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Abatement, R&D and growth with a pollution ceiling

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ABSTRACT

The consequences of the 2 °C climate target and the implicitly imposed ceiling on CO_2 have been analyzed in several studies. We use an endogenous growth model with a ceiling and an abatement option to study the effect of the ceiling on the allocation of limited funds for R&D, abatement and capital accumulation. It is found that the advantagenousness of abatement rises with the cost advantage of fossil fuel versus backstop. If the cost advantage is sufficiently large at some point in time it outweighs the costs of abatement and the gains of R&D and capital accumulation. The reallocation of production towards abatement may cause an increase or decrease in long-run consumption. In the latter case, abatement allows an intertemporal consumption trade-off which may even justify the disregard of everlasting growth. In case of stock dependent fossil fuel costs, an abatement induced speed-up of technology development may cause an increase in fossil fuel stock left in situ.

1. Introduction

In the last few decades, the concerns about climate change have risen to such levels that a considerable number of nations agreed in the Kyoto Protocol to limit the global temperature increase. Probably the best known political project in this regard is the 2 °C climate target that was finally endorsed by the United Nation Framework Conference on Climate Change in Cancun (UNFCCC, 2010). The basic assumption of the climate target is that the consequences of climate change are manageable as long as the target is met. Otherwise, climate change costs may increase sharply to unaffordable levels. Several technologies can be deployed to keep the global temperature increase below the 2 °C target. The best known ones are probably renewables such as solar, wind, biomass and water power. These energy sources can replace fossil fuel driven energy generation, which is the main source of CO_2 emissions and the driving force of global warming.[1] Recently, with carbon capture and storage (CCS) a new CO_2 abatement technology has been developed that can tackle climate change. The CCS technology separates CO_2 from conventional power plants and stores it in exploited fossil fuel deposits. It thus permit the utilization of fossil fuel while avoiding CO_2 emissions. Other possibilities of CO_2 abatement are the enhancement of fossil fuel efficiency and the switch to less polluting fossil fuels. An example of the former is increasing the efficiency of coal-fired power plants, and switching from coal to natural gas for power generation is an example of the latter.

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[1] 75% of CO_2 emissions stem from burning fossil fuel, cf. Hoel (2011) and Van der Ploeg and Withagen (2012).

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The literature has dealt with climate change in two different ways. On the one hand, a large number of authors explicitly consider the damage caused by CO_2 by assuming a damage function or a negative effect of CO_2 on utility or production. Farzin (1996), Hoel and Kverndokk (1996), Tahvonen (1997), Hoel (2011), and Van der Ploeg and Withagen (2012) follow this approach. On the other hand, Amigues et al. (2014), Chakravorty et al. (2006a), Chakravorty et al. (2006b), Chakravorty et al. (2008), Chakravorty et al. (2012), Coulomb and Henriet (2011), Eichner and Pethig (2013), Henriet (2012), Kollenbach (2014), and Lafforgue et al. (2008) impose an exogenous ceiling on the stock of CO_2 in the atmosphere.[2] Since a maximal concentration of CO_2 is proportional to a maximal temperature rise, the ceiling reflects the 2 °C target.[3] Other international agreements, such as the Montreal Protocol on Substances that Deplete the Ozone Layer, also impose a ceiling on specific concentrations. Therefore, it seems likely, or at least it is to be hoped, that a Kyoto follow up agreement will implicitly or explicitly include a CO_2 ceiling.

As the ceiling is given exogenously, the two approaches answer two different questions. While the first approach determines the first best solution to deal with climate change or, more generally pollution, the second approach asks for the second best solution, given the ceiling. Until recently, the effects of a ceiling were analyzed only in Hotelling type models.[4] Therefore, neither capital nor R&D have been considered, which are both important determinants for economic development and may serve as substitutes for exhaustible fossil fuel. Chakravorty et al. (2012) allow for technological development by assuming a learning-by-doing effect, while Henriet (2012) explicitly considers research. However, Henriet (2012) assumes that research determines the time until a backstop is available. Thus, long term growth cannot be explained by her model. To our knowledge, only Kollenbach (2014) considers capital and continuous research driven technological progress, which reduces the costs of a backstop.[5] By integrating an emission ceiling in the endogenous growth model of Tsur and Zemel (2005), he shows that in the short run the ceiling increases the scarcity of fossil fuel and therefore boosts the attractiveness of research. Consequently, more final goods may be invested in R&D and fewer in capital. However, abatement is not considered by Kollenbach (2014).

Abatement is well known in environmental literature. It has been discussed by Keeler et al. (1972), d'Arge (1971), Smulders and Gradus (1996), Amigues et al. (2014), Chakravorty et al. (2006a), Coulomb and Henriet (2011), Lafforgue et al. (2008), Le Kama et al. (2013), and Hoel and Jensen (2012). All studies use the realistic assumption that abatement is costly. Therefore, it competes with costly research and capital accumulation for limited funds in an endogenous growth model in the vein of Tsur and Zemel (2005) and Kollenbach (2014).[6] This aspect is covered neither by Tsur and Zemel (2005) and Kollenbach (2014) nor by the above-mentioned studies related to abatement, which do not consider capital and R&D. To investigate the trade-off between R&D, capital accumulation and abatement we integrate abatement into the model of Tsur and Zemel (2005) and Kollenbach (2014), respectively.

Abatement expenditures allow a higher extraction rate of cheap fossil fuels without violating the ceiling. Therefore, abatement expenditures imply a reduction of energy costs. If the lower energy costs outweigh not only the costs of abatement but also the gains of capital accumulation and research, positive abatement expenditures are optimal. Thus, the advantageousness of abatement is higher the lower the unit costs of abatement are, and the higher the cost advantage of fossil fuel compared to backstop. The reallocation of production from research and/or capital accumulation towards abatement expenditures allows an intertemporal consumption trade-off. In some cases, e.g. if the impact of capital and technology on production is low and the initial emission stock close to the ceiling, the trade-off implies a lower long-run consumption level, or even the disregard of permanent growth. In the latter case, the abatement option causes a poverty trap. However, abatement expenditures may also increase long-run consumption, e.g. if the reduction of energy costs always outweigh the costs of abatement.

By introducing stock dependent fossil fuel extraction costs, we show that abatement expenditures may alter the total extraction of fossil fuel. If the marginal extraction costs of the last fossil fuel unit are low enough to allow the physical exhaustion of fossil fuel, but not low enough to guarantee it, the physical exhaustion of fossil fuel and the stock left in situ depend on the development of technology. If abatement expenditures speed up (slow down) technological progress, the fossil fuel stock left in situ may be increased (decreased).

The outline of the paper is as follows. In Section 2 we describe the model. The (constrained) social optimum is determined in Section 3. The optimal evolution of the economy is explained in Section 4. Section 5 adds stock dependent fossil fuel extraction costs to the analysis, and Section 6 concludes.

2. Model

We use the framework developed by Tsur and Zemel (2005), which is augmented by a ceiling on CO_2 emissions and an abatement option.[7] In the following, the assumptions of the model are briefly discussed. A composite good $Y = F(K, x)$ is

[2] A more general pollution ceiling was considered by Smulders and Gradus (1996).

[3] According to Graßl et al. (2003) the maximal concentration lies between 400 and 450 ppm, whereas Hansen et al. (2008) advocate a value of 350 ppm to keep the planet as it was during the development of human civilization.

[4] This model type goes back to the seminal work of Hotelling (1931).

[5] The literature concerning the substitution of fossil fuel by capital and/or technology goes back at least to Stiglitz (1974), Solow (1974), Dasgupta and Heal (1974), and Hartwick (1977). Several endogenous growth studies have also analyzed this question, cf. for example Barbier (1999) and Schou (2000). A comprehensive review of the endogenous growth theory covering environmental concerns is given by Pittel (2002).

[6] Another R&D approach, which is used by Acemoglu et al. (2012), assumes a given number of scientists who have to be allocated among R&D sectors or firms.

[7] For a more detailed discussion of the assumption we refer to Tsur and Zemel (2005). The ceiling was already introduced into Tsur and Zemel's (2005) model by Kollenbach (2014). For the sake of simplicity, the time index t is suppressed as long as it is not necessary for understanding.