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Real Options Theory: An Alternative Methodology Applicable to Investment Analyses in R & D Projects

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ABSTRACT

Background: Objective: write the main objective for your paper. **Results:** write the main and most important results for your paper**. Conclusion:** write the main conclusion for your paper.

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INTRODUCTION

Conventional research and development (R&D) long term investment evaluation methods, such as the Net Present Value (NPV) and the Return on Investment (ROI) methods sustain basic shortcomings. These methods ignore outcome uncertainty, the choice of investment timing and the irreversibility of resource commitment.

R&D project evaluation is often complex, due to substantial uncertainty found in different project phases, including the research and marketing phases. The stages can be sequentially evaluated through the differentiation between the many phases of an R&D program.

Each stage provides a gateway into the next stage. In addition, the time spent in each R&D phase affords the collection of other, relevant information to program evaluation. Essentially, each stage offers the manager an option to invest or not to invest in the next – and usually more expensive – phases of the R&D program.

The value of technological “options” has been repeatedly used as a qualitative argument by researchers by the private and public sectors both, in supporting long-term strategic investigation. The technological option is the value of the opportunity broached by an R&D project in its initial stage, to invest later in a new technological area. Unfortunately, traditional empirical methods basing on cash flow estimates totally ignored the value of such opportunities; thus, risk research projects entailing substantial expected long-term returns were unduly penalized. Long term research has been traditionally supported at more modest levels than those preferred by their supporters.

Conversely, scenario-building and decision tree analyses are also often-used methods for the evaluation of R&D projects, since both allow for risk estimation in evaluation via the simplification of the complex return on risky projects problem. However, these traditional models show flaws as concerns the investment’s potential profitability.

For this purpose, the ROT has been given growing attention in financial theory and innovation management. Through the lenses of the ROT, the interaction among irreversibility, flexibility and uncertainty entails considerable difference in the evaluation of an investment alternative and should be considered in the pricing process. Modeling managerial uncertainties and flexibilities available during a project’s life cycle is of the essence to establish what an investment risk is.

The ROT is used to evaluate real assets, that is, those not traded in the marketplace. Capital investment projects, intellectual property evaluation, sources of natural resources and research and development project evaluation are examples of real assets that can be evaluated using this theory. A real option is the flexibility a manager has to make decisions involving real assets. As new information is obtained and cash flow uncertainties

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are cleared, managers can make decisions that will positively influence the project's final value (Dixit and Pindyck, 1994).

The decisions managers often have to contend with are: What is right time to invest, abandon or temporarily stop a project? When should a project's operating characteristics be changed, and also when should an asset be replaced by another? Thus, a capital investment project can be regarded as an ensemble of real options on a real asset: the project.

Throughout this paper, the authors will seek to produce theoretical and empirical evidence using Geske's (1979) model, as adapted for real situations by Kemma (1993) and designated by Perlitz, Peske and Schrank (1999) as an alternative methodology to evaluate compounded options.

Authors such as Perlitz, Peske and Schrank (1999), Amram and Kulatilaka (2000), Boer (2000) and Silva *et al*. (2012) have cast more attention to the application of real options compared to other traditional investment evaluation methods. Real option-based models provide a first step towards the integration between finance and strategy, to the extent that its results coincide with pre-judgment from a senior manager's experience. There is a need to understand how corporate strategy and execution interact with each other and how this affects business opportunities.

An emerging trend in research and development project evaluation contemplates the use of the options approach, affording a more flexible understanding of future growth opportunities throughout the process. The options approach is the most appropriate in a world of uncertainties, since it sees the project as an initial investment that creates future commercial opportunities.

As postulated by Herath and Park (1999), it is usually difficult to justify R&D projects by means of the simple use of traditional methods; consequently, companies tend to under-invest in R&D. the real options approach bridges the shortcomings of the net present value (NPV) criterion when applied to projects under high uncertainty levels.

This paper is divided into five parts: an introduction, followed by the theoretical framework on the financial options theory, materials and methods, results and conclusion.

Literature Review: The Financial Options Theory:

According to Hull (1997), "options are asset purchase and sale agreements, whose prices depend on the value of the asset object of the agreement", that is to say, a purchase option (call) is a claim that the contract bearer has to buy the asset object of the agreement at a pre-established exercise price, on an established future date, on which this type of option presents a payment function as following:

C(T) = Max (S(T) - K, zero) (1)

Where:
C(T) is the buy option value on date T;
T is the expiration date;
S(T) is the asset price at date T;
K is the actual price;
"Max" means "the greater of".

A sell option (put) gives its bearer the right to sell the asset object of the agreement at an exercise price on a future date. The function (put) given by the equation:

P(T) = Max (K - S(T), zero) (2)

Where:
P(T) is the sell value option at date T;
T is the expiration date;
S(T) is the asset price at date T;
K is the actual price;
"Max" mean "the greater of".

The milestone in the ROT theoretical development is the effort produced by Black and Sholes (1973), who developed an analytical formulation to evaluate European call options. European options are those whose exercise can only happen as the security matures.

American options are those that can be exercised at any time until maturity. This characteristic confers upon American options a value at least equal to the value of similar European options. Option evaluation requires the establishment of an optimal investment policy, that is, the contract asset value from which the option will be exercised should be established, such as to maximize the present value of its remuneration. For the real options theory, the establishment of this policy is a core factor, since the best selling time in an investment project could be determined.

The main contribution from the Black and Sholes (1973) paper perhaps was not the equation in and by itself, but, rather, the proposed methodology. Building a dynamic asset portfolio independent from its owner's risk preferences allowed it to be used. The major difference resides in the analyses of discounted interest rates applicable to the stock's future remuneration.

Classically, options evaluation is made following two approaches: the Black and Scholes (1973) continuous time approach and the discrete-time model proposed by Cox, Ross and Rubinstein (1979) and the multi-stage binomial tree developed by Rendleman and Bartter (1979). The work of Cox, Ross and Rubinstein shows how to use a binomial tree to treat the early stock option exercise following a lognormal process. Its algorithm is a special lattice model used to solve control optimization problems. The trinomial tree was introduced by Clewlow and Strickland (1998).

An important parameter for investments and option evaluation models is volatility. An asset's volatility is the measure that seeks to identify the uncertainty of its future price movements, that is, the greater the volatility, the greater the risk to the investor; however, the chance to do good business will also be greater.

According to Hull (1997), this is due to two main causes:

- The random arrival at the marketplace of new information concerning the stock (or company) behavior.
- Trading involving the security causes the volatility, but empirical tests did not prove or disprove any of these theories.

Also according to Hull (1997), volatility can be divided into:

- Historical volatility;
- Future volatility;
- Implicit volatility, this being the comparison between current and future prices.

Volatility estimations vary with the time horizon in consideration and, for risk management purposes, short term estimations are highly relevant.

It was, however, the pioneer work developed by Black and Sholes (1973) and Merton (1973) to evaluate financial options that provided the subsidies to the idea of incorporating pricing methods to the problem of evaluating real investments under uncertainty, which is presented in the following session.

The Real Options Theory:

Along the past decade, however, the effectiveness of the methodologies presented in the previous session was intensely challenged. Dixit and Pindyck (1994), for example, show that the applications of these methodologies may induce mistaken investment decisions, the reason is that they ignore two important characteristics of these decisions: irreversibility, that is, the fact that the investment is a sunk cost such that the investor will be unable to salvage his funds in full in case of regret; and the possibility of postponing the investment decision. These characteristics, together with future uncertainty, prompt the investment opportunity to be analogous to a financial option.

In the presence of uncertainty, a company having an irreversible investment opportunity carries one option: the company has the right – but not the obligation – to purchase an asset (the project) in the future, at an exercise price (the investment). When the company invests, it exercises or kills this investment option. The problem is that the investment option carries a value to be entered as an opportunity cost at the time the company invests. This value can be quite high and investment rules ignoring it – typically, NPV and IRR rules – may entail significant errors.

The ROT appears as a methodology to evaluate real assets as, for example, investment projects, which take into account the operating and managerial flexibilities along the project's working life. Differently than traditional techniques such as the NPV, its dynamic characteristic is conducive to more realistic outcomes.

Application of the ROT as an investment evaluation methodology is a novel practice. Its main concept is founded on the financial options theory, establishing an analogy between options and managerial decisions along the working life of an investment project.

The expression "Real Options" was initially used by Myers (1977), highlighting that a company's new expansion investments can be interpreted as being analogous to call options.

Managerial flexibility is a possibility of, but not an obligation to, changing a project at different stages of its operating working life. Myers (1987) proposed the Options Theory as the best approach to evaluate projects containing significant operating and strategic options, suggesting that the Theory can integrate strategy and finance.

The importance of investing in R&D was seen by Porter (1992) as being the most important factor of competitive advantage, due to the changes in the nature of competition and the increased pressure exerted by globalization upon organizations. The author observes that the investment in intangible assets (human resources, technology and corporate image) and in capabilities required for competitiveness, such as R&D, capacity-

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building of human resources, information technology, organizational development and customer and supplier relations to be a competitive differential.

What is seen from all this is that, without reinvestments, both the company's tangible assets (physical and financial assets) and intangible assets will depreciate. Much more than this: notably, investments are fundamental to maintain competitive advantage both in cost leadership and in differentiation.

A company will make decisions vis-à-vis a project throughout its entire life. Upon evaluating a project today, it is assumed that future decisions will be optimal; however, what these decisions will be is unknown, since most of the information remains to be found. Therefore, the possibility of postponing the investment represents an important option that should not be discarded upon evaluating an investment project. It was seen that the opportunity to invest in real assets presents characteristics of investments on options on financial assets, for which reason these investment opportunities are called "real options".

Net Present Value:

Companies make capital investments to create and explore profit opportunities. Generally, a decision-making process to invest in a new project involves building a discounted cash flow through a very simple procedure. Initially, the present value of the expected sequence of cash flows that the project will yield is computed. Then the present value of the flow of expenses required to pursue the project is computed. Finally, the difference between the two values is computed, that is, NPV.

The NPV concept is considered the most consistent method with the company's objective of maximizing stockholders' wealth. Other alternative methods (such as the payback period and the internal rate of return), despite being considerably used in the corporate universe, have been deemed inferior to the NPV in existing literature.

According to Ross *et al*. (1998), the NPV looms as one of the most important concepts of financial management. At the time of an investment, only the amount to be invested in the project is known (the outlay) while the project's returns (inflows) are only estimated. Thus, we should know the relationship between $1 today and a possible uncertain $1 in the future prior to deciding about a specific project.

The NPV method is the present value of all cash flows discounted at the cost of capital, minus the cost of the investment also discounted at the cost of capital. Its greatest competitor is the Internal Rate of Return (IRR) method, which represents the discount rate that brings all cash flows to zero.

The main difference between the two methods is that the NPV method assumes reinvestments at the rate equal to the cost of capital, which the IRR method assumes reinvestment at its own rate. The first method has the advantage of showing how much value is added to the company for each investment contemplated.

In principle, each project has its own cost of capital. In practice, companies cluster similar projects in risk classes and apply the same cost of capital to projects of a same class. The existence of a positive NPV is defined as the basic criterion to accept or reject a given project and the order of NPVs is the choice criterion among different investment alternatives.

The critical variable in determining NPV and IRR are the cash flow and the cost of capital. When the investment evaluation is done at company level, all investment projects considered should be included, analysis, in this manger, uses the company's financial statements, such as the income statement and the balance sheet. Both can be used to explain the elements contained in the cash flow, as described annually to be capitalized. The sum of each annual cash flow minus the required investments, duly discounted, will compute the value of the company.

Trigeorgis (1996) argues in favor of an expanded or strategic criterion, reflecting two value components: the traditional NPV (static or passive) of discounted direct cash flows, and the value of the flexibility and strategic interactions option. Real options, in this manner, complement the net present value theory, adding an important dimension of flexibility to it.

The critical point of the NPV approach resides in the decision of what discount rate to use. Discount rates are influenced by the project's risk level and duration, and tend to increase on a par with interest and inflation rates.

R&D Model as a Real Option:

Irreversibility, uncertainty and the possibility of postponement are three important characteristics of investment decision-making. In practice, investors' decisions take each one and its interactions into account. Since the options approach is an attempt at theoretically modeling the investors' decisions, understanding them requires, above all, a more careful analysis of these characteristics (Dixit and Pindyck. 1994).

Why is an investment decision a sunk, and therefore irreversible, cost? First, because specific investments made by a company or industry are mostly sunk costs. Advertising investments, for example, are specific to each company and therefore unsalvageable. In turn, an automaker is specific of this industry. An ill-succeeded investment in this case would only contain changes of salvaging by the same of the plant to another company in the same industry, probably at a substantial discount.

Second, even non-company-or-industry-specific investments are partially irreversible. Computers, trucks and office equipment, for example, can be resold to companies from different industries, but at prices lower than their replacement cost.

Third, irreversibility may be produced by regulation or by institutional arrangements. Part of the investments in public service concessions reverts to the government at the end of the concession or in the case of breach of contract. Controls imposed on capitals may limit the sale of assets by foreign investors, while investments in human capital are also irreversible, due to high contracting, training and severance costs.

The uncertainty about the future is the second important characteristic of the investment decision-making. Project and investment option values and the investment decision itself are affected by the uncertainty associated to relevant variables, such as product price, input costs, interest rates, exchange rates, credit supply and regulation. The importance of uncertainty to investment decision-making will be a recurrent theme throughout this paper.

The third characteristic is the possibility of postponing the investment. Evidently, companies not always have this possibility. Strategic considerations may prompt the company to antedate investments to inhibit effective competitor growth or the entry of potential competitors in the industry.

In most cases, however, project postponement is doable. The company should always compare the cost of postponing – the risk of new companies entering the industry or cash flow losses – with the benefits of waiting for new information to subsidize the investment decision. These may be significant enough to justify postponements.

ROT evaluates a research and development project as an option, to be or not to be exercised in the future, depending on the presence of favorable or unfavorable conditions. The R&D project can be seen as an option, for which a certain premium was paid (the investment in research) during an initial phase, should the project seem promising at the end of such phase (maturity), it will be exercised and the value of the investment in production and marketing will be paid.

According to Herath and Park (1999), an investment in R&D can be seen as a cost (of a real option in which the commercial project will proceed only if the R&D phase is successful). More specifically, the new project's marketing investment cost can be seen as the exercise price and the present value of the future cash flow ensuing from the sales, to be seen as the value of the underlying asset. The date of introducing the new product in the marketplace can be seen as the exercise date. While it is assumed that the marketing decision will probably occur on a future date T_t, the decision maker could consider the option of postponing the marketing decision, according to Figure 1. The option to wait in this case has a value whilst the marketing option is not exercised.

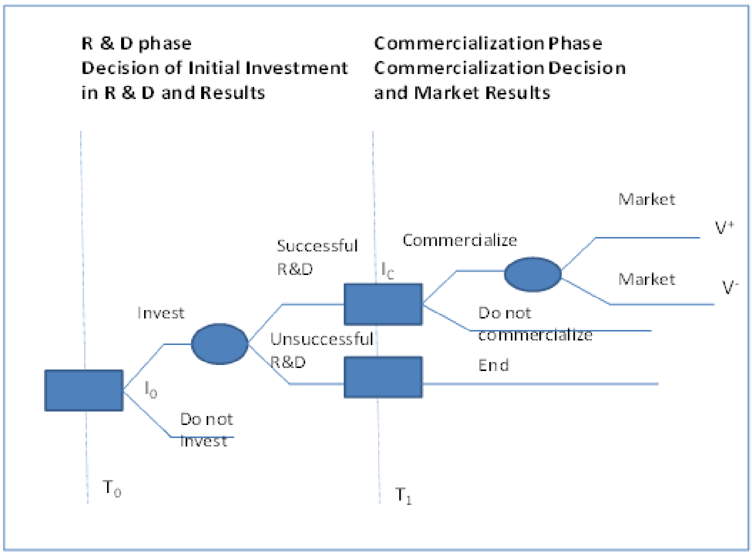

Fig. 1: Typical decision tree for investment processes.

A call option creates future opportunities (such as the development of new product lines or efficiency improvements) without compromising the company under its total investment burden. This is the issue the breeds the differences between traditional approaches and the ROT, since an eventual loss will be limited to the amount invested, the gain potential is limited and the greater the commercial uncertainty, the greater will the project value be.

R&D options have an important advantage over asset options, that is, the purchase of an asset option has no direct effect upon the exercise price or the asset price, while “the greater purpose of the R&D option is to influence future investments favorably by cost-curbing or by improving returns”. Therefore, an R&D option is, arguably, more valuable than an asset option, since it is possible to act upon its future value.

Consider the effect of the R&D option upon an asset value. Mitchell and Hamilton (1988) suggest an R&D option structure similar to that used for the asset option (Figure 2). It is assumed that the company expects to make future investments at a cost C (analogous to the exercise price), which will yield a return R (analogous to the asset value), when acquired.

The investment will be feasible for R > C, and the value of the investment is shown as “B”. However, successful R&D programs may entail a cost reduction of the potential investment from C to C1. R&D programs can also improve return, from R to R1. The expected result is that R&D programs carry the potential to yield benefit “A”, which increases the total value of the investment.

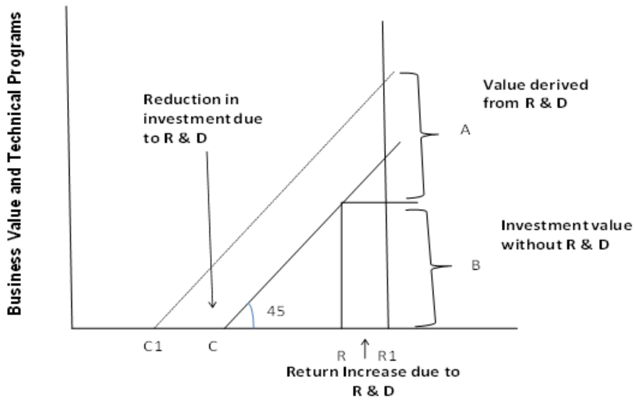

Fig. 2: R & D impact option on future investments.

Such analysis corroborates what ROT literature has indicated, that is, investment analyses carried via the traditional manner has ignored the flexibilities present in the projects. This fact occurs because traditional analyses are done as if all decisions had to be made at the beginning of the project, which, as previously indicated, is naturally a false hypothesis.

R&D projects associated to new product launches have cast substantial challenges before the companies as concerns financial analysis. Literature criticizing traditional metrics abounds. Examples are Mitchell and Hamilton (1988), Faulkner (1996), Lint and Pennigs (1998), among others. According to these authors, metrics such as the IRR, ROI and NPV tend to underestimate the research’s current value, since they do not consider the value of flexibility associated to this type of project.

Differently from traditional metrics that only contemplate the decision of investing or not investing in the project, placing investors in an inactive scenario, the real options method allows the consideration of other options along the project such as abandoning, proceeding or, should the case be, postponing the project depending on the scenario analyzed.

Another important issue addressed by ROT is uncertainty. According to Dixit and Pyndik (1994), the managerial flexibility incorporated to the uncertainty context that new product launch projects contain allows new information to be factored in throughout the project, and thence the course of action can be changed aiming to maximize project outcomes.

Market uncertainty is related to the future value of innovation, which in turn is strongly correlated to market demand. Subjectivity at the time of kicking off projects of this type brings about an intense difficulty in choosing a method. According to Luehraman (1998), although the authors have effectively demonstrated the advantages of the ROT vis-à-vis traditional metrics, they have not been equally successful in providing practical methodologies to approach this tool.

The Geske model presents an option on option pricing theory, or compound option model, which can be generalized for corporate liability values. The equations of a compound call option contemplates a purchase option on stocks, which in itself is an option of the company’s assets.

Such perspective incorporates the effects of leverage upon option pricing and, consequently, the variance of the stock rate of return, which is not constant as assumed by Black-Scholes, but, rather, is a function of the stock price level. The Black-Scholes model is a special case in the compound option equation. This new model for calls and puts corrects some important biases in the Black-Scholes model.

Studies indicated that the value obtained through the Geske (1979) model, except for approximations, is 92% greater than that obtained by the traditional model. Traditional models compared by the study were: Net Present Value – Investment in Production and Marketing; Net Present Value – Sale of Rights; Decision Tree Analysis and Net Present Value by the Kallberg and Laurin (1997) method.

Such analysis corroborates what has been mentioned in ROT literature, that is, investment analysis as traditionally done has ignored the flexibilities contained in the projects. This fact occurs because traditional analyses are done as if all decisions had to be made at the beginning of the project, which, as previously indicated, is naturally a false hypothesis.

MATERIALS AND METHODS

The Geske Model:

The solution to evaluate compound options was initially suggested by Geske (1979), who presents a situation containing the data from an R&D project with two growth opportunities with the initial investment made in year 1, followed by follow-up investments (K^* investment in the test phase) in year 2 and finally follow up investments in production capacity in year 3.

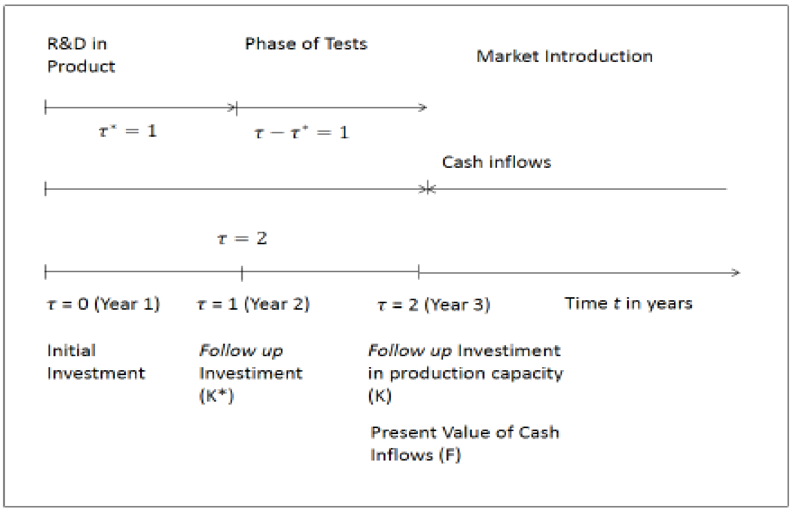

Fig. 3: Generic model of the R & D process.

Perlitz, Peske e Schrank (1999) suggest that Geske's (1979) model be used in the computation of options containing the previously described project characteristics. According to the authors, assuming that the project value will follow a geometric Brownian motion, this compound option can be analytically evaluated in terms of the bivariate normal distribution. A compound option can be analytically evaluated by Geske's (1979) approach, basing on the Black-Scholes model, and adjusted for Kemna's (1993) real options evaluation, as follows:

$$C = Fe^{-r\tau}M(k,h;\rho) - ke^{-r\tau}M\left(k-\sigma\sqrt{\tau^*}, k-\sigma\sqrt{\tau};\rho\right) - k^*e^{-r\tau}N(k-\sigma\sqrt{\tau^*}) \quad (3)$$

Where, for the calculation of ρ, h and k have the following equations:

$$\rho = \left(\frac{\tau^*}{\tau}\right)^{\frac{1}{2}} \quad (4)$$

$$h = \frac{ln\left(\frac{F}{K}\right)+\frac{1}{2}\sigma^2\tau}{\sigma\sqrt{\tau}} \quad (5)$$

$$k = \frac{ln\left(\frac{F}{F_C}\right)+\frac{1}{2}\sigma^2\tau^*}{\sigma\sqrt{\tau^*}} \quad (6)$$

$N\left(k - \sigma\sqrt{\tau^*}\right)$ = univariate cumulative normal distribution function (7)

σ = volatility of the rate of change of the second follow up investment;
K = present value of the capital expenditure of the second investment for time $\tau - \tau^*$;
K^* = present value of the first year capital expenditure of the first investment for time τ^*;
r = riskless interest rate;
τ = time to maturity of the first option within the compound option;
τ^* = time to maturity of the simple option for the second venture;
F = present value of the cash inflow discounted to the beginning of the second investment;
F_C = critical value of the project above which the first call option will be exercised;

$M(k,h;\rho) =$ bivariate cumulative normal distribution function with k and h as the upper and lower integral limits, and correlation coefficient ρ.

Results:

Case Study:

The simulation method employed adheres to the following assumptions to apply the real options theory. They are:

- Irreversibility: Once a certain amount has been invested in research – that is, a sunk cost – it is not possible to salvage such amount should the project not proceed.
- Uncertainty: A research and development project is carried out under uncertainties, be they technical (whether the product will work or not work is unknown) or economic (market conditions, for example). These uncertainties will only be dissipated through investing in research and proceeding with the project.
- Timing: Once the project has been kicked off, the company has the possibility of choosing the time to launch it in the marketplace, after having evaluated its feasibility. Having began the research effort several options are found, such as: abandonment of the project should it look unpromising; temporarily mothballing the project waiting for the resolution of uncertainties and for a better moment to launch the product in the marketplace; development and marketing by the company owning the project; sale of the marketing rights to a third party.
- Volatility: The volatility of the net present value of future capital inflows is an important parameter to be considered, albeit difficult to estimate. Past data can be used to determine the expected volatility, assuming that past volatility will be replicated in the future. Depending on the project being analyzed, this information cannot be obtained because no prior projects exist; the data is then gathered without the company. Nicholas (1994) suggests that companies in the pharmaceutical industry generally assume a volatility rate between 40% and 60%, due to the high risks involved. Low volatility will be used for the example that follows.
- Capital inflows: Begin after the second risk evaluation when the proposed product is approved and launched in the marketplace. However, to compute the option value, the capital inflow should be discounted back to the beginning of the second risk evaluation, thus using the company's cost of capital.

BETA Product Development Project:

The example used here is from a company called ALPHA having an R & D project in which is divided into phases that are similar between the research departments of various companies. The company´s name and product are not given because of confidentiality agreement.

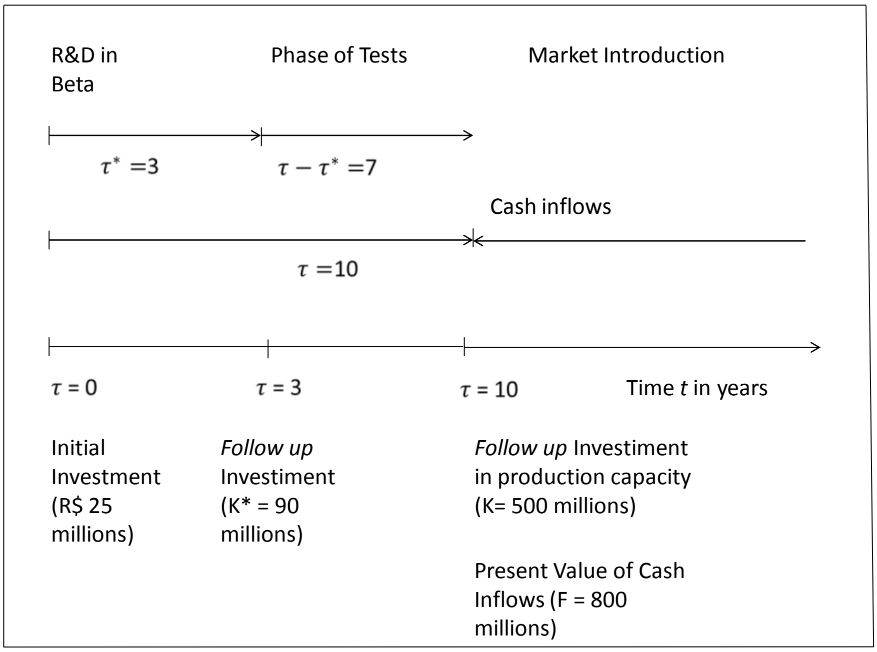

Fig. 4: R & D process model for the ALPHA company´s BETA product.

It is assumed that the company ALPHA conducts research for the creation of a new product called BETA. The initial investment is R$ 25,000,000.00. After completing the verification process by the board of directors they decided to continue the promising composed option which is the continuity for the next phases or stages through an additional investment of R$ 90,000,000.00 (test phase). The company will invest over R$ 500,000.00 (production and marketing). After 10 years, at the beginning of the 11th year, it is expected to enter the company´s product in the market or sell the patent, resulting in a capital entry with present value for the 10th year of R$ 800,000,000.00 (see Lint and Pennings, (1998) ; Luehman (1998) to estimate future cash flows). The company assumes a volatility rate of 25% as being appropriate to the project. The interest rate for a risk-free application will be 4% and the company´s cost of capital will be 14%. Figure 4 shows the R & D process model for BETA product, which contains information on the project.

Specifically, the information on Figure 4 can be expressed as follows:

Initial investment = R$ 25 millions
F = R$ 800 millions
$\sigma = 0{,}25$
K = R$ 500 millions
K* = R$ 90 millions
F_C = R$ 613,978 millions
r = 4%
τ^* = 3 years
τ = 10 years
Capital cost = 14%

To solve the problem we first calculate the $\rho,\ k,\ h, N\ e\ M$ as indicated in the equations presented earlier.

$$\rho = \left(\frac{\tau^*}{\tau}\right)^{\frac{1}{2}} = \left(\frac{3}{10}\right)^{\frac{1}{2}} = 0{,}547$$

$$h = \frac{ln\left(\frac{F}{K}\right) + \frac{1}{2}\sigma^2\tau}{\sigma\sqrt{\tau}} = \frac{ln\left(\frac{800}{500}\right) + \frac{1}{2}(0{,}25)^2 10}{0{,}25\sqrt{10}} = 0{,}99$$

$$k = \frac{ln\left(\frac{F}{F_C}\right) + \frac{1}{2}\sigma^2\tau^*}{\sigma\sqrt{\tau^*}} == \frac{ln\left(\frac{800}{613{,}978}\right) + \frac{1}{2}(0{,}25)^2 3}{0{,}25\sqrt{3}} = 0{,}82$$

$$N\left(k - \sigma\sqrt{\tau^*}\right) = N\left(0{,}82 - 0{,}25\sqrt{3}\right) = N(0{,}39) = 0{,}1517$$

$$M\left(k - \sigma\sqrt{\tau^*}, k - \sigma\sqrt{\tau};\ \rho\right) = M\left(0{,}82 - 0{,}25\sqrt{3}, 0{,}82 - 0{,}25\sqrt{10}; 0{,}547\right) =$$
$$= M(0{,}39, 0{,}03; 0{,}547) \cong 0{,}42$$
$$M(k, h; \rho) = M(0{,}82, 0{,}99; 0{,}547) \cong 0{,}71$$

Then, using equation (3) option pricing composed of Kemna (1993), results in a value for the compound option:

$$\mathbf{C = 800e^{-0{,}04(10)}0{,}71 - 500e^{-0{,}04(10)}\ 0{,}42 - 90e^{-0{,}04(10)}\ 0{,}1517}$$

C = (800)(0,67)(0,71) – (500)(0,67)(0,42) – (90)(0,67)(0,1517)

C = 380,56 – 140,7 – 9,15

C = 230,71

The value of this project consists of assets present value allocated (assets in place) and the present value of growth opportunities funded through the evaluation of option-based approach value.

Project value = sunk cost + growth opportunities

- The present value of the initial investment (sunk cost) is R$ 25 million
- The growth opportunities present value is equal to the value of the compound option G = R$ 230.71 million;

The value of investing in the BETA project, therefore, has a total value equal to:

Net Present Value (Geske) = R$ 230,71 – R$ 25 = R$ 205,71 milhões

Therefore,

The investment in the Beta project is R$ 205.71 million**.**

The net present value of the project calculated in the traditional way (Perlitz, Peske and Schrank, 1999), using the cost of capital of 14% would result in a value of:

$VPL_{Trad} = - 25 – [90*(1,14^{-3})] + [(800-500)*(1,14^{-10})] = - 4,82$ millions

Perlitz, Peske and Schrank (1999) present the following arguments for the fact that the traditional NPV is substantially smaller than the amounts obtained by the real options method. The authors feel there are some effects in favor of the investments in risky R&D projects when valuated by the real options pricing method, these being:

- NPV techniques are highly dependent on the discount rates applied. In the case of R&D projects these rates are often risk-adjusted, that is, they entail heavy discounts. The real options pricing method avoids the use of the risk-adjusted rate.
- In addition, the discount rate effect is strengthened by long time horizons applied to R&D investment decisions.
- Long time horizons allow more time to reach to changes in conditions. In the example, there is a possibility of stopping the investment or invest if the results from previous phases are known. This effect is taken into account in the evaluations of real options and not in the traditional NPV.
- The high volatility of R&D outlays positively influences the option value because great returns can be yielded, but small returns can also be avoided by a reaction to changes in conditions. In the NPV calculation, high volatilities entail a risk premium over the discount rate, and, consequently, a lower NPV.

Conclusion:

The static use of tradition investment evaluation techniques, mainly the NPV and the Discounted Cash Flow methods, has sustained harsh criticism, since they have not been able to capture the value of managerial flexibility contained in many projects. These models have been proposed for R&D application; however, they all have their advantages and disadvantages.

It is incumbent upon management to know which model should be chosen, seeking to apply the best fit to the peculiarities of a given project. This may be a barrier against the application of the theory, since there is no standard method to apply to each and every investment analysis. Since the decision-making process is not simple and, often times, involves thousands or even millions of dollars, management should be attentive to this new tool, paying some premium in the quest for the best solution.

ROT, as applied to a real research and development investment analysis proved satisfactory to bridge the gap between theory and practice.

Finally, although the ROT is in a development and consolidation stage, the authors suggest that it should be used as a promising tool in the decision-making process.

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