Real Options Valuation of a Wind Farm

Mariano Méndez
ESIC Business and Marketing School
Alfredo Goyanes
Saphire Finance LLP
Prosper Lamothe
Business Finance Department
Universidad Autónoma de Madrid

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Abstract:

The present paper values a Wind Farm investment project as a Compound Real Option. By combining the different uncertainties, we evaluate the volatility of the project. The value of the project is calculated using binomial lattices including Market and Private Risks.

Keywords:

Real Options with Market and Private Risks, Compound Real Options, Wind Farm Valuation, Binomial Lattices.

INTRODUCTION

The present paper is derived from the assessment of a portfolio of investment projects in alternative energy sources in Eastern European countries. We shall herein set out the valuation methodology applied to one of the projects, although figures have been altered and, in some cases, hidden to preserve confidentiality.

The technique selected for valuation is the Cox, Ross and Rubinstein (1979) binomial model –hereinafter referred to as CRR. As Smith (2005) has demonstrated, results using this model are very similar to those reported from the Monte Carlo simulation model. However, CRR has the advantage of a valuation process that is intuitive and transparent for investors, thus overcoming the “black box” feeling that valuation with Monte Carlo had formerly aroused among some of the investment bank’s customers.

The project was exposed to systematic or market risk as given by the Capital Asset Pricing Model, CAPM[1], stemming from such factors as electric power prices, euro/local currency exchange rates or domestic interest rates.

It was also affected by non-systematic, technical or private risks, whose subjective success/failure probabilities were assessed and made available to us by company experts.

We have applied the notion of separation between private and market risks in Real Option valuation -which was first introduced by Smith and Nau (1995)- according to the technique used in binomial lattices by Villiger and Bogdan (2005).

The volatility assessment needed to replicate the process of diffusion in the value of the project is based on the Market Asset Disclaimer or MAD assumption by Copeland and Antikarov (2001) -hereinafter referred to as CA.

We thus adopt this hypothesis and apply the technique developed by CA (2001) and later extended by Brandao, Dyer and Hahn (2005) to subsume all the market uncertainties of the project into a single one.

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[1] For CAPM and the breaking down of exposure into systematic and specific risks, readers are referred to Grinblatt and Titman (2002)

Existing literature includes a previous paper on Real Options valuation of Wind Farms by Venetsanosa, Angelopouloua and Tsoutsosb (2002). Their methodology was ruled out for the following reasons:

Two main Real Options are identified in their analysis: Enlargement –in our case, once the farm is operational, enlarging it is no longer feasible given the size of the surface available for installation; Postponing development –not contemplated, since the objective is to launch the project as soon as possible, given the current conditions and stage of development.

The above-mentioned authors take volatility in the American electric power market (75%) as a proxy to assess a renewable energy project in Greece. Such a volatility level is more than ten times the levels we detected in our analysis. Bearing in mind the degree of options' sensitivity to volatility, we considered that the results thus obtained overvalued the project.

Finally, their model does not allow to factor in the private risks of the project's development stage.

JUSTIFYING THE DECISION TO CHOOSE RO VALUATION

Models based on the Real Options (RO) methodology, as opposed to the NPV method, make it possible to assess those uncertain projects that have managerial flexibility, i.e. projects throughout whose life investors may, with their decisions, alter the results produced by their investment as they receive new information.

ROs are not applicable to all projects. They contribute value solely in those projects over the course of whose lives new information can be obtained, while there exists the possibility of reacting to this new information by means of our decisions. That is the case here, because:

- The project is divided into a series of independent and successive stages, with the possibility of deciding, ahead of each stage, whether pursuing the investment is advisable or not.
- Abandoning the project is a possibility available at any time before its final launching.

- Private risks can only surface when investing in the project.
- Market risk leads to changes in the value of the project throughout its life.

PROJECT DESCRIPTION

Installing a wind farm[2] requires going through a series of steps over a period of time that may span approximately 5 years. Each project milestone involves making an outlay and has an associated probability of success/failure.

The investment project can be abandoned any time in the course of this 5-year development period, but no residual value would be recovered –or such a value would be minimal. However, given the sequential nature of the project, we would avoid incurring greater losses should the information we were getting not match what we had anticipated.

The process begins by finding a site, gathering meteorological data, and starting wind speed measurements with the help of a 30-meter tower.

Using these measurements, which may extend over approximately two years, we will be able to estimate wind speeds at a height of 80 to 100 metres. This will allow us to forecast the air generators' production output and thus get a more accurate picture of the project's Cash Flows.

Connection to the power grid is subsequently requested and a construction permit is applied for. Finally, an operating permit is requested. The next step will be to decide whether to launch the project or not.

Should the decision be taken to launch, the project would generate cash flows from the beginning of operations through the end of the air generators' average life, which is estimated to be some 20 years.

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[2] As a source of detailed information in Spanish about each development stage in a wind energy project, we recommend the Danish Wind Industry Association website: http://www.windpower.org/composite-188.htm.

Income is procured by selling the electric power that is generated to the power company. Since, in practice, the air generators' annual power production follows a normal distribution which shows a small mean deviation and is independent from year to year, the cash flow generated over the project life is usually relatively stable. If we add to this the fact that the price of electric power derived from alternative sources is subject to governmental regulation, we should expect the volatility of the project's cash flows -if indeed it is launched- not to be very high.

The project under examination has reached the stage in which it needs to be decided whether to conduct wind measurements at 80 metres and whether to apply for connection to the power grid. Schematically, the project's development process is depicted in Exhibit 1.

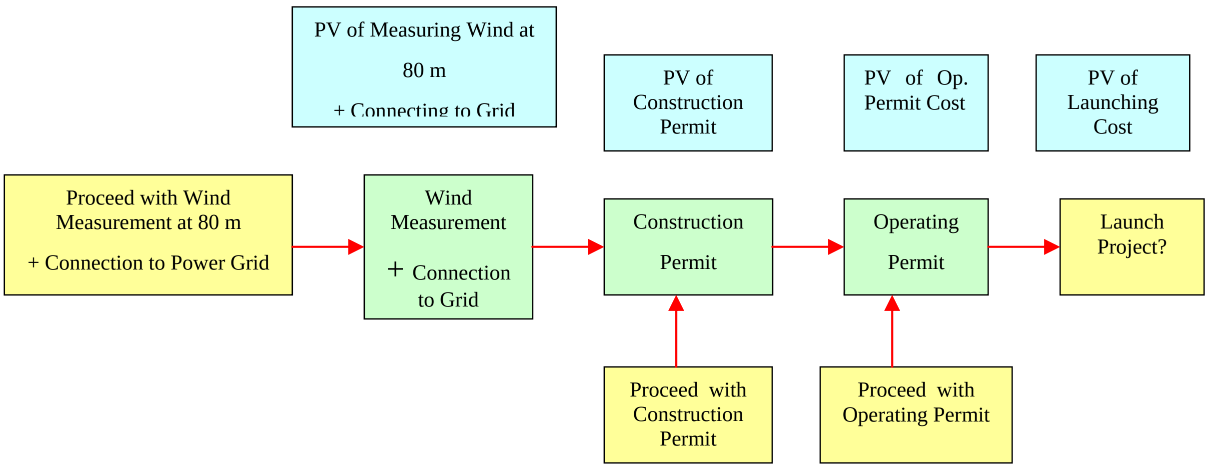


Exhibit 1

This diagram represents:

- Decisions/options inside yellow boxes.
- The possibilities of successfully going through each stage inside a green box.
- The Present Value (PV) of the cost of each stage inside a blue box.

Table 1 shows the cost of each stage and its subjective probability of success/failure, up to the possible launching of the farm, as estimated by experts. The costs for each stage have been discounted using the risk-free rate at time 0, so that the analysis can be carried out using real options, since those values will be introduced in the binomial lattice as the project's strike call price.

The value of the cash flows has been discounted at the project's Weighted Average Cost of Capital (WACC), for this will be the initial value of the binomial sequence.

Table 1

Mill. Local currency

Stage	Present Value	Quarters to Start	Probability of Success	Conditional Probability
Wind Measurement and Grid Connect	-29	0	72%	72%
Construction Permit	-69	2	60%	43%
Operating Permit	-9	4	40%	17%
Launching	-9.813	8		17%
Total Cost of the Project	-9.920	8		17%
All cost discounted at r_f				
Present Value of Cash Flows	13.673	8		17%
Discounted at WACC				

WACC calculations are based on interest rates for the 10-year bond from the country of origin adjusted with the Company's credit risk premium.

As for the market risk premium in the country of origin and the Company's Beta, we use the data provided in A. Damodaran's's[3] website for country premiums and average betas for European and American industrial sectors.

TYPES OF REAL OPTIONS IN THE PROJECT UNDER EXAMINATION

Following an analysis of the project's managerial flexibilities up to its launching, it was concluded that we were dealing here with a RO that is made up of two ROs:

- **Option to abandon:** The project may be abandoned at any time before its launching, which in financial terms is known as an American put option. This option has an associated value, in that it makes possible to avoid bigger losses should forecasted states of the market turn to be unfavourable.
- **Sequential call option:** As each stage is completed, we have the option to decide whether or not we wish to invest in the next stage. In financial terms, this is known as a European call option. The decision rule is as follows: If we invest 29 million MU in undertaking the wind studies and in connecting to the grid, we

[3] http://pages.stern.nyu.edu/~adamodar/

acquire the right/option to invest in the following stage; yet we will only do so if the project's estimated value at that point exceeds 29 million MU.

ASSESSING THE PROJECT'S VOLATILITY

In order to calculate the parameters of the binomial sequence, we need to know the project's volatility. The fact that the project is not traded in any market and that no historical information is available poses a problem.

Various alternative solutions are often used to assess volatility:

- Taking the market return volatility of a similar company; an approximation would thereby be made that might lead to error, since finding a company whose characteristics exactly match those of the project would be no easy task.
- Using the volatility of those elements that generate the project's cash flows, such as, for instance, the volatility of electric power prices; however, these elements only partially reflect the project's uncertainty.

We decide to adopt, as the most feasible alternative, the assumption stemming from the Market Asset Disclaimer, or MAD assumption, which was developed by CA (2001).

In the absence of an effective method of assessing the volatility of one-off projects with no reflection in the market, this assumption suggests using the project itself without options as the best asset estimate.

We thus turn the market into a complete market, for we assume the project's market value to be its present value and assess volatility by simulating its expected returns from year 0 to year 1. This allows us to combine all market uncertainties into a single one: the volatility of the project.

This methodology is very well documented in CA's book (2001), chapters 9 to 11, and is also very clearly explained in Brandao et al (2005), where even the original Excel files, with parameters simulated in @Risk, can be consulted.

The CA (2001) method consists of the following steps:

1) We build the electronic sheet that allows us to ascertain the present value of the project at time 0 (PV_0), using the project's WACC as discount rate.
2) We model the project's uncertainties.
3) We use a Monte Carlo simulation programme of the @Risk type to generate the distribution of present values (PV) at date 0 and date 1, adding to those at date 1 the cash flows (CF_1) expected for that period. The volatility that we will use in the project will thus be determined with the following formula:

$$z = \ln\left(\frac{PV_1 + CF_1}{PV_0}\right)$$

This z value is calculated by keeping the project's present value at 0 (PV_0) constant and iterating the variables of the model, so that they allow the present value at date1 to change:

$$PV_1 = \sum_{t=2}^{n} \frac{CF_t}{(1+WACC)^{t-1}}$$

We calculate the standard deviation of the distribution of returns from date 0 to date 1 and use this volatility as the project's volatility. Since we assume that the value of the project (PV) follows a lognormal distribution with constant volatility, we use that same volatility figure throughout the project life.

MODELISING THE PROJECT'S UNCERTAINTIES

Once the electronic sheet needed to estimate the Cash Flows generated by the farm has been created, the following uncertainties are introduced:

Cost uncertainty

Due to the fact that the expected launching date will be in 2 years time and that 83% of the project's total cost will be paid with a loan in euros granted by a local bank, we identify two significant sources of risk:

Local currency/euro exchange rate risk, modelised using a geometric Brownian motion[4] with 0 growth rate:

$$C_{t+1} = C_t e^{\sigma\varepsilon\sqrt{\Delta t}}$$

with C_t being the exchange rate, σ the standard deviation of the exchange rate return over the past year, Δt the time interval -in our case 1 year-, and ε a random realisation of a normal distribution with 0 mean and 1 standard deviation.

Local interest rate risk, modelised through a triangular distribution in which we use the current value as the most probable value, and the current value minus 1% and plus 1%, respectively, as the minimum and maximum values.

Revenue uncertainty

Revenue uncertainty is modelised using two variables:

On the one hand, the gross annual production, represented by a normal distribution that is deemed to be independent from year to year. This distribution is based on studies about wind characteristics carried out in the prospective site for the wind farm location.

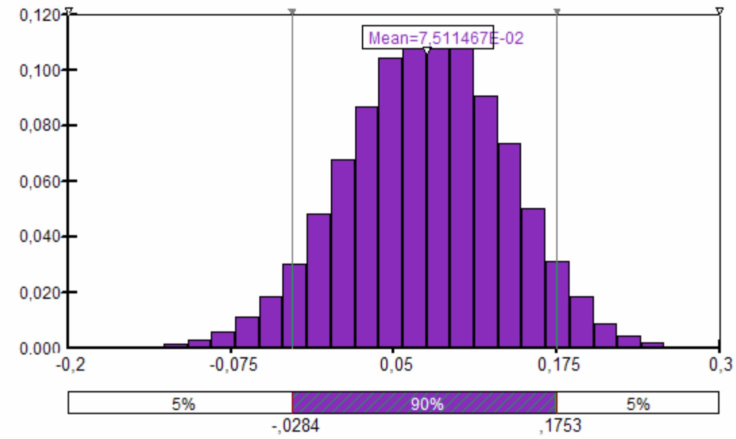
On the other hand, the electric power price, which is regulated, thus allowing us to consider that it will only fluctuate with inflation, which we modelise as a triangular distribution with the current value as the most probable value, and the current value minus 1% and plus 1%, respectively, as the minimum and maximum values.

MONTE CARLO SIMULATION AND VOLATILITY ASSESSMENT

Once all project uncertainties have been analysed and introduced in the discounted cash flow model, we may apply the above-stated formula. The outcome of this analysis is an average volatility of σ = 6.2% for 50,000 simulations. The distribution of returns is represented in Exhibit 2.

[4] The formula in discrete time of a geometric Brownian motion is represented by the following expression: $C_{t+1} = C_t e^{\left(\left(\mu - \frac{1}{2}\sigma^2\right)\Delta t \ + \ \sigma\varepsilon\sqrt{\Delta t}\right)}$; we will assume that the drift $\left(\mu - \frac{1}{2}\sigma^2\right)$ is, in our case, 0.

Exhibit 2



BINOMIAL METHOD FOR THE VALUATION OF COMPOUND OPTIONS WITH PRIVATE RISK

The binomial method developed by CRR (1979) is based on valuation as established by the non-arbitrage theory, thereby obtaining a series of parameters for the evolution of the asset value and its risk-neutral probabilities.

Let us now focus on the parameters needed to apply the method, providing a brief intuitive description of what each of them represents[5].

The model is built on the notion that the value of an asset may change over time, either through an increase or a decrease in value. It then proves that, in a non-arbitrage environment, this value change is independent of the return on the asset. This implies that the asset is risk-free and, as such, it will have to be discounted at the risk-free rate.

Intuition tells us that market risk is implicit in asset volatility and that its up and down factor depends solely on the latter. Therefore, the value of an asset is independent of the market's bullish or bearish expectations regarding its rate of return going forward.

Parameters representing upward and downward changes in asset value are described by the letters u and d, and their respective formulas are as follows:

$$u = e^{(\sigma\sqrt{\Delta t})};\ d = \frac{1}{u}$$

[5] For readers interested in the model, we recommend Mascareñas, Lamothe, López and Luna (2004) as an introduction, Hull (2003) -chapters 10 and 12- for a more advanced analysis, and Neftci (1996) -chapter 2- for more in-depth mathematical assessment.

with σ being the annual standard deviation of asset returns, and Δt the time change from one period to the next, which allows us to adjust annual volatility to the period we are considering.

Risk-neutral probabilities of an increase (u) or a decrease (d) in value are represented by p and q:

$$p = \frac{(1+r_f) - d}{u - d}\ ;\ q = 1 - p$$

with r_f being the return on the risk-free asset.

The risk-neutral probabilities are multiplied by the future value of the asset, so that, when its increased and decreased values are weighed with their associated probabilities and discounted at the risk-free rate, the value thus obtained equals the value of the asset at time 0. For instance, if the value of the asset is currently 100, its increased value is 120 and its decreased value is 90, and the existing risk-free rate is 10%, the risk-neutral probabilities are those for which the following equation holds:

$$V_0 = \frac{V_u p + V_d (1-p)}{(1+r_f)}$$

Therefore:

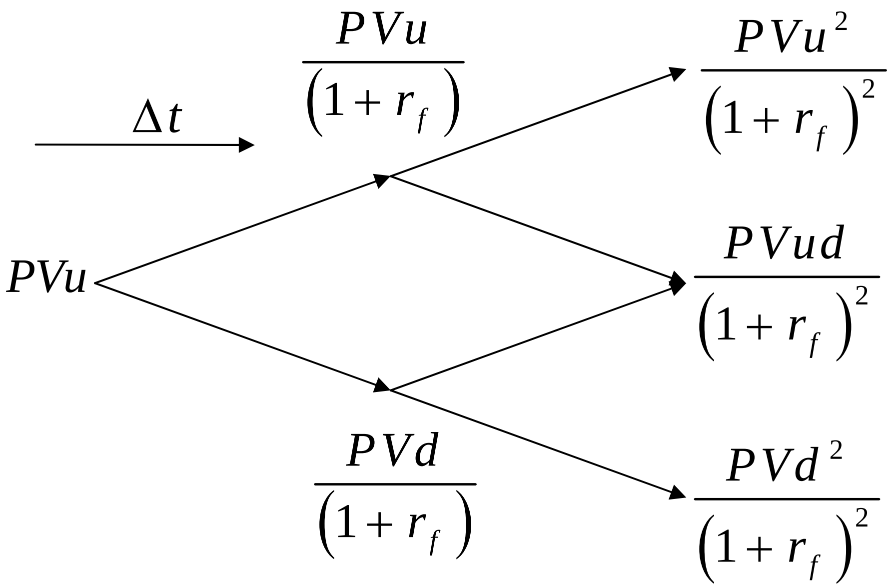
$$100 = \frac{120p + 90(1-p)}{(1.1)};\ p = 0.69$$

Once the parameters have been described, let us focus on the data needed for valuation, namely:

- The present value of the project's expected cash flows (PV).
- The expected volatility of the project's return (σ).
- The risk-free interest rate (r_f).
- The investment cost of launching the project (I).
- The estimated probability of success for each decision stage (s).
- The cost of intermediate investments (C).

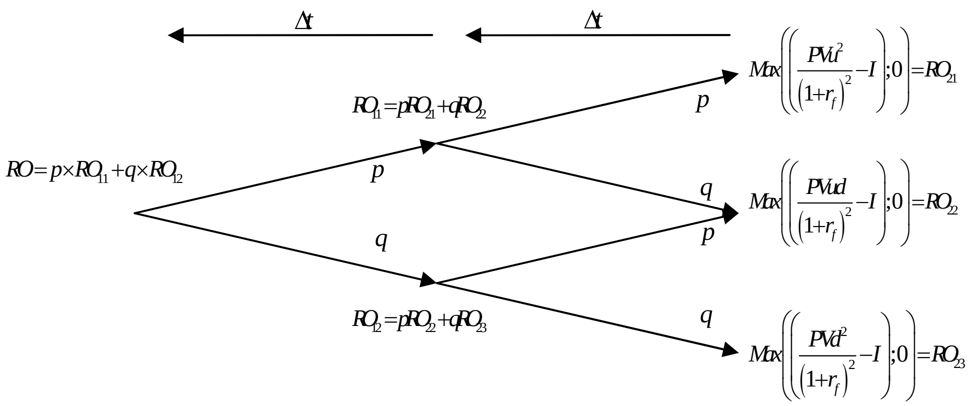
The process involves three stages:

1) We create the process of asset value diffusion on the basis of the upward (u) and downward (d) changes in the project's present value (PV) and we discount it at the risk-free rate r_f:

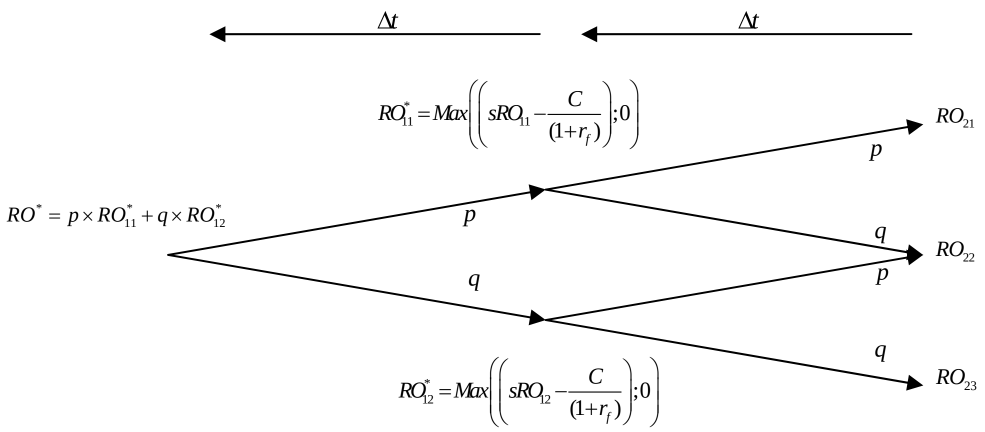


2) We compare the previous value with the investment cost of launching the project (I) discounted to the present date, and we choose the highest value between the figure thus obtained and 0 in order to determine the value of the RO in this node.

We adjust recursively from the end date to the initial date according to the risk-neutral probabilities of upward and downward movements. That is, we estimate the expectation of an occurrence of these values.



3) We introduce private risk, i.e. the probabilities of success (s) estimated by the company, to be able to complete stage 1 of the project. We also add the expected cost (C) needed to go through this stage and we discount it at the risk-free rate r_f. Then we apply, once again, the rule of optimisation between the project value and 0, choosing only above 0 values. We thereby obtain the option's end value, RO*.



MAXIMISATION RULE

The maximisation rule that factors in private risk is thus given by the following formula:

$$Max\left\{\left[\left(RO \cdot p + RO \cdot q\right) \cdot Probability - PV\ of\ stage\ cost\right];0\right\}$$

- We shall invest only if the project's expected value, adjusted with the probability of reaching that state, is higher than the investment cost. In other words, we shall purchase the next stage of the project solely if the value of this stage multiplied by its probability is higher than the outlay that we need to make.
- Otherwise we shall abandon the project and, at that point, its value will be reduced to 0.

CALCULATING BINOMIAL PARAMETERS

We calculate the parameters of the binomial lattice on the basis of the following information about the project: ΔTime = 0.25 (3 months); σ = 6.16%; $r_{fannual}$ = 6.2%; $r_{fquaterly}$ = 1.74%

We thereby obtain the values in Table 2:

Table 2

$u = e^{0.062\sqrt{0.25}} = 1.03$	$d = \dfrac{1}{1.03} = 0.97$
$p = \dfrac{(1+0.0174)-0.97}{1.03-0.97} = 77.47\%$	$q = 1 - 0.7747 = 22.53\%$

APPLYING BINOMIAL LATTICES TO THE PROJECT

We create the binomial diffusion process starting with the present value of the project's cash flows, and we discount it at the quarterly risk-free rate. This is shown in Table 3.

Table 3

Quarter	0	1	2	3	4	5	6	7	8
Binomial PV	13.673	13.862	14.054	14.249	14.446	14.646	14.849	15.054	15.263
		13.029	13.209	13.392	13.578	13.766	13.956	14.149	14.345
			12.415	12.587	12.761	12.938	13.117	13.299	13.483
				11.830	11.994	12.160	12.329	12.499	12.672
					11.273	11.429	11.587	11.748	11.910
						10.742	10.891	11.042	11.194
							10.236	10.378	10.521
								9.754	9.889
Mill. MU									9.294

We include the options available over the course of the project life.

Table 4

State of Market Option Value Decision Mill. MU	0	1	2	3	4	5	6	7	8
	13.673 584 Proceed	14.103 898 Proceed	14.547 944 Proceed	15.006 1.765 Proceed	15.478 1.844 Proceed	15.965 4.833 Proceed	16.468 5.036 Proceed	16.986 5.241 Proceed	17.521 5.450 Proceed
		13.256 698 Proceed	13.673 741 Proceed	14.103 1.422 Proceed	14.547 1.496 Proceed	15.006 3.953 Proceed	15.478 4.143 Proceed	15.965 4.336 Proceed	16.468 4.532 Proceed
			12.851 550 Proceed	13.256 1.100 Proceed	13.673 1.170 Proceed	14.103 3.125 Proceed	14.547 3.304 Proceed	15.006 3.486 Proceed	15.478 3.670 Proceed
				12.459 798 Proceed	12.851 863 Proceed	13.256 2.347 Proceed	13.673 2.516 Proceed	14.103 2.686 Proceed	14.547 2.859 Proceed
					12.078 575 Proceed	12.459 1.616 Proceed	12.851 1.774 Proceed	13.256 1.935 Proceed	13.673 2.098 Proceed
						11.710 935 Proceed	12.078 1.078 Proceed	12.459 1.229 Proceed	12.851 1.382 Proceed
							11.352 450 Proceed	11.710 565 Proceed	12.078 709 Proceed
								11.006 59 Proceed	11.352 76 Proceed
									10.670 0 Abandon

Quarter	0	1	2	3	4	5	6	7	8
Prob. Success	72%		60%		40%				
Investment	-29		-69		-9				-9.813
Stage	Wind Measurement 80 m Connection to Grid		Construction Permit		Operation Permit				Launch

We resolve the sequence by applying the maximisation rules, thus obtaining the value of the option to invest in the project, which equals 584 million MU in local currency.

As shown in Table 4, launching the project is the optimum choice in all possible states of the market, except one. This outcome signifies that, in most cases, the project's NPV will turn out to be positive.

COMPARING ROs WITH NPV

To establish a comparison between the value obtained with the RO method and the NPV, the values derived from both methodologies are shown in Table 5.

Table 5

Stage	PV at time 0	Probability	Adjusted PV
Wind Measurement and Grid Connect			
Wind Measurement and Grid Connect	-29	100%	-29
Construction Permit	-69	100%	-69
Operating Permit	-9	100%	-9
Launching	-9.813	17%	-1696
Total Project Cost			-1803
Present Value Cash Flows	13.673	17%	2363
Probability-adjusted NPV			**560**
Value of Option to Invest			**584**
Value of Optionality			**25**

The figures in Table 5 reveal that the NPV undervalues the project by 25 million MU, because it does not take into account the managerial flexibility of the project throughout its development. The NPV considers that the investment process, once set in motion, is irreversible and that there will never exist unfavourable or more-favourable-than-foreseen states of the market when going ahead with the project.

CONCLUSIONS

The major risks for the project occur during its development stage, for the conditioned probability of overcoming all stages up to the launching stage is 17%.

Given the nature of this type of investment, a low volatility level in its rate of return was to be expected. This level of uncertainty is very effectively captured by the methodology proposed by CA (2001), because it manages to summarise each and everyone of the project's estimated market risks in a 6.2% volatility –a figure that falls within the range of values that are expected in the launching of this type of investment according to the experience of the project experts.

We therefore consider that it would not have been appropriate, in this particular case, to estimate volatilities using the returns of listed shares of similar companies: since the value of the option is a direct and growing function of the volatility level, we would have overvalued the project.

For instance, a volatility of 34% (a usual level for share returns) would have led to an option value of 730 million MU. In this case, we would have overvalued the project by 146 million MU.

If the project had not had such a positive NPV (in-the-money, according to the options terminology), such a difference would have led us to make the mistake of investing in a project with returns significantly below estimates.

Therefore, whichever RO method is used, we recommend that the analysis be focused on modelising and capturing the project's uncertainties, for these are its major sources of value.

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