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Real Option Valuation: Development and Application of a Model - A Case Study

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Abstract

Decision making in the corporate field requires companies to manage risk the most efficient way, in order to maximize their confidence when planning their future actions. Real investments, that is investments on tangible and productive assets, such as plant, machinery, information technology tools and others, conceal uncertainties and multiple types of risk, that traditional valuation techniques, such as the DCF analysis, typically ignore. The Real Option approach is among the methodologies that have gained a lot of academic and corporate interest through the years, and has been acknowledged as an investment valuation tool which can capture a project's implicit risks and opportunities effectively. We apply a Real Option model to a real case study concerning the development and commercialization of an innovative Product in the agribusiness industry. We use the GBM and Monte Carlo Simulation to value the option and conduct a sensitivity analysis with respect to the project's source of uncertainty, through which the high correlation between the value of the option and the growth rate of the investment is unraveled.

Keywords: Dynamic management – investment valuation – decision making- Real investments-Real Options

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Introduction

Decision making in the corporate field requires companies to manage risk the most efficient way, in order to maximize their confidence when planning their future actions.

Real investments, that is investments on tangible and productive assets, such as plant, machinery, information technology tools and others, conceal uncertainties and multiple types of risk, that traditional valuation techniques, such as the DCF analysis, typically ignore. In order to address the above, academic research has focused on unraveling alternative - complementary valuation techniques, while businesses seek on applying these techniques on their investment projects to make less risky decisions and thus ensure their advantageous position in the marketplace.

The Real Option approach is among the methodologies that have gained a lot of academic and corporate interest through the years, and has been acknowledged as an investment valuation tool which can capture a project's implicit risks and opportunities effectively.

To this end, the purpose of this thesis is to provide a detailed description of Real Options' contribution in Real Investments valuation and corporate decision making, exploring both their advantages and limitations reported. We focus on a valuation framework composed by the traditional DCF analysis, and the Real Option approach which is acknowledged to constitute an effective strategic valuation methodology in the Real Investments industry[1].

We first review the state of the art of the DCF-Real Option framework, which we then apply to a real case study which is currently in progress and concerns the development and commercialization of an innovative Product in line with a Biotechnology industry.

The rest of this thesis is organized as follows:

Section 1 constitutes a comprehensive description of the Real Options as investment assessment tools, exploring the advantages and limitations reported so far. The next section represents a well-structured framework, identified by the literature which integrates the NPV analysis with the Real Option approach –we name this Real-NPV– , while provides the state of the art for this technique. Section 3 is a more specialized presentation of the Biotechnology industry nowadays, providing description on potential sources of risk and how these can be addressed using the above mentioned valuation framework. In addition, section 4 represents a real case study, where the before identified sources of risk in Biotechnology industry are measured and addressed through a Real Option model, which then assess the investment of Biological Control companies on innovative products they developed. A detailed summary of our findings is then provided in section 5.

The Real Option approach

Background

Real options are options on real assets, such as land, plant, equipment that derive their value from the possibilities embedded when investing on such assets. Possibilities may include opportunities and sources of uncertainty that are not explicitly recognizable by managers and provide companies with a multitude of potential actions such as to change the timing, scale or any other aspect of an investment in response to potential changes of market conditions. In order to identify the available possibilities, a company needs to conduct both a qualitative and quantitative analysis of the project’s Opportunities and Threats, and then construct a specialized Real option model towards its quantitative capital assessment.

The popularity that the Real Option approach has gained through the years in the real investment domain, stems from the recognition that real investments conceal uncertainties that cannot be fully captured using traditional assessment methodologies. These uncertainties evolve as potential future sources of risk that may affect the future cash-flows of a project significantly.

Based on these sources of risk and uncertainty, there is a number of potential outcomes that an investment may reveal in the future, that vary depending on the social, economical and environmental conditions under which an investment is carried out, as well as on more business-oriented factors.

The difference between risk and uncertainty lies in the future horizon prediction that someone can make regarding future states of a project.

Investment under risk: Future states in the investment horizon are most likely similar to the history. We know the future states and their corresponding probabilities. Risk comes from the fact that we do not know which of the states will occur.

Investment under uncertainty: Future states in the investment horizon are likely to be dissimilar to history. Novelty is significant. We can only try to understand the forces that are driving the system and based on our previous experience and fundamental constraints determine the new environment they would lead us into. [2]

In this context, Courtney et al. [3] categorized the possible cases of investments based on the amount of uncertainty they involve.

1. A clear-enough future: In this category, a single forecast is precise enough to determine the correct strategy. Traditional tools such as forecasting and NPV calculations are sufficient to provide reasonably accurate calculations.

2. Alternate futures: In this case, a few discrete outcomes that define the future are known, with some variables known with varying degrees of risk. In most instances, probability distributions are sufficient for making strategic decisions, but they are more involved than a simple NPV. Monte Carlo simulations on an NPV model, real options valuation, and game theoretic approaches to management would allow management to move forward with adequate confidence, but the actual outcome cannot be predicted.

3. A range of futures: With this category, only a range of possible outcomes are known. No natural scenarios such as those found in category 1 are evident.

The quantitative requirements for decision making are complex and could involve a number of real options, latent demand research, technology forecasting, and/or scenario planning. A firm entering new markets or developing new technologies would fall in this category.

4. True ambiguity: With this category, there is no basis for forecasting the future.

Providing a new consumer product or technology with no possible measurement of acceptance or regulatory environment would be an example of this kind of uncertainty. In short, the strategic decision must be made with zero information. Analogies and case studies of previous attempts to introduce unknown technologies might help in the strategic decision; otherwise a range of solutions might be found from building nonlinear models of consumer behavior and so on.

The above mentioned categories reveal a qualitative overview of the potential investment cases, illustrating the complexities a company faces when making strategic decisions under conditions of risk and uncertainty. More importantly, the authors argue that only 50% of investment projects fall into the first category, in which case the NPV valuation would work effectively. The rest of the projects, fall to categories II-IV, that contain various degrees of uncertainty regarding their future outcomes, whereas managers typically assess their projects as if they fell into category I. As such, they don't fully consider the residual risks and uncertainties when making their strategic decisions.

On the other hand, the Real Option approach accounts the above mentioned uncertainties involved in projects that reside in categories II-IV, and provides investors with the flexibility to act accordingly.

This flexibility derives from the main concepts behind the option theory, i.e. the right but not the obligation to proceed with a specific action. As such, flexibility is a critical element in the decision making process and is associated with a variety of actions, based on which a respective categorization of the so far revealed real option has been reported [4]

The table below illustrates the main categories so far identified in the literature, a brief description of them and the characteristics of the business sectors that each type of Real Option is expected to be applied effectively.

Note that the reported ROs are not mutually exclusive in all cases, depending on more specific aspects of the investment and the associated industry they are applied to.

Types of Real Options in Real Investments

Type	Description	Business specifics
Timing Options	The most important option of this category refers to the delay of an investment. It is available prior to any capital investment decision and is valuable when the existing uncertainties are expected to be resolved to a degree in the future.	This specific type of RO is most valuable in investments that include barriers before entering the market place, such as proprietary technology, patents, licences and other challenges that may affect their entry. Furthermore, the option to delay an investment is useful when market demand is uncertain or during periods of volatile interest rates.
Growth Options	This type of option allows a company to grow if market conditions are better than expected. This may occur by: • Increasing the capacity of an existing product line • Expanding into new geographic markets • Adding new products into an existing product line	Growth options typically arise from another action, e.g. from the exercise of another option, in which case the value of the exercised option increases in value since a number of other options revealed through its exercise.
Defer Options	These options provide a company with the flexibility to alter operations according to changes of the market demand during the lifecycle of project. Deferring an investment may occur at the input or output level.	For example at an output level a company is able to produce customizable products, like BMW. Furthermore, a company may switch from a production resource to another, for example switch from oil to gas, if this is at their financial benefit.
Abandonment Options	This type of option derives its value from the fact that DCF analysis typically assumes that the assets will be used over a specified economic life, whereas market conditions might deteriorate and cause lower than expected cash-flows. The abandonment may refer to: • Full abandonment of the project • Reducing the extent of development • Temporarily suspend operations	Suspending operations of a project may be valuable to investments associated with the natural resource industry, such as mining, oil, timber extraction.

Learning Options	Learning options arise from making a small number of investments to test the market resonance before proceeding with a much larger investment Note also that the learning option can also give rise to either a growth option if the small investment in market research indicates profitability or an exit option if the learning option indicates poor market conditions.	Learning options hold of high value especially in investments where new products and early stage innovations are going to be launched in the market, such as Biotechnology and Research investments The learning option can also give rise to either a growth option if the small investment in market research indicates profitability or an abandonment option if the learning option indicates poor market conditions.

Table 1: Types of Real Options

Real Option Valuation

Real options combine the use of decision trees with the theory and insight developed for valuing financial options. The concepts used in the decision tree are incorporated into developing the Real Option analysis framework. They are not a replacement for DCF methodologies but they rather add a layer of sophistication which tries to objectively ascribe a value to the optionality that managers often feel exists within their projects.

Most of this value can be explained by future expectations. As discussed previously, traditional methods of valuation can be considered inappropriate especially if used as stand-alone valuation tools. For example, if one tries to evaluate an early-stage investment in R&D using DCF, they are likely to conclude that the project displays negative static NPV and therefore the investment should not be made.

The motivation for using an option-based approach arises from its potential to conceptualize and quantify the option premium or flexibility component of value, that other methodologies ignore. Therefore real options analysis attempts to answer how much those option are worth.

An option creates value by generating future decision rights. The theory of real option -where the underlying is a real asset- is derived from theories originally developed in finance to account for the value of passive instruments, such as stocks.

Research and development requires investment capital, all of which is sunk and irreversible many years before a consumable product is ready**.** Regulatory approval, trademarks, and distribution then follow this with various degrees of uncertainty. The evidence to date is that using a real options paradigm can save firms from making large sunk-cost investments while simultaneously increasing firm value. As Copeland and Keenan suggest[1, 5], recognizing real options can help managers assess the profitability of new projects and can provide them with the flexibility in deciding whether and when to proceed with new and later phases of projects.

Practical Limitations – Sources of error

While Real Options are acknowledged as an attractive way of conceiving the flexibilities-optionalities embedded in real investment projects, their implementation presents a number of practical limitations.
According to the literature review[6], managers are reluctant to adopt the RO technique in their investment decision processes arguing that they are developed for well-defined financial instruments and thus cannot incorporate multifaceted corporate variables that rely on different market conditions. As such, through the Option valuation, the appraisal of the project is based more on assumptions rather on exact numbers and may lead to wrong estimations.
The above mentioned limitations that these two valuation approaches present when used separately have led to the flourish of the Real-NPV

framework, which collects both methodologies' characteristics that can provide more insights on the way a project might evolve [1].

The Real-NPV framework

The proposed valuation model is a two-fold approach in the decision making process, since it requires both the qualitative and quantitative assessment of the investment and its future expectations. As such, the Real Option - DCF framework requires the contribution of more than one business sectors, that is the corporate finance and corporate strategy, that have long be independent in corporations [7].

The proposed model combines the insights provided by the DCF analysis with the practices used in the Option theory and pricing. As such, it constitutes a more dynamic approach towards corporate investment management[2], since it assess an investment at various levels of its lifetime while updates its expected future states based on the resolution of the originally existed market uncertainties.

Real-NPV state of the art

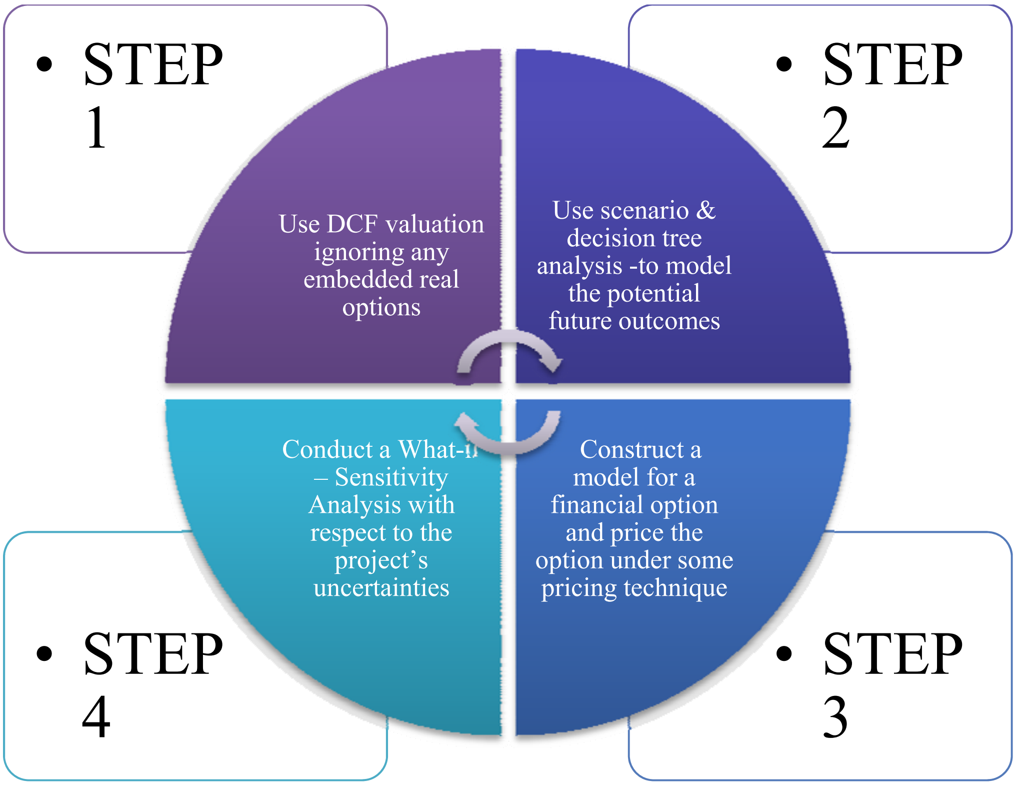
The proposed algorithm for the Real-NPV framework consists of 4 steps:
First step requires conducting the discounted cash flow (DCF) analysis ignoring any embedded real options –assuming their value is zero.
Though this analysis we get a primary indicator of the investment's value through its NPV.
Sequentially, the second step requires performing a qualitative analysis of the investment, that is identifying any factors that can modify the result given through the DCF analysis and thus affect the future outcome of the project. We specify these factors as the sources of uncertainty that the project conceals.

To this end, we generate a number of Scenario cases, that illustrate based on changes of these factors the potential outcomes. Based on the paths identified that would potentially change the future outcomes, we value the according Real Option. Step two can be illustrated/modeled via an n-nominal tree, in which nodes represent future states of the investment while the edges represent the respective conditions –e.g. market variable shifts- that have led to these states.

In step three, the sources of uncertainty of the project are identified and the project is being valued upon the different scenarios. The Option is being calculated for the total of the different scenarios through a backward induction from the last phase of the project to present, providing a whole view of the project's evolution on these scenarios.

Last step requires modeling the value of the project with respect to the project's uncertainties, that is called Sensitivity Analysis.

The above algorithm steps are illustrated in the graph given below:



Graph 1: Algorithm of the Real Option-DCF approach

The Case Study

The case study provided in the next sections is in line with an economic feasibility analysis conducted in order to evaluate an innovative biologically developed product which is planned to be launched to the market in order to replicate chemical products' utility that are used in the agribusiness industry.

The process which a company follows before launching its product to the market is:

First they conduct the R&D phase during which development, trials, and testing take place. Afterwards, if the results of the above phase are successful, they apply their product to the local regulation authorities, which in turn they conduct the required analysis, in terms of environmental and health applicability of the product, a process which is time and money consuming for the applying company.

Should the product succeed the above regulatory assessment, the company is able to commercialize their product , gain market share and establish relationships with customers. To this end, such investments typically have negative earnings during their early stages of development and the company is being valued using estimates of the future earnings and cash flows under different decision scenarios.

Before proceeding with the economic analysis of the project, we should stress out some important factors that affect the analysis that follows.

- The validity of the regulation approval is approximately 10 years, which means that after this period of time the company must again register their product for a renewal assessment. In this context, we conduct the financial analysis for the time horizon of ten years.
- Besides the fact that the product commercialized is patent protected, the company is not considered monopolistic since chemical products or other ones with similar structure and functionality, is possible to replicate its utility and effects. Thus, competition is an existing source of risk in this type of investments.

Step 1: DCF ANALYSIS

In order to conduct the expected DCF analysis of the project, we must first identify the project's expected inflows and outflows, as well as other parameters that will be used with respect to the literature review and financial reports on similar projects[8-10].

Time horizon

According to the above notes, that is the product's validity is for ten years, we generated the expected cash-flows of the project for ten years horizon.

Project Outflows

The costs of the project are defined in the below table. They are specified based on similar projects in the industry[8, 9].These include the costs for Research and Development of the product, the Regulation fees that the company must pay in order to be able to launch the product in the market and the commercialization costs after product has been tested successfully by the regulatory authorities.

Project Costs	R&D	140,000,000
	Regulation Authorities fees and approval	500,000
	Commercialization	10,000,000
	Operating Costs	23,500,000

Table 2: Project Outflows in Total by Category – in €

During the lifetime of the project the operating costs are considered fixed and equal to 23,5 millions as shown in table 2.

Project Inflows

The project's inflows are constituted by the revenues each year the product sales will provide the company.

In 2012 the market value of investment in biological CropScience is reported to be approximately 1,3 billion dollars, i.e. 1 billion EUR, inferring the growth rate of 16%.[9], [11] The formula given below[12, 13] is used in the DCF analysis in order to obtain project's revenues for each year of the 10 year lifetime of the project.

$$\text{Revenues}(i) = \text{Revenues} * (1+\mu)^{i}$$

Where for the purpose of this thesis we use an intermediate growth rate 10%.

Success Rate

Another important factor in order to obtain the project's Value is the probability of these expected cashflows to occur, that is the probability the product will get approved by the regulatory authorities, which will allow the company to commercialize the product and receive the above mentioned inflows. If the product fails the above process, then management of the company will have to come up with a different strategic plan, such as to re-apply for a second assessment, defraying the regulatory fees for a second trial or even abandon the project entirely.
In this context, for the purposes of this analysis, NPV is based on the assumption that the project will gain value only if the product will be accepted by the regulatory authorities, by probability P_{auth}=25%.
According to the above assumption, NPV of the project is given by the formula:

$$ENPV = \sum_{i=1}^{n} \rho_i DCF_i = \sum_{i=1}^{n} \rho_i \frac{CF_{it}}{(1+r_d)^t} = 0{,}25 \sum_{i=1}^{n} \frac{CF_{it}}{(1+r_d)^t}$$

Discount Rate

The discount rate which we used for this analysis is project-specific and was inferred by financial analyses conducted for similar projects in the Biotechnology industry[10]. According to the literature review, these types of projects contain great amounts of risks and uncertainty and thus should be assessed using higher cost of capital, i.e. between 15-20%. In this particular DCF analysis we use risk rate=17% [11].

NPV

Based on the above assumptions and input, we calculate the Net Present Value of the project, without taking into account any embedded real options, for a time horizon of 10 years. This specific time horizon is being used, since as mentioned above the validation of a biological control product that made it through the authorities approval, is 10 years as indicated in the respective legislation upon Biological control agents [8]. To this end, the expected DCF analysis indicates the value of the project to reach € 396 millions.

The detailed DCF analysis is provided in Appendix I, table 1.

Step 2: Real Option Incorporation

Through the above DCF analysis we determine the estimate of the future cash flows as if it were certain with no room to fluctuate. We know that the estimate is not accurate therefore we have to use a risk premium to remunerate for the uncertainty of the estimate. However in the calculations we assume that the size of the cash flows is fixed. Nevertheless, decisions along the project path depend exactly on parameters that may change in the course of time. Imagine that that a competing project shows outstanding efficacy results. This might impact our sales estimations; and maybe the sales estimations are even that low that they do not justify further investments in the project. Revaluing the project management then decides to abandon it because of non-profitability. Such scenarios are not considered in the DCF framework. To get a realistic value of the project it is therefore reasonable to model the uncertainty of the parameters that influence project related decisions.

Concretely we should model the economic potential of the project, i.e. the estimated peak revenues; the revenues potential is most prone to uncertainty and has a crucial impact on the profitability of the project. We therefore have to assess, in addition to the parameters used in the DCF calculations, the parameters that affect the project's revenues estimates.

In order to model the real option we first need to identify the sources of uncertainty.

The Project uncertainties are reflected as volatilities, that is up and down movements, in the expected sales. The volatility is directly affected by the uncertainty associated with the products, the performance of the company, the company's risk profile and product market conditions. In sectors like biotechnology where the risk is high and the returns are obtained after long periods into the future, the volatility is expected to be high. The volatility for companies in the biotechnology sector takes values between 20% and 70% [14]. Country and market conditions, company performance and size are responsible for the width of this range. For small biotechnology companies, the uncertainty in the form of fluctuation in sales revenues might even go up to 50%-60%. In the study, based on the company official's view, volatility of sales is chosen as 40%.

Identification of Embedded Real Options

In order to identify potential options given to managers during the lifetime of the project, we first need to model the different scenarios that await the investment and identify the points where decisions regarding the project's evolution are provided to management.

Decision Tree Analysis

In order to illustrate the different decision scenarios mentioned above we use a decision tree.

Decision tree analysis is a method of modeling decision situations that are characterized by a sequence of subsequent decisions and uncertainties. This is typical for long-term R&D projects that consist of multiple stages with certain probabilities of success and which require decisions to be made in certain times throughout the life of the project.

In this context, the decision tree approach is effectively the use of DCF in conjunction with probabilities of success. In addition to introducing the much needed concept of flexibility into the financial model it also provides an insight into how the development process can be managed to minimize risk.

The decision tree allows alternative decision paths to be described including data on their costs and possible outcomes. Probabilities are used to weight different outcomes, while these probabilities are subjective and are one of the most important inputs for decision tree analysis.

There are three kind of nodes in the decision tree:

1. Decision node is represented by a square. Branches coming from a decision node depict actions that can be made.

2. Chance node is represented by a circle. Each branch represents an individual state of nature that can occur when the uncertainty resolves

3. Termination node is where the project is discontinued.

Beginning on the left side of the tree the first thing to happen is typically a decision followed by other decisions or chance events in chronological order. On each node of the tree, certain projects can be attached. The options are represented by branches from a decision node, and must be such that the decision-maker can choose only one option. Thus the tree portrays the future potential cash flows as emanating from a series of decision points, or nodes as in a decision tree where the probabilities of success and failure are multiplied by the cash-flows associated with each particular outcome.

More specifically, in this project first decision node is the R&D phase of the project. The R&D is a costly process requiring approximately 120 millions.

The second node of the path includes the probabilities that a biological product will get approved by the regulatory authorities. The submission of a product requires the deposit of a considerable amount as an application fee, which in best cases reaches Euro 500.000. Even more the examination of the product's validity in terms of environmental and health protection is a time-consuming process. According to the relevant analysis conducted, the probability of an innovative product to be approved by the regulatory authorities is pauth =.25, while the corresponding failure is 1- pauth = 0.75[1].

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[1] *It should be noted here that the above probabilities correspond in the case where the new product contains ingredients that are not already registered in the ANNEX-I listing of European active ingredients*

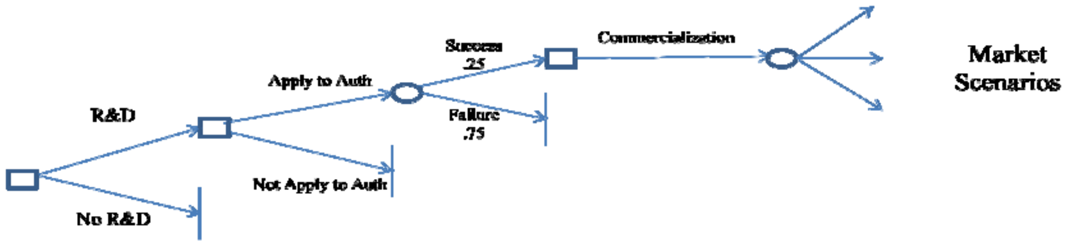


Figure 1: Decision Tree of the Bio-product lifecycle before commercialization

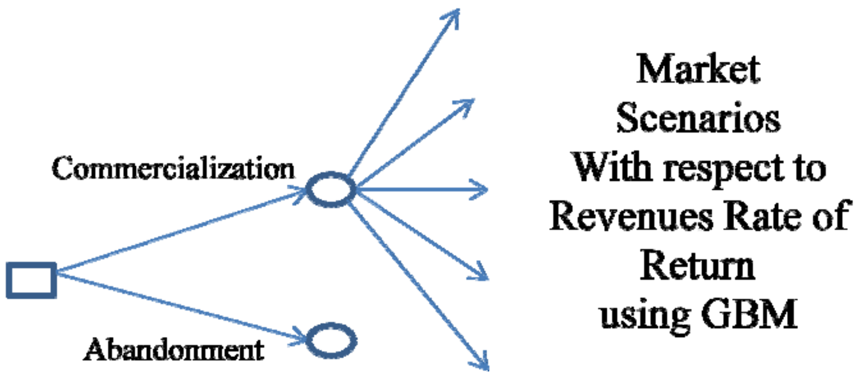


Figure 2: Decision Tree of the Bio-product lifecycle after commercialization

Step 3: Valuation of the Real Option

The Real Option that corresponds to this investment is path-independent, that is its payoff does not depend on previous payoffs of the option at sequential stages.

In this context, the Real Option that we are using in this project is a European Call option with expiry time ten years. The European option can be exercised at maturity, i.e. the end of the project's lifecycle.

The RO specified above, is valued using the Monte Carlo Simulation technique, using the payoff equation V=max{S-K,0}, where S is the Spot price of the underlying, that is the average of the revenues identified for each simulated path and K is the Strike Price- in our case the NPV obtained from DCF - that is the average of the revenues identified for each simulated path. This equation indicates that on specified times of the lifetime of the project, should the Value of the option exceed the NPV of the project as obtained through the DCF analysis, the investor should exercise the option. In order to do that we need first to identify the different market scenarios according to the project's source of uncertainty, that is its expected future revenues. The project's revenues dynamics can be modeled using the stochastic differential equation that is described by Wiener process or Geometric Brownian Motion given in the formula below[15, 16].

$$\frac{dR_t}{R_t} = \mu_t dt + \sigma_t dz_t$$

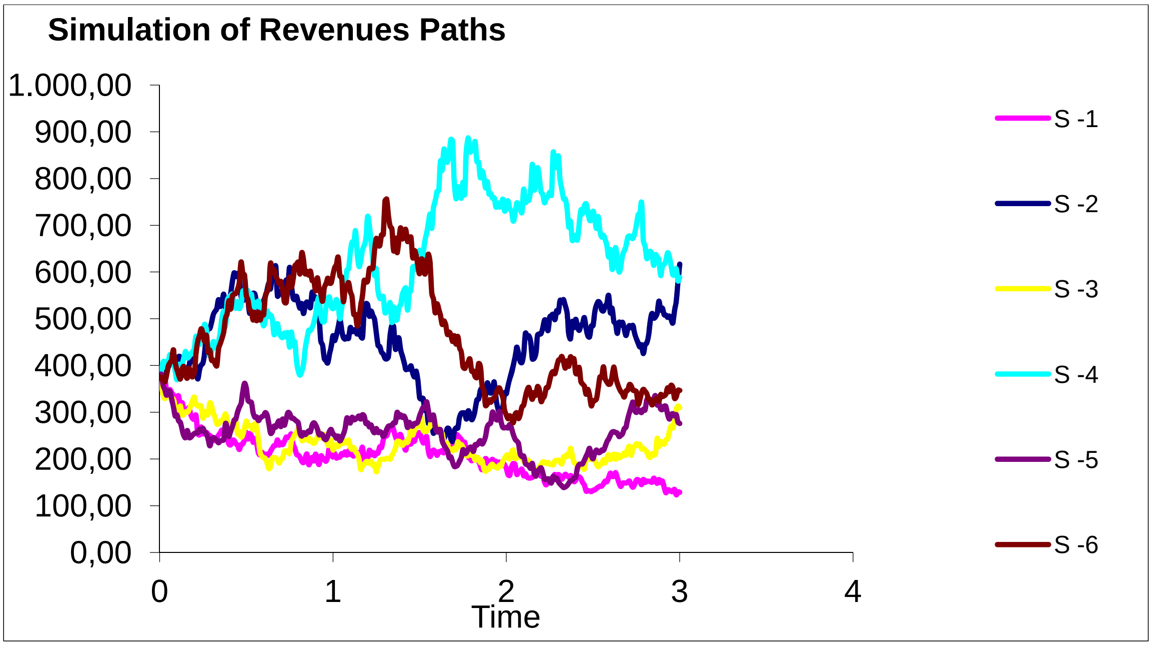
Where R=project Revenues

μ_t=growth rate

σ_t=volatility of revenues

z_t=Wiener increment-random variable that reflects the draw from a normal distribution Φ(0,1)

Assigning an intermediate growth rate of μ_t=10%, σ=40% as specified above, we generate 300 random Revenue prices for a time horizon of 10 years (Δt=0,01). The below graph illustrates 6 potential revenue paths as calculated using the differential equation mentioned above



In order to evaluate the option price we use the Monte Carlo Simulation. The above generation of the Revenues of the project is being used as input in the Monte Carlo process, which requires the calculation of the payoff formula of the Real option for every distinct path generated by the Geometric Brownian motion and take the mean payoff of all 6 options[2], using the Call option payoff formula :

V=max{Ri-K,0} where Ri is the average Revenues for step i and K is the strike price, where here we assume that is the NPV of the project as it was retrieved via the DCF analysis.[3]The mean payoff is being discounted in the risk-neutral rate, i.e. at 6%, for ten years.

	S-1	S-2	S-3	S-4	S-5	S-6
Average revenues over each path	860.76	952.66	503.35	286.17	367.18	607.37

[2] Increasing the number of simulations generates more accurate results. For the purposes of this analysis we generate 6 simulation paths.

[3] Other strike prices can be used according to a company's requirements and expectations. For example, a company might decide to exercise the option if the value of the project is less than a proportion of their total revenues.

Inflow over each path	837.24	929.14	479.83	262.65	343.66	583.85
Expected Cashflow at year 10 over each path	627.93	696.85	359.87	196.99	257.75	437.89
Payoff over each path (max{Ri-K,0})	231.14	300.06	-	-	-	41.10
MeanPayoff	95.38					
netPayoff	**15.77**					

Table 2: Valuation of the RO for each scenario path – numbers in millions €

Step 4: Sensitivity Analysis

In addition to the above methodology we also conduct a sensitivity analysis upon the NPV of the project as retrieved via the DCF and the expected rate of return. This approach will provide the investor with better insights regarding the project's value, and lead him to a more efficient decision, since we take into account the volatility of the growth rate which at step 1 we considered relatively high (10%) as the literature review and other reports indicated.

To this end, we calculate the NPV of the project for a growth rate 0%-16%[4]. Results of the above analysis are illustrated in the table and graph below.

Growth Rate (%)	RO Value
0%	9.090.000,00
1%	8.880.000,00
2%	8.100.000,00
3%	5.360.000,00
4%	7.630.000,00
5%	5.850.000,00

[4] We use maximum growth rate =16% since this rate of return was indicated as maximum in literature and above this growth rate the option value is 0 for all scenario paths, i.e. the option should not be exercised.

6%	6.520.000,00
7%	5.070.000,00
8%	2.480.000,00
9%	2.030.000,00
10%	2.040.000,00
11%	1.500.000,00
12%	540.000,00
13%	1.820.000,00
14%	430.000,00
15%	0,00
16%	0,00
17%	0,00
18%	0,00
19%	0,00
20%	0,00
21%	0,00

Table 3 : Sensitivity Analysis -Growth Rate and RO Value

Graph 2: Real Option value to changes of Growth Rate

If the option has value at the beginning of the project then the option should be exercised and thus the company should abandon the project at its early stages.

Findings

In the sections above we evaluated an innovative biotech project using the combination of the DCF analysis and the Real Option approach. We can see that the DCF analysis is not adequate to assess a new project, which at its early stages provides the company with no inflows. Furthermore, the NPV of the project using the above specified parameters is positive, which indicates that the company should proceed with the investment. On the other hand, the Real Option approach provides a way to quantify the project's sources of risk and value the investment with respect to them, that in our case is the project's revenues. According to the literature review, the revenues of such investments are relatively high, giving a growth rate of 16%.In order to model the uncertainty involved with project's revenues we generate 6 scenarios using the Geometric Brownian Motion where the stochastic variable follows the Wiener Process. To this end, we calculate the Real Option using the payoff formula of a European Call. In this context the Real Option has value which indicates that the option should be exercised before the project being commercialized in the market.

In our DCF analysis and Real Option valuation we use a intermediate growth rate of 10%. Additionally, we conduct a sensitivity analysis where the rate of return varies between 0% - 20%. We find that the volatility of the growth rate affects to a high degree the Real Option value. As shown in the graph above, for low growth rates -0-6%-, the Real Option has relatively high values, a fact which indicates that the option should be exercised. Between 6% and 7% we observe the steepness of the slope, decreasing the Real Option value, which afterwards stabilizes to relatively low values, giving 0 for growth rates more than 13%. As such, another important finding is the correlation between the RO value and the volatility of the rate of return.

Conclusion

To sum up, the present thesis explores the use of the Real Option approach in valuing Real Investments. The Real Option approach, while being explored and analyzed for decades at academic level, it has not gained that much interest and adoption in the corporate field. In this context, we propose that this approach is more useful and efficient when used along with other valuation approaches, providing investors with a layer of sophistication regarding their investment's uncertainties and risks, rather than used as a stand-alone methodology.

To this end, this thesis presents a real case study of a Biotech company's valuation. The company is developing an innovative biological control product, which plans to be launched to the Agribusiness sector and gain market share among other competitors, mostly chemically developed products that replicate in utility. Being an innovative R&D company, at the early stages of the investment, there are not any inflows from the processes , thus the investment can be valued only assuming its future cash-flows. We argue that traditional valuation methodologies cannot capture the uncertainties and risks that this type of investment conceals. As such, we propose the incorporation of the Real Option approach in order to identify the potential risks and uncertainties associated with the future revenues of the project. We model the below mentioned sources of uncertainties using the Geometric Brownian Motion upon which we incorporate the value of the Option -provided via the Monte Carlo

Simulation- in the DCF analysis, to gain insights regarding the project's value. At a second step we conduct a sensitivity analysis, illustrating the correlation of the volatility of the rate of return to the value of the option, which we find relatively high.

Appendix

	2012	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
R&D	(140,000)											
Approval	(500)											
Commercialization	(10,000)											
Revenues		376,000	413,600	454,960	500,456	550,501	605,551	666,106	732,717	805,989	886,588	975,247
Tax Rate(25%)		(94,000)	(103,400)	(113,740)	(125,114)	(137,625)	(151,388)	(166,526)	(183,179)	(201,497)	(221,647)	(243,811)
Operating Costs		(23,520)	(23,520)	(23,520)	(23,520)	(23,520)	(23,520)	(23,520)	(23,520)	(23,520)	(23,520)	(23,520)
ExpCashflow		258,480	286,680	317,700	351,822	389,356	430,644	476,060	526,018	580,972	641,421	707,915
Discount Factor(17%)			0.8547009	0.7305136	0.6243706	0.5336500	0.4561112	0.3898386	0.3331954	0.2847824	0.2434037	0.2080374
NetCashflow		258,480	245,026	232,084	219,667	207,780	196,421	185,587	175,267	165,451	156,124	147,273
rNPV	**396,790**											

Table 1: DCF Analysis, Expected Cash-flows (in € 000) - Step 1

		Random Numbers		S -1	S -2	S -3	S -4	S -5	S -6
Period	Time	Uniform	Normal	S + ΔS	S + ΔS	S + ΔS	S + ΔS	S + ΔS	S + ΔS
0	0			$ 376,00	$ 376,00	$ 376,00	$ 376,00	$ 376,00	$ 376,00
1	0,01	0,376675	-0,31423	$ 376,38	$ 370,97	$ 345,68	$ 393,96	$ 393,72	$ 369,29
2	0,02	0,397932	-0,2587	$ 372,86	$ 395,28	$ 334,63	$ 388,20	$ 382,59	$ 377,69
3	0,03	0,38682	-0,28762	$ 368,94	$ 400,33	$ 354,97	$ 407,29	$ 388,70	$ 380,44
4	0,04	0,754645	0,689179	$ 379,48	$ 404,87	$ 372,96	$ 415,09	$ 396,30	$ 379,72
5	0,05	0,167976	-0,96219	$ 365,25	$ 407,32	$ 409,35	$ 458,85	$ 380,34	$ 394,75
6	0,06	0,887049	1,210982	$ 383,31	$ 400,01	$ 441,63	$ 464,25	$ 375,94	$ 366,89
7	0,07	0,840685	0,997278	$ 398,99	$ 375,97	$ 406,74	$ 466,06	$ 374,90	$ 388,50
8	0,08	0,193134	-0,86641	$ 385,56	$ 370,88	$ 416,21	$ 456,28	$ 415,54	$ 379,69
9	0,09	0,707501	0,5461	$ 394,37	$ 364,16	$ 429,66	$ 475,93	$ 397,68	$ 341,32
10	0,1	0,773138	0,749221	$ 406,58	$ 398,23	$ 443,17	$ 478,17	$ 389,91	$ 340,65

Table 2 : GBM for ten steps – revenue generation in line with the growth rate- Step 2

References

1. THOMAS E. COPELAND, P.T.K., *Making Real Options Real*, in *The McKinsey Quarterly*. 1998.
2. Bryan, L., *Dynamic Management: Better decisions in uncertain times.* McKinsey Quarterly, 2009.
3. Hugh Courtney, J.K., Patrick Viguerie, *Strategy under Uncertainty*, in *Harvard Business Review*. 1999, Harvard Business School Press: Cambridge.
4. Turvey, C.G., *Mycogen as a Case Study in Real Options.* Review of Agricultural Economics, 2001. **23**(1): p. 243-264.
5. Thomas E. Copeland , P.T.K., *How much is flexibility worth.* McKinsey Quarterly, 1998. **2**.
6. Bowman E., M.G., *Real Options Analysis and Strategic Decision Making.* Organization Science, 2001. **12** (6): p. 772-777.
7. L., S.H.T., *Strategic Investment:Real Options and Games*. 2008: Princeton University Press.
8. http://europa.eu/legislation_summaries/food_safety/plant_health_checks/sa0016_en.htm.
9. http://www.marketsandmarkets.com/PressReleases/biopesticide.asp.
10. Bayer, *Bayer Annual Report*. 2011.
11. G., M.P., *2007 Barriers to adoption of biological control agents and biological pesticides.* , in *CAB Reviews: perspectives in agriculture, veterinary science, nutrition and natural resources*. 2007, CABI Publishing: Wallingford, UK.
12. Hull, J., *Options, Futures, & Other Derivatives*. 2009: Prentice Hall.
13. Wilmott, P., *Paul Wilmott Introduces Quantitative Finance*. 2007: Wiley.
14. Bahar Celikkol Erbas, S.A.M., *An economic valuation of a biotechnology R&D project in a developing economy.* Electronic Journal of Biotechnology, 2012. **15**(3).
15. Schwartz, E.S. and M. Moon, *Rational Pricing of Internet Companies Revisited.* Financial Review, 2001. **36**(4): p. 7-26.
16. Ozorio, L.d.M., *The Choice of Stochastic Process in Real Option Valuation*