Climate policy and the macro economy

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Abstract

This paper outlines three challenges related to effective climate change policy. Economists understand the theoretical solution - a Pigovian tax - but the reality is more complex. First, estimating the social cost of carbon is challenging because accurately identifying the links and parameters of integrated assessment models can be difficult. Second, multilateral coordination issues hinder the effectiveness of global climate policy. Climate change is a non-excludable global public good, which results in free-riding incentives and policy leakage. Third, intergenerational and distributional concerns complicate climate policy. Present costs and delayed benefits may lead to intergenerational redistribution, affecting current generations and political support.

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1. Introduction

Nobel Laureate William Nordhaus (2019) calls climate change 'the ultimate challenge' for economists today. One can define climate change as changes to some moments of the weather distribution over time (Auffhammer 2018; Hsiang and Kopp 2018). This could be changes to only the mean temperature or only the variance, or changes to higher moments. It could also be changes resulting from a combination of these. While experts generally acknowledge the harmful nature of climate change (despite some regions potentially experiencing net benefits from higher temperatures), there is disagreement among economists and other scientists regarding the extent of damages.

So why is the climate crisis and the mitigation of climate change so difficult? In theory, economists are aware of the solution: the implementation of a globally standardized carbon tax equivalent to the social cost of carbon, which would align social and private costs. However, there are several challenges that impede this otherwise optimal solution.

This paper aims to address three significant challenges or dilemmas associated with effective climate policy. It presents both the general economic literature on the frontier of the field and my own research findings.

First, even assuming that the textbook solution of carbon taxation is problem-free on other dimensions (e.g. practical/administrative and political feasibility), it is difficult to know the size of the tax required to 'align private and social costs'. The first question is thus: What is the size of the social cost of carbon? Economists and economic models have provided substantially different answers to this question - numbers ranging from 0 dollars per tonne of CO_2 to several hundred dollars (see for instance Nordhaus (2019), Auffhammer (2018), and Pindyck (2013)). The estimates come from the DICE model as developed by Nordhaus (1991) or other integrated assessment models. However, these models encounter a critical issue: they provide a wide range of estimates depending on their parameterization and, to a lesser extent, the assumptions made (Pindyck 2013). For instance, the social discount factor which there is generally not consensus about (cf. the debate between Stern (2007) and Nordhaus) can lead to a several-hundred-percent variation in the social cost of carbon. Likewise, damage function estimates are highly uncertain because of identification issues of the underlying econometric estimations, and they also have a large effect on the social cost of carbon.

The problems associated with standard macroeconomic and econometric modeling approaches have led some researchers to propose the possibility of simply asking individuals, whether they are ordinary citizens or experts, about the social cost of carbon, optimal discounting, and climate damages. Pindyck (2013), for example, argues strongly in favor of expert elicitation when it comes to determining the damage function of climate change.

Questionnaires administered to climate economists reveal uncertainty in this aspect, with one survey yielding responses ranging from 0 to 500 dollars when asked about the appropriate carbon price for the year 2020 (Drupp et al. 2022). However, the large majority of the economists assessed the appropriate carbon price to be larger than the actual market price. Likewise, the actual carbon price observed in various quota systems has historically been generally lower than what model estimates would suggest (see e.g. Timilsina (2018)). Lack of knowledge is thus not the only explanation for the relatively mild regulation. Barriers to effective climate change policies also include political considerations, both domestically and globally.

This brings us to the second issue in climate policy: substantial coordination problems in multilateral policy. Climate change is a global public good that is non-excludable, meaning it is impossible to prevent free-riding countries from benefiting from climate improvements. Moreover, with increasing globalisation, there is a significant risk of leakage resulting from unilateral policy. Leakage involves the loss of production for the country implementing the policy while also leading to the outsourcing of carbon emissions, which can make climate policy both environmentally and economically inefficient overall. Fortunately, there are several approaches to addressing this issue. In fact, a considerable body of literature focuses on how to effectively conduct unilateral policies while minimising leakage (for instance, Hoel (1996), Arroyo-Currás et al. (2015), and Baylis et al. (2013)).

Another branch of literature that addresses coordination problems in climate policies is the field of game theory. Notably, Nordhaus (2015) demonstrates that there are no cooperative equilibria in climate policy, meaning that in the absence of stabilising measures (e.g. punishments for deviating), no single country will have the incentive to implement effective climate policy. Rather, they will want to free-ride and hope the rest of the world takes care of the problem. However, this approach, along with related literature, assumes a binary framework where a country can either participate or free-ride on carbon taxes, with no intermediate options. Alternatively, it is possible to consider a continuous version of the problem, examining how a country's climate policy ambition depends on the behavior of other countries. In this context, the determination of optimal policies, such as the size of the carbon tax, becomes continuous, leading to different implications. Jørgensen and Nielsen (2022) show that the optimal noncooperative climate tax is positive but smaller than the optimal cooperative tax.

Thirdly, intergenerational and distributional issues further complicate the implementation of optimal climate policy. If effective climate policy entails long-term benefits and short-term costs, its implementation can result in intergenerational redistribution, with present individuals potentially experiencing a decline in welfare in the absence of corrective measures. The upfront costs can manifest as direct payments, such as investments in green technology and capital, as well as secondary effects stemming from the policy's implementation. These effects may include negative welfare impacts resulting from tighter government budgets or increased interest rates. The literature on the economic implications of climate policy is expanding, as is the research on potential instruments for mitigating intergenerational inequality.

The intergenerational problems may help explain the current political resistance to implementing climate policy, as elected politicians are accountable to present generations. Additionally, there is the issue of intragenerational distributional concerns, whereby the impacts of climate policy are not evenly distributed among individuals.
While this topic is highly relevant, it falls beyond the scope of this paper.

It is important to note that there are other issues that this article does not address. One such issue is the political feasibility of implementing taxes as a solution. Politicians often favour subsidies, public investments, and other expenditure-based solutions, possibly because they align better with voters' preferences.

The rest of the paper is structured as follows. Section 2 presents the DICE model and discusses the concept of the social cost of carbon. In Section 3, I present the issues related to unilateral climate policy and the issue of free-riding. Here, I include a discussion about how optimal policy changes when we go from the first best to the second best. In Section 4, I present the issue of inter-generational free-riding and the generational dilemmas of climate policy. Finally, Section 5 concludes.

2. What is the magnitude of the social cost of carbon?

The social cost of carbon is the theoretical concept which captures the value of the damages caused by one tonne of carbon in the atmosphere. There is an extensive debate in the economic literature about this value - especially fuelled by the debate between the Nordhaus and Stern proponents who estimate rather different numbers. In the end, much of the discrepancy between the estimates provided by Nordhaus and those provided by Stern (2007) comes down to different social discount factors and not, as one could imagine, different model assumptions (see Pindyck (2013)). The social discount factor is the discount rate of future vs current generations where Stern argues that Nordhaus discounts too much and that we cannot value future cohorts less than current. This implies that Stern gets rather higher SCC's than Nordhaus. The social discount factor is thus also a philosophical and ethical parameter which is hard to pin down on only economic grounds

Importantly, however, the social discount factor is not the only modeling issue which has large effects on the SCC estimates. In Section 2.2, I discuss how the specification of the damage function also has the potential to change the SCC by several hundred percent.

In relation to the discussion about the social cost of carbon, the concept of the optimal global warming emerges, denoting the temperature level at which the incremental advantages of temperature reduction equate to the incremental costs incurred. However, a prevailing challenge lies in the reliance of optimal warming on uncertain parameters and specifications. Economic models frequently generate optimal warming estimates that surpass prevailing policy objectives. For instance, Nordhaus (2019) argues that even with the most pessimistic damage predictions, his simulations yield optimal temperature increases of above three degrees. This stands in sharp contrast to predominant international agreements, such as the Paris Agreement, which aims for a maximum temperature rise of 1.5 degrees Celsius and no more than 2 degrees Celsius.

The discrepancies between results (which are used for policy advice) interestingly stem from the same class of models. Namely, integrated assessment models of economics and climate change. Pindyck (2013) argues that this class of models is useless for policy guidance because their predictions are imprecise and driven by parameters and assumptions which are chosen ad hoc and are essentially impossible to estimate.

2.1. Integrated assessment models and the DICE model

Nordhaus (2019) defines integrated assessment models as approaches that integrate two or more domains into one framework. In climate economics, we integrate climate science into economics.[1] The Dynamic Integrated model of the Climate and the Economy (DICE) can be reduced to the problem

$$Max_{c(t)}W = max_{c(t)} \left| \int_0^\infty U\,[c\,(t)]e^{pt}dt \right]$$

subject to

$$c(t) = M\,(y(t);z(t);\alpha;\in(t)$$

Here, the agent maximises the discounted stream of utility subject to consumption being a function of variables that are endogenous in the model, y(t), (for instance, temperature and economic variables), variables that are exogenous in the model, z(t), (for instance, the size of the population), a vector of parameters, α, and potential stochastic variables, $\in(t)$.

A standard integrated assessment model would include an equation stating how output affects emissions $E(t) = \psi(Y\,(t))$, how emissions (which is a flow variable) develops into a carbon stock $S(t) = \chi(\mathrm{E}(t))$, and how temperature/warming is a function of the stock of carbon in the atmosphere $T(t) = \phi(S(t))$. One could denote this the *climate module* of the model, and together with the damage function -

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[1] See Hsiang and Kopp (2018) for a comprehensible review of the science of climate change.

which provides the feedback of the climate on the economy - this module is what integrates climate science into economics.

Critics would then argue that this climate module is lacking precision and empirical foundation and is not useful for estimation and policy advice. It is, however, important to note that analysis from integrated assessment models are used for numerous different purposes which might not all be sensitive to imprecision in a given parameter or specification.

2.2. The damage function

In the models, there is a feedback loop between the climate and the economy. The economy generates emissions which affect temperature, and temperature affects the economy via damages to (for instance) the total factor productivity. One can also model the feedback from damages in other ways, like direct damages to the utility of agents.

Specifying the correct damage function is not trivial since there is no data on how the economy is affected at e.g. temperatures which are 4 degrees above the pre-industrial level. In the simple version, one can think of damages, $D(t)$ as entering the model through an otherwise constant total factor productivity,[2] $A(t)$

$$A(t) = 1 - D(t).$$

A meta study by Nordhaus and Moffat (2017) estimates damages of 2% of GDP at 3 degrees warming and 8% at 6 degrees highlighting the convexity of climate damages.

Howard and Sterner (2017) argue that the damage function, $D(t)$, has previously been underestimated, implying that damages for a given temperature increase were too low. In their meta-analysis, trying to correct for previous errors (such as publication bias which automatically favour the early (low) estimates), they estimate a preferred damage function which they then evaluate in the 2013 version of the DICE model. They estimate 10 percent damages at 3 degrees warming and 40% damages at 6 degrees. Using their new damage function, the social cost of carbon increases with up to 400% depending on other assumptions. This highlights the importance of the specification of the damage function for the SCC and also illustrates the sensitivity of integrated assessment models and why one should be careful in interpreting the resulting SCC's.

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[2] A could also be trending, for instance, due to exogenous growth.

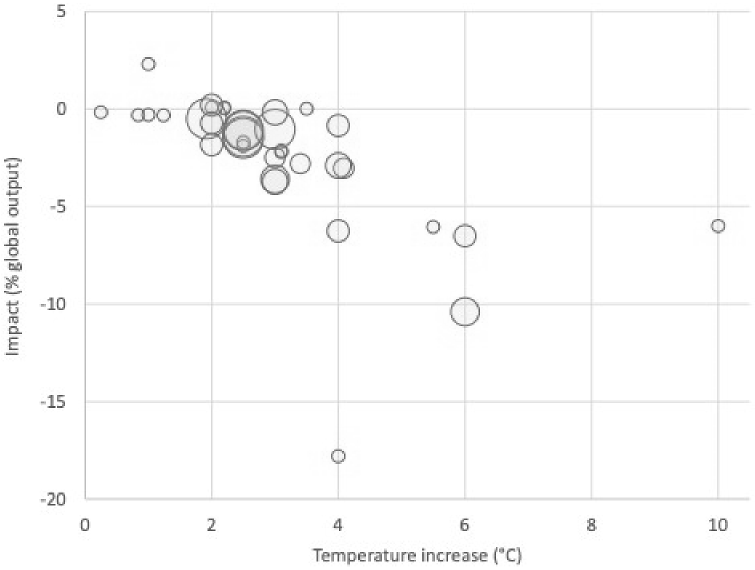

Figure 1:
Figure from Nordhaus and Moffat (2017) showing different estimates of climate damages. The size of circles illustrate the weight of the study

Furthermore, current damage functions fail to account for catastrophic events, general equilibrium effects, and non-market effects such as impacts on biodiversity (Auffhammer 2018). These are all difficult to estimate and economists might have to rely on expert knowledge and not the various econometric frameworks which current damage functions are based on.

2.3. The dynamic path

DICE types of models can be used to evaluate many different kinds of questions. For instance, they can be applied to determine the optimal approach for phasing in climate taxes, considering a targeted limit of 2 degrees Celsius for global warming. Notably, one prominent outcome is the ’hockey stick’ solution, which proposes the potential strategy of temporarily surpassing current emission levels, followed by a significant reduction in emissions at a later stage. This approach capitalizes on technological innovations and the overall growth of the economy.

It is not necessarily obvious whether taxes should start out small and then increase or be large to begin with. There are different (and opposing) views on this. Lemoine and Rudik (2017) present a previously overlooked mechanism that adds to the debate. They argue that the psychical concept ”inertia” implies that emission reductions can be postponed more than standard theory would predict. There is inertia in the link between emissions and temperature increase which means that emissions don’t immediately imply higher temperatures. A policymaker can take this fact into account and construct a policy that is better than that predicted by the "Hotelling rule" which states that one should reduce emissions such that marginal damages of emissions correspond to the marginal cost of reducing it. In the policy which takes account of inertia, it is actually beneficial to overshoot in terms of emissions and then sharply start to reduce towards the end of the target period. The intuition of this is that it is possible to earn interests on the money that you save from doing less today and then you can wait and spend it later. And you can wait more than in the Hotelling scenario because emissions occur relatively later because of inertia. In an opposing paper, Dietz and Venmans (2019) show that the delay factor is actually negligible for optimal global warming because it is off-set by the saturation of ocean carbon sinks.

Thus, it is unclear exactly how this hockey stick should optimally be implemented. Political considerations further complicate the matter, since the hockey stick solution relies on a credible commitment strategy from the government. In general, one can often find theoretical arguments for twisting the standard solutions of flat carbon taxes, but the simple textbook carbon tax is often a good rule of thumb (Landis et al. 2018; Böhringer, Lange, et al. 2014).

2.4. Uncertainty and expert elicitation

It is evident that the merger between climate science and economics is far from problem free. The seemingly simple solution of carbon taxes pose significant problems when one wants to convert theory into (even stylised) numbers and facts. This has lead a number of economists to propose expert elicitation as a second best solution. When integrated assessment models yield highly different projections because of even changes to single parameters (some of which are impossible to identity for econometric or even ethical reasons), it might be better to gather a number of scientists from various fields who can propose their best guesses of strategies, consequences, and costs (Pindyck 2013).

Drupp et al. (2022) asked more than 400 experts what their preferred 2020 carbon price was and found an average carbon price of $50 per ton of CO_2. They note that 98% of experts recommend higher prices than the current market price.

The expert solution is, however, for obvious reason not problem free either, but it might serve as an addition and sanity check to the estimates from the integrated assessment models.

3. Coordination problems

Aside from the large issue of estimating the social cost of carbon, there is another big challenge: coordination, or rather, the lack of coordination. The climate is a global public good which is inherently very different in nature from e.g. country-specific environmental goods (like water quality or air pollution). Managing global public goods require governance measures that do not currently exist. There is no world court which can punish countries who free-ride rather than cooperate in dealing with this global externality.

Nordhaus (2019) proposes climate clubs as the optimal solution to the free-riding problem. He defines a climate club as an agreement by a group of countries to reduce emissions **and**, importantly, it includes a feature where countries would be penalised if they deviated from the agreed path.

3.1. Leakage and differentiated taxes

In a situation where at least one country or region fails to implement the optimal carbon tax, we are no longer in a first best scenario according to the definition by Lipsey and Lancaster (1956). Now, one or more variables are constrained from reaching their optimal values which implies that other variables might also, optimally, take other values. This is the theoretical foundation of second best, which gives rise to the theoretical possibility of differentiated carbon taxes suddenly being optimal.

Böhringer and Rutherford (2002) presents four main arguments for why it can be optimal to deviate from the first-best uniform carbon tax. First, the existence of preexisting distortionary taxes might change how optimal climate policy should be implemented. Carbon taxes can potentially help correct some of the existing distortions from other taxes.

Secondly, policymakers can have distributional concerns for the adjustment period after the tax. Especially, the adjustment of labour supply can be a reason for policymakers to differentiate the carbon taxes. It can also be firm adjustments that policymakers take into account. Böhringer and Rutherford (2002), however, warns that policies focusing too much on the adjustment of labour involve a substantial trade-off with overall efficiency. A recent example of a green policy trying to navigate second best is the implementation of the green tax reform of Denmark which take both other taxes and distributional concerns into account by proposing a differentiated tax regime.

Third, in the presence of leakage, there might be arguments to deviate from uniform taxes in an attempt to minimise the leakage externality. Here, they argue that tradeexposed or energy-intensive industries could be examples of industries which should be subject to lower carbon taxes. In an empirical analysis from the US including nearly 500 manufacturing industries, Aldy and Pizer (2015) show that energy-intensive industries experience larger production declines following climate change policies compared to less energy intensive industries. This decline both stems from reduced exports and reduced domestic consumption meaning that domestic consumers substitute to foreign goods following domestic climate policies.

Christiansen and Jørgensen (2022) present a theoretical way to differentiate unilateral taxes to minimise leakage in a setup with two large countries or world regions which both affect prices and emissions.

In this paper, we propose to differentiate according to the supply price elasticities of the polluting inputs such that the most elastic inputs are subject to the highest taxes. Figure 2 shows the main result of the paper. Here, the red solid line indicates the optimal tax rate under full cooperation. This tax rate is equal to the social cost of carbon and is thus also the Pigouvian tax rate. In the non-cooperative case, optimal taxes are always lower as indicated by the two black lines.[3] In the case where $\alpha_1/\alpha_2 = 1$, the supply price elasticities of the two polluting goods of the model are equal which implies that the tax rates should also be equal. But as soon as one good becomes relatively more elastic, its tax rate should also be relatively higher as shown by the figure when moving to the right on the x-axis.

The intuition of the result is that the more elastic goods experience smaller price drops in response to the declining demand caused by the tax. Because we consider unilateral policy, there is a foreign country which is not subject to taxes - only the changing world prices. And here, it becomes important - for leakage concerns - how much world prices change in response to the changing demand. If a rigid input is taxed too much, world prices decline relatively much and incentivises the foreign country to use more of the input, leaving domestic policy inefficient because of high leakage rates. This differentiation could apply to some of the larger production inputs such as oil, coal, and gas. In practice, it would not be feasible with different tax rates on all goods.

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[3] This is in line with standard economic theory which would predict lower non-cooperative taxes because of the positive externality of carbon taxes on the rest of the world which the taxing country does not take into account.

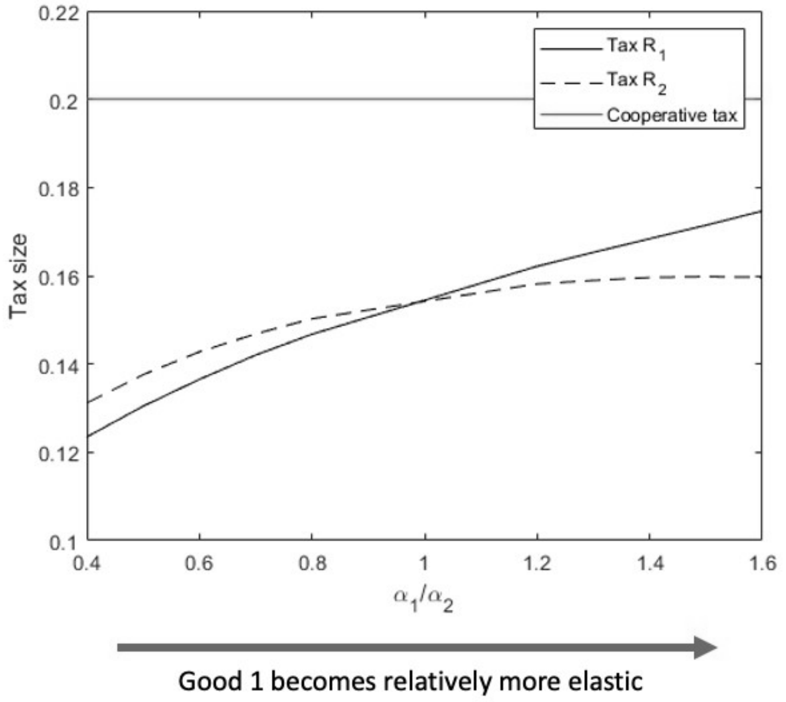

Figure 2:
Optimal unilateral taxes per unit of pollution of two goods with varying elasticities. For $\alpha_1/\alpha_2 = 1$, the goods are equally elastic. The red line is the cooperative tax rate which is optimal under full cooperation

The fourth argument for differentiated taxes by Böhringer and Rutherford (2002) is rooted in terms of trade motives. Large countries which are able to affect world prices can have incentives to differentiate carbon taxes in order to improve the terms of trade. For instance, countries who have a comparative advantage in energy-intensive goods would actually benefit from *higher* taxes on this type of production because it can shift some of the tax burden to other countries.

A fifth channel, which Böhringer and Rutherford (2002) do not consider is national security concerns. In the light of recent developments in the world, national security might be more salient for politicians. This also affects optimal climate policy - for instance because countries do not want to be dependent on specific countries in e.g. specific sectors. Kruse-Andersen (2022) show that taking these considerations into account also implies a differentiation of carbon taxes.

3.2. The carbon border adjustment mechanism

A policy tool that has been widely proposed for climate change regulation is the Carbon Border Adjustment Mechanism [CBAM] which provides a way to conduct effective climate policy in the absence of world coordination. The mechanism works by levying a tariff on imported goods corresponding to the climate taxes which are not paid in the producing country - thus ensuring fair competition and helping prevent carbon leakage. There are, however, several issues in relation to their practical properties. The adjustments seem theoretically neat and are easy to explain, but difficult in practice because of world trade agreements. Also, the administrative costs might be very high. It is not necessarily obvious how much a certain imported good emitted during production. Furthermore, export firms are not protected since the CBAM only applies to imported goods but do not help exporters who compete on unregulated markets. One possible solution to this problem is to subsidise the transition to green production, making home firms competitive on foreign markets again and potentially giving them an advantage the day that foreign markets are taxed.

For practical reasons, there is, however, still scope for research into conducting effective climate policy without the CBAM. Kruse-Andersen and Sørensen (2022) e.g. show that it is indeed possible to construct an efficient set of taxes and subsidies for a small economy which minimise leakage.

3.3. The strategic nature of unilateral carbon taxes

When talking about unilateral climate policy, the debate often automatically considers a binary problem: Do individual countries or agents participate in climate policy or not? I.e. in game theoretical language: Do they cooperate or defect? This type of game is also the one Nordhaus (2015) considers when he concludes that there ”are no stable cooperative equilibria”. In reality, however, the game is not necessarily binary, but could easily be considered continuous - i.e. how ambitious climate policy do we implement? Or, how large a carbon tax do we want?

Understanding the game of unilateral climate policy in such a way also changes the strategic predictions. Now, instead of considering whether countries cooperate or freeride, we can consider their responses to a change in the carbon tax rate in a neighbouring country. Do they raise their tax in response to a trading partner raising theirs, or do they rather lower it? This is the same as asking whether carbon taxes are strategic substitutes or complements as proposed by Bulow et al. (1985) and Cooper and John (1988).

In a stylised two-country model with one type of production and one end-of-pipe abatement measure, Jørgensen and Nielsen (2022) show that carbon taxes might, in fact, be strategic complements for several reasons. One can distinguish between motives that pull towards complementarity - i.e. motives that, all else equal, incentivise a country to meet tax increases of the foreign country with tax increases of their own (and vice versa) - and motives that pull towards substitutability - i.e. motives that, symmetrically, incentivise a country to meet foreign tax increases with home tax cuts. First, Jørgensen and Nielsen (2022) highlight tax competition as the main complementarity motive. When the foreign country has a higher tax rate, the home country can increase its tax rate as well with less fears of leakage. The competition for production is thus less fierce with higher foreign taxes. Intuitively, this illustrates a situation where both countries might benefit from higher taxes, but are only willing to increase their taxes if the other does so (for any exogenous reason).

Secondly, the paper presents two substitutability motives. First, the tax base effect where the marginal cost of raising your tax is larger the more production you have to lose. If the other country increases its tax, some of the foreign production leaks to the home country which now will lose more by increasing taxes. This motive induces substitutability. Secondly, with higher taxes in the foreign country, total world production is smaller and emissions are thus also smaller. The state of the climate is thus better (all else equal) and the marginal benefit of the home country to introduce carbon taxes is reduced.

In addition to these three stylised effects, there are also several ambiguous second order effects - even in a very stylised setting. The more links and features of the economy one then introduces, the more complicated the picture.

Even in the highly stylised setting, it is not possible to, theoretically, show which of these dominate and the overall effect is thus ambiguous. In a simulation, however, we show that the baseline calibration yields complementarity of taxes. See Figure 3 which shows best response function of each of the two countries for carbon taxes. I.e. the optimal carbon tax of the country when taking the other country's tax level for given. We see that the functions are upward-sloping, indicating that each country would meet foreign tax increases with increases of their own - i.e. strategic complementarity.

This result serves to show that the idea of in-action for strategic reasons might be too simplified. Should countries refrain from implementing carbon taxes out of fear of reciprocal measures from neighbouring countries, they might inadvertently disregard certain underlying mechanisms. In fact, neighbouring countries might genuinely desire similar tax hikes, thereby creating a strategic deadlock at the global level.

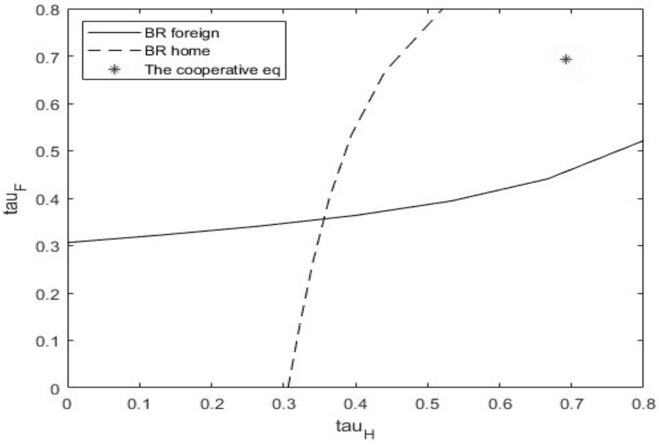

Figure 3:
Best response function of home and foreign country for carbon taxes.
The red cross is the optimal cooperative tax whereas the intersection is the Nash equilibrium for unilateral taxes. I.e. the tax rates where the countries mutually best respond

4. Dynamics and inter-generational issues

Another important aspect of climate policy and climate change externalities are their inter-temporal properties. We distinguish between intra-temporal and inter-temporal free-riding problems where the first refers to the problem presented in Section 3 where countries have incentives to deviate from coordinated policy. The second problem refers to the inherent challenge that the damages incurred by today's actions do not necessarily harm the cohorts of today, but more likely, future generations. The climate features inertia and greenhouse gases are long-lived in the atmosphere. For instance, carbon dioxide has a half-life of around 120 years.[4] Symmetrically, policies aimed at reducing climate change also have long-run effects, but might in contrast be associated with substantial up-front costs. Thus, effective climate policy implemented today will likely imply inter-generationally unequal effects, because current cohorts will pay for the initiatives whereas future cohorts will benefit.

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[4] https://meteor.geol.iastate.edu/gccourse/forcing/lifetimes.html

However, several papers argue that this view is too narrow. Sachs (2014) e.g. shows that using inter-generational fiscal policy - funding climate change mitigation with public debt - it is possible to have future generations both undertake the costs and reap the benefits of current climate policy. The paper argues that the important question is whether future generations are interested in this scheme. I.e. do the benefits outweigh the costs? Current generations are thus acting on behalf of future generations when taking this decision. But importantly, the nature of the problem shifts. Now, the problem of the current generation is **not** if they are willing to sacrifice consumption for the benefit of future generations, but merely assessing the future welfare potential and costs of climate policy. Sachs (2014) thus highlights that it might be possible to construct inter-generationally Pareto improving climate policies.

Later papers show that it is indeed possible to make climate change policies using measures that pass the inter-generational Pareto criterion. The inter-generational Pareto criterion states that no generation post policy is allowed to be worse off than in the business-as-usual scenario. Andersen et al. (2020) show that an appropriate set of taxes and abatement measures financed via green government bonds will result in a Pareto improvement such that all generations have at least the same welfare as in the business-as-usual scenario. Importantly, these debt-financing strategies require governments who are able to manage the debt in an optimal manner, and the paper does not deal with the issue of countries already having really high debt levels. Nevertheless, they point to the important point that the inter-generational trade-off might be less obvious or non-resolvable as sometimes stated in the debate.

4.1. Transition costs of climate policy

Another inter-generational issue in relation to the green transition is adjustment costs or transition costs after the implementation of climate policy. Even if a policy in itself is not costly, there might be costs related to the adjustment period. Often these costs range over a period of approximately a generation depending on the size of the transition. This means that it is important to assess not only the long-run properties of climate policy but also the dynamic adjustment.

In a review of the costs of climate change abatement, Gillingham and Stock (2018) emphasise the importance of including both dynamic and static costs when evaluating abatement options. Focusing only on the static initial payments might skew the picture and favour programs which are only optimal in the short run. Dynamic effects also include research spillovers and lock-in effects from large capital investments (in intermediate solutions).

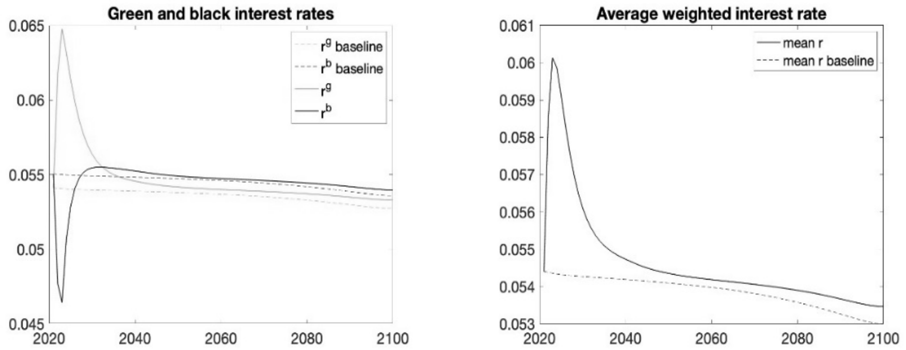

Figure 4:
From Jørgensen (2022). Left panel: The effects on green and black interest rates of a carbon tax of $50 per tonne of CO_2 resulting in 21% less black capital. The dotted line is the benchmark scenario where the interest rate is only affected by demographics and climate change. Right panel: The average interest rate weighted with the size of the capital stocks.

Apart from the direct costs of both climate change and associated mitigation strategies, there are also secondary effects on the general economy

4.2. Climate change mitigation and the real interest rate

One example of the secondary macroeconomic effects stemming from climate change mitigation is the impact on interest rates as a result of the transition towards a greener economy, necessitating substantial capital investments by businesses. This shift from carbon-intensive black capital to sustainable green capital will exert influence on interest rates in the coming generation. Jørgensen (2022) demonstrates that interest rates are likely to experience temporary increases of up to 1 percentage point (a $75 carbon tax per tonne of CO_2 in response to the green transition). In a closed large economy with two types of assets - green and black - and adjustment costs on capital, the paper shows how the rigid responses of capital to green policies affect interest rates which instantly jump after the implementation of carbon taxes. In the paper, agents can invest in either green or black assets which give equal long run returns (after correcting for warm glow/green preferences). However, carbon taxes incentivise a shift in the optimal allocation of capital which is too costly to implement over night.

The primary outcome of the paper is depicted in Figure 4, where the dashed lines represent the baseline trajectory in the absence of climate policy but incorporating exogenous demographic projections (reflecting increased longevity and decreased fertility). The left panel illustrates the trajectory of interest rates for green and black capital. In this context, green capital refers to non-polluting capital, while black capital denotes polluting capital. As the government imposes taxes on carbon emissions, the use of black capital becomes costlier due to the associated carbon taxes. Consequently, the tax incentivises a shift from black to green capital, which is reflected in the observed interest rates.

As a consequence of the reduced demand for investments in black capital, the interest rate for this type of capital experiences a decline, while conversely, the interest rate for green capital sees an increase. This dynamic is depicted in the right panel of Figure 4, which illustrates the average weighted interest rate, representing the average return on savings. The observed effects arise from a tax policy that leads to a 21% reduction in black capital.

The transition period, lasting around 20-30 years, which is slightly shorter than a generation, represents the time frame within which the interest rate levels progressively return to the baseline trajectory. The temporary increase in interest rates resulting from the green transition will be experienced by the generation living at the time of implementation. In terms of long-term effects, climate policy has negligible impact on the interest rate, apart from minor effects stemming from an improved climate leading to higher factor productivities. Thus, this serves as an illustration of a transient shortterm effect with intergenerational implications.

5. Conclusion

In this paper, I have highlighted some of the main issues of climate policy with special emphasis on the in-action bias caused by non-cooperation. Especially, I have shown how optimal climate policy in reality – in second best - becomes a complicated matter. Here, the first best uniform carbon tax equal to the social cost of carbon is not necessarily the entire solution. The optimal strategy changes when the world is subject to coordination failures, uncertainty, technology spillovers etc. Auffhammer (2018) gives the example of the German Energiewende subsidy which compensated solar installations at a very high rate, leading firms to innovate and reduce costs. Thus the German government programme, subsidised low-cost solar energy for the rest of the world as well (Gerarden 2023).

In addition to intra-country externalities, there are inter-generational externalities that are significant in both size and qualitative nature. However, the intergenerational dilemma is less straightforward than it is sometimes portrayed in public debates. It is not necessarily evident that current generations have to be worse off after the implementation of climate policy. This prediction largely depends on how green initiatives are financed, with debt-financing being an apparent means of passing on the burden to those who also experience the benefits.

And finally, economists are still struggling with assessing the costs and consequences of climate change. However, as Pindyck (2013) states, this should not be a reason to ignore the problem. Understanding the inherent uncertainty in the estimates of the social cost of carbon qualifies the debate and also has implications for optimal policy.

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