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Inducing low-carbon investment in the electric power industry through a price floor for emissions trading

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HIGHLIGHTS

- ► We model the investment decision of an electricity generating company.
- ► The company can invest in low and high carbon technologies.
- ► We investigate different carbon price floor designs.
- ► A carbon price floor leads to earlier investment into low-carbon technology.

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ABSTRACT

Uncertainty about long-term climate policy is a major driving force in the evolution of the carbon market price. Since this price enters the investment decision process of regulated firms, this uncertainty increases the cost of capital for investors and might deter investments into new technologies at the company level. We apply a real options-based approach to assess the impact of climate change policy in the form of a constant or growing price floor on investment decisions of a single firm in a competitive environment. This firm has the opportunity to switch from a high-carbon "dirty" technology to a low-carbon "clean" technology. Using Monte Carlo simulation and dynamic programming techniques for real data, we determine the optimal CO_2 price floor level and growth rate in order to induce investments into the low-carbon technology. We find that a carbon price floor can be used to induce earlier low-carbon technology investment and show this result to be robust to a large variety of input parameter settings.

1. Introduction

In the context of reducing long-term carbon price uncertainty stemming from ambiguous climate change policy, some contributions in the academic literature have suggested several forms of regulatory price management, mainly in the form of a price cap or safety valve (Pizer, 2002; Jacoby and Ellerman, 2004; Szolgayová et al., 2008).[1] If realized abatement costs turn out to be higher than expected the price cap serves as a ceiling on the carbon price and emitters can buy additional permits at the specified price.[2] McKibbin and Wilcoxen (2002), Helm (2008a, 2008b), Burtraw et al. (2010), Fell and Morgenstern (2009), and Philibert (2009) extend this discussion by analyzing a "symmetric safety valve", also referred to as a price collar. This approach not only insures emitters against higher than expected costs, but also sets a minimum carbon price, thereby downward bounding compliance costs. Experience from the EU ETS, the world's largest multinational carbon trading scheme, provides evidence that there has been downward pressure on allowance prices in both phases (2005–2007; 2008-2012), albeit for different reasons, causing abatement costs to fall short of the perceived marginal damages of greenhouse gas emissions. Due to this, a thorough discussion of a regulatory minimum price for emission allowances has begun.

A price floor reduces uncertainty over future profitability by guaranteeing a minimum rate of return to an investor or firm pondering an investment decision. This argument is particularly important in the energy sector, which is characterized by capital-intensive and long-lived power plants. Since it influences the long-term price signal distribution a minimum carbon price

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[1] The idea of combining price (tax) and quantity (allowances) instruments, usually referred to as a hybrid system, was initially suggested by Roberts and Spence (1976). Alternative ways to reduce climate policy uncertainties are mentioned in e.g., Lambie (2010).

[2] Murray et al. (2008) extend the concept of a price ceiling with an unlimited volume of extra permits by the idea of an allowance reserve that caps this volume.

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creates incentives to invest in new low-carbon technologies over and above those already induced by the unconstrained market price (Weber and Neuhoff, 2010). Abatement will still take place if the costs of CO_2-reductions are lower than the price of allowances, since profit-maximizing firms will implement the emissions reductions and sell the surplus allowances. The price floor might therefore primarily be seen as an instrument of industrial rather than environmental policy. A second argument in favor of the implementation of a price floor is the possibility that it would limit the volatility of carbon market prices (cp. Grüll and Taschini, 2011).[3] In times of growing volatility in fuel prices this fact would favor renewable energy.

An intensive academic discussion about such a downside insurance in carbon markets started only recently with the work of Burtraw et al. (2010). This is surprising given that the concept of a price floor has already found its way into legislation in the United Kingdom and Australia (Treasury, 2010; Australian Government, 2011).[4] In the case of the UK the floor is one of several measures for encouraging low-carbon energy investments (Department of Energy & Climate Change, 2011). Commencing on 1 April 2013 at around 15.70 GBP/ton CO_2, following a straight line to 30 GBP/ton in 2020 and targeting 70 GBP/ton in 2030, the UK price floor is designed to top up the carbon price of the EU ETS – which the UK is a member of – to a national target level. Since other countries under the EU ETS do not have a similar price floor, this measure will increase abatement costs in the UK relative to other EU countries. UK legislators justify this higher burden by arguing that regulatory uncertainty about future carbon prices may undermine robust long-term price signals and incentives and that the carbon price from the EU ETS might not be strong and stable enough to stimulate sufficient investments in low-carbon technologies.[5] The EU Commission implicitly agrees to this diagnosis when stating that, in order to boost low-carbon technologies, "[…] appropriate measures need to be considered, including revisiting the agreed linear reduction of the ETS cap" (European Commission, 2011). Interestingly, "The Prince of Wales's EU Corporate Leaders Group on climate change (EUCLG)" – comprising some of Europe's largest businesses – recently sent a letter to EU decision makers calling for political action to increase the price of carbon to a level that will make low-carbon investments more competitive. In this sense an additional option evolves from a cap-and-trade system: establishing a regulatory minimum price for emission allowances could be used to promote technological innovation to a greater extent than automatically induced by the long-term price signals from the unconstrained market.

Taking this logic as our starting point, we contribute to this debate about price management in the form of a floor price on the carbon market. Setting aside organizational questions concerning the implementation of the floor as well as welfare effects (for these we refer to Wood and Jotzo, 2011; Fankhauser and Hepburn, 2010; and Helm, 2008a, 2008b) we focus on how the investment decisions of a profit maximizing firm in the electric power sector under multiple sources of uncertainty are affected by the introduction of a regulator determined minimum permit price. We employ a real options-based model of an individual electricity producer who currently operates a "dirty" power generation technology, which we define as a technology that has considerably higher CO_2 emissions per production unit than alternative technologies. This implies that the firm has comparatively large compliance costs. The company furthermore faces an investment decision which would permit it to switch to a "clean" generation technology, i.e., a technology with low carbon emissions per production unit. By simulating sets of cash flow paths as functions of technology specific costs related to operation, fuel and carbon emissions, and using dynamic programming techniques to compare the expected outcome of the project investment with the value of delaying this decision, we show that a regulatory intervention in the form of a price management mechanism in the CO_2-market influences the optimal timing of the investment decision of this company. In particular, we demonstrate that the introduction of a price floor can lead to an earlier adoption of low-carbon technologies. In this case, the CO_2-market can be considered to act as an instrument for technology policy.

The methodology we apply is similar to that used in several previous contributions dealing with investment decisions in the power sector under different dimensions of uncertainties. Comparable studies are, among others, Laurikka and Koljonen (2006), Fuss et al. (2008, 2009), Szolgayová et al. (2008), Yang et al. (2008), Fuss and Szolgayová (2010), Chen and Tseng (2011), Kettunen et al. (2011) and Zhu and Fan (2011). However, none of these evaluates the influence of a carbon price floor on the micro-level investment decision in general and on the timing of the technology switch specifically. The only study employing, at least in passing, a price floor in a quantitative model is Abadie et al. (2011). The present study differs from the latter in two respects. First, we employ a different technique to solve the optimization problem of investment decision-making under uncertainty. Second, we do not only perform a detailed analysis of a constant floor price level but investigate three different designs of the floor. Specifically, we perform in-depth investigations of a constant price floor as well as of mechanisms with linearly and exponentially increasing minimum prices. In addition, we endogenously compute the floor price necessary to trigger abandonment of the "dirty" technology at an earlier time. Finally, we perform a number of robustness checks using a large variety of different input parameter settings. These tests qualitatively substantiate our main finding of the existence of a trigger minimum price design.

In what follows, Section 2 presents the model we use to analyze the influence of a price floor on a firm's optimal investment decision. Section 3 contains results from Monte Carlo simulations and backward dynamic programming as well as robustness checks. Section 4 concludes.

2. The model

We model a single power generating firm which is a price taker in all markets and supplies a specific amount of electricity inelastically. For the sake of simplicity, we assume the firm to be risk neutral. It has to comply with an emissions trading system by obtaining emission permits covering its production needs. Consistent with the common perception of auctioning being the most transparent and preferred method of allocating allowances in operating ETS, we assume the firm to buy the necessary carbon certificates at the end of each compliance period. This ensures that the company never holds any surplus certificates which it would wish to sell back to the market.[6]

[3] Note that Fankhauser and Hepburn (2010) distinguish between two sources of volatility: market-induced volatility and volatility induced by regulation. They view only the latter as harmful.

[4] The cap-and-trade system of the Regional Greenhouse Gas Initiative (RGGI), which currently comprises 10 states in the northeastern U.S. uses a hybrid system with a minimum reserve price which is announced prior to each new CO_2 allowance auction.

[5] Grubb and Neuhoff (2006) argue that uncertainty concerning expected permit prices is a major reason for firms to delay investment under the EU ETS.

[6] Note that we disregard the possibility of strategically buying emissions permits early for redemption in later years (this is the situation which obtained in Phase I of the EU ETS, where buying early for later redemption was not possible). Under this assumption, information about future climate policy – e.g., an increase in the emissions cap – will not be reflected in today's prices. Allowing for banking