Investment in Zero Carbon Technologies under Uncertainty about Future Climate Policy: Should Governments Target CCS Instead of Renewables?

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Introduction

Parties to the Paris treaty restated their commitment to the 2ºC target, and agreed to pursue efforts to limit the temperature increase to 1.5ºC. In order to keep global warming below the 2ºC target, a third of oil reserves, a half of gas reserves, and more than 80 percent of coal reserves must stay in the ground, according to McGlade and Ekins (2015). These estimates, combined with the IEA prediction of a 50% growth in total energy demand in the next 25 years, implies that production of zero carbon energy must increase radically in the coming years. Yet, it is highly uncertain whether the Paris targets will be reached. The uncertainty might reflect that future emissions goals of countries are uncertain, for example, because country-specific costs of climate change are still not known. Alternatively, current governments might announce deep emissions cuts for the future, but it is uncertain whether future governments will implement necessary policies to meet the announced targets.

In this paper, we study investments in R&D and production capacity in zero carbon technologies under uncertainty about future climate policy. Zero carbon energy technologies differ with respect to their properties. Renewables are decreasing returns to scale technologies, reflecting that locations differ with respect to wind and sun conditions. Coal and natural gas power with Carbon Capture and Storage (CCS), on the other hand, are (close to) constant returns to scale technologies. The full cost of these technologies exceeds the full cost of conventional coal and natural gas power, and hence investors will not choose CCS technologies as long as climate policy is not significantly tightened.

We pose the following research questions: I) How do the different properties of renewables and CCS electricity technology affect the investment decisions of private firms under uncertainty? and II) Does the market outcome depart from the first-best social outcome?

Uncertainty

We analyse two types of climate policy uncertainty: Either, there is uncertainty about the marginal damage cost of greenhouse gas (GHG) emissions, or there is uncertainty about the ability of the politicians to impose a stringent climate policy. For the first type (scientific uncertainty), we assume that the climate policy will be optimal, that is, if the marginal damage cost of GHG emissions turns out to be low, the future carbon tax will be low, and if the marginal damage cost of GHG turns out to be high, the future carbon tax will be high. For the second type of uncertainty (policy uncertainty), we assume that the marginal damage cost of GHG emissions is known to be high, but it is uncertain whether the future carbon tax will be equal to the true marginal damage cost of GHG emissions or lower. Hence, under both types of uncertainty the future carbon tax can take two values; it will either be high or low.

The interpretation of the high and low tax differs between the two types of uncertainty. Under scientific uncertainty, the high tax shows the social cost of carbon if this value turns out to be high, whereas under policy uncertainty, the high tax shows the true (and ex ante known) social cost of carbon. Under scientific uncertainty, the low tax shows the social cost of carbon if this value turns out to be low, whereas under policy uncertainty, the low tax is simply a tax below the true social cost of carbon and should therefore not have been imposed.

Theory model

We first set up a theory model. Here, there are two zero-carbon electricity technologies; renewable energy, for example wind power, and fossil-based electricity production with CCS and no emissions. In addition, there is a conventional fossil-fuel based technology.

Our model has three periods. In the first period, a representative innovator decides under uncertainty the level of R&D for the two types of zero-carbon technologies; more R&D will lower the cost of investment of a technology. We assume that the conventional fossil energy technology is mature, that is, R&D will not lower its cost of investment. In the second period, a representative power producer may invest in power capacities in the three electricity technologies – still under uncertainty. Finally, in the third period, the uncertainty (carbon tax) is revealed, and then production and consumption of electricity are determined, that is, the electricity market clears.

We solve the model by backward induction. In period 2, that is, when R&D expenditures are predetermined, there exists three equilibrium regimes. In all three regimes, there is investment in renewable electricity capacity as the cost of the cheapest renewable capacity is assumed to be low. The three regimes differ with respect to the competiveness of conventional fossil electricity relative to CCS electricity. Either there is investment in conventional power capacity but not in CCS electricity (regime 1), or there is investment in both conventional power and CCS electricity (regime 2), or there is investment in CCS electricity capacity but not in conventional fossil electricity (regime 3).

We then solve the complete model. We show that under scientific uncertainty, where the future carbon tax policy is assumed to be optimal, the market outcome is first best. Under policy uncertainty, the market outcome will be the same as in the case of scientific uncertainty – private actors are exposed to the same uncertain taxes – but the equilibrium is not first-best because of the non-optimal carbon tax policy. The possibility that a carbon tax below the true social cost of carbon might be imposed perverts private investments so that their equilibrium values differ from the social optimal ones.

Numerical simulations

We complement the theoretical analysis by establishing a stylized numerical model for the European electricity market in 2030 that builds on the theory model. We mainly use parameters and variables from the numerical energy market model LIBEMOD, see Aune et al. (2008; 2015) and LIBEMOD (2015), to determine the parameters in the numerical model. LIBEMOD determines simultaneously investment, extraction, production, trade, transport and consumption of eight energy goods, including electricity, in 30 European countries. In addition, the model determines prices and quantities of energy goods traded globally, and emissions of CO2 by sectors and countries.

We use the 2030 reference scenario in Aune et al. (2015) as the starting point of picking parameter values. Here, the LIBEMOD model is run for 2030 under the assumption that the following EU targets are reached: i) a 40 percent reduction in GHG emissions relative to 1990, which is split between one emissions goal for the ETS sectors and another emissions goal for the non-ETS sectors, and ii) a renewable share in final energy consumption of 27 percent. Like in the LIBEMOD model run, we assume that the ETS emissions goal is accomplished by imposing an EU-wide quota system in the ETS sector, whereas an EU-wide subsidy on renewable energy is offered in order to reach the renewable target. In the numerical simulations, we impose that the non-ETS emissions goal is reached through electrification of activities in the non-ETS sectors. Finally, in the numerical simulations we assume that the low carbon tax is 5 euro/t CO2, which is a rough estimate of the ETS price over the last 5-10 years, whereas we vary the high tax.

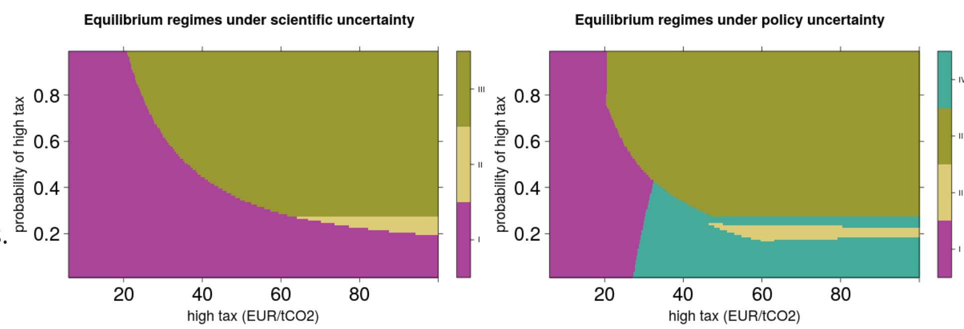

Figure 1 Equilibrium regimes under scientific uncertainty with optimal carbon tax policy and under policy uncertainty with non-optimal carbon tax policy when R&D is determined by the current government

In Figure 1, the panel to the left shows the case when there is scientific uncertainty and the future carbon tax policy is optimal. With optimal policy, regime I (no CCS electricity) exists if the probability of a high tax is high and the level of the high tax is low, or the probability of a high tax is low and the level of the high tax is high. For most other combinations of the probability of a high tax and the level of the high tax, the equilibria are in regime III (no conventional fossil fuel electricity). Finally, if the level of the high tax exceeds 60 euro/tCO2 and the probability of a high tax is in the range of 20 to 30 percent, then the equilibria are in regime II (capacity investments in all electricity technologies).

With policy uncertainty and non-optimal carbon tax policy, the current government has an incentive to correct the R&D investments chosen by the private actors, see discussion above. The right panel in Figure 1 shows the equilibrium regimes when the current government chooses R&D levels that maximize expected social welfare, taking into account the decisions of the private actors in stages 2 and 3. As seen from the Figure, all three regimes exist in equilibrium, but again the set of combinations sustaining regime II is small. Also, with non-optimal carbon tax policy there are combinations of level of the high tax/probability of a high tax for which none of the three regimes exist. For these cases, there will be investment in renewables only (Regime IV in Figure 1). To sum up, our results suggest that there might be coexistence of conventional fossil fuel electricity and CCS electricity, but this exists only for a small set of combinations of level of the high tax and probability of a high tax.

We have compared R&D in CCS electricity and renewables when the government determines R&D under policy uncertainty relative to the case of private innovators deciding on R&D under policy (or scientific) uncertainty (for the same combinations of level of the high tax and probability of a high tax). We find that there exists a large set of combinations for which the current government chooses R&D in renewables above the level chosen by private innovators. However, for a small set of combinations, the current government chooses R&D in renewables below the level chosen by private innovators but R&D in CCS electricity above the level chosen by private innovators. Hence, whether the current government should support R&D investments when the future carbon tax policy might be non-optimal, depends on the true value of the social cost of carbon.

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Plenary Session 3: Climate Policy

Summarized by Arjan Trinks, PhD Student, University of Groningen

This session was chaired by Herman Volleberg, Professor, Tilburg University/PBL Netherlands Environmental Assessment Agency, The Netherlands. He was joined by Ian Parry, Principal Environmental Fiscal Policy Expert, IMF, Washington DC, USA; Carolyn Fischer, Senior Fellow, Resources of the Future, Washington DC, USA; and Michael Grubb, Professor of Energy and Climate Change, University College London, United Kingdom.

Ian Parry presented the carbon pricing approach. As of now, only a small part of GHG emissions are priced in any way, so the global average price of carbon is about $1 per ton. He stressed that policy makers need quantitative information about how policy instruments affect emissions, their economic and fiscal impact and the important trade-offs that they present. A spreadsheet model from the IMF, designed for simplicity and transparency, could be a useful tool for this purpose.

Carolyn Fischer presented that how in a second-best (or nth-best) world there may be a case for renewable energy targets, even though they could force more expensive abatement. Among the other market failures that need addressing are issues like R&D spillovers, network effects, scale effects, learning-by-doing effects, imperfect competition, political constraints on adequately pricing emissions and behavioral gaps on the demand side.

Michael Grubb made the case for distinguishing between satisficing behavior in the short run (behavioral economics), optimizing behavior in the medium run (neo-classical economics) and transforming behavior in the long run (evolutionary and institutional economics) when discussing climate policy. As an example of transformative behavior is the shift to solar as costs fall rapidly, spurred by the support from German and Japanese governments. The carbon price needed to spur this innovation would probably have been hundreds of dollars, and would have been politically unacceptable.

Dual Plenary Session 1: Long-term Energy Scenarios

Summarised by Minwoo Hyun, Green Business and Policy Program, Graduate School of Green Growth, KAIST College of Business

This first dual plenary session was chaired by Christian von Hirschhausen, Technical University Berlin, Germany. He was joined by Ruud Egging, Norwegian University of Science and Technology, Trondheim, Norway; Christian Breyer, Lappeenranta University, Finland: Scenarios for a Lower-Carbon World and Christophe Bonnery, Enedis, France: Economics & Prospectives.

Christian, chair of the session, emphasized the roles of scenarios and modeling on establishing policy process in the introduction of this session.

In the first presentation, pointing out the possibility of mixed interpretations from the scenario studies, Ruud argues that a good scenario generally gives relevant insights into policy decision making. He presented the integration of modeling types including I.A.M., C.G.E., and partial equilibrium with account of their relative strengths. Also, he highlighted the challenges from the process of blending each modeling characteristics such as spatial and temporal granularity, units of measurement, and model linkage methods.

Christian Breyer subsequently provided considerably realistic implications about 100% renewable energy system at a global level. In pursuit of making the lower-carbon future, he pointed out various crucial technologies set consisted of solar PV, wind power, electricity storage, and conversion technologies. He also maintained that high-spatial and temporal resolution-based modelling needs to be applied to suggest unique implications into climate policy.

Christophe presented a recapitulation of the points given in this session and re-emphasized significance of comprehensive thinking on economics in order to build concrete energy scenarios.