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Introductory Comment

The Green Paradox: A Supply-Side View of the Climate Problem

Hans-Werner Sinn*

The climate problem is one of mankind's biggest challenges. Averting disaster requires nothing less than worldwide collective policy action. However, policies that ignore the laws of economics may prove futile, if not downright counterproductive. In particular, policies aimed at reducing future demand for fossil fuels could backfire by inducing resource owners to bring forward their extraction plans, thus accelerating global warming. I have called this behaviour the Green Paradox.

Economists and policy makers alike long overlooked the possibility of a Green Paradox because the behaviour of resource owners played no specific role in the economics of climate change. Although it has long been recognized that the anthropogenic carbon accumulating in the atmosphere is basically the same as the carbon taken from the ground and that, except for sequestration, no technical devices exist that could change the proportions accumulating in the sea, biomass, and atmosphere, this has rarely been incorporated into climate models or addressed by policy makers in the past. Instead the focus was on the demand side of the market. It was thought that to mitigate the climate problem, it would be effective and sufficient to require better insulation of homes, to extract higher mileage from car engines, to subsidize green energy through tariffs, to morally discredit fossil fuel consumption, to tax the use of fossil fuels, or to subsidize the development of green technologies, because it was taken for granted that supply would follow demand. Resource suppliers were perceived to be like car producers, facing flat marginal cost curves and producing what is demanded at given prices. However, unlike cars, fossil resources sold in the market are already there (i.e., in the earth's crust) and thus cannot be "produced" in the normal sense of the word. Extraction and exploration costs are typically small relative to user costs. This means that we cannot assume that the supply reactions of resource owners will be elastic.

Fortunately, the period of ignoring the obvious appears to be coming to an end. Although the supply-side view of the climate problem is not yet widely recognized by the public, both the Intergovernmental Panel on Climate Change and the literature on the economics of climate change are now giving at least as much weight to the supply side as to the demand side. The focus is on the intertemporal dimension of supply decisions, merging the traditional theory of

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exhaustible resources with the theory of climate change. Exhausting the stock of carbon resources in the ground and accumulating waste carbon in the atmosphere are now viewed and modelled as a single decision.

The Hotelling View

In the spirit of Hotelling (1931), the new models typically assume that resource owners optimize the composition of their wealth portfolios, with wealth consisting of both the physical resource in the ground and the financial wealth that can result from extracting and selling some of the resource. Ideally, resource owners will choose portfolios that equate the rates of return on both the physical and financial assets. However, resource owners are blind to the carbon externality they cause.

Under the Hotelling rule, it is essential that resource owners be forward-looking (i.e., that they base their behaviour on *expectations* of future prices). This means that policies aimed at limiting or reducing the possibility of generating resource-derived revenues in the future will induce resource owners to bring their sales forward to the present. This, in turn, will depress current market prices and increase resource demand, thus accelerating global warming.

The Green Paradox, Fossil Fuel Prices, and Overextraction

In my view, the Green Paradox is not simply a theoretical possibility. I believe it explains why fossil fuel prices have failed to rise since the 1980s, despite decreasing stocks of fossil fuels and the vigorous growth of the world economy. The emergence of green policy movements around the world, rising public awareness of the climate problem, and increased calls for demand-reducing policy measures, ranging from taxes and demand constraints to subsidies on green technologies, have alarmed resource owners. In fact, while most of us perceived these developments as a breakthrough in the battle against global warming, resource owners viewed them as efforts that threatened to destroy their markets. Thus, in anticipation of the implementation of these policies, they accelerated their extraction of fossil fuels, bringing about decades of low energy prices. In fact, as of this writing (April 2015), oil prices, in real terms, are at about the same levels as just *before* the May 1979 price jump that led to the second oil crisis.

Concerns about the increasing influence of environmental activists may also explain the strange behaviour of the owners of German lignite fields. While Germany's lignite resources rank tenth in the world and account for less than 2 percent of the available global stock, its 17 percent market share makes it the world's leader in terms of current extraction. What else but fear of threats from Germany's Green Party—arguably the world's most powerful environmental party—to close lignite mines and prohibit extraction can explain this behaviour?

Of course there are probably other reasons for overextraction, including rising political tensions in the Middle East, which have increased the threat of expropriation. However, this only heightens the risk of global warming. For resource owners, it does not matter whether expropriation occurs through a coup d'état in a particular country, or through pressure from environmentalists to reduce dependence on fossil fuels. In either case, resource owners will seek to protect their interests by bringing at least some of their extraction forward.

This symposium on the Green Paradox and Climate Policy contains three important review articles written by experts in the field (Jensen et al. 2015; Long 2015; and van der Ploeg and Withagen 2015). The articles primarily present the theoretical literature because there has been very little empirical research on the Green Paradox to date. Using different models of fossil fuel extraction, they examine the impacts of a variety of announced or implemented green policies, focusing on the roles of stock-dependent extraction costs, spatially differentiated policies, and backstop technologies, in order to identify when well-intentioned policies are likely to backfire and result in a Green Paradox outcome. Overall, they find that the literature confirms the risk of Green Paradox outcomes and strengthens the case for taking a supply-side view of the climate problem.

While it is not possible to review the symposium articles in detail here, I would still like to comment on some of the key issues they raise.

The Price Wedge

My work on the Green Paradox (Sinn 2008a, 2008b, 2008c) focuses on the "price wedge" that may be created by green policies. Consider a baseline scenario (with an intertemporal market equilibrium and rational expectations) that is distorted by a green policy aimed at the demand side of the market (e.g., subsidies for green backstop technologies, enforced technological demand constraints, carbon taxes). This policy depresses producer prices during some periods relative to what they would have been without the policy, resulting in a price wedge. More specifically, I define the price wedge at a particular point in time as the difference between the old, pre-policy price and the new producer price, which would arise if suppliers did not adjust the fossil fuel extraction path to the new policy.

My analysis is based on the standard assumption made by traditional resource models whereby rising prices will always stay above (and be bounded away from) rising stock-dependent unit extraction costs due to increasing scarcity and on-going depletion. This assumption implies that laissez-faire markets will exhaust the available stock as time goes to infinity. Assuming marginal policy measures, I showed that producers will:

(1) Bring their extraction forward if the present value of the expected price wedge (discounted using the rate of return on financial assets) *increases* over time; (2) not change the extraction path if the present value of the expected price wedge remains *constant* over time; and (3) postpone extraction if the present value of the expected price wedge *decreases* over time.[1]

The first of the three outcomes is a Green Paradox, in both its weak and strong forms. It is a weak paradox because global warming accelerates at least for a while. It is a strong paradox because it moves the economy further away from an intertemporal Pareto optimum, which requires a slower speed of global warming than would occur in competitive markets.[2]

[1]This analysis draws on earlier work (Long and Sinn 1985) that examines the effects of exogenous price changes on extraction, as well as analysis of nonconstant sales tax rates in a resource extraction model (Sinn 1982).
[2]See Sinn (2007, 2008a) for a generalization of the Solow-Stiglitz efficiency rule (Solow 1974; Stiglitz 1974) to the case of global warming due to the accumulation of carbon in the atmosphere.

Backstop Technologies

Two of the symposium articles (van der Ploeg and Withagen; Jensen, Mohlin, Pittel, and Sterner) emphasize the impact of a backstop technology that produces a perfect energy substitute at a fixed unit cost, thus preventing the extraction of fossil fuels with extraction costs above this unit cost. They also note that subsidies that reduce the unit cost of the backstop would accelerate global warming for a while (weak Green Paradox) but would reduce the total amount of carbon released into the atmosphere. For those who view reducing the carbon budget as the primary goal of climate policy, this is a satisfactory outcome.

Unfortunately, I am less optimistic about the potential role of backstop technologies. First, it is not clear to me why reducing the total long-term carbon budget should be considered more beneficial to human welfare than postponing extraction. Focusing on the final carbon budget would make sense in a hypothetical world with no time preferences and discounting. But without discounting, a welfare analysis of resource extraction would be meaningless, even in the absence of global warming, as the optimal rate of resource extraction would be zero. I believe that even hard-core philosophers would agree that this problem excludes a lexicographic ordering of social preferences for postponing versus avoiding climate damages forever.

Second, I do not see anything in the real world that even comes close to being the perfect backstop assumed in theoretical models. Wind and solar power, often considered the most likely candidates, will be able to replace some fossil fuel, but certainly not all, because they are so volatile. The economic cost of storage devices such as pump storage or methanization plants that could smooth the supply of green electricity is extremely high.[3] For example, in 2013, Germany would have needed 3,500 pump-storage plants, more than a hundred times the number it had at the time, to smooth its energy from wind and solar power, although the latter accounted for only 3 percent of final energy consumption. I fear that the only effective smoothing strategy would be one that is based on the intermittent production of energy from fossil fuel to cover periods when wind or solar is not available. But this smoothing strategy can only work if the green energy supply is small enough to prevent production spikes from exceeding aggregate demand, something that already occurs in Germany from time to time. Thus, beyond a certain production level, wind and solar energy would switch from being substitutes to complements of fossil fuels. This means that they cannot serve as the backstop technology assumed in many Green Paradox models.

Thus, at best, subsidies for green energy would reduce the demand for fossil fuels at all points in time but would not impose the hard ceiling on prices assumed in the models. The subsidies would shift the (period-specific) resource demand curves downwards, creating the price wedge discussed earlier. At worst, subsidies for wind and solar energy would *increase* the demand for complementary fossil fuels if wind and solar energy were already extensively used, thus reducing the price wedge at the margin.

Nuclear fission and nuclear fusion have the potential to serve as backstops that induce hard price ceilings. However, the former has been discredited by the Fukushima accident and thus does not appear to offer a politically feasible alternative. Nuclear fusion could potentially garner

[3]See H.-W. Sinn, "Schafft es Deutschland, den Zappelstrom zu bändigen?", public lecture, Ifo Annual Meeting, available at: http://mediathek.cesifo-group.de/iptv/player/macros/cesifo/mediathek?content=3583749&idx=2&category=2196209669.

more political support. However, decades of promises of imminent breakthroughs have given way to more pessimistic expectations. At best, the availability of a nuclear fusion backstop can be anticipated with time-dependent probabilities, but such probabilistic expectations translate into a mathematically expected price wedge that has implications similar to those discussed earlier.

Scenarios that Avoid the Green Paradox

Of course, there are model assumptions that would eliminate the risk of a Green Paradox outcome. For example, it is possible that mankind would, under laissez faire, not exhaust the entire resource stock, because, with the passage of time, the marginal willingness to pay for dwindling fossil resources rises more slowly than the unit extraction costs resulting from the depletion of the better fields. In this case, any permanent demand-reducing measures of the kind discussed earlier would eliminate some of the stock that could be profitably extracted and hence put a limit on the earth's maximum temperature (see Withagen and van der Ploeg 2015). However, we cannot know today whether the underlying conditions for this optimistic scenario will hold because this all depends on technologies and preferences in a far distant and uncertain future.

Alternatively, we might want to design a strategy that ensures a gradual decline in the present value of the price wedge over time, thus giving resource owners an incentive to extract later. However, I doubt that it will ever be politically possible to fine-tune such a policy and to commit to its implementation over the long term. In the real world, there are no commitment devices that bind successive generations. New generations of policymakers will reoptimize, and when the world does get warmer, they may face increasing political pressure to intensify their green policies, thus increasing the price wedge more than originally envisaged. In any case, resource owners are likely to anticipate such policy changes and react by bringing forward their fossil fuel extraction.

Carbon Leakage

The efficacy of demand policies may deteriorate further if only *some* resource-consuming countries implement green policies, since their demand restraint would be outweighed by additional consumption in other countries. In this case, the Green Paradox would be reinforced by carbon leakage, rendering any unilateral actions toward solving the climate problem futile.

To illustrate this point, let's assume that the green policy consists of implementing a cap-and-trade system in a subgroup of countries, with quantity constraints tightening over time. Let's also assume for a moment that resource owners do not react by changing their extraction path. Under these conditions, at each point in time, the world market price for fossil fuels will be lower than it would have been without the policy because the cap reduces world-wide demand. Consumers in countries not participating in the emissions trading system would enjoy the lower world market price, and their energy demand would increase, while consumers in participating countries would be forced to pay a higher energy price and consume less because they would also have to pay for the emissions certificates. Consider now the possibility of an adjustment reaction affecting the extraction path and suppose that, without such an

adjustment, the tightening of the cap would be fast enough to cause the present value of the world-market price wedge to increase over time. In this case, the price signal would again induce resource owners to bring forward extraction to the present to minimize revenue losses.

These green policies carried out by only a group of countries are inefficient for two reasons. First, the energy no longer consumed by these countries will be consumed by non-participating countries instead. Second, the nonparticipating countries will also consume the additional quantities of energy that resource owners extract and sell because of the Green Paradox. In an initial phase, this would lead to more than 100 percent leakage because nonparticipating countries would consume more carbon than the countries introducing the cap-and-trade system would cut.[4]

Conclusions

My pessimistic conclusions about the efficacy of green demand-reducing policies have no doubt disappointed many environmental activists. However, the climate problem is too important to be left to ideologues. The purpose of green policies is not to provide the public with a warm glow from charitable actions but rather to cool the earth.

I would argue that nothing short of binding global agreements on quantity constraints can successfully reduce the speed of global warming. Measures that simply work through price signals are not sufficiently reliable to do the job, as it is the *changes* in prices, rather than their levels, that will determine success; and it is easy enough to get the price changes wrong through reoptimization by successive generations of policy makers.

The first step toward imposing quantity constraints should be to extend the existing UN emissions trading system (initially introduced through the Kyoto agreement) to the entire world and to add national or supranational cap-and-trade systems similar to Europe's. If the United States, China, and India could be convinced to sign such a treaty, 71 percent of world-wide CO_2 output would be covered. In a second step, we should attempt to convince most of the rest of the world to participate. By definition, such a global system would be safe from international leakage and would not fall victim to the Green Paradox. In my opinion, this approach offers the only potential solution to the world's climate problem, which, as Stern et al. (2006) have remarked, is the world's greatest market externality ever.

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[4]For a discussion of this possibility, see Sinn (2008b, 2008c) and Long (2015).

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