Option of switching an investment project into an agrobusiness project
OPTION OF SWITCHING AN INVESTMENT PROJECT
INTO AN AGRIBUSINESS PROJECT

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OPTION OF SWITCHING AN INVESTMENT PROJECT INTO AN AGRIBUSINESS PROJECT

Key-words: Finance, Investment Analysis, Real Options, Quadrinomial Model, Agribusiness.

ABSTRACT

In this article we discuss the application of real options theory to analyze an agribusiness investment project. Traditional analyses, using present value of a projected cash flow, cannot respond satisfactorily to the uncertainties of the environment. The theory of real options complements traditional analysis when assessing the flexibilities that permeate such investment projects. Next, we proceed to study the switch option of an ethanol manufacturing project to a flexible project, in which either ethanol or sugar can be produced. For this purpose, we utilized the tools found in the quadrinomial model. The result obtained is the calculation of the value of the switch option, which increases the value of the non flexible project. In accordance with the theory of real options, acquiring operational flexibility increases the value of the project studied.

INTRODUCTION

The main objective of a company management is to enhance value for the owners, through the participation in the worth of the company. One of the critical activities required in order to attain such goal is the evaluation of new investment projects. The tool most often employed in the choice of projects is the verification of the net present value – NPV – of the projected cash flows.

This methodology has its limitations. (BREALEY & MYERS, 2000, p.71). The impossibility of evaluating opportunities that are intrinsic to the projects and the difficulty faced in the selection of the most suitable discount rate have led to the development of more comprehensive evaluation models.

Real options analysis – ROA – is the most successful approach for dealing with such limitations. An offshoot from the financial options, the real options enable one to evaluate the opportunities embedded in the projects, changing projects that might be scraped into ventures that may be successfully implemented by the companies.

The ROA has ample application in the analysis of projects for natural resources exploration, where the implicit opportunities are plentiful, but the results are, a priori, uncertain.

Brazil is the only country with vast quantities of undeveloped agricultural lands of the world. Of the 60 million hectares – Mha (every hectare corresponds to ten thousand square meters) of farming land, it is estimated that, in 2004, only some 30 Mha were being utilized. Even conceding to the environmental considerations, such quantity of lands represents an enormous opportunity. The recent advance of soya beans, corn and cotton cultures into the Midwest Region provides a good illustration of how one may take advantage of such opportunity.

One agribusiness sector in especial appears as an excellent opportunity for investments. The combination of the world wide concerns regarding global warming, the high prices of oil and its byproducts and the search for alternative sources of fuel provides an exceptional scenario for ethanol, known in
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Brazil as anhydrous alcohol. The country is the largest alcohol producer in the world, with the lowest production costs and a state-of-the-art technology that is fully suited to the local conditions.

Sugar and alcohol investment projects did not possess an analysis tool, which enabled one to evaluate the flexibilities inherent to the business.

The present job applies the real options theory to the evaluation of an agribusiness venture. For this purpose, the panorama of the sugar-alcohol sector is presented, by highlighting the perspectives involved in the sector. Subsequently, the work presents the quadrinomial model, which is a development of the binomial model for dealing with projects that include two sources of uncertainty. The following phase reviews a project involving the erection of an alcohol distilling plant and leading to the final considerations.

PANORAMA OF THE SUGAR-ALCOHOL SECTOR

The sugar-alcohol sector is closely related to the Brazilian development process.

Sugar cane was brought from the São Tomé and Madeira islands by Martim Afonso de Souza, in 1530. At the end of the XVI century, Brazil had been converted into the largest producer and supplier of sugar in the world. Sugar was one of the main reasons for the invasion of Brazil by the Dutch, in 1624. Driven out in 1654 and having assured themselves with the full knowledge of the techniques for growing sugar cane, the Dutch started to develop such culture in the Antilles, which played a strong role for the decline of this economic cycle, as it was being replaced by the gold cycle (XVIII Century).

The first petroleum shock occurring in 1973, had a strong impact in the Brazilian Balance of Payments. In the period of one year, the imports of fuel jumped from US$600 million to more than US$2 billion (UNICA, 2004). In response to this crisis, on November 14, 1975, the Government introduced the National Alcohol Program (Proálcool), which was designed to supply the country with an alternate, less-polluting fuel as compared with fossil fuels. Initially, the program was limited to the addition of anhydrous fuel to the gasoline. In 1979, upon the second oil price shock, investments were made for development and sales of cars driven by anhydrous alcohol. In 1985 and 1986, the production of alcohol fueled cars reaches a peak. They are responsible for 96% of all new cars sold in the country. In 1990, a substantial drop hits the production of alcohol driven cars, which then accounted for only 13% of the total production of vehicles in the country, due in especial to the shortage of the products at the pumps of service stations. The simultaneous occurrence of attractive prices in the international sugar market prices and the low price of the alcohol, caused a major part of the sugar cane production to be converted into sugar for exports, leading to a shortage in the domestic market. The production of alcohol fueled cars saw a drastic fall, to a point in which these cars started to be produced only upon specific order. At the end of the 1990’s, the remaining fleet of alcohol operated cars running on the streets amounted to a little more than 4 million units.

A new drive for the production for alcohol began in mid-2003, upon the introduction of flex-fuel cars in the market. This allows the car to be filled with either alcohol or gasoline or with a mixture of both at any proportion. There is a growing acceptance of this technology, as twin-fuel cars account for 53.6% of the sales of new cars in 2005. ANFAVEA, (2006).

Historically, sugar has always been a strong product in Brazilian exports. The world sugar market is a mature market, where consumption increases are slight. In 2004, the USDA estimated a worldwide production of 144 million metric tons, for a consumption of 139 million metric tons. Brazil is the main sugar producer, with a production of 25 million metric tons in 2003/2004, which accounts for 17% of world production. The five larges producers (Brazil, India, the European Union, China and the United States) are responsible for half of the world sugar production.
Brazil is also the largest export of sugar in the world, with exports totaling 14 million metric tons for a market of 45 million metric tons (32% of the market). The five largest exporters – Brazil, Thailand, the European Union, Australia, and India – account for 67% of world exports.

It must be stressed that the sugar market is strongly protected in the countries of the northern hemisphere, by means of heavy subsidies and import barriers. In 2003, the Brazilian sugar had a cost 44% lower than the average cost of the international market, while the cost of producing sugar from sugar beat (a process used in the European Union) is 163% costlier than the average cost (UNICA, 2004). Heavy subsidies enable the European Union to be a major exporter of sugar, even facing one of the highest production costs in the world. Producer in Brazil, along with the Federal Government, have questioned the European subsidies before the World Trade Organization – OMC, achieving an important victory, in 2004. However, the process for developing sugar markets – as we as for the other agricultural commodities – is a long-term effort, with meager results on the short run.

To sum up, Brazil already is the main player in the world sugar market, with outstanding participation in the trading and great competitiveness, due especially to the low cost of production. There is a surplus of sugar in the world, with the consuming market seeing low growth rates in a closed and fiercely competitive market. Therefore, the increase of sugar exports is supposed to occur at a slow pace, with no forecast of significant changes on the short term.

The Kyoto protocol, signed 1997, is the first joint international effort to fight the greenhouse effect. In order to comply, the industrialized countries are – among other measures - encouraging the adding of ethanol (anhydrous alcohol) to the gasoline. The adding of a small percentage of ethanol to the gasoline assists with the attempts for lowering the consumption of fossil fuels, replaces the adding of Lead/MTBE to the gasoline, without the need of introducing modifications on the existing fleet.

The industrialized countries are reluctant to adopt this action, in view of the large volume of ethanol involved in this decision and doubts as to the capability of the producer countries to supply large quantities of ethanol with no change in the prices. The maintenance of the oil prices at levels above US$50,00 a barrel (corresponds to 158.98 liters), since 2003, has been a great incentive to the implementation of this measure. In 2003, the Japanese government authorized (but did not impose) the adding of ethanol to the gasoline, up to a proportion of 3%, a quantity that does not required in retrofitting of vehicles.

Alcohol has a changing market. Before the advent of the Proálcool program, the industrial production of alcohol in Brazil was negligible. Upon the beginning of the Proálcool, in 1975, the Brazilian alcohol production gained scale, and reached a peak in 1989, with the production of 15.4 million cubic meters (Mm³) of alcohol. In the beginning of 2006, there were 60 new on-going investments in the sector (45 of them in São Paulo), which should raise the domestic production of sugar cane by 27%, the vast majority to meet the increasing demand for alcohol. Brazil has a nominal capacity for producing 16.7 Mm³ of alcohol and is forecast to reach 20.6 Mm³ by 2012. The alcohol production in 2004 was of 14.7 Mm³ (UDOP, 2006).

Anhydrous alcohol (ethanol) is produced in the Central-Southern Region at a cost nearing US$0.63/gallon (3.785 liters). Gasoline has been priced, in the world market, at values in excess of US$1.00/gallon since the year 2003, and the trend is for such prices to remain at this level. The ethanol produced from corn in the United States (USA) has a production cost higher than US$1.05/gallon. The American government subsidizes the production with US$0.52/gallon, in addition to taxing the imports with US$0.54 per gallon. The growth of the USA production is based on national security (achieving less dependence on imported fuels); reduction of emission of pollutants (by adding ethanol to the gasoline) and industry lobbying (especially, the NCGA – National Corn Growers Association). Driven by the increase of domestic consumption, the
USA is enjoying a vigorous growth in the production of ethanol, in the quest for self-sufficiency. Thus the production of ethanol rose from 4.9 Mm³ in 1997 to 8.7 Mm³ in 2004, and the prospects are that it should reach 19 Mm³ by 2010, exceeding the Brazilian production (CRISTALSER, 2004; BNDES, 2004). The biggest benefits from the growth of the American market is the stability and liquidity of international prices for ethanol. As an evidence of its importance, the commodity has made a debut in the Chicago Board of Trade – CBOT on 23/03/2005.

The European Community (EEC) and Japan maintains programs for addition of alcohol to the gasoline, motivated especially by the compliance with the Kyoto Protocol. The potential markets are 8.5 Mm³ (EEC) and 3 Mm³ (Japan).

International ethanol trading had been stable with volumes nearing 3.2 Mm³ per year, with Brazil supplying approximately a quarter of this volume. Due to the factors described before, the ethanol commerce is enjoying great expansion. In 2004, the world ethanol market rose from a volume of 6.9 Mm³, with Brazilian exports reaching 2.3 Mm³ (AGRICULTURA, 2005).

The international ethanol trading is enjoying unimpeded growth. Brazil is an important supplier of ethanol to the foreign markets, with exports in 2004 nearing 500 million US dollars. The command of the technology and good weather conditions are being reinforced by investments in infrastructure and increased production, with the purpose of enhancing and consolidating the country’s market share in the world ethanol markets.

**REAL OPTIONS**

For a long time, the utilization of options remained restricted to financial assets which had abundant data while the market price of the underlying asset could be observed directly. The use of stochastic differential equations reinforced the unsuitability for use in management applications.

The dissemination of personal computers can be considered the factor of greatest encouragement for utilization of options in “non-financial” evaluations. The use of algebraic grids and solutions as a replacement for the Itô calculation, has made the calculation more comprehensive and easier to implement.

While most of the financial options can be evaluated by the Black-Scholes-Merton model, real options are provided with certain particulars that set them apart from the evaluation by this model. ANKUM and SMIT (1993, p.243) highlight the diverging points between the options:

The financial option is exclusive of the investor; no one else can exercise the option on behalf of him. The real option depends upon the characteristic of the market. In monopolistic markets, the exclusivist character holds; however, in competitive markets, the right to invest if public and, in some instances, any investor may joint the market.

The efficiency of financial markets can quickly adjust the prices, by reacting to information and neutralizing compensation above market. Under real options, the markets are less efficient, and allow companies that produce and maintain competitive advantages to earn gains above those of the marketplace.

While evaluating a real option, the biggest difficulty is the fact that, most of the times, the target asset of the real option cannot be traded in the market. One form of overcoming this restriction is using the replicated portfolio technique. This approach is seldom used, because it is just about impossible to find an asset that is perfectly correlated to the project (twin-asset), whose prices are known to the public.

COPELAND e ANTIKAROV (2001) suggest the use of the NPV of the non-flexible project, as an underlying asset subject to risk (twin-asset), calling this utilization Marketed Asset Disclaimer – MAD. They consider that there is nothing that relates more to the project than the project itself. Copeland e Antikarov (2001, p. 97) assert that “(...) if (the assumptions) are acceptable in the NPV analysis, then we may assume to be reasonable that the present value of a non-flexible project is the value it would have, if it were a traded asset.”
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THE QUADRINOMIAL MODEL

Real options are usually classified in four large groups: the option of postponing, forsaking, expanding, and canceling. Additionally, the options of downsizing, temporary shutdown and switching. The switch may involve raw materials or products. Switching products is different from the expanding option, as it does not involve increasing production capacity. The project being evaluated has the ability of producing both alcohol and sugar. Thus, its analysis may be classified as an evaluation of a switch option. For learning purposes, it was decided to name it “switch option”.

Both the price of alcohol and sugar have their own volatility, which provides a full range of combination of values between the two. COPELAND e ANTIKAROV (2001, p.279-286) present a quadrinomial approach with a binary tree, with two sources of uncertainty. As shown in Figure 1, this tree has four branching on each node, and is expanded until reaching 120 possibilities on he tenth year of the analysis. For this tree to be calculated, one has to find the volatilities of each source of uncertainty (p) between the sources of uncertainty.

Figure 1 – Prices of alcohol and sugar in a multi-step quadrinomial tree
Source: COPELAND; ANTIKAROV, 2001 (Adapted).

The correlation shows how is the behavior of variations occurring at the same time with the prices of sugar and of alcohol. Zero correlation indicates that the prices oscillate independently one from the other. Positive correlation shows that the prices oscillate in a similar manner. In this situation, rises in the prices of alcohol are normally accompanied by rises of the prices of sugar. Drops in the prices of a product normally occur simultaneously with reductions on the other product. Positive correlation increases the general volatility of the project, due to the greater probability of occurrence of extreme values of the two prices at the same price. At the negative correlation, a price rise in one of the products (alcohol or sugar) is normally accompanied by a reduction of the price of the other product. Thus, a change in price tends to be neutralized by a change in the price of the other product, reducing the general volatility of the project.
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The calculation of the neutral risk probability of the quadrinomial tree may be obtained with the following equations:\(^1\):

\[
\begin{align*}
 Pu_{al} &= \left( u_{al} u_{aq} + u_{aq} g_{al} \Delta t + u_{aq} g_{aq} \Delta t + \rho_{alaq} u_{al} u_{aq} \Delta t \right) / 4 u_{al} u_{aq} \\
 Pu_{dl} &= \left( d_{al} u_{aq} + u_{aq} g_{al} \Delta t + d_{aq} g_{aq} \Delta t - \rho_{alaq} u_{al} u_{aq} \Delta t \right) / 4 u_{al} u_{aq} \\
 Pd_{ul} &= \left( u_{ul} u_{aq} + d_{aq} g_{al} \Delta t + u_{aq} g_{aq} \Delta t - \rho_{alaq} u_{al} u_{aq} \Delta t \right) / 4 u_{al} u_{aq} \\
 Pd_{dl} &= \left( d_{ul} u_{aq} + d_{aq} g_{al} \Delta t + d_{aq} g_{aq} \Delta t + \rho_{alaq} u_{al} u_{aq} \Delta t \right) / 4 u_{al} u_{aq}
\end{align*}
\]

Where:

\( u_{al} \) and \( u_{aq} \) = ascending movements of alcohol and sugar
\( d_{al} \) and \( d_{aq} \) = descending movements of alcohol and sugar
\( g_{al} \) and \( g_{aq} \) = expected growth rate of the prices of alcohol and of sugar
\( \rho_{alaq} \) = correlation between variations of the prices of alcohol and sugar

The switch option exists when the asset accepts several inputs or can produce various products, at a switching cost that is not prohibitive. The classical example of the switch option is the operation of an electrical thermal plant, which is capable to burn gas, oil or coal. According to CUTHBERTSON and NITZSCHE (2001, p.535), the payoff of this option is:

\[
\text{Payoff} = \max \left[ S_1 - S_2 - CS, 0 \right]
\]

where:

\( S_1 \) = NPV of the current operation mode 1
\( S_2 \) = NPV of operation mode 2
\( CS \) = Cost of switching from operation mode 1 to mode 2

In the project being reviewed, the cost of switching involves the construction of a plant that would be capable of producing either alcohol or sugar. Once the investment is made, the switch of the product being manufactured does not incur conversion costs.

The production of texts on real options has attained large dissemination in the academic medium, with diversified production of texts concentrated on the analysis of projects for exploration of natural resources. The specific treatment of the switch option began with KULATILAKA and TRIGEORGIS (1994). Ever since, this option has been used by various authors:\(^2\).

---

\(^1\) The mathematical development of the quadrinomial model may be verified in COPELAND and ANTIKAROV (2001, p. 281-287); CLEWLOW and STRICKLAND (1998, p. 44-51).

\(^2\) Among others, the emphasis may be placed on works by CHIN-TSAI and CHENG-RU (2004) who evaluate the option of switching between local and international production in an exporter company; MADLENARA, KUMBAROGLU, and EDIGET (2005) established the irreversibility of the switch option in electrical investments; PENNINGS and SLEUWAEGEN (2004) reviewed the switching between exports, creation of a local subsidiary, forming of joint venture and licensing of production; RESE and ROEMER (2004) covered the changing of the commercial partner as a switch option.
The utilization of real options in agribusiness is still incipient. Several works were found in English, such as those by SCHATZKI (2003), who considers the option of switching for landowners between agricultural production and reforestation; MUSSHOF and ODENING (2005), who analyzed the option of switching from traditional to organic vegetable growing in Germany and GE, MOURITS and HUIRNE (2005), who evaluated the value of flexibility in the control of livestock diseases. The last two works were submitted during the Ninth International Congress on Real Options, held in 2005, the first congress to hold a specific panel on Agriculture, health and the Environment.

In the Portuguese language, in addition to the dissertation which has led to this work, there are the thesis by (SILVA, 1999), who uses options to analyze the effects of industrial policies on agricultural and industrial chains and by FIGUEIREDO NETO (2003) who reviews land-lease contracts as an option for planting, in addition to the article by SOUZA et all (2004) in consideration of a contract on forestry partnership.

THE PROCESS FOR MANUFACTURE OF SUGAR AND ALCOHOL

In Brazil, using less than 1% of the agricultural lands, 4.5 million hectares of sugar cane were being planted in 2001. (VITTI et al, 2003). Sugar cane is a renewable crop, with a large energy-related potential: each ton has the energy potential equivalent to 1.2 barrel of oil (CTC, 2002). Brazil is the largest sugar cane producer in the world, followed by India and Australia. Historically, 55% of the Brazilian sugar cane is converted into alcohol and 45% into sugar. Sugar cane is grown in the Mid-West and in the North-Northeast Regions of the country, which in view of the climate regimen, permits two harvesting periods, which means, the whole year.

The process for production of sugar and alcohol involves an agricultural phase and an industrial phase. The agricultural phase comprises the planting, cultivation, cutting and transportation of the sugar cane. In the industrial phase, the activities involving milling, distilling of alcohol and/or production of sugar.

After being planted, the sugar cane will take from twelve to eighteen months to reach harvesting stage and be processed the first time. A commercial plantation of sugar cane provides, as an average, five annual harvests. The two largest producing regions of sugar cane are the Southeast Region, with approximately 3 million hectares, with the State of São Paulo accounting for 2.6 million hectares, with an average productivity of 79 t/ha (tons per hectare) and the Northeast Region, with a little more than 1 million hectares and average productivity of 56 t/ha.

Historically, the planting of sugar cane was performed on owned property, in a clear strategy of industrial verticalization. During the past few years, a trend of reduction of this production mode was noted, with the plants leasing land with the purpose of growing sugar cane or even purchasing sugar cane directly from producers – under contracts stipulating that the industry undertakes to buy sugar cane at market prices. Such change denotes that the sector is becoming more professional, being beneficial for the industry, as it frees the plant from the heavy burden of buying land and for the regional development, by fostering a professional stance of agriculture and the emergence of land lessors.

Currently, more than 80% of sugar cane harvesting is done manually. The cutting activity is performed, in its vast majority, by workers holding a temporary job, where the pay is based on tons of harvested sugar cane. The cutting operation is preceded by the burning of the plant’s straw, which makes the work safer and more productive. Setting fire to the sugar cane plantations leads to the production of large smoke clouds, polluting the cities and disrupting air traffic, even causing outage of electrical power lines. In the State of São Paulo, legislation has been passed stipulating deadlines for phasing out the use of fire in the handling of sugar cane harvest. Thus, 25% of the cultivated area of the State of São Paulo is already being harvested by machinery (ÚNICA 2004). The legislation
does not deal with the effects of this measure on the generation of jobs, because it is estimated that the sugar-alcohol sector employs more than 1 million people and the activity that is more labor intensive is the harvesting of sugar cane.

Sugar cane is carried from the fields to the plant on specially designed trucks, provided with automatic loading and unloading. Transportation has significant economic impact on the composition of industrial costs and, as a rule, it is desirable for transport distance to be a maximum of 35 km.

The sugar-cane milling process covers various stages of preparation and milling. The milling process generates juice and bagasse, with the latter being burned in boilers and enabling energy self-sufficiency of the plants, which can sell their surplus electric power to the market.

Alcohol is obtained by distilling the juice after fermentation (or of a mixture of molasses and fermented juice).

In the process for fabrication of sugar, the juice is subjected to sulfating, decanting, concentration, crystallization and centrifugation, whereupon sugar and the molasses byproduct are obtained. The sugar plants normally manufacture a little alcohol, by taking advantage of the molasses generated during the production of sugar.

The milling process at a sugar plantation or alcohol distillery can be performed in various forms. The first stage is the mandatory establishment of sugar-cane plantations, in order to provide the supply of raw material. The facility can start the industrial phase as a (alcohol) distillery, and begin producing sugar at a second stage, or remain indefinitely as a distillery. The process may also begin its industrial phase as a (sugar) plant, and later decide whether or not to invest on alcohol production. Another form of process conduction is to begin operations with the capability of producing both alcohol and sugar.

A distillery can be switched into a sugar plant and vice-versa, upon additional investments; however, owning a facility with operational flexibility always means that a part of the industrial plant will remain idle.

**DATA INPUT PARAMETERS**

**Investment on plantations**

Investments on development of sugar-cane plantations are considerable and must be made sufficiently ahead of the industrial investments. For the project being analyzed, the investments for development of sugar-cane cuttings or scions precede industrial investments by 3 years, and will continue during the subsequent 10 years, using funds generated by the project itself. As mentioned before, new projects are not based on the purchase of land for planting of sugar cane. The project follows this strategy, by purchasing only the necessary land for development of cuttings. The supply of sugar cane for the plant is accomplished by a basket of sugar cane purchased from third parties and sugar cane produced in leased lands. The sugar-cane growing area at the beginning of the project is estimated as 6,000 hectares, increasing linearly until reaching the area of 30,000 hectares, by the tenth year. The sugar cane production in tons is presented in CHART 1.

**CHART 1 – Annual production of sugar cane – 1.000 tons**

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<tbody>
<tr>
<td>Own</td>
<td>63,4</td>
<td>56,3</td>
<td>49,3</td>
<td>360,8</td>
<td>660,8</td>
<td>930,8</td>
<td>1.125,8</td>
<td>1.565,8</td>
<td>1.880,8</td>
<td>1.807,4</td>
</tr>
<tr>
<td>Others</td>
<td>691,1</td>
<td>929,3</td>
<td>1.167,5</td>
<td>1.061,6</td>
<td>941,6</td>
<td>851,6</td>
<td>676,6</td>
<td>661,6</td>
<td>581,6</td>
<td>890,0</td>
</tr>
<tr>
<td>Total</td>
<td>754,5</td>
<td>985,6</td>
<td>1.216,8</td>
<td>1.422,4</td>
<td>1.602,4</td>
<td>1.782,4</td>
<td>1.802,4</td>
<td>2.227,4</td>
<td>2.462,4</td>
<td>2.697,4</td>
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Source: GONÇALVES, 2005.
**Industrial Investments for production of alcohol**

Industrial investments are preceded by various bureaucratic stages, which begin with the incorporation of a new business, run through the securing of various administrative and environmental licenses, and arrive at the financial structuring of the Project.

The investments for construction of the industrial facility, including the milling, boiler and distillery processes of the Project, are estimated to amount to 53 million reais. This amount includes the pre-operation investments for developing the sugar-cane plantations.

**Switch option to sugar production**

In order to exercise the switch option, the Project needs to accomplish the complementary investments required for production of sugar; namely, the erection of the plant. The additional investments are estimated at 87.6 million reais. In modeling this option, the erection of the Plant must necessarily be preceded by the erection of the distillery.

**Operational costs**

Operational costs involve the following stages: growing and maintaining sugar-cane plantations, cutting and hauling the sugar cane, milling and production of alcohol and vary, in accordance with the volume produced as shown in CHART2.

The modification of the Project for production of sugar implies in changes only in the industrial costs, as described in CHART 3.

### CHART 2 – Operational costs of alcohol project – 1.000 reais

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<tbody>
<tr>
<td>Agricultural</td>
<td>26.160</td>
<td>34.554</td>
<td>47.798</td>
<td>51.389</td>
<td>54.005</td>
<td>57.395</td>
<td>58.005</td>
<td>67.310</td>
<td>70.933</td>
<td>81.766</td>
</tr>
<tr>
<td>Total</td>
<td>40.350</td>
<td>53.001</td>
<td>67.803</td>
<td>72.277</td>
<td>75.656</td>
<td>82.000</td>
<td>82.375</td>
<td>94.237</td>
<td>100.070</td>
<td>112.233</td>
</tr>
</tbody>
</table>

Source: GONÇALVES, 2005.

### CHART 3 – Operational costs of sugar project – 1.000 reais

<table>
<thead>
<tr>
<th></th>
<th></th>
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<tr>
<td>Agricultural</td>
<td>26.160</td>
<td>34.554</td>
<td>47.798</td>
<td>51.389</td>
<td>54.005</td>
<td>57.395</td>
<td>58.005</td>
<td>67.310</td>
<td>70.933</td>
<td>81.766</td>
</tr>
<tr>
<td>Total</td>
<td>49.136</td>
<td>58.119</td>
<td>72.627</td>
<td>77.057</td>
<td>80.223</td>
<td>86.207</td>
<td>86.470</td>
<td>98.399</td>
<td>104.189</td>
<td>116.313</td>
</tr>
</tbody>
</table>

Source: GONÇALVES, 2005.
Option of switching an investment project into an agribusiness project

**Useful life of project**

The Project, as well as the other industrial projects of the sugar-alcohol sector, does not have a predefined service life, and an analytical approach should be employed for its analysis. The sector’s technology is assumed to be mature and, provided that proper preventive maintenance is performed, the equipment should have indefinite durability. However, the project evaluation horizon was defined as being of 10 years, with the last year being assumed as a perpetuity. For this purpose, it was assumed that the annual investments required for maintaining productive capacity are of an amount corresponding to annual depreciation.

**The prices of sugar and of alcohol**

Alcohol and sugar are agricultural-industrial commodities, whose prices are influenced by supply and demand, both of the domestic and of the foreign markets. In order to perform the evaluation of the project, the initial values of R$750.00 for one cubic meter of anhydrous alcohol and R$525.00 for one metric ton of sugar were used. The price of hydrated alcohol was estimated as being 93% of the price of anhydrous alcohol; namely, R$698.00 per cubic meter.

**Calculation of annual volatility**

The volatility of the price of anhydrous alcohol was calculated using the monthly average of the prices of the first maturity date of futures contracts traded at the BM&F. The ethanol market was under strong control of the government until 1997. The trading in the future market of anhydrous alcohol began in May 2000, which is the starting point of the historical series of the calculation. The prices were collected until the end of 2004. An annual volatility of 10.98% was found as the series was updated. The futures contracts for sugar started to be traded at the BM&F in January 1996. The month average prices of the first maturity date of crystal sugar contracts were collected up to December 2004. Calculations performed on the series of sugar prices determined an annual volatility of 15.93%. The recommendation by HULL (1999, p.25) of having a historical series of prices of the same magnitude as the projection horizon had to be waived in view of the lack of input data.

**Risk-free rate**

The risk-free rate to be used should be the real one; namely, the rate obtained after removing the expected inflation for the period. This is required in order to remove the effects of inflation from the interest rate, because the project was also being evaluated without assuming it. The rate must also be assumed post taxes, in accordance with the current literature.

The risk-free rate selected for this Project was 6%. Several works produced in Brazil assume this rate to be consistent with the panorama of high interest rates in force in the country. DIAS (1996), MARRECO (2001) and BRASIL (2002) have adopted this rate.

**Probabilities of the quadrinomial model**

While reviewing the series of prices for alcohol and sugar, we found the value of 0.5432 in the calculation of correlation between the variations of prices of the variables. Such value is commensurate with the relationship between the two commodities that, in spite of having distinct uses, share the same sources of uncertainty, especially regarding the availability of the raw material, sugar cane.

The values determined for probability of increases in the price of alcohol, combined with increases in the price of sugar – $P_{u_a u_s}$ – probability of increase in the price of alcohol combined with a drop in the price of sugar – $P_{u_d a_s}$ – probability of drop in the price of alcohol combined with a rise in the price of sugar – $P_{d_u a_s}$ – probability of drop in the price of alcohol combined with a drop in the price of sugar – $P_{d_d a_s}$ – are shown in TABLE 1.
The Project’s Cashflow

The information obtained enable the establishment of the FCDE – Available Cash flow of the Project. The basic FCDE – manufacturing of alcohol alone – is shown in TABLE 2. Deductions on the sales add up to 16.25% of the price of sugar and 3.65% of the price of alcohol. The rates for Income Tax and Social Contribution over Profit add up to 35%, and are levied cumulatively on the Gross Operating Profits.

Based on the Project’s basic FCDE, one can put together the project’s FCDE for manufacturing of sugar. Although it is named as Sugar Project, the FCDE assumes the optimal operation of the Plant, which would designate 65% of the sugar cane for production of sugar and use the remainder of this input material for production of alcohol, adding to the process the residual molasses generated in the production of sugar. The production of sugar entails change of the initial investment, revenues, deductions on sales, costs, taxes and depreciation. Refer to TABLE 3 for the Sugar Project FCDE.

One may calculate the Net Present Value – NPV of the projects using the data obtained in the FCDE’s. In order to produce this calculation, a discount rate of 6% a year was used. Thus were calculated the NPV of the Alcohol Project (54.5 million reais) and of the Sugar Project (less 50.5 million reais). Based on this initial calculation, only the erection of the distiller would be feasible and the Sugar Project would be shelved.
TABLE 2 – FCDE for the Alcohol Project – thousands of R$  

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Sugar Production (tons)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Anhydrous Alcohol Production (m³)</td>
<td>41.701</td>
<td>54.478</td>
<td>67.256</td>
<td>78.619</td>
<td>88.568</td>
<td>98.517</td>
<td>99.622</td>
<td>123.113</td>
<td>136.101</td>
<td>149.090</td>
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<tr>
<td>Hydrated Alcohol Production (m³)</td>
<td>18.657</td>
<td>24.375</td>
<td>30.089</td>
<td>35.173</td>
<td>39.624</td>
<td>44.075</td>
<td>44.570</td>
<td>55.079</td>
<td>60.890</td>
<td>66.701</td>
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<tr>
<td>Price of Sugar (R$/ton)</td>
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<td>525</td>
<td>525</td>
<td>525</td>
<td>525</td>
<td>525</td>
<td>525</td>
<td>525</td>
<td>525</td>
<td>525</td>
<td></td>
</tr>
<tr>
<td>Price Anhydrous Alcohol (R$/m³)</td>
<td>750</td>
<td>750</td>
<td>750</td>
<td>750</td>
<td>750</td>
<td>750</td>
<td>750</td>
<td>750</td>
<td>750</td>
<td>750</td>
<td></td>
</tr>
<tr>
<td>Price Hydrated Alcohol (R$/m³)</td>
<td>698</td>
<td>698</td>
<td>698</td>
<td>698</td>
<td>698</td>
<td>698</td>
<td>698</td>
<td>698</td>
<td>698</td>
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<td></td>
</tr>
<tr>
<td>Sugar Revenues (R$)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>Anhydrous Alcohol Revenues (R$)</td>
<td>31.276</td>
<td>40.859</td>
<td>50.442</td>
<td>58.964</td>
<td>66.426</td>
<td>73.887</td>
<td>74.716</td>
<td>92.364</td>
<td>102.076</td>
<td>111.818</td>
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<td>Hydrated Alcohol Revenues (R$)</td>
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<td>17.000</td>
<td>20.987</td>
<td>24.533</td>
<td>27.636</td>
<td>30.742</td>
<td>31.087</td>
<td>34.418</td>
<td>42.471</td>
<td>46.524</td>
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<td>Gross Operating Revenues</td>
<td>44.289</td>
<td>57.859</td>
<td>71.429</td>
<td>83.497</td>
<td>94.065</td>
<td>104.650</td>
<td>105.804</td>
<td>130.752</td>
<td>144.547</td>
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<td>(2.112)</td>
<td>(2.607)</td>
<td>(3.048)</td>
<td>(3.433)</td>
<td>(3.819)</td>
<td>(3.862)</td>
<td>(4.772)</td>
<td>(5.276)</td>
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<tr>
<td>Net Operating Revenues</td>
<td>42.672</td>
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<td>80.449</td>
<td>90.630</td>
<td>100.811</td>
<td>101.942</td>
<td>125.980</td>
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<td>Total Costs</td>
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<td>(53.001)</td>
<td>(67.803)</td>
<td>(72.277)</td>
<td>(75.656)</td>
<td>(82.000)</td>
<td>(82.375)</td>
<td>(94.257)</td>
<td>(100.070)</td>
<td>(112.233)</td>
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</table>

Source: GONÇALVES, 2005.
### TABLE 3 – FCDE of Sugar Project – thousands of R$.

<table>
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<tr>
<th></th>
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<td>Sugar Production (tons)</td>
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<td>118.088</td>
<td>124.200</td>
<td>154.170</td>
<td>171.949</td>
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<td>50.365</td>
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<td>65.988</td>
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<td>525</td>
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<td>525</td>
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<td>750</td>
<td>750</td>
<td>750</td>
<td>750</td>
<td>750</td>
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</tr>
<tr>
<td>Price Hydrated Alcohol (R$/m³)</td>
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<td>698</td>
<td>698</td>
<td>698</td>
<td>698</td>
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<td>698</td>
<td>698</td>
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<td>Sugar Revenues (R$)</td>
<td>21.785</td>
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<td>51.836</td>
<td>58.600</td>
<td>61.996</td>
<td>65.205</td>
<td>80.939</td>
<td>90.273</td>
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<td>Anhydrous Alcohol Revenues (R$)</td>
<td>18.586</td>
<td>24.280</td>
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<td>37.774</td>
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<td>45.187</td>
<td>49.491</td>
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<tr>
<td>Gross Operating Revenues</td>
<td>48.104</td>
<td>62.843</td>
<td>77.582</td>
<td>92.575</td>
<td>104.326</td>
<td>115.487</td>
<td>117.223</td>
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<td>160.356</td>
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<tr>
<td>Net Operating Revenues</td>
<td>43.603</td>
<td>56.963</td>
<td>70.323</td>
<td>82.665</td>
<td>93.134</td>
<td>103.460</td>
<td>104.728</td>
<td>129.438</td>
<td>143.129</td>
<td>156.775</td>
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<td>Total Costs</td>
<td>(49.136)</td>
<td>(58.119)</td>
<td>(72.627)</td>
<td>(77.057)</td>
<td>(80.223)</td>
<td>(86.207)</td>
<td>(86.470)</td>
<td>(98.399)</td>
<td>(104.189)</td>
<td>(116.315)</td>
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<tr>
<td>Gross Operating Profit</td>
<td>(5.533)</td>
<td>(1.156)</td>
<td>(2.304)</td>
<td>(2.607)</td>
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<td>18.258</td>
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<td>Provision I. Tax &amp; Social Contrib.</td>
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<td>(1.077)</td>
<td>(2.465)</td>
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<td>(7.410)</td>
<td>(7.700)</td>
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<td>Net Profit</td>
<td>(5.533)</td>
<td>(1.156)</td>
<td>(2.304)</td>
<td>4.530</td>
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<td>13.963</td>
<td>14.777</td>
<td>25.130</td>
<td>31.529</td>
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<tr>
<td>Net Availability</td>
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<td>(3.994)</td>
<td>848</td>
<td>(549)</td>
<td>4.412</td>
<td>11.563</td>
<td>15.403</td>
<td>15.221</td>
<td>26.429</td>
<td>37.788</td>
<td>35.585</td>
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<tr>
<td>Accumulated Availability</td>
<td>(139.025)</td>
<td>(143.019)</td>
<td>(142.170)</td>
<td>(142.720)</td>
<td>(138.308)</td>
<td>(126.745)</td>
<td>(111.342)</td>
<td>(96.121)</td>
<td>(69.693)</td>
<td>(31.905)</td>
<td>3.680</td>
</tr>
</tbody>
</table>

Source: GONÇALVES, 2005.
Option of switching an investment project into an agribusiness project

CALCULATION OF OPTION VALUE

The calculation of the option value is made in several stages. Based on the binomial analysis, two quadrinomial trees were assembled with the possible prices of the alcohol and sugar. The joining of these trees covers all possibilities of combination between the prices for alcohol and for sugar, partially presented in TABLE 4.

TABLE 4 – Combinations of price of alcohol and sugar
In reais per cubic meter and per ton

Source: Produced by the author.
Option of switching an investment project into an agribusiness project

Using the two binomial trees, on each node, the free cash flow of the project – FCDE is calculated for the alcohol project and for the sugar project. The result obtained is partially presented in TABLE 5.

TABLE 5 – Combinations of FCDE of alcohol and sugar
In thousands of reais

![Diagram showing combinations of FCDE values]

Source: Produced by the author.
Option of switching an investment project into an agribusiness project

In the following phase, the quadrinomial tree is assembled with the switch options for each pair of prices for alcohol and for sugar. This tree was obtained with the calculation of the maximum \((\text{FCDE}_{\text{al}}, \text{FCDE}_{\text{aç}})\) on each node and is partially shown in TABLE 6.

![Quadrinomial Tree Diagram]

TABLE 6 – Maximum FCDE for alcohol and sugar
In thousands of reais

<table>
<thead>
<tr>
<th>t0</th>
<th>t1</th>
<th>t2</th>
<th>t3</th>
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</thead>
<tbody>
<tr>
<td>(51,451)</td>
<td>7,419</td>
<td>14,890</td>
<td>27,403</td>
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<tr>
<td>7,419</td>
<td>7,646</td>
<td>24,316</td>
<td>24,316</td>
</tr>
<tr>
<td>(187)</td>
<td>2,378</td>
<td>4,654</td>
<td>9,087</td>
</tr>
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<td>(187)</td>
<td>8,300</td>
<td>11,034</td>
<td>18,324</td>
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<td>848</td>
<td>(5,655)</td>
<td>9,037</td>
<td>9,037</td>
</tr>
<tr>
<td>(3,229)</td>
<td>(5,683)</td>
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<td>(12,186)</td>
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<td>9,037</td>
<td>9,037</td>
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<tr>
<td>(13,077)</td>
<td>(13,077)</td>
<td>(13,077)</td>
<td>(13,077)</td>
</tr>
</tbody>
</table>

Source: Produced by the author
Note: The combinations in boldface are the situations where it is preferred to produce sugar.

To complement the calculations of the quadrinomial model, based on the neutral probabilities presented in TABLE 1 and in the table of maximum FCDE between the projects, the quadrinomial tree of the flexible project was assembled and is partially shown in TABLE 7.

In the analysis of the quadrinomial tree for the flexible project, it is seen that the flexible project’s value – with annual volatility of 10.98% for alcohol and 15.43% for sugar; correlation between the variations of the prices of 54.32% and risk-free interest rate of 6% per year – is of 345.6 million reais. If we assume that the net present value of the non-flexible sugar project is less R$50.5 million, one concludes that the value of the flexibility option of this project is 396.1 million reais, as demonstrated in TABLE 8.
Option of switching an investment project into an agribusiness project

TABLE 7 – Calculation of option value
In thousands of reais

Source: Produced by the author

TABLE 8 – Results of the quadrinomial model
Million R$

<table>
<thead>
<tr>
<th>Project</th>
<th>Traditional NPV</th>
<th>Value with flexibility</th>
<th>Value of the option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible</td>
<td>(50,5)</td>
<td>345,6</td>
<td>396,1</td>
</tr>
</tbody>
</table>

Source: GONÇALVES, 2005.
Option of switching an investment project into an agribusiness project

**FINAL CONSIDERATIONS**

The application of the real options theory was made for evaluation of the existing flexibilities of an agricultural-industrial Project. Such analysis was made by application of the quadrinomial model on a sugar & alcohol investment. The use of such modeling was required in view of the fact that the project being evaluated has two sources of uncertainty – the prices of alcohol and of sugar. The use of a binomial model appears to be insufficient to capture the effect of simultaneous variations on the prices of both commodities. The use of quadrinomial trees appears to be a more suitable tool for such instance.

The quadrinomial model, which allows one to analyze in one single tree of events the combinations of the prices for alcohol and sugar, enabling the manager of the project to select for production the product that yields the best result at the given time. On TABLE 6, the situations under which it would be preferable to produce sugar in order to achieve the best FCDE are shown in boldface.

Interpreting the results obtained in TABLE 8, it is seen that the analysis of projects through the real options theory is superior than analyzing with the traditional NPV for flexible projects. Such results are in accordance with the assumptions of the real options theory.

A few of the assumptions were adopted for the purpose of simplification of the job. No consideration was given to the fact that sugar-cane plantation productivity is dependent upon weather conditions, and varies on each harvest. Inflation was assumed to neutral, with uniform effects on costs and incomes.

This project has other implicit options, liable to be evaluated. The development of sugar-cane crops may be considered as an option both in the expansion sense, and in the sense of deferral. The project is capable of producing innumerable combinations of quantities of alcohol and sugar. The switch option may be analyzed as a option of deferral.

Therefore, the real options theory can be successfully applied for evaluation of agricultural-industrial projects. The evaluation of the sugar-alcohol project using the quadrinomial model evaluated the flexibility of change in the end product, justifying the additional investment for construction of the sugar plant.
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