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When to Invest in Carbon Capture and Storage Technology: A Mathematical Model

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The European Union introduced the Emission Trading Scheme (ETS) in 2005, a scheme in which CO_2 emission permits are traded, as a key element in its plan to adhere to the Kyoto Protocol on emission reduction. The market for CO_2 emission permits penalises heavy polluters and rewards cleaner electricity generation technologies such as generation from renewable sources

However, renewable generation tends to be intermittent so there is still a role for fossil fuel-based generation to maintain system stability. Traditional coal plants are amongst the largest emitters of CO_2 per unit of electricity generated. If coal plants are to be feasible despite policy objectives of minimising CO_2 emissions then an attractive approach, in theory, is to capture the carbon released during combustion and store it permanently. Despite a huge research effort into carbon capture and storage (CCS), there is still no commercially operating CCS power plant anywhere in the world.

The goal of this paper is to determine the optimal time to invest in retrofitting a CCS unit onto an existing power plant in (i) a region subject to a (deterministically evolving) carbon tax, such as the carbon floor introduced in Great Britain (GB) in April 2013, and (ii) in a region where there is uncertainty in the price of CO_2 emissions, such as in the rest of Europe subject to the (stochastically evolving) ETS permit price. We do this by finding the investment time that maximises the net present value (NPV) of the option to invest in CCS.

The decision the investor faces today, based on estimates of the total investment cost, will be different to their decision in the future if future investment costs have fall. For this reason we include the novel feature of an investment cost function that decreases over time as this new technology matures.

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[1] Walsh, D.M., O'Sullivan, K., Lee, W.T. and Devine, M.T. 2014. When to invest in carbon capture and storage technology: a mathematical model. Energy Econ. 42, 219-225.

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We take the example of a 500 MW super critical pulverised coal (SCPC) power plant with 80% capacity factor, assumed to be operating as a baseload plant, and an estimate of 214.5M€ for the investment cost to retrofit the plant with a CCS unit, decreasing at a rate of 2% per year (these parameters are taken from Abadie and Chamorro (2008)). In the case of the investment decision in GB where the high level of the carbon floor gives effective certainty to the cost of emissions, simple calculus techniques allowed us to determine the optimal time to invest. We found that it was optimal to wait and not invest until 2020 in GB (i.e. the NPV of the option is maximised in 2020 in GB).

Due to the inherent volatility in the price of a traded permit, the calculation of the optimal time to invest in a CCS retrofit in the rest of Europe was more difficult as it required the use of stochastic calculus since the NPV isn't a smooth function of investment time. With reasonable assumptions we were able to show that it was not optimal to invest within the normal lifetime of a coal plant (40 years), starting from the current low level of the ETS permit price.

A key result in this analysis is that if the volatility in the ETS permit price increases, then the optimal time to invest also increases. This is a clear indication that the volatility introduced by a tradeable permit has an adverse effect on encouraging investment in carbon abatement technologies such as CCS.

The policy implications of this work are clear. There is widespread consensus that the ETS is not working efficiently at incentivising the switch to cleaner generation technologies. This work provides evidence of the merits of a tax based system, such as the carbon floor in GB, to accelerate investment in carbon abatement technologies over a tradeable permit scheme subject to volatility such as the ETS.

References

Abadie, L. And Chamorro, J. 2008 European CO_2 prices and carbon capture investments. Energy Econ. 30, 2992-3015.