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Is there really a green paradox? ☆

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ABSTRACT

In the absence of a CO_2 tax, the anticipation of a cheaper renewable backstop increases current emissions of CO_2. Since the date at which renewables are phased in is brought forward and more generally future emissions of CO_2 will decrease, the effect on global warming is unclear. Green welfare falls if the backstop is relatively expensive and full exhaustion of fossil fuels is optimal, but may increase if the backstop is sufficiently cheap relative to the cost of extracting the last drop of fossil fuels plus marginal global warming damages as then it is attractive to leave more fossil fuels unexploited and thus limit CO_2 emissions. We establish these results by analyzing depletion of non-renewable fossil fuels followed by a switch to a clean renewable backstop, paying attention to timing of the switch and the amount of fossil fuels remaining unexploited. We also discuss the potential for limit pricing when the non-renewable resource is owned by a monopolist. Finally, we show that if backstops are already used and more backstops become economically viable as the price of fossil fuels rises, a lower cost of the backstop will either postpone fossil fuel exhaustion or leave more fossil fuel in situ, thus boosting green welfare. However, if a market economy does not internalize global warming externalities and renewables have not kicked in yet, full exhaustion of fossil fuel will occur in finite time and a backstop subsidy always curbs green welfare.

1. Introduction

The accumulation of CO_2 due to the extraction and use of fossil fuels is the main cause of climate change. In a somewhat different context D'Arge and Kogiku [3] cite Boulding [1]: "… the 'pure' mining problem must be coupled with the 'pure' pollution problem and questions like these become relevant: which should we run out first, air to breathe or fossil fuels to pollute the air we breathe?". In the design of optimal climate policy one could neglect the exhaustibility of fossil fuels by arguing that they are abundant until the far future, as is the case for coal or oil from tar sands. However, this may lead to the failure of climate policy. In the absence of renewable resources such as solar or wind energy, some fossil fuels such as

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oil and gas are essentially available in limited amounts (see Edenhofer and Kalkuhl [5]) and their optimal intertemporal use needs to be determined in conjunction with any adverse effects this may have on global warming. The optimal policy of extracting such fossil fuels and combating climate change should take into account the order in which the fuels are to be extracted. In doing so, differences in extraction costs for the various sources of energy as well as differences in the contributions the resources make to climate change play a role. With the availability of renewable backstops these problems persist. In addition, the timing, order and speed of extraction in conjunction with the introduction of the backstop are crucial for future welfare.

Our aim is to first present a dynamic welfare analysis in a world where climate change poses a serious negative externality. We explicitly consider exhaustibility of some fossil fuels, but following the pioneering work of Tahvonen [33] we also study renewable backstops.[1] Backstops are defined in our paper as renewable resources that are perfect substitutes for fossil fuel and not constrained by exhaustibility. By characterizing the first-best outcome and the time path of the optimal carbon tax, we obtain a natural benchmark for considering the second-best policy of subsidizing the carbon-free substitute in a market economy. This is motivated by Sinn's [29,30] argument, building on the earlier contributions by Sinn [27,28], that this, somewhat paradoxically, may have detrimental climate effects. Sinn's 'Green Paradox' has received a lot of attention both in the press and in academia. It is firmly linked to fighting climate change through fossil-fuel demand-reducing policies that are *intended* to flatten the time profile of carbon emissions. The impact of such policies is paradoxical if they steepen rather than flatten the extraction path of fossil fuel—*despite good intentions*. Sinn argues that the paradox occurs if and only if demand-reducing policies become more stringent over time. These arguments have recently also been scrutinized more rigorously by Hoel [17] and Gerlagh [9].

We first derive the socially optimal depletion paths for fossil fuels and use of renewables. Implementing the optimum in a market economy in our model requires a rising carbon tax to internalize global warming externalities, but no subsidy on renewables. Our point of departure is then a market economy where the government has at its disposal a very special form of demand-reducing policy, i.e., a subsidy on renewable energy whose rate is constant over time, which it resorts to when it finds it impossible to levy a rising CO_2 tax. Following Gerlagh [9], one could distinguish a *weak* Green Paradox which occurs if fossil fuel is produced more quickly due to the anticipation of cheaper renewables from a *strong* Green Paradox which says that green welfare falls on account of the subsidy. In this specific, albeit realistic second-best setting we demonstrate that the anticipation of cheaper renewables leads to faster extraction of fossil fuel and raises current emissions of CO_2 (weak Green Paradox). We provide examples where following an increase in the subsidy on the carbon-free backstop green welfare increases (no strong Green Paradox) if it is optimal to leave some of the fossil fuel reserves forever unexploited. But the subsidy leads to quicker exhaustion of fossil fuel and a fall in green welfare (strong Green Paradox) if fossil fuel is fully exhausted in finite time.

We emphasize the following features of our analysis. In the first place, we study in detail the situation where marginal extraction costs of the non-renewable resource depend on the existing stock. It follows that lowering the cost of supplying the renewable backstop may lead to a positive remaining stock of fossil fuel reserves when the backstop price is lower than the marginal extraction costs at low resource stocks.

Secondly, we focus on backstops which do not cause CO_2 emissions such as solar or wind energy, [2] beginning with the case where the unit production costs of the backstop are constant. Whether a backstop technology is cheap relative to fossil fuel depends on its own production cost and the total cost associated with fossil fuel, consisting of the stock dependent extraction costs and the damage caused by the accumulation of CO_2 emissions.[3] Therefore, the relative cheapness of backstops from a social perspective is changing over time with a decreasing stock of fossil fuel and an increasing stock of CO_2.

We pay special attention to the case where these backstops are still relatively expensive, possibly not when it comes to the marginal production costs once capacity is installed but surely when it comes to the costs of increasing capacity, due to intermittence and repair (especially of offshore wind mills). As far as the electricity industry is concerned, solar energy is currently 50% more expensive than conventional electricity, wind energy has the same cost and is (apart from the problem of intermittence) competitive, and biomass, CCS coal/gas and advanced natural gas combined cycle have mark-ups of 10%, 60% and 20%, respectively [21]. These mark-ups for renewable energy sources are measured from a very low base and may

[1] Papers addressing externalities and exhaustibility, but abstracting from a backstop, include Krautkraemer [19], who is mainly interested in preservation in view of amenity values, Withagen [37], who shows that initial use of the exhaustible resource is smaller than without the externality, Ulph and Ulph [36], who deal with optimal (dynamic) taxation of fossil fuels and their detrimental effect on the environment, and Sinclair [26], who argues that with endogenous growth optimal fossil fuel taxes may fall rather than rise over time.

[2] We thus abstract from heavily polluting and expensive backstops [23]. An example of this is the tar sands, because their reserves are much larger than conventional oil and gas reserves. Although burning oil from tar sands yields the same emissions as burning conventional oil, a lot of energy is used in producing oil from tar sands and therefore CO_2 emissions are much higher. In a recent study for the European Commission, Brandt [2] reports that emissions of greenhouse gases are on average 23% higher than from conventional oil, and in some cases much more. This has led the EU to consider a ban on oil from tar sands. Tar sands also adversely affect the livelihood of indigenous communities via large-scale leakage of toxic waste in groundwater and destruction of ancient forests larger than the size of England. We also abstract from coal which is heavily polluting (emissions from coal-fired plants are 30% higher than oil-fired plants), but cheap to exploit (depending on location and soil characteristics). Also, the process of making coal liquid so that it can be a substitute for oil in transportation takes a lot of energy.

[3] Useful studies on the costs of producing various renewable and non-renewable forms of energy are Shihab Eldin [25], European Commission [8], Neuhoff [20] and Paltsev et al. [21]. Some care must be taken, since the costs vary much across studies. Part of the reason is that the costs depend on which application energy is used.