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Real Options Application on Innovation and R&D Projects

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Master in Finance

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Iscte-Iul

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Dedicated to my family and friends, thank you for all the support.
To my supervisor, professor José Carlos Dias for thoroughly accompanying me.
Special thanks to my father and brother, they know why.

Resumo

Alguns diriam que a inovação é um dos pontos-chave que transformou o mundo naquilo que é e como o conhecemos. À semelhança de tudo na vida, há prós e contras. O ser-humano trilhou caminhos para evoluir e mudar nossa a experiência de vida, muitas vezes afetando negativamente o ambiente em que nos inserimos e outras espécies. A esperança leva-nos a crer que o curso das nossas ações tem vindo a alterar-se e que estamos cada vez mais atentos a todos os fatores e que a inovação, em conjunto com outros conceitos, será capaz de prover sustentabilidade e levar-nos até ao próximo nível de evolução.

As contemporâneas teorias económicas e de finanças empresariais, realçam a importância de avaliação de projetos sob a alçada de uma abordagem dinâmica e o racional de incorporar cláusulas contratuais em projetos, usualmente conhecidas como opções reais. A combinação destes dois conceitos resulta numa forma flexível e num processo pronto a mudanças, que será capaz de resultar em maiores retornos tanto para projetos de inovação como para projetos de investigação e desenvolvimento (I&D).

Tendo lido teorias apresentadas por estudiosos, tanto da área de finanças como de inovação, escreveram e como têm vindo a analisar a junção de ambos os tópicos, na minha dissertação, eu proponho uma extensão às metodologias existentes com a inclusão de uma possível decisão de "lançar mais cedo o resultado do projeto", quando possível para certos projetos, podendo resultar em maiores retornos e melhor posicionamento de uma empresa em mercados competitivos.

Palavras-chave: Inovação, Investigação, Desenvolvimento, Opções reais, Evolução, Flexibilidade de gestão, Análise dinâmica.

Abstract

Some would say that innovation is one of the key points that brought the world to what we know it to be. Much like everything in life, there are pros and cons. The human species has paved ways to evolve and change the life experience, many times negatively affecting our surroundings and other species. Hope leads us to believe that the course of action is changing and being increasingly attentive towards all the factors, and that innovation along with other concepts will be able to provide sustainability and get us to the next level of evolution.

Contemporary economic and corporate finance theory highlights the relevance of project valuation under a dynamic approach and the rationale behind making room to incorporate a company's contractual claims on projects, commonly known as real options. The combination of these two concepts results in an iterative and adaptation-ready process, which may be able to result in higher payoffs and better results both for innovation and research & development (R&D) projects.

Having read what scholars in the finance and innovation theories have written and how they have analysed the junction of both, in this dissertation, we propose an extension to the existing valuation methodologies with the existence of an "early launch" optimal decision for certain projects, resulting in higher payoffs and stronger positioning in a competitive market.

Keywords: Innovation, Research, Development, Real Options Approach, Evolution, Managerial flexibility, Dynamic analysis.

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1. Introduction

Managerial flexibility has increasing relevance on the contemporary financial scenario, innovative endeavours tend to be endowed with aggravated idiosyncratic risk due to all the surrounding uncertainties.

Real options approach (ROA) when applied to innovation projects presents itself as a useful tool to provide flexibility and enhance the outcomes.

The work developed in this dissertation gains relevance due to the increase of the existing possible decisions contained in the analysis of a real option over an innovation project, and the later shown way on how the existence of this decision increases both the option and the project's value.

Firstly, we aim to provide the reader an overview of the topics, with an analysis of part of the written documents and developed models. Afterwards, we present the central question/hypothesis in which the proposed model extension is based upon "Can it be better to launch a project's result earlier to the initially planned even though the result is in a less developed status?".

To what concerns existing empirical data, this is a fairly new concept and there is not much of a proper record of how companies utilise the contractual claims and this financial framework, causing this dissertation not to rely much on data analysis.

In terms of valuation methodology, the model we propose is an extension to the Huchzermeier and Loch (2001). We incorporate the optimal decision to launch a project earlier than the planned if this is possible, goes accordingly to its specificities and makes sense to the involved stakeholders. In this section, we present our theoretical contribution to the valuation methodology and a *MS Excel*-mounted example.

Following the methodology chapter, we will present and analyse the results from a financial and economic rationale going beyond the purely mathematical results, in a way as to give meaning to the problem's resolution. Lastly, the reader will be able to find the conclusions.

To summarise, this work takes the format of a dissertation and on a personal note, my motivation behind this theme choice come as a combination of my master's specialisation in corporate finance, having attended the *Real options* course, and a pleasant taste I acquired on the innovation concept on the final project of my bachelor's degree in *Finance and Accounting* at *Iscte*.

2. Literature review

In order to answer our research question and properly tackle what it is aimed with this dissertation, we believe it is logical that this section, firstly and separately, addresses the two topics: Innovation and Real Options; and then proceed with an analysis of what and how the fusion of both these topics has been evolving and the way the financial community perceives the theme.

a. Innovation

As exposed above, firstly we would like to address the innovation concept, this serving as an explanation of how companies can actually innovate, the types of analysis that should occur before decision making, a proposed decision-making methodology with a project management theory basis, different types of innovation and, lastly, how this concept can actually develop both companies and economies worldwide.

Google's textbook definition for innovation falls somewhat short and unfounded: "The action or process of innovating". This feels way too generalised for the application in the business world.

When asked, in 2016, to define innovation by the *Idea to value* website, two recognised innovation experts gave the following answers. Innovation is:

"A feasible relevant offering such as a product, service, process or experience with a viable business model that is perceived as new and is adopted by customers."

- Gijs Van Wulfen

and

"The fundamental way the company brings constant value to their customers' business or life and consequently to their shareholders and stakeholders."

- Paul Hobcraft

The combination of both these quotes results in the way that innovation is to be perceived nowadays, a viable and sustainable business should be simultaneously focused on its financial performance and sustainability while evolving and creating value to all involved entities, having this encrypted in a company's mindset can be one of the keys to succeed in innovative endeavours.

Once we now have a fancy definition of innovation, it is of interest to know what are the topics a company can focus on innovating. We can divide these into three main topics: (i) Products & services; (ii) Processes; and (iii) Business models.

The first one of these can be looked upon as the most usual focus of innovation projects. Products and services are the link between a company and its customers and the main way for the company to preserve and increase its customer base. Through what is commercialized the company is also able to express its message to the targeted public and make the world know and understand what they are all about, match with possible consumers and elevate its financial performance.

It is usual to differentiate between incremental and disruptive innovation over products and services when referring to the degree at which it revolutionises or not the *status quo* of a company or even its competitive industry.

Taking into consideration nowadays world status, it is safe to say that some of the industries that are innovating the most are the pharmaceutical, mainly due to Covid-19 pandemic with companies like Moderna and Pfizer-BioNTech with the development of vaccines in such short time and launching them into the market; the space exploration financed by private companies (SpaceX, Blue Origin and Virgin Galactic), which may just be the beginning of a new era of knowledge and science; and, the digital platforms for various types of goods and services that run in a way as to give response to customers' needs in troubled times such as the pandemic.

Innovation efforts focused on processes aim to implement changes in the stages that the business conventionally is being run. These changes are most of all in the internal organisation of a company, various goals can be behind such endeavours being normally mentioned four: time economy, in a way that companies can increase their production and give response to a larger consumer base; higher profitability, through the simultaneous integration of processes within the firm's limits and the possibility to concomitantly increase revenues and decrease costs; reduction of error probability, this mainly through automatization and definition of steps for each task; and, exploration of new ways to produce and serve, taking into consideration inside players and the organisation itself and external factors such as the environment, political cycles and the community, it is also a healthy way to enhance creativity.

Historically, steam machines from the industrial revolution and Henry Ford's assembly line are some relevant landmarks of this type of innovation.

Lastly, remains to address the Business Model innovation, this would be the way the company proceeds to deliver value to its customers; this concept comes in a form as to answer three questions:

a. Who are the customers?

b. What should be the value proposal to give response to customers' needs and simultaneously create sustainable value to shareholders and stakeholders?

c. In order to accomplish the value proposal what are the needed tools and resources?

A consideration to be done over this concept is that the innovative-type company does not have to stick to a *modus operandi* as some traditional companies tend to do. Companies are able to review and update their business mindset and adapt smartly after evaluating both internal and external circumstances.

This last sentence leads to the question of what a company should analyse before taking on an innovation endeavour. Separating external from internal factors of a company, business theory often suggests the following:

i. External

- PESTLE analysis which is a methodology to process the outsides of a company in terms of market, industry, business and, even, country. These initials stand for the Political, Economic, Social, Technological, Legal and Environmental factors that play a role on how a company act;
- Focusing more intensively on the industry a company is in, a common approach is the one proposed by Porter (1979) in "How competitive forces shape strategy", the famous Five Forces Model which contemplates the level of suppliers' power, buyers' entry/exit costs, the threat of substitute products, the intensity of the competitive landscape and the facility with which new entrants become players in the market.

ii. Internal

A healthy way for a company to proceed this part of the analysis is to mix a strategy focused investigation with a marketing one and link the results to the external reasonings.

- Strategic analysis should be able to cover multiple concepts such as the duality between problem and market, competitors, clients/users, KSF (key success factors), trends and orthodoxies;
- Marketing strategy should define the company's mission, vision, values, business goals, segmentation, targeting and positioning.

A final mix between the external and internal factors is usually a SWOT or a Dynamic SWOT (Strengths, Weaknesses, Opportunities and Threats), being the first two initials relative to inside factors and the last two linked to outside aspects. This methodology can help analysts to come up with solutions for a gap either in the company itself or in the industry.

Presenting one of the many decision methodologies a company can adapt to choose what is their next innovation step, we would like to bring in *The Value Roadmap*, a technique introduced by Garcia and Bray (1997). Firstly, and solely, the authors applied this for technologies, but throughout the years users have extended the application of this platform to plenty other concepts.

Generally, this is the display of *The Value Roadmap*:

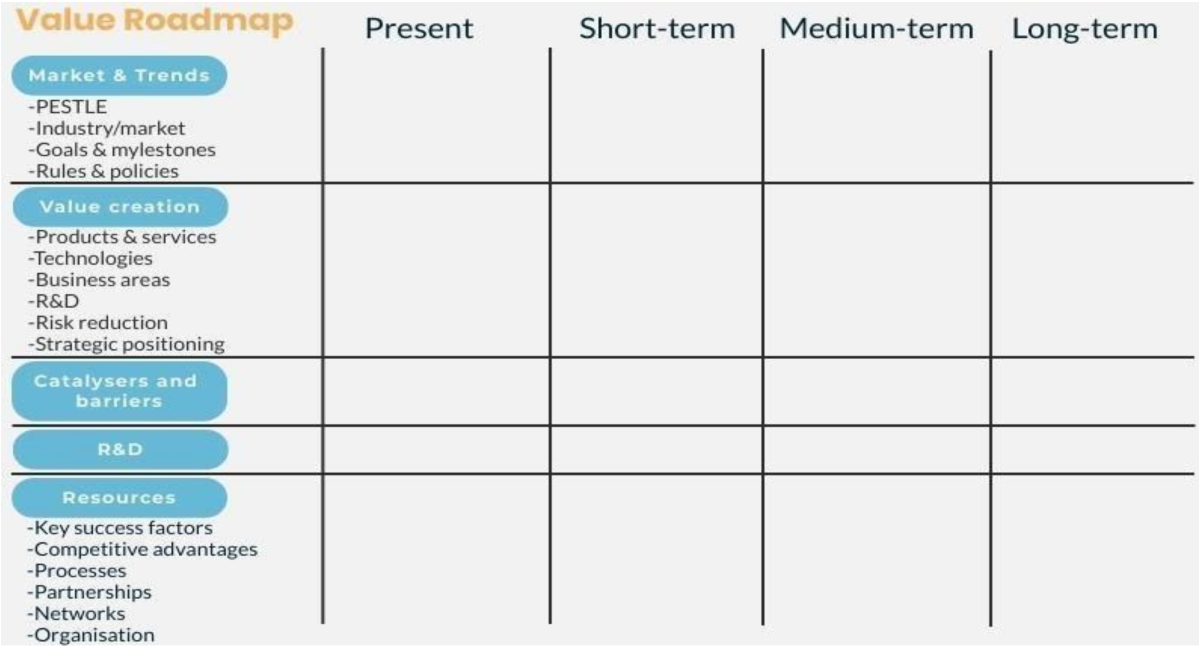

Figure 1. Value roadmap.

Source: own work based on Garcia and Bray (1997).

This tool is adaptable to the specificities of each company and its innovation projects and follows an Agile-theory project management perspective.

To properly complete the board, the company must give answer to the following questions:

i. *Why* this business/market?

ii. *What* products and services?

iii. *How* can we achieve our goals?

The last question the company must answer is: *When* should we engage/release this project? The timing question along with implied uncertainty and the need for managerial flexibility in this type of investments is where the *Real Options approach* becomes useful and exactly what links the two themes in this dissertation.

The last thing we would like to show the reader in this first part of the literature review is how innovation and R&D is linked to success in the real world. For this we would like to present some data and findings shown on the *Global Innovation Index 2020*.

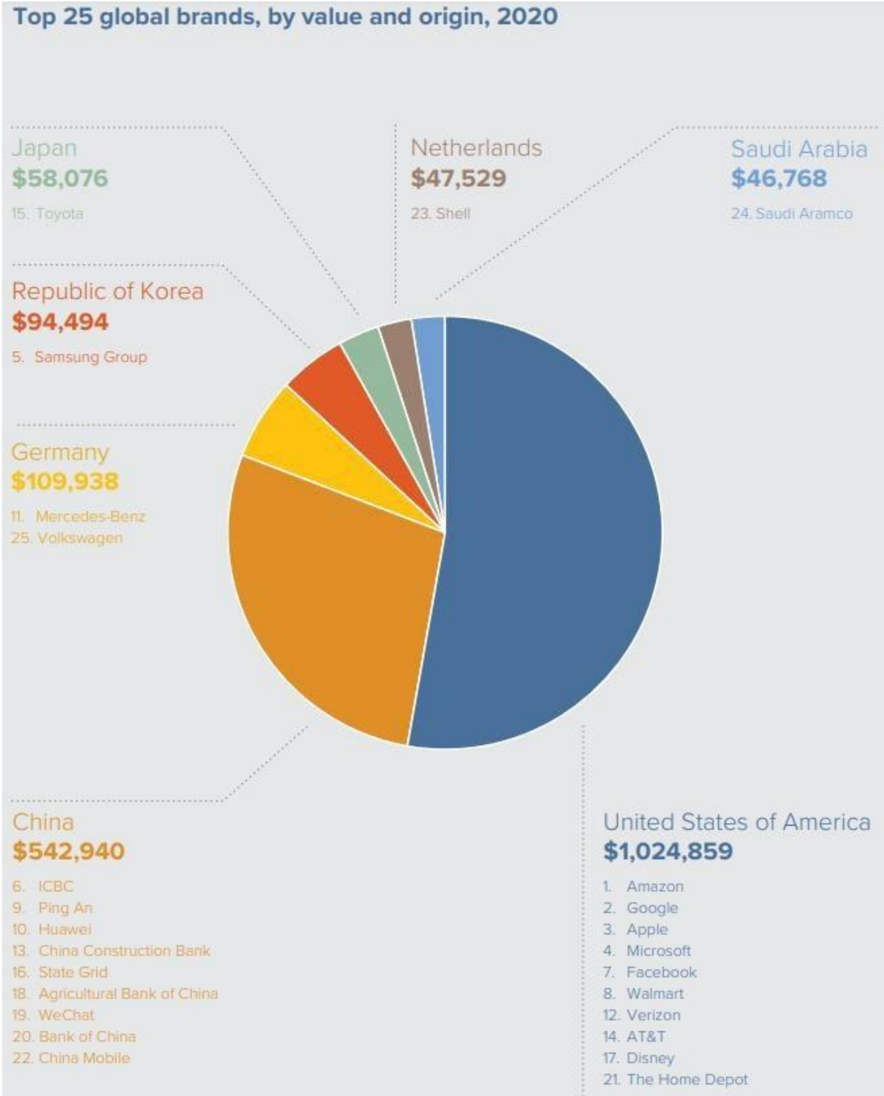

Figure 2. Top 25 Global Brands, by value and origin, 2020.

Source: Global Innovation Index 2020, chapter 1, page 27.

Note: figures in US$ millions.

In this pie chart, there are the 25 biggest brands worldwide by value and divided by their home countries. The USA is the country that has the biggest slice and the 3 biggest companies contributing to its aggregated value are Amazon, Google and Apple. All these are companies with continuous innovation either through their platforms, ways to operate or products and services, they also happen to be the three higher valued brands.

Microsoft and Samsung come in the fourth and fifth places, respectively, and are also inserted in high-innovative businesses.

China has the second highest aggregated firm value, much through financial and insurance organisations who also tend to have commitments to evolving rationally and innovatively in a way so that they can give response to a high number of consumers.

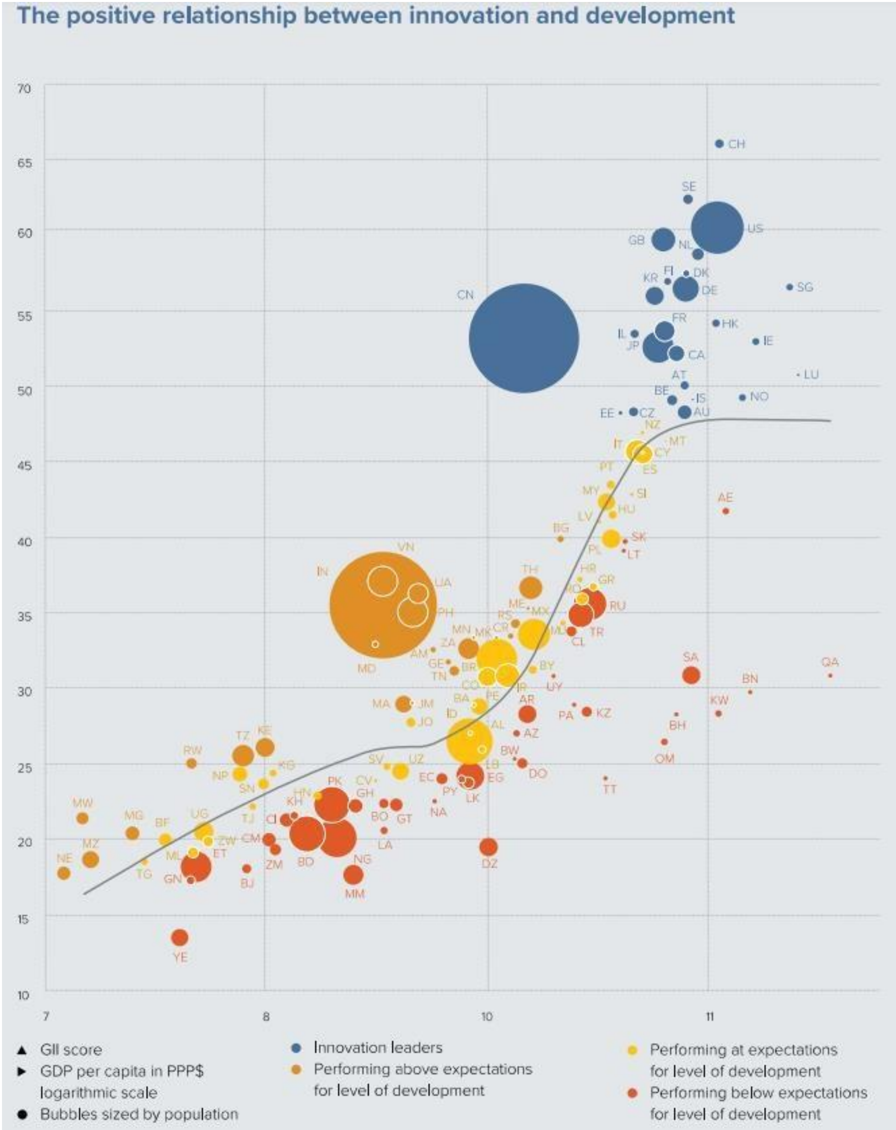

Figure 3. Positive relationship between innovation and development.
Source: Global Innovation Index 2020, chapter 1, page 20.

"Notes: As in past editions, Figure 1.6 presents the GII scores plotted against GDP per capita in natural logs and in PPP US$. The main element of the figure is the trend line, which shows the expected levels of innovation performance for a given economy relative to its level of GDP per capita. The figure presents all economies covered in the GII 2020 against this trend line. The trend line is the cubic spline with five knots determined by Harrell's default percentiles (R2 = 0.6827). Economies that are close to the trend line are those whose innovation performance is in line with expectations given its level of development (yellow). The further above an economy is in relation to this trend line, the better its innovation performance is relative to its level of development and thus other peer economies at similar levels. In contrast, those economies located below the trend line are those whose innovation performance is below expectations (red)."

In this chart, we are able to analyse how well a country is developing and cross it with the score of the *Global Innovation Index 2020*'s entourage has attributed to that country's efforts to innovate. We are also able to review and analyse the data in proportion to a country's population size and whether it is performing above, below or at its expectation levels.

Switzerland (CH) is leading in terms of innovative grade and Luxembourg (LU) has the highest GDP per capita in PPP$ logarithmic scale.

Both these countries present themselves to be performing above expectations and come as innovation leaders.

China and India are the two most populated countries and are recorded to be performing above expectations, since innovation can be seen as one of the ways for them to be growing economically and simultaneously shelter such high numbers of population.

With this data analysis, our goal is to show the reader that innovation is one of the key success factors for sustainable and value creating performances both in micro and macroeconomics.

b. Real Options approach (ROA)

In this second part of the literature review section, we aim to provide the reader the basis to understand this framework of analysis, its types and ways of usage. Moreover, in this section, we proceed with the presentation of the corresponding option parameters and a brief explanation of learned methodologies on how to evaluate them.

The final goal of this section is to specify which category of option a practitioner is working with in an innovation project.

Firstly, one must understand that real options are an extension and application of the historically known, financial options instrument to companies' contractual claims on real assets. The evaluation methods and the particularities for these contingent claims are also an adaptation from the option pricing theory.

The scholar definition for real options often is that these instruments are a right/contractual claim to change the course of action a company is in relative to an asset, project or investment opportunity. The usual decision dichotomy is between either making use of the right or abandoning the position. This possibility to change the company's strategy translates to managerial flexibility that decision-makers can benefit from after receiving new relevant information enhancing the upside potential while limiting the eventual downside losses.

The *ROA* gains special relevance once it assimilates some key project features, such as: timing, uncertainty and irreversibility.

During the passage by the “Real options” course, we got the chance to get familiar with different uses for this instrument, namely:

i) Option to defer or to delay;

ii) Option to expand;

iii) Corporate growth options;

iv) Option to contract;

v) Option to temporarily shut down and restart operations;

vi) Option to abandon for salvage value;

vii) Compound options;

viii) Option to switch;

ix) Multiple options.

Source: Real Options - MSc Finance, Lecture Notes, Dias (2021).

These various uses are self-explanatory just through their names. As we will see later in this section, real options on an innovation project come in the form of compound options since at the end of each innovation stage the exercising of a decision generates new option possibilities to the practitioner.

Although in corporate finance theory we are presented with the above various possibilities linked to the ROA, to better understand this concept, we must proceed with the traditional division between call and put options and a subdivision between American-style and European-style ones. This will alter the way the practitioner perceives real options and define a proper way to evaluate them.

Getting back to the previously mentioned term of “managerial flexibility”, it allows the project analysts to go beyond the traditional/static *Net Present Value* (NPV) evaluation approach, once it assumes that a company is stuck with the first decision/judgement made on an endeavour without the possibility to rationally adapt to new information and circumstances.

The ROA evaluates a project through the following:

$$Expanded\ NPV\ =\ Static\ NPV\ +\ Option\ premium\ . \quad (1)$$

In this sense, one cannot discard the relevance of the static NPV approach because it is a building block for this methodology, but, under this theory, the user has to increase the discounted cash-flows by the attributed value to flexibility on a project.

The bottom line is that there is value in managerial flexibility in the ROA, since it can increase the upside potential while limiting the downside effects if consciously and vigorously used.

During my student journey using real options, I learnt how to evaluate them through the backwards induction binomial model of Cox et al. (1979) and the Black and Scholes (1973) and Merton (1973) (BSM) model. In order to properly understand the use of these models, firstly, the user must recognise the relevant variables. The managers' toolkit framework proposed by Luehrman (1998) comes handy in the sense that it parametrises the relevant factors and transposes them from the financial to the real world.

For the purpose of, later on this dissertation, analysing real options when applied to innovation endeavours, it makes sense to define that these options will take the form of a call option, since these instruments will represent opportunities to invest, innovate and perform R&D projects (Huchzermeier and Loch, 2001; Dixit and Pindyck, 1994).

This being stated we are going to be handling call-type options, and to simplify, the notation will be exactly the one proposed by Luehrman (1998).

i. For the BSM model:

$\boldsymbol{X} = \boldsymbol{K}$ - (Upfront) investment cost**,** strike price;

$\boldsymbol{S_t}$ - Underlying asset price of a call option;

$\boldsymbol{V_t}$- Present value (PV) of a project's cash flows at the valuation date $\boldsymbol{t}$ (corresponds to S_t)**;**

$\boldsymbol{\tau} = \boldsymbol{T} - \boldsymbol{t}$ - Option's time to expiry date;

$\boldsymbol{T}$ - Option's maturity date;

$\boldsymbol{\sigma}$ - Uncertainty over the future project's cash flows, standard deviation of the returns;

$\boldsymbol{r}$ - Risk-free interest rate;

$\boldsymbol{q}$ - Rate of return shortfall.

The call option value is given by the following equation:

$$C_t = V_t . e^{-q.\tau} . N(d_1) - K . e^{-r.\tau} . N(d_2) \ , \tag{2}$$

where:

$$d_1 = \frac{\ln\left(\frac{V_t}{X}\right) + (r - q + 0.5 \times \sigma^2) \times \tau}{\sigma \times \sqrt{\tau}} \tag{3}$$

and

$$d_2 = \frac{\ln\left(\frac{V_t}{X}\right) + (r - q - 0.5 \times \sigma^2) \times \tau}{\sigma \times \sqrt{\tau}} \ , \tag{4}$$

with $N(.)$ representing the standard normal distribution.

ii. For the Binomial model:

$\boldsymbol{u} = e^{\sigma\times\sqrt{\Delta t}}$ - effect on V_t of an up move on the binomial tree;

$\boldsymbol{d} = e^{-\sigma\times\sqrt{\Delta t}}$ - effect on V_t of a down move on the binomial tree;

$\boldsymbol{n}$ - number of periods;

$\Delta\boldsymbol{t} = \frac{T-t}{n} = \frac{\tau}{n}$ - length of each time period.

The up and down movement risk-neutral probabilities are given by:

$$q_u = \frac{e^{(r-q)\times\Delta t} - d}{u-d} \quad (5)$$

$$q_d = 1 - q_u. \quad (6)$$

This methodology uses backward induction through the binomial tree by using the formula:

$$Max[(V_{i+1,j+1} \times q_u + V_{i+1,j} \times q_d) \times e^{-r\times\Delta t} - X_i; 0], \quad (7)$$

until the user can evaluate the option and the underlying value asset at time 0, and then proceed to add it to the static NPV.

As a final remark to the real options evaluating theory, we would like to present Luehrman's two-dimensional option decision space which is an interesting, useful and parameterized tool for managers to construct and support their managerial judgements.

For the correct use of this, one must be familiar with two option value metrics that define the bidimensional decision space.

1. $NPV_q = \frac{V_t^*}{PV(X)} = \frac{V_t\times e^{-q\times\tau}}{X\times e^{-r\times\tau}}$.

$$(8)$$

This can be interpreted as an adaptation of the traditional type NPV, containing the same information, but taking into consideration the time value of money adjacent to the possibility of deferring the investment decision;

2. $Cumulative\ volatility = \sigma \times \sqrt{\tau}$.

$$(9)$$

This metric makes room for changes in the underlying asset's value over time and contemplates the possibility for an exchange of the decision on whether or not to invest and go through with a project.

A few adaptations to the auxiliar calculations have to be made, namely, to compute the parameters:

$$d_1 = \frac{\ln{(NPV_q)}}{\sigma \times \sqrt{\tau}} + \frac{\sigma \times \sqrt{\tau}}{2}, \quad (10)$$

$$d_2 = \frac{\ln{(NPV_q)}}{\sigma \times \sqrt{\tau}} - \frac{\sigma \times \sqrt{\tau}}{2}. \quad (11)$$

Graphically, we often find the following scheme:

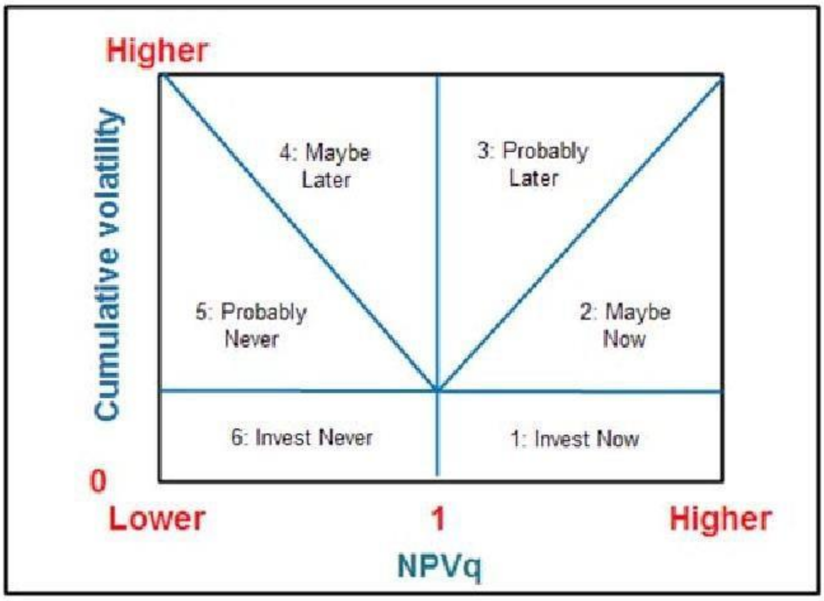

Figure 4. Two-dimensional option decision space.

Source: Luehrman (1998).

This being mentioned, we conclude this brief literature review on the real options concept, usages, types and evaluation methods.

To carry on to the third and last part of this dissertation section, the reader should retain that from now on, we will be focusing on call-type options either American-style or European-style and, due to each project's characteristics, difficulty to generalise and the existence of different stages and steps, the binomial model with the adequate adaptations will come in as a more reasonable way to proceed with the fusion between innovation and the ROA.

c. Real options approach on innovation and R&D projects

It is now time to merge the two presented above topics, see how one can process this use and analyse what theorists and scholars have been developing in this corporate finance area.

Before doing so, we feel it is of extreme relevance to bring the game theory into this complex innovation equation. When applied to this topic it advances on how a company should strategically interact with its competitors.

Quoting Ndiaye (2012), "The opportunity to invest can be seen as a call option, involving the right to acquire an asset for a specified price for a determined future time. In this perspective, game theory, separately, provides parallel answers highlighting the behaviour of the firm on the market.”.

The duality arises from the different perceptions monopolistic and competitive companies hold over the innovation concept. The first ones, if in a protected position, will not be putting in much effort to innovate simply due to the fact that they feel secure and non-threatened by considerably smaller others. The second type of companies on this pair are the ones that should aim to continuously be thriving through innovation endeavours, in a way as to solidify their performance and market position, as well as increase revenues and decrease costs, through innovation they can hold a rather shorter or longer monopolistic market position once they are a step ahead of their competitors.

In the same article mentioned above, the author elaborates on how the ROA takes the static game theory where players hold the notion of *Nash equilibrium* to the dynamic game theory where this notion evolves to *evolutionary stable strategy* (ESS). This concept refers to the position players take on a changing game and was first introduced by Smith and Price (1973).

Once innovation comes in a somewhat crucial format for perfectly competitive markets, this dissertation will mostly be leaning over this typology and the way companies act when in one of these.

And, for the purpose of using real options over innovation endeavours it is only logical to apply it to the Product & services and Processes innovation types since these will have an actual involvement of real assets expenditure and project costs, while business model innovation is over a company’s mindset and more of a conceptual evolution on how the company perceives its surroundings and interacts with them in order to create sustainable value.

The two types of innovation real options can be used over have different processes, generically their formats will only change in terms of obtained results, whether commercialisation or operation, respectively.

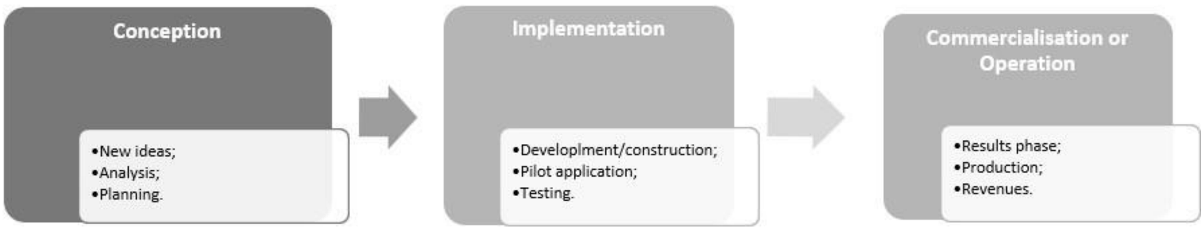

Figure 5- Innovation phases.

Source: own work adapted from “The Innovation Process” by Tiwari (2007).

The first two phases are the ones where the company’s teams will have to make important decisions, consciously integrating and pondering the different management areas the firm has working in each project.

The implementation phase is really the one where the ROA is going to be of use, once managers will have to be adapting their decisions to new information coming from both inside and outside environments when already engaged in a project.

As written by Costa and Paixão (2014):

“From the range of investment projects stand out the research and development projects (R&D projects), which are extremely important in some economic sectors as the pharmaceutical and high-tech industries, in order to create new products or services. These projects should be viewed as a collection of sequential decisions, which involve a R&D phase, multi-stage, and a commercialization phase, with different risks and uncertainties, which will be decreasing as the project develops”.

From the above citation, we would like the reader to withhold three things from which the following developments are going to be based on:

i) Various stages and periods: An innovation endeavour should be phased throughout its duration in a way as to leave space for real options to be exercised during its lifetime instead of the case where a company is glued to an initial decision; this is a subdivision within the implementation stage presented in *Figure 5*;

ii) Sequential decisions: By the end of each period and with the company receiving relevant information whether from inside, outside or the combination of both environments, the company will have to decide if the project is to be moving forward, abandoned or to take a different treatment. Relating to the *ROA* theory we are now dealing with compound options which, by definition, are the case where a project’s success is dependent on decisions taken on previous phases impacting choices made later;

iii) Decreasing risks and uncertainties as time goes by: It is reasonable to extrapolate that as time goes by and a project is developed, concepts start becoming a reality, uncertainty and risks (typically idiosyncratic) are reduced and an organisation can start to plan on how to proceed with the results. Huchzermeier and Loch (2001) identify five sources of uncertainty over innovation and R&D projects, the ones coming from the project itself are the scheduling, performance and budgets, while the risks emanating from the market are the payoffs and the performance requirements for the introduced (or yet to be introduced) product or service.

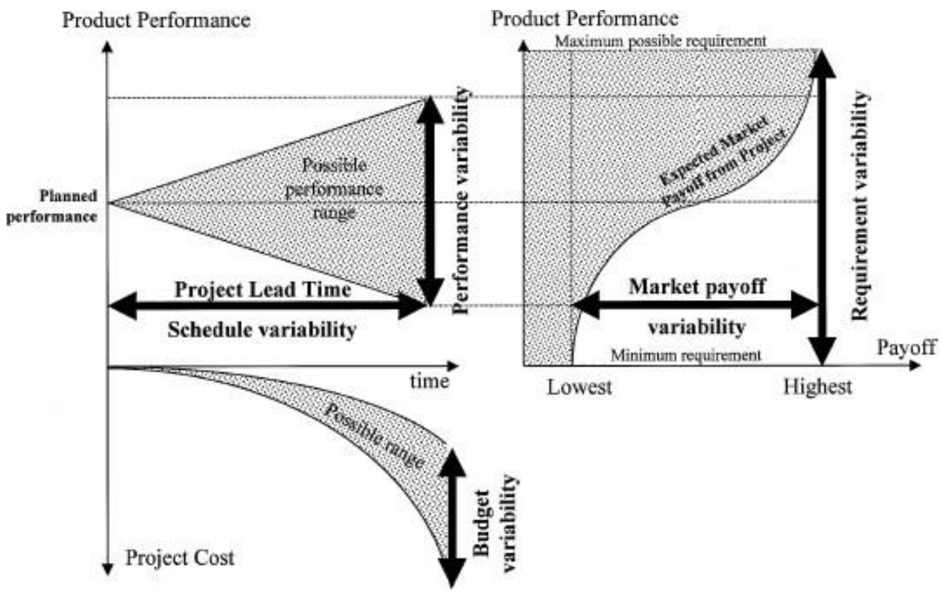

Figure 6. Five types of operational variability.
Source: Huchzermeier and Loch (2001).

This figure enables the viewer to understand and cross the dynamics of the mentioned five types of uncertainties and risks and how they evolve across time and affect the project's payoff.

In this sense, the use of real options and the existence of managerial flexibility boosts the existing investment opportunities at each point in time, since it improves the upside potential while limiting downside losses (Kogut and Kulatilaka (1994); Trigeorgis (1997)).

Keeping the user tuned to the above mentioned 2001 article written by Huchzermeier and Loch, we feel it is of relevance to show how they dispute one key point of the ROA introduced by Dixit and Pindyck in 1994 when this approach is applied to innovation. In 1994, Dixit and Pindyck stated "(...) higher uncertainty in the payoffs of the investment increases the value of managerial flexibility, or the value of the real option (...)". Through different information sources the later writers find the relation established between the presented above sources of uncertainty/risk and the value of managerial flexibility is not clear in innovation and R&D projects, so much that it can reduce the real option value instead of enhancing it. Huchzermeier and Loch then proceed to institute a duality based on when the uncertainty and risks sources over the project are resolved before or after decisions are taken. If uncertainty is resolved before decision making, managerial flexibility can be applied to protect an organisation against the downside scenario which implies a greater degree of value attached to the real option; while, in case uncertainty is resolved after decisions are made or whether it reduces the chances that managerial flexibility can be of use, it minimises the option value of flexibility since more variability diminishes an organisation's capability to respond.

Parallel to the usual methods of evaluating "typical" real options, the ROA on innovation requires some adaptations to contain the specificities of this type of project and in order to righteously propose evaluation. In this part of the literature review, we introduce the reader to the *Dynamic Programming Approach* developed by Huchzermeier and Loch to evaluate real options when used in innovative processes. The model computes the value V of the project at each moment t through the following equation system:

$$V_{(t,i)} = \begin{cases} 0, & Decison: Abandon; \\ -c_t + \dfrac{p.V_{(t+1,i+0.5)} + (1-p).V_{(t+1,i-0.5)}}{1+r}, & Decison: Continue; \\ -c_t - d_t + \dfrac{p.V_{(t+1,i+1.5)} + (1-p).V_{(t+1,i+0.5)}}{1+r}, & Decision: Improve. \end{cases} \tag{12}$$

Note: the values $i = 0.5$ and $i = 1.5$ assume that in the decision to continue the project's value can go up or down by 0.5 with probability p or $(1-p)$; or, in the decision to improve the project may improve by 1.5 or 0.5 with probability p or $(1-p)$, respectively. These values can logically be different depending on the assumptions one makes for the analysis.

Now it is important to understand what is behind this equation and carefully define the variables.

The probability *p* is obtained through:

$$p_{i,j} = \begin{cases} \frac{p}{N}, & if\ j \in \{i+\frac{1}{2}, \dots, i+\frac{N}{2}\} \\ \frac{1-p}{N}, & if\ j \in \{i-\frac{1}{2}, \dots, i-\frac{N}{2}\} \\ 0, & otherwise \end{cases} \tag{13}$$

The authors generalise the binomial distribution by allowing a project's success or unsuccess to be distributed over the next N performance scenarios with transitional probabilities.

This distribution mean is $((N+1)/4(2p-1)+i$ and its variance is given by $((N+1)/8[N/3 + (N+1)$ $(⅓ - (((2p-1)$ $\text{^}2)/2))$. Over this probability's topic, Huchzermeier and Loch (2001), define an especially relevant scenario around the case where $p = 0.5$, linking theprobabilities topic to the expected value $E[i]$ for performance level i at time $t = 0$, meaning that the project plan is initially unbiased if $E[i]$, at time $t = 0$, equals zero. Two cases arise from this deduction:

- If $p > 0.5$, the project plan is "pessimistic" and implies that the true expected performance level at launch ($t = 0$) is $E[i]$ > 0;
- If $p < 0.5$, the project plan is "optimistic" and implies that the true expected performance level at launch ($t = 0$) is $E[i]$ < 0.

The authors present a 3-option case at each stage for the management team, each one having different associated costs, where c_t represents the continuation costs just to keep a team holding the innovation endeavour and d_t represents the costs to take further developments on what the firm has at time t. Typically, improvement costs will be higher as the project becomes clearer and closer to reality. This happens because it gets harder to improve and increase existing features, if one considers these p is then given by:

$$p_{i,j} = \begin{cases} \frac{p}{N}, & if\ j \in \{i+1+\frac{1}{2}, \dots, i+1+\frac{N}{2}\} \\ \frac{1-p}{N}, & if\ j \in \{i+1-\frac{1}{2}, \dots, i+1-\frac{N}{2}\} \\ 0, & otherwise. \end{cases} \tag{14}$$

Some themes remain equal to traditional option analysis: to enter a project initial cost $\boldsymbol{X}$ must be covered by a company, costs and revenues should take into consideration the time-value of money getting discounted at the risk-free rate $\boldsymbol{r}$. Project's continuation or improvement costs are to be paid at the start of each period and the project is launched at time $\boldsymbol{T}$ generating its payoffs depending on its performance degree $\boldsymbol{i}$.

Considering we are now taking into analysis Products & Services and Processes innovations,a small extension must be performed to the types of payoffs a project can result in:

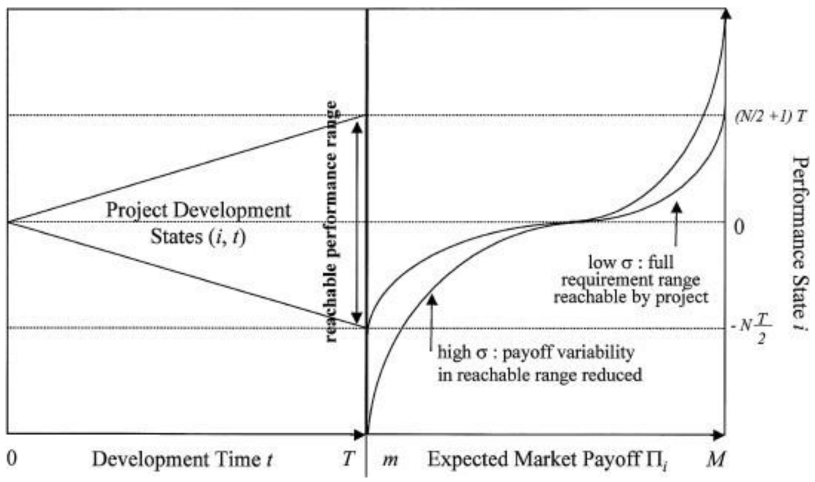

Figure 7. Relation between project's development and payoffs.

Source: Huchzermeier and Loch (2001).

Notes:

1. Here, the Expected Market Payoff can also take the form of Expect Operational Payoff, either through production/number of provided services capacity or a decrease in costs and/or time.

2. The fact this function takes a convex-concave shape is an important property, since the authors show it as the essential driver of how the "(...) performance variability "washes out" payoff variability." preposition.

All the above being stated and explained, we are now in the position to correctly proceed with the valuation of a real option on innovation according to this methodology.

This is simply another adaptation of the binomial model with the use of the backwards-looking induction considering the possible scenarios created by each of the available decisions at each point in time.

3. Hypothesis

As mentioned before in this dissertation, the hypothesis this study leans over is if whether it is always logical to keep improving a product or service/keep investing on a process when compared to launching it in an earlier stage for it to start presenting results, obviously at a point where it already can meet the necessities it was set out to give response to.

Presenting an analogy to the real world, a company may be able to create something that is tremendously innovative and disruptive but sometimes it will not match the real market needs at a certain point in time, possibly being replaced by a simpler solution. One can easily translate this analogy to the innovation that relies upon the production processes.

Setting out an example of how it may be better to improve a project until a certain point where it is ready to be launched, we would like to analyse the *Apple Inc.* present way of operating on new releases of the *iPhone* device.

Ever since the early days of this product, the company would release two versions of the same model, the reader may be able to remember the 3G and 3GS or the 4 and 4S. These would basically be the same device, but one would incorporate optimised features. The company kept this process up. Nowadays they variate a similar product in diverse ways such as size, memory capacity, camera quality among others. Sometimes, they even relaunched a past model with adaptations. One of the latest models, the iPhone 12, has 4 versions available in the market: 12, 12 Mini, 12 Pro and 12 Pro Max.

The innovative process is the same for all these versions, what remains to be done is the adaptation and inclusion of certain features that may be able to segment the market within a single product, this results in different customer targets and, therefore, different sources of income.

The company launches the products when the project team feels it is ready to succeed in the market, we know they could keep improving it, and they are going to in the future model, but at that certain point in time the developing team perceives it is adequate to launch.

This type of process can be confronted with various questions, science assumes that one of its own characteristics is that a theory should be open to debate.

This dissertation's fundamental question is:

What are the gains of launching results earlier than planned and in a lower development stage, and how can the ROA play a role in this matter?

Following this section, we present the reader with an *Excel* example to illustrate this and analyse its results.

4. Methodology

Once again, we would like to recall the reader that the proposed methodology to test the hypothesis is an extension to the Huchzermeier and Loch (2001) model.

As such, firstly, we are going to present an example of this very same model and how we have proceeded to compute it in Excel. The example comes adapted from Costa and Paixão (2014),these authors analyse real options applied to innovation and equate the existence of a company's budget to choose how to allocate resources through the projects. For the intended purpose of explaining on how the model acts, we are only going to pick one of the projects out oftheir 2014 paper.

After the explanation we will present both the case study and the application of our proposed model, carrying the reader throughout the steps and presenting all the variables involved.

4.1. Costa and Paixão (2014) example and the use of Huchzermeier and Loch (2001) model

Keeping in mind that although there is a *Dynamic Programming Approach* proposed by Huchzermeier and Loch to evaluate the use of real options on innovation, we are going to follow the trinomial tree path to evaluate these.

begin

$V(m,i) \leftarrow \pi(i),\ i \in P_m;$

for $t = m-1$ **to** 0 **do**

for $i \in P_t$ **do**

$$V(t,i) \leftarrow Max \begin{cases} 0, & \text{(decision : abandon)} \\ -c_t + \frac{p \times V(t+1,i+0.5)+(1-p)\times V(t+1,i-0.5)}{1+r}, & \text{(decision : continue)} \\ -c_t - d_t + \frac{p \times V(t+1,i+1.5)+(1-p)\times V(t+1,i+0.5)}{1+r} & \text{(decision : improve)} \end{cases}$$

end;

end;

end.

Figure 8. Dynamic Programming Procedure of Huchzermeier and Loch (2001). Source: Costa and Paixão (2014).

To properly start the explanation, we must introduce the built assumptions in order to modeltheir work.

a. Similarly, to Huchzermeier and Loch, they assume that the performance level i in each period t $(t = 0, \ldots, m-1)$, follows a binomial distribution, independently of the path followed during the development of the project. Specifically, the product performance level in period $t = 0, \ldots, m-1$ for the period $t+1$;

b. For each period $t = 0,\ldots,m$, they define the system of product performance states by (t, i).

c. They set out three possible scenarios for the project's course after each decision, as well as three possible decisions: Abandon, Continue and Improve. This results in two existent trinomial trees.

One for the performance level i built under the possibilities for the project of:

i) Improving in $1/2$, with probability p, or decreasing by $1/2$, with probability $1 - p$, when a "Continue" decision in taken; or

ii) Improving in $3/2$, with probability p, or improving only by $1/2$, with probability $1 - p$, with an "Improve" decision; or

iii) An "Abandon" decision will result in a throw of what was achieved so far, retrieving a null value for the company when analysing outcomes, although what was invested so far will represent a loss.

d. *Ad hoc*, the probabilities are going to be simply $p = 50\% = 0.5$ and, consequently, $1 - p = 50\% = 0.5$;

e. Number of periods $m = 3$;

f. The expected market return is given by $\pi(i) = u + F_{i} \cdot (U - u)$.

Here we must present a deeper insight of what supports this equation and the involved parameters:

i. $[u, U]$, u and $U \in \mathfrak{R}$ is the existing range of possible returns for the project, in this one the range is $[5{,}490]$;

ii. D comes as a random variable representing the level of performance required by the market for a project. The authors assume that D follows a normal distribution with parameters $\mu = 0 \; and \; \sigma = 2$;

iii. c_t and d_t represent, respectively, the continuation and improvement costs set to occur at each time t in the project under analysis;

Period *t*	c_t	d_t
0	10	17
1	26	32
2	39	64

Table 1. Project costs for each moment and related with which decision. Source: Own work, developed in MS Excel. Based on Costa and Paixão (2014).

iv. I is the initial investment required to start the project, basically the resources needed to start working on an endeavour, for this project it amounts up to a value of 87;

v. F_i is the probability distribution function for the D random variable with the presented above parameters;

g. Risk-free interest rate r is equal to 8%.

Taking into consideration all the above assumptions, one can sketch the trinomial tree for the performance level i:

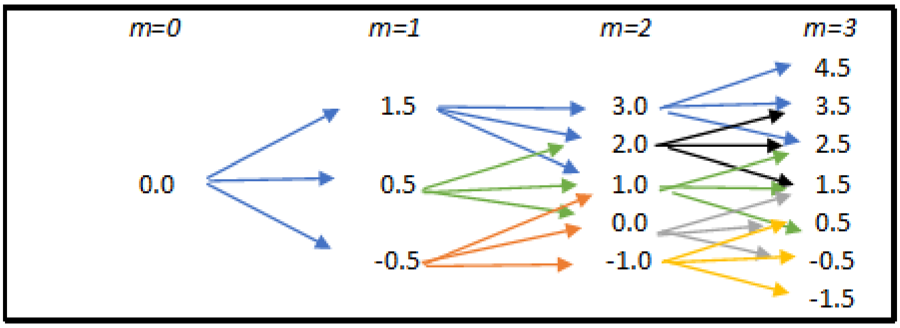

Figure 7. Trinomial tree for the Performance level i of the project under analysis. Source: Own work, developed in MS Excel. Based on Costa and Paixão (2014).

As previously mentioned in *Literature Review* chapter, the evaluation model in itself is given by the following system:

$$p_{i,j} = \begin{cases} \frac{p}{N}, & if\ j \in \{i + 1 + \frac{1}{2}, \dots, i + 1 + \frac{N}{2}\} \\ \frac{1-p}{N}, & if\ j \in \{i + 1 - \frac{1}{2}, \dots, i + 1 - \frac{N}{2}\} \\ 0, & otherwise. \end{cases} \tag{12}$$

We now have all the necessary tools to evaluate the project and the real option, which we have formulated in *MS Excel*, obtaining the same results as Costa and Paixão (2014).

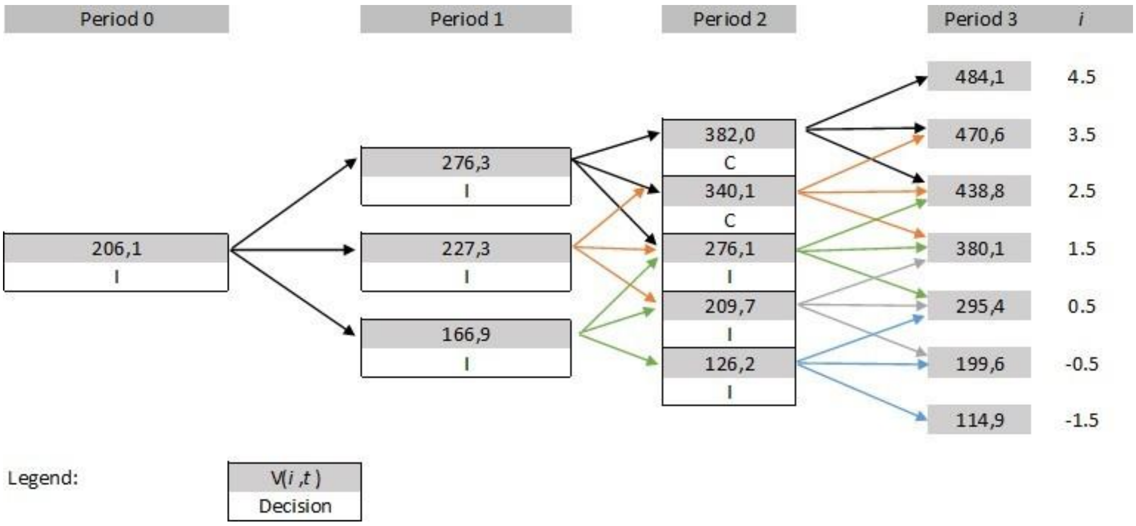

Figure 8. Trinomial tree for the value $V(i, t)$ of the project at each point in time.

Source: Own work, developed in MS Excel. Based on Costa and Paixão (2014).

Let us now pick the situation where the project would achieve, at time $t = 3$, a performance level i of 3.5 when the project follows the $(206.1; 276.3; 340.1; 470.6)$ value path and lean over this case in a way as to understand the values:

Period *t*	0	1	2
df (discount factor)	1	0.925925	0.857338
*df * Cost*	104	29.6296	33.4361
DCF Value	167.0657		

Therefore, at time $t = 0$, the option's value would be of $206.1 - 167.0657 = 39{,}0343$. Without managerial flexibility, the project's static NPV would be of $470.6 - 167.0657 = 303.5343$. Once we add the use of the real options approach, the now strategic NPV is equal to $303.5343 + 39.0343 = 342.5685$.

Hopefully, by now, the reader is familiar and able to understand the dynamics of the Huchzermeier and Loch (2001) valuation methodology, here exemplified with an adapted example from Costa and Paixão (2014).

Having all this explained, we now invite the reader to understand the proposed theoretical and practical extension. On a last note, in terms of parameter definitions and the used symbology, we will carry on with the ones presented so far.

4.2. Proposed methodology extension and example

This section is the most relevant one of this dissertation, where we gather and articulate all that was mentioned during the paper and how this can result in a new methodology and approach to be used by innovative companies.

We'll start by presenting the problem that serves as a numeric example and a basis for the afterwards analysis.

a. Problem

A company, let us name it *Megatech inc.*, operates in the computer software and devices market, which we all know to be a perfect competition one.

The company is considering taking on a new endeavour to be commercialised and to penetrate in the market. Obviously, they'll have to add features and attractive innovations in order to capture the target's attention and stand out from the other competitors. One other thing the company has to equate is the time at which they will be able to launch the new device.

The project planning department came up with the following process for the project:

i. The device is to be developed in six stages, by chronological order: two for hardware and components testing (HT), two for software development (SD), and two last ones for the product's design conception (DC);

ii. There is a chance to skip the last stage, one of the design conception ones in case the company agrees the device is ready to enter the market and succeed. This is the case scenario where there would not be much in terms of project's gains by taking on the costs of one other designing phase;

iii. In what concerns costs, the initial investment needed to set up the work environment and allocate the company's resources to this project is € 1,000 million.

Then the team predicts the following cost structure to incur during the project itself:

m	*Stage*	c_t	d_t	$c_t + d_t$
0	HD-1	150	130	280
1	HD-2	180	160	340
2	SD-1	140	120	260
3	SD-2	160	140	300
4	DC-1	120	100	220
5	DC-2	140	120	260

Table 2. Project costs for each stage depending on the team's decision at each point in time.

Source: Own work, developed in MS Excel.

Note: figures in € million.

This table allows us to conclude that to continue the project the company will incur the c_t cost amount, while when the decision is to improve, these costs will be augmented by d_t and the company will have to invest the sum of both values to proceed with the decision;

iv. The project is to be developed over the period of one year, each stage having two months, therefore $m = 6$, and $T = 1$ year;

v. The *risk-free interest rate* r is equal to 6%, combining this with the bullet point iv., we can calculate $\Delta t = \frac{1}{6} \simeq 0.1667$, we can now obtain the *risk-free interest rate per period* which equals $\Delta t \times r = \frac{1}{6} \times 6\% \simeq 1\%$;

vi. At $t = 0$, i.e., at the beginning of the project, the performance level i is equal to 0, and the scenario distribution after each decision is given by:

- May improve in 0.6, with probability p, or may decrease in 0.6, with probability $1 - p$, in the continuation decision; or,
- May improve in 1.3, with probability p, or may improve in 0.6, with probability $1 - p$, in the improvement decision case.

vii. The $[\mathrm{u}, \mathrm{U}]$ range is between the values of $u = 58$ and $U = 5{,}632$;

viii. The expected market return is given by $\pi(i) = u + F(i)x(U - u)$, where D follows a normal distribution with parameters $\mu = 0$, $\sigma = 2$, D standing for a random variable representing the level of performance required by the market for the project;

ix. Once again, the ad hoc probabilities p and $1 - p$, come as a simplified value, each one being equal to 0.5.

Starting by showing the performance level i trinomial tree, the following is obtained:

$m=0$	$m=1$	$m=2$	$m=3$	$m=4$	$m=5$	$m=6$
						7.8
					6.5	7.1
				5.2	5.8	6.4
			3.9	4.5	4.6	5.2
		2.6	3.2	3.3	3.9	4.5
	1.3	2	2	2.6	2.7	3.3
0	0.6	0.7	1.4	1.4	2	2.1
	-0.6	0.0	0.1	0.8	0.8	1.4
		-1.2	-0.6	-0.5	0.2	0.2
			-1.8	-1.2	-1.1	-0.4
				-2.4	-1.8	-1.7
					-3	-2.4
						-3.6

Figure 9. Trinomial tree for the Performance level i of the project under analysis.

Source: Own work, developed in MS Excel.

Getting back to the estimated market returns equation $\pi(i) = u + F(i)x(U - u)$, and adapting it to the project's inputs, for this example $\pi(i) = 58 + N(i) \times (5632 - 58)$ and considering the possibility to early launch the project into the market, there are 24 possible outcomes:

i	$\pi(i)$	i	$\pi(i)$
-3.6	228.5726	2.1	4,813.4076
-3	430.3833	2.7	5,138.6565
-2.4	699.3983	3.3	5,356.246
-1.8	1,083.9511	3.9	5,489.3722
-1.7	1,159.771	4.5	5,563.8608
-1.1	1,680.9241	4.6	5,572.2238
-0.5	2,294.8109	5.2	5,606.0185
0.1	2,956.1389	5.8	5,621.6
0.2	3,067.0004	6.4	5,628.1699
0.8	3,711.3208	6.5	5,628.7837
1.4	4,283.2946	7.1	5,630.9264
2	4,747.6556	7.8	5,631.7319

Table 3. Possible project's market returns.

Source: Own work, developed in MS Excel.

Note: figures in € million.

One can compute the project's value at each moment, taking into consideration the decisions taken at each point and now incorporating the possibility to early launch the result at m=5

The system of equations (12) will now be the same for every moment except for the one where the company can exercise the new possible decision.

For this specific problem, at m=5, the value will be given by a four-branch maximization equation system:

$$V(i,5) = Max\ (0; -c_t + (p.V_{(t+1,i+0.5)} + (1-p).V_{(t+1,i-0.5)})/\ (1+r); -c_t - d_t + (p.V_{(t+1,i+0.5)} + (1-p).V_{(t+1,i-0.5)})/(1+r); \pi_i) \quad (15)$$

Combining all the above prepositions, the following trinomial tree for this project is obtained, and as it is possible to confirm, in quite a few cases, it shows that it may be more advantageous to early launch the product onto the market:

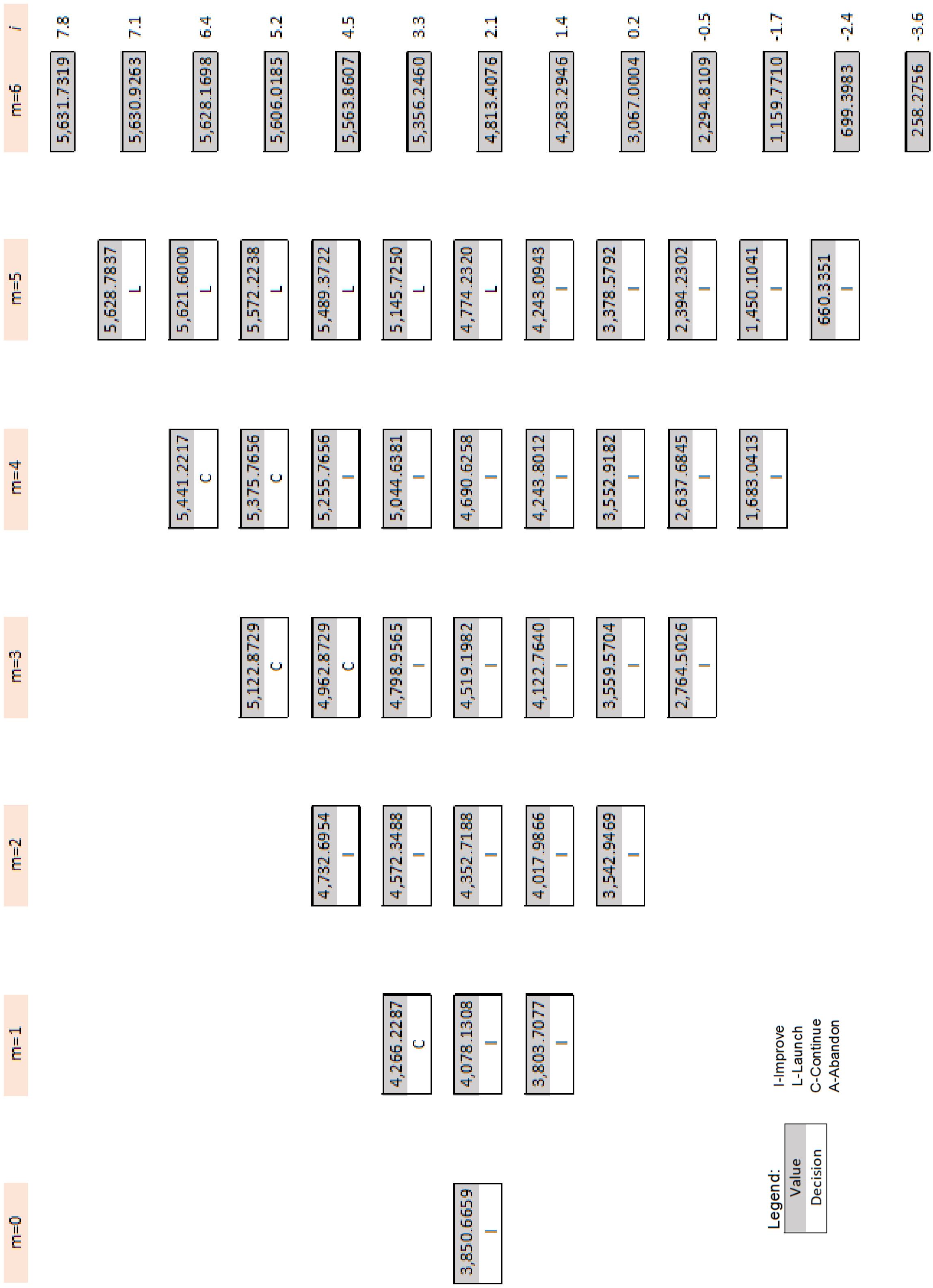

Figure 10. Trinomial tree for the value $V_{(i,t)}$ of the project at each point in time.

Source: Own work, developed in MS Excel.

A big question remains to be answered:

What is the financial and economic rationale behind all these numbers?

We chose to pick 3 different possible outcome scenarios and to perform an analysis of their discounted cash flows, the option value in each case and consequently both the static and strategic NPV. The reader will be able to better understand the financial thinking process behind the analysis by matching the analysis with what was shown so far regarding this specific problem.

b. Analysis

i. Present value (PV) of investment

	Time						
Scenario 1	0	1	2	3	4	5	Launch at m=6, V(7.8;6)=5,631.7319
df (discount factor)	1.0000	0.9901	0.9803	0.9706	0.9610	0.9515	
df*Investment	1,280.0000	336.6337	254.8770	291.1770	211.4157	247.3811	
PV of Investment	2,111.7305						
Scenario 2	0	1	2	3	4	5	Launch at m=6, V(2.1;5)=4,813.4076
df (discount factor)	1.0000	0.9901	0.9803	0.9706	0.9610	0.9515	
df*Investment	1,130.0000	158.4158	117.6355	135.8826	96.0980	114.1759	
PV of Investment	1,752.2180						
Scenario 3	0	1	2	3	4	5	Launch at m=5, V(6.5;5)=5,628.7837
df (discount factor)	1.0000	0.9901	0.9803	0.9706	0.9610	0.9515	
df*Investment	1,280.0000	158.4158	254.8770	135.8826	96.0980	0.0000	
PV of Investment	1,925.2735						

Table 4. Present value of investment analysis for the project costs depending on each decision and for 3 possible scenarios.

Source: Own work, developed in MS Excel.

Notes: figures in € million and negative values since these are cash outflows.

Scenario 3 is the one that serves to exemplify the possibility of early launching the product, let us focus on how it unravels compared to the others. Scenario 1 is the "always improve" case while Scenario 2 is the "just continue" company's mindset over the project.

ii. Real Options approach

We proceed by presenting a table where the reader can analyse the key values that are obtained through the ROA.

The terminal value (TV) of the project will be dependent on the performance level i at which the project launches its results.

For the scholar interpretation of this problem, one last assumption remains to be inferred, that of the traditionally seen static project cash-flows without flexibility V_t is equal to $4{,}500.0000$ in the inexistence of flexibility, while the $PV(Investment)$ under this scope would be of $2{,}000.0000$.

This way, the static NPV would be given by:

$$Static\ NPV = -PV(Investment) + V_{(i,\,t)}\ , \tag{16}$$

resulting in a $Static\ NPV = 2{,}500.0000$.

In the case where there is the presence of managerial flexibility, the $Strategic\ NPV$ is given by $V_{(0,0)}$ obtained in *Figure 10*: €$3{,}850.6659\ million$.

The $Option\ value$ is given through the following formula:

$$Option\ value = Strategic\ NPV - Static\ NPV, \tag{17}$$

this meaning that the managerial flexibility in this project is valued at €$1{,}350.6659\ million$.

Then, we proceeded with a comparison of which scenario would be the one to differ the most, in terms of return surplus, from the case where no managerial flexibility was to be involved, obtaining the following results:

Project's return	
Scenario 1	5,631.7319
Scenario 2	4,813.4076
Scenario 3	5,628.7837
PV(Investment)	
Scenario 1	2,111.7305
Scenario 2	1,752.2079
Scenario 3	1,925.2735
3) The static NPV would be of:	
2,500.0000	
4) The strategic NPV would be of:	
Scenario 1	1,020.0014
Scenario 2	561.1997
Scenario 3	1,203.5102

Table 5. Project's return surpluses compared to the static NPV.

Source: Own work, developed in MS Excel.

Note: figures in € million.

At this point, we would like to call the reader's attention to the surplus of Scenario 3 and how it turns out to be a bigger value than for the other two possibilities.

In order to numerate on how much the proposed model extension adds value to the real option when compared to the one developed by Huchzermeier and Loch (2001), we valued this option through both models, the latter one valuing it in approximately €$1{,}283.3364\ million$, a smaller value than the one obtained through our valuation proposal.

This proves that for this specific problem, early launching constitutes a viable decision and a valuable possibility.

Lastly, for this problem we have decided to perform two sensitivity analysis to understand on how its expected market returns would fluctuate through a modification of the normal distribution parameters.

This serves to perceive how changes in the project itself or in surrounding factors could affect what is now being assumed and the obtained calculations.

The conclusions to take out of the following *MS Excel* sensitivity analysis tables can be resumed to two statements:

- With an increase of the normal distribution's *standard deviation* for the project in analysis it is expected that for the same performance level i the project will return lower market returns π_i; and,
- With an increase of the normal distribution's *mean* for the project under analysis it is to expect that for the same performance level i the project will retribute lower market returns π_i.

This may come as a logical conceptual understanding in the way that with higher involved risk σ, the same performance level i due through its exposure to higher volatility is expected to result in lower payoffs than those it would obtain in a less risky environment. In terms of the performance level i mean indicator μ, the explanation is set up on whether the performance level i of a project is below, above or at the mean value obtained for the population under analysis, as the mean increases, a project by presenting the same performance level i is expected to return lower returns.

On a last note, for the analysis, we have only included the performance levels for the three mentioned scenarios.

i. Standard deviation

	Scenario 1	Scenario 2	Scenario 3
5631.7319	7.8	2.1	6.5
1	5632.0000	5532.4237	5632.0000
2	5631.7319	4813.4076	5628.7837
3	5606.0185	4283.2946	5547.6646
4	5489.3722	3960.9616	5341.6989
5	5301.0162	3752.2090	5092.4341
6	5092.4341	3607.6940	4855.3732
7	4893.0085	3502.2383	4647.8790
8	4713.5156	3422.0874	4471.2012
9	4555.8705	3359.1943	4321.6700
10	4418.5656	3308.5682	4194.7658

Table 6. Standard deviation sensitivity analysis.

Source: Own work, developed in MS Excel.

Note: figures in € million.

ii. Mean

	Scenario 1	Scenario 2	Scenario 3
5631.7319	7.8	2.1	6.5
-4	5631.99999	5625.622191	5631.9996
-3	5631.999814	5601.977622	5631.9943
-2	5631.997329	5519.504331	5631.9404
-1	5631.96983	5294.378595	5631.5072
0	5631.731911	4813.40762	5628.7837
1	5630.1220	4009.0759	5615.3908
2	5621.6000	2956.1389	5563.8608
3	5586.3069	1877.1040	5408.7103
4	5471.9339	1011.4668	5043.1082
5	5181.8624	467.8521	4368.7791
6	4606.0489	200.6278	3395.1891
7	3711.3208	97.8140	2294.8109
8	2622.9996	66.8564	1321.2209
9	1586.6869	59.5624	646.8918
10	814.2026	58.2178	281.2897

Table 7. Mean sensitivity analysis.

Source: Own work, developed in MS Excel.

Note: figures in € million.

5. Results and conclusions

So far, we have shown that the early launching decision makes sense, but we do feel that a bit more of economic and financial theories insights are due.

The numeric part being exemplified and analysed, we would like now to look at the conceptual component that could explain corporate reasonings to launch a project's result before it would eventually reach a final and more developed stage.

In this section, we will try to establish a link between the *Literature review* and the presented problem to test the proposed methodology and highlight three main concepts in order to explain why it does make sense in a theoretical way.

Starting by one of the basics of economics and finance, we do have the *time value of money*. This is a simple understanding that money is worth more at an earlier point in time that in a later one, this involves the discounting of cash flows and the less they are discounted the higher they will be worth at a present time. In a project, this happens if it starts retrieving results earlier than what was defined in the planning phase, which is also an indicator that the company performed well in developing the specific endeavour.

Secondly, we would like to once again bring into discussion the *game theory* and the perfect competition markets scenario. In the presented problem for discussion of the proposed methodology, one of the characteristics was that *Megatech inc.* was inserted in a perfect competition market, the technological one of computer software and devices. In the *Literature review*, we have introduced the idea that innovation represented a key success factor and competitive advantage for companies that would have to fight for their place in the market while in a monopolistic scenario, innovation is not a main concern since there is not much of a threat to the company's leadership. In the problem, by exercising the early launching decision, *Megatech inc.* could also take into consideration the game theory specifically the case where in an innovative environment, the so-called static game theory evolves to a dynamic one where players leave aside the notion of Nash equilibrium and aim to achieve an *ESS* (evolutionary stable strategy) (Smith and Price, 1973). Reminding that this is the desired position for players to be in an ever-changing and evolving domain, since they would be a step ahead of other competitors.

Lastly, a company should always take into consideration its stakeholders in this type of decision and work cooperatively with all of them in a way as to take into consideration their inputs and satisfy them with the results. What this means is that different types of stakeholder will have different views and desires on what is to be done at each moment, the use of real options on an innovation project can enhance their decision power and decentralise it.

This is a way to integrate every involved entity in the project and create a team mentality, these concepts play a big role in today's corporate world.

To conclude, real options approach applied to innovation is a useful financial framework as previously shown by authors since managerial flexibility is one of the keys to success in this type of project.

Having all the above displayed, we believe in the relevance of our contribution to the existing evaluation models, both in mathematical and theoretical purposes.

A final consideration we would like to leave the reader with is that both for companies and countries, innovation is one of the keys to a better world and opens the doors to the never-ending possibilities that we, humans, thrive upon due to our willingness to reach the next social and economic levels when keeping in mind that there is always room to perform improvements to what we know and have at each moment.

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