THE OPTION VALUE OF SWITCHING INPUTS IN A BIODIESEL PLANT

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Abstract

There has been a growing concern in recent years about the quality of our environment and dependence on fossil fuels to supply the energy needs of the world, which has created an interest in the development of renewable and less polluting energy sources. One of these alternatives is the biodiesel fuel, which has many advantages over the fossil based diesel, or petrodiesel. In this paper we use the real options approach to determine the value of the managerial flexibility embedded in a biodiesel plant that has the option to switch inputs among different grain commodities. Our results indicate that the option to choose inputs has significant value if we assume that future prices follow stochastic processes such as Geometric Brownian Motion and Mean Reversion Models, and can be sufficient to recommend the use of input commodities that would not be optimal under traditional valuation methods. We also show that the choice of model and parameters has a significant impact on the valuation of this class of projects.

Key words: Biodiesel; Real Options, Monte Carlo Simulation; Mean Reverting Models.

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1. Introduction

Due to the growing environmental concern and dependency on fossil fuels, several countries have searched for renewable and less polluting alternatives for their energy needs. One of these alternatives is the biodiesel, which is obtained from the processing of vegetable oils. Aside from the sustainability advantages, the implementation of an energy program based on the use of vegetable oils has also the potential to create opportunities for large social benefits for rural workers in the field, as well as the increase in the demand for qualified labor for the processing phases.

Biodiesel production in Brazil has evolved steadily since 2005, when diesel fuel with a mix of up to 2% of biodiesel was first authorized by government regulatory agencies. This mix became mandatory in 2008, and will increase to 5% in 2013. One objective for this drive is to diversify the Brazilian energy matrix, reducing the reliance on fossil oil derivatives as well as atmospheric emissions (LEIRAS, 2006). At the same time, an increased demand for biodiesel is expected to create new markets for vegetable oils and job opportunities in the less developed rural regions of the country.

The literature on the analysis of biodiesel projects is scarce and focuses mainly on the cost of biodiesel production. LEIRAS (2006) and BARROS (2006) analyze the economic feasibility of the implementation of biodiesel plants by focusing on the production costs, considering the complete cycle from the production of the inputs to the sale of biodiesel oil and its byproducts. None of these works, however, consider the managerial flexibilities in the form of switching options that are embedded in this class of project, such as the flexibility to choose inputs for the biodiesel production, although there are unpublished reports that the Brazilian oil company, Petrobrás, has used real option analysis to value investments in biodiesel production[1].

In this article we discuss the importance of using the appropriate tools for the analysis of a biodiesel production process where there is flexibility to choose between two inputs (soybeans and castor beans). We show that this flexibility is not captured by traditional valuation methods and propose a real options approach where we compare two different

[1] Personal communication with Marco Antonio Dias, Petrobrás.

stochastic models for input price uncertainty. We focus on the incremental value created by the option to switch inputs in the investment in a biodiesel production plant, rather than the feasibility analysis of the full plant, which will be dependent on other factors not present in this work. We considered a project in the Northeastern region of Brazil where the soil is appropriate for the types of crops in consideration and which concentrates nearly 80% of all the country's production of castor bean. We also assumed that the processing plant will be installed close to the production area, thus eliminating the associated costs of transportation.

This article is organized as follows. After this introduction, in the next section we present the stochastic processes used in the model of input prices. In section 3 we provide some background on the biodiesel industry in Brazilian and the world, as well as details of the production process. In section 4 we present the model used for the valuation of the input flexibility. The results are shown in section 5, and in section 6 we present our conclusions, limitations and suggestions for future research.

2. Modeling of stochastic processes

A stochastic process represents a variable which changes randomly over time, at least partially, and can be classified as stationary, when its statistical parameters are constant over a given period of time, or non stationary (DIXIT & PINDYCK, 1994). One of the stochastic processes which is commonly used for modeling of financial and real assets is the Geometric Brownian Motion (GBM), which is a lognormal diffusion process where the variance increases linearly with time. The lognormal property of the GBM makes it ideal to model asset prices, which grow exponentially and cannot have negative values. On the other hand, the GBM may not be appropriate to model assets such as interest rates, exchange rates and commodities, as it may not be a realistic representation of actual price movements for these types of assets.

2.1. Mean Reverting Models

The Mean Reverting Model (MRM) is used to model assets that have prices that may have a long term equilibrium price level. DIXIT & PINDICK (1994, p.74) point out that the prices of some commodities tend to revert towards its marginal cost of production in the long term, despite random fluctuations in the short term. The hypothesis of market equilibrium explains this logic, as an increase (decrease) in prices would stimulate an increase (decrease) in supply, which naturally, contributes to a decrease (increase) in prices. DIAS (1996, p. 116) separates the MRM's in two groups. The first is used in economic and production applications and is based on the Ornstein-Uhlenbeck process. The latter is used in stock market applications (interest rates, inflation, amongst other variables), and uses the family of equations described in SHIMKO (1992, pg.11).

The simplest form of this process is the Ornstein-Uhlenbeck Arithmetic Model, described by the following stochastic equation:

$$dx(t) = \eta(\bar{x} - x)dt + \sigma dz(t) \tag{1}$$

In this equation, $\bar{x}$ is the level for which the variable x tends to revert and η is the reversion speed, as it factors the difference $(\bar{x} - x)$, creating the convergence effect of this process. DIXIT & PINDICK (1994, p.90-91), show that the variable $x(t)$ has a normal distribution and demonstrate Equations (2) and (3) respectively for mean and variance:

$$E[x(t)] = x(0)e^{-\eta t} + \bar{x}(1 - e^{-\eta t}) \tag{2}$$

$$Var[x(t)] = \frac{\sigma^2}{2\eta}\left(1 - e^{-2\eta t}\right) \tag{3}$$

In the application of this stochastic process for commodities, it is common to have $x = \ln P$ ¸ in order to prevent the occurrence of negative prices in the simulation. Therefore, the prices are lognormaly distributed, with an average of $E[P(t)] = e^{E[x(t)]}$. Equations (4) and (5) can be used to simulate the Orenstein-Uhlenbeck Arithmetic Model (DIAS, 2001, p.7).

$$P(t) = \exp\left(x(t) - 0.5\,\mathrm{var}[x(t)]\right) \tag{4}$$

$$x(t) = x(t-1)\,e^{-\eta\Delta t} + [\ln(\bar{P}) + \left(\frac{r-\rho}{\eta}\right)](1 - e^{-\eta\Delta t}) + \sigma\sqrt{\frac{1 - e^{-2\eta\Delta t}}{2\eta}}\,\mathrm{N}(0,1) \tag{5}$$

where ρ is the risk adjusted discount rate.

3. Biodiesel

Biodiesel may be broadly defined as "any biomass fuel that may substitute completely or partially diesel oil originating from fossils in automobiles and stationary engines". This definition applies to the mono-alkyl esters of long chain fatty acids, obtained primarily through methylic and ethylic transesterification of vegetable oils or fats which may be used directly as fuel in diesel engines, in total or partial substitution of fossil diesel. In Brazil, fossil diesel, or petrodiesel, represents 36% of each barrel of oil processed in the country. The main consumption area is the transport sector, with approximately 57% of all oil derivatives, of which 89% is used for road transport (SCHROEDER, 1996).

The idea of using vegetable oil as fuel began in 1859, when Rudolph Diesel presented a diesel engine that could be operated with peanut oil (CHALKLEY, 1919). The use in larger quantities, however, did not attract greater attention, except during crisis situations such as the Second World War and the periods of energy shortage in the 1970's (RODRIGUES et al., 2003). More recently, with the increase in demand and the drop in discoveries of new oil reserves, the importance of developing renewable fuels became apparent. In 2003, Brazil consumed 36 billion liters of diesel, with import costs alone of US$800 million (RODRIGUES et al., 2003). Due to the abundance of fertile land and water in Brazil, large scale production of biodiesel is possible and may allow the country to become a net exporter of the product, as has occurred with ethanol.

Biodiesel may be produced from multiple biomass sources, such as soybeans, cottonseed, castor beans, palm, babassu coconut, sunflower, jatropha, peanuts, canola, avocado, and others. While it is usually produced from seeds or directly from vegetable oils, biodiesel may also be produced from animal fat and from used cooking oil. Some of the advantages of biodiesel relative to petrodiesel are greater lubricating capacity, reduction in emission of compounds containing sulfur, biodegradability and reduction of gases that are harmful to the environment.

Biodiesel is an environmentally correct, less polluting and renewable fuel, with proven advantages over conventional diesel. When burned in a diesel engine, it releases 36% less particles than petrodiesel, while offering no toxicity to human being. There is still the possibility of commercializing its byproducts such as glycerol and derivates, as well as the husks from the oil seeds that can be used as animal feed, allowing profits to be made along all stages of its production process. Another advantage of biodiesel is that it may be used directly in engines without any modifications or greater spending in maintenance due to the fact that its chemical-physical properties are basically identical to that of conventional diesel.

3.1. World Overview

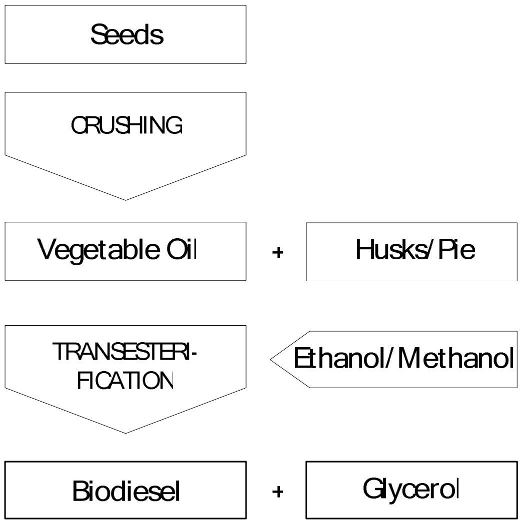
Biodiesel has powered vehicles in the United States and around the world with millions of miles with success. The States of Minnesota and North Dakota require by law that all commercialized diesel must have at least 2% biodiesel. Due to this, in North Dakota alone the annual carbon monoxide emission will drop by 80 tons, hydrocarbons by 9 tons, particles by 7 tons, 7 tons of acid rain agents will not go into the environment, as well as a reduction of 80% in emission of cancerigenous agents. In France, by law, all diesel fuel must contain 5% of biodiesel in its mixture, which generates benefits not only by reducing vehicle pollution, by also by reducing the dependency on imported petroleum.

Biodiesel is largely used in Austria and Germany and is currently gaining approval within many countries of the European Common Market. Germany strongly recommends the use of biodiesel in boats, as it is a biodegradable fuel, in order to eliminate any ecological problems during an oil leak. In recent years, mass transit authorities in the United States have participated in some successful biodiesel demonstration programs. These programs have shown that biodiesel reduces the gas emissions to acceptable levels in relation to the EPA Target Program (EPA), while at the same time maintaining the same consumption per kilometer, engine performance and engine longevity as with conventional petroleum diesel fuel.

3.2. The Biodiesel Production Process

Biodiesel is a methylic ester produced by a chemical process (transesterification) which react vegetable oils (new or used) with alcohol in contact with a catalyst. The transesterification may be replaced by processes such as esterification or cracking. The vegetable oil however, is obtained by crushing grains which create the husks or pie as byproducts, depending on which oil seed is used as input. **Figure 1**, shows a simplified version of the processes involved in the production of biodiesel.

Figure 1: Simplified biodiesel production process



Among the alcohols that may be used in the process are methanol, ethanol, propanol, butanol and methilic alchohol, with methanol being the most commonly used due to its low cost and greater chemical reactivity (BENDER, 1999). The glycerol is produced as a byproduct of the transesterification, and has great importance to the cosmetic industry as well as other high-value applications. The detailed chemical reactions and its respective mass proportion are shown by MENDES (2005). **Figure 2** shows in detail such reactions.

Figure 2: Biodiesel Chemical Reaction (transesterification de glycerides)

Oil (Triglycerides)	**+**	**Alcohol**	**=**	**Ester(biodiesel)**	**+**	**Glycerol**
1.000 kg (aprox.)	**+**	**100 kg**	**=**	**1.000 kg**	**+**	**100 kg**
ETHYLIC Route (ethanol reagent)						
$C_{57}H_{104}O_9$	+	$3C_2H_6O$	=	$3C_{20}H_{38}O_3$	+	$C_3H_80_3$
954 Kg	+	140 Kg	=	1000 Kg	+	94 Kg
METHYÍLIC Route (methanol reagent)						
$C_{57}H_{104}O_9$	+	$3CH_4O$	=	$3C_{19}H_{36}O_3$	+	$C_3H_80_3$
995 Kg	+	140 Kg	=	1005 Kg	+	94 Kg

Source: MENDES (2005).

In Brazil, since 2005 there a minimum volume percentage of 2% (B2 mixture) biodiesel in diesel fuel used in the country is required by law, although these values may be reduced by the government in face of supply and production conditions, biofuel performance in diesel engines and social implications. This minimum will be raised to 5% by the year 2013.

3.3. Castor beans

Due to its ease of cultivation, castor beans are one of the oil seeds that may be used as input for the production of biodiesel. According to BELTRÃO et al. (2004), of the 452 municipalities in the Northeast of Brazil that showed potential for producing castor beans, 189 are found in the state of Bahia, where 700kg per hectare were produced in the 2006/2007 harvest, in an area of approximately 170 thousand hectares. This represents 152,300 tons, approximately 78% of the total national production. Castor oil may be used in medicine, in the confection of cosmetics and toiletry products. Its derivatives include high performance lubricating oil for the aeronautical industry and plastic foam for the automotive industry. The crushing byproduct, the castor bean pie has use in agriculture as organic material for fertilizer, and as animal feed, as long as the pie undergoes a process to remove the ricin, which is a toxic protein that is present in the castor seeds.

Castor has a greater productivity in obtaining vegetable oil relative to soybean, but it produces fewer husks (pie) as byproducts of the crushing process, which strongly affects the cash flows generated by the byproducts. Table 1 shows a comparison of productivity of soybean and castor bean grains, amongst other relevant physical information. We may note that the oil extraction process is not 100% efficient and due to this the resulting husks or pie still contains a percentage of oil. For example, of each 100kg of soybean grains 18kg of oil are extracted, as indicated in column 3 of Table 1. As the efficiency of extraction is 66%, around 34% x 18kg = 6.12kg of oil still remains in the husks, which corresponds to 7.11% of the total 86kg of husks produced. In this process there are losses, which for soybean are around 2% (12kg of oil produced +86kg of husks =98kg).

Table 1: Grain Productivity for obtaining oil

Input	Capacity	Oil in Grain	Efficiency (Extraction)	Oil Produced			Husks Produced		
	(Kg/ha)	%	%	% weight	(Kg/ha)	(L/ha)	% weight	(Kg/ha)	oil % weight
Soybean	76	18	66	12	9,0	9,8	86	65,4	7,11
Peanut	30	35	83	29	8,7	9,5	69	20,7	8,62
Sunflower	60	35	83	29	17,4	18,2	68	41,0	8,71
Castor bean	40	40	75	30	12,0	13,1	68	27,2	14,70
Sesame	60	60	75	45	27,0	29,4	53	31,8	28,30
Cotton	30	16	69	11	3,3	3,6	82	24,6	6,05
Babassu	50	60	75	45	22,5	24,6	53	26,5	28,30
Cacau	50	40	85	34	17,0	18,5	64	32,0	9,37
Brazil Nut	40	45	66	30	11,8	12,9	67	26,8	22,84
Cupuassu	40	25	76	19	7,6	7,8	79	31,6	7,59

Source: TERRA VIVA (1999). *1 hectare (ha) = 10.000 m^2*

Though castor bean is currently not considered a commodity, in this paper we assume it as such, considering that the development of the biodiesel market will turn this culture into a more openly negotiated item.

3.4. Soy

Soy is one of the more attractive raw materials for the production of biodiesel, as from the 374,3 million tons of the ten main oil grains produced between 2004/05, soybean represented 212,5 million, or 57% of the world production (BIODIESELBR). The Brazilian production is about 62 million tons, which represents 30% of the total world production of soybeans. The soybean oil is produced by a crushing process and has as byproduct the soybean husks. Approximately 12% of the weight in grains is transformed into oil, while the rest into husks, which is used mainly in the production of animal feed.

4. Method

We assume that the biodiesel plant can choose between soybean and castor bean as inputs for the production process each month, and that the resulting biodiesel selling price does not depend on which input was used to produce it. This means that the cost and revenues will be calculated for a production of 1,000 liters of biodiesel, independent of whether they are produced from soybean or castor bean. The model also considers that the quantity (kg/ton of oil) of glycerol produced is also independent of the vegetable oil from which it was extracted, as illustrated in Figure 2 and confirmed in Equations (6) and (7). Hence, once the quantities of glycerol are accounted for in the flows of biodiesel from soybean and castor bean in the same proportion, it is irrelevant for the decision making process and thus was not considered in the option. The price of the castor bean pie byproduct of the crushing of that seed, is assumed to be constant during the process seen as there is not enough market data to model futures prices. We assume that there is sufficient flexibility in the plant to allow the options to be exercised monthly.

Unlike European countries which use rapeseed oil obtained from a non-edible vegetable culture, there is an additional difficulty in the Brazilian case as, some of the cultures that are potentially useable for the production of biodiesel are also foodstocks. This means that the future growth of the demand for vegetable oil could result in an increase in price for this culture, and, consequently an increase in price of biodiesel.

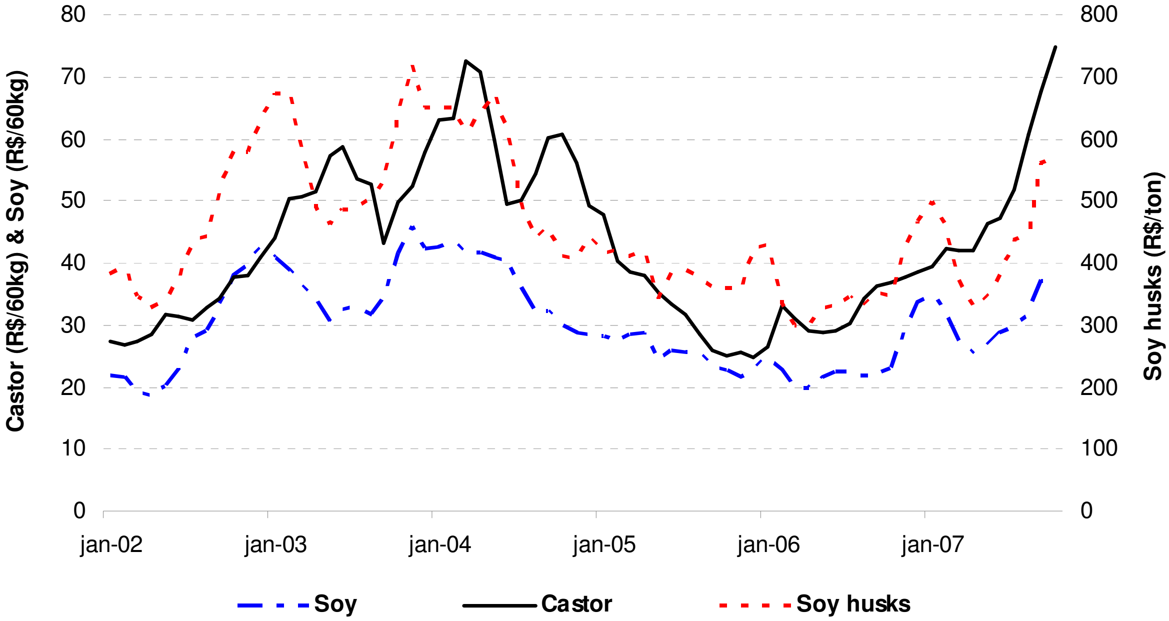
We assume that the stochastic processes for the prices of the variables may be a GBM or a MRM, and model the problem both ways. We will see that the latter provides a better approximation to actual data, due to the nature of commodity prices.

4.1. Data Collection

The historic prices series of soybean and castor bean used were based on the daily price series by SEAGRI (Secretaria de Agricultura, Irrigação e Reforma Agrária da Bahia), available *on-line*, expressed as monthly prices taken from the arithmetic mean of daily prices. Due to the lack of historic price data for soybean husks in Bahia, an estimate was made for this byproduct based on the correlation between soybean and soybean husks price series in Sao Paulo, according to the ABIOVE (Associação Brasileira de Óleos Vegetais) monthly price series for such inputs, available online. As the market for castor bean pie is still in its early stages and has low liquidity, it was not possible to use the same procedure. Hence, the current price (R$ 750/ton) was chosen as the best estimate for future prices.

The prices are shown in local currency by 60kg BAG (R$/60kg) for grains (soybean and castor bean) and in tons, for respective pies. The price series are monthly, collected from January/02 to October/07 (resulting in 70 periods) and were deflated by the IGP-DI (FGV). In **Figure 3** as follows, the series are shown together, in different scales;

Figure 3: Deflated Price Series for Soy, soybean husks and castor bean price - Bahia



4.2. Model

The model proposed in this article takes into consideration the quantity of grains (in tons) necessary for the production of 1000 liters of biodiesel. This value depends, primarily on the amount of oil and the efficiency of oil extraction per grain. Based on Table 1 and Figure 2, the following chemical reactions were created for the production of biodiesel:

Soybean

128,06 BAGS of 60 kg → 6.770 kg of soybean husks + 910 kg of soybean oil

910 kg of soil oil + 128,44 kg of methanol → 1.000 l biodiesel + 86,24 kg glycerol

Castor Bean

52,86 BAGS of 60 kg → 2.220 kg of castor bean husks + 950 kg of castor oil

950 kg of castor oil + 133,87 kg of methanol → 1.000 l biodiesel + 89,89 kg glycerol

Both the biodiesel fuel and the glycerol that result from the use of either grain are almost chemically identical, so considering the chemical reactions shown previously, it becomes possible to determine the cash flows for the production of 1000 liters of biodiesel made from each of the inputs.

The cash flows do not take into consideration any indirect costs related to the productive process, as we have assumed that such costs are the same for all oil seeds. As the aim of this paper is to analyze the flexibilities of the production process and not to value the economic feasibility, this simplification maintains the relative values of each option, since the indirect costs affect both cash flows in approximately the same proportion (same geographical and productive conditions). Hence, the simplification does not alter the validity of the results.

For the production of biodiesel, using soybean and castor bean, the cash flows are shown in Equations (6) and (7), respectively.

$$CF_{Biodiesel} = (Incomes_{Biodiesel}) - (Costs_{Biodiesel})$$

$$CF_{BioSoy} = (1000 \times P_{Biod} + 6{,}77 \times P_{Soy.husks} + 0{,}086 \times P_{Glic}) - (0{,}128 \times P_{Methanol} + 128{,}06 \times P_{Soy.bag}) \quad (6)$$

$$CF_{BiodCastor} = (1000 \times P_{Biod} + 2{,}22 \times P_{Castor.husks} + 0{,}090 \times P_{Glic}) - (0{,}134 \times P_{Methanol} + 52{,}86 \times P_{Castor.bag}) \quad (7)$$

In these cash flows, the price of biodiesel is expressed in R$/liter, methanol, the husks and the glycerol in R$/ton and the price in grains in R$/bag. In the flexible production of biodiesel (using soybean or castor bean), the optimal cash flow is greatest at the two values shown. As the producer of biodiesel can choose on any given month which grain to use (soybean or castor bean) and as the decision is not affected by the decision made on the previous month (at no cost, seen as the implementation cost of the plant is an initial cost, prior to the production), the problem may be modeled as an exercise of a series of European Options.

5. Results

5.1. Handling of Collected Data

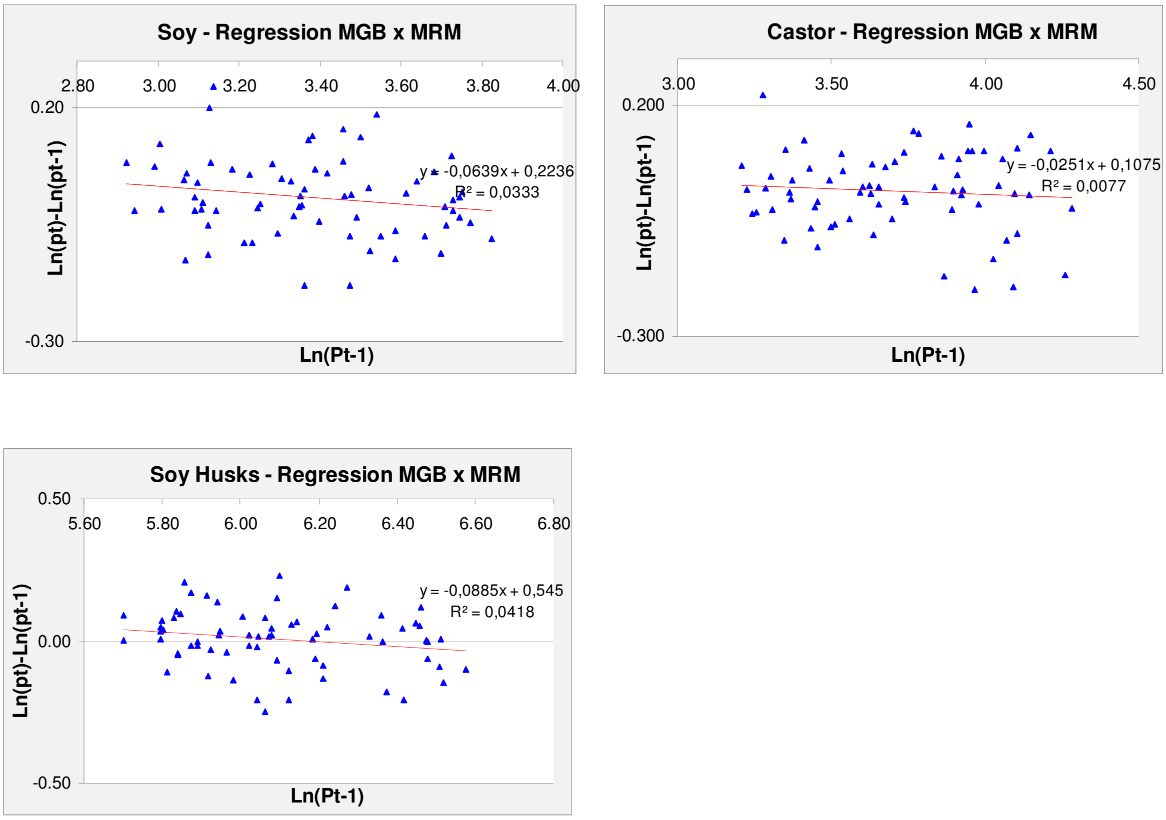
Once obtained, the historic price data were used to calculate the volatility of each of the inputs and of the soybean husks byproduct. The volatilities (σ) were calculated by the standard deviation of the returns *Ln(Pt/Pt-1)* of monthly prices. These volatilities were transformed to annual values, using the multiplication factor $\sqrt{12}$ (twelve months in one year).

Later, we attempted to reject the GBM, through the rejection test used by DIAS (2005). This test is based on the simple linear regression between the return log (natural) of variable prices in relation to the current level of the log of the price of the variable, in an attempt to find indications that the return depends on the current price level. Equation (8) represents the regression equation.

$$Ln(P_t) - Ln(P_{t-1}) = a + (b-1)Ln(P_{t-1}) + \xi_t \tag{8}$$

If the prices follow a GBM, the gradient of the curve should be close to zero ($b \approx 1$). In the same manner, for the MRM alternative hypothesis, the parameter b should indicate a negative value and significantly different than 1 (high prices tend to fall and low prices tend to increase). In **Figure 4** the regressions are shown for soybean and castor bean. Although it is not possible to reject the GBM, real options literature shows that this is not an easy task. DIAS (2005) notes that econometric tests applied to a petroleum price series could not reject he GBM hypothesis when 30 years of data were used and only when 117 years of data were used was the GBM rejected in favor of the MRM.

Figure 4 – Regression results for the rejection of the GBM in favor of the MRM for analyzed inputs.



Based on the history of non-rejection, the hypothesis to use the MRM was not discarded and a new linear regression was considered to calculate the necessary parameters for the MRM. This new regression tries to find a relation between the natural log of variable prices and the difference between the natural log of price in the preceding instant and the natural log of mean price of the evaluated series, as seen in Equation(9).

$$Ln(P_t) = a + b\,[\,Ln(P_{t-1}) - Ln(\overline{P})\,] \tag{9}$$

In this case, there are strong indications of mean reversion in the data series for their respective price means, due to the high determination coefficients (R^2). The coefficient for mean reverting velocity is such that $\eta = -\ln(b)/\Delta t$. **Figure 5** shows the regression results for soybean and castor bean.

Figure 5 – Linear Regression of analyzed input prices

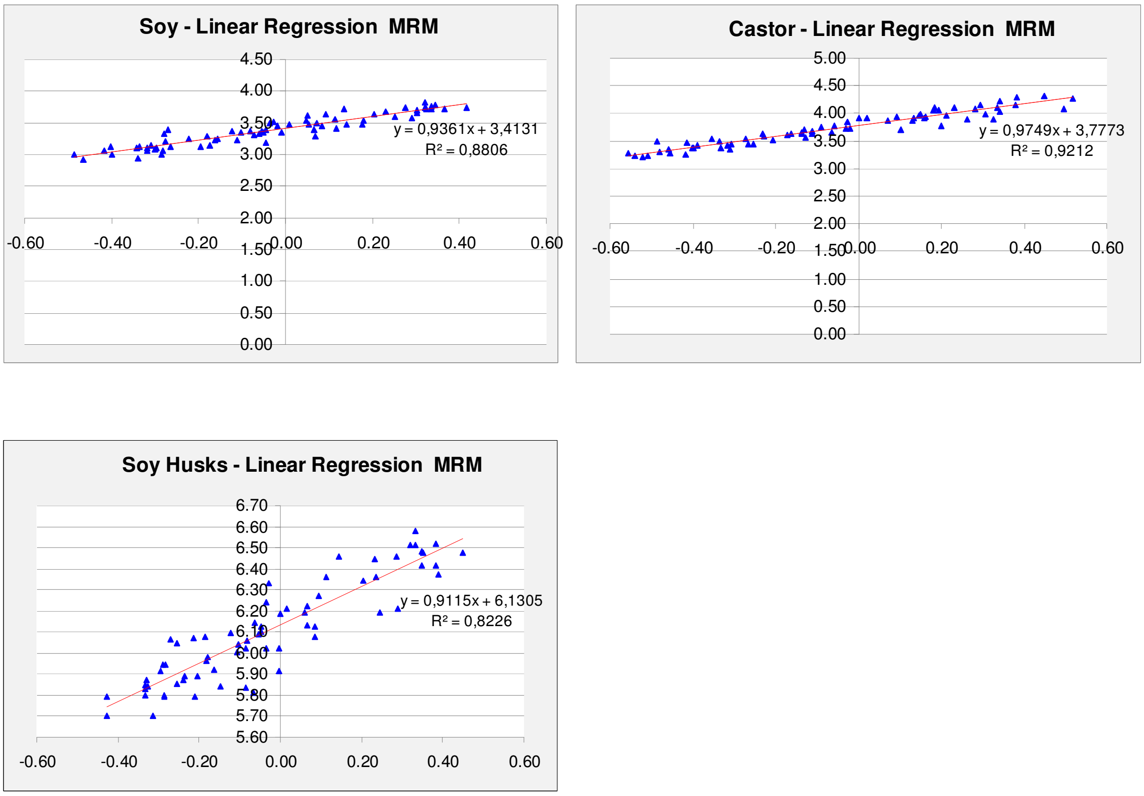


Table 2 shows the results found for the MRM parameters for each of the inputs (and byproducts) analyzed.

Table 2: MRM parameters for soybean, castor bean and soybean FARELO

	Soy		Castor		Soy FARELO	
	R$/BAG 60 kg		R$/60 BAG kg		R$/ton	
	Month	Annual	Month	Annual	Month	Annual
Volatility - σ	8,55%	29,63%	8,49%	29,41%	10,25%	35,52%
Mean Rev, Coef - η	0,0660	0,7924	0,0254	0,3050	0,0877	1,0529
Long term Mean Price - $\overline{P}$	30,19		43,13		458,33	
Initial Price - P_0	37,70		74,81		570,43	

* *Estimated as Monthly Vol. x $12^{1/2}$*

As done for the MRM, the parameters for each of the analyzed inputs (and byproducts) were found for the GBM. These parameters are shown in **Table 3**.

Table 3: GBM parameters for soybean, castor bean and soybean FARELO

	Soy		**Castor**		**Soy Husks**	
	R$/BAG 60 kg		R$/60 BAG kg		R$/ton	
	Month	Annual	Month	Month	Annual	Month
Volatility - σ	8,55%	29,63%	8,49%	29,41%	10,25%	35,52%
$v = (r\text{-}\sigma^2/2)$	0,0963%	1,6106%	0,1017%	1,6744%	-0,0637%	-0,3098%
Initial Price - P_0	37,70		74,81		570,43	

In the absence of historical series of biodiesel prices (still regulated by government auctions) and given the difficulty of obtaining the historic price series of glycerol and methanol, constant exogenous prices were given for these three variables during the evaluation period. The arbitrary price for biodiesel was of R$1.863/liter, based on the average prices of the seventh public purchase auction of biodiesel by the Agencia Nacional do Petroleo, Gas Natural e Biocombustiveis (ANP, 2007). For glycerol the price was set at US$ 325/ton (or R$650/ton, using the conversion rate of R$2.00/1US$), informed by the "Glycerol Market Report" for the month of September in 2007 (OLEOLINE, 2007). The price for methanol was US$599/ton (or R$1198/ton, using the conversion rate of R$2.00/1US$), according to MB do Brasil Consultoria em biocombustiveis (MB do Brasil, 2007). It is important to state that this does not interfere in the comparison of castor bean and soybean cash flows, as they have basically the same effect on both cash flows.

Table 4 shows only the first six months of these expected cash flows (from a total of 60 months), using the MRM and the GBM as stochastic processes of prices, discounted at the risk free rate of 6% per year. These flows were based on the parameters presented in **Tables 2** and **3**, and applied in Equations (6) and(7). The NPV presented is the result of all the project flows (60 months) and not only of the first six months presented in **Table 4**.

Table 4: Cash Flows of the first six months for non-flexible projects using MRM and GBM for the production of 1,000 liters of biodiesel (Flows in R$)

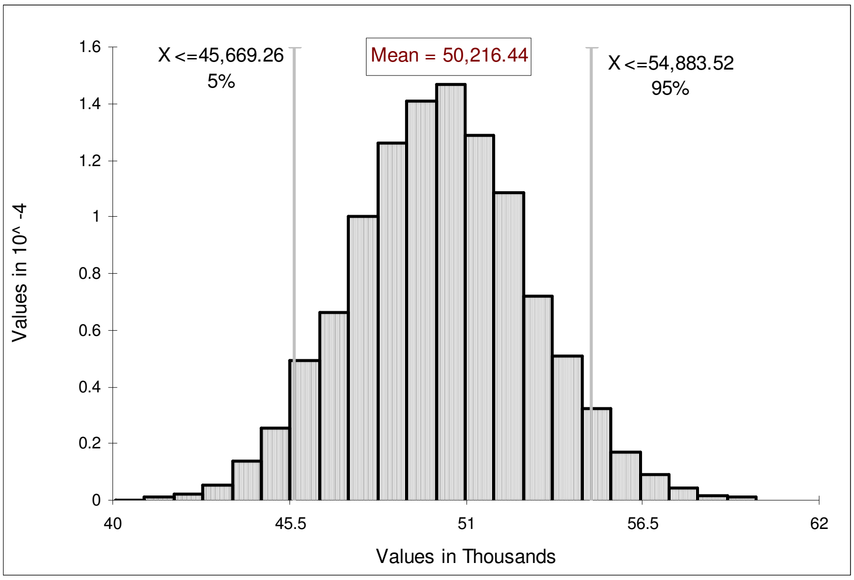
PRICES (MRM)	Month 0	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
Soy	37,6961	37,0981	36,6076	36,1543	35,7350	35,3469	34,9874
Castor	74,8057	73,6472	72,6611	71,7124	70,7995	69,9207	69,0744
Soy Husks	570,4339	558,0675	548,2826	539,5133	531,6423	524,5679	518,2017
CASH FLOWS							
Soy Biodiesel							
FCL1		792,94	789,51	788,19	788,59	790,38	793,31
NPV	47.139,87						
Castor Biodiesel							
FCL2		(466,76)	(414,63)	(364,49)	(316,23)	(269,78)	(222,05)
NPV	19.185,46						

PRICES (GBM)	Month 0	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
Soy	37,6961	37,6991	37,7022	37,7052	37,7082	37,7112	37,7143
Castor	74,8057	74,8120	74,8183	74,8427	74,8310	74,8374	74,8437
Soy Husks	570,4339	570,4036	570,3733	570,3431	570,3128	570,2825	570,2523
CASH FLOWS							
Soy Biodiesel							
FCL1		799,50	798,91	798,32	797,72	797,13	796,54
NPV	40.938,27						
Castor Biodiesel							
FCL2		(528,32)	(528,66)	(528,99)	(529,33)	529,66	530,00
NPV	(28.122,24)						

5.2. Results

The calculation of the options value was done through a Monte Carlo Simulation with a total of 10,000 iterations. The expected value found for the cash flow when evaluating the biodiesel production with two grain possibilities (soybean or castor bean) and the MRM as the model for prices was of R$50,216.44 which leads us to value the input conversion option of biodiesel production, relative to a producer that uses only soybean at R$3,076.57 per 1000 liters of biodiesel produced. Figure 6 shows the probability distribution of the NPV considering the MRM as a stochastic process.

Figure 6: Probability Distribution of cash flows generated by the MRM simulation.



5.3. Comparison to the GBM

For the project with options, the GBM had NPV's greater than those found using the MRM, though this does not always hold true since this result depends fundamentally on the parameters adopted for the modeling. In the case of initial prices being lower than their long term values, it is possible that for the mean reverting velocity to be stronger than the Brownian diffusion and, consequently cause a larger impact in deterministic prices. **Table 5** shows the NPV's of simplified cash flows using the MRM and GBM for basic projects (only one input) and for an option project (two inputs). Despite the difference in option value found by the GBM and MRM, it is noted that in both cases, the option of being able to use soybean or castor bean in biodiesel production has value.

Table 5: Project Value with and without Options (R$/1000 liters of biodiesel)

Stochastic Process:		**MRM**		**GBM**	
	Input	NPV by FCD	NPV w/ options	NPV by FCD	NPV w/options
Basic Project	Soy	47.139,87	50.216,44	40.938,27	87.744,82
	Castor	19.185,46		(28.122,24)	
Option Value	Soy		3.076,57		46.806,55
	Castor		31.031,04		115.867,06

6. Conclusions

We analyzed the vale of the flexibility of biodiesel plant that may choose, each month, the optimum input for its biodiesel production process, considering that the production costs are equal for both of the inputs. The results indicated that the existence of this managerial flexibility increases the value of the project in all situations analyzed, even in the more conservative mean reverting models. We concluded that the option to switch inputs in this case has significant value and that the real options analysis may generate more favorable scenarios for implementation projects of biodiesel production plants.

Given the significant differences in the results, the choice for stochastic process and its parameters is an important factor in the valuation of these types of projects. At actual prices, the traditional DCF analysis may reject the use of a given oil seed as production input, but due to the differences between the stochastic processes used in the modeling of future prices, it is possible to find results indicating different conclusions. It must be noted that the study analyzed only gains derived from flexibilities inherent to the biodiesel production process, therefore it is does not provide insights into the feasibility of a production plant.

The introduction of biodiesel in the Brazilian energy matrix does not involve only the substitution of conventional diesel by a renewable source of energy. The impacts of large scale implementation of these production units in Brazil will affect the rural areas of the country, the industry, the environment, income generation and international prices of these products. Contrary to the heavily subsidized Pro-Álcool ethanol production program of the 1970's, biodiesel production has been mostly market based, so the feasibility of this development model depends fundamentally on the economic feasibility of each of these production facilities. In this sense, taking into consideration the competitive advantages that the flexibility to choose inputs and products offers a biodiesel production plant through the application of real options method, the correct evaluation for risk and revenues of these types of projects may attract private capital necessary for the volume of investment required.

This study has a few limitations. We did not consider any tax effects on the production chain of biodiesel, despite a few incentives created by the Brazilian government to foster biodiesel production. Other works that aim to analyze the economic feasibility of a biodiesel plant certainly should take into consideration these fiscal incentives, as they may influence the decision between using soybean or castor bean as the raw material for the production of biodiesel in a way that is different from the approach taken in this article. For example, a decree of Dec 6, 2004 provides tax incentives for the production of biodiesel made from castor bean in the poorer North and Northeastern regions. The transport costs were also considered in our analysis, which may be relevant if the castor bean and soybean production centers are far apart from the biodiesel plant, nor the impacts caused by the increase in production and demand for biodiesel. There are also several other seed that can be used as inputs, such as cotton, jatropha, palm, which were not modeled in this article.

7. References

ANP - Agência Nacional do Petróleo, Gás Natural e biocombustíveis. *7º Leilão Público de compra de biodiesel realizado em 14/11/2007* – Resultado parcial antes da análise dos recursos. Disponível em: <http://anp.gov.br/doc/biodiesel/Resultado_7parc_ Leilão.pdf>; Acesso em 16 dez. 2007.

BARROS, G.S.A.C. et al. Custos de Produção de biodiesel no Brasil. *Revista de Política Agrícola*, v. XV, p. 36-50, 2006.

BELTRÃO, N.E.M. et al. **Zoneamento e época de plantio da mamoneira para o nordeste brasileiro**, 2004.

BENDER, M. **Economic feasibility review for community-scale farmer cooperatives for biodiesel**. biores. Technol., v. 70, p. 81-87, 1999.

BIODIESELBR. Disponível em: <http://www.biodieselbr.com> Acesso em: 16 dez. 2007

CHALKLEY, A.P. **Moteurs diesel : type fixe et type marine**. Paris : Dunod, 1919.

DIAS, M.A.G. **Opções Reais Híbridas com Aplicações em Petróleo**; Tese de Doutorado; PUC – Rio de Janeiro, RJ; Janeiro 2005.

DIAS, M.A.G. **Selection of Alternatives of Investment in Information for Oilfield Development Using Evolutionary Real Options Approach**. Los Angeles: Proceedings of the 5th Annual International Conference on Real Options, 2001.

DIAS, M.A.G. **Investimento sob incerteza em Exploração e Produção de Petróleo**. Dissertação (Mestrado em Engenharia de Produção); PUC - Rio de Janeiro, RJ; 1996.

DIXIT, A.K., PINDICK, R.S. **Investment under Uncertainty**. Princeton: Princeton University Press, 1994.

LEIRAS, A. A **cadeia produtiva do biodiesel: uma avaliação econômica para o caso da Bahia**. 156f. Dissertação (Programa de Pós-Graduação em Engenharia Industrial) - Departamento de Engenharia Industrial, PUC – Rio de Janeiro. 2006.

MB DO BRASIL CONSULTORIA EM BIOCOMBUSTÍVEIS (2007). Disponível em: <http://mbdobrasil.com.br/modules.php?name=News&File=article&sid=177>; Acesso em: 16 dez. 2007.

MENDES, R.A.. **Diagnóstico, Análise de Governança e Proposição de Gestão para a Cadeia Produtiva do biodiesel da Mamona (CP/BDM): o Caso do Ceará**. Fortaleza, 2005. XIX, 159 fl., Dissertação (Mestrado em Engenharia de Transportes) Programa de Mestrado em Engenharia de Transportes, Centro de Tecnologia, Universidade Federal do Ceará, Fortaleza, 2005.

OLEOLINE – **The oleochemical e-business site**. Disponível em <http://www.oleoline.com>; Acesso em: 16 dez. 2007.

RODRIGUES, R. A. et al. **Estudo tecnológico da produção de biocombustíveis a partir de óleos vegetais**. Projeto de final de Curso - Escola de Química, Universidade Federal do Rio de Janeiro. Rio de Janeiro. 2003.

SCHROEDER, E. M.; CASTRO, J.C. **Transporte Rodoviário de Carga: Situação Atual e Perspectivas**. 1996.

SEAGRI - Secretaria da Agricultura, Irrigação e Reforma Agrária da Bahia, Disponível em: <http://www.seagri.ba.gov.br>; Acesso em: 16 dez. 2007.

SHIMKO, D.C. **Finance in Continuous Time. A Primer**. 1st ed. Local Kolb Publishing Company, 1992, 110 p.

TERRA VIVA. **Mini-fábrica de ração e adubo e óleo comestível ou combustível**. Instituto de promoção agrícola e desenvolvimento Rural, Programa Terra Viva, Mariana, MG.1999.