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The Real Options Component of Firm Market Value: The Case Of US High Tech Companies

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Biographical Note

Lucélia Maria da Silva Graça was born in Braga, 1998. She completed the BSc in Management in 2020 at the Faculty of Economics of the University of Coimbra. She also studied for a semester in Brno, Czech Republic, at the University of Technology, under the Erasmus program.

After completing the bachelor's degree, Lucélia enrolled in the Master in Finance program at the School of Economics and Management of the University of Porto. The present dissertation is regarded as the last stage of the Master.

Between October 2021 and March 2022, Lucélia was an intern at a North American Hedge Fund – Creighton AI – headquartered in Newport Beach, with team members in Porto.

I dedicate this dissertation to my grandmother,
Maria Teresa Macedo Couto,
and to my mother,
Eduarda Maria Couto da Silva Graça,
who always believed in me.
Even when my soul was weakened and without light,
they always saw me enlightened.
Even when sadness and tiredness were my allies,
they always knew I would make it.
If I'm still standing today,
it's because they put my pieces together every time.
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Now? Now it's time to be a Master!

"Without commitment, you'll never start, but more importantly, without consistency, you'll never finish!"

Denzel Washington in NAACP Image Awards – 2017

Abstract

Like many other innovations, the Theory of Real Options has been increasingly implemented in predicting the value of investments. However, little research has been done and little empirical evidence explored, on how to quantitatively measure these options. This dissertation contributes to the scarcity of studies in this field as well as to the evolution of the financial world, which until then, has been a little reluctant to use different models, other than the conventional ones.

Therefore, we quantitatively test if the value of real options can be estimated through the fraction of the market value of companies that does not correspond to their assets in place. The sample consists of 35 American high-tech companies, listed on the NASDAQ market, analysed between December 31st, 2009, and December 31st, 2019, inclusive.

From our results, we found that the research and development activity, the stock beta and the skewness of stock returns have a positive relationship with the proportion of real options present in companies and the financial leverage and size a negative relationship. Our findings corroborate the majority of the existing literature, however, the sign we obtain in the variable used as a proxy for company size goes against what previous authors have been finding in other studies.

Keywords: Real Options, Tech Companies, Python Language, R&D, Stock Beta, Skewness, Financial Leverage, Company Size, NASDAQ, US

JEL Codes: C01, G11, G32, L86, N72

Sumário

Como muitas outras inovações, a Teoria das Opções Reais tem sido cada vez mais implementada na previsão do valor dos investimentos. No entanto, pouca pesquisa foi feita e pouca evidência empírica explorada sobre como medir quantitativamente essas opções. Esta dissertação contribui para a escassez de estudos nesta área, bem como para a evolução do mundo financeiro, que até então, se mostrava um pouco relutante em utilizar modelos diferentes dos convencionais.

Assim, testamos quantitativamente se o valor das opções reais pode ser estimado através da fração do valor de mercado das empresas que não corresponde aos seus ativos no local. A amostra é composta por 35 empresas americanas de alta tecnologia, listadas no mercado NASDAQ, analisadas entre 31 de dezembro de 2009 e 31 de dezembro de 2019, inclusive.

A partir dos nossos resultados, descobrimos que a atividade de pesquisa e desenvolvimento, o beta alavancado e a assimetria dos retornos das ações têm uma relação positiva com a proporção de opções reais presentes nas empresas e a alavancagem financeira e tamanho uma relação negativa. Os nossos achados corroboram a esmagadora maioria da literatura existente, porém, o sinal que obtemos na variável utilizada como proxy para o tamanho da empresa vai contra o que o que alguns autores têm evidenciado em outros estudos.

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Chapter 1

Introduction

"There are no easy methods
to solve difficult problems."

René Descartes

The blind trust of experts and academics in conventional financial valuation models is a long-running debate in financial markets. The Discounted Cash Flow (DCF), which has been discussed in finance books or academic classes for years, shows its limited accuracy in valuating financial investments in practice. However, distrust in this and other traditional models is nothing new. For some decades now, decision-makers have seen this as an obstacle to innovation, efficiency and competitive advantage.

While the introduction of Option Pricing Theory (OPT) has been accepted by those who do not consider it the perfect replacement, it is far from being accepted in the corporate world without objections. The OPT incorporates the flexibility factor that no other model incorporates, making it possible to obtain more accurate results and with a higher probability of acceptance of a given project. The fact that this model attributes value to something that has not yet been effectively carried out, makes the corporate world reluctant to accept its introduction into their daily practices. Now, just as conventional models have their limitations, this model also has them. The problem arises from the complexity that a model would need to have, to capture all the possible factors that affect decision-making. In the contemporary inability to develop an even more complete model, which is not only possible to solve through red-level encryption computer programs, the best method is the Real Options approach (Kemna, 1993).

Currently, the increase in the literature supporting the Theory of Real Options has encouraged the theoretical development of risk-return dynamics. Thus, explanations emerged about the impact of the size factor and other factors on the real options value. In this way, and as suggested by the Theory of Real Options, the assessment of the total value of a company results from the sum of its current assets and its real options portfolio. It is believed that a significant part of the company's valuation corresponds to decisions that have not yet been taken, but that their future execution is sponsored by the company's resources without impediments. Although real options models are a good starting point for the evolution of financial valuation techniques, very few studies empirically contribute to the valuation of companies based on them. A substantial percentage of the companies present in the market do not use real options models in the valuation of investment opportunities. Despite this, studies indicate that companies that use these techniques perform better than those that do not (R. L. McDonald, 2000).

Typically, the investment opportunities that a company holds are not visible to agents who do not belong to the company. Thus, in order to estimate investment opportunities, the real options method can be used to assess the behaviour of proxy variables used in this valuation. It is believed that the closest value of these opportunities is defined by these variables, but knowledge about the performance of these proxies is scarce. Thus, it is estimated that so far, the best estimation index of investment opportunities is the market-to-book assets ratio (Adam & Goyal, 2008).

The assumption that goes hand in hand with conventional theories of decision-making is that investments are irreversible and do not have the opportunity to be delayed. However, this thought does not pay attention to the fact that some elements that help value growth in the investment system present a significant degree of uncertainty. Given the limitations it entails, future investment opportunities may be questioned, and the investors may be motivated by a decrease in their investment (Zhou & Yin, 2021).

The present dissertation contributes to the expansion of the scarce current evidence on the market estimate of the real options portfolio and to the provision of yet another empirical study that can be used, improved and/or an engine for future analyses. In addition, we intend to collaborate with the evolution of the financial area, which is increasingly evident, abandoning the unilateral and irrevocable view that only conventional models and techniques – Net Present Value (NPV), DCF among others – work and start to broaden minds by assuming that more recently developed models can be a supplement or, perhaps, a replacement for existing ones.

Evidence on this topic is insufficient, especially when the companies under study are from the technological sector. However, some studies have appeared to support this gap in the literature, such as Damodaran (2001), who among explanations of some of the variables contained in this dissertation, defines the concept of a technology company. The preference for this industry involves two main points that converge to the points addressed by De Andrés-Alonso et al. (2006). First, companies in this market expect to reveal a large dimension of their value associated with real options. This characteristic is interesting because, when compared to other sectors, technology companies tend to have higher market values. Secondly, directing the study to just one sector will allow us to isolate the impact of certain elements directly related to the company. Despite all this scarcity of evidence, more specifically in the area of R&D with real options, empirical research on real options in other industries and areas is abundant. Examples include real estate (Lucius, 2001), strategic management (Trigeorgis & Reuer, 2017), projects (Wang & de Neufville, 2005), joint ventures (Reuer & Tong, 2005), human capital investment (Jacobs, 2007) among many others.

World development would not be the same if the fourth industrial revolution were not a trend. Technological innovation is the main impetus for the evolution not only of the world but specifically of the United States of America (USA) since it is a leading country due to its powerful technological industry. This is a country that not only has the largest economy in the world but also leads the number of start-ups created and the concentration of high-tech companies. It also represents number one in patenting. Both decision-making and business products and structures play a key role in the growth of high-tech start-ups (Mowery et al., 1996).

Approximately a decade of events is analysed so that the study has sufficient and robust data. The observation region (USA) has a particularly important footprint here since, in addition to this type of study having not yet been carried out there, it will make it possible to discover differences with existing studies in Europe, as well as to understand whether certain factors only have an impact in the proportion of a company's real options, given its location. Our sample comprises 35 US technology companies listed on the National Association of Securities Dealers Automated Quotations (NASDAQ) stock market from December 2009 to December 2019, inclusive. The period under analysis is based on a stable temporary window, without major events and/or catastrophes, capable of identifying patterns not arising from these extraordinary occurrences. The study is carried out after 2008, given that is the year that date the end of the financial crisis resulting from the fall of Lehman Brothers, and before 2020, given the Covid-19 pandemic at the time.

This dissertation is organized as follows. Chapter 2 is dedicated to reviewing the relevant literature to the study. Chapter 3 corresponds to the methodology that we will use, to later apply the data. Chapter 4 is the description of the sample and interpretation of the results. Chapter 5 is the concluding remarks that summarize the entire study.

Chapter 2

Literature Review

The flexibility represented by real options in companies gives them an advantageous strategic value in relation to others that do not have options. Kulatilaka and Marks (1988) compare two companies to demonstrate this. One of them only uses a fixed technology, while the other has a range of technology options. Predictably, the latter has superior strategic value.

There is a vast literature that shows that after a fall in companies' stock prices, the volatility of stock returns increases. This behaviour is due to the fact that returns and volatility present a positive relationship with each other. This correlation seems stronger for smaller companies with little financial leverage (Duffee, 1995). Thus, the market assessment of a company is composed of the sum of two elements: (i) the value of the existing business and (ii) the Value of Future Growth Opportunities (VGO). From this calculation, it appears that for technology-intensive companies, on average, 70% of its value corresponds only to the VGO. Given that Free Cash Flows (FCFs) are particularly complex to calculate for fast-growing companies, choosing the options approach – which is less tied to FCFs – is more suitable when compared to DCF-based techniques. The use of the options model allows companies and investors to obtain superior performance in their investments (Jägle, 1999).

The geographic location of companies is important to understand different strategies and performance. The fact that companies are based in different countries may explain the changes found in the value of growth options. In a study by Tong et al. (2008), 2,352 companies from 12 different countries were observed between 1997 and 1999, empirically showing that the value of growth options differs by country and sector. In their results, the authors show that the USA has the second-highest average value of growth options during the period under analysis, right after Chile. The countries in the sample represent 4 different continents – American, European, Asian and African – and the American continent is also the one with the highest average value of growth options. This study converges with Porter's line of thought, who stated years before that the limitations or opportunities of the business are not only linked to its means and competencies, but also to the environment that surrounds the company (Porter, 1991).

2.1 Real Options and the Conventional Investment Valuation Models

The importance of real options stems from the inability of traditional investment valuation models to take project flexibility into account. Since the emergence of this approach, through the studies of Black and Scholes, Myers to Copeland, the ineffectiveness of traditional models has been a crucial point of discussion in finance. Financial and business evolution has reached a point where its repercussion in the practical world is no longer a utopia, but a firm foothold in economies around the world. It is, therefore, crucial to continue to shape opinions so that future investment assessments are as accurate as possible.

The traditional NPV method, as well as others, can and often does give rise to calculation errors that cost the company deeply in the future. The incomplete valuation of investments through it defends two basic grounds that indicate that decision-making can only be taken today, or never. This exclusivity of choice is neither suitable nor advantageous for companies as it neglects not only the present value but also the future value of the uncertain investment (Ross, 1995).

The wide range of valuation methods capable of defining the value of return flows is nothing new. Assuming that the returns are certain, the model to be used is the discounted present value. However, things get more complicated when the returns are uncertain – which is most of the time – requiring the replacement of the conventional method with a more accurate one (Ross, 1978).

Growing dissatisfaction in the business and financial world with discounted cash flow techniques has led to an increase in literature and evidence on the value of flexibility. While some managers recognize that the existence of real options is an asset for the company, others see them as unfavourable, in the sense that the company must commit to a defined action plan. Busby and Pitts (1997) carried out a study with senior finance executives in the United Kingdom, whose position was in industrial companies, assessing the influence that these models had on their investment decisions. Although the overwhelming majority of executives remembered at least one moment when real options were crucial in the decision-making process, few of the companies had techniques capable of evaluating these same options *a priori*. An interesting feature found throughout the study was the reluctance that some of the respondents revealed to have about real options, due to their impact on organizational commitment to a project.

A question then emerges that many experts in the field have been trying to answer: why do not companies use the Real Options approach more often when making investment decisions? Lander and Pinches (1998) try to answer this conundrum by exposing three possible foundations. First, is the misunderstanding or lack of knowledge of the models currently used by corporate professionals. Second, is the possible transgression in the practice of the propositions that the model requires to be fulfilled. Finally, the usefulness of the model can be harmed when put into practice, as the necessary mathematics for the execution responds to the implementation of extra propositions. In the same article, the authors also identify 16 key areas of real options applicability, including R&D, competition, and corporate strategies.

The idealization of the concept of real options emerged in the 70s, as the value that depends on the company's future investment. Real options should not be confused with financial options, and the value of an investment project of a very uncertain nature is the sum of the project's NPV and the future real option. With this model, companies are entitled to investment decisions (Myers, 1977).

Although the concept of Real Options has several theoretical works on how to delineate and examine investment possibilities, the model is not widely used by corporate agents. Defer option, build time option, operational scale change option, abandon option, exchange options, growth options and multiple iteration options are the seven categories of real options presented by Trigeorgis (1993). The author explores flexibility as well as an option-based valuation approach, highlighting the importance of incorporating real and financial options into the model used along with a firm's financial and investment decisions.

Two important peculiarities of investment costs are their irreversibility and the possibility of deferral. That is, if the company chooses to invest now, the costs of that investment are expenses that cannot be recovered. Therefore, there is the possibility of deferring the investment – through real options – until conditions are as favourable as possible (Pindyck, 1990).

In 1994, in an interview with Harvard Business Review, Nancy A. Nichols (1994) questioned the CFO of the Merck company at the time, Judy Lewent, about how she valued her investments since traditional financial tools were not always profitable. The CFO confided that she was using an option valuation method, as it allowed her to enjoy the flexibility that conventional financial methods did not have. Judy Lewent claimed to be able to assess the uncertainty and to have the advantage of having a right to the research project, which she was not required to exercise. That is, at any moment in time, the company could abandon the research it was carrying out exercising its right. Hence, in the same interview, Lewent highlights other advantages that this approach brings that may not be palpable now but may be in the future. Even if Merck decides to abandon a project at a certain stage, there is value resulting from all the research so far, as they will have found scientific information that will be an asset in the future, or even for other projects.

There is a conviction in some literature that a fraction of the companies' market value represents their options portfolio. This means that the value lies in future decision-making, which, therefore, has not yet been carried out, but for which companies are prepared and have sufficient resources to do so. This possibility of deciding in the future whether an investment should be made or not gives investors and companies an advantage over competitors who do not have this option (Dixit & Pindyck, 1994).

Conventional investment valuation models imply that managers' strategic decisions cannot be postponed. In other words, the organization will lose the ability to invest in a given project forever if it does not choose to invest at this time. If the company chooses uninformed decisions or with uncertain points, it runs the risk that the entire investment project will be a failure. Therefore, in order for this not to happen, the company can postpone the investment decision until the moment when the information obtained is sufficient to justify the action (Dixit & Pindyck, 1995).

The decision to invest in a project whose acquisition is irreversible and comes with uncertainty is equivalent to giving up the possibility of investing in the future (R. McDonald & Siegel, 1986). With the decision to invest now comes the trade-off of not being able to do so in the future and therefore wasting all the time between now and the future that can be presented with essential information for that very decision. The real options approach responds exactly to this trade-off, giving the company the possibility to make the same decision, or a different one, about the same investment, in the future (Hsu & Lambrecht, 2007).

2.2 The Field of R&D

Since the 1980s, real options fundamentals used in R&D project management have been a growing topic. Projects in this area are characterized by their high risk and uncertainty features. Selecting the best R&D projects, or comparing projects with different results and risk levels, is a demanding task.

The analysis of research and development programs lacks the support of a technique or financial model that is sufficiently robust, but easy to understand, that allows professionals to assign an estimate to the R&D work. Given the uncertainty in this area about possible financial advantages for companies, it is difficult to obtain results with conventional valuation models. There is evidence that the extent of use of assessment methods, as well as the choice of R&D projects, has been less explored than it could be. Not many decades ago, Option Pricing Theory (OPT) was suggested as a valuation method, with potentially significant value additions for business management. In this way, the OPT closes this gap by providing relatively simple applicability, capable of evaluating R&D projects. The area of finance was the one that gave wings to this theory that was, and continues to be, empirically tested. However, the difficulty of evaluating R&D currently remains, given the scarcity of data in this field not available by companies, and the inability to estimate it as an investment or price. Despite this obstacle, it is plausible to carry out an estimation of these values only with the data currently available, performing a conversion of the expected future cash values, into estimated cash values with volatility considered (Newton & Pearson, 1994).

The debate on the real options model applied to R&D and Technology Management lacks in-depth knowledge and research. Most of the time, only the advantages that the model brings are highlighted and not its applicability in the real context. Although this method allows the valuation of projects in this area, and technology-related acquisitions that would not otherwise be possible, there is a dearth of empirical work around it, so its practical usefulness is assured (Perlitz et al., 1999). Given this present calculation difficulty in practice, companies often estimate the value of their growth options using R&D costs as a proxy (A. Bernardo et al., 2000).

Following the real options approach, the prediction is that R&D costs are linked to the returns of companies. In a study of British companies carried out by Al-Horani et al. (2003), the authors corroborate the previous assumption and highlight two important conclusions. First, they find a positive relationship between R&D activity and the cross-section of expected returns. Second, they suggest that considering this variable in their model gives their study explanatory powers.

The process used in high-risk or immature market projects, when it is not possible for companies to meet their financial objectives, is based on a real options approach. Given the difficulty of conventional methods in estimating the value of R&D, it is necessary to introduce another approach, in order to keep the team in this area motivated to continue to pursue business objectives. The ease of this approach is being able to include incentives that are not palpable, such as honour or job promotion, making the R&D team continue to be enthusiastic about performing the functions required by the company (Gao & Jiang, 2010).

R&D intensity can be defined as a proxy for a company's growth options. In this way and corroborating what Myers (1977) had previously stated, the greater the R&D expenses, the more accentuated the negative effects of leverage on the company's performance (Aivazian et al., 2001).

2.4 The Impact of Leverage

Myers' conjecture (1977) is based on two hypotheses. The first indicates that the higher the leverage, the worse the company's performance, which is measured through return on assets, sales growth and stock return. The second states that, in the unpredictability of industry growth opportunities, outstanding debt contributes more negatively to the company's performance, contrary to situations in which this growth is predicted or does not exist. In line with this thought, Aivazian et al. (2001) test the same hypotheses and highlight three key points. First, they corroborate that in the failure to forecast growth opportunities, the greater the leverage, the worse the company's performance. Second, the authors define growth through an analysis of the industry perspective, rather than the company as a singular body. Finally, they show that regardless of whether the sector's growth is predicted or not, leverage always presents a negative relationship with the company's value, contradicting the conjecture previously defined by Myers.

The differentiated growth of companies is a factor that deserves to be highlighted. When a company is in the growth phase of its life cycle, its value is undermined by growth opportunities (Anthony & Ramesh, 1992). Given the influence that debt has on investment decision-making, the implications on the market value of companies depend on the level of growth that the company has. In other words, when companies have high growth, leverage and corporate value are characterized by a negative correlation, however, the opposite happens when companies are low growth (McConnell & Servaes, 1995).

The company's ability to effectively generate options or, in other words, incur debt to multiply its profitability, is known as financial leverage. Underinvestment difficulties due to agency problems or financial obstacles will intensify with the presence of leverage. Likewise, investment options accounted for at market value will decrease as this factor increases (Callen & Gelb, 1999).

Debt can be a barrier to the efficient use of investment options and may even induce the option holder to wrongfully exercise it before the debt settlement date. This behaviour can be justified by the agency problems of companies that are caused when conflicts between shareholders and debtors arise (Childs et al., 2000).

According to Anderson and Garcia-Feijóo (2006), there is a negative relationship between stock market values and the degree of leverage. For companies characterized as large and with low book-to-market equity[1] (B/M) when investment accelerates before the categorization year, market values increase and the degree of leverage decreases. When companies are small and have high B/M the exact opposite happens. Cross-sectional and time-series regressions seem to be explained by investment growth.

Both growth options and the degree of leverage are factors that affect not only prices but, consequently, market returns. Although the existing literature portrays in a relatively simple way the result of growth options in the company's strategy, it is not verified in the stock return. The relationship between growth options and stock returns has been presented in the literature as being negative. The omitted stress/leverage elements may have the book-to-market ratio as a proxy (Trigeorgis & Lambertides, 2014).

2.5 Risk, Volatility and Uncertainty

Although some criticisms arise about the validity of Kester's model (Kester, 1984), he was a pioneer in defining the value of growth options, through the fraction of company capitalization that is not explained by assets in place. When deciding to exercise an option, time plays a particularly important role. The possibility for the decision-maker to postpone the investment, to be informed about future events, allows him not to incur costly and irreversible expenses. The longer the time between having the growth option and effectively exercising it, the greater the value of the investment. In situations where the project has a negative NPV, nothing is lost if there is a possibility of delay. That is, assuming there is a real opportunity for the project to have value in the future, it is worth keeping options for future exercise. Thus, it is deduced that the risk and the value of the growth option present a positive relationship.

Empirical evidence supports the hypothesis that the risk of a share is greater, the greater the fraction of the value of a share due to future investment options, *ceteris paribus*. An example of this behaviour can be shown through the analysis of high technology companies.

[1] According to the authors, large (big) companies with low book to market equity are represented by B/L and small companies with high book to market equity by S/H.

Given that companies in this industry have much of their value associated with opportunities for future growth, the risk of equities will naturally be greater than mature companies that have much of their value accounted for by the stream of earnings resulting from existing assets. The relationship between a company's beta – which measures systematic risk – and certain measures of growth opportunities is similarly positive for the reasons described above. This relationship does not seem to be affected by the incorporation of the company size variable, thus revealing independence between this variable and the stock risk due to growth effects (Chung & Charoenwong, 1991).

A rational R&D manager, faced with a choice between mutually exclusive projects, which have the same payoffs and expected costs, but different levels of risk and different ranges of possible outcomes, should choose the project with higher risk. This behaviour remains even if the R&D manager presents himself as being risk-averse. The logic behind this choice is mainly due to two reasons. On the one hand, although the project with less risk is less likely to fail, the project with greater risk cannot incur greater losses. On the other hand, the expected payoffs of the riskier project are, to a large extent, higher if the manager is successful. When there is the possibility of choosing more than one project, the choice for the riskiest remains, since holding portfolios with this risk brings potential benefits that would not otherwise exist (Morris et al., 1991).

The technological innovation of companies can be predicted through the use of patents. The citation of patents has an immediate impact on the market values of companies, however, the result in their productivity takes longer to be reflected. This impact delay can translate into valued real options, since, while allowing companies to delay their investments, it also allows them to hold the exclusive right to develop a given innovation. Consequently, the greater the uncertainty, the greater the value of real options (Bloom & Van Reenen, 2001).

The real options approach states that the greater the uncertainty, the lower the incentives to invest. Bulan (2005) uses panel data from US companies to verify this assumption, studying the impact of real options on capital budget decision-making. The author also divides the uncertainty by industry and by firm-specific and the results are the same, illustrating an increase in investment when uncertainty is reduced.

In the economic and financial world, valuating internet companies is still an ongoing debate. The fact that most of these companies present valuations that are considered, many times, dramatically high, has, in many cases, a rational explanation. Since they present very high initial growth rates, with certain volatility over time, the value of their shares follows the same path even if there is the possibility of the company going bankrupt. Stock prices in this sector are extremely volatile, as one of the factors in the valuation is the cost structure, and these tend to change as new relevant information becomes available (Schwartz & Moon, 2000).

Most of the literature that addresses volatility under a real options lens shows that there is a positive relationship between this variable and company valuations. However, Bernardo and Chowdhry (2002) partially disagree with this statement and add that it can be verified if the increasing volatility does not come from noise when observing the signals that are important in the valuation of the company's performance. Market value tends to be higher when the uncertainty of company resources is volatile.

The financial press has been addressing the question for some time as to why young tech companies are so valued, even when they have less than zero profits. Emerging corporations have a larger fraction of real options than assets in place. In an empirical analysis of intangible assets, through the use of a real options model, Garner et al. (2002) use a sample of 243 internet and biotechnology companies, to define the categorical factors of growth opportunities. During the analysis, they discover that the speed with which a company innovates is, in fact, decisive in its market value. Volatility also plays an important role, showing a positive relationship with a real growth option, when it is at-the-money. If the opposite happens and the option is deep-in-the-money, its volatility sensitivity decreases considerably. Years later, Ottoo (2020) wrote in his book that a considerable part of the assets of several companies corresponds to growth opportunities, specifically when the analysed companies are in an initial/emerging phase. The author also identifies six essential variables when evaluating the success of start-ups and emerging companies.

The real options of companies are the reason for the positive relationship between volatility and stock returns. This correlation is stronger the greater the dimension of real options present in the company. When companies exercise their real options, their sensitivity to changes in volatility is considerably reduced. The evidence that presupposes a negative return-volatility relationship when the aggregate levels of companies are studied seems to come from market factors as a whole, which have an impact both on returns and on their volatility (Grullon et al., 2012).

2.6 The Impact of Company Dimension/Volume

The uncertainty between the existence of market inefficiency and a failure in the pricing model is often part of managers' analysis. The tests used to calculate market efficiency are based on CAPM and, as companies of different sizes are used, their results can be affected by the size factor (Basu, 1977).

The lack of specificity that the CAPM model presents is well known by academics and experts, and for this reason, a growing wave of empirical evidence has been observed. Over a 40-year spectrum on the New York Stock Exchange (NYSE), risk-adjusted returns were considerably higher for small companies than for large companies. This result is linked to uncertainty as to whether it is due to the size factor or whether this factor is simply a proxy for one or more size-related factors (Banz, 1981).

If the size factor is certain to exist, the reason for its existence is uncertain. It can be attractive to use this factor in certain situations, facilitating the explanation of the results, however, until a coherent line of thought is found, caution should be exercised in its interpretation. Klein and Bawa (1977) present a conceivable interpretation based on their model directly linked to the size of a company. They analyse the behaviour of investors who have different levels of information and conclude that there is a limitation of diversification, for different subsets of securities in the market. It is known that the smaller the companies, the more difficult it will be to obtain the necessary financing to buy and exercise the options. Thus, the size of the company is positively related to the value of real options (Adam & Goyal, 2008). That said, the likelihood that the amount of information generated, and the size of the company are related is high, leading most investors to choose not to own shares in very small companies. The combination of size and book-to-market equity makes it possible to assess the impact of average stock returns related to five factors: price-earnings ratio, leverage, market beta, book-to-market size and equity (Fama & French, 1992).

Chapter 3

Methodology

Similar to the methodology used by De Andrés-Alonso et al. (2006), our model assumes the use of five explanatory variables - Financial Leverage (FL), Stock Beta (BL), Skewness (SKN), Research and Development (RDR), Company Dimension (DIM) - and a control variable - Capital Stock (CS) - to test the hypothesis that the fraction of the value of companies not counted by their assets in place reflects investors' expectations about the value of real options (ROV).

Each explanatory variable underwent a *t-test* and the value presented as its *p-value* was analysed to determine its significance for our study. Only the variables that presented a value equal to or less than 0.1 (10%) were used for the analysis of the results.

3.1 Estimation of the Dependent or Response Variable

ROV

Real Options Value

The dependent variable ROV is defined as the real options value. The numerator is the difference between the Market Value of Assets (MVA) and the Value of Assets in Place (VAIP). The denominator is represented entirely by the Market Value of Assets, which translates into the subtraction of liabilities from the Market Value of Equity (MVE). We calculate the value of liabilities through the difference between Book Value of Assets (BVA) and Book Value of Equity (BVE).

$$ROV = \frac{MVA - VAIP}{MVA} = \frac{(MVE - BVE + BVA) - VAIP}{MVE - BVE + BVA} \tag{3.1}$$

VAIP, FCF, WACC

Value of Assets in Place, Free-Cash-Flow and Weighted Average Cost of Capital

The Value of the company's Assets in Place (VAIP) is represented by the company's Free Cash Flow discounted to its Weighted Average Cost of Capital (WACC).

$$VAIP = \frac{FCF_{AIP}}{WACC} \tag{3.2}$$

We obtained the Free Cash Flow generated by Assets in Place (FCF_{AIP}) by subtracting the amount of Income Taxes from the Earnings Before Interest and Taxes (EBIT). This approach assumes that replacement investments in current assets are equivalent to accounting depreciation.

$$FCF_{AIP} = EBIT - Income\ Taxes \tag{3.3}$$

The WACC used to discount the FCF_{AIP} should summarize the average cost of capital from all sources. For companies that had a debt value greater than 0, the discount rate was calculated by adding the Weighted value of Equity Capital (WEC) to the Weighted value of Debt Capital (WDC). For those whose debt reported a value of zero and consequently had a capital structure financed entirely by its equity, their WACC was equalled to their WEC.

$$WACC = WEC + WDC = w_e * k_e + w_d + k_d * (1 - t) \tag{3.4}$$

Where w_e (w_d) is the percentage of financing from equity (debt), k_e (k_d) is the cost of equity (debt) and t is the corporate tax rate.

The percentage of financing through equity is the division of the Book Value of Equity by the sum of Total Debt and Book Value of Equity. The same denominator is maintained for the calculation of the financing value through debt, changing only the numerator by the Total Debt.

$$w_e = \frac{BVE}{TD + BVE} \tag{3.5}$$

$$w_d = \frac{TD}{TD + BVE} \tag{3.6}$$

The cost of equity proxy is made using the principles of the Capital Asset Pricing Model (CAPM). The Market Risk Premium (MRP) results from subtracting the Risk-Free (r_f) from the Expected Return of the Market (r_M). The r_M is the average of the index returns and the r_f (risk-free) is the rate of return on a possible investment with payment pre-defined that is assumed to fulfil all payment obligations. The Equity Beta (BL) – also called stock beta, levered beta or just beta – measures the volatility of the stock relative to the market, specifically the degree of sensitivity of each company's stock price to changes in the market.

$$k_e = r_f + MRP * BL = r_f + (r_M - r_f) * BL \tag{3.7}$$

As a proxy for each company's cost of debt, we divide the Interest on Debt by the Total Debt, thus obtaining the effective rate that each company pays on its debt.

$$k_d = \frac{Interest\ on\ debt}{TD} \tag{3.8}$$

3.2 Explanatory Variables

RDR

Research and Development Ratio

As stated by Mitchell & Hamilton (1988) and Newton and Pearson (1994) research and development expenses normally work as an approximation of the value of a company's growth options. Thus, it is expected that the greater the dimension of these expenses, the greater the value of real options, *ceteris paribus*. Therefore, we expect to find a positive relationship between this ratio (RDR) and the dependent variable (ROV). We define Research and Development activity (RDR) as the ratio of R&D expenses to sales.

FL

Financial Leverage

In several studies Myers (1977), McConell and Servaes (1995) and Callen and Gelb (1999) state that the emergence of problems related to underinvestment tends to be exacerbated with the increase in corporate leverage. The financial leverage ratio is calculated by dividing the debt with cost by the total assets. For this reason, we expect to observe a negative relationship between the dependent variable and this ratio since a decrease in corporate leverage will translate, *ceteris paribus*, into an increase in real options value.

DIM/VOL

Company Size

The Dimension or Volume of the company (DIM/VOL) is also an important and impacting factor in the proportion of real options present in a company. It is estimated that the larger a company, the better its preparation to obtain the necessary funding to acquire or exercise its options (Adam & Goyal, 2008). To capture the size of the companies and reduce the noise that can arise when processing data, we estimate this variable based on the logarithm of total assets. Thus, we expect to find evidence of a positive relationship between this variable and the ROV.

SKN & BL

Risk and Skewness

The greater the risk of return, the greater the probability that a company will hold and exercise real options. Real options come, among many other things, to protect against avoidable risks. As the value of the option is positively related to the risk of the underlying asset, an increase in the risk of that asset will consequently translate into an increase in the proportion of the value of options to invest. Along with the same thinking, the more volatile a stock, the more likely an investor is to hold real options. Since the stock beta (BL) reflects the volatility of a company's stock compared to the volatility of the market, the higher the beta, the greater the volatility associated with that company and, consequently, the greater the proportion of real options of the same company.

The Skewness (SKN) was calculated through the weekly stock returns of each company and is expected to present a positive relationship with the dependent variable, since the greater the financial flexibility in terms of real options, the greater the asymmetry (Del Viva et al., 2017).

3.3 The model

Some studies in this area – such as the one that I am using as a benchmark – tend to use the traditional regression of the OLS model when making their estimates, often capturing only the differences between companies. We went a little further and opted for panel data analysis, thus considering the effects of cross-section and time series in a single model. This arrangement of the data allows considering not only the effects of heterogeneity between companies, but also avoiding multicollinearity between variables (Hsiao & Hsiao, 2004), a higher number of degrees of freedom and, consequently, a higher efficiency.

Among several models, two stand out as being suitable for our study: (i) random effects and (ii) fixed effects model. Both models capture the specific effects of companies, thus making it possible to consider the heterogeneity of our data. Once the elaboration of the models is concluded, the question remains of which one to choose and collect the results from. The solution that presents itself as the most viable nowadays, when deciding which model to use, is the calculation of the Hausmann Test (Baltagi, 2008). In a simple and summarized way, if the result of the *p-value* of this test is greater than 5%, the most adequate model is the Random Effects model, otherwise, Fixed Effects (Hausman & Taylor, 1981).

To estimate the models described above we used the Jupyter[2] Notebooks using Python programming language installed through Anaconda[3]. Our study uses Python as well as libraries to explore the data properties like the valuation of regression. Specifically in our study, we use the following Python packages: *statsmodels*[4] to apply the usual statistical/econometrics models; *pandas*[5] (whose name comes from panel data) that provides data structures and tools

[2] For more information, please visit https://jupyter.org/

[3] To contextualize, Anaconda is a software distribution that packages programming languages related with Data Analytics (namely Python and R) and a related subset of packages and modules. Jupyter Notebook is a web application that provides a graphical environment to use those libraries and programming languages in order to explore the data and associated model.

[4] For more information, please visit https://www.statsmodels.org/stable/api.html

[5] For more information, please visit https://pandas.pydata.org/docs/

to analyse our data; *linearmodels* [6] which allows regression of panel data and other estimators; *PanelOLS* [7] and *RandomEffects* [8] models that allow us to perform regression and estimate company-specific effects. To choose the model to be used – Fixed or Random Effects – we proceed to the estimation of the Hausman Test by importing *NumPy* [9], which is an essential package in the scientific computation ecosystem of this language, *numpy.linalg* [10] is a submodule that lets us call linear algebra functions, and finally we use the *stats* module which belongs to the *Scipy* [11] library and which also allows us to call the statistical functions necessary for the calculations we need to do compute.

To test if the variables previously described can explain the real options value we estimated the model described below using the panel data method for US companies listed on the NASDAQ stock market. The proposal of data analysis in this configuration has the advantage of allowing us to insert information referring not only to cross-section analysis but also to time series. In this way, we hope that the use of this approach will allow the capture of the heterogeneity of the data. Thus, the regression used us is as follows:

$$ROV_{it} = \alpha_0 + \alpha_1 RDR_{it} + a_2 BL_{it} + a_3 SKN_{it} + a_4 FL_{it} + a_5 DIM_{it} + a_6 CS_{it} + \varepsilon_{it} \quad (3.9)$$

Where *i* represents each company, *t* represents the time period, α_j represents the coefficients to be estimated, $j = [0,6]$ and e_{it} the error term.

Table 1 summarizes the expected behaviours of the explanatory variables in relation to the dependent variable. That is, it describes what signal we expect to find in the results of our regressions considering what the previous literature suggests.

6 For more information, please visit https://pypi.org/project/linearmodels/
7 For more information, please visit https://pypi.org/project/linearmodels/
8 For more information, please visit https://timeseriesreasoning.com/contents/the-random-effects-regression-model-for-panel-data-sets/
9 For more information, please visit https://numpy.org/doc/stable/
10 For more information, please visit https://numpy.org/doc/stable/reference/routines.linalg.html
11 For more information, please visit https://docs.scipy.org/doc/scipy/tutorial/stats.html

Table 1

Expected relation between the explanatory variables and the dependent variable

	Real Options Value (ROV)
Research & Development Ratio (RDR)	+
Stock Beta (BL)	+
Skewness (SKN)	+
Financial Leverage (FL)	-
Size (DIM/VOL)	+/None

3.4 Robustness

We tested the robustness in order to check if under different conditions the results are the same. For this, we proceeded to replace the variable DIM with the variable VOL. This new variable is estimated based on the natural logarithm of net sales, which were chosen because they do not contain information that could be affected by the company's capital financing structure.

Other variables were thought of as a proxy for the size of the company, but they were not used since they had information that distorted the reality of the size of the company. If we had used a variable that estimates the size of the company through its equity, and that is largely financed by debt from third parties, it will be indicated as being of small dimension even if in reality its assets tell a different story.

Chapter 4

Data Sample and Descriptive Statistics

We use quantitative data provided by Thomson Reuters Eikon – DataStream. The data allows us to produce several metrics and financial ratios capable of testing whether the market value of companies reflects investors' expectations about the value of real options.

We gather a population of technology companies during an interval of 10 years and through quantitative methods assess what fraction of the market value of these companies is not due to their assets in place, possibly observing the representation of the value of Real Options.

Since balanced panel data were used, companies needed to simultaneously meet a variety of criteria in order to be eligible for our study. Thus, they had to (i) be active (ii) be listed on the United States NASDAQ stock market during the examination period (iii) be American (iv) belong to the Information Technology sector characterized by the number 45 in the GICS (Global Industry Classification Standard) (v) provide balance sheets and income statements in the Thomson Reuters DataStream required to compute our proxies (vi) present stock prices from January 1st, 2009, to December 31st, 2019, to be able to calculate weekly returns and also (viii) present a positive Free Cash-Flow (FCF_{AIP}), Book Value of Equity (BVE) and Real Options Value (ROV).

Since not all companies met the necessary criteria described above, our population was reduced to a sample of 35 companies. Our final dataset then comprises three industry groups: Software & Services (GICS codes: 45101010[12], 45102010, 45102020, 45102030, 45103010, 45103020), Technology Equipment Hardware & Equipment (GICS codes: 45201020, 45202030) and Semiconductors & Semiconductor (GICS codes: 45301010, 45301020)[13].

The choice of time period used in our sample is not random and has been extensively studied. In order to analyse a predominantly stable financial period, it is indeed essential to

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[12] The GICS 451010 and consequently 45101010 were discontinued in 2018, and companies in this industry were then included in the GICS 45102030. See more details in https://www.msci.com/documents/1296102/5603800/GICS+Structure+Revisions+in+2018.pdf/1b11d2e8-c482-4000-89f3-190225f02dc3

[13] See appendix 1 for more detailed information on the GICS of the companies in this study.

investigate possible major events that may have shaken the US economy in recent years. Therefore, two were detected, the great recession of 2008-2009, with the fall of Lehman Brothers, included, and the beginning of the pandemic in 2020. In order to not include any of these occurrences in our sample but at the same time collect recent data, we chose to work with financial information between December 31st, 2009 – since the great recession is estimated to have ended in June of that year (Verick & Islam, 2010) – and December 31st, 2019 – to not capture the impact of the pandemic on our results.

The Descriptive Statistics for all the variables are shown in Table 2. Typically, these estimates confirm the forecast of investors' expectations about the value of real options in companies.

Table 2

Descriptive Statistics

	ROV	RDR	BL	SKN	FL	DIM	VOL	CS
N	35	35	35	35	35	35	35	35
Mean	0.7248	0.1336	1.1865	-0.1895	0.1292	14.9781	14.4731	0.0952
Median	0.7468	0.1331	1.1448	-0.1796	0.0910	14.8614	14.1403	0.0666
Std. Dev.	0.1495	0.0632	0.3696	0.8022	0.1394	2.0229	1.9999	0.0811
Min	0.1653	0.0216	0.3469	-3.7750	0.0000	10.6588	10.0593	0.0078
Max	0.9954	0.3536	2.7328	3.0668	0.6182	19.7433	19.3975	0.4140
Percentile								
25	0.6233	0.0910	0.9662	-0.5963	0.0000	13.5627	13.2342	0.0374
50	0.7468	0.1331	1.1448	-0.1796	0.0910	14.8614	14.1403	0.0666
75	0.8459	0.1638	1.3706	0.2619	0.2402	16.0092	15.4462	0.1309

Table 2 Notes:
[1] ROV measures the proportion of real options. It is defined as the ratio of Market Value of Assets minus the Value of Assets in Place to the Market Value of Assets. Market Value of Assets is calculated as the

Market Value of Equity minus the Book Value of Equity plus the Book Value of Assets. Value of Assets in Place is estimated as the ratio between the Free-Cash-Flow to the Firm and the Weighted Average Cost of Capital. Cost of Capital is estimated by adding the Weighted value of Debt Capital and the Weighted value of Equity Capital, where the market portfolio is approximated by the NASDAQ Index and the risk-free rate by the returns on long-term US Treasury bonds.
[2] RDR is defined as the ratio between the Research and Development expenses and the total sales.
[3] BL is the stock beta.
[4] SKN measures the skewness of stock returns.
[5] FL is the Financial Leverage, and it is calculated by dividing the book value of corporate debt with cost by the Book Value of Assets.
[6] DIM is the company's dimension, and it is estimated on the basis of the natural log of the Book Value of Assets.
[7] VOL is the company's volume, and it is estimated on the basis of the natural log of Net Sales.
[8] CS is the Capital Stock, used as a control variable, and it is defined as the ratio of the Net Value of Property, Plant, and Equipment to the Book Value of Assets.
[9] Data is obtained from Thomson Reuters Eikon – DataStream. SKN coefficient is calculated using weekly returns from 1st January 2009 through 31st December 2019. The remaining variables are estimated using accounting and market data between 31st December 2009 to 2019. The sample englobes all US firms included in the Thomson Reuters Eikon – DataStream technology sector and listed on the NASDAQ stock market. We exclude companies for which data is not available, and those reporting Free-Cash-Flows to the Firm, Book Value of Equity or Real Options value less than zero.

It is observed that the real options value corresponds on average to 72.48%. Although it is possible to perceive a vast average proportion of real options present in companies, there is a great dispersion between them, since the individual values vary between 16.53% and 99.54%. The authors Andres-Alonso et al. (2006) found an average ROV value of 75.22% for companies listed on the main OECD (Organization for Economic Co-operation and Development) stock markets. Although it seems that the values are similar, they are not subject to comparison since the authors did not use panel data but instead cross-section data.

By computing the three standard percentiles, we observed that only 25% of our data set is less than 62.33%. Since our sample is made up of a total of 35 companies, only 8 of them have a percentage of real options value less than 62.33%. These statistics indicate that a large slice of the companies present in our study has a large share of real options.

Table 3 presents the averages of all variables present in the model, organized by industry according to the GICS guidelines.

Table 3

The average of variables per industry group

	Software & Services (GICS: 4510)	**Technology Hardware & Equipment (GICS: 4520)**	**Semiconductors & Semiconductor Equipment (GICS: 4530)**
ROV	0.7164	0.7561	0.7221
RDR	0.1312	0.1121	0.1510
BL	1.1271	1.3523	1.1999
SKN	-0.1694	-0.2511	-0.1907
FL	0.1371	0.0918	0.1366
DIM	14.9103	15.7223	14.6604
VOL	14.3660	15.3983	14.1214
CS	0.0684	0.0571	0.1689
Total companies	19	6	10

Table 3 Notes:
[1] ROV, RDR, BL, SKN, FL, DIM, VOL and CS are defined as in Table 2.

It is noticeable that the Technology Hardware & Equipment industry has a higher percentage of real options. As the literature predicts, there is a positive relationship between ROV and the explanatory variables BL and DIM and a negative relationship with FL. However, the variables RDR and SKN seem to follow a different direction from that explained in the literature, that is, the higher the ROV, the lower the RDR and SKN. These relationships described now may have a decisive factor – the companies being organized by GICS – and nothing can be concluded with certainty. Table 3 merely presents an overview of the behaviour of the averages of the variables when organized by industry.

To statistically measure the relationships between the variables and what they represent, we prepared Table 4, which reports the Pearson Correlation Coefficients between them. It should be noted that the correlation only seeks to understand how and in which direction one variable behaves concerning the other. This statistical method does not allow us to identify whether there is causality between both variables.

Table 4

Pearson's Correlation Coefficients between variables

	ROV	**RDR**	**BL**	**SKN**	**FL**	**DIM**	**VOL**	**CS**
ROV	1							
RDR	0.2230	1						
BL	0.4648	-0.1069	1					
SKN	0.1098	0.0025	0.0192	1				
FL	-0.2500	-0.1045	0.1406	-0.0297	1			
DIM	-0.3907	0.0066	-0.1110	-0.0028	0.3091	1		
VOL	-0.3732	-0.0245	-0.0810	0.0025	0.2690	0.9830	1	
CS	-0.1590	0.0741	-0.0486	0.0411	0.0697	0.3058	0.3460	1

Table 4 Notes:
[1] ROV, RDR, BL, SKN, FL, DIM, VOL and CS are defined as in Table 2.

Through the calculation of Pearson's Correlation coefficients, it is possible to see that the pairs of variables that present a greater modular correlation are the ROV with the BE and the DIM with the VOL. It is possible to conclude that there is a strong correlation between ROV and BE that follow the same direction and therefore when one increases the other tends to increase as well. The relationship between the ROV and the DIM/VOL is represented by a negative sign indicating that their behaviours follow opposite directions and therefore when one increases, the other tends to decrease. What we can clearly see is that the correlation between VOL and DIM is almost perfect positive, indicating that, in addition to having a strong relationship, they will be good substitutes for each other. Despite these two evident behaviours, it is difficult to conclude anything beyond that, since the remaining correlations present values very close to zero. That is, given that the remaining correlations lie between -0.2 and 0.3, it is difficult to estimate the behaviour of two variables since relationships with these values are considered to be of weak and very weak origin.

We also studied the trend of the average ROV during the analysis period[14], which is presented in Table 5.

Table 5

Average of Real Options Value trend over time

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
77%	73%	67%	69%	72%	76%	74%	74%	75%	68%	74%

Although we can observe that the value does not vary much over the years, we also see that between 2009 and 2011 the average percentage of Real Options present in companies suffered a constant decrease. From 2013 to 2019, the average fraction corresponding to Real options remained practically constant, around 70-75%, except in 2018, which for some reason not visible at first, lowered the 70% threshold.

[14] This trend can be seen graphically in Appendix 2.

Chapter 5

Empirical Results

The results presented in this section are a consequence of the model proposed in Chapter 4 – Methodology. Thus, and as briefly explained above, the approach we used was the Random Effects and Fixed Effects, models. These econometric techniques allowed us to consider the heterogeneity of our data as well as the specific effects of each company. From now on, we calculate, test and conclude the impact – if any – of our explanatory variables on the real options value. It should be remembered that among the six explanatory variables, a control variable – CS – is added.

Two models are presented in this section, so B[15] was created to test the robustness of A[16]. Once there is robustness, it is possible to perceive that although there may be small variations related to the model hypothesis, the results remain true. To prepare for this test, we replaced the variable DIM – estimated through the natural logarithm of total assets – with the variable VOL – estimated through the logarithm of net sales. Since none of the variables considers the equity or debt dimension of the companies, we believe that the VOL would be the perfect replacement for the DIM.

Both models were submitted to the Hausman specification test to define which type of model – Fixed Effects vs. Random Effects – best estimated our results. In a relatively simplified way, this test evaluates the endogeneity of the model. When executing it, a null hypothesis is defined which indicates that the covariance between the independent variables and the alpha is zero. However, since the *p-value* presents values considered high, the null hypothesis cannot be rejected and, therefore, the Random Effects model becomes preferable to the Fixed Effects model. The degrees of freedom of the models as well as the likelihood function were also estimated (*Chi-square test*).

The results of both models are shown in Table 6.

[15] Random Effects model that contains the VOL variable as a substitute of the DIM variable.
[16] Main model estimated exactly as described in Chapter 4 – Methodology, Section 3.3., Regression (3.9).

Table 6

Regression Results – Random Effects Model

	Model A	**Model B**
Constant	0.6485***	0.6943***
	(6.5737)	(7.1376)
RDR	0.7789***	0.7586***
	(4.5915)	(4.4610)
BE	0.1811***	0.1818***
	(9.8432)	(9.9437)
SKN	0.0142**	0.0140**
	(2.4333)	(2.3988)
FL	-0.1635***	-0.1647***
	(-2.9831)	(-3.1073)
DIM	-0.0134**	
	(-2.1176)	
VOL		-0.0172***
		(-2.6637)
CS	-0.1878	-0.1505
	(-1.5639)	(-1.2308)
Entities	35	35
Time Periods	11	11
Degrees of Freedom	7	7
X^2	10.6633	9.0449
R^2	0.2787	0.2830
R^2 (Between)	0.5964	0.5962
R^2 (Within)	0.2206	0.2267
F statistic	24.344	24.871

Table 6 Notes:
[1] Model A presents the results from the regressions of the Random Effects Model. Through Jupiter notebook web application, using Python programming language, we estimated the regressions in order to define the value of real options based on the explanatory variables Research and Development Ratio (RDR), Stock Beta (BL), Financial Leverage (FL)), Skewness of Returns (SKN), Company Dimension (DIM) and the control variable Capital Stock (CS). The regression is as follows:

$$ROV_{it} = \alpha_0 + \alpha_1 RDR_{it} + a_2 BL_{it} + a_3 SKN_{it} + a_4 FL_{it} + a_5 DIM_{it} + a_6 CS_{it} + \varepsilon_{it}$$

Where i represents each company, i = [1,35], t represents the time period, t = [1,11], α_j represents the coefficients to be estimated, j = [0,6] and ε_{it} the error term.
[2] Model B follows the same guidelines as model A, being only subject to the replacement of the explanatory variable DIM by VOL.
[3] ROV, RDR, BL, SKN, FL, DIM, VOL and CS are defined as in Table 2.
[4] The *t-statistics* are in parentheses, *** denotes significance at the 1% level and ** at the 5% level.

The results of the regression estimation of the random effects model presented in the table above reveal that, in both models, the explanatory variables RDR, BE and FL are statistically significant at the 1% level, SKN is at the level 5% and the control variable CS, has no explanatory power.

When testing the robustness, it is possible to see that there is an increase in the explanatory power of the size of a company, when the variable is calculated through the natural logarithm of net sales. In the main model (A), the DIM variable is statistically relevant at the 5% level, while in the robustness test model (B) the VOL variable becomes statistically significant at the 1% level.

Our results demonstrate that the real options value (ROV) has a positive relationship with the research and development ratio (RDR), stock returns asymmetry (SKN) and equity beta (BL) and a negative relationship with size (DIM or VOL) and leverage (FL).

These findings thus indicate that the real options value responds to changes in the independent variables, as the real options approach suggests, supporting that this proportion is in fact connected to the investor expectations about the value of real options held by a company. Thus, our hypothesis stands.

As predicted by Al-Horani et al. (2003), Adam and Goyal (2008) and many others, the positive and high coefficient of the RDR suggests that when pricing companies, investors consider that the higher the value invested in R&D, the greater the value of growth opportunities and, consequently, the greater the value of Real Options present in the company.

The beta (BL) and skewness (SKN) results corroborate the research and conclusions made by the authors Chung and Charoenwong (1991) that a shift in the distribution of company returns to the right as well as an increase in systematic risk reflects through the impact of growth choices. This impact is observed in the positive values of the coefficients of these two explanatory variables. This result also highlights what Berk et al. (1999), Bloom and Van Reenen (2001) among others, stated about the positive effect that an increase in risk has on the holding of real options. For all intents and purposes, holding these options protect companies and/or investors against risks that they would not otherwise be able to protect.

Regarding the impact of leverage on the proportion of real options, this is negative, as predicted by the literature. Myers (1977), Aivazian et al. (2001), Anderson and Garcia-Feijóo, (2006) and others, show that an increase in the company's debt level translates into a decrease in growth opportunities which, therefore, will give wings to the problem of underinvestment. Consequently, the proportion of real options will naturally be smaller.

The most curious and interesting result to explore for us, however, was the fact that the size of the company, which although it does not yet have a consensus among experts about its true impact on the proportion of real options, presents a negative and significant coefficient. Adam and Goyal (2008), De Andrés-Alonso et al. (2006), Lee (2017) are some of the authors who show that there is a positive impact between the size of the company and the value of real options. Banz (1981) and Basu (1977) state that the impact of firm size on real options is undefined and nothing can be concluded with certainty. We think there are at least 2 plausible reasons for the sign to be negative. First of all, start-ups usually present a greater investment in R&D than bigger companies. This is due to the fact that this type of companies are in the first phase of the life cycle of a technological company – the innovation phase. Not only does this stage correspond to the moment when new ideas are planned, tested and executed, but it is also a candidate to be one of the phases that takes the longest to overcome. This is due to the fact that these same ideas need to go through a whole period of experimentation until they can effectively become part of the company's structure. As we have already demonstrated that the greater the R&D activity, the greater the proportion of Real Options, we can likewise deduce that size will have an opposite behaviour. Secondly, smaller technological companies have more growth opportunities, fewer assets in place and, consequently, a higher proportion of real options.

Chapter 6

Concluding Remarks

According to the approach through the lens of real options, the market value of companies that is not explained by their assets in place reflects their proportion of real options – or options portfolio.

Thus, using panel data from 35 high-tech American companies, the analysis of the proportion of real options was carried out from December 31st, 2009, to December 31st, 2019. All companies met the previously defined criteria to be legible for the study, among them, the fact that they have to be listed on the NASDAQ index. The Random Effects model was the one that best suited the type of data used according to the Hausmann Test.

There is a great discussion still going on about what variables affect the proportion of real options present in a company. We have shown and robustly tested a model that indicates that three factors – Research and Development (RDR), Stock Beta (BL) and Skewness (SKN) – have a positive impact and two – Dimension or Volume (DIM/VOL) and Financial Leverage (FL) – have a negative impact on the Real Options Value (ROV). Our findings corroborate the literature by Newton and Pearson (1994), Bernardo et al. (2000), Myers (1977), Trigeorgis and Lambertides (2014) among many others, but specifically collide with the findings of Adam and Goyal (2008), De Andrés-Alonso et al. (2006) and Lee (2017). The results of this dissertation thus show that investors' expectations about the value of a company's real options can be measured through the market value part that does not correspond to the companies' assets in place.

This analysis brings some contributions to the literature, specifically the fact that it shows a negative relationship between the size of the company and the proportion of real options. In addition, it contributes not only to the increase in the literature in the last decade – which it is scarce – but also to the increase in quantitative studies in the area of real options, allowing future authors, analysts, professors, among others, to take this study and reproduce it under other conditions.

The analysis carried out here obviously has some barriers that make it difficult to go deeper into certain details. First, the scarce literature review on real options, specifically, applied to quantitative studies. As a rule, the studies found related to the area are related to the development of models and the implementation of these models. There is an enormous difficulty when quantifying not only the real options but also the variables that affect them. It is difficult to concretely measure something that does not have a physical form, that is, it is not observable as Cash-Flows, for example.

Second, added to this measurement difficulty, contributing to the lack of literary robustness, there is the difficulty of changing minds. Although this approach and its advantages over CAPM, DCF, among others, have been discussed for some years, the minds of analysts and professionals in the business world remain very closed and not inclined to change. This stubbornness jeopardizes the evolution of the financial market and closes the door to an improvement in forecasting and accuracy of results.

Thirdly, the calculation of the value of assets in place causes the display to be reduced considerably since negative FCF cannot be considered. Thus, it becomes difficult to generalize and deduce the same findings for the population and not just for the sample.

Fourth, the multicollinearity between variables and the heterogeneity of companies made data processing difficult, requiring the use of some advanced Python language and an exhaustive study of different paths and alternatives that could be taken. Autocorrelation can also be a problem in model development when the sample in question has a high volume of data.

Finally, and allied to the first point, is the specific scarcity of literature that studies the impact of company size on real options. There is not only a lack of literature but also a lack of discussion and debate on the subject. To evolve, it is necessary to present and demonstrate different points of view that are an asset for precise studies. In our study, it became difficult to draw specific conclusions about the impact of this variable on the ROV, as there was not much that we could conclude beyond what our results showed.

The range of possibilities for improvement in this study is substantial. It is not possible to enumerate all the possible improvements or additions to this study and for that reason, we chose the three that we think are the main ones.

Future research could eventually extend the study to other countries, from different geographical areas – for example, Europe, Japan, and Singapore – thus allowing to assess whether different cultures influence the holding of real options or not.

A second research proposal would be to replicate this study in different sectors and see if technological information is the one that holds a higher proportion of real options or not.

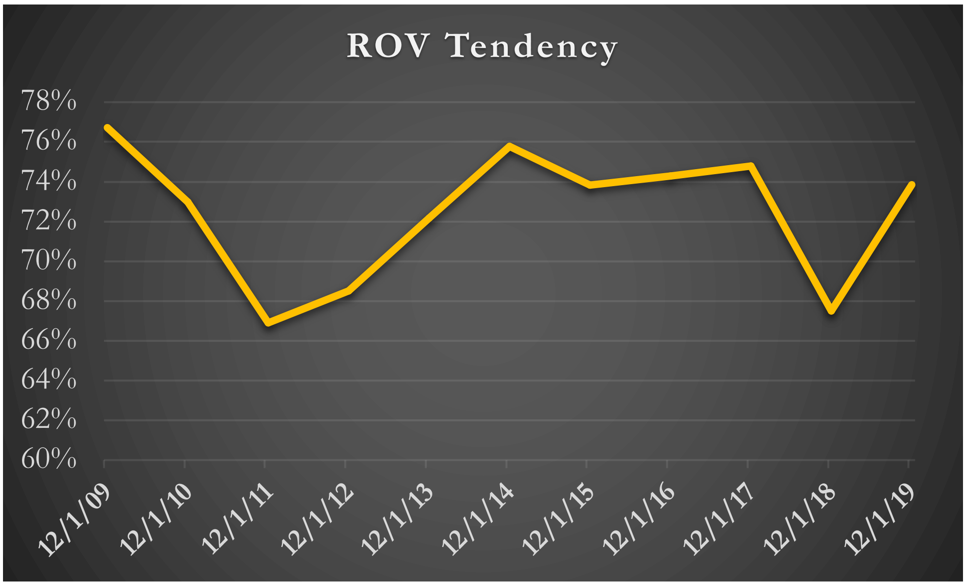
Finally, a suggestion to extend our analysis would be the research and incorporation of new explanatory variables that give explanatory power to the model, such as the life stage in which the companies are.

Appendixes

Appendix 1 – GICS of the companies

<table>
<tr><th colspan="2">Sector</th><th colspan="2">Industry Group</th><th colspan="2">Industry</th><th colspan="2">Sub-Industry</th><th colspan="2">Companies Ticker</th></tr>
<tr><td rowspan="10">45</td><td rowspan="10">Information Technology</td><td rowspan="6">4510</td><td rowspan="6">Software & Services</td><td>451010</td><td>Internet Software & Services **</td><td>45101010</td><td>Internet Software & Services **</td><td colspan="2">AKAM, GOOGL</td></tr>
<tr><td rowspan="3">451020</td><td rowspan="3">IT Services</td><td>45102010</td><td>IT Consulting & Other Services</td><td colspan="2">DOX</td></tr>
<tr><td>45102020</td><td>Data Processing & Outsourced Services</td><td colspan="2">CSGS, XRX</td></tr>
<tr><td>45102030</td><td>Internet Services & Infrastructure**</td><td colspan="2">AKAM, GOOGL</td></tr>
<tr><td rowspan="2">451030</td><td rowspan="2">Software</td><td>45103010</td><td>Application Software</td><td>ADBE, AMSWA, ANSS, BLKB, CTXS, EBIX, INTU, MANH, SNPS, VRNT</td><td rowspan="2">OSPN, ZD</td></tr>
<tr><td>45103020</td><td>Systems Software</td><td>CHKP, MSFT</td></tr>
<tr><td rowspan="2">4520</td><td rowspan="2">Technology Hardware & Equipment</td><td>452010</td><td>Communications Equipment</td><td>45201020</td><td>Communications Equipment</td><td colspan="2">CSCO, DGII, NTGR, FFIV</td></tr>
<tr><td>452020</td><td>Technology Hardware, Storage & Peripherals</td><td>45202030</td><td>Technology Hardware, Storage & Peripherals</td><td colspan="2">AAPL, NTAP</td></tr>
<tr><td rowspan="2">4530</td><td rowspan="2">Semiconductors & Semiconductor Equipment</td><td rowspan="2">453010</td><td rowspan="2">Semiconductors & Semiconductor Equipment</td><td>45301010</td><td>Semiconductor Equipment</td><td colspan="2">CCMP</td></tr>
<tr><td>45301020</td><td>Semiconductors</td><td colspan="2">ADI, DIOD, INTC, MCHP, MPWR, NVEC, SLAB, SWKS, TXN</td></tr>
</table>

Appendix 2 – Average ROV trend over time



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