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International capital markets, oil producers and the Green Paradox

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ABSTRACT

A rapidly rising carbon tax leads to faster extraction of fossil fuels and accelerates global warming. We analyze how general equilibrium effects operating through the international capital market affect this Green Paradox. In a two-region, two-period world with identical homothetic preferences and without investment, the global interest rate falls and the Green Paradox weakens. With investment or a relatively more impatient oil-importing region, the Green Paradox may be strengthened because the future oil demand function shifts downward or because the interest rate rises. If the oil-importing region is very much more patient than the oil-exporting region, the Green Paradox may be reversed but in our calibrated model the effects are tiny. With exploration and endogenous initial oil reserves, a future carbon tax lowers cumulative oil extraction in partial equilibrium. If the boost to current oil extraction is weakened, strengthened or reversed in general equilibrium, so is the fall in cumulative extraction. A partial and general equilibrium welfare analysis of a future carbon tax, both for full and partial exhaustion, is given. The effects of stock-dependent extraction costs are separately discussed in an Appendix.

1. Introduction

The idea that a rapidly rising carbon tax or a subsidy for renewable energy encourages oil producers to extract oil more quickly[1] and accelerates global warming has gained traction and is known as the Green Paradox (cf. Sinn, 2008, 2012; Gerlagh, 2011). The underlying mechanism is that a future carbon tax forces oil producers to supply less oil in the future due to lower future demand, which implies that current oil supply goes up. This pushes the current oil price down and therefore boosts today's demand for oil. This is true when a given stock of oil is fully exhausted, but the effect is also present when stock-dependent extraction costs lead to partial exhaustion of reserves albeit that more of reserves are left abandoned.

It is well understood under which conditions the Green Paradox manifests itself in partial equilibrium settings, where the level of investment and the interest rate are taken as given (cf. Sinn, 2008, 2012; Gerlagh, 2011).[2] However, front-loading of oil extraction also influences the global supply of savings and the demand for capital, so that the interest rate must adjust to

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[1] We refer throughout to 'oil' as short-hand for 'exhaustible fossil fuel resources' such as oil, natural gas and coal.

[2] Studying climate policy in a partial equilibrium framework gives rise to an inconsistency. On the one hand, single-country models with a given interest rate such as Sinn (2008) should be interpreted as models of the entire world economy, because climate change is a global problem. On the other hand, the justification for assuming the interest as given is that we deal with an open economy that is so small compared to the rest of the world that we can neglect its influence on the interest rate. Therefore, it seems a serious shortcoming to abstract from general equilibrium effects of climate policy. We thank an anonymous referee for pointing this out.

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clear bonds and capital markets. Although integrated assessment models of climate change like DICE and RICE typically do allow for endogenous changes in investment and the interest rate (cf. Nordhaus, 1992; Nordhaus and Yang, 1996; van der Ploeg and Withagen, 2014; Golosov et al., 2014; Rezai and van der Ploeg, 2014), they do not provide a decomposition analysis to assess the importance of effects operating through the international capital market for the Green Paradox.

Intuition suggests that a rapidly rising carbon tax increases current output relative to future output, which boosts global savings and depresses the global interest rate. The lower interest rate flattens the equilibrium oil price path and induces less current oil demand relative to future oil demand, which leads to less current extraction relative to future extraction. However, in general equilibrium changes in the wealth positions of oil importers and oil exporters due to climate policy will affect the interest rate as well. Moreover, changes in investment will impinge on future oil demand. Our objective is to gain a better understanding of these general equilibrium effects and to show that the benchmark general equilibrium result of mitigation of the Green Paradox is not robust when we allow for investment or when we allow for asymmetric preferences between oil importers and oil exporters. It is then possible that the Green Paradox is reinforced or reversed in general equilibrium.

We use a two-country, two-period model of oil importers and oil producers, where the interest rate and current and future real oil prices are determined from the conditions for clearing the markets for financial assets and oil, and the Hotelling rule governs optimal oil extraction (cf. Dixit, 1981; Marion and Svensson, 1984; van Wijnbergen, 1985; Djajić, 1988). We suppose that all markets operate under perfect competition and that only the oil-importing countries produce final goods which can be used for consumption and investment. We analyze the effects of changes in future carbon taxes on current oil extraction and the interest rate. In addition, we are interested in the amount of oil that is left unexploited in the crust of the earth as this affects the ultimate degree of global warming. We focus on changes in future taxes instead of optimal climate policy (typically requiring immediate action), because in reality gradually greening policies are observed and strong current action is lacking.

In general equilibrium the interest rate plays a role on both the production and consumption side of the economy. Demand for oil depends on oil prices, which are intertemporally related via the Hotelling rule and feature the interest rate as the opportunity cost of conserving oil. Furthermore, the level of investment depends on the interest rate, because it determines the marginal cost of renting a unit of capital. On the demand side the interest rate determines the relative price of current and future consumption. Moreover, each region's wealth is affected by the interest rate. The interplay between these aspects drives the direction of the change in the interest rate induced by climate policy. The importance of investment for the Green Paradox arises from the imperfect substitutability of capital and oil, which implies that changes in investment shift the future oil demand function. The effects on the interest rate and investment together determine the general equilibrium repercussions for the Green Paradox.

Starting with the case of full exhaustion without extraction and exploration cost we demonstrate that in general equilibrium the Green Paradox induced by a future carbon tax is mitigated if oil importers and oil exporters have identical homothetic preferences over current and future consumption and there are no investment possibilities. Although our results suggest that mitigation is still the most likely outcome under more general conditions with investment possibilities and asymmetric preferences between regions, we are also able to construct cases under which strengthening or reversal of the Green Paradox occurs. In particular, we show that a reversal can occur if oil producers are very much more impatient than oil importers, but in our calibrated model the effects are tiny. Strengthening of the Green Paradox can occur if oil producers are relatively patient or if there is investment in physical capital. When investment in physical capital is possible, it is less likely that the Green Paradox will be reversed. Accounting for partial exhaustion of the stock of oil reserves by imposing exploration costs, we show that in partial equilibrium a future carbon tax ensures that more oil will be locked in the crust of the earth. We demonstrate that general equilibrium effects have similar repercussions for cumulative extraction as they have for current extraction. Our welfare analysis shows that 'green welfare' goes down in the calibrated model with full exhaustion upon an increase in the future carbon tax, but goes up in the specification with partial exhaustion. Furthermore, the welfare analysis suggests that the difference in green welfare effects between the partial and general equilibrium model are small.

Besides general equilibrium effects, there are at least five other factors driving in the direction of a mitigated Green Paradox that we obtain in our case with identical homothetic preferences without investment. First, Hart and Spiro (2011, p. 7834) reported that "scarcity rents seem to have been marginal or non-existent empirically", so that Green Paradox effects will not be large. Potential explanations for this observation are a finite planning horizon of resource owners (Spiro, 2014) and endogenous field openings (Venables, 2015). Moreover, the emerging abundance of shale gas and other forms of unconventional fossil energy reserves might curb existing Hotelling rents even further. Second, a heavily polluting backstop alongside oil and clean renewable resources tends to mitigate the Green Paradox (van der Ploeg and Withagen, 2012b; Michielsen, 2014). Third, if extraction costs of fossil fuel increase with subsoil reserves, climate policy potentially decreases cumulative extraction and cumulative carbon emissions, the beneficial welfare effects of which mitigate the adverse welfare effects of Green Paradox (e.g., Hoel, 2012; van der Ploeg and Withagen, 2012a; van der Ploeg, 2014). Fourth, learning by doing in the renewables sector can mitigate the Green Paradox (Nachtigall and Rübbelke, 2014). Finally, the Green Paradox that occurs after subsidizing renewables might be mitigated if fossil and renewable energy are used simultaneously due to increasing marginal production costs of renewables (cf. van der Ploeg and Withagen, 2012a; Grafton et al., 2013) or imperfect substitution between fossil and renewable resources (Michielsen, 2014).

The model that we use in our analysis is closely related to the models in Eichner and Pehtig (2011) and Ritter and Schopf (2014). Eichner and Pehtig (2011) study unilateral climate policies in a two-period, three-country model with a finite endowment of oil. Next to the oil-exporting region and the oil-importing region that imposes or strengthens climate policies, they also take into account a second, 'non-abating' oil-importing region. In this setting, they explore conditions under which