Valuation of Onshore Mature Oil Fields: The New Bidding Rounds in Brazil

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Abstract

In this paper we present the valuation of a hypothetical onshore mature oil field using the Real Options approach, based on the new bidding rounds organized by the Brazilian Petroleum Agency (ANP) since 2005. We use a discrete-time approach and a binomial decision tree with risk-neutral probabilities based on Copeland & Antikarov (2001) and considering four steps to obtain the project value. This approach also gives the possibility of including concurrent real options represented by new production wells and divestiture.
Keywords: mature oil fields; valuation; real option; discrete-time; binomial tree

1 Introduction

A new scenario, made up of small onshore oil & gas fields auctions organized by the Brazilian Petroleum Agency (ANP) since 2005, allowed the creation of a new sector in Brazil, made of small size oil & gas producers. The valuation of a mature oil field using the real options approach intends to capture the managerial and operational flexibilities value that such project presents. Those flexibilities are many times represented by the improvement of the recovery factor through the opening of more production oil wells, and divestitures, considering improving the oil production through the drilling of more wells and the recovery factor improvement, and stopping the production and returning the oil field to the Brazilian Petroleum Agency (ANP).

This paper is organized as follows. Section 1 presents this introduction. Section 2 presents a brief review of the Brazilian Oil & Gas sector since 1999 and the first two auctions made by the ANP in Brazil, focused on small oil and gas fields, most of them mature fields. Section 3 discusses the Real Option approach for the oil & gas sector as compared to the Discounted Cash Flow method. Section 4 presents the methodology for the valuation. Section 5 presents a hypothetical onshore mature oil field valuation based on the discrete-time and binomial decision tree method, and in section 6 we conclude.

2 ANP`s Small Oil & Gas Fields Auctions

The Brazilian oil & gas sector is a particular one. In 1997, a new law opened up the Brazilian oil & gas sector to the private investments. Before that, Petrobras had the monopoly of the oil & gas exploration & production in Brazil. The Brazilian Petroleum Agency (ANP) was created as a government agency that could regulate that new market. Since 1999 the ANP has organized bidding rounds where offshore and onshore blocks were offered in Brazil. From 1999 to 2006 more than 3,000 blocks were offered, and the oil companies purchased about 19% of them. Large oil companies such as Shell and Chevron Texaco have been operating offshore Brazil in the oil & gas exploration & production since the Brazilian oil & gas market opened.

In October 2005, the ANP organized the 7th Bidding Round, phase B. This auction offered onshore small oil & gas fields, all of them in the states of Bahia and Sergipe, which had been returned by Petrobras to ANP after the opening of the Brazilian oil & gas sector in 1997. The presence of oil & gas in most of them was already confirmed by Petrobras, including the volume still to be produced and the API grade.

Based on the successful experiences of Canada and the US, where more than 23,000 small and average size companies produce oil & gas, ANP intended to develop a new sector in Brazil for small oil & gas producers. Bloomberg News (07/04/2006) reported that the increasing oil prices have made small oil companies in the US produce oil from small oil fields returned by large oil companies. Bloomberg also mentioned that those older oil fields "..are turning into big business for a batch of smaller firms", stressing that about 7 percent of U.S. production comes from oil & gas fields the large oil companies abandoned.

ANP organized two auctions focused on small onshore oil & gas fields in Brazil: the 7th Bidding Round, phase B (2005), and the 2nd Marginal Oil & Gas Fields Bidding Round (2006). As the presence of oil and gas had been already confirmed in most of them, the present uncertainties were mainly oil prices, rig rates, and other oil fields service rates. Table 1 presents the ANP bidding rounds results.

Round	Year	Blocks at Auction	Purchased	Percentage	Firms
1st	1999	27	12	44.44	11
2nd	2000	23	21	91.3	16
3rd	2001	53	34	64.15	22
4th	2002	54	21	38.89	14
5th	2003	908	101	11.12	6
6th	2004	913	154	16.87	19
7th - A	2005	1,134	251	22.13	22
Total		3,112	594	19.09	
7th - B	2005	17	16	94.12	
2nd Marg	2006	14	11	78.57	
Total		31	27	87.10	

Table 1. ANP`s Bidding Round Results

The success of the new auctions can be demonstrated by the high rate of purchased blocks: 94% in the 7th and 78% in the 2nd. 31 blocks were offered at both auctions. Since then, ANP has announced that every year it will organize a new auction on small onshore oil & gas fields, which can be the dawn of a new kind of oil exploration and production in Brazil.

It should be emphasized that in the onshore mature oil & gas fields operations (the Brazilian case), the presence of oil & gas had been confirmed before. There is no geological risk and the cash generation after the well drilling is guaranteed.

3 Real Option Approach

The Discounted Cash Flow (DFC) approach considers that the Net Present Value (NPV) of a project or firm is calculated by discounting the future projected cash flows at a discount rate which takes into account the risk of the project. Often the discounted rate is calculated by using the CAPM and the Weight Average Cost of Capital (WACC). This valuation method considers a static capital structure for debt and equity.

On the other hand, DCF analysis does not take into account the managerial flexibilities the project or firm could have, and the value of each one of them, and oil & gas projects usually have such managerial flexibilities. Dias (2004) presents a literature overview on Real Options in Petroleum. Trigeorgis (1993) considers that a Discounted Cash Flow (DCF) method undervalue projects with managerial flexibilities. Brandão (2002) considers that real assets with managerial flexibility can have their future cash flows affected by decisions made from the project managers.

Brandão, Dyer & Hahn (2005a) and Dias (2004) consider that the traditional Discounted Cash Flow (DCF) method cannot show the value of the operational flexibilities into a project. The oil & gas projects usually have many operational flexibilities related to deferral of the investments, enhancements, and divestiture. All of these flexibilities are influenced by the project uncertainties such as the oil & gas prices, type of oil, recovery factor, and the volume of hydrocarbons to be produced. Dias (2005) emphasized that the Real Options approach complements the traditional approach represented by the Discounted Cash Flow (DCF) method and the Net Present Value (NPV). According to Dias (2005), to maximize the Net Present Value (NPV) one should consider the managerial flexibilities, market uncertainties and technical uncertainties.

Regarding mature oil fields, Dias (2005) reports that Chevron used the Real Options method to invest in an onshore mature field in California, while at the same time, chose not to invest in oil exploration in Canada.

Cox, Ross & Rubinstein (1979) developed a binomial lattice model based on a discrete time approximation to the underlying stochastic process for Real Options. This method was used by Copeland & Antikarov (2001) when they developed their discrete time approach.

4 Methodology

The methodology we use is based on Copeland & Antikarov (2001), Brandão *et al.*(2005a), Brandão *et al.*(2005b), and Godinho (2006). Copeland & Antikarov (2001) proposed that the value of a project with managerial flexibility should be valuated through four steps. The first step represents the valuation of the project without flexibility using DCF to determine the Present Value (PV) of the project. According to Copeland & Antikarov (2001), this value is the best unbiased estimate of the project's market value. That represents the Copeland & Antikarov (2001) Marketed Asset Disclaimer (MAD) proposal. We also assume that the project return rates are normally distributed, following a random walk, which implies that the project value can be modeled through a Geometric Brownian Model (GBM).

The second step intends to capture the most relevant uncertainties of the project and to obtain the project volatility. These uncertainties are combined into a Monte Carlo Simulation, and the volatility of the whole project is obtained. At this point the suggestions made by Brandão *et al.* (2005b) and Godinho (2006) are incorporated into the second step of Copeland & Antikarov (2001) methodology. The Cash Flow at the moment 1 varies according to the Monte Carlo Simulation. The Cash Flow at the moments 2,3,4, … n represent a regular outcome related to each value the Cash Flow 1 assumes. As in Brandão *et al.* (2005b, p.104), "If a standard Geometric Brownian Movement approximation is used (this article case), then this step requires only the estimation of the volatility of the process in any arbitrary period because the volatility of a Geometric Brownian Movement process remains constant over time".

Into the Monte Carlo Simulation, z represents the project returns. The iterations promoted by the Monte Carlo Simulation obtain possible values for z. After 10,000 simulations, the Standard Deviation of the project returns is obtained.

Standard Deviation of Z, where $Z = \text{LN}\ \dfrac{(PV_1 + FCF_1)}{PV_0}$

The third step represents the construction of the binomial tree, without Real Options. The Brandão *et al.*(2005a) approach is used instead of the Copeland & Antikarov (2001) lattice. As reported by Brandão *et al*.(2005b, p.104), the increasing number of options make a lattice become more complex and susceptible to errors. Panko (1998) reports on the high errors rates when a lattice with many options is used. At the same time, the Copeland & Antikarov (2001) methodology is used considering the Risk Free Rate and the Risk Neutral Probabilities. The Risk Neutral Probabilities are the ones for the up and down movements of every branch of the binomial tree. We refer to Cox *et al.*(1979) and Hull (2003) for details associated with the binomial approximation.

The fourth and last step is the inclusion of the project flexibilities at specific time periods such as Expansion Options, Deferral Options, Divestiture Options etc. The result is a new value for the project, one that comprehends a static approach through a DCF, and the operational flexibilities value obtained by the project options.

To value each one of the Real Options it is just necessary to measure the difference between the value of the project with managerial flexibilities and the value of the project without flexibility. We refer the reader to Brandão *et al.*(2005a) for a detailed discussion of this method.

5 Mature Oil Field Valuation

The hypothetical mature oil field to be valued is based on the results at the Brazil's ANP 7th Bidding Round, phase B, Petrobras Auction CORP 001/2002 (cancelled), and the onshore oil field operated by the Federal University of Bahia at Quiambina, state of Bahia, Brazil.

5.1 Step 1 - The hypothetical mature oil field valuation without flexibilities

- The reserves will be exhausted in 10 years, from 2007 to 2016..
- Equipments and Rod Pumps cost – US$800,000.
- Production wells to be reopened – 04.
- Cost to reopen the 04 production wells, called Workover – US$500,000.
- Cost of well interventions every 02 years – US$100,000.
- Maintenance costs are assumed to be US$50,000 per year.
- Cost to close the production wells and divesting at the end of the operations (10 years), considered as a cash flow provision at the beginning of the project – US$800,000.
- Average winning bidding (used in this oil field) at the ANP 7th Bidding Round – US$100,000.
- The initial estimate of the oil volume to be produced is 200,000 oil barrels @ US$50 per barrel.
- Royalties represent 5% on the gross revenue.
- Taxes represent 34% on the income.
- The oil prices will rise 1.7% every year until 2030, according to the International Energy Agency (IEA) in 2006.
- The variable cost is considered US$8 per oil barrel.
- The cost of capital is assumed to be 10% per year and the Risk Free Rate is assumed to be 5% per year.

Mature Oil Field Operations - Budget in US$

	Year										
Description	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Reserves		200,000	168,000	138,000	111,000	87,000	65,000	46,000	30,000	17,000	7,000
Production-Oil Barrels		32,000	30,000	27,000	24,000	22,000	19,000	16,000	13,000	10,000	7,000
Workover	(500,000)										
Interventions			(100,000)		(100,000)		(100,000)		(100,000)		
Maintenance		(50,000)	(50,000)	(50,000)	(50,000)	(50,000)	(50,000)	(50,000)	(50,000)	(50,000)	(50,000)
Facilities / Rod Pump	(800,000)										
Cost/Barrell-US$8		(256,000)	(240,000)	(216,000)	(192,000)	(176,000)	(152,000)	(128,000)	(104,000)	(80,000)	(56,000)
Price/Barrel US$50		1,627,200	1,551,434	1,420,027	1,283,704	1,196,734	1,051,113	900,195	743,842	581,914	414,264
Average Bidding	(100,000)										
Divest	(800,000)										
Royalty-5%		(81,360)	(77,572)	(71,001)	(64,185)	(59,837)	(52,556)	(45,010)	(37,192)	(29,096)	(20,713)
Income before Taxes		1,239,840	1,083,862	1,083,026	877,519	910,897	696,557	677,185	452,650	422,818	287,551
Income Before Taxes		1,239,840	1,083,862	1,083,026	877,519	910,897	696,557	677,185	452,650	422,818	287,551
Taxes 34%		(421,546)	(368,513)	(368,229)	(298,357)	(309,705)	(236,829)	(230,243)	(153,901)	(143,758)	(97,767)
Net Income	(2,200,000)	818,294	715,349	714,797	579,163	601,192	459,728	446,942	298,749	279,060	189,784
FCF	**(2,200,000)**	**818,294**	**715,349**	**714,797**	**579,163**	**601,192**	**459,728**	**446,942**	**298,749**	**279,060**	**189,784**
IRR	**25.64%**										
NPV	**1,260,751**										
Cost of Capital	**10.00%**										

Table 2. Project Cash Flow showing the oil reserves depletion, the Free Cash Flow (FCF) per year, and the Net Present Value (NPV).

Table 2 presents the projection of the oil field cash flow. The project NPV is US$1,260,751. The Present Value (PV) is US$3,460,751, considering the investments of US$2,200,000. According to the first step of the valuation - Copeland & Antikarov (2001) - the value of the project without flexibilities is US$3,460,751. This is the project value to be used in the binomial tree construction.

5.2 Step 2 – The Project Volatility

As there is no uncertainty regarding the presence of oil, reserve volume and API grade, it is assumed that the main uncertainty that affects the project is the oil prices volatility. We also assume that the project returns are normally distributed, and can be modeled as a Geometric Brownian Movement (GBM) with constant volatility.

Dias (2005) reports that for commodities prices such as oil, many authors consider the Mean Reversion Model (MRM) a better model for price evolution. But he emphasized that the Unit Root Test of Dickey-Fuller cannot reject the Geometric Brownian Movement (GBM) for the period of 34 years. The period considered in this evaluation, regarding the Brent oil prices volatility, was from January 1970 to September 2006.

The main uncertainty, the Brent oil prices, is modeled as a Geometric Brownian Movement (GBM). They have a log-normal distribution. It is a period of time when the oil prices volatility is greater due the first oil crisis in 1974, after the Yom Kippur war. The calculated volatility for the Brent oil prices is equal to 33.71% per year, which will be considered when running the Monte Carlo Simulation. After 10,000 iterations the Monte Carlo Simulation indicates a project volatility of 47.35% per year as follows, table 3:

Statistic	Value
Minimum	-335.12%
Maximum	177.06%
Mean	-0.95%
Std Dev	**47.35%**
Variance	0.224169205
Skewness	-0.499166775
Kurtosis	4.04135359
Median	1.99%
Mode	9.32%

Table 3. Monte Carlo Simulation Results

5.3 Step 3 – Modeling the Binomial Tree

We will model the binomial lattice and the project flexibilities as a decision tree using the following input parameters, according to Copeland & Antikarov (2001):

The Project Value without Flexibilities.
Project Present Value (PV): US$3,460,751.

Project Volatility from the Monte Carlo Simulation: $\sigma = 47.35\%$

The Risk Free Rate $Rf = 5.00\%$

The up movement factor $u = e^{\sigma\sqrt{t}}$ = 1.6056

The down movement factor $d = 1/u$ = 0.6228

The Risk Neutral Probability $p = \dfrac{(1+Rf)-d}{(u-d)} = \dfrac{(1+0.05)-0.6228}{(1.6056-0.6228)} = 43.47\%$

The Complementary Probability $q = (1-p)$ = (1-0.4347) = 56.53%

5.4 Step 4 – Modeling the Real Options

The project Real Options are modeled in the same binomial tree. The first one to be modeled is the Option to reopen three more production wells and the improvement of the reserves recovery factor, each one of them in the years 1, 2 and 3. The second Option is the one to divest which represents closing the production wells, selling the rod pumps, and return the oil field to the Brazilian Petroleum Agency (ANP). This Option will be exercised if oil prices are low enough in the years 6, 7 and 8. The last option is a combination of the Expansion and Divestiture Options in the same oil field and the same operation. All three Options are explained in sections 5.4.1, 5.4.2 and 5.4.3.

5.4.1 Option to Expansion

The expansion option means improving the oil production of the oil field. This can be done by reopening additional production wells previously drilled by Petrobras when the field was operated before the Brazilian Petroleum Agency (ANP) auction. Besides, well engineering techniques will guarantee the improvement of the oil recovery factor. Melo & Aboud (2006) presented new well engineering techniques used in Brazil, which improved the oil field production by 37%. Borba *et al.*(2004) showed that through geological data reinterpretation new wells had been drilled at Pilar field, Brazil, improving the oil production as many as five times.

We assume that the improvements of the expansion options represent 20% in the year 1, 15% in year 2 and 10% in year 3. The costs are the well reopening, well engineering techniques, and a new rod pump, which represent US$400,000, and can be made in the years 1, 2 and 3. In the figures 1 and 2 we show a portion of the decision tree. The option to expansion increases the project value to US$3,772,998, which represents an option of US$312,247, or and increase of 9.02%.

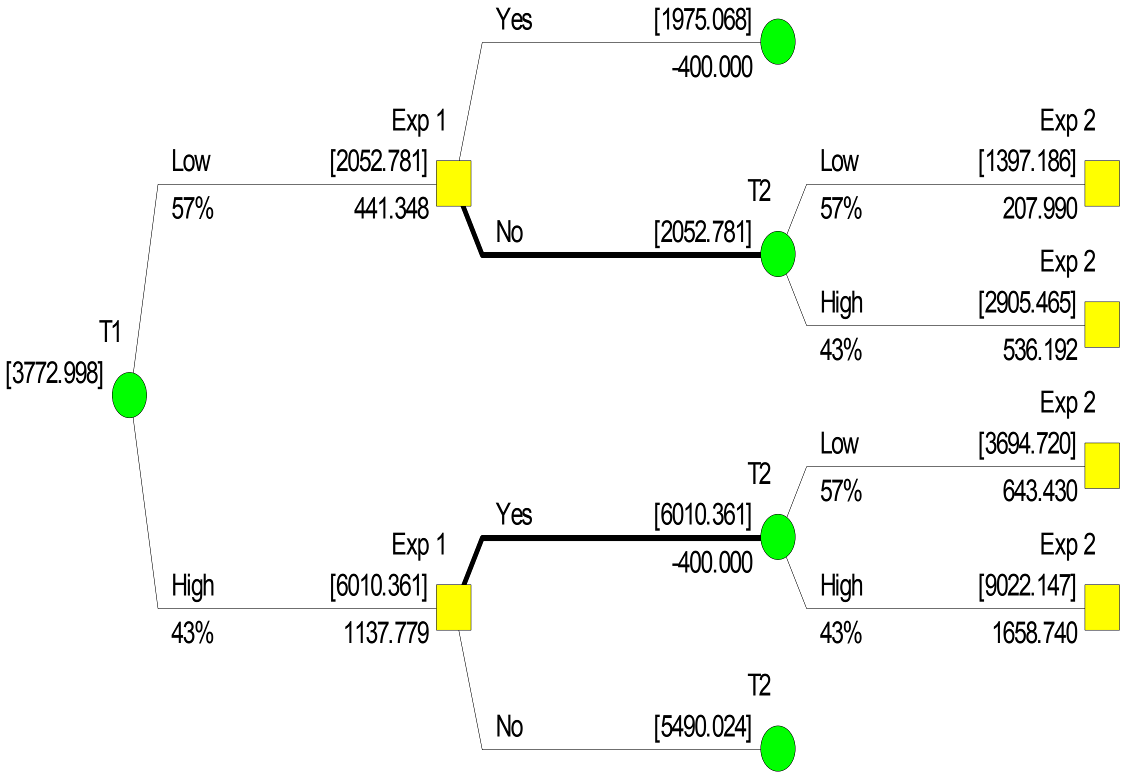

Figure 1. Option to Expansion. The new oil field value with the Options reach US$3,772,998.

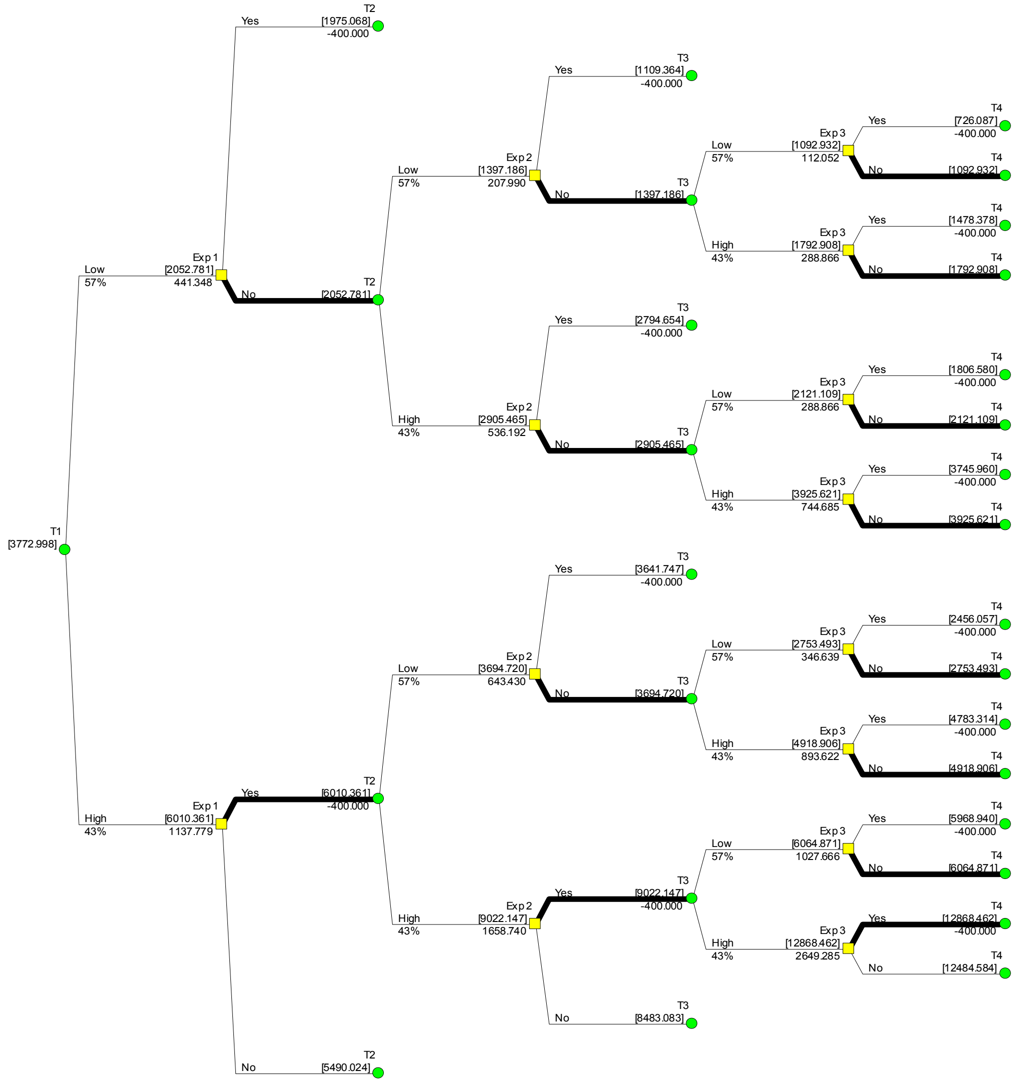

Figure 2. Option to Expansion. The new oil field value with the Options reach US$3,772,998. The option to expansion is shown in the 3 years it can be exercised.

5.4.2 Divestiture Option

The option to divest implies terminating all oil production and returning the oil field to the Brazilian Petroleum Agency (ANP), which could occur, for example, in a scenario of falling oil prices which could inhibit the operation of the oil field.

The assets that can be negotiated are the ones with more liquidity, which we assume are the rod pumps, which have an estimated value of US$340,000 in year 6, US$300,000 in year 7, and US$260,000 in year 8. That means the strike price in a Put Option. The inclusion of the option to divest increases the value of the oil field to US$3,620,674, which represents an option value of US$159,923, or 4.62%. Figure 3 shows part of the binomial tree.

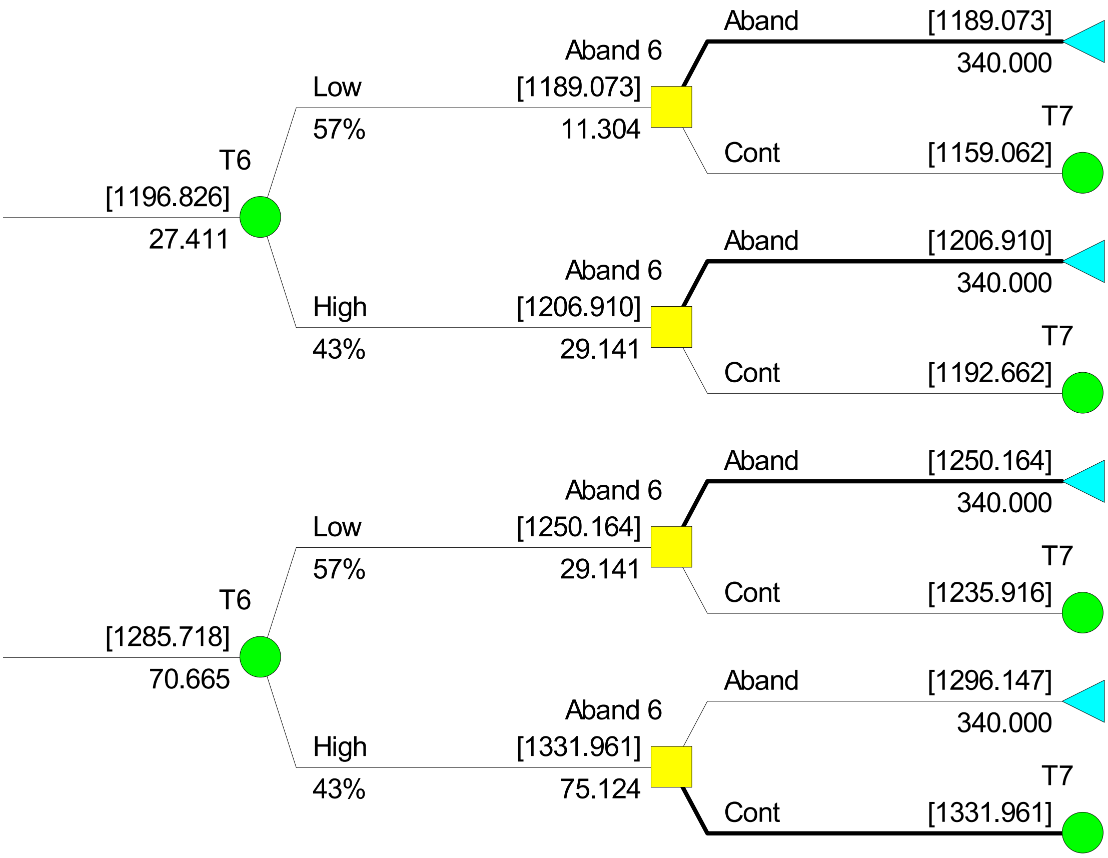

Figure 3. Part of the binomial tree is shown - year 6 – and the Divestiture Options are exercised at 3 scenarios.

5.4.3 Option to Expansion and Divest

The third possibility comprehends the combined options to Expand and Divest in the same oil field. The exercise prices, conditions and years of exercise are the same as explained in **5.4.1** and **5.4.2.**

So, in the years 1, 2 and 3 there is a Call Option that can be exercised – reopening oil wells and improving the oil production – and in the years 6, 7 and 8 a Put Option can be exercised. The Rod Pumps could be sold and the oil field is returned to the Brazilian Petroleum Agency (ANP).

The flexibility these options give to the oil field increased its value to US$3,926,001, and the oil field value is increased by 13.44%. The value of the options to Expansion and Divest is US$465,250. In the figure 4 we can see the decision tree model of the oil field value.

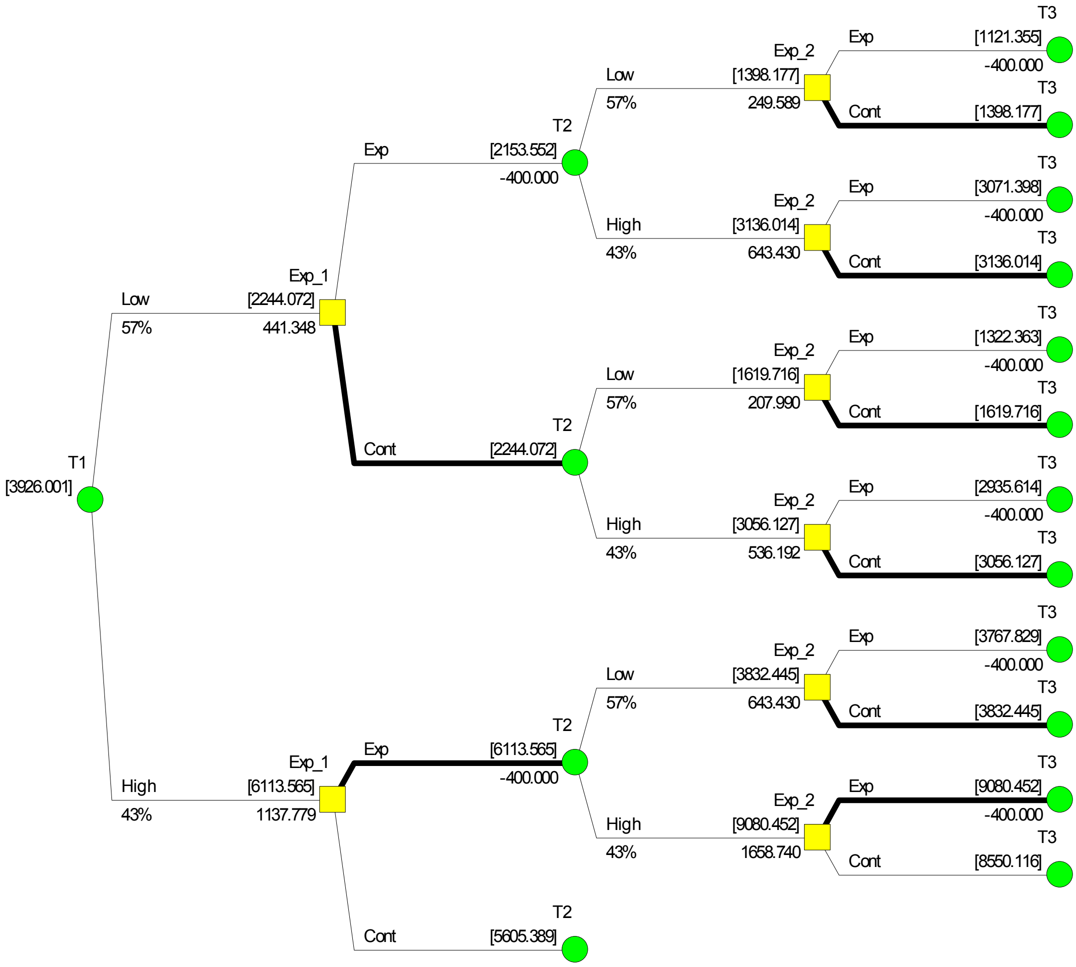

Figure 4. Part of the binomial model is shown. The new oil field value is US$3,926,001.

6 Conclusion

This paper presents two main points. The first one discusses the new scenario represented by the new auctions of onshore small oil and gas fields in Brazil. That can represent a new opportunity in Brazil for small companies in a sector which up to now has been dominated by the oil majors. These small oil and gas fields have attracted the interest of many small companies, newcomers in the oil sector.

The successful experiences of Canada and the Unites States show that this new market, considering the opportunities for small oil companies, cannot be underestimated. The success achieved in the first two auctions organized by the Brazilian Petroleum Agency (ANP) has shown it.

The second point relates to how a project such as this can be valuated, considering that the high volatility of the oil prices and the flexibilities that those projects present, such as improving the production through new well techniques, drilling more wells, postponing operations and investments, and even divestiture, among many others, show that the traditional approach represented by the Discounted Cash Flow (DCF) valuation cannot alone be used to help the decision makers make optimal decisions.

We show that another approach can be used, one that can value the managerial and operational flexibilities inherent to these types of projects, such as the real options method. Table 4 shows how the flexibilities increase the oil field value as determined in this paper, when compared to the valuation without flexibilities through a DCF.

Oil Field Values		
	US$	%
Expansion RO	312,247	9.02
Divestiture RO	159,923	4.62
Exp+Divest RO	465,250	13.44
DCF Value	3,460,751	

Table 4. It shows the value of each one of the Real Options.

At the same time it should be stressed it is a hypothetical oil field, since this new scenario in Brazil has only just begun. The new oil & gas fields operations will give us the historical data that should be evaluated, analyzed, and compared with the hypotheses considered in the field definitions.

We should also emphasize that other possibilities of Real Options could be investigated. For instance, Real Options related to postponing the beginning of operations in the oil field, and even stopping the production – in a scenario of falling oil prices – to restart the production later in a better oil prices scenario. Besides, we could consider more uncertainties associated with the project, such as the volatility of the rig prices and other services in an oil field.

The Mean Reversion Movement (MRM) could also be compared with the Geometric Brownian Movement (GBM), considering the volatility and the impact of both of them in the project Real Options value.

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