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Financing climate policies through climate bonds – A three stage model and empirics

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ABSTRACT

The funding of climate mitigation and adaptation policies has become an essential issue in climate negotiations. Emissions trading schemes (ETS) and carbon tax policies are widely discussed as viable mitigation strategies, the revenue from which might then be used for adaptation efforts. In most current models, the burden of enacting mitigation and adaptation policies falls on current generations. This paper expands on a recent article by Sachs (2014) that proposes intertemporal burden sharing, suggesting that implementation of climate policies would represent a Pareto improving strategy for both current and future generations. In particular, this paper proposes that green bonds (also referred to as climate bonds) represent an immediately implementable opportunity to initiate Sachs' plan; the issuance of green bonds could fund immediate investment in climate mitigation such that the debt might be repaid by the future generations, those who benefit most from reduced environmental damages. The Sachs model is a discrete time overlapping generations model which we generalize and turn into a continuous time version exhibiting three major stages. We solve this three phase model by using a new numerical procedure called NMPC that allows for finite horizon solutions and phase changes. We show that the issued bonds can be repaid and the debt is sustainable within a finite time horizon. We also study econometrically whether the current macroeconomic environment is conducive to successfully phasing in such climate bonds.

1. Introduction

The implementation of climate change oriented policies raises challenging questions concerning the manner in which policies and infrastructure will be financed. If one starts with the current climate stabilization policies that utilize emissions trading, carbon tax, and other regulatory measures to phase out fossil fuel energy and phase in renewable energy, the essential issue is the cost of mitigation and adaptation efforts. Most of the current measures show up as a cost for the current generation. In this paper, we propose an intertemporal model that allows for burden sharing between current and future generations. Sachs (2014) suggests the use of long term bonds that reimburse the current generation's mitigation and adaptation costs, and that are repaid by future generations through taxation. This funding strategy can be, as Sachs (2014) shows, welfare improving.

The potential high cost of action for current generations is implicit in the typical Integrated Assessment Model, or IAM, (Nordhaus, 2008), in tipping point models, as well as in more complex mitigation and adaptation models that are based on

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the IAM. Sachs (2014) proposes an innovative intertemporal financial approach that might help to guide the development of a new framework employing the IAM, as well as tipping point models, such as Greiner et al. (2010), and the infrastructure models against climate risk, such as Klasen et al. (2015), Maurer et al. (2013), Bonen et al. (2016) and Stocker et al. (2013).

Here, however, we propose a simple model, based on Sachs (2014), that uses a discrete time framework with overlapping generations. In the original two period model, the current generation undertakes climate change efforts financed through long maturity bonds. The current generation remains financially as well off as without mitigation while improving environmental well-being of future generations. In fact as Sachs shows, this intergenerational tax-and-transfer policy turns climate change mitigation and adaptation policies into a Pareto improving strategy for both generations.

The bonds proposed by Sachs (2014), and this paper, do not mature for a number of generations. While such long term investment is out of the ordinary, evidence in Arezki et al. (2016) shows that possible funding is consistent with investment strategies of sovereign wealth funds, pensions funds, insurance companies, and mutual funds. Such institutions have nearly $100 trillion in combined assets under management.[1] Moreover, in the current low interest rate environment, sovereign wealth funds and central banks have accumulated large excess savings of approximately $15 trillion. This is to say that there is an enormous amount of wealth, far surpassing the US nominal GDP (about $18 trillion in 2015), which represents potential investment in long term climate projects.

We thus set up a growth model with three stages where climate policies are funded through the issuance of green bonds, and where future generations repay the bonds while reaping the benefits of the enacted climate mitigation policies. Where Sachs (2014) proposes a discrete time model, we use here a continuous time model which embeds the stages of the Sachs overlapping generations model into a continuous time version. The integrated multiple stage climate model helps to analyze how public finance can help, through green bonds, to fund climate policies that phase out fossil fuel energy and phase in renewable energy.

We propose a model in three stages. The first stage represents business as usual (BAU), with damage to the environment a byproduct of the production process. In a second stage climate policies are carried out through private agents in a market economy, but those agents are reimbursed for their effort by the issuance of green bonds. Sovereign debt may rise as environmental and climate effects are reduced to a sustainable level. Finally, in the third stage, the future generation pays back the bonds through an income tax. The latter generation does not experience elevated climate damages and their welfare is improved. After this period, once the bonds are repaid and greenhouse gases (GHG) are stabilized at a low level, the income tax can be reduced.

To solve, calibrate, and test such a new model of climate change policies with stages and regimes in continuous time, and to show that such a debt augmented growth model stays within the bounds of a sustainable fiscal policy, the project employs a new method, nonlinear model predictive control (NMPC), that solves complex dynamic systems with different nonlinearities for a finite decision horizon. This algorithm helps solve those intertemporal models with finite horizon and with regime changes. The different stages over the long horizon mode are linked, and give us piecewise solutions, where the next initial state uses the information from the previous stage. This gives us sufficient information of what might happen over the entire solution paths.

In order to make the model empirically applicable, we also examine how the terms of public financial instruments such as green bonds are determined. There are a wide variety of green bonds of different maturities issued by a variety of institutions, both public and private. Since we are discussing here bonds of long maturity, relevant literature comes from the discussion of stretching the maturities of public bonds that started with the controllability of public debt; see Cole and Kehoe (1998) and Arellano et al. (2013). Thus we will have to add a thorough exploration of the existing climate bonds, their maturity structure, their institutional issuers and backing, when we suggest to phase in the new green bonds corresponding with our model.

A major empirical concern will be determining the drivers of long term bonds when issued and traded in the financial markets. Public finance literature, see Arellano et al. (2013), has pointed out several determinants for the issuing of long term bonds. The main macroeconomic drivers of long maturity bonds appear to be interest rates, inflation rates and output. Higher inflation rates, for example, seem to reduce the issuing of long term bonds significantly. High interest rates also give incentives to reduce the duration of bonds. Decreased output and income is also associated with reduced long maturity bonds issuance. In Section 5, using econometric analysis of currently issued green bonds, we consider the various determinants of the maturity structures of bonds, in particularly the drivers of long term bond issuance. We establish that the current macroeconomic environment appears to be conducive to issue long maturity climate bonds.

The remainder of the paper is structured as follows. Section 2 elaborates on issuing and trading of existing climate bonds. Section 3 presents our three stage model. Section 4 presents the numerical results using NMPC solution procedure. Section 5 presents some econometric results. Section 6 concludes.

2. Climate change and climate bonds

Since the green bonds suggested here have to be phased in to existing markets, we next present a short review of the issues involved in financing mitigation and adaption efforts using green bonds. Crucial issues include the current climate

[1] For more details of the available funds looking for investment, see Arezki et al. (2016).