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Operating flexibility at power plants: A market valuation

Luis M. Abadie *

Basque Centre for Climate Change (BC3), Alameda Urquijo 4, 4º, 48008 Bilbao, Spain

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ABSTRACT

This paper addresses the valuation of an operating coal-fired power plant and a natural gas power plant when they operate as base load, independently of margins, and when the plant is cycling, running only when the electricity price is higher than the variable costs (fuel, emissions and variable O&M). Three sources of risk are considered: electricity prices, the fuel used and carbon allowances.

Parameters are calibrated with market data and well-known valuation techniques such as contingent claim analysis are used. The results show the importance of operating flexibility in the appraisal of power plants as a result of price volatility. The effect of setting an increasing floor for emission allowance prices is also analysed. The model used is a general one which includes the existence of correlations also obtained via market trading prices.

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Introduction

The margins of coal- and natural gas-fired power plants depend on trends in electricity prices and in the prices of the fuels used, and on the efficiency of the generation process used. When CO_2 emission allowances are needed to produce electricity their price must also be factored in. This is the case in the 28 European Union (EU) Member States plus Iceland, Liechtenstein and Norway, which take part in the EU Emissions Trading Scheme (EU ETS).[1] The emission allowances needed depend on the generation technology (coal or natural gas in this paper) and on efficiency: this gives rise to a certain figure for emissions in $KgCO_2$ per MW h produced.

Since 2013 power generators in the EU must buy all their allowances, except for eight Member States[2] which joined the EU recently and are allowed to continue granting limited numbers of free allowances to existing power plants until 2019. Auctioning is therefore the general rule.

When emission allowance prices are taken into consideration, margins are usually referred to as the Clean Spark Spread (CSS) for natural gas-fired power plants and the Clean Dark Spread (CDS) for coal-fired power plants [4]. Variable O&M costs[3] must be subtracted from these margins. The price of emission allowances may condition both the choice of technology for investment and the decision to produce electricity at a given time with one technology or the other. Thus, in its report entitled Energy Technology Perspectives [10] the International Energy Agency (IEA) considers that "*While the integrity of the emissions cap remains secure, a price lower than EUR 10/tCO_2 is not enough to put gas ahead of coal in power generation in Europe, and provides only limited incentives to renewables and nuclear (which are actively supported through other means at present). Low demand in the EU ETS also undermines the development of new projects in developing countries under the Clean Development Mechanism (CDM).*"

Volatility in the prices of electricity, of the fuel used and of emission allowances means that sometimes it is more profitable to produce with coal and sometimes with natural gas.

At present there are contracts on the futures markets with long maturity dates,[4] which make it possible to draw up valuations using the technique of contingent valuation analysis, as in this paper.

Ghosh and Ramesh [9] investigate the development of an options market for power trading.

Zambujal-Oliveira [17] analyse the deferral option with a 3 year license for starting plant construction for an investment in combined cycle natural gas power plants using the real option methodology. This deferral option is associated with the spread between electricity and variable costs. Their study assumes two stochastic variables (electricity price and natural gas price) that evolve according to Geometric Brownian Motion processes (GBM) without correlation. The numerical method used to solve this problem is

* Tel.: +34 94 401 46 90.
E-mail address: lm.abadie@bc3research.org

[1] See EU Emissions Trading http://ec.europa.eu/clima/publications/docs/factsheet_ets_2013_en.pdf.

[2] Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Poland and Romania.

[3] When there are no costs due to emission allowances the terms used are Spark Spread (SS) and Dark Spread (DS).

[4] Contracts for electricity prices with maturity periods of up to 56 months are used, and with maturity up to 80 months for natural gas.

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that of binomial trees, with the volatility of the project return over time being estimated using Monte Carlo simulations. The volatility of electricity and natural gas prices is estimated using market data. The conclusion reached is that investors should delay investment. The same study also analyses the sensitivity of results to changes in project volatility, option maturity, electricity demand and carbon prices.

Botterud and Korpås [5] use the real option approach to evaluate the optimal timing of investments of a firm in new power generation capacity with an optimisation model with other market participants. The model is applied to analyse an investment in a gas-fired power plant. In their model the electricity spot price is a function of installed capacity and demand level, and load growth is modelled with a discrete stochastic process. According to Botterud and Korpås [5] the use of contingent claims analysis or risk-neutral valuation avoids the problem of determining an appropriate risk-adjusted discount rate. In a case study from the Nordic electricity market these authors analyse the effect of uncertainty on optimal investment time and examine how a fixed or variable capacity payment would influence the investment decision. Their model takes into account that prices in the electricity market can be reduced when a new investment is made. Backward stochastic dynamic programing is used to solve the investment problem.

The flexibility of choosing the optimum time to implement a decision to invest or disinvest has been studied by several authors:

Brekke and Schieldrop [6] study investment in two types of power plant: one that uses inflexible technology and the other flexible technology, with the ability to change the type of fuel used. Their investment option has an infinite lifetime, and the frontier between the investment region and the wait region is calculated. The solution used by these authors is analytical, and the stochastic processes are of the Geometric Brownian Motion (GBM) type.

Abadie and Chamorro [3] analyse investment in power plants when there is flexibility in the choice of fuel type at all times, with fuel-change costs, and limited time in which to exercise the option to build the power plant. The frontier between the investment region and the wait region is solved using numerical methods (bi-dimensional trees) and the stochastic processes considered are of the mean-reverting type.

Näsäkkälä and Fleten [14] study the value of peak and base load types at gas plants and find the upgrading threshold that gives the optimal type of gas plant as a function of the Spark Spread (SS). When the investment cost is below the threshold of the optimum technology the power plant is built. They show the Spark Spread (SS) as the sum of two stochastic processes, one where the short-term deviation reverts toward zero the other towards the equilibrium price, which they assume follows an arithmetic Brownian motion process. In this study the option to build the power plant is infinite, and an analytical solution is therefore found.

Laurikka and Koljonen [12] analyse the consequences of the EU ETS in the option to wait and the option to alter operating scale in investment decisions in a country-specific setting in Finland. The case study shows that uncertainty regarding the allocation of emission allowances is critical in a quantitative investment appraisal of fossil fuel-fired power plants. They use two stochastic processes (electricity and emission allowances), while the prices of the fuel used are deterministic. They use a Montecarlo simulation with mean-reverting stochastic processes.

Fleten and Näsäkkälä [8] analyse investments in gas-fired power plants based on the Spark Spread with the sum of a short-term deviation and an equilibrium price (two-factor model),[5] and find that the flexibility of choice of the optimum investment decision time has a significant value. They also find the thresholds for energy prices for which it is optimal to make an investment. The effects of deterministic emission costs are taken into account. These authors consider an infinite time period for exercising the investment option and solve the problem using analytical methods.

Kockar et al. [11] analyse the effects of emission constraints and an Emission Trading Scheme (ETS) on decisions by generators and on market clearing. They propose a method for including the outcomes of purchasing and selling carbon allowances in the generation scheduling procedure. The method is illustrated with a five unit system. One basic assumption is that the initial allowances are obtained for free. They also analyse how the aggregation of emissions allowances of generators belonging to the same company can affect market clearing, because that company may have a diversified portfolio with generation assets that use various technologies. The method used consists of solving a mixed integer minimisation problem, where the function to be minimised includes the total generation costs, start-up costs and costs associated with buying and selling carbon allowances.

Shahnazari et al. [15] use real option theory to investigate the optimal timing for converting a coal-fired power plant to natural gas in response to carbon prices.

A recent paper by Martínez Ceseña et al. [13] reviews real options theory applied to electricity generation projects, emphasising renewable energy projects.

This paper draws up a total valuation and a valuation per MW h produced for two types of thermal power plant: natural gas and coal-fired plants. It is assumed that investment can be made now, given the trends in demand and the planning for the phasing out of certain plants currently in operation, and that if it is decided not to invest at this time another company will do so and the opportunity will be lost. In this case it is assumed that there is no wait option due to the high probability of losing it, and the most significant issue is operating flexibility. The option to defer under exogenous competition is studied by Smit and Trigeorgis [16]. The choice of the two types of thermal power plant is based on their weight in the generation mix and the fact that the paper sets out to examine the economic impact of flexibility. Other types of power plant, e.g. nuclear plants, do not have this flexibility of operation, and some renewables, e.g. wind and solar energy, would operate at all times except in special circumstances such as grid congestion. A third reason for the choice is the existence of markets where the prices of the corresponding commodities are traded, thanks to which the valuation method applied can be used. There are other generation technologies, such as Integrated Gasification Combined Cycle technology (IGCC), for which the model proposed can, even though they are not considered in this paper, be easily adapted by changing the relevant parameters, e.g. thermal efficiency.

The valuation is conducted with the technique known as contingent claim analysis,[6] which simulates trends in prices discounting the drift of the risk market value, which is equivalent to modelling the behaviour of prices on the corresponding futures market: since those prices are certain they can be discounted at the riskless rate.[7]

This paper uses three sources of risk (electricity, fuel and carbon) with stochastic behaviour. Other papers also consider three sources, but with other methods and other purposes, e.g. Abadie et al. [1] evaluate two alternatives CCS technologies, the first of which uses CO_2 for enhanced oil recovery (EOR) paired with

[5] The same stochastic model and data that Näsäkkälä and Fleten [14].

[6] See Dixit and Pindyck [7] in regard to this valuation technique.

[7] Alternatively, real world price results could have been simulated discounted at a rate including the risk market price, but this method is difficult to use given that it is usually quite hard accurately to estimate real-world prices for a future date. However the results of the two approaches are equivalent.

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