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Option value of gasification technology within an emissions trading scheme

Harri Laurikka*

Laboratory of Energy Economics and Power Plant Engineering, Helsinki University of Technology, P.O. Box 4100, 02015 TKK, Finland

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Abstract

Investment analysis is mostly implemented with Discounted Cash Flow (DCF) methods, such as the Net Present Value (NPV). The problem in a typical application of these methods is the limited ability to value real options, management's ability to adapt to changing market conditions or to revise decisions. This paper presents a simulation model, in which the investment is regarded as a single-firm problem in an operating environment with multiple exogenous and stochastic prices. The simulation model is used to explore the impact of emissions trading, and in particular the European Union Emissions Trading Scheme (EU ETS), on investments in Integrated Gasification Combined Cycle (IGCC) plants. Two real case studies are presented: modifications of an existing condensing power plant and a new combined heat and power plant. The benefit of the selected approach is that it can take into account the value of multiple simultaneous real options better than a standard DCF analysis. The results show that a straightforward application of DCF analysis can lead to biased results in competitive energy markets within an emissions trading scheme, where a number of uncertainties potentially combined with several real options can make quantitative investment appraisals very complex.

Keywords: Emissions trading; Gasification; Investment

1. Introduction

Investment analysis is mostly implemented with Discounted Cash Flow (DCF) methods, such as the Net Present Value (NPV). A DCF analysis essentially involves discounting the expected net cash flows from an investment at a discount rate that reflects the risk of those cash flows. Typically the analysis is based on scenarios, which presume management's passive commitment to certain operating strategies, and is accompanied with a sensitivity analysis to the components of the cash flow. The problem in the approach is its limited ability to value active flexibility or *real options*.[1] A real option is a right, but not an obligation, to take action concerning an investment project: for example, to alter operating scale or to switch inputs, such as fuels. It thus refers to management's ability to adapt to changing market conditions or to revise decisions.

This paper presents a simulation model, in which the investment is regarded as a single-firm problem in an operating environment with multiple exogenous and stochastic prices.[2] The simulation model is used to explore the impact of emissions trading, and in particular the European Union Emissions Trading Scheme (EU ETS),[3] on investments in a specific energy production technology. Two real case studies are studied. The benefit of the selected approach is that it can take into account the value of multiple simultaneous real options better than a standard DCF analysis.

Valuation of real options requires an expansion of the standard analysis. As a simple equation: the Extended Net Present Value (NPV_{ext}) is equal to the standard Net Present Value (NPV) plus the value of the real options (O)

*Tel.: +358 40 762 0979; fax: +358 9 451 3674.
E-mail address: harri.laurikka@greenstream.net.

[1]For an overview on real options, see e.g. Dixit and Pindyck (1994), Trigeorgis (1995) or Schwartz and Trigeorgis (2001).

[2]For a taxonomy on energy system models, see Ventosa et al. (2005). As the prices are exogenous, it is implicitly assumed that the investment is small compared to the market size and cannot hence significantly affect any of the market prices. "Stochastic" refers to the fact that the prices at least partly depend on random events.

[3]For more on the EU ETS, see http://europa.eu.int/comm/environment/climat/emission.htm.

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(Trigeorgis, 1995). Literature provides different methods to the estimation of NPV_{ext} ranging from contingent claims analysis to dynamic programming and to simulation (e.g. Dixit and Pindyck, 1994; Amram and Kulatilaka, 1999). All the methods have strengths and weaknesses, and set different requirements for the problem formulation and availability of data. For example, contingent claims analysis is based on the idea that determination of the risk-adjusted discount rate is avoided through market-traded assets, such as futures for commodities. The method works, if the project cash flows can be completely replicated with market-traded assets, which is not currently the case, e.g. in heat and power projects within the EU ETS. In such cases, the determination of the risk-adjusted discount rate is necessary.

Laurikka and Koljonen (2005) applied Monte Carlo simulation for valuation of a power generation investment within the EU ETS using two stochastic variables (price of electricity and emission allowance price) in a risk-adjusted framework. The simulation model presented here is also based on a risk-adjusted framework, but can simultaneously deal with multiple stochastic variables, such as prices of electricity, emission allowance, and fuels, to estimate the value of flexibility.

The object of the case studies of this paper is the Integrated Gasification Combined Cycle (IGCC) technology. Solid fuel gasification technologies, such as IGCC, are promising alternatives for future heat and power generation due to the high generating efficiency and favourable characteristics regarding potential carbon dioxide capture (e.g. Harmoinen et al., 2002; Lako, 2004). The IGCC technology is expected to find first commercial applications in oil refineries and coal power condensed power plants (Harmoinen et al., 2002).

Section 2 describes the basic structure of the model and the common data applied in the case studies. Specifications in the model, the case-specific data, and the model outcomes are presented in Sections 3 (gasification of biomass in an existing condensing power plant) and 4 (gasification of coal in a residential CHP plant). Section 5 concludes.

2. Model

The model in this paper estimates the expected change in the Extended Net Present Value ($E(\Delta NPV_{ext})$) through the investment:

$$\Delta NPV_{ext} = NPV_{ext,2} - NPV_{ext,1} = \Delta NPV + \Delta O, \quad (1)$$

where $NPV_{ext,2}$ and $NPV_{ext,1}$ is the Extended Net Present Value after and before the investment, respectively, ΔNPV is the change in the NPV and ΔO the change in the option value.

A simple Monte Carlo simulation, in which multiple futures are generated in terms of a set of state variables, such as market prices of electricity, emission allowance and fuels, is used to evaluate ΔNPV_{ext}. In both case studies (Sections 3 and 4), there are 4–5 relevant state variables, which depend on random events in discrete time. The time period in the model is a year. As the value of the state variables fluctuates in the simulation, the reactions of the plant management are modelled so that they aim at cash flow maximization.

The stochastic processes used in the simulation mimic one-factor mean-reverting Ito processes, the Ornstein–Uhlenbeck processes (Dixit and Pindyck, 1994, pp. 74, 75). Mean-reverting processes in economic applications are based on the idea that in the long-term high prices for a commodity will increase its production capacity and hence cause the price to "revert to the long-term mean" and vice versa. In valuation of a real option, such a process gives a more conservative value than an equivalent process, where probability distributions are wider.

The state variables x_i for each period t ($x_{i,t}$) are modelled so that

$$E(X_{i,t}) = X_i^* + (X_{i,start} - X_i^*)e^{-\kappa t} \quad (2)$$

with X_i being the natural logarithm[4] of the stochastic variable (x_i), $E(X)$ its expected value, $X_{i,start}$ the selected initial value, X_i* the natural logarithm of the mean value and κ the speed of mean reversion. Further, the volatility of X_i is given as

$$\sigma(X_{i,t}) = \frac{\sigma^2}{2\kappa}(1 - e^{-2\kappa t}). \quad (3)$$

Stochastic state variables used in this paper are presented in Tables 1 and 2 with their key parameters: long-run average values, volatilities, speeds of mean reversion, and correlations to the other state variables. These parameters are considered static, and they are based on historical data and the market data at the time of writing. It is important to note that this approach presumes a certain continuum in the energy market. For example, price volatilities are assumed fairly low and biomass is assumed to be less integrated to the global energy market (low correlations to the prices of coal, oil and gas) also in the future. It is worth noting that the long-run average prices (x*) are *not necessarily equal to an expected value*.

Not much is known about the long-term behaviour of emission allowance prices at the time of writing. For this reason, *scenarios* are made on the price and volatility of allowances (Table 3).

All the state variables, except the annual average price of electricity (p_e) are assumed constant within a year for simplicity. The seasonal fluctuation of the electricity price is modelled endogenously. Similarly to Laurikka and Koljonen (2005) it is assumed that the annual average price of electricity (p_e) directly depends on the allowance price (see, e.g., Koljonen et al., 2004; Electrowatt-Ekono, 2003a), so that

$$p_e = p_{e,base} + \gamma \cdot p_{CO_2}, \quad (4)$$

[4]The logarithm is used, since it is assumed that state variables cannot be negative.