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Flexible Use of Diesel or Biodiesel: an approach via Real Options

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ABSTRACT: Our main goal is to study the development of biodiesel as a renewable energy source in Brazilian reality. Specifically, we shall discuss the flexibility between traditional diesel and biodiesel. It will be evaluated the option pricing of a diesel-run device where it is possible to use diesel or biodiesel. The evaluation will be done by means of a Real Options Approach, where the choice is modeled on a European options sequence. We also comment on the added gains for a country like Brazil.

Keywords: investment under uncertainty, real options, flexibility, renewable energy sources.

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1. INTRODUCTION

1.1 Motivation

Finding alternative sources of energy is an ever-increasing question in evidence, since the progressive exhaustion of primary energy reserves of a mineral source, such as coal and petroleum, and the further rise in the global temperature. In this context, the development of biodiesel as a source of renewable energy plays a leading role primarily in relation to the Brazilian energy matrix, where mineral diesel weighs considerably higher compared to other countries.

The technological breakthroughs associated with biodiesel combine with this potential market can increase the efficiency of the mineral diesel consumer sectors, especially in transportation. This higher technical efficiency is translated in economic terms through an option; an economic agent who demands diesel can choose a lower-cost fuel, with positive impact on the expected cash flow of his projects and, consequently, their Net Present Value.

Therefore, the purpose of this study is to assess this flexibility between mineral diesel and biodiesel. To do so we will use an approach using real options, in which the choice of fuel is modeled on a sequence of European options. These Switch Input Real Options generate value for the project and minimize risks relating to shortage in energy supply, another recurring problem in today's world.

1.2 Mineral Diesel x Biodiesel

The possibility of switching fuels has technical backing, since both have very similar physicochemical characteristics, such as density and calorific power[1]. Calorific power gives us an idea of energy contained in the fuel and released in the engine's combustion process. Other characteristics of chemical composition differ slightly, such as the cetane number, especially important for diesel engines, where combustion is started by compression (unlike the Otto engine, where there is a spark for ignition). Therefore, the higher the fuel's cetane number, the greater its knock-resistance. This explains why the quality of conventional diesel is improved when a proportion of biodiesel is added. Since biodiesel has a higher cetane number, the mix increases the cetane number of the mineral diesel.

The differences between fuels are only much more relevant when we include pollutants in the comparison. As we can see from the following table, CO_2 emission (main gas associated with the greenhouse effect) is always positive in the use of mineral diesel, while biodiesel maintains a steady balance, considering its renewable characteristics. When analyzing the sulfur content, which is a highly pollutant and corrosive element, biodiesel offers a competitive edge in relation to mineral diesel.

[1] The density of mineral diesel obtained in the automobile gas station network is 0.82 kg/L and that of biodiesel is 0.89 kg/L. The calorific power of mineral diesel varies at around 45 MJ/kg while that of biodiesel varies around 40 MJ/kg.

Table I
Comparison between Diesel and Biodiesel

	Mineral diesel	Biodiesel
Composition	Hydrocarbons C8 – C22	Esters C12 - C18
Source	Non-renewable	Renewable
Raw material	Petroleum	Vegetable oil
Viscosity	3 - 6 cSt	3 - 12 cSt
Distillation	160 - 360º C	240 - 330º C
Application	Diesel engine	Diesel engine
Cetane number	40 – 50	50 - 70
Calorific power	45 MJ/Kg	39.4 - 41.8 MJ/Kg
Sulfur	0 - 0.2%	0 - 0.0024%
CO_2 Balance	Emission	Emission & Sequester

Sources: Petrobras and Tecpar[2]

The diesel and biodiesel characteristics are, therefore, very similar. This offers a real possibility of substituting diesel for biodiesel by owners of equipment with a diesel engine. Diesel may be used as fuel for power generation or in the transportation sector, with trucks, cars, tractors, trains, and so on. This real possibility of switching is described as follows by the European Biodiesel Board*:*

> *"In the transport sector, it may be effectively used both when blended with fossil diesel fuel and in pure form. Tests undertaken by motor manufacturers in the European Union on blends with diesel oil up to 5-10%, or at 25-30% and 100% pure have resulted in guarantees for each type of use…"*

Silva et allii (2006)[3] also describe similar experiments in Brazil with a tractor diesel engine. Tests were performed on an unaltered engine as follows: 100% with biodiesel, 100% with diesel and 50% biodiesel and diesel. In the above article it was noted that the engine runs normally on diesel of biodiesel and that there is a small loss in the engine's performance when running on biodiesel. On average the power of the engine tested with pure biodiesel was 94% of the power of the same engine tested with mineral diesel. For the sake of comparison, substituting gasoline for ethanol causes a drop to 70% on average in the efficiency of the flexi-fuel Otto engines when using ethanol as fuel.

Recently, engine manufacturers, such as Scania, Massey Ferguson and Valtra authorized the use of biodiesel B100 in their engines. The assured use of B100 is provided only by biodiesel standards EN14214 (European) and ASTMD6751 (American).

This result is of the utmost importance, since we will consider the hypothesis that there is no cost for transforming equipment to permit the flexible choice of fuel to be used. Similarly, a drop in efficiency to 94% is presumed when using one fuel or the other.

[2] Paraná Institute of Technology
[3] Article by professors from USP, Unesp and the Federal University of Lavras (UFLA) presented at a congress in 2006.

1.3 Real Option Theory precedents

Literature relating to option project assessment began in the seminal work of Tourinho (1979), in his doctorate thesis at the University of California. When using the option pricing technique for the very first time in a real capital budget problem (evaluating the reserve of natural resources), the theory in question gave rise to a wide variety of applications in the last twenty years. This approach was called "Real Options Theory" and from a practical viewpoint is one of the major advances in the field of corporate finance.

The assessment of natural resources is recovered by Brennan & Schwartz (1985), who apply the Real Options modeling to forest reserves.

Among the different applications and real option ratings, the matter of specific interest to us in this study is the switch input real options. Analyses on this type of real option appeared early in the literature, mentioned by Kulatilaka (1986, 1988), Triantis & Hodder (1990), Fine & Freund (1990) and He & Pindyck (1992). The idea is that the flexible choice between different technologies or inputs creates a value for the real asset in question (whether factory, machine or vehicle). Trigeorgis & Kuatilaka (1994) show that, in the absence of a cost for switching, the value of a flexible project in inputs may be regarded as the value of a rigid project plus the sum of the value of option to switch in future periods.

2. MODELING OF THE PROBLEM

2.1 Choosing the appropriate stochastic process

The method adopted to valorize the real option of switching from diesel to biodiesel will be the evaluation by dynamic cash flows. These dynamic cash flows are created from Monte Carlo Simulations. Therefore, in this section the mathematic framework will be characterized referring to the understanding of stochastic processes and Geometric Brownian Motion.

Uncertainty is a determining factor for the existence of flexibilities and, consequently, of real options. This uncertainty may be modeled using stochastic processes. According to Dixit & Pindyck (1994), a stochastic process is defined as a law of probability for the development of x_t (a variable x in time span t). Stochastic processes may be continuous or discrete and stationary or non-stationary.

A stochastic process is continuous when the tie span t in question is a continuous variable. Characterization of a stationary stochastic process, however, involves the idea that the statistical properties (characteristics of the distribution of probabilities) of the variable are constant over time, unlike the non-stationary process.

The Brownian Movement[4] is a stochastic process with the following characteristics: (i) distribution of probability for future values of the process depend only on the current value of the variable[5] ; (ii) independent increments, namely, distribution of probabilities for the variation of the process over time is irrespective of any other time span; (iii) variations of the process during any interval of time follow a normal distribution, with linearly increasing variance in relation to the time span.

[4] Also known as Wiener Process

[5] Definition of a Markov process.

A stochastic process that fits the above characteristics is the Geometric Brownian Motion (GBM). The GBM of variable x can be described as in the following differential equation:

$$dx = \mu \cdot x \cdot dt + \sigma \cdot x \cdot dz \qquad \text{(equation 2.1.1)}$$

where,
dx = variation in price of random variable x
μ = drift parameter (a constant)
x = value of random variable
dt = variation in time
σ = volatility
dz = Wiener process increment[6]

From the Wiener process characteristics it is found that percentual variations of variable *x* follow a normal distribution. Since the percentual variations can be understood as changes in the natural logarithm of *x,* then absolute variations of variable *x* follow a normal-log distribution.

This characteristic is important, since the sources of uncertainty in the following evaluation are the prices of diesel and biodiesel. Prices can only take non-negative values, which is a characteristic of the normal-log distribution. Characterization of these distributions is used for modeling and generating values by simulation in order to build the cash flows for analyzing real options.

A very widespread simulation methodology is the Monte Carlo simulation, where random numbers of a certain distribution of probability are created and used as parameters for extracting values of an accumulated distribution for a given random variable *x.*

Stochastic processes other than GBM can also be used for price modeling, such as the Mean Reversal (MRM) or jump processes. Econometric tests can be used to choose the stochastic process best suited to a certain random variable.

Using the Dickey-Fuller unit root test, Pindyck & Rubinfeld (1991) do not reject the GBM hypothesis for nominal oil prices in a 34-year data series. Other attempts using real prices or shorter series also failed to reject the GBM hypothesis. Dixit & Pindyck (1994) performed tests for a 117-year oil price series and the GBM was rejected in favor of MRM. However, Maddala & Kim (1998) query whether the use of very long time series was suitable, since structural changes may have occurred in the market.

Accordingly, during the study, diesel and biodiesel prices will be modeled on stochastic processes such as the GBM, and the Monte Carlo Simulation methodology will be used to create future price series of the two uncertain variables. This will help calculate the switching real option between diesel and biodiesel.

2.2 Building the case study

In our study, the sources of uncertainty are the price of mineral diesel and of biodiesel. The price of mineral diesel normally fluctuates in line with the price fluctuations of its feedstock, which is petroleum. Since it is a widely consumed petroleum byproduct, mineral diesel is sold worldwide and market data are easily available.

The problem's other source of uncertainty is the price of biodiesel. Biodiesel, as mentioned earlier, is a fuel that has only become economically feasible in recent years because of the soaring prices of a barrel of oil and for environmental reasons. In some countries, such

[6] The Wiener or Brownian Motion process refers to a random variable *z* that respects the three characteristics defined in the section.

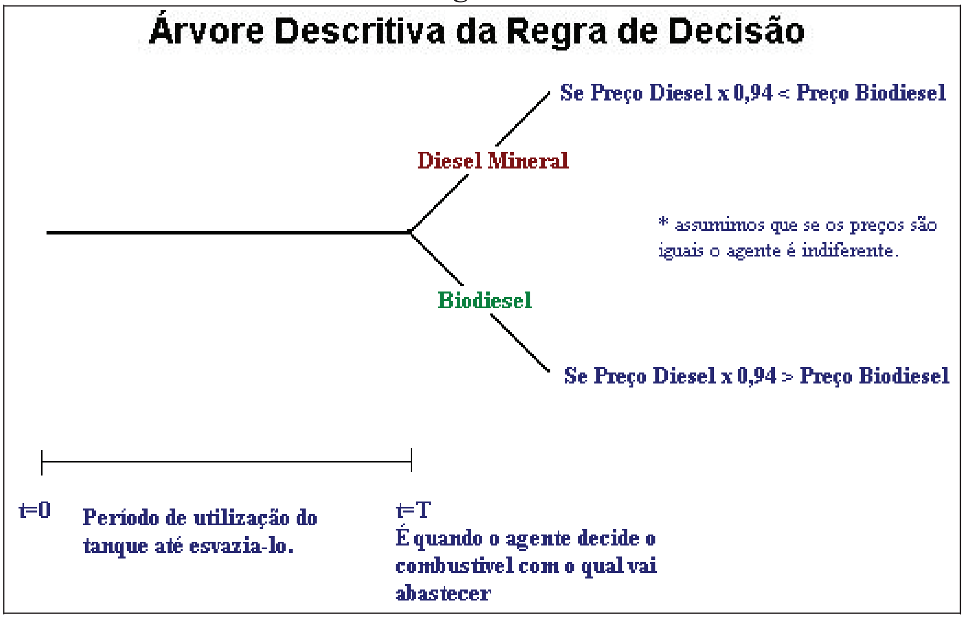
as Germany, for example, biodiesel is already sold at service stations, but past prices are not yet available, as in the case of diesel, on which volatility can be mapped.

We will use soy[7] past prices as proxy[8] for calculating the volatilities and correlation.

After mapping the sources of uncertainty, we found that the flexibility of the bearer of diesel engine equipment is the choice between the two fuels. We first present the result obtained from a test undertaken by Silva et allii (2006) showing that there is a slight different in the engine's performance if running on mineral diesel or pure biodiesel (B100). We will, therefore, start with the premise that, in terms of performance, the agent considers under the fuel price differential a factor representing the drop to 94% when fueled with B100 against the use of mineral diesel.

So the rule of decision with which the agent is faced can be characterized. Whenever the equipment's fuel tank is filled, the price of the two fuels must be noted and the fuel with the lower price chosen. The decision tree for each period in which the agent has to fill the tank is given below.

Figure I



Therefore, at each period the agent is faced with the following decision rule when choosing the fuel:

$$Min(0.94 \cdot DieselPrice_t ; BiodieselPrice_t)$$

By the decision rule defined above, we find that the agent confronts a sequence of decision rules every month when the price changes. Therefore, the amount spent to fill the tank with flexibility of choice will be:

$$G = \sum_{t=1}^{T} Min(0{,}94 \cdot Pd_t ; Pb_t) \cdot n \cdot q \qquad \text{(equation 2.2.1)}$$

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[7] Soy was chosen basically for two reasons. The first is that soy is a commodity negotiated with considerable liquidity on the international market, which allows us easier access to data such as past prices. Second, because soy plays a leading role in Brazilian agriculture and, at least in the short term, is one of the main sources of vegetable oil for biodiesel production.

[8] We mention here a study by ABIOVE demonstrating that 80% of the costs to obtain biodiesel refer to the cost of raw material.

where,
G = Fueling expenses
Pd_t = Price of diesel per liter in time span t
Pb_t = Price of biodiesel per liter in time span t
n = number of times the tank is filled per month
q = liter capacity of tank
T = time of use of the diesel engine equipment

For the following exercise, the equipment's working life will be stipulated as 15 years[9]. Simulations undertaken will be discretized in monthly periods; that is, in a given month there will be no variation in price, so that the decision to be taken by the agent for the first fueling in the month will be the same as the last, until the price changes again and a new evaluation is made. In the case under analysis the engine is fueled five times a month and the fuel tank capacity is 350 liters[10].

The problem in question, therefore, is a classic case of input real options. The flexibility of fuel choice every month when fuel prices vary can be interpreted as a sequence of European options. In the case herein, we have a total of 180 months, resulting in a total 180 options to switch fuels. The value of the real option to switch fuels is given by the difference between the value of the rigid cash flow (using only diesel fuel) and the value of the flexible cash flow (possibility of choosing between diesel and biodiesel).

2.3 Data collection

The initial diesel price to be used in the problem will be R$ 1,87 per liter. Therefore, the price used was for the diesel producer according to a survey made by the National Petroleum Agency (ANP) for the first week in March 2007, which gave a value of R$ 1,36315, to which was added a hypothetical margin of 10% for distributors so that $1{,}36315 \times 1{,}10 = 1{,}50$. The tax load on diesel (CIDE and ICMS)[11] varies around 25%. So the pump price adopted in the study will be R$1,87 per liter.

The initial biodiesel price per liter to be used in the problem will be R$ 2,41. To achieve this, we used the average price obtained in the fourth biodiesel auction held by ANP, to reach the average price of R$ 1.746,66 per cubic meter. This gives us a price of approximately R$ 1,75 per liter[12], which when added to the same distribution margin of 10% plus 25% tax, gives us a selling price of R$ 2,41 per liter.

The term of the real option is 15 years a mentioned earlier, based on the average age of the fleet of diesel-run freight vehicles in Brazil.

The risk-free interest rate used in the study must be a real interest rate with maturity similar to that of the term stipulated for the real option maturity. In this case, a real interest rate will be used for the 15-year term and an alternative to obtaining this rate is to use market coupons of public bonds indexed to inflation, such as NTN-B (indexed to IPCA). As reference we used the real interest rate obtained in the NTN-B market quotation with maturity date at

[9] ANTT data (National Land Transportation Agency) show that the average age of the freight vehicles in Brazil is 16.3 years.
[10] Standard fuel tank capacity of a Scania truck. Data taken from the site: www.scania.com.br
[11] CIDE: Contribution of Intervention in Economic Domain
ICMS: Tax on Circulation of Goods and Services (VAT)
[12] Conversion of cubic meters to a liter: 1 m^3 = 1000 liters.

03/15/2023 (16-year maturity as proxy of the 15-year maturity of the real option). On 03/16/2007 this real interest rate was 7.45% p.a.[13]

Since the price variation in the problem is monthly, this annual interest rate was converted to a monthly interest rate using the following calculation: $(1+0{,}0745)^{1/12}-1$, which gives us a real interest rate of 0.60% per month.

Convenience yield for real options is analogous to the dividend rate found in valorizing financial options. Fuels are storable goods and the convenience yield may be interpreted as the set of benefits (discounting storage costs) created by the stored units. In the case of fuels, these benefits may mean smoother production, preventing product shortage, easy to plan production and sales, etc.

The convenience yield can be estimated using the indicatives in futures markets. Based on the hypothesis of non-arbitration, we then have:

$$F_t = P \times e^{(r-\delta)t} \qquad \text{(equation 2.3.1)}$$

where,
F_t = future price
P = cash price
r = risk-free interest rate
δ = convenience yield
t = maturity term of future contract

Therefore, in the existence of futures markets, we can take from the markets the values of convenience yields. Unlike the petroleum market, the diesel market has not developed a future market, which makes it impossible to accurately calculate the convenience yield for the fuel. Nor does biodiesel have a futures market and uses the convenience yield of the soy market, for example, which is not recommendable in methodological terms. This is because, by the very definition of convenience yield, it is not reasonable to presume that inventory costs and benefits of biodiesel and soy (which is a priority product for food) are similar, since biodiesel is a fuel with different physical characteristics and attends a different market. At the same time, it can be felt that biodiesel has a similar convenience yield to that of diesel since it supplies the same market and has similar storage costs.

Accordingly, at first the convenience yield will be considered null (inventory benefits equal to storage costs) for diesel and biodiesel. However, in the section on analysis of sensitivities, simulations will be performed with different convenience yields to asses their impact on the value of the switch real option between filling up with diesel or biodiesel.

Historic series of monthly prices were used to calculate volatilities and correlation, deflated by the accumulated inflation factor of the National Amplified Consumer Price Index (IPCA)[14] until February 2007.

For the mineral diesel price we obtained the historic series of the diesel price on the home market published by ANP.

In the case of biodiesel, as mentioned above, there are no past prices for the fuel. The soy volatility, therefore, will be used as proxy for biodiesel volatility, considering its representativeness in the oilseed market and its liquidity characteristics on the international

[13] Information obtained on average rates negotiated in the market on 03/16/2007 and published by ANDIMA on the site www.andima.com.br.

[14] The use of the IPCA as index to deflate the price series is due to the fact that it is an official index adopted by the Central Bank of Brazil as a price performance reference in Brazil.

market. Similarly the estimated correlation between diesel and biodiesel will be derived, in fact, from the correlation of mineral diesel and soy prices.

The variation rates of monthly diesel prices were calculated based on the approximation given by the following formula, in which the return in a certain time span t is given by:

$$v = \ln\left(F_t \middle/ P_{t-1} \right) \qquad \text{(equation 2.3.2)}$$

A monthly average variation rate for the mineral diesel price, using a simple arithmetic mean, was 1.14%. We obtained a monthly average variation rate of 0.16% for biodiesel, using the international soy price series and converting to reais using the closing exchange rate for the month.

To calculate volatility of both mineral diesel and biodiesel[15] past prices we used the following formula of a non-biased estimator for the standard deviation of a sample:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} \left(u_i - \bar{u}\right)^2}{n-1}} \qquad \text{(equation 2.3.3)}$$

Therefore, we arrived at a volatility of 3.60% for the price of mineral diesel and a volatility of 7.99% for biodiesel. For the correlation, the value was –0.04.

It is worth pointing out that, since it is a very young market, these volatilities may undergo significant variations, since the biodiesel market is developed with a large number of producers and consumers. In most cases it is found that this volatility tends to drop when the market develops. Consequently, in a later section in the study a sensitivity analysis is done regarding the value of the real option in different volatile scenarios.

2.4 Solving the problem

Therefore, based on equation 2.1.1, the variations in diesel and biodiesel prices adopt the following process:

$$dP_d = 0{,}0114 \cdot P_d \cdot dt + 0{,}036 \cdot P_d \cdot dz \qquad \text{(equation 2.4.1)}$$

$$dP_b = 0{,}0016 \cdot P_b \cdot dt + 0{,}080 \cdot P_b \cdot dz \qquad \text{(equation 2.4.2)}$$

For simulations on P_d and P_b, we derive from Ito's lemma[16] an equation for the stochastic process of P so that:

$$P_1 = P_0 \times e^{\left(\mu - \sigma^2 / 2\right)\partial t + \sigma \times \varepsilon \sqrt{\partial t}} \qquad \text{(equation 2.4.3)}$$

It must be mentioned that if we consider the value of μ merely as the drift parameter observed above, we would, in fact, reach the Real Geometric Brownian Motion. However, it is necessary to simulate the risk-neutral Geometric Brownian Motion for the created dynamic cash flows to be discounted at a risk-free rate.

The risk-neutral probability measure is that which makes the expected return of the basic asset (in this case diesel and biodiesel) the risk-free rate. Uncertainty is included in the real probabilities so that they are transformed in the new risk-neutral probability measurements, thereby being able to discount the values using the risk-free rate. This risk-

[15] Using past soy prices as proxy.

[16] See Hull (2003), page 411.

neutral probability measure is an equivalent martingale measure[17], which can discount the values obtained in the simulation by the risk-free rate.

The risk-neutral drift μ in equation 2.4.3 can be calculated in two ways, considering the equalities:

$$\mu = \alpha - \pi = r - \delta \qquad \text{(equation 2.4.4)}$$

where,

μ = risk-neutral drift

α = real drift

π = risk premium

r = risk-free interest rate

δ = convenience yield

Thus, courses can be simulated for cash flows of the fuel expenses of the diesel equipment bearer.

The present value of the cash flow when only fueling with diesel is given by:

$$VP_{rigido} = \sum_{t=1}^{180} \frac{rb \times E(Pd_t) \times 350 \times 5}{(1+r)^t} \qquad \text{(equation 2.4.5)}$$

where Pd_t follows the stochastic process defined by equation 2.4.1

A cash flow is then created for fuel expenses where the diesel equipment bearer has the option to fill up with diesel or biodiesel, depending on which fuel is cheaper.

The present value of the dynamic cash flow created by the simulations in which the use of diesel or biodiesel in the equipment is flexible is given by the following equation:

$$VP_{flexibilidade} = \sum_{t=1}^{180} \frac{E[\min(rb \times Pd_t \, ; \, Pb_t)] \times 350 \times 5}{(1+r)^t} \qquad \text{(equation 2.4.6)}$$

where Pd_t and Pb_t adopt the aforementioned stochastic processes.

The value of the real option of change between the two fuels is given by the difference between the two cash flows:

$$V_{opção} = VP_{rigido} - VP_{flexibilidade}$$

Ten thousand simulations of the correlated processes of the diesel and biodiesel price were performed to calculate the present value of fuel expenditure based on the expected price of each fuel at each time span t=1 until t=180.

The results were as follows:

$VP_{rigido} = R\$552.054{,}40$

$VP_{flexível} = R\$436.615{,}80$

$V_{opção} = R\$115.438{,}60$

So the value of the possible option of switching between diesel and biodiesel for the consumer agent of this fuel is R$ 115.438,60, if this agent has this option for a 15-year period using diesel equipment.

[17] A stochastic process is a martingale under probability measure P if its expected value is its current value.

3. SENSITIVITY ANALYSIS

Unlike financial options, the object asset of real options is real assets. Estimating parameters for real assets is much harder work and less reliable than estimating financial assets, even more so because of data limitations, such as that commented in the case of biodiesel (no past prices).

Considering this restraint referring to the quality of the adopted parameters, we will now undertake a sensitivity analysis. So this section will be devoted to evaluating how the real option value varies considering the variations in some parameters.

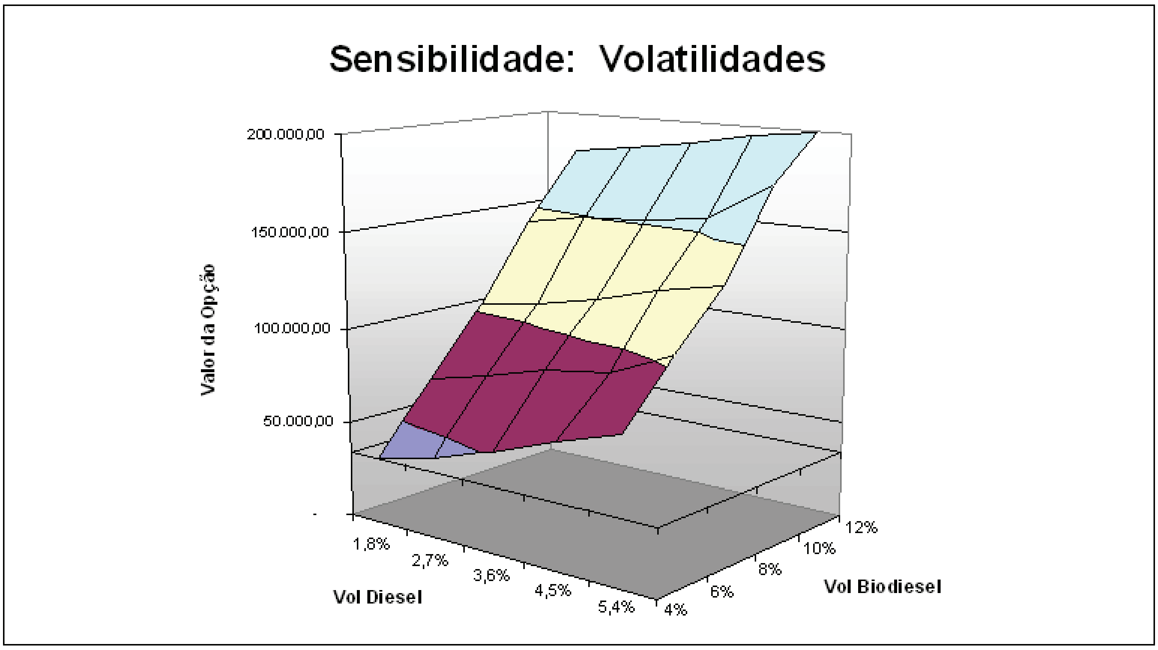
The first analysis will be done in relation to the volatility of diesel and of biodiesel. Intuitively we find that the higher the volatility of the object asset, the higher the option value. On the supposition of 25 possible combinations of volatilities for diesel and biodiesel we now have the following data for the real option value:

Table II
Sensitivity to Volatility

		4,0%	6,0%	7,99%	10,0%	12,0%
Volatilities for diesel	1,8%	34.385,05	68.658,17	103.633,00	143.939,00	179.035,00
	2,7%	41.557,47	76.856,26	108.520,40	149.511,90	184.117,20
	3,6%	52.101,65	85.990,32	115.438,60	151.933,60	188.737,10
	4,5%	63.912,89	89.957,18	124.510,10	156.130,70	195.398,20
	5,4%	75.014,28	104.398,50	131.934,50	176.533,80	200.915,10

We find that the real option value is extremely sensitive to the variation in volatilities of the two fuels. In the scenario of lowest volatilities, the Real Option value of change between diesel and biodiesel was R$ 34.385,05 while in the highest volatilities scenario, the real option value may reach R$ 200.915,10. The sensitivity of the option value to alterations in volatilities can be more clearly observed in the following graph:

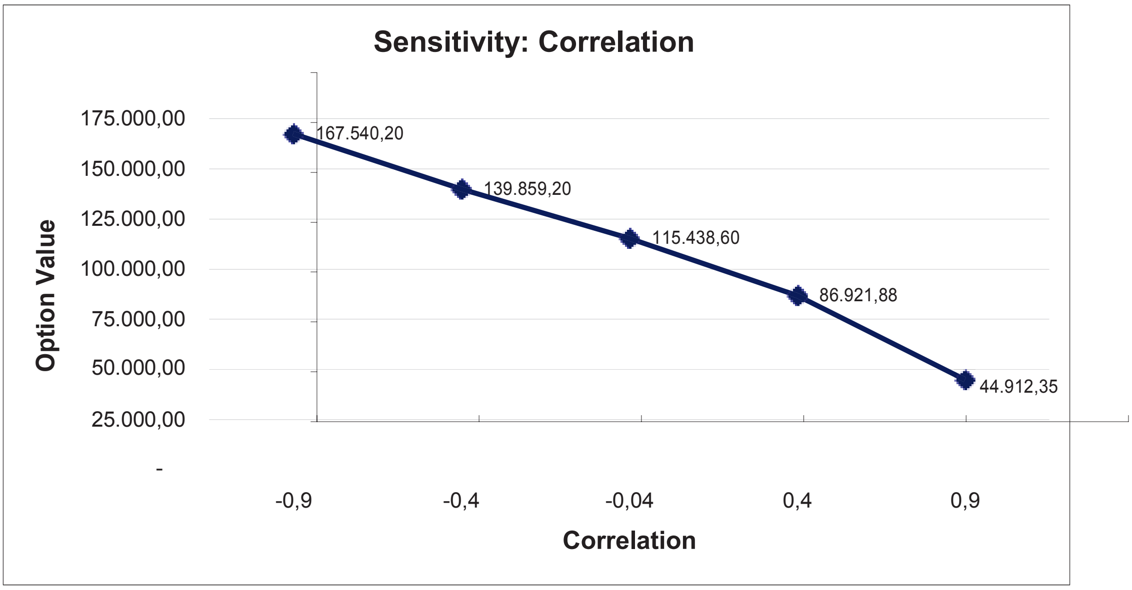
Figure II



The greater the fuel volatility, the more uncertain is the agent at the time of fueling. In other words, wider fuel price variations are a higher risk for the consumer, who gives more value to the flexibility of choice of the cheaper fuel. At the limit, it is understandable that the more volatile the fuel price, the greater the price difference between them, which offers significant saving when there is a possibility for switching.

The estimated correlation between mineral diesel and biodiesel was –0.04, namely, very close to zero. However, simulations were performed with variations of the correlation value between both fuels in order to determine the sensitivity in the value of the Switch Real Option. The results are given in the following graph:

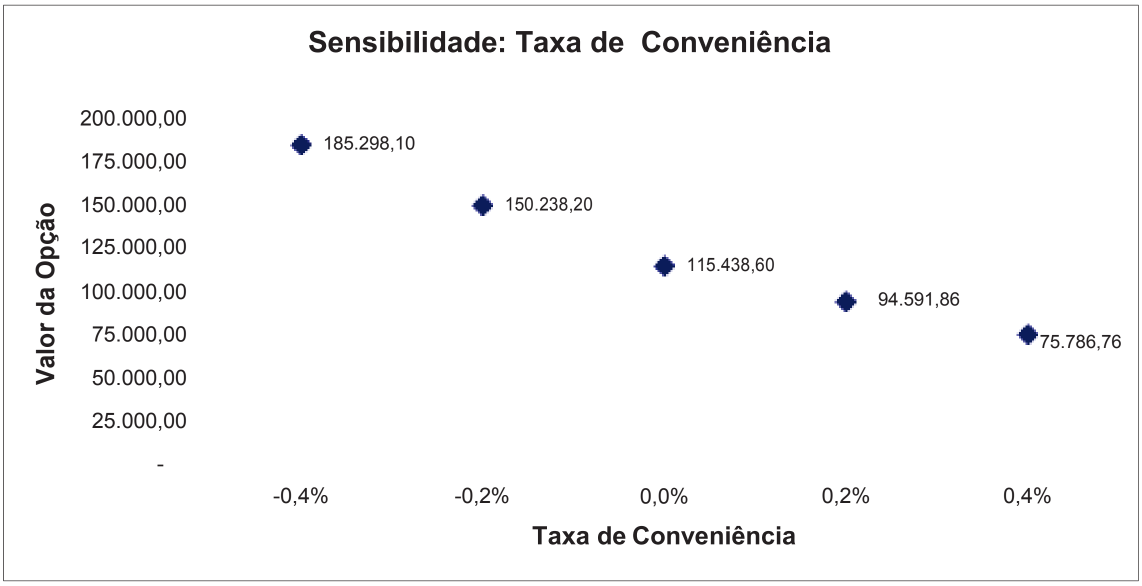
Figure III



The value of the option examined in this study is impacted should the correlation of diesel and biodiesel vary. The notion of this result is simple. If the two processes are negatively correlated (that is, the diesel price rises and the biodiesel price drops), the consumer may be able to switch the fuel and economize. Similarly, if the processes have a correlation close to 1, it is expected that when there is a rise in the price of diesel the price of biodiesel will also rise. This means less value for the flexibility of choice of the cheaper fuel.

The convenience yield for diesel and biodiesel for solving the problem was zero, that is, the cost and benefit of storage are the same. However, in practice it is common for the convenience yield of real assets to vary according to market factors. In this way further simulations were performed to evaluate the value of the switch Real Option, if the convenience yield were to change. Cases were simulated where storage costs exceed the benefits and situations where storage benefits exceed the costs. The results of the simulations can be seen in the following graph:

Figure IV



As mentioned earlier, the convenience yield may be interpreted analogously to the dividend rate in the pricing models of financial options. The idea is that the convenience yield gives the value in time of the underlying asset price; therefore, for a higher convenience yield, the lower the real value of the prices of underlying assets and, consequently, the lower the real option to switch value is given by the difference between diesel and biodiesel prices.

Therefore, we find that even in conditions where the parameters are flexibilized in a wide range of diversified values, the real option to switch between diesel and biodiesel still has significant value. This shows that when introducing biodiesel for sale on the market the bearer of diesel equipment has a valuable flexibility when confronting the sources of uncertainty.

4. CONCLUSIONS

The Real Option Theory has spread even further and as each day passes becomes more relevant in the decisions under uncertainty. It was initially applied to assessing investment projects, but can now be extended to situations as discussed herein. Here the Real Options Theory was the framework employed to show the value created for a diesel consumer agent when given the input switch option to biodiesel.

Through problem solving and the simulations performed, it is found that the large-scale introduction of biodiesel in the market creates a considerable value for the agents that run diesel-run equipment as real assets. Such equipment may be automobiles, trucks, farm machinery and thermal power plants.

The value of the switch real option in the problem can be interpreted as a value created by reducing risks of the diesel consumer agents. The reason for this is that once they have the option to use another fuel, the variance of their fuel expenses will of course diminish, since they will always choose the cheaper fuel.

Even when relaxing the parameters used to calculate the switch real option in situations where the agent's flexibility has less value (lower volatilities of diesel and biodiesel or correlation close to 1), the result obtained was also significant for the real option value.

The result is even more significant when considering the presence of mineral diesel in the Brazilian energy matrix and the large inventory of real assets in the economy that use mineral diesel as an input. When placing biodiesel on the market in the distribution networks, these real assets in the Brazilian economy will now have an inbuilt real option. The added value in the economy by creating these real options tends to be high. Therefore, since Brazil has an essentially diesel-run transportation modal it is noticeable that risk reduction in this sector leads to an added risk reduction for the economy. Once the biodiesel market is developed in Brazil, the value created by the switch real option will benefit the economy.

As a suggestion for future research, the model proposed above can be applied to more specific case studies in agricultural sectors for equipment such as farm machinery, or in the energy sector with diesel-run thermal power plants. Moreover, one of the limitations of the model herein was the absence of past price data for biodiesel. Future studies could use a series of biodiesel prices to estimate parameters and reassess the model. Another alternative would be to alter the modeling from stochastic processes to such processes as mean reverse or jump processes and assesses the value of the switch real option in such cases.

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