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Selfish Bureaucrats and Policy Heterogeneity in Nordhaus' dice

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JEL classification: D73, Q54

Key words: climate policy, price heterogeneity, selfish bureaucrats

Selfish Bureaucrats and Policy Heterogeneity in Nordhaus' DICE

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Abstract

Nordhaus' seminal DICE model assesses first-best climate policy, a useful but unrealistic yardstick. I propose a measure of policy inefficacy if carbon prices are heterogeneous and use observed prices to recalibrate the DICE model. I introduce a model of climate policy with selfish bureaucrats, and calibrate it to carbon dioxide emissions in the European Union and the policy models used by the IPCC. This model also implies a measure of policy inefficacy that I use to recalibrate DICE. The global mean temperature is 1℃ perhaps 2℃ higher in the recalibrated than in the original DICE model.
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1. Introduction

Professor Dr. William D. Nordhaus was the first economist to discuss climate change, wondering whether we *can* control carbon dioxide (Nordhaus, 1975). Nordhaus (1977) concluded that we can, presenting a way to do so at the lowest possible cost. d'Arge (1979) showed that the impacts of climate change—nuclear winter in his case—can be monetised. Building on that, Nordhaus (1982) first analyzed statically optimal climate policy, an analysis he refined later with newer numbers (Nordhaus, 1991a,b), with dynamic optimality (Nordhaus, 1992, 1993), and again with multiple countries (Nordhaus and Yang, 1996). Nordhaus thus

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[1] I am grateful to Robert Mendelsohn for organizing this special issue in honour of William Nordhaus.

showed the economics profession how to analyze climate policy. Although climate change is the mother of all externalities—global, ubiquitous, long-term, uncertain, inequitable—it is not beyond economic analysis, as demonstrated by Nordhaus' work.

Throughout his career, Nordhaus has been firmly committed to analysing first-best climate policy, which is indeed the yardstick against which to measure any and all climate policy. However, actions by governments, taken in the name of climate change, are sometimes easier to understand as exercises in rent-seeking than as exercises in greenhouse gas emission reduction. Unfortunately, the climate economics literature has largely followed in Nordhaus' footsteps, assuming smart, well-informed, and selfless social planners. In this paper, I set out two alternatives—selfish bureaucrats and heterogeneous carbon prices—and explore the implications using Nordhaus' seminal DICE model.

Pigou (1920) argued for the use of taxes and subsidies to internalize externalities and restore efficiency (see Bator, 1958, for a formal treatment). Dales (1968) added tradable permits. The desirable properties of these policy instruments are well-established (Baumol and Oates, 1971, Baumol, 1972, Montgomery, 1972). It is also well-known that equimarginal principle does not hold if there is market power (Buchanan, 1969, Barnett, 1980), distortionary taxation (Krutilla, 1991, Goulder et al., 1999, Barrage, 2020), a second market imperfection (Fischer, 2008) or a concern for equity (Stiglitz, 2019)—carbon taxes should rarely be uniform. Indeed, the double dividend literature designs policy instruments to take advantage of prior market distortions so as to reduce the costs of greenhouse gas emission reduction (Goulder, 1995, Patuelli et al., 2005, van Heerden et al., 2006).

I do not consider such arguments in this paper. Although a uniform carbon price is the cheapest way to reduce greenhouse gas emissions in an economy with a single imperfection, it requires international cooperation on providing a public good, which is hard (Carraro and Siniscalco, 1992, Barrett, 1994, Nordhaus and Yang, 1996). International tax harmonization is beyond current politics; even Member States of the European Union jealously guard the sovereignty of fiscal policy. Linking national systems of tradable permits would be an alternative route to a globally uniform carbon price (Rehdanz and Tol, 2005, Haites, 2016) but has floundered (Ranson and Stavins, 2016). So we observe different carbon prices in different parts of the world. Also within countries, policy implementation is far from perfect. This implies that climate policy is needlessly expensive (Böhringer et al., 2009) or that, for any given expenditure on climate policy, emission reduction is needlessly ineffective. In Section 2, I present a measure of policy inefficacy, calibrate it, and adjust DICE to take this into account.

This first calibration is phenomenological. In Section 3, I consider a structural model. I introduce administrative costs for emissions monitoring and compliance with regulations, and bureaucrats who seek to increase their desk by introducing unnecessary administration. I calibrate this model, and extend DICE to include a climatocracy.

Section 4 shows the implications for emissions and climate. Section 5 concludes.

2. Heterogeneous taxes

2.1. Uniform taxation

Let us consider a tax τ to incentivize emission reduction, measured by relative emission reduction effort R. Polluters, indexed by $i = 1, 2, ...I$, have costs C_i:

$$C_i = 0.5\alpha_i R_i^2 Y_i + \tau(1 - R_i)E_i \tag{1}$$

where E_i are uncontrolled emissions, Y_i is output, and α_i is a parameter. The first-order condition is

$$\frac{\partial C_i}{\partial R_i} = -\tau E_i + \alpha_i R_i Y_i = 0 \Rightarrow R_i = \tau \frac{E_i}{\alpha_i Y_i} \tag{2}$$

Emissions are reduced further if the tax is higher, or if emission reduction cheaper. Suppose the benefits of emission reduction are given by

$$B = \beta \sum_i R_i E_i \tag{3}$$

Maximizing net benefits $B - \sum_i 0.5\alpha_i R_i^2 Y_i$ (taxes are transfers) leads to optimal emission reduction $R_i = \beta \frac{E_i}{\alpha_i Y_i}$ and Pigou tax $\tau = \beta$.

2.2. Heterogeneous taxes

For a uniform tax τ, the total costs of emission reduction (net of taxes) equal

$$C_U(\tau) = \sum_i C_i = 0.5\tau^2 \sum_i \frac{E_i^2}{\alpha_i Y_i} \tag{4}$$

and for heterogeneous taxes τ_i

$$C_H(\tau_i) = 0.5 \sum_i \tau_i^2 \frac{E_i^2}{\alpha_i Y_i} \tag{5}$$

Total emission reduction for a uniform tax is

$$R_U(\tau) = \sum_i R_i E_i = \tau \sum_i \frac{E_i^2}{\alpha_i Y_i} \tag{6}$$

and for heterogeneous taxes

$$R_H(\tau_i) = \sum_i \tau_i \frac{E_i^2}{\alpha_i Y_i} \tag{7}$$

The two cases can be compared, either by considering the difference in emission reduction for the same cost or by the difference in costs for the same emission reduction. To start with the latter, the same total emission reduction $R_U = R_H$ implies an equivalent uniform tax

$$\tau_R = \frac{\sum_i \tau_i \frac{E_i^2}{\alpha_i Y_i}}{\sum_i \frac{E_i^2}{\alpha_i Y_i}} \tag{8}$$

and relative cost

$$\frac{C_H(\tau_i)}{C_U(\tau_R)} = \frac{\sum_i \frac{E_i^2}{\alpha_i Y_i} \sum_i \tau_i^2 \frac{E_i^2}{\alpha_i Y_i}}{\left(\sum_i \tau_i \frac{E_i^2}{\alpha_i Y_i}\right)^2} > 1 \tag{9}$$

The inequality follows as a uniform tax is the least-cost solution for a given target. Heterogeneous taxes achieve the same emission reduction at a higher cost. Equation (9) is a measure of the relative *inefficiency* of heterogeneous taxation.

The same total emission reduction costs $C_U = C_H$ also implies an equivalent uniform carbon tax

$$\tau_C = \sqrt{\frac{\sum_i \tau_i^2 \frac{E_i^2}{\alpha_i Y_i}}{\sum_i \frac{E_i^2}{\alpha_i Y_i}}} \tag{10}$$

and relative emission reduction

$$\frac{R_H(\tau_i)}{R_U(\tau_C)} = \frac{\sum_i \tau_i \frac{E_i^2}{\alpha_i Y_i}}{\sqrt{\sum_i \frac{E_i^2}{\alpha_i Y_i} \sum_i \tau_i^2 \frac{E_i^2}{\alpha_i Y_i}}} \tag{11}$$

We see that

$$\frac{R_H(\tau_i)}{R_U(\tau_C)} = \sqrt{\frac{C_U(\tau_R)}{C_H(\tau_i)}} < 1 \tag{12}$$

so that less emission reduction is achieved for the same total cost. Equation (12) is a measure of the relative *inefficacy* of heterogeneous taxation.

If we assume $\frac{E_i^2}{\alpha_i Y_i} = 1$ then $\tau_R = \sum_i \tau_i$ and

$$\frac{C_H(\tau_i)}{C_U(\tau_R)} = \frac{I \sum_i \tau_i^2}{\left(\sum_i \tau_i\right)^2} \tag{13}$$

This ratio is greater than one, because numerator minus denominator equals the variance of τ_i times I^2. We also have $\tau_C = \sqrt{\sum_i \tau_i^2}$ and

$$\frac{R_H(\tau_i)}{R_U(\tau_C)} = \frac{\sum_i \tau_i}{\sqrt{I \sum_i \tau_i^2}} \tag{14}$$

The interpretation is intuitive: The greater the spread of carbon prices, the lower the relative efficacy of climate policy. This interpretation carries over to Equation (12), with moments replaced by weighted moments.

2.3. *Calibration*

Figure 1 shows the histogram of carbon taxes applied in various countries in the world[2] and recent prices of emission permits in cap-and-trade system.[3] Carbon taxes vary widely, from \$0.30/tC in Poland to \$466/tC in Sweden. Carbon prices vary less widely but still show a considerable range, from \$4/tC in Chongqing to \$107/tC in the European Union. These carbon taxes and prices imply that $R_H/R_U = 0.63$ in Equation (14)—that is, heterogeneity of carbon prices reduces the relative efficacy of climate policy by more than a third.

Figure 1 also shows the probability density functions of the published estimates of the social cost of carbon for frequently used pure rates of time preference (data from Tol, 2018). As the observed carbon prices are the same order of magnitude as the estimates of the *global* social cost of carbon, the range of carbon prices is more readily interpreted as heterogeneity rather than as non-cooperative behaviour (see Ricke et al., 2018, Tol, 2019, for estimates of the *national* social costs of carbon).

Comparing the histogram of the observed carbon prices to the probability densities of the estimated social cost of carbon, current climate policy appears to be based on relatively high utility discount rates. The *Mean Integrated Squared Error* is 3.9% for a pure rate of time preference of 3.0%, 4.0% for 2.0%, 4.2% for 1.5%, and 4.3% for 1.0% or less. This vindicates Nordhaus' argument that the discount rate used for climate policy analysis should be close to the discount rate used to evaluate other investments (Nordhaus, 1997, 2007).

3. Emission reduction with bureaucrats

3.1. *Zero administrative cost*

Equation (1) assumes that administrative costs are zero, and Equation (2) shows the corresponding optimal response of a polluter to a pollution tax.

3.2. *Variable administrative cost*

Now suppose that there is an administrative cost AR_iE_i for reporting, proportional to emissions *reduced*. Firms already monitor and report energy use, so monitoring and reporting emissions is costless. The assumption here is that there is additional reporting on emission reduction. The cost function then becomes

$$C_i = 0.5\alpha_i R_i^2 Y_i + AR_iE_i + \tau(1 - R_i)E_i \tag{15}$$

and emission reduction

$$R_i = \max\left\{0, \frac{(\tau - A)E_i}{\alpha_i Y_i}\right\} \tag{16}$$

That is, administrative costs reduce abatement, and may even prevent abatement altogether if the marginal administrative costs exceed the tax rate.

[2] Source World Bank Carbon Pricing Dashboard

[3] Source International Carbon Action Partnership

3.3. Selfish administrators

Now introduce a regulator who aims to maximise net social benefits as well as the size of the administration. One way to formulate this is

$$W = \beta \sum_i R_i E_i - \sum_i 0.5 \alpha_i R_i^2 Y_i - A \sum_i R_i E_i + \phi \ln \left(A \sum_i R_i E_i \right) \tag{17}$$

The first-order conditions are

$$\frac{\partial W}{\partial A} = \frac{\phi}{A} - \sum_i R_i E_i = 0 \Rightarrow A = \frac{\phi}{\sum_i R_i E_i} \tag{18}$$

and, assuming $\tau > A$,

$$\frac{\partial W}{\partial \tau} = \left(\beta - A + \frac{\phi}{\sum_i R_i E_i} \right) \sum_i \frac{E_i^2}{\alpha_i Y_i} - \sum_i \alpha_i Y_i \frac{(\tau - A) E_i^2}{\alpha_i^2 Y_i^2} = 0 \Rightarrow \tau = \beta - A \tag{19}$$

This simplifies to the Pigou tax for $\phi = 0$.

3.4. Calibration

In the model, the carbon tax is split into two: One part goes to reducing emissions, and another part to financing a climate bureaucracy. This implies that a carbon tax is less effective in reducing emissions than it could have been. As there are no observations of the size of the climatocracy, the model can only be calibrated by contrasting actual greenhouse gas emission reduction to expected greenhouse gas emission reduction.

This is problematic in two ways. First, we do not observe actual emission *reduction*. We observe actual emissions, or rather we impute greenhouse gas emissions from energy use and agricultural production. Emission reduction is the difference between the actual and a counterfactual, what emissions would have been had there been no climate policy. I solve this as follows. The World Bank has good data, going back to 1960, for carbon dioxide emissions and economic activity for the countries that currently make up the European Union. Between 1960 and 2004, the emission intensity of the European economies fell, on average, by 1.8% per year. Extrapolating that trend (and assuming economic growth as observed), emissions in 2017 would have been 3.8 million metric tonnes of carbon dioxide. Observed emissions were 3.3 $MtCO_2$.

Figure 3 shows the observed emissions and the projected emissions for the 28 countries of the European Union, including the 95% confidence interval of the projection, as well as the observed and projected emission intensity. This simple analysis suggests that climate policy in the EU has statistically significantly reduced emissions.

Since 2005, EU emissions have been regulated by a system of cap-and-trade. Using the observed prices and a model for climate policy evaluation tells us how much emissions should have fallen. However, and this is the second problem, models disagree strongly about the impact of climate policy on emissions. This is typically reported as a wide range of carbon prices needed to meet a particular target (Clarke et al., 2014), but that can of course be inverted to a wide range of emission reductions resulting from a particular carbon price. The IIASA database has scenarios with and without climate policy for 19 different models. Regressing emission reduction in 2020 on carbon price, controlling for model fixed effects and clustering standard errors at the model level, I find that emissions fall by 0.3% per \$1/tCO_2.

Figure 2 shows the results per model. The figure displays the efficacy of near-term climate policy, here measured as the fraction emission reduction from baseline in 2020 divided by the carbon tax in the same year. The models strongly disagree. The most pessimistic model finds that a carbon tax of \$1/tCO_2 would reduce emissions by 0.1%, the most optimistic model by more than 1.5%. The weighted average of 0.3% is closer to the more pessimistic end of the spectrum. I therefore also show the median (of the reported scenarios), which is about 0.6% per \$1/tCO_2.

If the average of these models is correct, given the observed carbon prices, EU emissions should have fallen to 2.4 MtCO_2. See Figure 3. The "observed" emission reduction is only 30% of the "expected" emission reduction. That is, more than two-thirds of the carbon tax was wasted on, in this interpretation, administrative costs.

The EU ETS applies to only half of greenhouse gas emissions, so inefficacy is more than one-third rather than more than two-thirds. Then again, EU Member States are supposed to regulate the other half of greenhouse gas emissions by means other than the EU ETS. I therefore use an inefficacy of one-third as the base case, and two-thirds in a sensitivity analysis.

If the median of these model runs is correct, given the observed carbon prices, EU emissions should have fallen to 1.6 MtCO_2. See Figure 3. The "observed" emission reduction is only 17% of the "expected" emission reduction. That is, more than four-fifths of the carbon tax was diverted to administrative costs. This is such an extreme outcome that it is ignored below.

Note that the median is far from the optimistic extreme. See Figure 2. The models in the IIASA database are the ones used in the assessment reports of the IPCC. These models appear to be biased towards cheap climate policy.

4. Results

4.1. Amending DICE

I use the Excel version of DICE2016. Amending DICE is straightforward. Following the discussion above, only a fraction (two-thirds) of the marginal damage costs is effective as a carbon tax. This is my base case. As a first sensitivity analysis, I reduce that fraction to one-third.

This simple amendment ignores two complications. The first is that if the carbon tax is less than the Pigou tax, climate change will be more pronounced and the Pigou tax consequently higher. Then again, emission reduction costs are lower, economic growth faster, and the Pigou tax consequently higher. In the implementation used here, the former effect dominates the later prior to 2050. I show results with and without this effect.

The second complication is that the costs of emission reduction are different, and hence economic growth. Specifically, the costs of emission reduction are quadratic in abatement, in both the model above and in DICE, but administrative costs are linear. This means that, for the same carbon tax, total emission reduction costs are lower; average emission reduction costs, per unit of emissions avoided, are higher. I show results with and without this effect.

4.2. Findings

Figure 4 shows the *effective* carbon price for six scenarios. The carbon price is highest in the original DICE scenario, which represents globally cooperative climate policy, and lowest in the base case, which represent non-cooperative climate policy. These two scenarios are due to Nordhaus.

If carbon prices are heterogeneous or used to finance a climatocracy, the signal to reduce emissions is muted. This is shown in the curves labelled "low inefficacy" and "high inefficacy". The size of the effect is as assumed, one-third or two-thirds.

Figure 4 also reveals that the effects of the feedbacks of climate policy on climate change ("Pigou tax") and via abatement costs on economic growth ("administrative costs") are minimal.

The pattern shown in Figure 4 is reflected in Figure **??**. In the base scenario, in a hundred years' time, emissions are some 85% of what they would have been without any climate policy. In the original, cooperative scenario, the economy is fully decarbonised a century from now—virtue of the assumed backstop. If one-third of climate policy is wasted on price heterogeneity or administrative procedures, full decarbonisation is achieved twenty years later. If two-thirds is wasted, emission reduction is only 55% in 2135.

Figure 6 shows the same order. In the base case, the world warms, and rising, by 7℃ by the start of the 23rd century. This is reduced to 4℃, and falling, in Nordhaus' first-best scenario. Ineffective climate policy adds about 0.75℃ warming, and highly ineffective climate policy 1.5℃.

The size of the climatocracy is limited. In the base case, expenditures of climate administration cost peak at 0.22% of total economic output in 2090. After that, the the economy grows faster than the carbon price times the emission control rate times emissions. If climate policy is highly ineffective, expenditure on the climatocracy peaks in 2120 at 0.24%. This is a substantial sum of money to waste, but can conceivably escape public and political scrutiny.

5. Conclusion

Professor William D. Nordhaus taught the economics profession how to analyze first-best climate policy. Unfortunately, his policy advice—a carbon tax, a uniform carbon tax, and nothing but a carbon tax—has fallen on deaf ears. I therefore extend Nordhaus' seminal DICE model, first in an *ad hoc* way to account for the inefficacy that comes with carbon price heterogeneity, and second in a more structural way by introducing desk-maximising bureaucrats, again expressing this in a measure of inefficacy. I calibrate both extensions, the former to carbon prices observed around the world, the latter to emissions in the European Union and predictions by models used by the IPCC. The extended DICE model shows higher emissions and more warming than the original one, by 1℃ maybe 2℃.

Several things can and should be improved about the research presented above. Although static approximations to DICE often give practically the same results as the dynamically optimized model, it would be good to check that for the current extensions.

More importantly, numerical models are only as good as their calibration. Besides the undue emphasis on first-best analyses, Nordhaus has another unfortunate legacy: an emphasis of ex ante analysis. Starting his research well before there was climate policy, Nordhaus had little choice. We now have thirty years of experience attempting to reduce emissions, but the economics literature has made too little use of that data (this is now beginning to change, see Aichele and Felbermayr, 2012, Bel and Joseph, 2015, Almer and Winkler, 2017, Fowlie et al., 2018, Andersson, 2019, Maamoun, 2019, Xiang and Lawley, 2019, Metcalf and Stock, 2020). The calibration used above is simple, perhaps too simple. It does point to potentially serious problems with the models used for climate policy analysis.

Finally, alternative models of selfish bureaucrats should be tried. The specification used here was chosen for analytical tractability. And partial civil servants are not the only policy imperfection. The impact of regulatory capture and lobbying on climate policy should be studied too (Stigler, 1971, Krueger, 1974).

None of this diminishes Nordhaus' contributions to the economics of climate change. He, I am sure, would like nothing better than the field to move beyond his work. We should, building on the foundations he so expertly laid.

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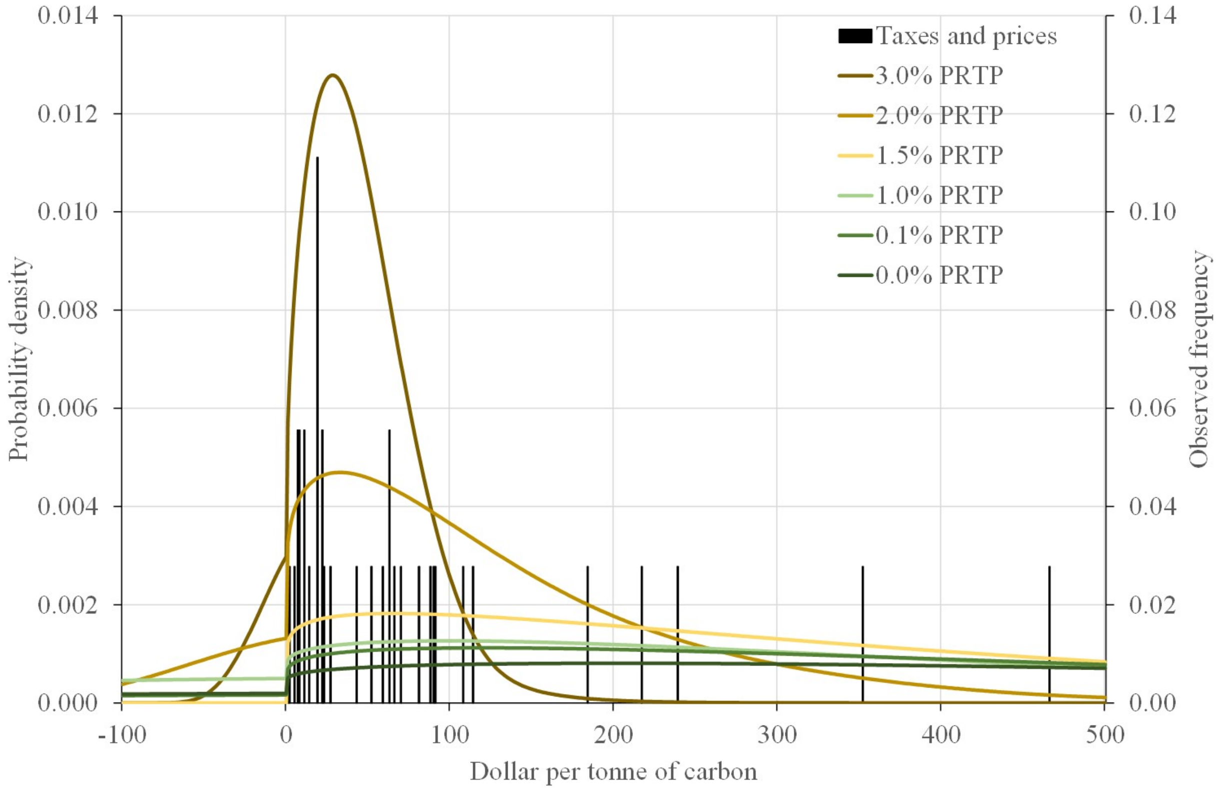

Figure 1: Histogram of observed carbon taxes and prices (bars) and probability density of estimated social cost of carbon for various pure rates of time preferences (lines).

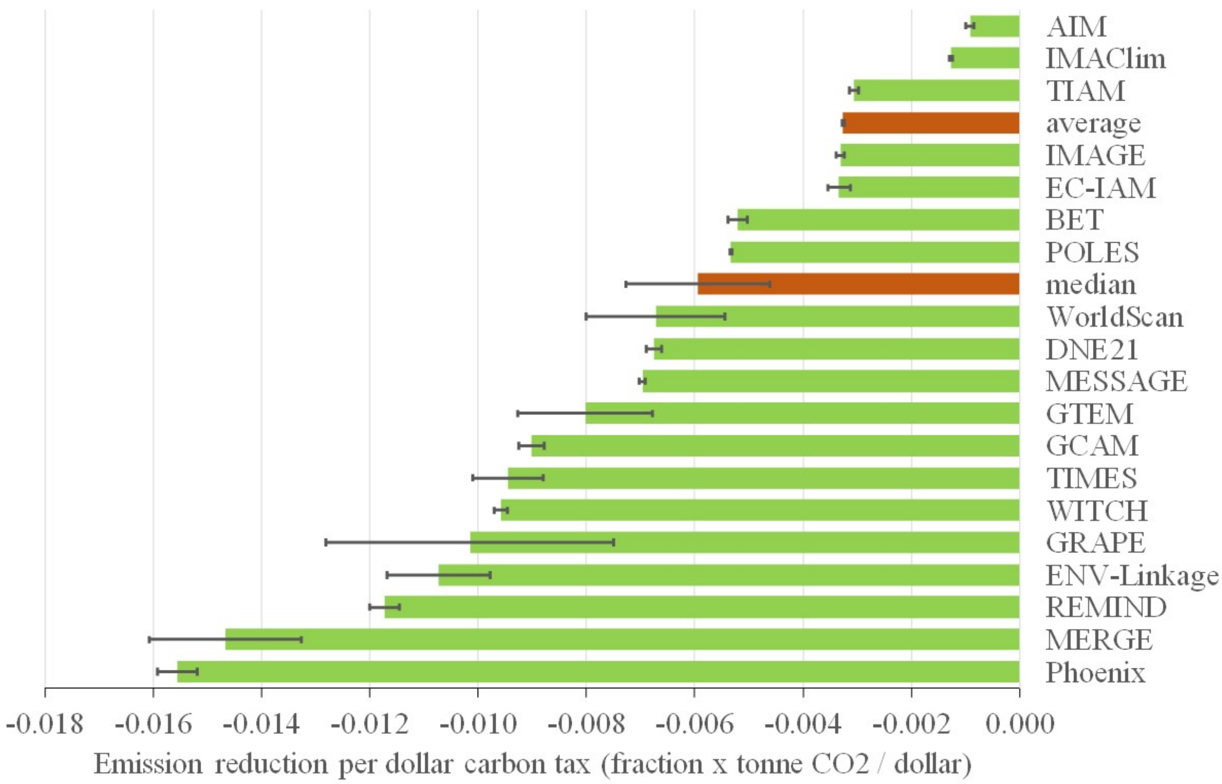

Figure 2: Efficacy of near-term climate policy by model.

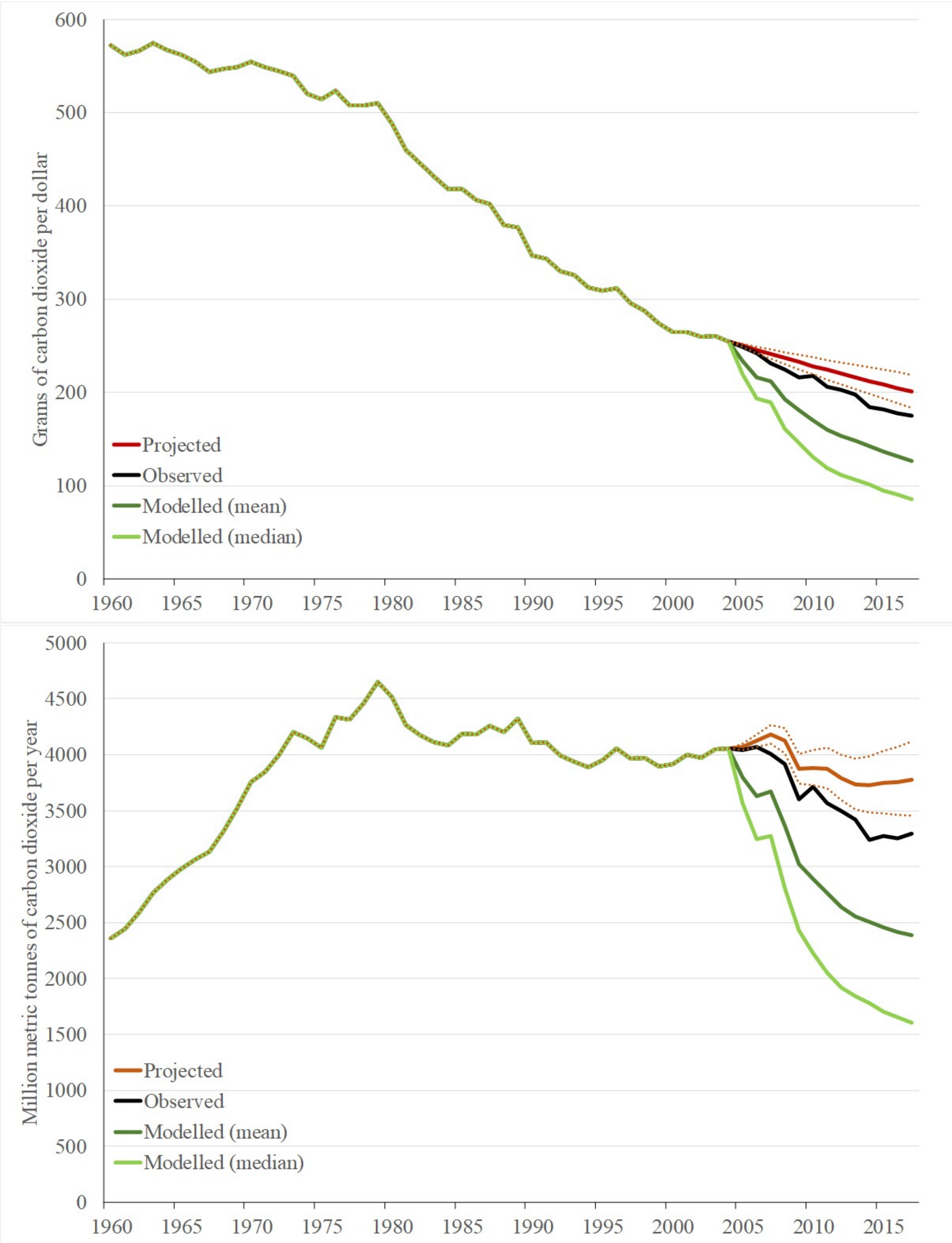

Figure 3: Carbon dioxide emissions (bottom panel) and emission intensity (top panel) in the countries of the European Union as observed, projected, and predicted by models.

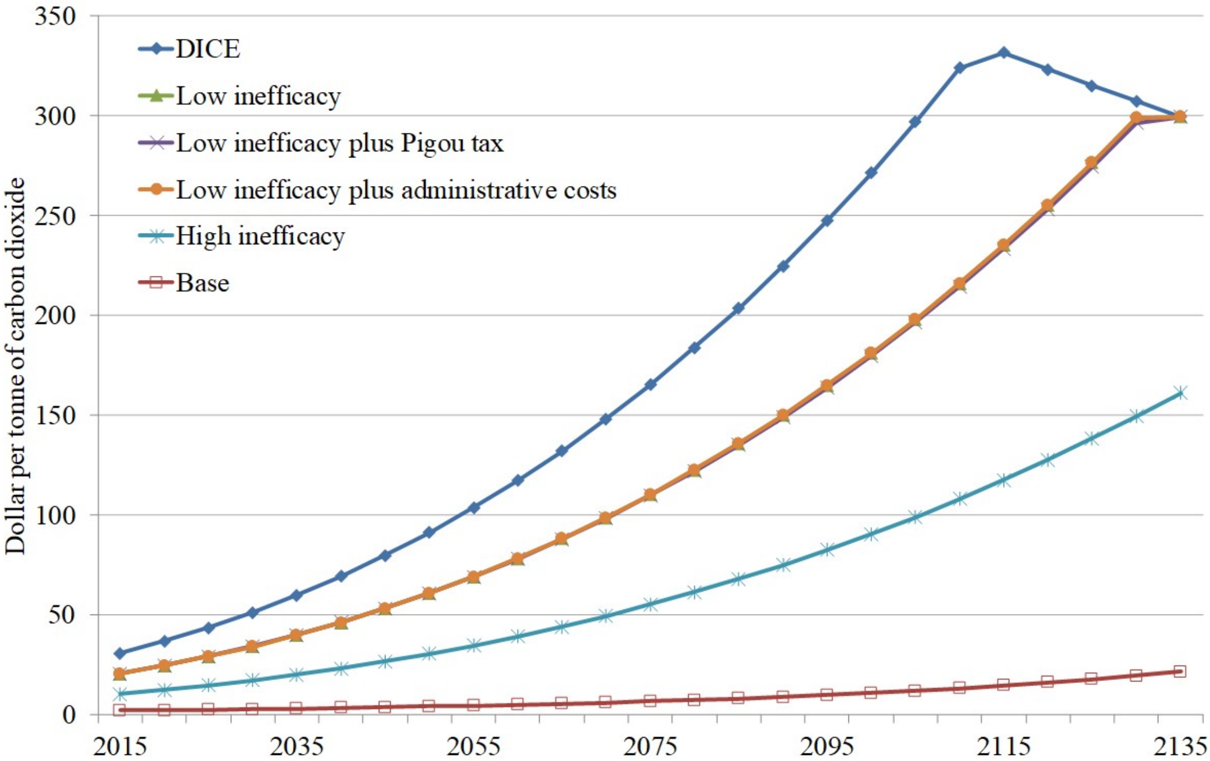

Figure 4: The effective carbon tax for six alternative scenarios.

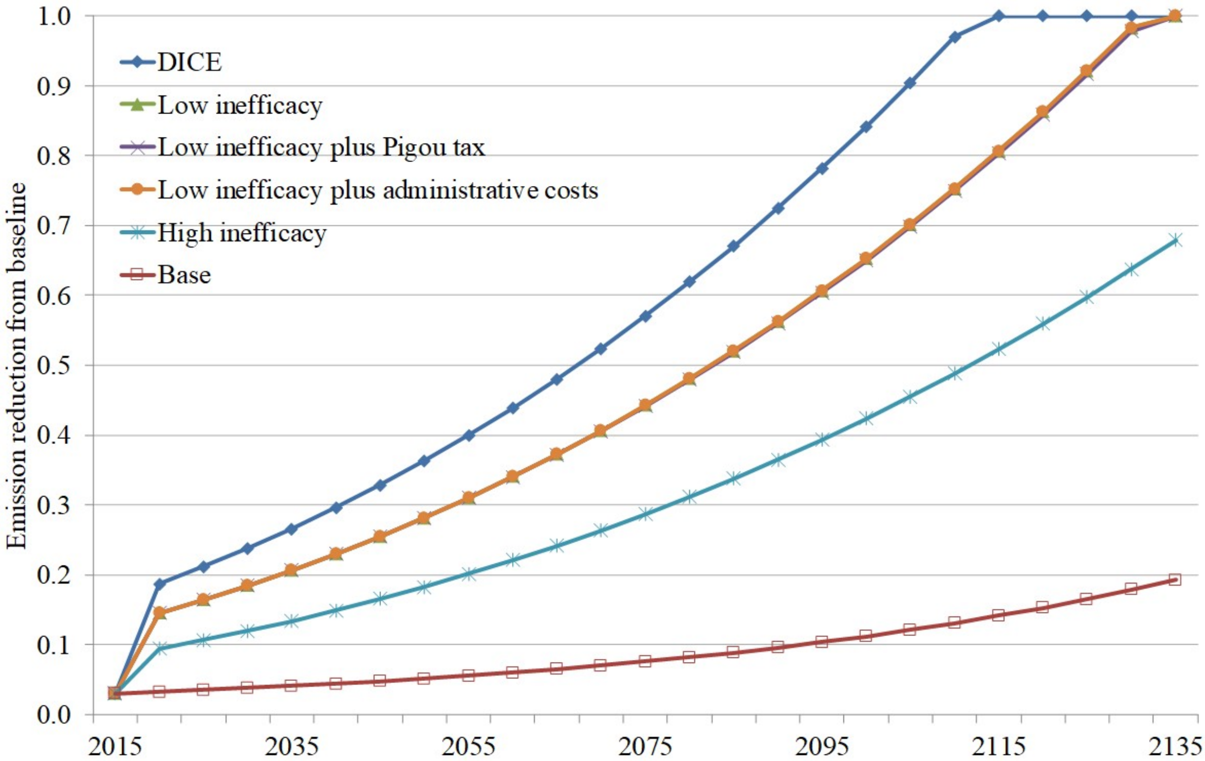

Figure 5: Emission reduction from baseline in six alternative scenarios.

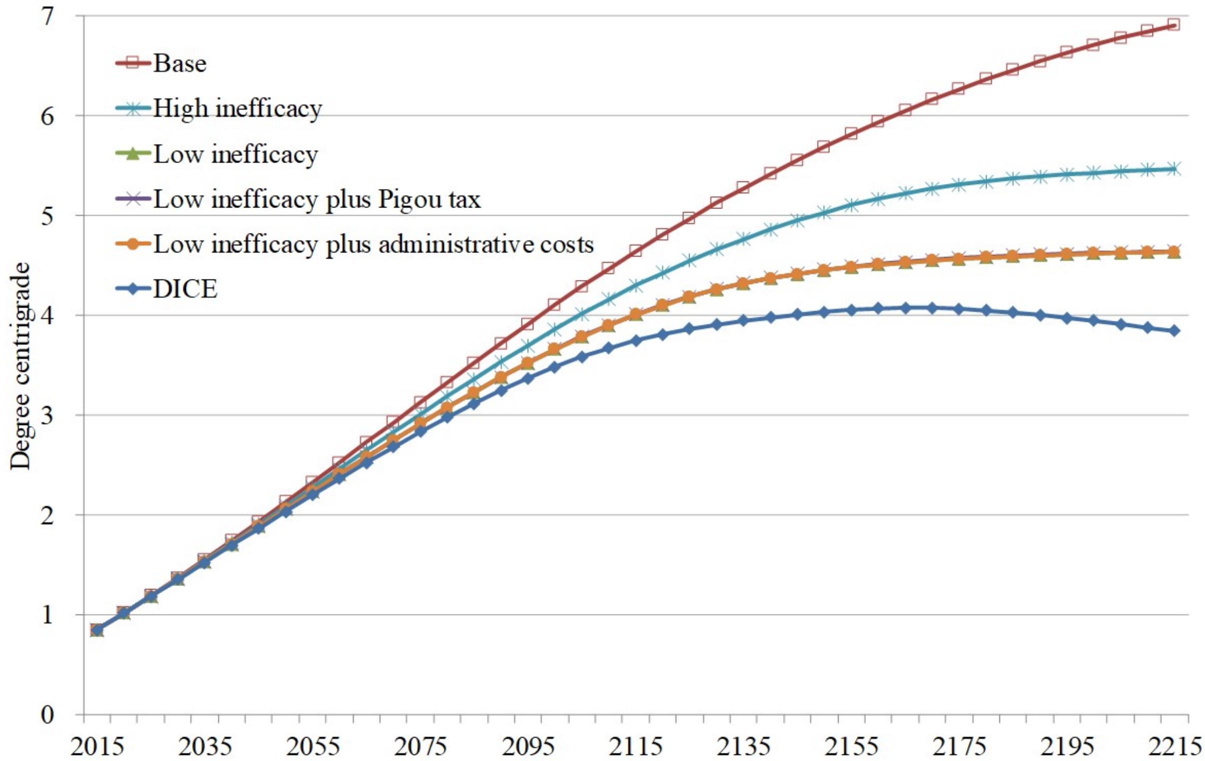

Figure 6: Global annual mean surface air temperature for six alternative scenarios.