productive efficiency is achieved regardless of the underlying wealth distribution. As a result, $\chi(\epsilon)$ is determined solely by regional differences in climate exposure captured in ϵ, and is independent of the distribution of wealth.[1]

In the absence of climate uncertainty, we can also solve for the distribution of asset holdings in closed form and use it to obtain the following result.

Lemma 2 *Suppose $\sigma_\nu = 0$. Then, the global emissions in a laissez-faire equilibrium are equal to $\xi_d\mathbf{K}^{LF}$, where:*

$$\mathbf{K}^{LF} = \frac{\alpha\beta}{1+\alpha\beta}. \tag{18}$$

The proof is in Appendix A. When regions face no *climate uncertainty*, the laissez-faire global emissions are independent of regions' heterogeneity. This independence from the wealth distribution reflects log preferences: with logarithmic utility, the Euler equation

[1] As we discuss in Section 5, the same logic applies to the constrained-efficient planner: since free capital mobility ensures productive efficiency in any feasible allocation, there is nothing to be gained from distorting the distribution of capital across regions, and $\chi(\epsilon)$ coincides with the laissez-faire outcome in the planner's problem as well.

implies that each region's savings are proportional to its wealth, so aggregate capital depends only on α and β, not on the cross-sectional wealth distribution. When there is *climate uncertainty*, it is not possible to obtain an expression for global emissions in closed form but we can establish the following result:

Proposition 1 (Laissez-faire Economy) *Global emissions in a laissez-faire economy, $\xi_d \mathbf{K}^{LF}$, are increasing in climate uncertainty, σ_ν.*

As is standard in incomplete market models, uncertainty in future wage income, here stemming from uncertain climate exposure ν, induces agents to save more for precautionary reasons, and in equilibrium, this additional saving translates into a higher capital stock and more emissions.[2] The proof is in Appendix A.

4 First Best Benchmark

To better grasp the role of inequality in shaping climate policy, we set as a benchmark the optimal policy that would prevail if the planner were allowed to freely redistribute resources across regions.

When transfers are available, the planner can equalize marginal utilities directly, decoupling the climate motive from the redistribution motive. The optimal climate policy in this case therefore reflects pure efficiency and serves as the natural reference point for the constrained-efficient analysis in Section 5. Formally, we augment the budget constraints (3) and (4) with transfers:

$$c_0 + a \leq y - m + \mathtt{T}_0(y), \tag{19}$$

$$c_1 \leq w(\epsilon) + Ra + \mathtt{T}_1(y, \epsilon), \tag{20}$$

[2] In Section 5.3, we show that this need not be the case in a constrained-efficient economy when carbon capture is available.

where $(\mathtt{T}_0(y), \mathtt{T}_1(y,\epsilon))$ are cross-regional transfers, with the additional requirement that $\sum_y \mathtt{T}_0(y) = 0$ and $\sum_\epsilon \mathtt{T}_1(y,\epsilon) = 0$.

We impose throughout the following assumption, which ensures that carbon capture is socially desirable.

Assumption 1 $\beta\gamma(\xi_g + \xi_d) > 1 + \beta\alpha + \frac{\xi_d}{\xi_g}$

As we will see, this assumption is a necessary condition for an interior solution for $\mathbf{M}$. Intuitively, diverting one unit of capital from the final good sector into carbon capture reduces net atmospheric carbon by $\xi_g + \xi_d$, raising second-period output by $\gamma(\xi_g + \xi_d)$. Such a decision entails a direct cost of α units of foregone output in the second period, since diverted resources could have been used as capital, and an opportunity cost of $1 + \xi_d/\xi_g$ units of first-period consumption: by directing the freed capital to consumption and simultaneously reducing carbon capture by ξ_d/ξ_g to keep net emissions unchanged, the planner recovers $1 + \xi_d/\xi_g$ units of first-period consumption without any climate or production cost.

The following result characterizes the solution to a planner's problem in which we replace the budget constraints (3) and (4) with the budget constraints (19) and (20).

Proposition 2 (Pareto Optimal Climate Policy) *The Pareto Optimal Climate Policy in an economy with elasticity of the damage function, γ, and discount factor, β, is*

$$\mathbf{K}^{FB} = \frac{\alpha}{\gamma(\xi_g + \xi_d)}, \tag{21}$$

$$\mathbf{M}^{FB} = 1 - \frac{1 + \alpha\beta + \frac{\xi_d}{\xi_g}}{\beta\gamma(\xi_g + \xi_d)}. \tag{22}$$

The proof is in Appendix A.

It is easy to see that Assumption 1 guarantees that $\mathbf{M}^{FB} > 0$ and $\mathbf{K}^{FB} < \mathbf{K}^{\mathrm{LF}}$.[3] Then,

[3] The closed-form expression for $\mathbf{K}^{\mathrm{LF}}$ in Lemma 2 corresponds to the case $\sigma_\nu = 0$. By Proposition 1, $\mathbf{K}^{\mathrm{LF}}$ is increasing in σ_ν, so the comparison $\mathbf{K}^{FB} < \mathbf{K}^{\mathrm{LF}}$ holds for any $\sigma_\nu \geq 0$.

the Pareto optimal allocation implies lower emissions (smaller $\mathbf{K}$), positive carbon capture (larger $\mathbf{M}$), and thus lower global net emissions to curb climate change. Not surprisingly, when transfers are unconstrained, there is a complete separation between climate and redistributive motives, and the optimal climate policy prescribes the same level of emission cuts and carbon capture as in a representative region economy.[4]

5 Constrained-Efficient Climate Policies

We now investigate what combination of emissions and carbon capture maximizes social welfare from a utilitarian perspective, and how global net emissions depend on the underlying heterogeneity. To this end, we focus on constrained-efficient allocations: the best a global planner can do when she cannot overcome the constraints on private choices imposed by missing markets. All she can do is direct different choices by households or firms, while respecting individual constraint sets and market clearing conditions. Still, two features of this problem make the planner capable of improving on the market allocation. First, she knows that her choices affect equilibrium prices. Second, she is aware of the climate externalities.

5.1 Efficiency and Limits to Redistribution

In this economy, there is in principle a tension between achieving efficiency by fixing the climate externality and addressing existing inequality across regions. To study this tension, we follow Dávila et al. (2012) in setting up a utilitarian planner who assigns equal weights to regional welfare and cannot make direct transfers of resources across regions.

[4]To see this, consider a representative region economy in which the single region receives the mean values $(\bar{y}, \bar{\varepsilon})$ of all random variables. In that economy, marginal utilities are trivially equalized. The proof of Proposition 2 shows that equalizing marginal utilities is the only step needed to obtain $(\mathbf{K}^{FB}, \mathbf{M}^{FB})$, irrespective of the underlying distributions. Therefore, the first best of the heterogeneous-region economy coincides with the solution of the representative region problem at mean values.

In our model, however, some redistribution is still embedded in the choice of m: carbon capture is a public good, and contributions can therefore be indexed to regional wealth without requiring explicit transfers.[5]

It is reasonable to expect that redistribution through m might also be limited in reality. A simple way to consider this possibility is by imposing an additional constraint on the planner's problem consisting of a minimum contribution that she can ask from each region[6]. Moreover, since in practice *climate vulnerability* is a variable difficult to measure, we also preclude the possibility of making the contributions contingent on ϵ. This amounts to imposing the following constraint on the global planner's choice:

$$m(y) \geq \underline{m}, \tag{23}$$

for each y, where $\underline{m} \in [0, \mathbf{M}]$ denotes the minimum carbon capture required from each region. Since $m(y) \geq 0$, direct transfers across regions are precluded; redistribution operates solely through differentiated responsibilities in carbon capture. Setting $\underline{m} = 0$ maximizes this scope, allowing the poorest regions to be fully exempted while wealthier ones bear a disproportionate burden. As $\underline{m}$ increases, the contribution schedule becomes more uniform, compressing the redistributive margin.

The constrained-efficient allocation is formally defined as follows:

Definition 1 *A constrained-efficient allocation solves the global planner ´s problem, which is*

$$\max_{\substack{c_0(y,z),\, a(y,z),\\ c_1(y,z,\nu),\, m(y),\\ L(\epsilon),\, K(\epsilon),\, \mathbf{K},\, \mathbf{M}}} \int\int \left\{ u(c_0(y,z)) + \beta \int u(c_1(y,z,\nu))\psi(\nu)\, \mathrm{d}\nu \right\} g(y)\phi(z)\, \mathrm{d}y\, \mathrm{d}z \tag{24}$$

[5] As discussed in the introduction, other abatement policies do not share this property: the resources freed by reducing one's own emissions remain with the contributing region, making redistribution contingent on explicit transfers that we rule out.

[6] Taking the global $\mathbf{M}$ as given, requiring a minimum contribution is equivalent to imposing an upper bound on the contribution of each country, which captures the idea of imposing limits to redistribution.

subject to $\mathbf{S} = \Pi(\mathbf{K}, \mathbf{M})$, the budget constraints (3) and (4), the market clearing conditions (9) and (10), aggregate consistency (11), firm's optimality conditions (7) and (8), and the lower bound condition (23).

5.2 Characterization

In order to characterize the constrained-efficient allocation in closed form, it is useful to perform a change of variables. Specifically, we characterize the solution to the global social planner´s problem in terms of the following five objects: the global stock of capital $\mathbf{K}$, global carbon capture $\mathbf{M}$, the distribution of capital across regions χ, the distribution of asset holdings across households η, and the distribution of regional carbon capture μ. Thus, regional carbon capture is given by $m(y) = \mu(y)\mathbf{M}$. Consistent with the lower-bound condition (23), we impose

$$\mu(y) \geq \underline{\mu}, \tag{25}$$

for $\underline{\mu} \in [0, 1]$ and $\int \mu(y)g(y)\,\mathrm{d}y = 1$. A full description of the modified planner's problem is in Appendix B.

Using this change of variables, the first order conditions of the planner's problem with respect to $\mathbf{K}$ and $\mathbf{M}$ are:

$$\begin{aligned} 1 &= \beta R \frac{\int\int u'(c_1(y,\epsilon))\eta(y,z)g(y)h(\epsilon)\,\mathrm{d}y\,\mathrm{d}\epsilon}{\int\int u'(c_0(y,z))\eta(y,z)g(y)\phi(z)\,\mathrm{d}y\,\mathrm{d}z} - \Lambda^{\mathbf{K}}, & (26) \\ 1 &\geq \Lambda^{\mathbf{M}} & (27) \end{aligned}$$

where the last expression holds with equality if $\mathbf{M} > 0$.

These expressions capture the costs and benefits of carbon emissions and carbon capture at the global scale. In both cases, the left-hand side is the marginal cost of capital in terms of the consumption good in the first period; one more unit of capital represents one unit of global consumption foregone. The right-hand side is the benefit of the additional unit, net of the externality (the social cost of carbon[7]) captured by the terms $\Lambda^{\mathbf{K}}$ and $\Lambda^{\mathbf{M}}$. Using the functional form assumptions we can write the social cost of carbon as follows:

$$\begin{aligned}
\Lambda^{\mathbf{K}} &\equiv \frac{\beta}{\int\int u'(c_0)\,\eta\,g(y)\phi(z)\,dy\,dz} \\
&\quad \times \int\int u'(c_1)\left\{\gamma\xi_d c_1 + F_{L,K}(\eta-1) + F_{L,K}(1-\chi)\right\} g(y)h(\epsilon)\,dy\,d\epsilon, \qquad (28)\\
\Lambda^{\mathbf{M}} &\equiv \frac{\beta}{\int\int u'(c_0)\,\mu\,g(y)\phi(z)\,dy\,dz} \\
&\quad \times \int\int u'(c_1)\left\{\gamma\xi_g c_1\right\} g(y)h(\epsilon)\,dy\,d\epsilon. \qquad (29)
\end{aligned}$$

The role of heterogeneity shows up in $\Lambda^{\mathbf{K}}$ in two ways. First, the climate externality is valued using a planner's weighted discount factor, in which first-period marginal utilities are weighted by the distribution η. Second, $\Lambda^{\mathbf{K}}$ is the sum of three terms: the first, $\gamma\xi_d c_1$, is the standard climate externality, measuring the discounted marginal damage from one additional unit of emissions; the second and third, $F_{L,K}(\eta-1)$ and $F_{L,K}(1-\chi)$, are pecuniary externalities that arise because changing aggregate capital shifts wages differentially across households and regions. Together, $\Lambda^{\mathbf{K}}$ is the constrained planner's social cost of carbon, augmenting the standard damage term with the distributional consequences of changing aggregate capital.

Notice that if the distributions χ and η were degenerate - as they would in a representative region economy - these additional terms disappear, and the social cost of carbon equals the climate externality. Instead, in the economy with inequality, the planner chooses optimal net emissions, $\xi_d\mathbf{K} - \xi_g\mathbf{M}$, considering not only the climate externality but also the distributional consequences of regions' emissions and carbon capture over societal welfare.

On the benefit side, $\Lambda^{\mathbf{M}}$ is the social benefit of carbon capture, measuring the present discounted value of damages avoided from sequestering one unit of carbon. Unlike $\Lambda^{\mathbf{K}}$,

[7] A social benefit in the case of carbon capture.

it contains only the climate term $\gamma\xi_g c_1$ and no pecuniary externalities, reflecting the fact that carbon capture contributions do not affect relative factor prices.

To sum up, the constrained-efficient climate policy weighs three different concerns. First is efficiency, as there is an externality. The second is redistribution, as there is heterogeneity. Third is insurance, as the choice of climate policy affects the uncertainty faced by each region. In the next section, we analyze how these three different concerns interact to shape the optimal net emissions of the global economy and its distribution across regions.

5.3 Climate Policy and Inequality

We now characterize the solution to the global planner's problem. We first analyze how global carbon capture is distributed across regions through the choice of $\mu(y)$. We then focus on how gross emissions and carbon capture respond to different sources of inequality in the constrained-efficient solution.

As discussed in Section 5.1, the global planner's problem includes a minimum amount of carbon capture required from each region. The optimal choice of $\mu(y)$ takes the form of a cutoff $y^\star(\underline{\mu})$ such that the lower bound constraint (25) is indeed binding for all regions with $y \leq y^\star(\underline{\mu})$. We obtain $\mu(y)$ in closed form as follows:

Lemma 3 *Global carbon capture* $\mathbf{M}$ *is distributed among regions according to:*

$$\mu(y) = \begin{cases} \mathcal{H}(y, y^\star) & \text{if } y > y^\star \\ \underline{\mu} & \text{if } y \leq y^\star \end{cases}$$

where

$$\mathcal{H}(y, y^\star) = \frac{1 - \underline{\mu}G(y^\star)}{1 - G(y^\star)} + \frac{1}{\mathbf{M}}\left[y - \mathbb{E}[Y \mid Y \geq y^\star]\right],$$

and $y^\star$ *satisfies* $\mathcal{H}(y^\star, y^\star) = \underline{\mu}$.

The proof is in Appendix A.

Clearly, $\mathcal{H}(y, y^\star)$ is increasing in y, indicating that wealthier regions contribute more to carbon capture. To build intuition about when the lower bound binds, consider $\underline{\mu} = 0$ and suppose it is not binding for any region, so $y^\star$ equals the lower bound of the wealth distribution $\underline{y}$. Evaluating $\mathcal{H}(y, \underline{y})$ gives

$$\mu(y) = 1 + \frac{y - 1}{\mathbf{M}},$$

which is non-negative for all regions as long as $\underline{y} \geq 1 - \mathbf{M}$. As wealth inequality increases, however, and some regions fall below $1 - \mathbf{M}$, the unconstrained expression would require negative contributions from them, violating the lower bound. Instead, the planner assigns those regions a free pass on carbon capture responsibilities, with wealthier regions bearing the entire burden. The same logic applies for $\underline{\mu} > 0$: sufficiently poor regions are assigned the minimum contribution $\underline{\mu}$ rather than a free pass. Greater wealth inequality thus expands the set of regions for which the lower bound binds, reducing the scope for redistribution through differentiated responsibilities.

The following proposition is the main result of the paper. It establishes that the constrained-efficient aggregate allocation $\{\mathbf{K}, \mathbf{M}\}$ admits a representative-region characterization: it solves a single-region planner's problem with adjusted damage elasticity $\hat{\gamma}$ and discount factor $\hat{\beta}$, two sufficient statistics that summarize all heterogeneity in the model. The proof is in Appendix A.

Proposition 3 (Aggregation Result) *Let $\{\mathbf{K}, \mathbf{M}\}$ be part of the solution to the global planner's problem in an economy with wealth and climate heterogeneity. Then, $\{\mathbf{K}, \mathbf{M}\}$ also solve the planner's problem of a representative region economy where the elasticity of the damage function, $\hat{\gamma}$,* *and the discount factor, $\hat{\beta}$, are given by*

$$
\begin{aligned}
\hat{\gamma} &= \frac{\alpha}{\alpha - \Omega_0(\mathbf{K}, \mathbf{M})}\gamma \\
\hat{\beta} &= \frac{\alpha - \Omega_0(\mathbf{K}, \mathbf{M})}{\alpha \Omega_1(\mathbf{K}, \mathbf{M})}\beta
\end{aligned}
$$

where

$$
\begin{aligned}
\Omega_0(\mathbf{K}, \mathbf{M}) &= \int\int\int \frac{\alpha(\eta(y,z) - \mu(y))}{(1-\alpha)\chi(\epsilon) + \alpha\eta(y,z)} g(y)\phi(z)\psi \, dy \, dz \, d\nu, \\
\Omega_1(\mathbf{K}, \mathbf{M}) &= \int\int \frac{\Lambda + \frac{\alpha\beta}{1-\theta}\int\int\int \frac{\mu(y)}{(1-\alpha)\chi(\epsilon) + \alpha\eta(y,z)} g(y)\phi(z)\psi \, dy \, dz \, d\nu}{\Lambda + \frac{\alpha\beta}{1-\theta}\int \frac{1}{(1-\alpha)\chi(\epsilon) + \alpha\eta(y,z)} \psi \, d\nu} g(y)\phi(z) \, dy \, dz,
\end{aligned}
$$

$\theta = \mathbf{M}/(\mathbf{K} + \mathbf{M})$*, and Λ is the multiplier on the planner's constraint* (B.6).

The proposition provides an explicit way to solve global emissions and carbon capture in an economy with inequality relative to the (representative region) first best benchmark of Proposition 2. Heterogeneity enters $\hat{\gamma}$ and $\hat{\beta}$ exclusively through Ω_0 and Ω_1, which aggregate the distributions of capital, asset holdings, and carbon capture across regions. In order to know whether emissions and carbon capture are lower or higher than in the Pareto optimum, we need to know the sign of the function Ω_0 and whether Ω_1 is above or below one when evaluated at the constrained-efficient policy. For instance, if $\Omega_0 > 0$, the planner should act *as if* the elasticity of the climate damage function were larger and, therefore, pursue a more aggressive climate policy (more emission cuts and more carbon capture). In turn, if $\Omega_1 > 1$, the planner should act *as if* the discount factor were lower and pursue a less aggressive climate policy.

To build intuition about the forces that determine global emissions and carbon capture, we consider special cases that activate one source of heterogeneity at a time, and then analyze the interaction between wealth inequality and climate vulnerability. Proofs of all corollaries below are in Appendix A.

Wealth Inequality. Consider first the case where there is only wealth inequality. When wealth differences across regions are low enough that constraint (23) is not binding, the planner can equalize second-period consumption across all regions. We obtain:

Corollary 1 *Suppose $\sigma_z = \sigma_\nu = 0$, $\underline{m} = 0$, and condition (23) is not binding for any region (i.e., all regions contribute positively to carbon capture). Then $(\mathbf{K}, \mathbf{M}) = (\mathbf{K}^{FB}, \mathbf{M}^{FB})$.*

A separation between climate policy and inequality thus obtains: constrained efficiency prescribes the same emissions and carbon capture as the Pareto optimum. Still, wealthier regions bear a disproportionate share of carbon capture responsibilities.

When wealth differences are large enough that the poorest regions cannot contribute, this separation breaks down. One might expect a less ambitious climate response, since the costs of carbon capture now fall exclusively on wealthier regions, but the opposite is true:

Corollary 2 *Suppose $\sigma_z = \sigma_\nu = 0$, $\underline{m} = 0$, and constraint (23) is binding for some regions. Then $\mathbf{K} < \mathbf{K}^{FB}$ and $\mathbf{M} > \mathbf{M}^{FB}$.*

Constrained efficiency calls for a more, not less, stringent climate policy: lower emissions and more carbon capture than the first best. Carbon capture acts as a redistribution tool: poorer regions are exempt from contributing, receiving the climate benefits without bearing the costs, which fall disproportionately on wealthier regions. The planner achieves this by calling for more $\mathbf{M}$ and less $\mathbf{K}$. With less capital in production, R rises, and richer regions, holding more assets, gain proportionately more in the second period. The planner then requires them to contribute correspondingly more to $\mathbf{M}$: the gain from higher returns is recycled into higher global carbon capture, which reduces atmospheric damage and raises factor prices for all regions, including the poorest ones, who bear none of the cost.

In practice, political-economy constraints may limit the scope for differentiated responsibilities in climate agreements, where equal treatment of participating nations is a common principle. A natural benchmark is that carbon capture contributions cannot be conditioned on wealth and must instead be uniform across regions. Formally, this tightens constraint (23) to:

$$m(y) = \mathbf{M}, \tag{30}$$

for every y. Under such a uniform burden, any given climate target imposes the same absolute cost on all regions regardless of wealth, with no redistributive offset available. Constrained efficiency therefore calls for less ambitious targets than the first best. We obtain:

Corollary 3 *Suppose $\sigma_z = \sigma_v = 0$ and condition (30) holds. Then $\mathbf{K} > \mathbf{K}^{FB}$ and $\mathbf{M} < \mathbf{M}^{FB}$.*

The contrast with Corollary 2 is sharp: differentiated contributions turn carbon capture into a redistributive instrument that enables more ambitious targets; uniform contributions remove that instrument and push optimal policy in the opposite direction.

With uniform contributions, wages are identical across regions and second-period consumption differences reflect only heterogeneous savings: wealthier regions save more and earn more from their capital. To compress this inequality, the planner raises aggregate capital, which lowers the return on savings and hence the advantage of having saved more. Higher emissions and lower carbon capture follow as a byproduct. This is the mechanism identified in Dávila et al. (2012): a constrained planner distorts aggregate capital accumulation to redistribute through factor returns. As we show next, the same logic applies under climate heterogeneity, though the direction of the distortion reverses.

Together, these three cases show that the direction of the policy bias depends on the redistributive tools available to the planner, not on inequality itself. When carbon capture can be conditioned on wealth, inequality and climate ambition are complements; when it cannot, they become substitutes.

Adding climate heterogeneity. Next, we consider the case where both wealth inequality and climate heterogeneity are present. Along the wealth dimension, the setting resembles Corollary 1: the planner retains a redistributive margin by conditioning carbon capture on y. What is new is a second dimension of dispersion, since labor income varies with climate exposure z, for which no direct redistributive instrument exists. Unable to condition contributions on climate exposure, the planner falls back on aggregate capital as a residual instrument. We obtain:

Corollary 4 *Suppose $\sigma_\nu = 0$, $\sigma_z > 0$, and condition (23) is not binding with $\underline{m} = 0$. Then $\mathbf{K} < \mathbf{K}^{FB}$ and $\mathbf{M} > \mathbf{M}^{FB}$.*

In the spirit of Dávila et al. (2012), the planner again adjusts aggregate capital to redistribute through the return on savings, but the direction now reverses. At any given wealth level, more climate-exposed regions earn lower wages yet save more, making them more capital-intensive. Reducing capital raises the return on savings, disproportionately benefiting the most exposed regions and compressing consumption inequality along the climate dimension. With all regions contributing at an interior solution, the planner's optimality conditions leave total resources at their first-best level — the redistribution motive distorts the composition of aggregate savings but not its level. The reduction in capital is therefore matched one-for-one by higher carbon capture, shifting the composition from productive investment toward carbon capture.

Adding climate uncertainty. Finally, we consider the case where regional differences stem from wealth inequality and climate uncertainty ($\sigma_z = 0, \sigma_\nu > 0$). Climate uncertainty induces precautionary savings: regions set aside additional resources to insure against adverse climate outcomes. Crucially, the climate shock ν is orthogonal to wealth, so all regions face the same distribution of outcomes regardless of how wealthy they are. If carbon capture alone is sufficient to address wealth inequality, that is, condition (23) is not binding with $\underline{m} = 0$ — the additional consumption dispersion generated by climate uncertainty bears no relationship to wealth and exerts no influence on aggregate climate targets. We obtain:

Corollary 5 *Suppose $\sigma_z = 0$ and condition (23) is not binding with $\underline{m} = 0$. Then $(\mathbf{K}, \mathbf{M}) = (\mathbf{K}^{FB}, \mathbf{M}^{FB})$.*

Precautionary savings are therefore a blessing: the resources regions voluntarily set aside are channeled into both capital and carbon capture, and climate policy remains undistorted. The separation between climate policy and wealth inequality established in Corollary 1 thus extends naturally to a world with aggregate climate uncertainty. When condition (23) binds for some regions, however, this separation need not hold, a case we explore numerically in Section 6.

6 Numerical Example

In this section, we report the results of a numerical exercise that illustrates the interplay between climate policy and inequality. We first perform comparative statics with respect to wealth inequality, measured by σ_y, and the extent of feasible redistribution across regions, captured in $\underline{\mu}$. In each case, we compare the net global emissions under laissez-faire to those corresponding to the constrained efficient outcome. In addition, we report the schedule of net emissions across the wealth distribution.

6.1 Parameters

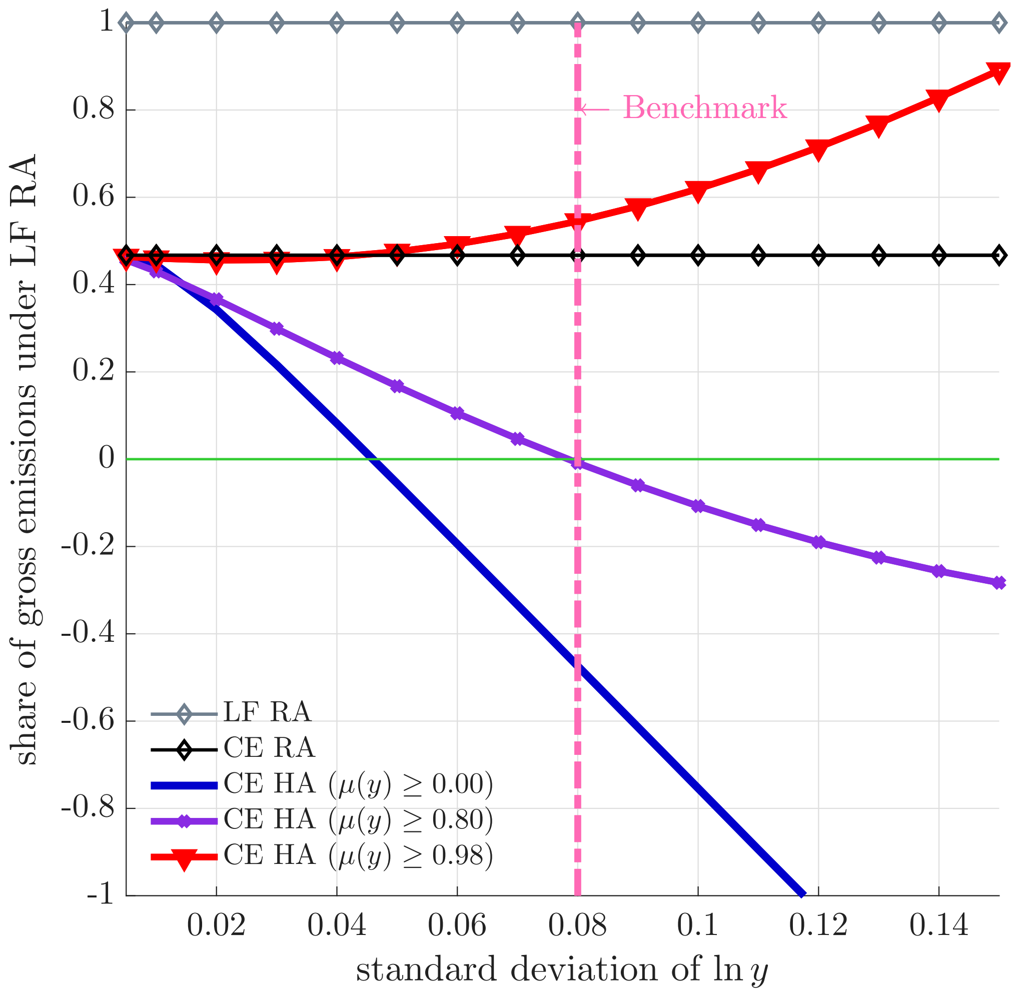
This exercise illustrates the qualitative predictions of the model; parameter values are chosen to generate plausible orders of magnitude while remaining consistent with the theoretical restrictions. Since the discount factor plays a limited role in the results, we set $\beta = 1$. We take $\alpha = 1/3$, which pins down the share of global income that accrues to owners of capital. For the parameter γ in the damage function, we take the average considered in Golosov et al. (2014). Since in their paper γ is associated with a given amount of global damage, we then set the degradation rate ξ_d so as to imply a global damage of 3% of global GDP in a business-as-usual scenario (BAU). To do that, we interpret the laissez-faire equilibrium without heterogeneity as BAU. In the case of the restoration rate ξ_g, we set it to the midpoint between the value that satisfies Assumption 1 with equality and the value that makes zero global net emissions optimal in the representative region economy (see Proposition 2).

We choose the stochastic properties of exposure shocks so that they are TFP-neutral at the global scale, which pins down $\mu_\epsilon = \gamma\sigma_\epsilon^2/2$. The value of σ_ϵ determines how capital is distributed across regions (see equation (16)). We set it equal to 24250, which implies a standard deviation of 0.82 in the distribution of capital $\chi(\epsilon)$. When considering an environment with heterogeneity, we attribute all dispersion to z, whereas in an environment with only exposure uncertainty we attribute it to ν. Finally, for the dispersion in wealth we consider a grid going from 0 to 0.15 and set the benchmark value of σ_y equal to 0.08. Table 1 in the appendix summarizes our parameter choice.

6.2 Results

Let us consider first the effect of varying σ_y, assuming there is no climate inequality, but imposing different limits to redistribution. We report global net emissions, $\xi_d\mathbf{K} - \xi_g\mathbf{M}$, as a

Figure 1: Global Net Emissions with Wealth Inequality.



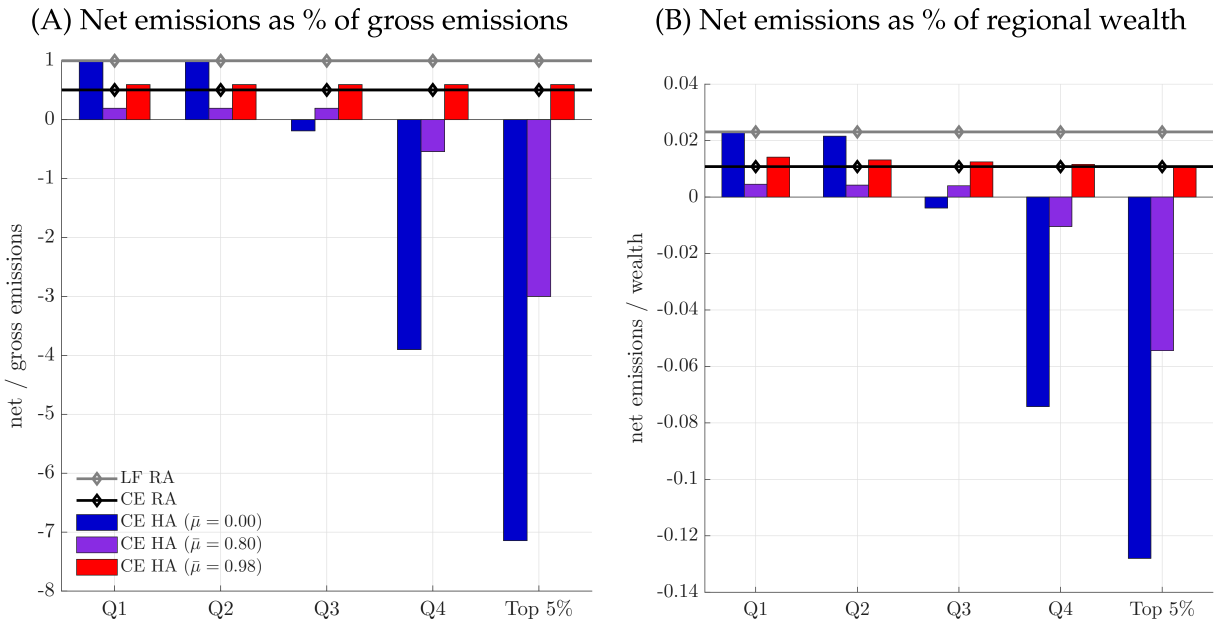
Notes: The horizontal axis measures the standard deviation of log wealth. ***LF RA***: laissez-faire equilibrium with $\sigma_y = \sigma_\epsilon = 0$; ***CE RA***: constrained efficient solution with $\sigma_y = \sigma_\epsilon = 0$; ***CE HA***: constrained efficient solution with $\sigma_\epsilon = 0$ and $\sigma_y > 0$.

share of the gross emissions that occur in the laissez-faire equilibrium of an economy with a representative region. In Figure 1, the diamond-marked horizontal lines correspond to outcomes of a representative region economy. In the laissez-faire outcome (*LF-RA*), there is no sequestration and thus net emissions and gross emissions are the same; this corresponds to the line at the top of the figure. In the constrained efficient outcome (*CE-RA*) climate policy calls for reducing global net emissions by approximately 50%. The fact that net zero is not optimal in this case is not surprising given our choice of the restoration rate ξ_g. Nevertheless, the wedge between these two horizontal lines is a measure of the extent to which mitigation and sequestration are desirable, from a societal perspective, in a representative agent environment.

The figure also depicts the constrained-efficient outcome in a world with different degrees of wealth inequality and in which the global planner faces limits to redistribution (*CE-HA*). We consider two extremes $\mu(y) \geq 0$ and $\mu(y) \geq 0.98$, and the intermediate case $\mu(y) \geq 0.8$ as an illustration; intermediate values of $\underline{\mu}$ yield outcomes that fall monotonically between these two bounds. The case $\mu(y) = 1$ is the uniform burden of Corollary 3; we approximate it with $\mu(y) \geq 0.98$ since the fully uniform case does not converge numerically. When inequality is low, all *CE-HA* lines originate at the *CE-RA* benchmark: the non-negativity constraint is not binding, and constrained efficiency replicates the first best, as in Corollary 1. As inequality grows and the constraint begins to bind, the schedules diverge. When the limits to redistribution are loose ($\mu(y) \geq 0$), more inequality *always* implies a more stringent climate policy, demanding more emission cuts and carbon capture relative to the first best, consistent with Corollary 2. Moreover, net zero emerges as a natural global objective when inequality is sufficiently large. This is still the case even if conditioning the contributions to each region's economic background becomes more difficult ($\mu(y) \geq 0.8$). Eventually, however, as the limits to redistribution become tighter ($\mu(y) \geq 0.98$), increasing wealth inequality leads to compromising on global climate goals, consistent with Corollary 3. In fact, as the figure shows, if inequality is too large and carbon capture responsibilities are close to uniform, optimal net emissions do not stray too far from the laissez-faire economy.

We now turn to the optimal net emissions schedule. Our benchmark corresponds to the economy with wealth inequality given by $\sigma_y = 0.08$. Figure 2 displays this schedule when regions are partitioned into quartiles of the wealth distribution, along with the burden

Figure 2: Net Emissions Schedule with Wealth Inequality.



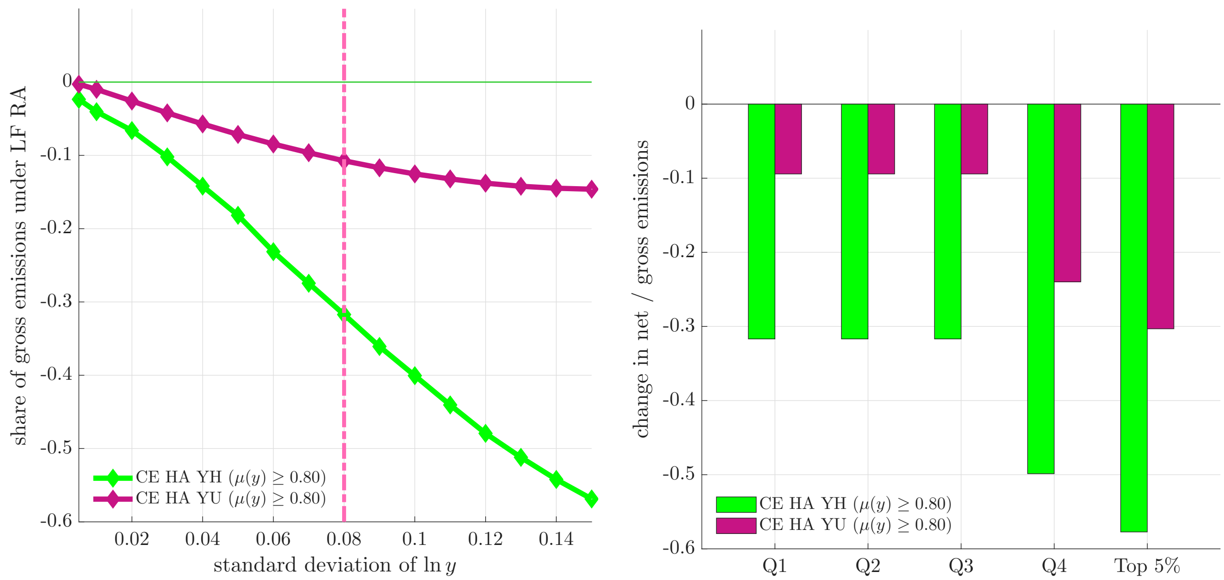
Notes: The left panel shows regional net emissions, $\xi_d k - \xi_g m$, as a percentage of aggregate gross emissions $\xi_d \mathbf{K}$, for quartiles of the wealth distribution and the top 5% of regions. The right panel shows net emissions as a percentage of regional wealth. In both cases, we report the ratio of group averages. ***LF RA***: laissez-faire equilibrium with $\sigma_y = \sigma_\epsilon = 0$; ***CE RA***: constrained efficient solution with $\sigma_\epsilon = \sigma_y = 0$; ***CE HA***: constrained efficient solution with $\sigma_\epsilon \geq 0$ and $\sigma_y > 0$.

corresponding to the richest 5% of regions. In the left-hand side, we express net emissions as a fraction of gross emissions under laissez-faire and in the right-hand side, as a fraction of the average wealth of each group. When limits to redistribution are loose ($\mu(y) \geq 0$), the poorest regions get a "free-pass" on sequestration efforts; their emissions are as large as they would be in the laissez-faire economy. Emissions are still positive for regions in the second quartile, but they engage in some carbon capture. Most of the capture is done, however, by regions in the top of the wealth distribution. As the limits to redistribution tighten ($\mu(y) \geq 0.80$), the net emissions schedule rotates counterclockwise which implies increasing the burden of carbon capture at the bottom of the distribution and alleviating it at the top. In the limit ($\mu(y) \geq 0.98$), the burden is almost uniform across regions but, as discussed previously, the global net emissions goal is far from net-zero.

Figure 3: Global Net Emissions with Wealth and Climate Inequality.

(A) Change in net emissions relative to an economy with wealth inequality only

(B) Change in net emissions relative to average gross emissions for $\sigma_y = 0.08$



Notes: The left panel shows the change in global net emissions prescribed by an economy with climate inequality relative to an economy without it. The right panel shows the change in the net emissions schedule of the policy that corresponds to $\sigma_y = 0.08$, which calls for the same global net emissions target under the two forms of climate inequality. ***CE HA YH***: constrained efficient solution with $\sigma_z > 0$, $\sigma_y > 0$ and $\sigma_\nu = 0$; ***CE HA YU***: constrained efficient solution with $\sigma_z = 0$, $\sigma_y > 0$ and $\sigma_\nu > 0$.

We now introduce climate inequality. We set $\underline{\mu} = 0.8$ as an intermediate value between the two extreme cases studied above: $\underline{\mu} = 0$ allows full redistribution through differentiated responsibilities, while $\underline{\mu} \approx 1$ approximates a uniform burden. Treating either extreme as the relevant scenario seems implausible, so we take $\underline{\mu} = 0.8$ as the benchmark. We then focus on $\sigma_y = 0.08$, the level of wealth inequality at which the constrained-efficient target is exactly global net-zero emissions.

In the left panel of Figure 3, we display the change in global net emissions relative to an economy with only wealth inequality when we introduce climate inequality. At low values of σ_y, the contribution lower bound is close to slack, and the figure directly illustrates the two corollaries: *CE HA YH* originates below zero, consistent with Corollary 4 (adding climate heterogeneity tightens the global target through the pecuniary redistribution channel), while *CE HA YU* originates at zero, consistent with Corollary 5 (when climate shocks are orthogonal to wealth and contributions are unconstrained, climate uncertainty leaves the target unchanged). As wealth inequality grows and the lower bound begins to bind, both schedules move further below zero. The gap widens because binding contribution constraints amplify the case for additional carbon capture: as more regions are exempted from contributing, the redistribution gain from a more ambitious climate program grows, reinforcing the initial incentive to shift savings from capital toward $\mathbf{M}$ for both sources of climate heterogeneity.

At the benchmark level of wealth inequality $\sigma_y = 0.08$, the wealth-only economy calls for exactly net-zero global emissions. Therefore, both economies with climate inequality call for a stricter target, that is, net negative global emissions. In the right panel of Figure 3, we fix σ_y at its benchmark and examine how the additional stringency is distributed across the wealth distribution. Both sources of climate heterogeneity achieve the stricter target primarily through additional carbon capture, but they differ in the extent to which productive capital contracts. Under climate uncertainty (*CE HA YU*), the adjustment operates almost entirely through $\mathbf{M}$: precautionary savings are directed toward carbon capture, and the additional burden falls on wealthier regions that absorb larger capture responsibilities. Under pre-existing climate differences (*CE HA YH*), capital also falls: lower $\mathbf{K}$ raises R, and regions with more savings accept larger $\mathbf{M}$ contributions in exchange for the higher return, leaving them approximately indifferent on net. Since the capital reduction is aggregate, it lowers gross emissions uniformly across the wealth distribution, a parallel downward shift visible across all quartiles, while the differentiated $\mathbf{M}$ schedule redistributes the remaining burden by wealth.

7 Conclusions

We lay out a model with heterogeneous regions and a carbon capture technology to study the effect that inequality has on the design of climate policy. Our focus is on the choice of the global net emissions target and the net emissions schedule across regions. We show that inequality has a non-trivial effect on climate policy, which ultimately depends both on its source and its magnitude.

We highlight two takeaways from our analysis. First, in an unequal world, the choice of a net emissions schedule across countries can be an effective tool to attain global climate goals. This requires the ability to make the contributions of each country to global carbon-capture conditional on their wealth. Second, if all nations are mandated to contribute uniformly to financing carbon capture, wealth inequality acts as a hindrance to collective climate efforts. In such a scenario, global emissions will remain high, and carbon sequestration will be low.

Our model can be extended to an infinite horizon setup, which is more suitable for a quantitative exploration that considers the relative importance of different sources of inequality. We leave this extension for future work.

From a positive perspective, the results in this paper resonate with some of the global climate goals outlined in the Paris Agreement. One of the commitments is to reach global net zero emissions by the year 2050. Following the agreement, countries have been evaluated individually regarding their progress towards net zero (see ClimateTracker). Nevertheless, whether it is optimal to attain the target country by country or in the aggregate remains an open question. In this paper, we show that the constrained-efficient policy in an economy with heterogeneous regions is to reach a homogeneous global net emissions target (i.e., "net-zero by 2050" from the Paris Agreement) with *net negative* emissions in high-income countries and *net positive* emissions in low-income ones.

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Appendix

A Proofs

Proof of Lemma 1

Using the functional forms, first order condition with respect to capital is:

$$R = \alpha \exp(-\gamma(\mathbf{S} + \epsilon))K(\epsilon)^{\alpha-1}L(\epsilon)^{1-\alpha}). \tag{A.1}$$

Since labor market clearing implies that $L(\epsilon) = 1$ in all regions, we can write

$$K(\epsilon) = \left(\frac{\alpha}{R}\right)^{\frac{1}{1-\alpha}} \exp\left(-\frac{\gamma}{1-\alpha}(\mathbf{S} + \epsilon)\right), \tag{A.2}$$

for all ϵ. Integrating across all regions:

$$\mathbf{K} = \left(\frac{\alpha}{R}\right)^{\frac{1}{1-\alpha}} \exp\left(-\frac{\gamma}{1-\alpha}\left(\mathbf{S} + \mu_\epsilon - \frac{\gamma}{1-\alpha}\frac{\sigma_\epsilon^2}{2}\right)\right), \tag{A.3}$$

where we have used the fact that if z and ν are normally distributed and independent, ϵ is also normally distributed. Hence, the share of global capital allocated to each region is

$$\chi(\epsilon) = \exp\left(-\frac{\gamma}{1-\alpha}\left(\epsilon - \mu_\epsilon + \frac{\gamma}{1-\alpha}\frac{\sigma_\epsilon^2}{2}\right)\right), \tag{A.4}$$

for all ϵ. For later use in the numerical example, note also that if $\mu_\epsilon = \gamma\sigma_\epsilon^2/2$, then the share of global capital allocated to each region is

$$\chi(\epsilon) = \exp\left(-\frac{\gamma}{1-\alpha}\left(\epsilon + \gamma\frac{\alpha}{1-\alpha}\frac{\sigma_\epsilon^2}{2}\right)\right), \tag{A.5}$$

for all ϵ.

To obtain the expression that characterizes the distribution of asset holdings, we use the Euler equation of each household in each region

$$\frac{1}{c_0(y,z)} = \beta R \mathbb{E}\left[\frac{1}{c_1(y,z,\nu)}\right], \tag{A.6}$$

for all y, z, and ν. Since the public good is not provided in equilibrium, household assets are $a(y,z) = \eta(y,z)\mathbf{K}$. Using this in the first period budget constraint budget constraints yields

$$c_0(y,z) = y - \eta(y,z)\mathbf{K}, \tag{A.7}$$

for all y, and z. Household consumption in the second period can be written as follows

$$c_1(y,\epsilon) = w(\epsilon) + \eta(y,z)R\mathbf{K}, \tag{A.8}$$

and thus

$$\frac{c_1(y,\epsilon)}{R} = \frac{w(\epsilon)}{R} + \eta(y,z)\mathbf{K}, \tag{A.9}$$

for all y, and ϵ. First order conditions of the final good firm´s problem imply

$$\frac{w(\epsilon)}{R} = \frac{1-\alpha}{\alpha}\chi(\epsilon)\mathbf{K}, \tag{A.10}$$

for all ϵ. Plugging this into (A.9), and using (A.7) and (A.6), yields (17).

Proof of Lemma 2

Without exposure uncertainty, $\sigma_\nu = 0$ and thus, $\epsilon = z$. Since the expectation operator in (17) becomes redundant because households do not face any uncertainty, we verify that

$$\eta(y,z) = \frac{1}{1+\beta}\left[\beta\frac{y}{\mathbf{K}} - \frac{1-\alpha}{\alpha}\chi(z)\right], \tag{A.11}$$

for all y and z, satisfies the Euler equation of each household. Integrating across all regions and using (14) and (15), we can solve for the global capital stock and obtain (18).

Proof of Proposition 1

Integrating both sides of (A.6) across all regions and using the expressions for household consumption deliver

$$\int\int \frac{1}{y-\eta(y,z)\mathbf{K}} g(y)\phi(z)\,\mathrm{d}y\,\mathrm{d}z = \beta\alpha \int\int \mathbb{E}\left[\frac{1}{(1-\alpha)\chi(\epsilon)\mathbf{K}+\alpha\eta(y,z)\mathbf{K}}\right] g(y)\phi(z)\,\mathrm{d}y\,\mathrm{d}z,$$

which determines the global stock of productive capital. The left-hand side increases with $\mathbf{K}$ and the right-hand side does the opposite. A solution is guaranteed because of properties of marginal utility when preferences are logarithmic. The expectation in the right-hand side is taken with respect to ν, which only affects the distribution of productive capital across regions, e.g., $\chi(\epsilon)$. Since marginal utility is convex with respect to $\chi(\epsilon)$, Jensen´s inequality implies that the right-hand side is larger in the presence of uncertainty, for any $\mathbf{K}$. This implies that the solution to the previous expression increases as the variance of σ_ν does.

Proof of Proposition 2

The FOCs of the planner's problem with respect to $\mathbf{K}$ and $\mathbf{M}$ are:

$$\begin{aligned} 1 &= \beta R \frac{\int\int u'(c_1(y,\varepsilon))\,\eta(y,z)\,g(y)h(\varepsilon)\,\mathrm{d}y\,\mathrm{d}\varepsilon}{\int\int u'(c_0(y,z))\,\eta(y,z)\,g(y)\phi(z)\,\mathrm{d}y\,\mathrm{d}z} - \Lambda^{\mathbf{K}}, &\text{(A.12)}\\ 1 &= \Lambda^{\mathbf{M}}, &\text{(A.13)} \end{aligned}$$

where

$$\begin{aligned} \Lambda^{\mathbf{K}} &\equiv \beta\,\frac{\int\int u'(c_1)\left[\gamma\xi_d\,c_1(y,\varepsilon)+F_{LK}(\eta(y,z)-1)+F_{LK}(1-\chi(\varepsilon))\right]g(y)h(\varepsilon)\,\mathrm{d}y\,\mathrm{d}\varepsilon}{\int\int u'(c_0)\,\eta(y,z)\,g(y)\phi(z)\,\mathrm{d}y\,\mathrm{d}z},\\ \Lambda^{\mathbf{M}} &\equiv \beta\,\frac{\int\int u'(c_1)\,\gamma\xi_g\,c_1(y,\varepsilon)\,g(y)h(\varepsilon)\,\mathrm{d}y\,\mathrm{d}\varepsilon}{\int u'(c_0)\,\mu(y)\,g(y)\,\mathrm{d}y}. \end{aligned}$$

The availability of transfers allows the planner to equalize marginal utilities across regions: $u'(c_0(y,z)) = \lambda_0$ and $u'(c_1(y,\varepsilon)) = \lambda_1$ for all (y,z,ε). Three simplifications follow. First, the η-weighted integrals in (A.12) reduce to λ_1/λ_0 using the normalization $\int\int \eta(y,z)g(y)\phi(z)\,\mathrm{d}y\,\mathrm{d}z = 1$. Second, the distributional correction terms inside $\Lambda^{\mathbf{K}}$ vanish: $\int\int(\eta(y,z)-1)g(y)\phi(z)\,\mathrm{d}y\,\mathrm{d}z = 0$ and $\int(1-\chi(\varepsilon))h(\varepsilon)\,\mathrm{d}\varepsilon = 0$ by the normalization conditions on η and χ. Hence $\Lambda^{\mathbf{K}} = \beta(\lambda_1/\lambda_0)\,\gamma\xi_d\,\mathbf{Y}_1$. Third, $\Lambda^{\mathbf{M}} = \beta(\lambda_1/\lambda_0)\,\gamma\xi_g\,\mathbf{Y}_1$ using $\int\mu(y)g(y)\,\mathrm{d}y = 1$. Using log utility, $\lambda_1/\lambda_0 = (1-\mathbf{K}-\mathbf{M})/\mathbf{Y}_1$, and firm optimality gives $R\mathbf{K} = \alpha\mathbf{Y}_1$. The FOCs reduce to:

$$
\begin{aligned}
1 &= \beta\alpha\frac{1-\mathbf{K}-\mathbf{M}}{\mathbf{K}} - \beta\,(1-\mathbf{K}-\mathbf{M})\,\gamma\xi_d, && \text{(A.14)}\\
1 &= \beta\,(1-\mathbf{K}-\mathbf{M})\,\gamma\xi_g, && \text{(A.15)}
\end{aligned}
$$

assuming an interior solution for $\mathbf{M}$. This is a system of two equations and two unknowns. The solution is:

$$
\begin{aligned}
\mathbf{K} &= \frac{\alpha}{\gamma(\xi_d+\xi_g)}, && \text{(A.16)}\\
\mathbf{M} &= 1-\mathbf{K}-\frac{1}{\beta\gamma\xi_g} = 1-\frac{1+\alpha\beta+\frac{\xi_d}{\xi_g}}{\beta\gamma(\xi_d+\xi_g)}. && \text{(A.17)}
\end{aligned}
$$

Proof of Lemma 3

We conjecture that, for any contributing region, the savings choice takes the form:

$$
\eta(y,z)\mathbf{K} = (\tilde{\eta}(y)+\tilde{\eta}(z))\mathbf{K}.
$$

Using this guess, the first-order condition with respect to $\mu(y)$, taken for a fixed contributing region y, is

$$
\int_z \frac{\mathbf{M}}{y-(\tilde{\eta}(y)+\tilde{\eta}(z))\mathbf{K}-\mu(y)\mathbf{M}}\,\phi(z)\,dz = \Lambda^{\mu}, \qquad \text{(A.18)}
$$

for any contributing region, where Λ^{μ} is the Lagrange multiplier for constraint (B.7). Since Λ^{μ} is a multiplier on a constraint that aggregates across regions, it is a scalar independent of y. Define $A(y) \equiv y - \tilde{\eta}(y)\mathbf{K} - \mu(y)\mathbf{M}$, so that first-period consumption equals $c_0(y,z) = A(y) - \tilde{\eta}(z)\mathbf{K}$. The condition becomes $\int_z \mathbf{M}/[A(y) - \tilde{\eta}(z)\mathbf{K}]\,\phi(z)\,dz = \Lambda^{\mu}$. Since this integral is strictly monotone in $A(y)$ and Λ^{μ} does not vary across contributing regions, $A(y)$ must equal a common constant A. Since $A(y) = A$, it follows that $\mu(y) = (y - \tilde{\eta}(y)\mathbf{K} - A)/\mathbf{M}$. The normalization $\int_{y \geq y^{\star}} \mu(y)\,g(y)\,dy = 1 - \overline{\mu}G(y^{\star})$ then pins down A, yielding the first expression in the lemma:

$$\mu(y) = \frac{1 - \overline{\mu}G(y^{\star})}{1 - G(y^{\star})} + \frac{y - \mathbb{E}[\mathtt{Y} \mid \mathtt{Y} \geq y^{\star}]}{\mathbf{M}} - \frac{\tilde{\eta}(y) - \mathbb{E}[\tilde{\eta}(\mathtt{Y}) \mid \mathtt{Y} \geq y^{\star}]}{\mathbf{M}},$$

for any contributing region. Now, the first-order condition with respect to $\eta(y,z)$, taken for a fixed contributing region (y,z), delivers

$$\frac{1}{c_0(y,z)} = \beta R \int_v \frac{1}{w(z,v) + R(\tilde{\eta}(y) + \tilde{\eta}(z))\mathbf{K}}\,\psi(v)\,dv + \Lambda^{\eta} \tag{A.19}$$

where Λ^{η} is the multiplier for constraint (B.6) and the integral is over v. Since $c_0(y,z) = A - \tilde{\eta}(z)\mathbf{K}$, the left-hand side depends on z but not on y. Therefore, the right-hand side cannot depend on y either, which requires $\tilde{\eta}(y)$ to be constant for contributing regions. Since $\tilde{\eta}(y)$ is constant, the term $\tilde{\eta}(y) - \mathbb{E}[\tilde{\eta}(\mathtt{Y}) \mid \mathtt{Y} \geq y^{\star}]$ in the first expression for $\mu(y)$ vanishes, yielding the second expression in the lemma:

$$\mu(y) = \frac{1 - \overline{\mu}G(y^{\star})}{1 - G(y^{\star})} + \frac{y - \mathbb{E}[\mathtt{Y} \mid \mathtt{Y} \geq y^{\star}]}{\mathbf{M}}.$$

Finally, $\tilde{\eta}(z)$ is defined implicitly by (A.19) for contributing regions, and $\mu(y) = \overline{\mu}$ for $y < y^{\star}$.

Proof of Proposition 3

We first solve the planner's problem by performing a change of variables from $(\mathbf{K}, \mathbf{M})$ to $(\mathbf{A}, \theta)$ with $\mathbf{A} = \mathbf{K} + \mathbf{M}$ and $\theta = \mathbf{M}/(\mathbf{K} + \mathbf{M})$. More precisely, we characterize the optimal $(1-\theta)\mathbf{A}$ and $\mathbf{A}$, then verify that the same expressions can be obtained by solving a representative-agent problem with modified preference and damage parameters.

Change of variables. For any feasible allocation, define $\mathbf{A} = \mathbf{K} + \mathbf{M}$ and $\theta = \mathbf{M}/\mathbf{A}$, so $\mathbf{K} = (1-\theta)\mathbf{A}$ and $\mathbf{M} = \theta\mathbf{A}$. Set $\tilde{a}(y,z) = a(y,z) + m(y)$ and $\tilde{\eta}(y,z) = \tilde{a}(y,z)/\mathbf{A}$ so that $\int\int \tilde{\eta}\, g\phi = 1$. Writing $\mu(y) = m(y)/\mathbf{M}$ and $\eta(y,z) = a(y,z)/\mathbf{K}$, one checks that

$$\tilde{\eta}(y,z) - \mu(y) = (1-\theta)(\eta(y,z) - \mu(y)), \qquad \tilde{\eta}(y,z) - \theta\mu(y) = (1-\theta)\eta(y,z). \tag{A.20}$$

First- and second-period consumption are

$$c_0(y,z) = y - \tilde{\eta}(y,z)\mathbf{A}, \qquad c_1(y,z,\epsilon) = F_K\big(\tilde{\eta}(y,z) - \theta\mu(y)\big)\mathbf{A} + F_L,$$

where $F_K \equiv (1-D)\tilde{F}_K$ and $F_L \equiv (1-D)\tilde{F}_L$ are equilibrium factor prices, with firms taking D as given. Note that c_0 does not depend on θ.

First-order conditions. The control variables are $(\mathbf{A}, \theta, \tilde{\eta}, \mu)$. Let Λ be the multiplier on $\int\int \tilde{\eta}\, g\phi = 1$. The first-order conditions with respect to $\mathbf{A}$, θ, and $\tilde{\eta}$ are:

$$\beta \int\int\int \frac{1}{c_1}\frac{\partial c_1}{\partial \theta}\, g\phi\psi = 0, \tag{A.21}$$

$$\int\int \frac{\tilde{\eta}}{y - \tilde{\eta}\mathbf{A}}\, g\phi = \beta \int\int\int \frac{1}{c_1}\frac{\partial c_1}{\partial \mathbf{A}}\, g\phi\psi, \tag{A.22}$$

$$\frac{\mathbf{A}}{y - \tilde{\eta}(y,z)\mathbf{A}} = \beta \int \frac{F_K \mathbf{A}}{c_1}\psi\, d\nu + \Lambda, \quad \text{for each } (y,z). \tag{A.23}$$

The $\tilde{\eta}$-FOC (A.23) uses $\partial c_1/\partial \tilde{\eta} = F_K \mathbf{A}$ directly.

Partial derivatives. Recall that $F = (1-D)\tilde{F}$. Since $\tilde{F}$ is Cobb-Douglas and D enters as a state variable, the scaling identities $F_{KK}\chi\mathbf{K} = (\alpha-1)F_K$ and $F_{LK}\chi\mathbf{K} = \alpha F_L$ hold, with the damage channel entering separately via $\gamma\Pi$ terms. Using these identities when differentiating c_1 with respect to θ and $\mathbf{A}$ yields:

$$\begin{aligned}
\frac{\partial c_1}{\partial \theta} &= -\mu\mathbf{A}F_K - F_{KK}\chi(\tilde{\eta}-\theta\mu)\mathbf{A}^2 - F_{LK}\chi\mathbf{A} + \gamma(\xi_d+\xi_g)\mathbf{A}\,c_1 \\
&= \frac{F_K\mathbf{A}(\tilde{\eta}-\mu)-\alpha c_1}{1-\theta} + \gamma(\xi_d+\xi_g)\mathbf{A}\,c_1, && \text{(A.24)} \\
\frac{\partial c_1}{\partial \mathbf{A}} &= F_K(\tilde{\eta}-\theta\mu) + F_{KK}\chi(\tilde{\eta}-\theta\mu)(1-\theta)\mathbf{A} + F_{LK}\chi(1-\theta) - \gamma\frac{\Pi(\mathbf{A},\theta)}{\mathbf{A}}c_1 \\
&= \frac{\alpha c_1}{\mathbf{A}} - \gamma\frac{\Pi(\mathbf{A},\theta)}{\mathbf{A}}\,c_1, && \text{(A.25)}
\end{aligned}$$

where $\Pi(\mathbf{A},\theta) = \xi_d(1-\theta)\mathbf{A} - \xi_g\theta\mathbf{A}$ are global carbon emissions.

Step 1: Solving for $\mathbf{K} = (1-\theta)\mathbf{A}$. Substituting (A.24) into (A.21), the damage term $\gamma(\xi_d+\xi_g)\mathbf{A}$ is constant in the integral and, after dividing by β:

$$\int\!\!\int\!\!\int \frac{F_K\mathbf{A}(\tilde{\eta}-\mu)}{(1-\theta)c_1}\,g\phi\psi = \frac{\alpha}{1-\theta} - \gamma(\xi_d+\xi_g)\mathbf{A}. \tag{A.26}$$

Using $F_L(\epsilon) = (1-\alpha)\chi(\epsilon)F_K(1-\theta)\mathbf{A}/\alpha$ gives $\alpha c_1/F_K = [\alpha(\tilde{\eta}-\theta\mu)+(1-\alpha)\chi(\epsilon)(1-\theta)]\mathbf{A}$. Invoking $\tilde{\eta}-\theta\mu = (1-\theta)\eta$ and $\tilde{\eta}-\mu = (1-\theta)(\eta-\mu)$ from (A.20) to simplify both the denominator and the numerator of the integral and rearranging:

$$\mathbf{K} = (1-\theta)\mathbf{A} = \frac{\alpha-\Omega_0}{\gamma(\xi_d+\xi_g)}, \tag{A.27}$$

where

$$\Omega_0 = \int\!\!\int \frac{\alpha(\eta(y,z)-\mu(y))}{(1-\alpha)\chi(\epsilon)+\alpha\eta(y,z)}\,g(y)\phi(z)\,dy\,dz. \tag{A.28}$$

Step 2: Solving for $\mathbf{A}$. Substituting the partial derivative (A.25) into the $\mathbf{A}$-FOC (A.22) and using (A.27) gives

$$\mathbf{A} = \frac{\int\int \frac{\tilde{\eta}\mathbf{A}}{y - \tilde{\eta}\mathbf{A}}\, g\phi \; - \; \beta\Omega_0}{\beta\gamma\xi_g}. \tag{A.29}$$

Let $\mathcal{R}(y,z) \equiv \beta \int \frac{F_K \mathbf{A}}{c_1} \psi \, dv + \Lambda$ denote the right-hand side of the $\tilde{\eta}$-FOC (A.23), so that $\mathbf{A}/(y - \tilde{\eta}\mathbf{A}) = \mathcal{R}(y,z)$. Multiplying (A.23) by $\tilde{\eta}$ and integrating, decompose $\tilde{\eta} = \mu + (\tilde{\eta} - \mu)$:

$$\int\int \frac{\tilde{\eta}\mathbf{A}}{y - \tilde{\eta}\mathbf{A}}\, g\phi = \int\int \mu\, \mathcal{R}\, g\phi + \int\int (\tilde{\eta} - \mu)\, \mathcal{R}\, g\phi. \tag{A.30}$$

For the second term, use $\tilde{\eta} - \mu = (1-\theta)(\eta - \mu)$ from (A.20) and expand $\mathcal{R}$ using $F_K\mathbf{A}/c_1 = \alpha/[(1-\theta)((1-\alpha)\chi + \alpha\eta)]$. The multiplier Λ vanishes since $\int\int(\eta - \mu)\, g\phi = 0$, and the remainder equals $\beta\Omega_0$ by (A.28). Hence:

$$\int\int \frac{\tilde{\eta}\mathbf{A}}{y - \tilde{\eta}\mathbf{A}}\, g\phi = \int\int \mu\, \mathcal{R}\, g\phi + \beta\Omega_0. \tag{A.31}$$

Substituting (A.31) into (A.29), the $\beta\Omega_0$ terms cancel:

$$\beta\gamma\xi_g \mathbf{A} = \int\int \mu(y)\, \mathcal{R}(y,z)\, g\phi. \tag{A.32}$$

Rearranging the $\tilde{\eta}$-FOC gives $y - \tilde{\eta}\mathbf{A} = \mathbf{A}/\mathcal{R}(y,z)$. Integrating over (y,z) and using $\int\int y\, g\phi = 1$ and $\int\int \tilde{\eta}\, g\phi = 1$:

$$1 - \mathbf{A} = \mathbf{A} \int\int \frac{1}{\mathcal{R}(y,z)}\, g\phi. \tag{A.33}$$

Multiplying (A.32) by $\int\int (1/\mathcal{R})\, g\phi$ and substituting (A.33) gives $\beta\gamma\xi_g(1 - \mathbf{A}) = \Omega_1$, where

$$\Omega_1 \equiv \int\int \mu\, \mathcal{R}\, g\phi \cdot \int\int \frac{1}{\mathcal{R}}\, g\phi. \tag{A.34}$$

Since $\int\int \mu \mathcal{R}\, g\phi = \Lambda + \frac{\alpha\beta}{1-\theta}\int\int \frac{\mu}{(1-\alpha)\chi+\alpha\eta}\, g\phi$ is constant in (y,z), the product (A.34) equals the ratio integral in the proposition:

$$\Omega_1 = \int\int \frac{\Lambda + \dfrac{\alpha\beta}{1-\theta}\displaystyle\int\int \frac{\mu(y)}{(1-\alpha)\chi(\epsilon)+\alpha\eta(y,z)}\, g\phi}{\Lambda + \dfrac{\alpha\beta}{1-\theta}\displaystyle\int \frac{1}{(1-\alpha)\chi(\epsilon)+\alpha\eta(y,z)}\psi}\, g(y)\phi(z)\, dy\, dz, \tag{A.35}$$

and hence

$$\mathbf{A} = \frac{\beta\gamma\xi_g - \Omega_1}{\beta\gamma\xi_g}. \tag{A.36}$$

Step 3: RA equivalence. Take a solution to the planner's problem and define

$$\hat{\gamma} = \frac{\alpha}{\alpha - \Omega_0}\gamma, \qquad \hat{\beta} = \frac{\alpha - \Omega_0}{\alpha\Omega_1}\beta. \tag{A.37}$$

Then suppose one solves for the first best allocation with these parameters. By Proposition 2, the solution to such problem is:

$$\mathbf{K} = \frac{\alpha}{\hat{\gamma}(\xi_g + \xi_d)} \tag{A.38}$$

$$\mathbf{M} = 1 - \frac{1 + \alpha\hat{\beta} + \frac{\xi_d}{\xi_g}}{\hat{\beta}\hat{\gamma}(\xi_g + \xi_d)} \tag{A.39}$$

which corresponds to the RA solution. Moreover, note that

$$\mathbf{K} + \mathbf{M} = \frac{\hat{\beta}\hat{\gamma}\xi_g - 1}{\hat{\beta}\hat{\gamma}\xi_g} \tag{A.40}$$

Using then (A.37), we recover (A.27) and (A.36), which completes the proof. □

Proof of Corollary 1

By Proposition 3, it suffices to show $\Omega_0 = 0$ and $\Omega_1 = 1$.

When $\sigma_z = \sigma_\nu = 0$, all regions share the same climate type, so $\chi(\varepsilon) = 1$ for all regions. Since the constraint $m(y) \geq 0$ is not binding, all regions are contributing, and as established in the proof of Lemma 3, $\tilde{\eta}(y)$ is constant for contributing regions; since z is degenerate, $\tilde{\eta}(z)$ is constant as well, so $\eta(y,z) = \bar{\eta}$ for all (y,z). Capital market clearing then gives $\bar{\eta} = 1$. For Ω_0, substituting $\chi = 1$ and $\eta = 1$ gives

$$\Omega_0 = \alpha\left[1 - \int \mu(y)\, g(y)\, dy\right],$$

which equals zero since $\int \mu(y)\, g(y)\, dy = 1$ by definition of $\mu(y) = m(y)/\mathbf{M}$. For Ω_1, with $\chi = 1$ and $\eta = 1$ the denominator $(1-\alpha)\chi(\varepsilon) + \alpha\eta(y,z) = 1$ for every region, so the integrand of Ω_1 equals $(\Lambda + \alpha\beta/(1-\theta))/(\Lambda + \alpha\beta/(1-\theta)) = 1$ for every region, giving $\Omega_1 = 1$. $\square$

Proof of Corollary 2

Since $\sigma_z = \sigma_\nu = 0$, we have $\chi = 1$ and $\eta = \eta(y)$. Classify regions as contributing (C: $y \geq y^*$, $\mu(y) > 0$) and non-contributing (N: $y < y^*$, $\mu(y) = 0$). By Lemma 3, $\eta(y) = \bar{\eta}$ for all $y \in C$. Since lower income implies lower savings, $\eta(y) < \bar{\eta}$ for $y \in N$ on a set of positive measure.

$\Omega_0 > 0$. With $\chi = 1$:

$$\Omega_0 = \alpha \int \frac{\eta(y) - \mu(y)}{(1-\alpha) + \alpha\eta(y)}\, g(y)\, dy.$$

Splitting over C and N and using $\eta = \bar{\eta}$ on C, market clearing ($\int \eta\, g = 1$ and $\int_C \mu\, g = 1$) gives $\int_C (\bar{\eta} - \mu)\, g\, dy = -\int_N \eta\, g\, dy$, so:

$$\Omega_0 = \alpha \int_N \eta(y)\left[\frac{1}{(1-\alpha) + \alpha\eta(y)} - \frac{1}{(1-\alpha) + \alpha\bar{\eta}}\right] g(y)\, dy > 0,$$

since $\eta(y) > 0$ and the bracket is strictly positive on N.

$\Omega_1 < 1$. With $\sigma_z = \sigma_v = 0$, the function $\mathcal{R}(y) = \frac{\alpha\beta}{(1-\theta)((1-\alpha)+\alpha\eta(y))} + \Lambda$ from the proof of Proposition 3 takes the constant value $\bar{\mathcal{R}} \equiv \mathcal{R}(\bar{\eta})$ on C and satisfies $\mathcal{R}(y) > \bar{\mathcal{R}}$ on N, since $\eta(y) < \bar{\eta}$ implies a smaller denominator. Since $\mu = 0$ on N and $\int_C \mu\, g = 1$:

$$\int \mu(y)\, \mathcal{R}(y)\, g(y)\, dy = \bar{\mathcal{R}} \int_C \mu\, g = \bar{\mathcal{R}}.$$

Since $\mathcal{R}(y) > \bar{\mathcal{R}}$ on N, which has positive mass:

$$\int \frac{1}{\mathcal{R}(y)}\, g(y)\, dy < \frac{1}{\bar{\mathcal{R}}}.$$

Therefore $\Omega_1 = \bar{\mathcal{R}} \cdot \int \frac{1}{\mathcal{R}}\, g < 1$. From (A.27): $\mathbf{K} = (\alpha - \Omega_0)/[\gamma(\xi_d + \xi_g)] < \mathbf{K}^{FB}$ since $\Omega_0 > 0$. From (A.36): $\mathbf{A} = (\beta\gamma\xi_g - \Omega_1)/(\beta\gamma\xi_g) > \mathbf{A}^{FB}$ since $\Omega_1 < 1$. Hence $\mathbf{M} = \mathbf{A} - \mathbf{K} > \mathbf{A}^{FB} - \mathbf{K}^{FB} = \mathbf{M}^{FB}$. □

Proof of Corollary 3

With $\sigma_z = \sigma_v = 0$, we have $\chi = 1$ and $\eta = \eta(y)$. Condition (30) sets $\mu(y) = 1$ for all y. The Ω_0 expression from Proposition 3 reduces to

$$\Omega_0 = \alpha \int f(\eta(y))\, g(y)\, dy, \qquad f(\eta) \equiv \frac{\eta - 1}{(1-\alpha) + \alpha\eta}.$$

Since $f''(\eta) = -2\alpha/(1-\alpha+\alpha\eta)^3 < 0$, the function f is strictly concave. With $f(1) = 0$, Jensen's inequality gives

$$\int f(\eta(y))\, g(y)\, dy < f\Big(\int \eta(y)\, g(y)\, dy\Big) = f(1) = 0,$$

where the strict inequality uses $\sigma_y > 0$ (so η is non-constant). Hence $\Omega_0 < 0$ and $\mathbf{K} = (\alpha - \Omega_0)/[\gamma(\xi_d + \xi_g)] > \mathbf{K}^{FB}$.

$\Omega_1 > 1$. With $\mu(y) = 1$ and $\chi = 1$, the Ω_1 expression from Proposition 3 simplifies to $\Omega_1 = \int \mathcal{R}(y)\, g(y)\, dy \cdot \int (1/\mathcal{R}(y))\, g(y)\, dy$, where $\mathcal{R}(y) = \alpha\beta/[(1-\theta)(1-\alpha+\alpha\eta(y))] + \Lambda$. By the Cauchy–Schwarz inequality applied to $(\sqrt{\mathcal{R}}, 1/\sqrt{\mathcal{R}})$:

$$\int \mathcal{R}(y)\, g(y)\, dy \cdot \int \frac{g(y)}{\mathcal{R}(y)}\, dy \;\geq\; \left(\int \sqrt{\mathcal{R}(y)} \cdot \frac{g(y)}{\sqrt{\mathcal{R}(y)}}\, dy\right)^2 = 1,$$

with strict inequality since $\mathcal{R}(y)$ is non-constant when $\sigma_y > 0$. Hence $\Omega_1 > 1$, $\mathbf{A} < \mathbf{A}^{FB}$, and therefore $\mathbf{M} = \mathbf{A} - \mathbf{K} < \mathbf{A}^{FB} - \mathbf{K}^{FB} = \mathbf{M}^{FB}$. $\square$

Proof of Corollary 4

By Proposition 3, it suffices to show $\Omega_0 > 0$ and $\Omega_1 = 1$.

With $\sigma_\nu = 0$, the Euler equation gives $c_0(y,z) = [y - m(y) + \omega(z)]/(1+\beta)$ and $c_1(y,z) = \beta F_K[y - m(y) + \omega(z)]/(1+\beta)$, where $\omega(z) \equiv (1-\alpha)\chi(z)(1-\theta)\mathbf{A}/\alpha$. Since condition (23) is not binding, all regions contribute at an interior solution. The planner's optimality condition for $\mu(y)$ (with multiplier $\tilde{\lambda}$ on $\int \mu\, g = 1$; the indirect effect through $a(y,z)$ vanishes by the Euler-equation envelope condition) gives $\theta\mathbf{A} \int \phi(z)/c_0(y,z)\, dz = \tilde{\lambda}$. Combined with $c_1 = \beta F_K c_0$, this yields

$$\int \frac{\phi(z)}{c_1(y,z)}\, dz = \frac{\tilde{\lambda}}{\beta F_K \theta \mathbf{A}} \equiv \bar{h} \quad \text{for all } y.$$

Let $\bar{\eta}(y) \equiv \int \eta(y,z)\, \phi(z)\, dz$. Substituting $1/[(1-\alpha)\chi(z) + \alpha\eta] = F_K(1-\theta)\mathbf{A}/(\alpha c_1)$ into the Ω_0 expression from Proposition 3 gives $\Omega_0 = (1-\theta)F_K\mathbf{A} \int\int (\eta - \mu)/c_1\, g\phi$. Since

$\int \phi / c_1 \, dz = \bar{h}$ and $\int (\bar{\eta} - \mu) \, g \, dy = 0$ by market clearing, replacing $\eta - \mu$ by $(\eta - \bar{\eta}) + (\bar{\eta} - \mu)$:

$$\Omega_0 = (1-\theta) F_K \mathbf{A} \int g(y) \left[\int \frac{\eta(y,z) - \bar{\eta}(y)}{c_1(y,z)} \, \phi(z) \, dz \right] dy.$$

Since $\omega(z)$ is decreasing in z, the savings formula $a(y,z) = [\beta(y - m(y)) - \omega(z)]/(1+\beta)$ gives $\partial\eta/\partial z = -\omega'(z)/[(1+\beta)K] > 0$ and $\partial c_1/\partial z = \beta F_K \omega'(z)/(1+\beta) < 0$ for fixed y. Thus $\eta(y,z)$ and $1/c_1(y,z)$ are both strictly increasing in z. Since $\int (\eta - \bar{\eta}) \, \phi \, dz = 0$, the inner integral is the covariance of two increasing functions of z, strictly positive when $\sigma_z > 0$:

$$\int \frac{\eta(y,z) - \bar{\eta}(y)}{c_1(y,z)} \, \phi(z) \, dz \ > \ 0 \quad \text{for each } y.$$

Hence $\Omega_0 > 0$ and $\mathbf{K} = (\alpha - \Omega_0)/[\gamma(\xi_d + \xi_g)] < \mathbf{K}^{FB}$.

Since $\bar{h}$ holds for all y, substituting the same key identity into the $\mathcal{R}(y)$ expression from Proposition 3 gives

$$\mathcal{R}(y) = \beta F_K \mathbf{A} \int \frac{\phi(z)}{c_1(y,z)} \, dz + \Lambda = \beta F_K \mathbf{A} \cdot \bar{h} + \Lambda \equiv \bar{\mathcal{R}},$$

which is constant across y. Hence $\Omega_1 = \bar{\mathcal{R}} \cdot \underbrace{\int \mu \, g}_{=1} \cdot \frac{1}{\bar{\mathcal{R}}} \cdot \underbrace{\int g}_{=1} = 1$, so $\mathbf{A} = \mathbf{A}^{FB}$. Since $\mathbf{K} < \mathbf{K}^{FB}$, it follows that $\mathbf{M} = \mathbf{A} - \mathbf{K} > \mathbf{A}^{FB} - \mathbf{K}^{FB} = \mathbf{M}^{FB}$. □

Proof of Corollary 5

By Proposition 3, it suffices to show $\Omega_0 = 0$ and $\Omega_1 = 1$.

With $\sigma_z = 0$, integrate out z trivially. Since condition (23) is not binding with $\underline{m} = 0$, all regions contribute at an interior solution. The planner's optimality condition for $\mu(y)$ (with multiplier $\tilde{\lambda}$ on $\int \mu \, g = 1$; the indirect effect through $a(y)$ vanishes by the Euler-equation envelope condition) gives $1/c_0(y) = \tilde{\lambda}/(\theta \mathbf{A})$ for all contributing y, hence $c_0(y) = \theta \mathbf{A}/\tilde{\lambda} \equiv \bar{c}_0$ (constant across y). Here $c_1(y,\nu) = F_K(1-\theta)\eta(y)\mathbf{A} + F_L(\nu)$ is independent of

$\mu(y)$ given the aggregate. The Euler equation then gives

$$\int \frac{\psi(\nu)}{c_1(y,\nu)}\, d\nu = \frac{1}{\beta F_K \bar{c}_0} \equiv \bar{h} \quad \text{for all } y.$$

$\Omega_0 = 0$. Substituting $1/[(1-\alpha)\chi(\nu) + \alpha\eta(y)] = F_K(1-\theta)\mathbf{A}/(\alpha c_1(y,\nu))$ into the Ω_0 expression from Proposition 3:

$$\Omega_0 \;=\; (1-\theta)F_K\mathbf{A}\int (\eta(y)-\mu(y))\cdot\left[\int \frac{\psi(\nu)}{c_1(y,\nu)}\, d\nu\right] g(y)\, dy \;=\; (1-\theta)F_K\mathbf{A}\cdot\bar{h}\cdot\underbrace{\int (\eta-\mu)\, g\, dy}_{=0} = 0.$$

$\Omega_1 = 1$. Since $\int \psi(\nu)/c_1(y,\nu)\, d\nu = \bar{h}$ for all y, the function $\mathcal{R}(y) = \beta F_K\mathbf{A}\cdot\bar{h} + \Lambda \equiv \bar{\mathcal{R}}$ is constant. Hence:

$$\Omega_1 = \int \mu(y)\,\bar{\mathcal{R}}\, g(y)\, dy \cdot \int \frac{g(y)}{\bar{\mathcal{R}}}\, dy = \bar{\mathcal{R}}\cdot\underbrace{\int \mu\, g}_{=1}\cdot\frac{1}{\bar{\mathcal{R}}}\cdot\underbrace{\int g}_{=1} = 1.$$

Hence $\mathbf{K} = \mathbf{K}^{FB}$, $\mathbf{A} = \mathbf{A}^{FB}$, and therefore $\mathbf{M} = \mathbf{M}^{FB}$. □

B Modified Planner's Problem

With the change of variables, the utilitarian planner's problem can be written as follows:

$$\max_{\substack{c_0(y,z),\,\eta(y,z),\,c_1(y,\epsilon)\\ \mu(y),\,\chi(\epsilon),\,\mathbf{K},\,\mathbf{M}}} \int\int \left\{u(c_0(y,z)) + \beta\mathbb{E}_\nu\left[u(c_1(y,\epsilon))\right]\right\} g(y)\phi(z)\, \mathrm{d}y\, \mathrm{d}z$$

subject to budget constraints:

$$c_0(y,z) \;=\; y - \eta(y,z)\mathbf{K} - \mu(y)\mathbf{M} \qquad \forall (y,z), \tag{B.1}$$

$$c_1(y,\epsilon) \;=\; w(\epsilon) + R\eta(y,z)\mathbf{K} \qquad \forall (y,\epsilon), \tag{B.2}$$

optimal conditions for regional-representative firms:

$$R = \alpha \exp\Big(-\gamma\left(\mathbf{S}+\epsilon\right)\Big)\Big(\chi(\epsilon)\mathbf{K}\Big)^{\alpha-1} \quad \forall\epsilon, \tag{B.3}$$

$$w(\epsilon) = (1-\alpha)\exp\Big(-\gamma\left(\mathbf{S}+\epsilon\right)\Big)\Big(\chi(\epsilon)\mathbf{K}\Big)^{\alpha} \quad \forall\epsilon. \tag{B.4}$$

and the constraints on the distributions

$$\int \chi(\epsilon)h(\epsilon)\,\mathrm{d}\epsilon = 1 \tag{B.5}$$

$$\int\int \eta(y,z)g(y)\phi(z)\,\mathrm{d}y\,\mathrm{d}z = 1 \tag{B.6}$$

$$\int \mu(y)g(y)\,\mathrm{d}y = 1 \tag{B.7}$$

We note that $\chi(\epsilon)$ is pinned down by constraints, and it will coincide with the laissez-faire outcome. Since capital is freely mobile across regions, it always flows to its most productive use, equalizing marginal products through the common return R. The firm's optimality condition then pins down $K(\epsilon) = \chi(\epsilon)\mathbf{K}$ as a function of ϵ and R alone; the wealth distribution never enters. This productive efficiency condition holds in any feasible allocation, so there is nothing to be gained from distorting $\chi(\epsilon)$ away from its laissez-faire value.

C Algorithm for Computation

1. Guess $\mathbf{K}$ and $\mathbf{M}$, and translate it into θ and $\mathbf{A}$. A good initial guess is the representative agent solution.

2. Check if all regions contribute for this initial guess. If not, find the last contributing region. This sets $y^\star$

3. Solve for $\{\Lambda, \eta, \mu\}$ as follows:

(a) Guess Λ and use this guess to obtain η from Euler equation both for contributing and non contributing regions.

(b) Obtain μ give $y^\star$.

(c) Check if η adds up to one. If not, adjust Λ

(d) Iterate until convergence.

4. Use $\{\Lambda, \eta, \mu\}$ to obtain $\{\Omega_0, \Omega_1\}$ according to the expressions of Proposition 3.

5. Compute new values for $\mathbf{K}$ and $\mathbf{M}$ using Proposition 3.

6. Iterate until convergence

D Parameter values

Table 1: Parameter values

Parameter	Symbol	Benchmark	Comment
Discount factor	β	1	
Capital intensity	α	0.33	
Damage Function			
Elasticity	γ	2.4e-05	$\diamond$
Degradation rate	ξ_d	5.1e+02	†
Restoration rate	ξ_g	5.6e+04	‡
Dispersion			
Wealth	σ_y	0.08	$\circledast$
Exposure	σ_ϵ	24250	

Notes: ($\diamond$) average reported in Golosov et al. (2014); (†) implied global production damage of 3%; (‡) guarantees slackness of Assumption 1 and positive global net emissions in the representative region case; ($\circledast$) sensitivity performed with a grid going from 0.01 to 0.15.