Energy Economics 47 (2015) 25–36

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

The Clean-Development Mechanism, stochastic permit prices and energy investments

Philipp Hieronymi [a,1], David Schüller [b,*]

[a] University of Illinois at Urbana-Champaign, Department of Mathematics, 1409 W. Green Street (MC-382), Urbana, IL 61801, USA
[b] University Duisburg-Essen, Mercator School of Management, LotharstraÃŸe 65, 47057 Duisburg, Germany

ARTICLE INFO

Article history:
Received 4 July 2013
Received in revised form 8 July 2014
Accepted 11 October 2014
Available online 10 November 2014

JEL classification:
C63
Q48

Keywords:
Energy investment
Investment under uncertainty
Clean Development Mechanism
Emission markets
Climate change

ABSTRACT

We analyze the impact on energy investments stemming from different emission permit classes, by considering permits that are allocated inside the European Emission Trading Scheme and secondary Certified Emission Reduction (sCER) permits originating from the Clean Development Mechanism. One price taking firm which is subject to emission regulation has the choice to invest in gas or wind power plant. The firm faces uncertainty regarding stochastically evolving permit prices, while it receives a premium on the electricity price for wind energy. As a first step, we determine the value of the option to invest into a gas power plant over time. Then, we calculate the investment probability of a gas power investment in a range of policy scenarios. We find that allowing the usage of sCER permits in the present policy framework has a positive impact on gas power investment. Decoupling the price processes has a similar effect. If the quota of sCER permits is doubled, the decrease in the investment probability for wind power is large. We carry out sensitivity tests for different parameter values, and find that investment behavior changes significantly with differing interest rates, the wind energy premium and volatility.

1. Introduction

Negotiations to reach a legally binding international agreement to combat climate change are on stalemate and proposals to postpone the final deadline to reach an agreement in 2015 have been put forward (Kossoy and Guigon, 2013). However, despite the slow pace of international negotiations, several countries are planning to set up their own cap-and-trade based Emission Trading Schemes (ETS) in the near future. These include Australia, China and Korea (Kossoy and Guigon, 2013). Thus, the question of how these markets will interact with each other and how the baseline–credit-schemes such as the Clean Development Mechanism (CDM) will continue to function in such a setting is of great importance. Besides the CDM the Joint Implementation Mechanism (JI) is another flexible mechanism based on provisions in the Kyoto Protocol. A program that is likely to join their ranks in the foreseeable future is the United Nations Collaborative Initiative on Reducing Emissions from Deforestation and Forest Degradation (REDD).

Uncertainty about a future climate change agreement and the way ETS markets are going to interact will have a major influence on future profit stream of energy companies. Furthermore, investment in the energy sector is generally considered as irreversible. Combining uncertainty and irreversibility with the possibility of waiting for new information to make a better informed decision, renders this problem suitable for an uncertainty analysis framework in the spirit of real-options analysis. This method is superior to calculating net present value (NPV) in such a situation, since the investor can take into account future realizations of the parameters that influence profitability, allowing him to optimally time the investment decision. An NPV analysis assigns a probability to these outcomes, but is not able to consider future market realizations, and react in a flexible manner to these. Since it does not take into account the flexibility dimension, it is also likely to yield a lower value of the investment project compared to the real-options approach. After the original development of financial options valuation by Black and Scholes (1973) and Merton (1973), their techniques were adopted for real-investments in the physical sense by Myers (1977). Dixit and Pindyck (1994) and Trigeoris (1996) provide a good overview with numerous examples. One of the first adoptions to the energy sector was undertaken by Herbelot (1992). Analyzing the decision of a coal-power plant owner to install a scrubber to fulfill sulfur emission limits, he finds that the net present value (NPV) increases substantially when the owner can decide flexibly when to start investing, due to the value of additional information. Insley (2003) investigates the same problem and finds that the low level of emission prices since 1993 led to few investment decisions in favor of scrubbers, while the preferred method of compliance was switching to

* Corresponding author. Tel.: +49 203 379 2851.
E-mail addresses: phierony@illinois.edu (P. Hieronymi), David.Schueller@uni-duisburg-essen.de (D. Schüller).
[1] Tel.: +1 217 300 4994.

http://dx.doi.org/10.1016/j.eneco.2014.10.008
0140-9883/

a low-sulfur coal type. The option to halt construction at any point played a pivotal role in the investment decision. Yang et al. (2008) investigate the impact of uncertain emission prices on the risk associated with investing either into a coal, gas or nuclear plant. They find that the degree of the investment risk caused by uncertain permit prices depends to a large degree on the merit-order of energy production, being lowest when gas or nuclear plants are first. Furthermore, including the possibility of price shocks, policy makers should try to let them happen as seldom as possible since investment will stagnate while waiting for new information on prices to be revealed. In contrast, Fuss et al. (2009) consider the case when a company can invest into a fossil, a carbon-capture and storage (CCS) module, and/or a renewable power plant. The owner is flexible with respect to the timing of investment and permit prices evolve stochastically. They find that when evaluating these options simultaneously, the option to retrofit the fossil plant with CCS leads to a postponement of the investment into renewable energy. Also, when considering the timing of climate policy they find that longer periods between jumps in prices lead to less emissions. Fuss et al. (2010) consider the impact of options on emission permits that are derived from REDD on energy investments. They find that REDD options may leave investment in carbon capture and storage technology (CCS) unaffected if they are priced as derivatives of CO_2 permits, since this would ensure a high enough price. However, one should not forget that CCS will remain a non-viable technology option for the medium-term future, and testing has even been banned in some countries.[2]

Studies that investigate the impact of the CDM on the option value of a gas power plant with a simultaneous renewable investment option under uncertainty in the developed world are largely absent in the literature. Some publications address the issue on a qualitative level,[3] while others address the issue on a Computable General Equilibrium level that does not incorporate the uncertainty dimension (Anger et al., 2008). However, as mentioned before new cap-and-trade emission markets are emerging worldwide and without an overarching structure of a global climate agreement, baseline–credit-markets such as the CDM will continue to play a role. Without a good understanding of how the interaction between these two markets influences the investment decisions of energy companies, it is not clear ex-ante that they will help to transform the energy infrastructure and strengthen sustainable development, which are the two foremost goals of the CDM.[4]

The contribution of this paper is to analyze the impact that the simultaneous availability of the two permit classes with differing price developments, one from a cap-and-trade scheme and one from a baseline–credit-scheme, has on the option value to invest into a gas power plant, or a renewable alternative. We use the EU ETS as an example for a cap-and-trade scheme and the CDM as an example of a baseline–credit scheme, since these are the dominant permit classes at the moment. We take the perspective of a government asking the following questions:

- What is the probability that in *t* years the value of the option to build a gas plant is larger than investing into a wind power plant under permit price uncertainty?
- What is the impact of being able to use permits originating from the Clean Development Mechanism on this probability?

The answer to the first question allows the government to evaluate if a policy environment leads investors to build wind power plants now, or if companies are willing to postpone their investment and choose gas power due to the option value of fossil energy. If it is the goal of a government to promote renewable energy investment, taking into account the option value of fossil energy is very important since this might significantly prolong a fossil based energy structure. Answering the second question then helps to evaluate the impact of different permit classes on investment behavior, which is of importance as more and more permit markets with different price development paths emerge around the world and are likely to be linked in the future.

In order to answer these questions, we employ a simplified real options framework where a single investor compares the option value to invest into a gas power plant to investing into a wind power plant. Once an investor has chosen the gas plant option he cannot switch back to the wind power plant at a later point in time. The uncertainty a gas plant faces stems from the price development of the two permit classes which are described by two geometric Brownian Motions (GBM). Since the wind power plant does not produce any CO_2 emissions, it can be considered as risk free with respect to permit costs, and no option value is calculated for this energy type. For given permit prices the value of the option to build a gas power plant is calculated. We then determine the probability of the following event at time *t*: An investor facing the choice between the gas power plant option and building a wind power plant, chooses the gas plant option. Furthermore, the impact of increasing or decreasing the quota of sCER permits a company can use is simulated. Finally, we perform a range of sensitivity checks with respect to the interest rate, the trend of the GBM, volatility of permit prices and the correlation between the two processes.

The rest of the paper is organized as follows: Section 2 introduces briefly the most important background issues, the CDM, the carbon market and the behavior of emission prices analyzed in the literature. In Section 3 the model is described, including the price-processes of the two permit classes. Section 4 contains the data information used in the model, concerning energy markets, the power plants, and the price processes. In Section 5 we present and discuss the results of our model, and draw policy conclusions. In Section 6 we conclude.

2. A short history of the carbon market and the CDM

2.1. The carbon market

The carbon market is largely dominated by European ETS transactions, being currently the only large scale mandatory ETS market in operation worldwide. The overall volume and the importance of the CDM have been growing steadily, coming to a halt in 2009 due to the uncertainty over a new climate change agreement. With a total value of 141.9 $ billion in 2010, the European ETS represented 82% of the market volume and the CDM 14% (Linacre et al., 2011). There are two asset classes pertaining to the CDM. The first is primary Certified Emission Reductions (pCER). These are credits that are obtained directly from projects. The second class, secondary Certified Emission Reductions (sCER), are resold pCER. The main difference between the two pertains to delivery risk. sCERs do not have a delivery risk, since they have been delivered already. However, this is a major issue with pCER. Regulations concerning what projects are CDM eligible change frequently and might discontinue an already existing permit flow (Bakker et al., 2011; Klepper, 2011). Therefore, it is uncertain if pCER will eventually be generated from a project. Despite the fact that they have already been delivered, the delivery risk of pCER does carry on to sCER in that without a constant stream of new permits from CDM projects, the market will

[2] http://www.n-tv.de/politik/Wie-ein-Ausweg-zur-Sackgasse-wurde-article4376091.html.

[3] See for example Blanco and Rodrigues (2008, p. 1517):" However, the low price of CERs and ERUs (Emission Reduction Units) on the EU ETS market can play an indirect negative role on wind energy and other technologies since their inflow to the EU ETS market further reduces the allowance prices in Europe and with them the little incentive that remains to invest in-house. An industry obliged to cut its emissions would prefer to import cheap JI or CDM credits instead of buying EU ETS credits or adapting its production process."

[4] "The purpose of the Clean Development Mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3" — http://unfccc.int/essential_background/kyoto_protocol/items/1678.php.