# Environmental policies that maximise welfare: the role of intergenerational inequality

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## Overview

Carbon emissions can be curbed down through a public intervention — for instance, a public decision that increases directly the fraction of renewables in the energy mix, or the implementation of a carbon tax. For a given target of reduction of carbon emissions, each policy instrument triggers different effects on prices, GDP and intergenerational inequality. In this context, the social choice as concerns the optimal mix of instruments is not necessarily trivial. This article relies on a dynamic general equilibrium model with overlapping generations in order to determine the optimal mix of instruments for different types of social preferences. This model is parameterised on German data. Results suggest that a social planner that takes account of the welfare of future generations and is highly averse to intergenerational inequality chooses to implement a relatively moderate, fully recycled carbon tax and to increase in parallel the fraction of renewables in the energy mix — even if the recycled tax favors growth and future generations. Only authorities with utilitarist preferences implement a low-carbon transition relying mostly on a fully recycled carbon tax. Overall, our article suggests that intergenerational redistributive effects can significantly influence the social choice as concerns environmental policies and the optimal mix of instruments.

## Methods

General equilibrium (GE) analysis applied to energy and environmental public policies has been developing since the 1970's. Sato (1967) and Solow (1978) popularized GE frameworks with CES production functions including energy as a third input. Energy- and environment-related computable GE models have been commonly used (e.g., Böhringer and Rutherford (1997), Parry and Williams (1999), Böhringer and Löschel (2006), Otto, Löschel and Dellink (2007)) notably on issues related with environmental taxes (Kiuila and Sleszynski (2003)), Wissema and Dellink (2007), Bretschger, Ramer and Schwark (2011)). Knopf et al. (2010) present different CGE models encapsulating an energy sector with a rising fraction of renewables in the energy mix in order to assess empirically the long-run costs of meeting the 450ppm environmental objective. However, the literature quoted above relies mainly on models that incorporate static general equilibrium mechanisms insofar as it does not aim at accounting precisely for intergenerational redistributive effects; and it is not mainly designed to adress the modelling of the intertemporal social choice that aim to lessen carbon emissions.

A complementary literature focuses on the dynamic dimension of environmental policies in general equilibrium, taking account of its impact on the intertemporal consumption/saving arbitrage and on the capital intensity of the economy. Solow (1986) indeed suggests that it is essential to capture intergenerational effects of the environment and points out that intergenerational issues ought to be analyzed within an overlapping generations model. Since John and Pecchenino (1994) and John et al. (1995), there is a significant literature on energy issues which has been developing within an overlapping generations (OLG) framework. Bovenberg and Heijdra (1998) develop this approach to conclude that environmental taxes trigger pro-youth effects. However, the above quoted OLG settings often rely on a theoretical approach involving most of the time a limited number of generations (e.g., two: a young and an old one). They are not mainly designed to address issues related with the interactions between the general equilibrium, the $CO_2$ emissions and the intertemporal social choice. Karp and Resai (2014) is a recent exception on this point though their OLG framework remains theoretical insofar as their agents live two periods.

The literature that relies on empirical, computable general equilibrium models with overlapping generations in order to analyse the effects on growth and intergenerational equity of environmental policies is scarce (Rasmussen, 2003; Carbone et al., 2012; Carbone et al., 2013; Rausch, 2013; Gonand and Jouvet, 2015). This paper is relatively close to these latter references. However, the GE-OLG framework used here differs from the available literature on several aspects. First, we do not focus exclusively on carbon tax issues but also consider the impacts of a decision increasing the fraction of the renewables in the energy mix. Second, our model incorporates more than 60 cohorts and is parameterised on annual data (and not on a 10-year time step as in Rausch (2013)), thus ensuring that the aggregate dynamics of the general equilibrium interactions is precisely modeled. Third, it encapsulates a modeling of carbon emissions. Fourth, we model the intertemporal social welfare taking into account parameters such as the social aversion to intergenerational inequality and the discount rate of the wellbeing of future generations. In doing so, we aim to determine the optimal social mix of instruments lessening carbon emissions. This latter issue has been recently addressed by Van der Ploeg and Withagen (2014) albeit in a different setting (i.e., a Ramsey growth model with climate damages but no OLG or parameterisation on empirical data).

This article relies on a general equilibrium model with overlapping generations in order to determine, on empirical data, the optimal mix of environmental policy instruments lessening carbon emissions from the point of view of the social planner. In doing so, it assesses empirically the dynamic impacts on growth and intertemporal welfare of a public decision increasing directly the fraction of renewables in the energy mix, and/or a carbon tax that is fully recycled through lower proportional taxes on private agents' income. Our model is parameterised on German data. It models carbon emissions in relation with the characteristics of the general equilibrium and the energy mix. Different social preferences are considered, with different values for the degree of aversion to intergenerational inequality and for the discount rate applied by the social planner to the welfare of future generations.

## Results

Our results show that, first, a carbon tax fully recycled through lower proportional taxes has more favourable effects on GDP that an increase of the fraction of renewables in the mix. Second, it also triggers stronger intergenerational redistributive effects - that favour future cohorts (as in Bovenberg and Heijdra (1998)) and weigh on current generations. Third, we derive, in our dynamic general equilibrium model, implicit abatement cost curves and curves of iso-reduction of carbon emissions.

We then develop an applied analysis of the social choice faced by the social planner seeking to lessen carbon emission while maximising its social welfare. We find that a social planner with utilitarist preferences prefers to achieve a significant diminution of carbon emission mostly by implementing a decentralised, fully recycled carbon tax. However, this result is essentially modified if other social preferences are considered. For instance, a social planner that does not take account of the wellbeing of future generations chooses to increase directly the fraction of renewables in the mix in order to curb down carbon emissions, and never decides to implement a carbon tax. This flows from the intergenerational redistributive effects of the carbon tax which favors future generations but not current generations, whereas a publicly implemented development of renewables is relatively less detrimental for the welfare of current cohorts.

Social planner that take account of future generations and aiming at significantly lessening carbon emissions optimally implement a mix of environmental policy instruments. The optimal policy, from the point of view of the social planner, encapsulates some direct public action increasing the fraction of renewables in the mix and some fully recycled carbon tax. The precise characteristics of the optimal mix depends here very much on the degree of the aversion of the social planner to intergenerational inequality. If the aversion is high, the social planner will maximise the social intertemporal welfare by a) implementing a relatively moderate carbon tax (with an average rate of around 50€/t between 2015 and 2050 if the target consists in lowering carbon emissions by 20% up to 2050 as compared to 2009) and b) increasing in parallel the fraction of renewables in the electrical mix, up to 40% in 2050. If the aversion of the social planner to intergenerational inequality is low, then the reduction of carbon emissions is optimally achieved by relying mostly on a fully recycled carbon tax, with an average rate of 90€/t over 2015-2050, with no new sizeable policy bolstering the development of renewables implemented in the future.

Even if a fully recycled carbon tax favours relatively more the future generations and bolsters economic growth in the long run, a social planner that does not take account of the welfare of future cohorts and/or that is averse to intergenerational inequality may choose to implement a mix of policy instruments, with some significant regulatory approach increasing directly the fraction of renewables in the energy mix.

## Conclusions

These results have policy implications. While a carbon tax maximises growth, it does not necessarily maximises the social welfare because it triggers intergenerational redistributive effects. Our model shows that, except in the utilitarist case, governments can optimally decide to implement regulations increasing the fraction of renewables in the energy mix along with the creation of a fully recycled carbon tax. The optimal policy depends then also from social preferences as concerns intergenerational inequality and the wellbeing of future generations. Incidentally, our model also suggests that a mix of a carbon tax and of a centralised policy favouring renewables may not be enough to meet targets of carbon emissions diminution as high as 70% or 80% in 2050, as often advocated for in the public debate.