# Fostering Renewables and Recycling a Carbon Tax: Joint Aggregate and Intergenerational Redistributive Effects

Frédéric Gonand*

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A rising share of renewables in the energy mix pushes up the average price of energy - so does a carbon tax. However the former fosters the accumulation of capital while the latter, if fully recycled, does not. Thus the effects of these two environmental policies on growth and intertemporal welfare differ. The present article assesses them.

General equilibrium (GE) analysis applied to energy issues 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 share of renewables in the energy mix, in order to assess empirically the long-run costs of meeting the 450ppm environmental objective. However, these models are not specifically designed to address issues such as the dynamics of the year-to-year effects on growth of environmental tax reforms and their implied intergenerational effects.

Some litterature focuses on the dynamics of environmental taxation in a general equilibrium setting and their intergenerational redistributive effects. It takes account of its impact on the intertemporal consumption/saving arbitrage and the capital intensity of the economy. To this end, John et al. (1995) rely on an overlapping generations (OLG) framework. OLG settings allow for modelling the interactions between the capital intensity of the economy, the environmental taxation and demographics. Bovenberg and Heijdra (1998) develop this approach to conclude that environmental taxes trigger pro-youth effects. Chiroleu-Assouline and Fodha (2006) also use an OLG model to argue that the favourable impact on growth of a recycled environmental tax ("second dividend") is closely related with the capital intensity of an economy and its dynamics over time. However, the above quoted OLG settings generally rely on a theoretical approach involving most of the time a limited number of generations (*e.g.*, two: a young and an old one). This bares the way to an empirical parameterisation that allows for a precise quantitative assessment of the mechanisms involved by a carbon tax with numerous cohorts, notably the consumption/saving arbitrage that drives the dynamics of the capital intensity.

*University of Paris-Dauphine (LEDa-CGEMP). E-mail: frederic.gonand@dauphine.fr

This paper aims at assessing empirically the dynamic impacts on growth and on intertemporal welfare (and thus on intergenerational equity) of a rising share of renewables in the energy mix and of a fully recycled carbon tax. It relies on a GE setting incorporating an energy module as in some of the models presented by Knopf et al. (2010). Our empirical computable GE model additionally encapsulates an empirical OLG framework with more than 60 cohorts each year and a public finance module, following here Auerbach and Kotlikoff (1987). In line with OECD (2005) and Brounen, Kok and Quigley (2012), the consumption of energy increases with age. Different policy scenarios are modeled as concerns the development of renewables in the energy mix and the implementation of an environmental tax. For illustrative purpose, it is parameterised on German data.

Results show that higher quantitative targets set by public authorities for the future development of renewables weigh on economic activity. Intuitively, the rise in the share of renewables in the energy mix fosters average energy prices for private agents, forcing them to buy at a higher price a good that is necessary for production and that has no perfect substitute. While lessening the demand for energy, it also fosters the stocks of capital and labour. In contrast, a carbon tax, if it is fully recycled, has a positive influence on GDP in the long run. This favourable influence on activity is related with the downward effect of the tax on the demand for energy in volume. Since the carbon tax weighs on the total demand for energy in volume, the rise in the total energy expenditures paid by private agents is less than the amount of the carbon tax collected and redistributed. Accordingly, the households' income, which encompasses energy expenditures and public spending, increases. This fosters consumption and growth and weighs on capital per unit of efficient labour. Eventually, recycling the revenue associated with the carbon tax with lower direct taxes entails slightly more favourable effects on growth than recycling the tax with a higher lump-sum public expenditures (*i.e.*, the second dividend is positive in the model). Intuitively, lessening distortionary taxes has a more favourable effect on activity than raising lump-sum public transfers. This result mirrors a joint influence of fiscal policy on the households' income and their life-cycle consumption/saving behaviour, entailing some additional capital deepening when taxes are lowered. In all the results, the macroeconomic magnitude of the effects on growth of these environmental policies remains subdued. In the long-run, around 2050, it is close to +/-0,5% of the level of the GDP. This is in line with the "elephant and rabbit" tale in energy economics (Hogan and Manne, 1977) according to which the size of the energy sector in the economy bares it to entail very sizeable effects on growth under normal circumstances.

As concerns the intergenerational effects, results suggest that higher quantitative targets set by public authorities for the future development of renewables trigger intergenerational redistributive effects. While they weigh on the future annual welfare of all cohorts, however, the detrimental effect in the short run is less pronounced for currently retired generations. This flows mainly from the joint influence of a permanent income effect and of an energy consumption effect. A carbon tax, if fully recycled, has pro-youth intergenerational redistributive properties. Eventually, recycling a carbon tax through lower direct, proportional taxes rather than higher lump-sum public expenditures conveys specific redistributive effects that also benefit to young and future generations.

Computing the intertemporal welfare of each cohort over its whole lifetime allows for precising and completing the analysis of intergenerational redistributive effects. Result suggest that a higher share of renewables in the energy mix weigh relatively more on the intertemporal welfare of young and future generations. Fiscal policy implementing a fully recycled carbon tax more than offsets the detrimental effects of increasing renewables on private agent's intertemporal welfare, and displays

pro-youth redistributive features. This result holds especially if the carbon tax is recycled through lower proportional taxes on income rather than higher public lump-sum expenditures.

The policy implication of this article is not that implementing a fully recycled carbon tax should be preferred to setting higher quantitative targets for renewables in the future energy mix. Rather, it implies that significant economic gains arise when both are implemented. The joint implementation of higher targets for the development of renewables and of a carbon tax fully recycled through lower proportional taxes on income allows a social planner for modifying the structure of the energy mix while achieving some neutrality as concerns the GDP and preserving some intergenerational equity in the long run.