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Carbon pricing, carbon sequestration and social discounting

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ABSTRACT

This paper studies the optimal taxation of carbon emissions in a dynastic economy. When the welfare function places direct Pareto weights on unborn generations, the social discount rate is lower than the discount rate of the current generation. I show that this welfare criterion has important consequences for the structure of the optimal regulatory system. In particular, I show that: (*i*) the optimal carbon tax does not in general equal the social cost of carbon; (*ii*) a subsidy on oil reserves is sometimes optimal; and (*iii*) carbon trading programs should limit the award of carbon offset allowances

1. Introduction

The mean lifetime of anthropogenic carbon dioxide is approximately 300 years (Archer, 2005). The problem of climate change is, therefore, intergenerational in nature. This paper studies optimal carbon policy in an economy that captures both the externality and the intergenerational aspect of climate change. I consider a welfare function that places direct Pareto weights on unborn generations, as opposed to future generations receiving weight only through the altruism of the current generation. This specification delivers a social discount rate that is lower than the discount rate of private individuals. The literature has argued for and against using a low discount rate in climate-economic models. While ethical considerations underly the argument for using a low discount rate, unrealistic savings and an optimal carbon price that is too high are the main arguments against it. This paper shows that a low discount rate has further implications for the structure of an optimal regulatory system. In particular, I show that standard policies to control carbon emissions, such as taxes or caps on *net* carbon emissions, are insufficient to achieve the social optimum. Non-standard carbon policies must be designed. These non-standard policies require mitigation technologies to be subsidized and carbon emissions to be taxed, but each at different rates: in general, the optimal subsidy for removing a ton of carbon from the atmosphere will not equal the optimal tax on creating a ton of carbon. Moreover, if carbon taxes and subsidies are set as equal, then it is optimal to also introduce a subsidy on the oil stock in situ. I also show that an optimal cap and trade scheme must include a cap on carbon-offset allowances.

I develop my argument in a model economy with altruistic generations and a climate externality. In the model, the extraction of an exhaustible resource ("oil") generates a climate externality ("carbon in the atmosphere") that can be offset

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with an available technology ("sequestration"). Each generation decides how much oil to consume and how much of its carbon emissions to sequester. Private individuals do not take into account the effect that both activities have on the aggregate carbon stock. Therefore, the equilibrium in the market economy is not optimal, and policy intervention is necessary.

To address intergenerational issues, I set up an economy composed of an infinite sequence of generations. Each generation consists of a continuum of altruistically linked individuals who live for only one period. I consider a welfare function that places direct weights on current as well as future unborn generations. By varying these weights, I can recover any point in the Pareto frontier between the present and future generations, and study how the optimal carbon policies are affected by alternative welfare criteria. One particular criterion is when only the current generation receives weight in the social welfare function. Future generations are still valued through the altruism of their ancestors. In this case, the social discount rate coincides with the private discount rate, and the planning problem corresponds to that of a representative infinitely lived individual. In this particular case, carbon taxes and sequestration subsidies are equal to the value of the externality, which I refer to as the "social cost of carbon". Alternatively, in a cap and trade economy, it is optimal for the government to set a cap on the net carbon emissions.

However, the social optimum associated with valuing future generations only through the altruism of the current generation is just one among many other efficient allocations. These alternative efficient allocations are each associated with positive weights on future generations in the welfare function, and each corresponds to a point on the Pareto frontier. Moreover, these welfare criteria imply a social discount rate that, at any point in time, is lower than the discount rate of the individuals in the society. The main contribution of this paper is to show that these efficient allocations cannot be implemented using standard carbon policies. First, the social cost of carbon in the planning problem is no longer a sufficient indicator of the optimal climate policies. And second, it is not enough to control the net carbon emissions. A social planner who cares about future generations wants to treat carbon emissions differently from emissions offsets.

The first main result of the paper is that, when social and private discount rates differ, an optimal tax scheme consists of a carbon tax on emissions and a subsidy on sequestration, but these two are not equal. Thus, creating a ton of carbon is no longer equivalent to removing a ton of carbon, even though both have the same effect on the aggregate externality. I provide an analytical derivation of the carbon tax formula for this case and show that the social and the private discount rates appear as an extra term in the tax rate. Importantly, the carbon tax is not equal to the social cost of carbon. This result is important because it shows that a different carbon tax *formula* (not just a higher *value* for the carbon tax) is optimal when climate-economic models use a low social discount rate. Moreover, it is not enough to solve for the path of carbon emissions in a social planner's problem and associate taxes with the social cost of carbon within that problem. When social and private discount rates differ, the design of optimal policies requires special attention.

It is important to notice that a social discount rate that is lower than the private one will have broader implications for the structure of the optimal tax system, not only for carbon policies. Specifically, it will call for a subsidization of all forms of capital accumulation in the economy. In this sense, an insight drawn from this paper is that the reserves of oil in situ are a form of capital accumulation for society and, therefore, should be treated differently from sequestration and other mitigation policies. It is a well-known principle in public finance that there are many ways to decentralize an optimal allocation. Therefore, I also show that an alternative optimal carbon policy is to set "standard" carbon emissions taxes and carbon sequestration subsidies (both equal to the social cost of carbon) and couple them with a subsidy on the reserves of oil in situ. That is, governments should pay firms for keeping fossil fuels underground. I theoretically characterize the optimal subsidy rate on oil reserves for this case and show that it is a function of the social and the private discount rates as well.

The literature that proposes a supply-side approach to environmental policies has already discussed the idea of paying firms for extracting less. Sinn (2008) considers subsidizing the oil stock in situ as an alternative to introducing a decreasing carbon tax rate. More recently, Harstad (2012) shows that it is optimal for governments to buy fossil-fuel deposits to prevent non-participants in a global climate treaty from burning the oil. This paper contributes to this literature by providing an alternative theoretical justification for this type of supply-side carbon policy. In this paper, a subsidy on the oil stock in situ is a tool to pursue climate equity.

The second main result of the paper is that an optimal cap and trade program must include a cap on carbon-offset allowances. If the government sets the net emissions caps equal to the carbon emitted in the optimal allocation, the economy will exhibit both too much depletion of fossil fuels and too much sequestration. By introducing a cap on carbon offsets that firms can use, the optimal cap and trade scheme embeds a mechanism to lock more oil under the earth's crust. It is interesting to see that this policy prescription resembles some of the features of actual policies. In particular, the European Union Emissions Trading Scheme (EU ETS), the California's greenhouse gas (GHG) cap-and-trade program and the Regional Greenhouse Gas Initiative (RGGI) set limits to the use of compliance carbon credits. Although the difficulty of quantifying and verifying the reductions in emissions coming from these projects is often the justification for these limits, this paper provides a new rationale for why these caps on carbon offsets are optimal.

The basic intuition behind the results of this paper is the simple rule in public finance that optimal policies require the number of instruments to equal the number of policy targets. Standard carbon policies provide only one instrument. If the carbon policies are meant to deal not only with the environmental externality itself but also with intergenerational equity, an additional lever is missing. Finally, I extend the basic model to include capital, an alternative sequestration technology and heterogeneous consumers, and I show that the main results and intuition carry over to these richer environments.