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Carbon sequestration, economic policies and growth

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ABSTRACT

We present a model of endogenous growth in which the use of a non-renewable resource in production yields CO_2 emissions whose accumulated stock negatively affects welfare. A CCS technology enables, via some effort, a partial reduction of these emissions.

We characterize the social optimum and how the availability of CCS technology affects it, and study the trajectories of the decentralized economy. We then analyze economic policies. We first derive the expression of the Pigovian carbon tax and we give a full interpretation of its level, which is unique. We then study the impacts of three different second-best policies: a carbon tax, a subsidy to sequestered carbon, and a subsidy to labor in CCS.

While all three tools foster CCS activity they generally have contrasting effects on resource extraction, carbon emissions, output and consumption. The carbon tax postpones resource extraction whereas the two subsidies accelerate it. Although the tax decreases short-term carbon emissions, the two subsidies can increase them, thus yielding a green paradox. The tax has a negative impact on the levels of output and consumption in the short-term, unlike the subsidies. The tax generally fosters growth whereas the subsidies reduce it; however, when the weight of the CCS sector in the economy is high, these impacts can be reversed.

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1. Introduction

The exploitation of fossil resources raises two concerns. The first is scarcity, because fossil resources are exhaustible by nature. The second is related to the emission of greenhouse gases associated with their combustion. Numerous models deal with this double issue; some of them in the context of partial equilibrium (e.g. Sinclair, 1992; Withagen, 1994; Ulph and Ulph, 1994; Hoel and Kverndokk, 1996; Farzin and Tahvonen, 1996; Tahvonen, 1997) and others within general equilibrium growth frameworks (e.g. Stollery, 1998; Schou, 2000, 2002; Groth and Schou, 2007; Grimaud and Rouge, 2008). A common feature of these papers lies in the fact that reducing carbon emissions necessarily means extracting less resource. Indeed, there is generally assumed to be a systematic link between resource extraction and polluting emissions, in the form of a simple functional relation (e.g. linear). In terms of economic policy, it is therefore equivalent to taxing either the pollution stream or the resource use itself. Nevertheless, it is now widely recognized that certain abatement technologies allow the reduction of emissions for a given amount of extracted resource. In particular, attention has recently been focused on the possibility of capturing and sequestering some fraction of the carbon embedded in fossil fuels, whether this capture occurs pre- or post-combustion. This has been reinforced by recent demonstrations of viability (for an overview, see IPCC special report, 2005). This process, often referred to as carbon capture and storage or carbon capture and sequestration (CCS), consists in separating carbon from hydrogen in the pre-combustion process or in separating carbon dioxide from other flux gases in the post-combustion process in an energy production plant. Once captured, the CO_2 is injected into a reservoir[1] for long-term storage. The availability of CCS technologies therefore means that the simple relation between resource extraction and carbon emissions is partially broken.

Here we consider the availability of such an abatement technology in the context of a theoretical general equilibrium model with endogenous growth and a polluting exhaustible resource. We study how the socially optimal trajectories of the economy are modified by the availability of the CCS option, and how the first-best outcome can be restored in a decentralized economy. We also study the impact of three different second-best policies: a carbon tax, a subsidy to sequestered carbon and a subsidy to labor in the CCS activity. Endogenous growth allows us in particular to analyze the effects of the availability of CCS technology and the economic policy tools on growth, along the transition path and at the steady-state.

Numerous uncertainties still surround the large-scale deployment of carbon capture technologies, especially with regard to the ecological consequences of massive carbon injection. The social acceptance of this abatement technique is also uncertain - for a survey on these issues, see for instance Jepma and Hauck (2011). Nevertheless, this technological option has become promising for the fossil energy extractive industry. For instance, Grimaud et al. (2011) show in an empirical model that, insofar as the right climate policy is implemented – a carbon tax in their model – the percentage of carbon sequestered can exceed 50%.

We develop a Romer-type endogenous growth model in which the production of final good requires the input of an extracted resource, whose stock is available in limited quantities. This resource use generates polluting emissions, which we take to be CO_2 emissions, whose flow in turn adds to the pre-existing stock of the pollutant – which features partial natural decay. Finally, this stock enters the utility function as an argument, making it possible to gauge how pollution accumulation negatively affects welfare. Here, we implicitly assume that the economy never reaches a critical level of carbon concentration that would yield an infinitely negative utility (for this type of assumption, see for instance Acemoglu et al., 2012). We then consider that a CCS technology is available. Via some effort, it allows for the partial reduction of the level of CO_2 release. We thus distinguish between the total potential CO_2 emissions associated with one unit of fossil resource (or equivalently the total carbon content per unit of resource) and the effective emissions, i.e. the fraction that remains after CO_2 removal. Note that we do not account for geological CO_2 leakage – on this issue, see for instance van der Zwaan and Gerlagh (2009). In this economy, the crucial trade-offs are made between current

[1] The sequestration reservoirs include depleted oil and gas fields, depleted coal mines, or deep saline aquifers. These various deposits differ in their respective capacities, their costs of access or their effectiveness in storing the carbon permanently.