Does Unilateral Decarbonization Pay For Itself?

By Adrien Bilal and Diego R. Känzig*

Anthropogenic greenhouse gas emissions are rapidly warming the Earth. Faced with rising temperatures, there are two alternatives: cope with their economic consequences, or reduce emissions.

Achieving broad emissions reductions is challenging because of the classic free-rider problem: a country that decarbonizes its economy pays for the full cost but only gets back a fraction of the associated gains, as all other countries also benefit from decarbonization. Despite substantial developments in international negotiations to coordinate emissions reductions since the 2015 Paris Conference of the Parties, global emissions have continued to rise nearly every year.

The free-rider problem is particularly acute under conventional climate change damage estimates. These estimates imply that *collective* decarbonization is economically viable if decarbonization costs are shared, but that *unilateral* decarbonization is not.

In this paper, we reconsider this argument in light of new damage estimates. We use damages based on global mean temperature as in Bilal and Känzig (2024), that are an order of magnitude larger than conventional estimates. Our main result is that broad *unilateral* decarbonization can, in fact, be cost-effective. For the United States and for the European Union, decarbonizing over 80% of economic activity pays for itself.

Our argument starts with a simple organizing framework. *Unilateral* decarbonization compares domestic benefits and costs of decarbonization. The domestic benefit of decarbonization is the Domestic Cost of Carbon: economic losses within a given country or region associated with emitting one ton of carbon dioxide. Of course, the Domestic Cost of Carbon of any given region is always lower than the Social Cost of Carbon that includes all worldwide damages. The domestic cost of decarbonization is the Marginal Abatement Cost: economic costs associated with greening a country's economy by the equivalent of one ton of carbon.

We measure the benefits and costs of decarbonization for the United States and the European Union. We estimate the impact of global temperature shocks on output per capita for each region. We then convert these damages into a Domestic Cost of Carbon using a climate-economy model estimated to match the reduced-form impacts.

We obtain Domestic Costs of Carbon of \$226 per ton for the United States and \$216 per ton for the European Union. These values are an order of magnitude above conventional estimates based on local temperature shocks: \$22 and \$28 per ton, respectively.

We combine these estimates with a Marginal Abatement Cost Curve. Given current technologies, abatement costs are already zero for partial greening of electricity generation and transportation, but rise steeply and exceed \$240 per ton for direct air capture.

Balancing the benefits and costs of decarbonization implies that it is unilaterally cost-effective to decarbonize 86% of the United States economy and 84% of the European Union economy under global temperature damages, an order of magnitude more than under local temperature damages. These results highlight that broad unilateral decarbonization may be less challenging than previously thought, at least in large economies.

* Bilal: Stanford University, adrienbilal@stanford.edu. Känzig: Northwestern University, dkaenzig@northwestern.edu. This working paper is in preparation for the American Economic Association Papers and Proceedings. We thank Jamil Farbes for sharing the abatement cost data, and Anna Russo and Augusto Ospital for helpful comments.

I. Conceptual Framework

To organize our cost-benefit analysis, we consider the simplest possible static framework. There is a set of regions indexed by i. We posit that economic well-being W_i depends on two quantities: global mean excess temperature $T \geq 0$ relative to baseline $T = 0$, and the fraction $D_i \in [0, 1]$ of the economy that is decarbonized, as follows: $W_i = Y_i(T) - C_i(D_i)Y_i(0)$. The function Y_i represents the size of the economy, for instance consumption or output. Decarbonization costs $C_i(D_i)Y_i(0)$ scale with the size of the economy.

Worldwide emissions $E = \sum_i E_i$ lead to excess warming through the relationship $T = S(E)$, where the function S represents the greenhouse gas feedback. Finally, emissions are proportional to the size of the economy: $E_i = (1 - D_i)Y_i(0)$.

We consider the decision problem of a region that behaves unilaterally and chooses its decarbonization rate without internalizing the global carbon externality:

$$\max_{D_i} Y_i(T) - C_i(D_i)Y_i(0)$$
$$\text{s.t. } T = S(E_{-i} + E_i),\ E_i = (1 - D_i)Y_i(0),$$

where $E_{-i} = \sum_{j \neq i} E_j$. The optimality condition leads to $-Y_i'(T)S'(E) = C_i'(D_i)$. This condition states that the Domestic Cost of Carbon $-Y_i'(T)S'(E)$ must equal the Marginal Abatement Cost $C_i'(D_i)$. The Domestic Cost of Carbon is in turn the product of climate damages as a function of temperature, $-Y_i'(T)$, times the climate sensitivity $S'(E)$.

By contrast, a world planner internalizes the global carbon externality and sets decarbonization to $C_i'(D_i) = -\sum_j Y_j'(T)S'(E)$. The world planner always chooses more decarbonization than regions acting unilaterally. In this paper we do not compare cooperative and non-cooperative solutions, but rather assess quantitatively how much unilateral decarbonization is cost-effective under global temperature damages.

II. Global Temperature Damages

We start by estimating climate damages $Y_i'(T)$ for two economies i: the United States and the European Union. Our conceptual framework is static for expositional simplicity, but in practice temperature may have dynamic effects on economic activity. Thus, we compare costs and benefits in present value.

We obtain global mean temperature data from Berkeley Earth. We use output per capita data from the Penn World Tables.

We rely on natural climate variability in global mean temperature as in Bilal and Känzig (2024), driven by phenomena such as solar cycles or El Niño. To address well-known co-integration challenges, we first construct temperature shocks as innovations to the global mean temperature process:

$$\widehat{T_{t+h}^{\text{shock}}} = T_{t+h} - (\hat{\alpha} + \hat{\beta}_1 T_t + \ldots + \hat{\beta}_p T_{t-p+1}),$$

where $\hat{\beta}_j$ denotes the coefficient estimates of the regression of temperature on its lag j and $\hat{\alpha}$ is the estimated intercept. We select a horizon of $h = 1$ as in Nath, Ramey and Klenow (2022) and set the number of lags to $p = 2$ in our main specification.

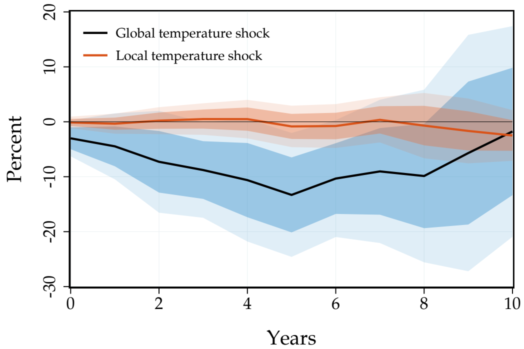
Equipped with our global temperature shocks, we use a local projection (Jordà, 2005) for horizons $h = 0, \ldots, 10$:

$$y_{i,t+h} - y_{i,t-1} = \theta_{i,h} T_t^{\text{shock}} + \mathbf{x}_{i,t}' \gamma_{i,h} + \varepsilon_{i,t+h},$$

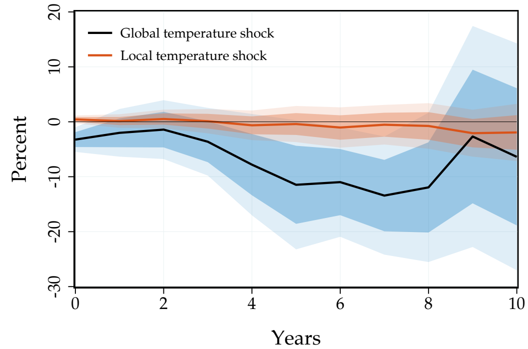
where $y_{i,t}$ is output per capita for region i in year t, T_t^{shock} is the global temperature shock and $\theta_{i,h}$ is the dynamic causal effect of interest for region i at horizon h. $\mathbf{x}_{i,t}$ is a vector of global and country-specific controls and $\varepsilon_{i,t}$ is an error term.

We estimate our local projections model separately for the United States and the European Union, exploiting time-series variation. We control for two lags of country-level GDP and temperature shocks, a set of recession dummies, two lags of world real GDP growth, and regional oil prices and treasury yields.

Figure 1 displays our results. A 1°C global temperature shock implies a peak



A. United States



B. European Union

Figure 1. The Effect of Global Temperature Shocks on Output Per Capita

Note: Impulse responses of United States and European Union real GDP per capita to global and local temperature shocks each normalized to 1°C. Sample period: 1960-2019. European Union based on 28 member countries, including the United Kingdom. Regional controls: WTI oil price and 10-year treasury yield for United States; Brent crude oil prices and German 10-year benchmark bond yield for the European Union. Solid lines: point estimates. Dark and light shaded areas: 68 and 90% confidence bands.

decline in output per capita in excess of 10% for both the United States and the European Union. Although the cumulative impacts are comparable, the effect is more delayed for the European Union. Our point estimates imply substantial losses for global temperature increases, but the confidence bands are also non-trivial. Our results should therefore be interpreted with some caution.

We also construct conventional climate damages estimated using similarly constructed local temperature variation $\widehat{T_{i,t}^{\text{shock}}}$ (Dell, Jones and Olken, 2012; Burke, Hsiang and Miguel, 2015; Nath, Ramey and Klenow, 2022). In line with these papers, we find much smaller and insignificant impacts in response to local temperature shocks. Bilal and Känzig (2024) show that this difference is driven by damaging extreme events: global temperature correlates strongly with heat waves, droughts, rainstorms and windstorms, whereas local temperature only weakly does, if at all.

III. The Domestic Cost of Carbon

The response of output per capita is informative of economic damages but does not exactly coincide with economic well-being. Thus, we microfound the function Y_i with the Neoclassical Growth Model and productivity damages from temperature. We estimate the damage function for each region by matching the empirical impulse responses in Figure 1 and obtain global temperature damage functions that peak between -4% and -5% and display persistent impacts. This estimated model delivers forward-looking welfare (see Bilal and Känzig (2024) for details).

This approach lets us construct counterfactuals for any path of temperature, not only the realized path of temperature underlying a global temperature shock and Figure 1. We combine our damage function estimates with the dynamic temperature response to a one-time carbon pulse of one ton from a state-of-the-art climate model (Dietz et al., 2021; Folini et al., 2024). Using a 2% baseline discount rate, we obtain 2024 Domestic Costs of Carbon of \$226 per ton for the United States, and \$216 per ton for the European Union.

To illustrate the magnitude of the underlying damage functions, we also consider a 2°C warming scenario from 2024 to 2100. Each region experiences a 27% permanent consumption equivalent welfare loss in 2024, and an output reduction of 51% by 2100 relative to baseline.

To contrast our results with local temperature damages, we construct Domestic Costs of Carbon with the same approach but target instead the impulse responses of output per capita to local tem-

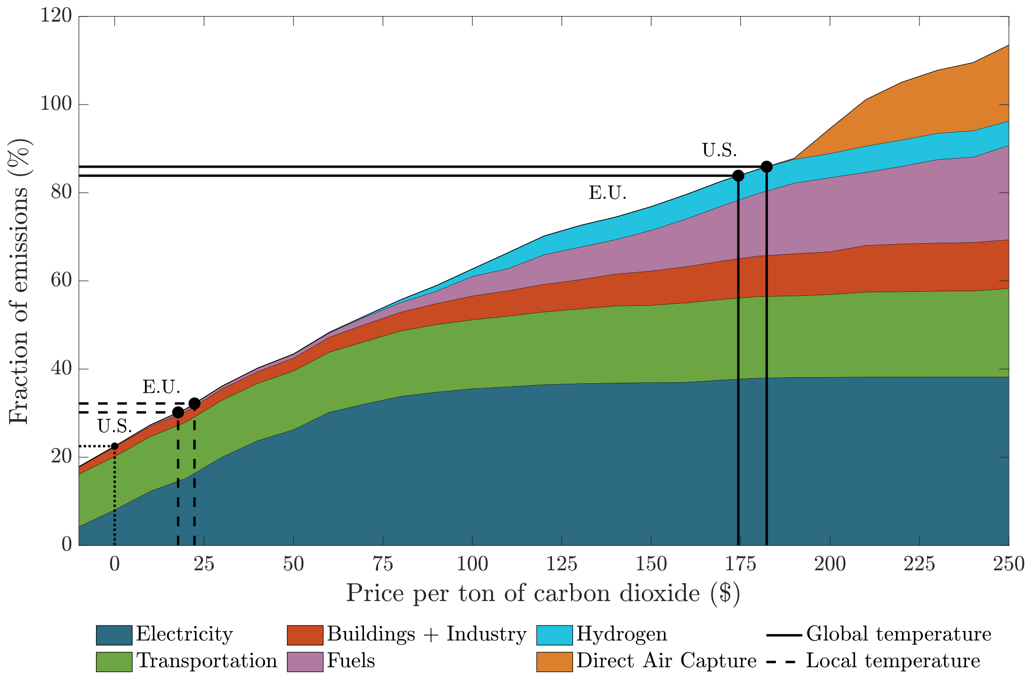


FIGURE 2. UNILATERAL DECARBONIZATION

Note: Marginal Abatement Cost Curve and Domestic Costs of Carbon for the United States and the European Union. Solid black lines: unilaterally optimal decarbonization under global temperature damages. Dashed black lines: unilaterally optimal decarbonization under local temperature damages. Dotted black line: unilateral decarbonization absent any damages. U.S.: United States. E.U.: European Union.

perature shocks in Figure 1. Consistently with the smaller estimates, we obtain Domestic Costs of Carbon that are seven times smaller: $22 per ton for the United States and $28 per ton for the European Union.

IV. Comparing Costs and Benefits

Equipped with our estimates of the Domestic Cost of Carbon, we compare them to decarbonization costs. To that end, we use the Marginal Abatement Cost Curve $C_i'(D)$ from the Environmental Defense Fund (2021). They provide a cost curve for the United States at current prices for decarbonization occurring by 2050. We assume that a constant fraction of each ton of carbon abated by 2050 is abated each year between 2024 and 2050.

To be consistent with the timing of carbon abatement, we construct revised Domestic Costs of Carbon that correspond to a gradual release of carbon between 2024 and 2050 instead of a full release in 2024. The resulting Domestic Costs of Carbon are thus adjusted downwards due to additional discounting: $182 per ton for the United States and $174 per ton for the European Union.

Obtaining cost curves constructed with the same methodology and assumptions for the United States and the European Union is challenging. Therefore, instead of using cost curves with different methodologies, we impose the same cost curve for the European Union when represented as costs by share of the economy that is decarbonized. This approach provides a useful first benchmark to assess the unilateral decarbonization potential of different regions. We leave the inclusion of consistently estimated abatement cost curves across regions for future work.

We obtain broad unilateral decarbonization under global temperature damages for the United States and the European Union. Figure 2 shows that equating marginal benefits and costs, the United States decarbonize 86% of their economy and the European Union decarbonizes 84% of its economy. Both economies nearly exhaust greening gains in renewable electricity generation, transportation and electric vehicles, and engage in some building insulation, hydrogen use and net zero fuels.

By contrast, unilateral decarbonization is much more modest under local temperature damages. For decarbonization by 2050, the adjusted Domestic Costs of Carbon become $18 per ton for the United States and $22 per ton for the European Union. These values imply 7 and 9 percentage points additional decarbonization relative to no climate damages at all (23% decarbonization), substantially less than the 63 and 61 additional percentage points under global temperature damages.

This comparison depends on the Domestic Costs of Carbon, but also on the shape of the Marginal Abatement Cost Curve. If it was flat—implying that broad decarbonization becomes rapidly prohibitively expensive—the gap between unilateral decarbonization under global and local temperature damages would be smaller. Given the nearly linear Marginal Abatement Cost Curve in Figure 2, unilateral decarbonization under global temperature damages is substantially larger.

V. Conclusion

This paper argues that broad unilateral decarbonization is cost-effective for large economies such as the United States and the European Union when considering climate damages estimated under global temperature. Of course, the Domestic Cost of Carbon scales with the size of the economy. Thus, countries with smaller economies may not find it cost-effective to unilaterally decarbonize. Given a worldwide Social Cost of Carbon of $1,367 per ton under global temperature damages (Bilal and Känzig, 2024), international coordination still has an important role to play.

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