Valuation of Flexible Power Plants in Brazil: a Real Options Approach

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ABSTRACT

In this paper we discuss the real options valuation of investments in flexible power plants. After the energy supply crisis lived in 2001, new investments in gas fired power plants were made to increase electricity generation in the short term, due to the reduced maturity time of these investments. More recently, the nationalization of the Bolivian natural gas reserves raised uncertainties over the prices and supply of this commodity. First we analyze an operating power plant which can switch fuels among natural gas and oil. Second, we study the option to temporarily shut down the plant. Finally, we assess the interaction between these two flexibilities. Valuation involves the use of two quadranomial trees, supporting correlated GBM for the fuel prices.

KEY-WORDS: real options, valuation, flexible power plants, quadranomial trees, commodity prices

1 INTRODUCTION

The Brazilian Power sector started its liberalization process in the beginning of the 90´s, in order to insert competition and attract private capital to investments in this sector. However, the results of the deregulation were not as successful as planned and, in 2001, the country suffered an energy supply crisis. New investments in gas fired power plants were the main alternative found in order to increase electricity generation in the short term, due to the reduced maturity time of these investments. However, more recently, the Bolivian natural gas reserves, from where most of the gas consumed in Brazil is extracted, have been nationalized, raising uncertainties over gas prices and supply.

The uncertainty and irreversibility of investments in this sector make investment analysis a more difficult task, since traditional investment analysis methods, such as the NPV, are not the most appropriate tools for the valuation of investments under these conditions. These methods don't take into account the managerial flexibility embedded in a project, and

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therefore, assume that investments are managed passively, and managers will not review their decisions.

However under the conditions of uncertainty and irreversibility, managerial flexibility may be highly valuable, and should be taken into account in a project valuation. The valuation of flexibility calls for a more sophisticated approach, such as the Real Options[4].

Recently, the literature on Real Options has grown a lot, and these techniques have been applied in a wide range of industry sectors, under many different approaches. Nevertheless, the real options approach in the energy sector has been mainly applied for the evaluation of Oil Investments.

During the last fifteen years, however, the application of real options analysis to power generation investments has increased a lot, due to the liberalization process of electricity markets in many countries.

The aim of this article is to present the valuation of a flexible power plant, which can operate burning either natural gas or oil. Initially we calculate the value of the option to switch among these fuels. Later, we evaluate the operational flexibility of the plant, that is, the option to temporarily shut down. Finally, we analyze the interaction between these two options. To do so, we use an extended and simplified version of the model proposed by Abadie and Chamorro (2006).

A review of some important contributions to the literature focused on thermal power plants is shown below.

2 REAL OPTIONS VALUATION APPLIED TO THERMAL POWER PLANTS

Apparently, the first application of real options analysis to a thermal power plant is shown in Kulatilaka (1993). The author assesses the switch option of a dual-fired boiler, which can alternate fuel from natural gas to oil and vice-versa. Dynamic programming is used to value the managerial flexibility, which turns out to be more valuable than the extra cost of the flexible technology.

Deng, Johnson and Sogomonian. (1998) use an analytical model to valuate thermal power plants which operate only when the spark spread is positive. Comparing the results of the real options approach to the “naive" NPV, the authors conclude that the first method provides values much closer to the market price of the assets than the traditional DCF method.

Brekke and Schieldrop (2000) analyze the switch option and the optimal timing of investing in a plant that can burn natural gas or oil. Analytically, they prove that the flexibility acquired with the flexible (dual-fired) technology reduces the value of the option to delay the investment.

Using Monte Carlo simulation and dynamic programming, Tseng and Barz (2002) assess a power plant capable of switching between 2 modes: on and off. For the first time in the literature, the operational restrictions of the plant, such as the time necessary to turn on and to turn off the plant are taken into account.

[4] Dixit and Pindyck (1994) present a very rigorous and complete review of the real options literature.

Fleten and Nasakkala (2003) analyze a license to build a power plant, held by an investor. Analytically, they evaluate the optimal timing and the option to abandon the investment, taking into account stochastic CO2 emission costs. They conclude that it's not optimal to build the plant, even if there were no emission costs.

Abadie and Chamorro (2006) use a quadranomial lattice to valuate the investment in an Integrated Gasification Combined Cycle, which can generate power burning either coal or natural gas. After analyzing the optimal time to invest, they show that there is a small region in the price space in which it's optimal to wait instead of investing.

Although the international literature contemplates many types of flexibility and a large variety of models, that is not the case in Brazil. The main contributions to the national literature are shown below.

Castro (2000) assesses the operational flexibility (option to shut down) of a gas fired power plant. The spot price of the electricity is obtained from NEWAVE, a simulation software developed by CEPEL to determine the optimal operation strategy of the Brazilian Power System. Using simulation and dynamic programming, the author calculates the value of the flexibility acquired by declaring the plant flexible.

Silva, Teixeira and Gomes (2001) also valuate the operational flexibility of a plant, using an analogous approach to Castro (2000). However, instead of using NEWAVE, the authors develop an empirical forecasting model for the electricity prices, based on the experience of professionals related to the Brazilian power market and on the time series of spot prices. The results obtained are very close to the ones by Castro (2000).

Using Monte Carlo simulation, Rocha, Moreira and David (2002) evaluate the effects of the "energy deficit cost" and the "normative value", two parameters regulated by the Electric Power Regulatory Agency, on the attractiveness of the investments in gas fired power plants. They conclude that a regulation based only on an increase in the energy deficit cost is not effective to attract the required investments in power plants. Therefore, the normative value should match the critical price required to invest immediately, in order to induce new investments.

Gomes (2002) assesses the optimal time to invest in flexible power plants. He uses NEWAVE and Monte Carlo Simulation to determine the value of the plants, and a binomial lattice to determine the best time to invest. Later, he develops an option game model to determine the optimal time to invest under duopoly assumptions.

Most of the real options models used in Brazil use the energy spot price as the only source of uncertainty, and the fuel cost is usually taken as a constant. However, due to a significant rise on the prices of fuels in association to the uncertainties of prices and supply of the natural gas imported from Bolivia, this should be a key component in the valuation model.

3 VALUATION OF THE POWER PLANT

3.1 The Base Case

The parameters adopted in the base case are show on TABLE 1.

TABLE 1
Parameters of the Base Case

Parameters	Gas Mode	Oil Mode
Plant Size (Mw) – P	300	300
Production Factor (% P) - PF	85	85
Efficiency (%) – E	50	30
Useful life (years) - T	25	25
Investment cost ($/Kw) - I	495	495
Operation Cost (US$/MWh) - ($C_{O\&M}$)	7.0	7.0
Initial Fuel Prices (US$/MBtu)	4.2	7.0
Volatility (%)	19.88	23.66
Correlation between fuels	0.74	0.74
Risk-neutral drift rate of fuels (%)	1.5	1.0
Risk free interest rate (%) – r	6.0	6.0
Cambial rate (R$/US$)	1.85	1.85
Energy Price (R$/MWh) - P_e	80.00	80.00

SOURCE: Produced by the authors[5].

Energy prices are taken as constant. Initially, the switch cost from gas mode to oil mode - C(g→o) – and the switch cost from oil mode to gas mode - C(o→g) – are considered nil.

The fuel prices are modeled as correlated Geometric Brownian Motion. Pindyck (1999, pg 24) suggests that the mean reverting rate of these commodities is slow, and the GBM assumption will be appropriate if the volatility is relatively constant. Pindyck (2004) argues that the fluctuations in volatilities of oil and natural gas are short-lived and should not have any significant impact on most real options and investment decisions related to the price of these commodities.

Even though these commodities are traded in US Dollars in Brazil, electricity prices and contracts are traded in Brazilian Reais. Therefore, a cambial rate was used to convert all the prices and costs from US Dollars to Brazilian Reais. This rate is taken as constant during the plant's useful life.

3.2 Valuation Models

3.2.1 Model for the power plant with option to switch

We make use of the quadranomial model presented in Copeland and Antikarov (2001) to assess the value of the power plant taking into consideration the imperfect correlation between oil and natural gas. The risk-neutral quadranomial probabilities are obtained according to the following equations:

$$Puu = (u_1u_2 + u_2g_1 + u_1g_2 + \rho_{12}\sigma_1\sigma_2\Delta t) / 4u_1u_2 \quad \textbf{(1)}$$

$$Pud = (u_1u_2 + u_2g_1 + d_1g_2 - \rho_{12}\sigma_1\sigma_2\Delta t) / 4u_1u_2 \quad \textbf{(2)}$$

$$Pdu = (u_1u_2 + d_2g_1 + u_1g_2 - \rho_{12}\sigma_1\sigma_2\Delta t) / 4u_1u_2 \quad \textbf{(3)}$$

$$Pdd = (u_1u_2 + d_2g_1 + d_1g_2 + \rho_{12}\sigma_1\sigma_2\Delta t) / 4u_1u_2 \quad \textbf{(4)}$$

[5] The technical parameters of the plant were taken from *Brazil: A Country Profile on Sustainable Energy Development* (2006).

Where:

$u_1 = \sigma_1\sqrt{\Delta t} \rightarrow$ up move of natural gas **(5)**

$d_1 = -u_1 \rightarrow$ down move of natural gas **(6)**

$u_2 = \sigma_2\sqrt{\Delta t} \rightarrow$ up move of oil **(7)**

$d_2 = -u_2 \rightarrow$ down move of oil **(8)**

g_1 and $g_2 \rightarrow$ expected risk-neutral growth rate of the prices of natural gas and oil per period

$\rho_{12} \rightarrow$ correlation between variations of the prices of natural gas and oil

In order to compute the value of the operating power plant, we use two quadranomial lattices with 100 steps[6]. This way, we illustrate the adjustments on natural gas prices, made once every three months in Brazil. The first lattice corresponds to initial operation in natural gas mode and the second one corresponds to initial operation in oil mode. Independently of the operating mode, the value of the plant at the last operating moment is nil:

Vg=0 if the end of the plant's life is reached in gas mode,

Vo=0 if the end of the plant's life is reached in oil mode,

where Vg represents the value of the natural gas lattice nodes and Vo represents the value of the oil lattice nodes. For anterior nodes, the best of two options is chosen[7]:

- continue: receive the cash flow of the current operating mode plus the present value of the corresponding lattice

- switch: receive the cash flow of the current non operating mode plus the present value of the non operating mode lattice, minus the corresponding switch cost.

The natural gas lattice values are obtained as follows:

$$Vg = MAX\,(CF_g + e^{-r\Delta t}\,(Puu \cdot Vg_{uu} + Pud \cdot Vg_{ud} + Pdu \cdot Vg_{du} + Pdd \cdot Vg_{dd}); (CF_o - C(g\rightarrow o) + e^{-r\Delta t}\,(Puu \cdot Vo_{uu} + Pud \cdot Vo_{ud} + Pdu \cdot Vo_{du} + Pdd \cdot Vo_{dd}))) \quad \textbf{(9)}$$

The oil lattice takes on the following values:

$$Vo = MAX\,(CF_o + e^{-r\Delta t}\,(Puu \cdot Vo_{uu} + Pud \cdot Vo_{ud} + Pdu \cdot Vo_{du} + Pdd \cdot Vo_{dd}); (CF_g - C(o\rightarrow g) + e^{-r\Delta t}\,(Puu \cdot Vg_{uu} + Pud \cdot Vg_{ud} + Pdu \cdot Vg_{du} + Pdd \cdot Vg_{dd}))) \quad \textbf{(10)}$$

Cash flows for natural gas operating mode are given by:

[6] Consequently, Δt=0.25.

[7] A similar approach using 2 binomial lattices can be found in Trigeorgis (1996, p. 177-184). Abadie and Chamorro (2006, p. 24-28) also present a similar approach using 2 quadranomial lattices.

$$CF_g = A \cdot P_e \cdot \Delta t - B_g \cdot P_g \cdot \Delta t - A \cdot C_{O\&M} \cdot 1.85 \cdot \Delta t \quad \textbf{(11)}$$

Cash flows for oil operating mode are given by:

$$CF_o = A \cdot P_e \cdot \Delta t - B_o \cdot P_o \cdot \Delta t - A \cdot C_{O\&M} \cdot 1.85 \cdot \Delta t \quad \textbf{(12)}$$

Where:

$A = P \cdot 365 \cdot 24 \cdot PF$ → Annual production in MWh

P_e → Current energy price

$B_g = (P \cdot 365 \cdot 24 \cdot PF \cdot 3{,}412) / E_g$ → Natural gas energy needed per year (MBtu/year)

$B_o = (P \cdot 365 \cdot 24 \cdot PF \cdot 3{,}412) / E_o$ → Oil energy needed per year (MBtu/year)

P_g → natural gas price at current node (R$/MBtu)

P_o → oil price at current node (R$/MBtu)

3.2.2 Model for the power plant with option to shut down temporarily

The model shown above can be easily adapted to allow the valuation of the option to temporarily shut down the power plant. This way, the operation of the plant can be seen as an option and not an obligation, and the plant operates only when cash flows are positive[8]. In order to do that, we truncate the cash flows by substituting equations 11 and 12 by 13 and 14, respectively:

$$CF_g = MAX((A \cdot P_e \cdot \Delta t - B_g \cdot P_g \cdot \Delta t - A \cdot C_{O\&M} \cdot 1.85 \cdot \Delta t); 0) \quad \textbf{(13)}$$

$$CF_o = MAX((A \cdot P_e \cdot \Delta t - B_o \cdot P_o \cdot \Delta t - A \cdot C_{O\&M} \cdot 1.85 \cdot \Delta t); 0) \quad \textbf{(14)}$$

4 RESULTS

4.1 Value of an operating power plant

The value obtained for the power plant characterized in the base case was R$203,286,000. Subtracting the initial investment of R$275,000,000 made to build the power plant, we find a negative NPV of R$71,714,000.

4.2 Value of the switch option

The value of the switch option is obtained based on TABLE 2, where the value of the plant is show, as a function of switching costs.

[8] A similar approach is shown in Trigeorgis (1996, p. 193). It does not take into consideration the costs of shutting down and restarting the plant.

TABLE 2
Value of an Operating Power Plant

Switching costs (R$) C(g→o) = C(o→g)	Plant's Value (R$)
0	203,286,000
10.000	203,013,000
30.000	202,566,000
50.000	202,149,000
100.000	201,254,000
1.000.000	192,832,000
Infinite	169,175,000

SOURCE: Produced by the authors.

As switch costs go up, flexibility loses its value. Therefore, when switch costs are infinite, flexibility has no value. The difference between the value of the plant with zero switching costs and the value of the plant with infinite switching costs corresponds to the value of the flexibility. The switch option value is R$34,111,000.

4.3 Value of the option to shut down temporarily

Truncating the cash flows and considering infinite switching costs, we obtain a value of R$534,129,000 for the power plant. From this value, we subtract the value of the plant without option to temporarily shut down, as shown at the last line of TABLE 2. The value of the option to shut down temporarily obtained is R$364,954,000.

4.4 Interaction between the switch option and the option to shut down temporarily

Valuating the plant with the switch option and the option to shut down temporarily, we obtain the value of R$545,189,000, which corresponds to a NPV of R$270,189,000.

Subtracting the value of the inflexible plant from the value of the plant with two flexibilities, we obtain the value of R$376,014,000 for the combination of the flexibilities.

Adding up the value of each single option, we obtain R$399,065,000. The sum of the isolated option values is 6.13% greater than the real value of the two options.

5 CONCLUDING REMARKS

In this paper we have analyzed the valuation of flexible power plants in Brazil as real options. In order to consider the uncertainty and correlation of the fuel prices, we have used quadranomial lattices. The model was shown due to its simplicity, flexibility and adequacy to determine the optimal operating policy of the plant.

Although the switch option value was low, due to higher prices and lower efficiency of oil, we should highlight that this flexibility may avoid the stopping of the plant in case of shortage of supply of natural gas imported from Bolivia.

The value obtained for the option to temporarily shut down the plant is very high. Moreover, the investment NPV was positive only when this flexibility was taken into account.

In line with the real options literature, we show the interaction of the two options. However, the interaction showed to be low.

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