

Application of Real Options Analysis in the Valuation of Investment in Biodiesel Production

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ABSTRACT

There are basically two main methods used in the valuation of capital investments; the discounted cash flow (DCF) techniques, and the option pricing valuation (OPV) method. The DCF techniques and other net present value (NPV) methods when used to value investment projects that have flexibility in them tend to underestimate the values of the projects, because they fail to capture the value of the flexibility embedded in such projects. For biodiesel production, such flexibility may include the option to defer, expand, contract or abandon the project, should the economic environment necessitate that. Most biodiesel production projects have been valued using the DCF techniques. This paper evaluates the economic feasibility of converting WVO from the Army Barracks as well as other feedstock into biodiesel, using the OPV method so as to incorporate managerial flexibility in the production process. The log-transformed binomial method (LTBM) is envisaged for the real options analysis.

INTRODUCTION

Biodiesel is a renewable fuel produced from sources including virgin and waste vegetable oils, and animal fats. As a transportation fuel, it is increasingly being used in federal, state, and other transit fleets, private trucking companies, and personal automobiles. The US Military is one of the largest consumers of conventional diesel oil; a non-renewable fossil fuel that is known to contribute to the emissions of greenhouse gases as well as increases US dependence on imported petroleum. Fortunately, huge quantities of waste vegetable oil (WVO) are disposed of at Military Canteens annually. The opportunity, therefore, exists for the US Department of Defense (US DOD) to get involved, one way or the other, in the production of biodiesel for use in their transportation vehicles. But with biodiesel production costing more than \$3/gallon, it sometimes begs the question whether

such an investment will be worth it? Cost is not, however, the only goal of the US Military in increasing its use of biodiesel as source of transportation fuel. In fact, improving its energy security and independence as well as environmental sustainability is also an integral part of its strategic goals. That notwithstanding, it is of importance to assess the economics of using biodiesel based on WVO and other feedstock.

There are basically two methods used in the valuation of capital investments, the discounted cash flow (DCF) techniques and option pricing valuation (OPV) methods. The DCF techniques and other net present value (NPV) methods when used to value investment projects that have flexibility in them tend to underestimate the values of the projects, because they fail to capture the value of the flexibility embedded in such projects. Real capital investments entail several managerial and operating flexibility [14]. In addition, if investment projects are irreversible then they should be valued using option pricing techniques, since the traditional NPV techniques are based only on expected future cash flows but not on their second moments i.e. their variability [7]. Conventional valuation techniques, such as DCF, are difficult to apply when accounting for managerial flexibility and hence undervalue the values of projects in capital budgeting [10]. Flexibility embedded in option pricing models makes them normally difficult to solve analytically, especially when the underlying asset (price of biodiesel) is a dividend-paying as well as a cash flow generating asset. A numerical technique will therefore be developed to analyze the problem. The log-transformed binomial method (LTBM) is envisaged for this study, because of the ease with which it incorporates flexibility and other options.

We will use the real option valuation approach to assess the economic value of biodiesel production, including the options to defer, and expand the project should the economic environment change. The total

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value of all the options calculated individually i.e. without interaction, will be different from when their interactions are incorporated. Without interaction the total value of the individual options will be overestimated [12], [13]. However, incorporating options interaction can also make the valuation computationally very demanding. In such cases, some traditional option valuation methods e.g. Black-Scholes may not be appropriate for the analysis without further modifications. This is not the case with the Log-transformed Binomial Method (LTBM), which can handle such interactions without loss of computational efficiency. Consequently, it is employed in this study. This paper uses the OPV method to evaluate the economic feasibility of converting WVO as well as other feedstock into biodiesel, so as to incorporate managerial flexibility in the production process. The log-transformed binomial method (LTBM) is envisaged for the real options analysis.

REAL OPTIONS ANALYSIS

Stochastic Process of the Price of Biodiesel

Let the price of the output variable (price of biodiesel) at time t , $P(t)$ be assumed to evolve as the stochastic process given by the geometric Brownian motion (GBM). Then

$$dP = \alpha P dt + \sigma P dW \quad \text{Equation (1)}$$

Where dW is a standard Wiener process, dt is an increment of time, σ the instantaneous standard deviation (volatility) and α the expected return on the price of biodiesel P .

Since there is a traded market for biofuels or their proxies, we will assume that the biofuel price uncertainties can be spanned by the capital markets. Hence, contingent claims analysis could be used to find the value of the project, $V(P, t)$. We assume V follows an Ito's process i.e. it is twice differentiable with respect to P and once with respect to time t and consequently also follows the stochastic process given in Equation (1).

Option Pricing Valuation (OPV) Method

The net present value of biodiesel production, including managerial flexibility, NPV can be given as

$$NPV = V - I + V_{opt} \quad \text{Equation (2)}$$

Where

V : Present Value of Biodiesel Project, \$

I : Initial capital investment, \$

V_{opt} : Total value of options embedded in the project, \$

Numerical Approximation of Real Option Model

Normally there exist no analytical solutions to option pricing models, especially, when the underlying asset (price of fuel) is a dividend-paying as well as, a cash flow generating asset. This study will therefore use numerical techniques to value the biodiesel investment project. An option is defined as the right, but not an obligation, to buy (if a call) or sell (if a put) a specified asset (e.g. common stock) by paying a pre-specified price (the exercise or strike price) on or before a specified date (the expiration or maturity date). If the option can be exercised before maturity, it is called an American option; if only at maturity, a European option [14].

Several models are available for valuing options. They range from analytical formulas to numerical techniques. Perhaps the most famous analytical method is the model developed in [2] and later modified in [11]. Other option valuation techniques include the binomial lattice method developed in [6], the log-transformed binomial method proposed in [12], the finite difference method proposed in [4], [5]. Furthermore, Monte Carlo simulation method has been developed to value European option in [3], which was later improved in [9] to value American options. The log-transformed binomial method is envisaged for this study, because of the ease with which it incorporates flexibility and other options.

i. Log-Transformed Binomial Method (LTBM) Numerical Technique

The log-transformed binomial method (LTBM) has been well described in [12]. It is summarized for the biodiesel project as given below.

If we let

$$X = \ln V(P, t) \quad \text{Equation (3)}$$

Then in any differential time interval, dt , dX follows an arithmetic Brownian motion, which under risk neutral valuation, will be given by the stochastic process given by [12]

$$dX = (r - 0.5\sigma^2)dt + \sigma dW \quad \text{Equation (4)}$$

Where the increments, dX are independent, identical, and normally distributed with mean $(r - 0.5\sigma^2)dt$, and variance $\sigma^2 dt$, while r is the risk-free interest rate e.g. US Treasury Bonds.

To approximate the continuous process in equation (4) the lifetime of the biodiesel project T can be subdivided into N equal discrete subintervals of magnitude τ so that

$$T = N * \tau \quad \text{Equation (5)}$$

It can be shown that within each discrete subinterval τ , X follows a Markov random walk with risk-neutral probability of moving up by an amount $\Delta X = H$ and down by an amount $\Delta X = -H$, p_u and p_d , given respectively, by [12]

$$p_u = 0.5 \left(1 + \frac{\mu * K}{H} \right) \quad \text{Equation (6)}$$

$$p_d = 1 - p_u = 1 - 0.5 \left(1 + \frac{\mu * K}{H} \right) \quad \text{Equation (7)}$$

Where μ , K , H are also given by:

$$K = \sigma^2 dt \quad \text{Equation (8)}$$

$$\mu = \frac{r}{\sigma^2} - 0.5 \quad \text{Equation (9)}$$

$$H = \sqrt{K + (\mu * K)^2} \quad \text{Equation (10)}$$

Once the state and time variables are transformed, as given above, the discrete-time approximation to the continuous process will be assured stability and consistency [12].

ii. LTBM Algorithm

Using the LTBM technique as described in [12], the net present value of the biodiesel project that incorporates the option value could be determined by four main steps, as given in Figure 1.

The option to defer is an American call option; the option to abandon is a compound call option; the option to contract is an European put option; the option to switch use i.e. abandon for salvage value is an American put option [13].

Step 1: Specify initial parameters (V , r , σ^2 , T , N , I), where I is initial capital investment of the biodiesel project. Additional parameter specification include cash flow (amount and timing), and real option data

Step 2: Calculate preliminary key variables

Time step (K), drift (m), state-step (H), and probabilities (p_u , p_d)

Step 3: Determine the terminal boundary values (at $j=N$)

Let j be the integer number of time-steps (each of length K)

Let i be the integer index of the state variable X corresponding to the net number of ups less downs (i.e. $X(i) = X_0 + iH$), and $R(i)$ be the total investment value (including embedded real options e.g. defer, expand, contract, abandon etc.) of the biodiesel project

At $j=N$, and for each i , project value $V(i) = \exp(X_0 + iH)$, $R(i) = \max(V(i), 0)$

Step 4: Backward iterative process

For each time step j ($j=N-1, \dots, 1$) and every second state variable i , calculate (from step $j+1$)

$$R'(i, j) = e^{-\left(\frac{rK}{\sigma^2}\right)} [p_u * R(i+1, j+1) + p_d * R(i-1, j+1)], \text{ a new revised value for } R(i),$$

A. Adjust for cash flows (dividends):

At each cash inflow (ex-dividend) time, determine downward extension of triangular path and shift (e) for each state variable index i : $R'(i) = R(i-e) + CF$

At each cash outflow (exercise) time: $R'(i) = R(i) - I$

B. Adjust for multiple real options:

Figure 1. Flow-chart for LTBM Algorithm

Model Parameters Estimation

Data for the model consist, basically, of the current and historical futures prices of No. 2 fuel oil i.e. conventional diesel, which is used as a proxy for biodiesel, and the risk-free interest rate r (e.g. U.S. Treasury Bills). They are financial market data and could therefore be obtained from, sources such as the New York Mercantile Exchange (NYMEX), US DOE-EIA (Energy Information Administration) and the Wall Street Journal. The main model parameter that needs to be estimated exogenously is the instantaneous standard deviation (volatility) of the price of biodiesel. Historical data of biodiesel prices or its proxy (No.2 fuel oil) is used for the estimation. For consistency with the assumptions and conventions in option valuation, the volatility of the underlying asset can be estimated from the continuously compounded return to the underlying asset (biodiesel or its proxy) [1], [8].

Let the continuously compounded return on the price of biodiesel or its proxy be given as

$$u_t = \ln\left(\frac{P_t}{P_{t-1}}\right) \text{ for } t = 1, 2, \dots, n+1 \quad \text{Equation (11)}$$

Where u_t is the return between $t-1$ and t , and P_t is the market price of biodiesel or its proxy (No.2 fuel oil) at time t . Then the annual volatility of the underlying asset (price of biodiesel) can be computed as [1], [8]

$$s = \sqrt{\frac{1}{n-1} \sum_{t=1}^n (u_t - \bar{u})^2} = \sqrt{\frac{1}{n-1} \sum_{t=1}^n u_t^2 - \frac{1}{n(n-1)} \left(\sum_{t=1}^n u_t \right)^2}$$

Equation (12)

Where n is the number of return data points (since the historical price data are $n+1$) and $\bar{u}$ the mean of the u_t 's

Once the value for the instantaneous standard deviation (volatility) s has been estimated it can be input into the numerical model as proposed, to determine the economic value of the biodiesel production.

MODEL RESULTS AND ANALYSIS

A case study is presented in this section to illustrate the application of using the LTBM model to value biodiesel production facility. We assume the following process and financial information for the analysis:

Plant Capacity = 1000 t of waste vegetable oils

Biodiesel Production = 930 t

Initial Capital Investment, I_0 = \$343/t or about \$320,000 (based on biodiesel produced)

Present Value of Project, V = \$300,000

Project Lifetime = 15 yrs.

Volatility of Project Value = 17%/yr. (based on price volatility of #2 fuel oil)

Risk-free Interest Rate = 5%/yr.

Managerial Flexibility (Real Options to be incorporated):

- i. Defer I_0 up to year 2
- ii. Expand production capacity by $e=50\%$ of V by investing I_E in year 5

Table 1: Standard Option Pricing Valuation of Individual Options (in \$1000)

OPTION TYPE	STRIKE PRICE (\$)	VALUE OF ASSET (\$)	OPTION VALUE (\$)
Defer Investment for 2 yrs.	320	300	33.3
Expand Biodiesel Production in Yr. 5	140	150	46.3

Using the information as given in the case study above, it can be shown in Table 1, that the option to defer investing \$320,000 in the biodiesel project by 2 years has a value of \$33,300, while the option to expand production in year 5, by investing \$140,000 additional capital to obtain 50% (or \$150,000) additional value of the project has a value of about \$46,300, resulting in a total combined real option value of \$79,600. This combined option value is sufficient to make the NPV (-\$20,000 without real options) positive value (i.e. -\$20,000 + \$79,600 = \$59,600). Under this circumstance the project will be accepted, since the NPV (after incorporating option value) is positive.

The combined value of all these options if evaluated individually would be substantially overstated, since these options may interact negatively. In fact, certain prior real options may alter the underlying asset and value of subsequent options. In addition, the presence of subsequent options would increase the effective underlying asset for prior options [12], [13]. The degree of interaction is a function of the type of option and the degree to which the exercise price overlap [13]. Options tend to

be more additive when they are of opposite types e.g. call and put options; when the times of possible exercise of the two options are closer; when the options are more out-of-the-money i.e. option have relatively high exercise prices for calls and low exercise prices for puts [13]. The use of LTBM allows the interactions of the various options to be incorporated. Table 2, illustrates the combined value of the option in cases where the options are in-the-money, at-the-money and out-of-the-money. When the options are out-of-the-money their values are smaller than when they are in-the-money or at-the-money, as illustrated in Table 2.

Table 2: Combined Option Pricing Valuation (in \$1000)

OPTION TYPE	STRIKE PRICE (I) (\$)	VALUE OF ASSET(V) (\$)	OPTION VALUE (\$)
In-the-money	280	300	136
At-the-money	300	300	116
Out-of-the-money	320	300	96

The traditional NPV i.e. the difference between V and I, is -\$20, 000. This negative number indicates that the investment project should be rejected, since NPV is negative. But by incorporating the option to defer the project by 2 years and also to expand the project in year 5, the combined option value is \$96,000 (based on the out-of-the-money option i.e. the original data from the case analysis). This, therefore, makes the expanded NPV i.e. the sum of the traditional NPV and the real options value together positive (\$96,000 - \$20,000 = \$76,000), and consequently, make the investment rather attractive. Without incorporating managerial flexibility (i.e. real options) the project would not have been undertaken, given NPV to be negative. It should also be noted that the combined options value are larger for in-the-money and at-the-money options i.e. \$136,000 and \$116,000, respectively, than for the out-of-the-money option value.

CONCLUSION

There are basically two methods used in the valuation of capital investments, the discounted cash flow (DCF) techniques and the option pricing valuation (OPV) methods. The DCF techniques and other net present value (NPV) methods when used to value investment projects that have flexibility in them tend to underestimate the values of the projects, because they fail to capture the value of the flexibility embedded in such projects. Most investments in

biodiesel projects have been evaluated using the traditional discounted cash flow (DCF) techniques. These techniques normally underestimate the value of such projects, because they fail to capture the value of the flexibility embedded in them. In fact, most capital investment projects can be deferred, contracted, abandoned or switched for salvage value, as well as expanded. In this paper, we analyzed the case where a biodiesel project can be deferred and also expanded. We used the log-transformed binomial method to analyze the managerial flexibility embedded in the project due to the option to defer the project by 2 years and also the option to expand the value of the project by 50%, if additional capital is invested in the fifth year.

The study shows that even when the traditional NPV method suggests rejecting a project because its value is negative, incorporating managerial flexibility could make such a project value become positive. It can also be shown that the value of the combined option, when calculated individually could be overstated because these individual options can interact negatively. Finally, it should be noted that the combined options value is larger for in-the-money and at-the-money options than for the out-of-the-money option value.

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