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On the Relevance of Green Paradoxes

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On the relevance of Green Paradoxes

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Global warming is caused by accumulation of CO2 in the atmosphere. A substantial part of this comes from burning fossil fuel, but increasingly it is also caused by the energy-intensive process of extraction fossil fuel such as the tar sands. Climate change can be mitigated by curbing fossil fuel demand by becoming more energy-efficient, switching demand from fossil fuels such as coal and tar sands to others such as gas which do less harm when it comes to global warming, substituting fossil fuel for renewables, making fossil fuel obsolete by locking more fossil fuel in the crust of the earth, capture and storage of CO2, and moving the direction of technical progress from dirty to clean growth.

Pricing carbon and supporting climate policies

A credibly announced time path of future carbon taxes suitably differentiated for the carbon content of the different types of fossil fuel can deliver the appropriate mitigation measures. What matters is that carbon is priced appropriately which can be achieved with a market for emission permits as well as with an appropriate carbon tax. If global warming is the only externality, pricing carbon will mitigate climate change by encouraging all of the aforementioned forms of curbing fossil fuel. In addition, it will encourage the market to invest in alternative carbon-extensive forms of energy and to invest in R&D directed at carbon-free renewables.

Although global warming is probably the most important externality facing our planet today, there may be many other market imperfections to do with climate change which require government intervention. For example, if there are network externalities leading to insufficient pipelines for transporting CO2, sequestration subsidies are needed to deliver CCS. Also, if markets fail to deliver sufficient green R&D (perhaps due the absence of effective patent markets) investment subsidies are called for. If climate change is mitigated insufficiently, climate adaptation measures such as dykes and other water defences are necessary. Although we will not dwell on these here, they often require government intervention because the benefits of adaptation accrue to many citizens and companies and are easily internalized, especially in developing economies which are most vulnerable.

Government failure and the Green Paradox

Government failure arises for many reasons such as capture by anti-climate lobbies consisting of companies that emit a lot of carbon. The most blatant forms of government failure occur if dirty fossil fuels such as petrol, coal in electricity generation or tar sands are subsidized rather than taxed. Another reason for government failure is that the governments of the planet find it due to all kinds of free-rider behaviour hard to cooperate and set an appropriate global carbon tax. For example, if a subset of countries (the Kyoto countries for short) levies a carbon tax and the non-Kyoto countries do not, then in the Kyoto countries consumer prices of fossil fuel rise whilst due to tax incidence producer prices fall throughout the world. This limits carbon emissions in the Kyoto countries, but boosts carbon emissions in the non-Kyoto countries. This so-called carbon leakage renders carbon taxation less productive.

Unintended effects can also occur if renewables such as solar or wind energy are subsidized when there is no political support for pricing carbon appropriately, because this encourages fossil fuel owners to extract their reserves more vigorously and lead to more rapid burning of fossil fuel. The resulting acceleration of global warming has been coined the Green Paradox (Sinn, 2008a,b). In the remainder we aim to shed light on the various guises the Green Paradox can take. This requires understanding of the fundamental arbitrage principle in resource economics, the Hotelling rule. It also requires understanding of first-best climate policies and modelling of the carbon stocks in the crust of the earth and the atmosphere as well as the exhaustibility of fossil fuel. We also study backstops, which are defined as renewable resources that are perfect substitutes for fossil fuel and are not constrained by exhaustibility. The optimal climate policy also needs to take account of the optimal order in which fossil fuels have to be extracted.

The Hotelling Rule.

In understanding Green Paradoxes the so-called Hotelling Rule, after the author of one of the seminal papers on resource economics (Hotelling, 1931), plays a crucial role. Oil in the ground can be considered as an asset that earns a rate of return, just as capital. If the interest rate is given, at say 2% per year, and if there are no extraction costs, the owner of an oil well is only willing to supply oil in two consecutive years if the oil price increases by 2%. If the increase would be smaller than 2%, the well owner would make a larger profit by supplying this year rather than next year, and vice versa. Extraction costs do not change the picture in an essential way. The net revenues, consisting of the market price minus the extraction costs, should increase at a rate equal to the interest rate, if demand in two adjacent periods is positive and should be met, as is the case in equilibrium. The rule should be modified to make it more realistic. For example, if the market is non-competitive, marginal rents should increase at the rate of interest. But if demand is iso-elastic and extraction costs are negligible, the Hotelling rule is unaffected as prices still increase at the market rate of interest. Also, a risk premium can be introduced in the Hotelling rule as keeping oil in the ground exposes one to volatile oil prices.

Is the green paradox merely a short-run inconvenience?

If renewables are available at a certain cost, say a fixed constant cost per unit, and if demand can also be met by these renewables, then this backstop cost puts an upper limit on the oil price. At the time of the switch to the carbon-free era, the price of oil must equal the price of renewables. The suppliers of oil, being aware of this time path of oil prices, will make sure that their stock is either fully depleted once the backstop price is reached, or they will equalize extraction cost including any carbon tax that may be levied and the backstop cost. The distinction between these two cases is crucial for understanding the green paradox (e.g., Hoel, 2011, 2013; van der Ploeg and Withagen, 2012a). In the former case a small subsidy on the backstop will not lead to leaving more oil in situ. All oil will be extracted anyway. But, given the now lower upper bound, oil will be extracted at a faster rate. This is precisely the green paradox: more extraction, earlier exhaustion and higher damages from climate change.

Consider now the second case where extraction costs depend on the remaining stock of oil reserves to reflect that extraction becomes more costly as less accessible reserves have to be explored. Matters then change drastically. A higher carbon tax or a subsidy to renewables encourages the market to leave more oil locked up in the crust of the earth, since extraction costs will at the switch to the carbon-free era have to be lower and this can occur only if more accessible reserves remain untouched. Hence, even though oil is extracted more rapidly, the total amount of oil extracted will fall. More oil is thus left in situ and cumulative CO2 emissions will be less. The effect on green welfare is ambiguous. For example, it may be positive if the future is discounted at a low rate and negative otherwise. However, cumulative emissions are likely to be most important in the fight against global warming and in this sense the green paradox can be seen as merely a short-run nuisance.

> A more detailed policy analysis must include the short-run changes in oil supply and the effect on global warming damages, but also the effect on total welfare, of which damages are just a part. Then one has to take into account that the instrument chosen, a subsidy, is not the most appropriate instrument. The climate problem is caused by CO2 accumulation. This externality should then be "solved" by taxing emissions, according to the damage they inflict. This will yield a first-best outcome. At best a subsidy is only second-best, because it has distortive effects. This is not to say that a carbon tax is always to be preferred. If the carbon tax does not precisely reflect marginal damages, then the distortion problem arises as well.

Limitations and extensions

In spite of the fact that the above discussion illustrates the issues at stake, it suffers from several shortcomings such as the perfect substitutability of energy sources (e.g., intermittent solar energy is not a substitute for oil), the exogenous fixed and constant rate of interest (i.e., the lack of macroeconomic underpinning), the lack of strategic non-competitive behaviour of oil-producing countries, the high level of aggregation not allowing for strategic and trade interactions between countries with different climate ambitions, perfect competition on the energy markets, the neglect of the relationship between growth and climate, etc. Here we delve into three of these issues a little bit more deeply.

a. Dirty backstops

We have already explained that stock-dependent extraction costs may lead to a mitigation or reversal of the green paradox if it leads to more oil left in the ground. Then physical exhaustibility is not the real problem. However, there are other energy sources that are abundant per se and whose extraction cost to all practical intents and purposes does not pose a limit on total extraction. This holds for coal and probably also for tar sands and shale gas. This does not mean that we do not have to worry about the green paradox. It is still important to know in what order resources should be exploited from a social welfare perspective, taking account of climate damages, and how such an optimum can be implemented in a market economy with the use of first-best or second-best policies (van der Ploeg and Withagen, 2012b). In a pure market context we extract the reserves which are easiest to extract first according to the so-called Herfindahl rule, but that need not be the case if one has to take account of climate externalities.

For example, coal will be abundant, cheap and dirty for still a long period of time to come, which may prevent the large scale introduction of renewables based on a myopic cost benefit analysis. But if account is taken of the harm by CO2 emissions there is a clear case for introducing renewables at an earlier stage than the market economy would do. Absent a proper carbon tax this will require a subsidy that is high enough to let coal use be banned: a moratorium on coal. Alternatively, a prohibitive coal tax can be imposed. One of the problems is of course the timing of the implementation of these policy measures. Some empirical work has been done in this field. However, given the huge uncertainties surrounding extraction costs and the positive and negative feedbacks in the carbon cycle, much more research needs to be done before sound policy proposals can be made.

Of particular relevance is the fact that the rapid emergence of new reserves of natural gas will change the terms of the climate policy debate. Gas is a good substitute for coal in electricity generation and a good substitute for oil in many applications, but not much oil is used to generate electricity and not much coal is used for petrochemicals. Oil and gas are thus not perfect substitutes and climate policy needs to take account of that.

b. Strategic interactions

Another weakness of the research performed so far is the emphasis on the global economy. This is important for several reasons. Since climate change is a global externality caused by greenhouse gases accumulation, a uniformly mixing pollutant, a solution calls for coordinated action. Such an action could in principle work to the advantages of all jurisdictions involved. But, as is illustrated by the difficulties to reach agreements on climate policies, the fact that all jurisdictions pursue their own (mostly short-term) interest will not lead to the first-best outcome. It is important to investigate what the likely outcomes will be in these more realistic circumstances. Another reason, related to the previous one, is that one important variable, namely the interest rate, can no longer be considered exogenous, but becomes part of the dynamic general equilibrium with many participating countries and markets. All this leads to challenging additional questions and extensions. One relevant question is whether in this decentralized framework green paradoxes are reinforced or attenuated.

A simple way of tackling this is to start by studying a world with one block of countries being endowed with fossil fuel, whereas other countries use oil and augmentable manmade capital to produce a tradable good. The latter countries also have the capacity to produce a backstop. Typically, ignoring extraction costs, the endogeneity of the interest rate will *mitigate* the green paradox. A future increase of a carbon tax in the oil-demanding country leads to a higher future producer price of oil in this country. At the same time the future interest rate has to be lower, because otherwise future demand for oil and capital input, and hence output, would decrease, whereas future demand for the final good increases (because it becomes cheap relative to present consumption), which can reasonably be ruled out in an equilibrium. So, today’s oil price, which equals the discounted future world market price, goes up more than if the interest rate were constant. This weakens the green paradox. The more rapid extraction of oil resulting from the green paradox is thus mitigated by the lower return on extracting assets. What is going on is that the more rapid extraction implies that oil producers have more revenue upfront and save more. The resulting increase in demand for financial assets implies that asset holders can be paid a lower interest rate and still hold the assets they wish to hold.

More generally, an effective climate policy hurts oil producers and an optimal carbon tax will contain an import tariff component to capture some of the oil scarcity rents (Liski and Tahvonen, 2004). Similarly, the oil producers will attempt to capture some of the climate rents in a strategic setting. One would also need to consider the strategic implications of oil producers restricting oil production to push up prices and gain revenue to pacify a boisterous population because this will make shale gas reserves in oil-importing countries profitable and will also encourage the introduction of hitherto unused renewables. Exerting monopoly power in the short run may thus lead to undermining of monopoly power in the long run. Also, it is important to analyze the strategic interactions between Kyoto and non-Kyoto blocks of countries. In this context, it is important to investigate carbon leakage when carbon taxes are set unilaterally in the presence of perfect future markets (Eichner and Pehtig, 2011). It is of interest to investigate whether a unilateral climate policy of the oil-importing block leads to dumping of oil on the market and many other important policy issues to do with strategic interactions. Such questions are still subject to current research.

Macroeconomics of growth and climate change

Most of the climate economics literature adopts a partial equilibrium framework. As just discussed, it is crucial to allow for capital markets and the determinants of global interest rates. More generally, it is important to cast the optimal climate policy in a framework of growth and development as in the initial stage of development there will be less appetite for fighting global warming than in the latter stages for development, and the nature of the dynamic paths depends crucially on the initial stocks of fossil fuel and manmade capital (e.g., van der Ploeg and Withagen, 2012c). It is also important to depart from the Ramsey growth model. Endogenous growth models with directed technical change stress the importance of subsidies to green research & development in order to kick-start green innovation and redirect the economy towards green growth (e.g., Acemoglu et al., 2012). The carbon tax then plays a much more modes role.

Empirics

Empirical analyses of the green paradox are severely hampered by the short history of climate policy. The literature assessing the empirical relevance of the Hotelling reaches ambiguous conclusions. Moreover, climate policies have not necessarily tightened over the last years. For example carbon taxation of oil products in OECD countries did not increase substantially from 1995 to 2010. However, one example relates to the discoveries of Dutch natural gas in the 1960s, because the initial plan was to extract gas reserves very fast as it was thought that nuclear energy would become the predominant way of producing electricity. Apart from this, it is safe to say that a sound econometric analysis cannot be performed given the present state of the available data. What can be done, and has been done, is to construct theoretical models that are calibrated numerically using empirical estimates for elasticities, parameters and exogenous variables (e.g., Michielsen, 2011). The conclusion is that green paradox effects are not important, since coal is important and natural gas has become much more abundant in recent years.

Uncertainty also refers to the extraction costs for fossil resources or costs of alternative renewable energies. Even estimates of current extraction costs are difficult to verify as they are usually private information of extracting firms. Estimates are furthermore subject to technological uncertainty. Further examples for data uncertainty are the estimates for reserves and resources of oil, coal and gas. Geological data derived from exploration activities are subject to interpretation and judgment. For renewables the data situation is even worse. To which degree this technological potential translates into ‘economic’ potential is difficult to assess given the still relatively high learning rates with respect to solar and also, to a lesser extent, with respect to wind.

Conclusion

The evidence for the existence of green paradoxes is not overwhelming. Neither economic theory nor the scarce empirical literature provides strong indications that green paradoxes are a clinching feature in the discussion of the optimal climate policy. The first-best policy is to have an effective and rising global price for carbon. Second-best policies such as a renewables subsidy or a future carbon tax cause short-run green paradox effects, but apart from this acceleration of extraction such policies reduce the total stock of fossil fuel that is left in the ground and thus curbs cumulative carbon emissions. The latter effect is bound to be more crucial in the fight against global warming, especially for low discount rates. Hence, further empirical work on multi-country models of international trade in the presence of backstops is in order. Also more attention should be paid to the strategic interaction between jurisdictions, based on their market power and objectives.

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