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Brown backstops versus the green paradox

Thomas O. Michielsen

New College, University of Oxford, Oxford OX1 3BN, United Kingdom

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ABSTRACT

Anticipated climate policies are ineffective when fossil fuel owners respond by shifting supply intertemporally (the green paradox). This mechanism relies crucially on the exhaustibility of fossil fuels. We analyze the effect of anticipated climate policies on emissions in a simple model with two fossil fuels: one scarce and dirty (e.g. oil), the other abundant and dirtier (e.g. coal). We derive conditions for a 'green orthodox': anticipated climate policies may reduce current emissions. The model can also be used to analyze spatial carbon leakage. Calibrations suggest that intertemporal carbon leakage (from 0% to 8%) is a relatively minor concern.

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Introduction

Well-intended climate policies may have perverse effects. Climate policies typically become stricter over time. Fossil fuel owners, deciding when to sell their scarce resources, may respond by speeding up extraction. This side effect can occur when fossil fuel reserves are limited and cheap to exploit: a reasonable characterization for conventional oil and natural gas, but much less for other important energy sources such as coal and unconventional oil. In this paper we ask whether climate policy has unintended consequences when there are two types of fossil fuels: one dirty and scarce, the other even dirtier and abundant.

Policies that reduce future dependence on fossil fuels might encourage suppliers, anticipating a future drop in demand, to bring forward the extraction of their resources. When present emissions are more harmful than future emissions, increasing carbon taxes can be counterproductive: a green paradox (Sinn, 2008a). Developing a carbon-free substitute for fossil fuels can cause a similar effect (Strand, 2007; Hoel, 2011). Cost reductions for the substitute decrease the scarcity value of fossil fuels, and thereby increase fossil fuel supply in all periods before exhaustion.[1]

The crucial feature that drives the above mechanism is the exhaustibility of the resource. This causes the tradeoff between current and future supply, and thus the effect of (expected) future policies on current supply and emissions. If the resource is fully abundant, resource owners supply the myopically optimal quantity in each period and the link between current and future markets is severed. Exhaustibility is a fair assumption for conventional oil and natural gas, which will be depleted in 50 to 70 years at current consumption rates.[2] Coal and unconventional oil are much more abundant however.

E-mail addresses: thomas.michielsen@new.ox.ac.uk, thomiks@gmx.net

[1] The green paradox may vanish when the substitute has an upward-sloping supply curve (Gerlagh, 2011). van der Ploeg and Withagen (2012a) find that the green paradox occurs for clean but expensive backstops (such as solar or wind), but not when the backstop is sufficiently cheap relative to emissions damages, as it is then attractive to leave part of the oil in the ground.

[2] BP (2010, p. 6, p. 12).

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Coal reserves are sufficient to last another 250 years, and tar sand deposits in Alberta are estimated at 1800 bln barrels.[3] The supply of these resources is primarily driven by costs rather than scarcity rents. Anticipated carbon taxes cause coal mines to shut down in the future, but do not increase near-term supply.

Coal and unconventional oil are significant from an economic and a climate change point of view. Coal satisfies a third of global energy demand and accounts for almost half of energy-related CO_2 emissions,[4] outranking petroleum in emission intensity by 30–40%. The IEA expects coal supply to increase by 60% in 2035 under business-as-usual policies[5]: twice as much as the projected increase in oil supply. Supply of unconventional oil, which is 20% more emission-intensive than petroleum (Charpentier et al., 2009), may increase fivefold to 11 mln barrels per day in 2035. These numbers suggest that in order to keep climate change within tolerable limits, it is imperative that coal and unconventional oil reserves remain largely unexploited (Gerlagh, 2011). A comprehensive assessment of the effectiveness of climate policies should take into account these dirty substitutes and their unique characteristics.[6,7]

In this paper, we develop a simple model with two time periods. We do not derive optimal policies, but present a descriptive analysis of the effect of future climate policies on emissions. We generalize assumptions in previous research along two important dimensions. Firstly, the model contains three energy types: a dirty exhaustible resource (e.g. oil), an even dirtier substitute (coal) and a clean substitute (solar). Secondly, we assume types to be imperfect substitutes for one another. Previous theoretical studies often assume perfect substitution (e.g. Hoel, 2011; van der Ploeg and Withagen, 2012a), which is unrealistic. We model climate policy as a future carbon tax or a decrease in the cost of the clean substitute. We calculate intertemporal carbon leakage as the increase in present emissions over the decrease in future emissions.

By virtue of the abundance of their resource, we assume that coal owners do not trade off present and future extraction. When faced with a demand reduction in the future, they will therefore not increase supply today. Oil emissions may leak away to the present, but the increase in current oil supply reduces demand for dirtier coal. Carbon taxes can cause negative leakage when the substitutability between oil and coal differs between periods. We may call this a 'strong green orthodox' (Grafton et al., 2012). Moreover, since carbon taxes decrease the price of oil relative to coal, a future tax delays rather than accelerates oil extraction when oil and coal are good substitutes in the future. Reducing the future cost of solar decreases present emissions when oil and coal are good substitutes or if the emission-intensity of coal is high.

Our contribution is twofold. Firstly, we offer a general theoretical framework that can make more accurate predictions than models that include only one or two energy types or assume perfect substitutability. The presence of an abundant dirty substitute reduces intertemporal leakage directly and indirectly, and may even cause negative leakage rates. By making more specific assumptions, we can obtain similar findings as in other papers on the green paradox. Secondly, our model is well-suited for empirical calibration. For carbon taxes, intertemporal leakage rates are less than 3%. For reductions in the future cost of renewables, leakage is between 7 and 8% for bioenergy, and 5% for renewable electricity. Bioenergy is a close substitute for oil, the most emission-intensive scarce fossil fuel, and hence more prone to intertemporal leakage than renewable electricity, which primarily competes with coal.

Though we focus on intertemporal leakage, our framework can also be used to analyze spatial carbon leakage, by relabeling the two time periods as two countries and setting the interest rate to zero. Calibrating a spatial version of the model, we find leakage rates ranging from 9% to 16%, within the range of estimates from computable general equilibrium models (Bohringer et al., 2012; Di Maria and van der Werf, 2012). These findings suggest that the green paradox is a small concern relative to spatial carbon leakage.

The rest of this paper is organized as follows. The section "Model" outlines the model. The section "Emission taxes" analyzes intertemporal and spatial leakages when carbon emissions are taxed in the future. The section "A cheaper clean backstop" studies the impact of reductions in the future cost of a clean substitute. We calibrate the models in the section "Empirical calibration". The section "Spatial carbon leakage" discusses implications of the model for spatial carbon leakage, and calibrates a spatial version of the model. The section "Conclusion" concludes. All proofs are relegated to the Appendix.

Model

Consider a model with three types of energy: an exhaustible resource, a dirty backstop and a clean backstop. The backstops are inexhaustible, supplied competitively and have constant marginal costs.[8] Though the word 'backstop' is sometimes used to denote a perfect substitute for an exhaustible resource, we explicitly allow for imperfect substitutability. The exhaustible resource is supplied competitively by a group of energy exporters and costless to extract. For the energy exporters, it is always optimal to fully exhaust the fossil resource stock S.[9] An energy-importing country derives utility from

[3] Alberta's Energy Reserves 2010 and Supply/Demand Outlook 2011–2020, p. 5.

[4] International Energy Statistics, Energy Information Administration.

[5] IEA (2010b,p. 201).

[6] van der Ploeg and Withagen (2012b) show that rising carbon taxes may not cause a green paradox when coal, rather than renewables, is the primary alternative for oil.

[7] Chakravorty et al. (1997) simulate a model with endogenous substitution between three fossil fuels and renewable energy, and find that cost reductions for renewable energy can greatly reduce climate change. Even with moderate cost reductions for renewables, more than 90% of global coal reserves will remain unexploited.

[8] An upward-sloping supply curve for the clean backstop reduces intertemporal carbon leakage (Gerlagh, 2011).

[9] Relaxing this assumption reduces intertemporal leakage (van der Ploeg and Withagen, 2012a; Fischer and Salant, 2010).

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