INTERNATIONAL
HELLENIC
UNIVERSITY

Real options

Corporate finance decision analysis

Athanasios Giannousis

UNIVERSITY CENTER OF INTERNATIONAL PROGRAMMES OF STUDIES
SCHOOL OF HUMANITIES, SOCIAL SCIENCES AND ECONOMICS

A thesis submitted for the degree of
Master of Science (MSc) in Banking and Finance

December 2021
Thessaloniki – Greece

Student Name: Athanasios Giannousis

SID: 1103190006

Supervisor: Dr. Christos Grose

I hereby declare that the work submitted is mine and that where I have made use of another's work, I have attributed the source(s) according to the Regulations set in the Student's Handbook.

December 2021

Thessaloniki - Greece

Abstract

This dissertation was written as part of the MSc in Banking and Finance at the International Hellenic University. This dissertation addresses the real options theory application in corporate investment decision analysis. Real options theory stands as an alternative for planning the corporate investment strategy, while recent advances, like those in artificial intelligence allow for traditional valuation methods, such as the discounted cash flow valuation method optimization. The question whether, and under which circumstances real options valuation is a better alternative for corporate investment decision analysis is addressed. The literature review indicates the applicability and worthiness of the real options theory in terms of decision analysis. Moreover, although novel technologies such as artificial intelligence allow for rapid improvements, these have not reached sufficient maturity yet in the field of real options valuation. Upon examining literature thoroughly, the empirical part of the this dissertation consists of the application of the real options valuation method for two investment projects of Kleemann S.A.. The real options valuation method has been applied using the DCF valuation principle and decision tools, for valuing a multistage investment plan.
The author states his acknowledgment and respect to the supervisor Dr. Grose, as well as to Mr. Zervas Aristeidis, the Kleemann Group CFO, and Apostolas Dimitrios, the Kleemann Group Financial Controlling Manager, who both provided data and were very open minded towards cooperating with the author.

Keywords: Real options valuation, DCF valuation, decision analysis

Athanasios Giannousis
15/12/2021

Preface

The author holds a MENg in Engineering and an MSc in Management, while completing a second MSc in Banking and Finance. This background and course of education reflects the interest in the manufacturing sector both from an engineering and from a financial aspect. The status of the greek industrial sector is rather promising, epsecially over the past couple of years, while the potential seems unlimited given the size of the global markets. Manufacturing excellence and premiums are a prerequisite for organic growth, but face significant limits unless organizations do not seek constant growth and expansion, specifically abroad. The author last two years experience in the Kleemann Group, in a merely engineering role, along with his educational background, and other business and educational stimuli have raised the interest on this research topic. Taking the huge number of investment opportunities into consideration, as well as considering the historically low cost of capital, drives the need to examine whether there is room for improving the unanimously applied DCF method. It is worth paving the road to the dissertation main parts by referring to the potential need to add a real options value component to the DCF value calculations, in an attempt to avoid both overinvesting on rather certain projects and underinvesting on promising and highly uncertain projects. Last but not least, the path towards constant corporate growth coincides with successful investment decisions and staying ahead from the competition.

List of tables and pictures

Contents

1 Introduction

Traditional investment valuation methods, such as the Discounted Cash Flow method provide robust and unbiassed results under a set of assumptions. Yet, when it comes to valuing multistage investments carrying multi period growth opportunities, the DCF model falls short since a major assumption is a stable discount rate until the reaching the valuation horizon. Real options valuation, especially combined with decision trees, mostly binomial decision trees, cater for valuing multi period investments, which may prove to be rather handy when planning a long term investment. In the real business world firms seldom proceed with single investments, not followed or preceded by supplementary investments. Real businesses make consecutive investments in order to achieve organic growth and under the context of implementing their strategic planning. Some typical setups where firms make consecutive investments to achieve a targeted growth is investing on research and development, on developing new products or on entering a new market. These setups fall within the range of applicability of the real options valuation, which cannot be implemented for investments on financial instruments such as stocks or bonds.

The intensifying competition and the continuous expansion of the potential markets for firms, mandate optimizing the investment analysis processes, especially when it comes to implementing strategic investments. Strategic investments are unfolded over multiple periods, where primary investments usually pave the road towards completing a major investment. The DCF model may result in an accurate valuation of sole projects with constant uncertainty over multiple periods, which evidently does not meet the aforementioned setup of performing strategic investments.

Inserting the real options theory into the investment analysis allows for handling investments as opportunities to grow; firms may either buy the right to grow or wait before making a move or even sell a priorly bought right to grow. This is another critical extension of the real option theory into the investment analysis, since the disinvesting decision is an option for firms which collect an abandonment value in this case.

Despite the real options valuation method is fancy and seems to match the real business world need better, it has not gained a lot of fans throughout financial managers. Some basic barriers to adopting the real options valuation method include increased complexity and significant biasness.

The real options valuation method can be either applied supplementary to the DCF method, inserting a second value component, the real value, or supplementary with decision trees and some DCF basis, in order to value multi period investments.

1.1 Aims and objectives

This dissertation aims to explore the real option theory application in investment analysis. Following concise literature review, the Discounted Cash Flows valuation method is unanimously applied not only due to the results acceptable and highly accurate results, but also due to the application ease. A major consideration that drove this dissertation topic selection is one deficiency foreseen in the DCF model; the assumption that uncertainty, incorporated by a discount rate, is assumed to remain stable throughout all the valuation horizon. With this consideration in view, this dissertation aims to fulfil the following objectives;

- examine the traditional investment analysis methods briefly
- examine the applicability of the real options theory in investment analysis
- examine whether a proposed real options valuation method is applicable
- examine the aforementioned real options valuation method complexity

1.2 Research questions

Having in mind the aforementioned introductory findings along with the aforementioned research objectives, this dissertation has been produced in order to address the following research questions;

- which is the advantages and disadvantages weighting if comparing the DCF model with the proposed real options method?
- are the real options valuation methods an applicable addition to the traditional investment analysis methods?
- does a real options valuation method produce handy results?
- what is the major contribution of the real options theory in investment analysis?

2 Investment analysis

The literature review findings in the investment analysis field are presented and discussed in this chapter. The weight is put on traditional investment analysis methods, focusing mainly on the Discounted Cash Flow analysis method.

2.1 Introduction

Investment analysis is a timeless task for firms' financial managers and executives. Although numerous models are suggested in literature, there only one method being applied unanimously, the Discounted Cash Flows method, where the future net cash flows are discounted to their present values using a constant discount rate. Another valuation method, usually applied before the Discounted Cash Flows method is the multiples method, which offer a fast answer to the question whether an investment is worth undertaking. Other valuation tools, mainly applied or incorporated on DCF results, include calculating the Net Present Value, the Internal Rate of Return, the Return on the Investment, and the Modified Payback Period (Koller, et al., 2005).

Every valuation method carries different advantages and disadvantages, in terms of applicability, complexity, assumptions, accuracy and results robustness. The task of valuing investments tend to get harder when investments face changing risk over different investment periods. Essentially, risk or volatility or uncertainty is the main challenge when valuing an investment (Lin & Smith, 2007).

The DCF valuation method is presented shortly below, along with decision trees and some quick references to options and options theory in investment analysis. This chapter aims to lay the foundations for the next chapter and allow for better understanding and making conclusions.

2.2 The discounted cash flow method

Various academics have argued about the applicability and reliability of the DCF method for multi stage investments, while others point out that the level of complexity of other, more sophisticated valuation methods is not worth adopting those instead of the DCF method. This dissertation does not aim to propose the examined, real options, valuation method as a universal substitution of the unanimously effective DCF method. On the contrary, the literature review findings suggest that the DCF valuation method could be enhanced by adding a real value component, especially when considering investments producing marginal DCF values (Cassia, et al., 2007).

The DCF valuation method is rather rigid, providing robust numbers, where, among others, the positive potential of investments is alienated, in favor of valuating on the safe side. A contemporary issue identified is the increasing need to make the best investment decisions before competition. Under this context, financial managers and executives should, no matter how, be able to foresee a promising investment with high uncertainty in the short and mid run. This is the example of entrepreneurs· many start-up firms have ended up generating huge revenues for larger organization that had an eye for promising investments (Cifuentes, 2016).

Yet, under no circumstances are financial managers and executives allowed to make investment decisions empirically and intuitively, since the money on the table is shareholders money. That drives the need for articulating a supplementary valuation method to enhance the DCF valuation method capacity to judge positively on low revenue yet high potential investments (Zhao & Huchzermeier, 2015).

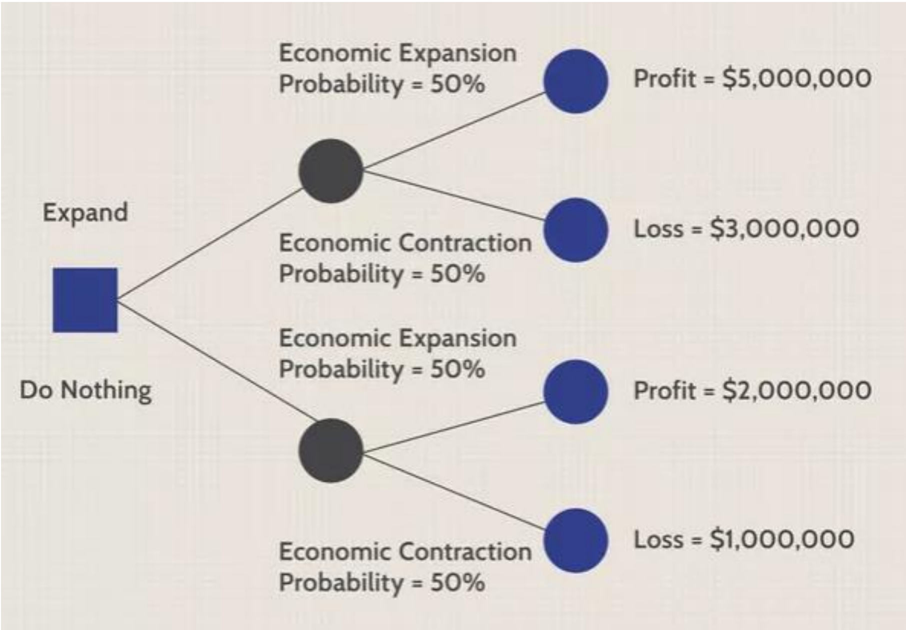
The principal of the discounted cash flows includes calculating the future cash flows and discounting them to their present values in order to calculate an investment net present value over a given time frame. Discounting is performed using the following formula ;

$$NPV = \sum_{t=1}^{n} \frac{Net\ annual\ future\ cash\ flows}{(1+r)^n} \quad (2.1)$$

where n equals the terminal year of the valuation and r equals a discount factor.

2.3 Decision trees

Decision trees are a Decision Analysis Science tool, applied in various fields, including finance and corporate finance. Decision trees serve as an investment analysis tool which is put in use when the investment environment is highly uncertain. Decision trees offer more flexibility than the DFC model, since it allows for deciding whether to undertake an investment now or in the future. Since uncertainty decreases over time, adopting a wait position, to see whether more information will be available or whether a market will be less volatile in the future is a rational decision. As mentioned in the introductory chapter, managers cannot gamble shareholders money and cannot either qualify investments sitting on biased or highly uncertain valuation model results (Pivoriene, 2015).



Picture 1: A sample decision tree applied in finance (Jiang, 2021)

Decision trees are implemented along with the DCF model since the net present value of a project is calculated using the DCF principles in every tree node. Given more information that may affect an investment under analysis, the less the implied uncertainty, firms may take advantage of decision tree analysis in order to decide upon the optimum timing of undertaking an investment.

Finally, it is worth mentioning that decision trees can be combined with the real options theory in order to build up real option valuation models, such as the model proposed and implemented in chapters four and five respectively.

2.4 Options

Finally, options are introduced shortly in this paragraph in order to allow for passing on to the real options valuation chapter. Options are derivative financial instruments, which resemble futures and forward contracts, yet without imposing on investors the obligation to buy or sell the respective underlying assets.

Option holders have the right to buy or sell, depending on the option type, an underlying asset, before the option reaches maturity, in a fixed price, named strike price.

Essentially, the common reason for buying or selling options is hedging risk, since option holders can mitigate the risk of an asset price collapsing or skyrocketing by buying sell or buy options at predetermined prices. On the contrary, the option seller is obliged to serve the holders' right to buy or sell an underlying asset. In other words, options are financial instruments which are used in order to mitigate markets, assets and investments volatility (Keming, 2021).

Having said that the options are bought or sold at predetermined prices, it is worth mentioning that the pricing theory and the whole mathematical theory underlying options prices is complex, and consists of stochastic processes, including random walk processes, such as the Wiener process, Markovian Chains and the famous Brownian move and the Black and Scholes formula. Given the topic of this dissertation does not focus on options pricing, no further detail is provided.

3 Real options valuation

The real options valuation method and respective literature review findings are presented in this chapter. After some short references to options theory, necessary for understanding the notion of options, the examined alternative valuation method is examined.

3.1 Introduction

As mentioned in the introductory chapter and the investment analysis chapter, derivatives provide investors the ability to mitigate potential losses on investments. Positively valued investments may still produce losses, either due to markets inefficiency or assumptions and historical data, inserted in the valuation process, not being confirmed. Especially when it comes to corporate finance and valuing investments, be them mergers and acquisitions, R&D investments or any other investment type, uncertainty can prove valuations and investment decisions wrong. The impact of uncertainty can be detrimental even for investments with huge potential and periodically easing off risk. Given that the number of available investments under corporate evaluation outweighs the investment capacity, the significance of the decision process is crucial.

Real options valuation offers the ability to value the course of positive uncertainty over time. Uncertainty refers not only to revenue but also to costs, while literature suggests that a project value may have up to two components; a DCF and a real value component. The real value component may be taken into consideration under specific circumstances and especially when the DCF valuation produces more pessimistic results than those anticipated. Given uncertainty is incorporated into the DCF model as the discount rate, projects with high uncertainty is expected to lead to low DCF value. Yet, under the concept of inserting a real value component, the two components will behave vice versa with regards to the evolution of uncertainty over time.

According to van Putten and MacMillan (2004), a project with high uncertainty will have a low DCF value component and a high real value component, in the short run. The higher the uncertainty, the higher the discount rate inserted in the DCF model, yet the real option component reflects the expectation for high mid to long term returns. Of course, in case the uncertainty is not projected to reduce over time, the investment is a no go, since no rational financial manager would gamble shareholders money on evidently non feasible projects (van Putten & MacMillanIan, 2004).

The breakthrough carried by the real options theory in investment analysis is that investments are tackled as a growth opportunity. As in every valuation method, firms have three possible decisions when considering undertaking an investment; buy, wait or uninvest. For projects with a largely positive DCF value or a largely positive real value firms should decide to invest or keep their commitment to an investment, if an undergoing project is considered. In case either value component points towards investing or in case the DCF value is close to a critical limit, but the real value component is significant, firms should also go for or keep supporting an investment. In case an ongoing investment, growing and mandating finance in periods, firms may consider leaving them and collecting a salvage value. According to van Putten and MacMillan (2004) and Cruz Rambaud and Sánchez Pérez (2016), real options theory may prove to be useful when considering abandoning an investment, in case either the revenue and/or costs deviate significantly from the projected values or reinvesting new capital to allow for an investment growth falls short (Cruz Rambaud & Sánchez Pérez, 2016; van Putten & MacMillanIan, 2004). In case the decision is uninvesting, firms collect a salvage value, proposed under the term “abandonment value” (Damodaran, 2005).

In the real business world, ongoing investments are under periodical valuation analysis along with new investments in order to provide for making a decision out of the three ones aforementioned. Under this context, the real options valuation can contribute to optimizing the accuracy of investment decisions and utterly to safeguard the projected overall corporate growth.

As far as limitations are concerned, real options valuation is not applicable to investments on financial instruments, and is more prone to subjectivity than the DCF valuation method according to various academics (Damodaran, 2005; Gennady, 2008; van Putten & MacMillanIan, 2004). That said, real options valuation may definitely be applied on valuing mergers and acquisitions, refunding projects, R&D investments, investments on technology and equipment, essentially on tangible assets.

3.2 The growth option and the DCF drawback

Modern financial theory embraces investments and investment opportunities as growth opportunities. According to literature, when valuing a company or largely when valuing an investment, assets, revenue, costs and last but not least the expected growth opportunities are to be approximated and discounted to their present value implementing any potential model, such as the DCF model (Copeland, et al., 2000; Damodaran, 2002; Damodaran, 2005).

The incentives behind corporate investments are various, yet organic growth is the prevalent one. Organic growth can be achieved via entering a new market, after an acquisition or merger, via developing a new product, after buying the respective know how or after completing an investment on research and development, etc.

When valuing using the discounted cash flow model, the valuation is typically performed assuming a constant discount rate, although discount rates are expected to vary significantly during at least two distinct time intervals; in the short run and in mid to long run.

In the short run, thus during the initial period right after an investment, after which a company enjoys high growth, for example through the steep increase in revenue, as a result of entering a new market or offering a new product. During this period of time, the firm enjoys a temporary competitive advantage or takes head in terms of cost or differentiation. Another major consideration is enjoying higher revenues due to shifting to economies of scale.

In the mid to long run, thus during a respective period of time, after the initial aftershock of the investment has faded, the impact of the investment on the corporate growth fades along.

Damodaran (2001) suggest that under the discounted cash flow model, firms are assumed to stay on a constantly positive growth track, based on following a constant reinvestment track so as to achieve constant growth (Damodaran, 2001)

Thus, the real options theory seems more coherent with firms behavior when it comes to valuing investments, since firms seek for acceptable, ideally premium, growth opportunities. Under this context, firms may undertake investments either for staying on a positive investment track or for mitigating losses from previous investments. More or less, firms are not always seeking for investments. On the contrary, firms evaluate their growth opportunities, in the broader strategic planning context, and may buy or sell a right to grow or a right to report losses respectively.

Under this context, the real options theory can be applied in investment analysis, where an investment decision resembles the call option decision, an abandonment decision resembles the put option decision and a waiting decision resembles the waiting before putting or calling an option. The essence of real options theory application to investment analysis is that firms consider their right to grow, instead of considering mere numbers. Real investments, referring to any kind of investment than on financial instruments, demand the investors commitment throughout a respectful period of time and may prove to be not only riskier but also less liquifiable than investments on intangible assets. Therefore, the real options theory may improve the investment decision process for real investments, especially due to the insertion of the abandonment value, linked with the put option.

All in all, real investments are significantly less flexible than investments on intangible financial products and require a mid to long term investors commitment. According to Trigeorgis & Brennan (2000) and Schwartz (2013), the real options valuation offers more room and more tools for valuing not only the expected return and profitability of an investment but also the induced flexibility and the required level of commitment brought by an investment (Schwartz, 2013; Trigeorgis & Brennan, 2000).

3.3 The reinvestment decision specifics

Globalization has expanded the field of operations for firms, also making not only the investment decision but also the reinvestment decision more complex. Increased complexity derives from the increased level of uncertainty. The ongoing pandemic has point out the level of uncertainty impact on multiple sectors affecting firms, from operations and sales to supply chain management. That said, producing a positive and acceptable DCF value is not sufficient when valuing real investments. Although a positive and acceptable DCF valued investment will most likely prove to be feasible and profitable, firms may be trapped into overseeing other more feasible and more profitable investments despite a lower DCF value. Strategic planning plays a crucial role, especially in real investments, where corporate growth is linked to long term commitment in investments. For example, a firm planning to enter a foreign market will most likely have to undertake a series of investments in the mid and long run in order to enjoy the strategic planning fruits.

According to Trigeorgis and Brennan (2000), the net present value of an investment can be affected by future reinvestment decisions, either positive or negative. Essentially, Amram and Nalin (2000) suggest that firms make reinvestment decisions considering the net present value of prior and future investments, in an attempt to maximize their value and essentially the corporate growth. Evidently, the discount rates vary against time, depending on reinvestment decisions, rendering the DCF valuation method less accurate in the mid and long run. Adopting the real options theory can allow for tackling changing discount rates as stochastic variables that have an impact on ongoing and future investments (Amram & Nalin, 2000; Trigeorgis & Brennan, 2000).

Firms may not always pick the top performing investments, as performance is measured by either the DCF or the real options valuation method. In fact, strategic investments may require a number of other supplementary and preparatory investments which lay the foundations and create the proper environment for unfolding a strategic investment. In other words, firms may improve the investing environment, especially when planning to enter a new foreign market, in order to reduce uncertainty and essentially in order to manipulate the applied discount rate on a big future investment valuation. Moreover, firms may not proceed to new investments on a specific market, making a wait decision in order to reevaluate the market evolution and the returns of prior investments. Under this context, firms may expect for either new growth opportunities arousal or for signs directing them towards abandoning prior investments. The real options valuation and respective theory can prove to be an effective, comprehensive tool for analyzing complex investment plans. The below proposed model can prove to be more effective in valuing complex investment plans in the long run.

3.4 Reinvestment decision analysis

As mentioned above, the real options valuation key advantage is more accurate and effective valuation of investments uncertainty over time. Various models examined in prior literature tackle uncertainty as a stochastic value, changing over time, which if compared against a constant discount rate used in the DCF model can better grasp the impact of uncertainty on a project value. According to Geroski, et al. (1997) and Harikae et al. (2021), the real world challenges shape uncertainty randomly, where uncertainty can be approximated as a random stochastic variable changing over time (Harikae, et al., 2021; Geroski, et al., 1997)

Although uncertainty has multiple components, it can be taken into account as a joint random stochastic variable, which reflects overall uncertainty, in order to simplify the valuation process. Yet, this joint stochastic variable may make it difficult to set a critical value above which investments should be undertaken.

According to van Putten and MacMillanIan (2004), a substantial bias of the real option valuation method is that investments with highly volatile costs in the short run would have a high real value, despite the volatility of revenues. That said, in case the volatility of costs exceed the volatility of revenues, an investment should be undertaken despite the calculated real value (van Putten & MacMillanIan, 2004).

Smith (2005) pointed out and expanded the aforementioned proposal by Putten and MacMillanIan (2004). The alternative investment analysis based on real options theory can lead to inaccurate results, in case the valuator is more pessimistic, since the increased values of uncertainty, regardless of whether it is revenue or costs or both derived, will result in a more optimistic real value calculation (Gennady, 2008; Smith, 2005).

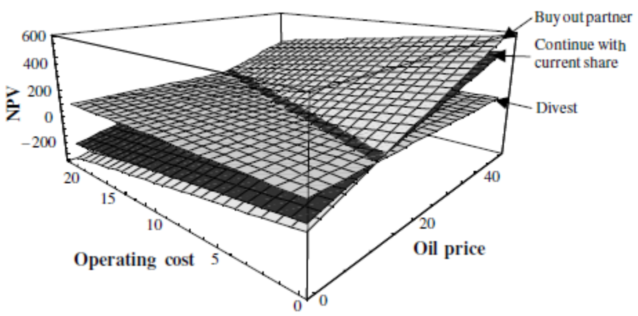
According to Brandao et al. (2005) and Arnold et al. (2007), binomial decision trees can be used to better focus on the uncertainty evolution over time and provide a more accurate and more flexible approach to investments real value (Arnold, et al., 2007; Brandão, et al., 2005).

A model, based on the real options theory, for investment analysis in the energy industry has been proposed by Gennady (2008). Smith suggested there are two major uncertainty variables; operating costs and the commodity selling price. The aforementioned three decision alternatives were considered, suggesting either acquiring the target firm, disinvesting or continuing with the current state, until something changes in the value calculated. The two uncertainty components create a three plane chart if plotted against the investment net present value (Gennady, 2008).

The model resulted in a significantly increased NPV if a reinvestment was considered at the end of the DCF valuation horizon (five years). More specifically, the NPV suggested by Smith (2005) was 7,4% higher against the one calculated by a mere DCF valuation up to the end of year five.

A major difference is brought to light by the aforementioned paper; firms rarely decide on single investments in a market or in a specific product or in a technology. On the contrary, firms opt for consecutive investments, implementing their strategic planning. For example, a lifts manufacturer in Greece entering the British market may start with slow and careful acquisitions in order to measure the potential market shares, before proceeding with acquiring a major target company. These consecutive investments pave the way towards achieving strategic goals, such as a yearly increase in revenue and market shares in a new foreign market. Therefore, the real option valuation model proposed by Gennady (2008) can be applied if considering a real business environment.

Another significant observation is the way the NPV changes over time and with respect to the uncertainty components. The lack of linearity observed in the aforementioned chart reflects, among others, the impact of reinvestments on uncertainty. This behavior can not be captured by a sole DCF valuation at any case. Consecutive reinvestments change the growth potential and lead to accumulating more value in nonlinear time intervals.



Picture 2: Fluctuating NPV over volatile two factor uncertainty (Smith, 2005, p. 99)

Jafarizadeh and Bratvold (2009) applied the model proposed by Gennady (2008) and Smith (2005) and took it a step further by introducing the Least Squares Monte Carlo Simulation in order to tackle the model complexity and take better grasp of the uncertainty impact on NPV in different time periods (Jafarizadeh & Bratvold, 2009). Moreover, they suggested that a proper, built for purpose real option valuation model can prove to far more useful than a mere DCF calculation. According to Jafarizadeh and

Bratvold (2009), the proposed model and its extension by applying the LSM[1], can assist financial managers in bringing strategic planning to life by making proper investments in order to tackle uncertainty over consecutive time intervals, utterly in order to achieve higher goal· the strategically planned corporate growth in the mid and long run.

Wang and Dyer (2010) suggested that using a model similar to the one proposed by Gennady (2008) and Smith (2005), based on binomial trees, can simplify calculating the impact of uncertainty, which can result in highly valuable and accurate results. Such a model results can prove to be rather handy in terms of financial managers addressing capital budgeting for mid to long term investments, given a respectful degree of managerial flexibility (Wang & Dyer, 2010).

Barton and Lawryshyn (2011) proposed an extension to the Smith (2005) model, by inserting the regression sum of squares error method, in order to simplify investment analysis when the cash flows volatility is significant in size and constantly changing (Barton & Lawryshyn, 2011).

3.5 The proposed model for valuing growth opportunities

Back to the aforementioned model, calculating and discounting the future cash flows from every investment is complex if done directly. Smith (2005) and other academics using a similar model, have proposed using another, auxiliary variable standing for the overall uncertainty. Upon calculating the joint uncertainty variable, the future cash flows can be calculated and discounted to their present values. Under this real options valuation model, an investment value is approximated as a function of a stochastic process describing uncertainty, where the joint random stochastic uncertainty variable is distributed (DePamphilis, 2018; Mun, 2002). The contribution of Gennady (2008) is crucial in terms of providing a model for valuing investments in the context of valuing corporate growth using real options (Gennady, 2008).

Assuming finite investing capacity, thus finite capital, firms and the financial managers have to decide upon buying some growth opportunities against others. According to van Putten and MacMillanIan (2004), making investment decisions only on DCF carries the risk of abolishing some great growth opportunities, while making investment decisions

[1] Least Squares Monte Carlo Simulation

only on real option valuations carries the risk of undertaking poorly performing investments. In the latter case, financial managers embracing real options valuation have a calculated alibi for essentially gambling shareholders money (van Putten & MacMillanIan, 2004). Under this context, Copeland and Tufano (2004) suggested a more realistic way to apply the real options valuation in the real business world (Copeland & Tufano, 2004). According to them, the real options valuation should be utilized when valuing growth opportunities, under the broad context of valuing consecutive and multistage investments. Some examples provided by Copeland and Tufano (2004) include investments on R&D, on geographical expansion etc.

When considering the real options valuation for multistage investments, each investment carries costs, independent of consecutive reinvestment decisions, and is considered to generate revenues consisting of an immediately observed component, due to the expansion of the firm, and an indirectly observed component reflecting the growth potential after future reinvestment decisions. At the same time, financial managers should consider potential limitations in future reinvestment decisions, such as limitations posed by the market. For example, if a long term plan to enter a new foreign market does not go as planned, the investing company would most likely refrain from making future reinvestment decisions (Copeland, et al., 2000).

In order to allow for modelling, the volatility of future cash flows, due to any reason, is taken as a random walk (Gennady, 2008; Smith, 2005). This random walk is inserted as a randomly distributed variable $S_{nom}(t)$;

$$\frac{dS^{nom}}{S_t^{nom}} = \mu dt + \sigma dW \quad (3.1)$$

where μ is the inflation, σ is the volatility of the revenue and dW is a real valued continuous-time stochastic process standard normally distributed. For time zero, the S_0 quantity is considered. If a reinvestment decision is on the table, the investing firm enjoys the increased value of a prior investment for a given period, upon whose expiration the investing firm should either reinvest or wait or abandon the prior investment.

The model puts more weight on the revenue volatility rather than on the costs volatility, since as mentioned above, the revenue uncertainty is a crucial factor for qualifying an under valuation investment. Moreover, it is worth restating that investments carrying largely volatile costs, where costs are more volatile than the expected revenue, should not be valued using the proposed model or any other real options valuation model, since the calculated value would be positively biased as a result of the high costs volatility (Copeland & Tufano, 2004; DePamphilis, 2018; van Putten & MacMillanIan, 2004).

The proposed model suggest that the future cash flows uncertainty is directly depending on each investment period cash flows and the revenue volatility is considered a continuous time variable. Moreover, the price of buying an option to grow is considered exogenous factor independent and non-stochastic.

The revenue for every previous period is known, while the future revenue is calculated on a probability basis taking the previous periods revenue into consideration as known. If Ω(t) resembles the set of factors shaping the future cash flows, the present value of the future cash flows can be denoted as E(Ω(t)) (Gennady, 2008).

For further describing the proposed model, it is worth noting that reinvestment decisions are made at the beginning of every investment period, while the volatility is calculated at the end of every investment period. Moreover, the time at which the investment value is calculated is denoted with t and the expiry time of the growth option is denoted with T (Gennady, 2008).

The decision is denoted with m at time t, where two denotes the decision to invest or reinvest, and one denoted the decisions to wait and not proceed to investing or reinvesting. Therefore, the future cash flows are valued both at time t and for a prior decision m_t=1 or m_t=2. The increase in revenue, resulting from a new investment, is described by the variable ξ, while investments are denoted with I (Gennady, 2008).

If an investment decision is made at time t, the respective investment costs, incorporating changes in the working capital, are denoted with c_t. The investments costs are considered zero in case the decision is to not invest, while the investments costs are calculated from the following formula in case the decision is to invest (Gennady, 2008);

$$c_{\mathrm{t}} = \mathrm{I}(\xi) + \overline{dWC}(\xi) \quad \textit{(3.2)}$$

The cash flows between two investment periods, depend on future and prior investment decisions and on the value of the randomly distributed stochastic variable $S^{nom}(t)$. Since the investment decisions are denoted as m_t, the future cash flows after a decision m_t can be calculated by the following formula (Gennady, 2008);

$$FCF^{m}(t) = FCF(S_t^{nom}, m_t, m_{t-1}, \dots, m_0, t) \text{ (3.3),}$$

while if inflation is inserted, the future cash flows after a decision m_t can be calculated by the following formula;

If inflation is also taken into account in the estimation of future cash flows, without taking into account any costs for the transition from one investment decision to another, future cash flows, as a function of investment decisions m_t, are calculated as follows:

$$FCF(t)(S_t, m_t) = EBIT(S_t, m_t) \times (1 - corporate\ tax\ rate) + A'_t(m_t) - I_t^{excluded}(m_t) - dWC'_t(m_t) \quad (3.4),$$

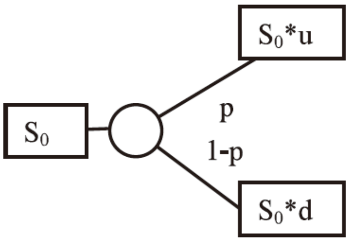
where $I_t^{excluded}(m_t)$ denotes the mutually exclusive investments, A'_t is the adjusted depreciation and $dWC'_t(m_t)$ denotes the change in working capital induced by an investment decision and adjusted for inflation μ.

Respectively, the EBIT(S_t,m_t) can be calculated applying the following formula;

$$EBIT(S_t, m_t) = (S_t, m_t)(1 - cost\ to\ sales\ ratio) - A'_t(m_t) \quad (3.5)$$

The increase in revenue consists of a direct component, actualized for time [t,T], due to the aftershock of a new investment, e.g. a firm acquiring a target company and receiving the target company revenues, and an indirect component which is experienced in the mid run.

At this point, the model is supplemented with the insertion of decision trees, in order to tackle computational complexity. The model consists of binomial decision trees, where the one arm is deciding to invest and the other arm is to decide to not invest, thus wait. As mentioned in the chapter 2, decision trees are solved using multiple methods, where the prevailing one is applying the Brownian move. Moreover, the dissertation author has attempted implementing machine learning to tackle the decision tree solving complexity. According to Gennady (2008), the restrictions under which the Brownian move can be implemented as simply as possible, without compromising the results accuracy, include consider finite capital, thus finite investment capacity, implementation of the straight line method for depreciating and not carrying losses from one investment period to the next investment period (Gennady, 2008). Furthermore, given the model resembles valuing options and specifically real options, all the figures inserted into the model are real terms rather than nominal terms, which is a prerequisite for allowing the recombination and thus the solution of the decision tree.



Picture 3: Revenue volatility for a given output S_o (Gennady, 2008, p. 181)

The factor u denotes an increase in revenue, which may be actualized under a probability p, while the factor d denotes a decrease in revenue, which may be actualized under a probability 1-p. The decision tree can expand to up to infinite periods, where each period consists of k discrete times.

$$u = \exp\left(\sigma\sqrt{\mathrm{k}^{-1}}\right) \text{ (3.6)}$$

$$d = {}^{1}/_{u} \text{ (3.7)}$$

where k is the number of distinct time states of which each period is composed.

The probability p can be calculated as a function of inflation and revenue increase of decrease;

$$p = \frac{1+\mu/k-d}{u-d} \text{ (3.8)}$$

Given that the aftershock increase in revenue lasts until time T, the firm may reinvest at any time from t to T. With j denoting the times the revenue increased, q denoting the times the firm reinvested before the valuation time, and t-j denoting the times the revenue decreased, then the revenue can be denoted as S_t(j,q).

The revenue at a period t can be calculated from the following formula, where the initial revenue is multiplied with two factors incorporating uncertainty and the product of the revenue increase factor ξ_i, adjusted for inflation changes;

$$S_t(j,q) = \frac{S_0 u^j d^{t-j} \prod_0^q \xi_i}{(1+\mu)^t} \text{ (3.9)}$$

The S_t(j,q) quantity is calculated in every tree node, until the horizon of the valuation is reached, which allows for reading a solved decision tree both forward and backwards.

The next step of the proposed valuation method consists of maximizing the value of an investment, which can be achieved via increasing the current and the future cash flows, and paying only the investment costs if the decision m_t=2. The decision tree is read forward in order to identify the path that leads to the maximum investment value, which can be calculated by the following equation, upon introducing a proper discount rate ρ and for l transitions between decisions 1 and 2;

$$\Lambda_t(S_t, m_t, t) = max_l(l)\,[FCF(S_t(j,q), m_t, t) - c_l + \rho E_t\big(\Lambda(S_{t+\Delta t}, l, t+\Delta t)\big)] \quad (3.10)$$

The aforementioned breakthrough offered by the real options valuation is that the discount rate can change at different investment periods. A proper measure for incorporating risk is the WACC, noting that deciding to invest or wait has a direct impact on the WACC. For simplification reasons and for avoiding inserting bias, in the context of this dissertation, the risk free rate is used as a discount rate. Moreover, using the risk free rate is consistent with the hedge funding process using derivatives, such as options (Jorion, 2021).

Finally, in order to calculate the present value of the future cash flows after one investment period, where an investment decision was made, the future cash flows are discounted using the WACC;

$$\mathrm{P}V^{AIP}\big(FCF_1(u)\big) = \frac{FCF_2(u^2)p + FCF_2(u,d)(1-p)}{1+WACC} \quad (3.11)$$

4 Research methodology

The research methodology applied for producing this dissertation is presented and commented in this chapter briefly.

4.1 Research strategy and approach

Upon defining the research questions, as provided in paragraph 1.2, the research strategy implented is a combination of literature review and case study. More specifically, a thogough literature review has been conducted in order to identify what the existing literature suggests on investments analysis in general and with a focus on the real options theory contribution to investments analysis. Moreover, the case study strategy has been selected as a means of implementing a proposed real options valuation model for analyzing multi stage investments. The case study was designed to sit on a DCF valuation provided by the Financial Department of Kleemann, but the model complexity ruled out a total usage of the valuation provided. Instead, some key figures provided in the firm valuation were utilized in order to close the distance of the case study from reality.

As far as the research approach is concerned, this dissertation follows an explorative and descriptive research approach in order to tackle the research questions omptimally. The explorative approach component is critical in order to identify the current status in investment analysis and in order to recognize the tradeoffs of both the DCF method and the real options valuation methods. Moreover, the descriptive research approach serves for describing the contribution, the operating principle, the advantages and the disadvantages of the proposed alternative investment valuation method.

4.2 Research method

This dissertation follows a combination of qualitative and quantitative research methods. As far as the qualitative part is considered, the pros and cons of an alternative investment valuation method have been compared against the unanimously adopted discounted cash flows valuation method. As far as the quantitative part is concerned, a multi stage investment has been valued using the proposed alternative valuation method, namely applying a combination of real options theory and decision trees.

4.3 Data collection methods

The data collected has been retrieved mainly from academic journals and periodicals, while some data has been retrieved from books as well. Moreover, secondary data provided by the Financial Department of Kleemann have been used, essentially to build a novel valuation model, sitting on imaginary figures with some realistic data additions.

4.4 Data analysis

The data analysis conducted under this dissertation context, whose results are provided in chapter five sits on implementing a real options valuation model proposed by Gennady (2008), which incorporates real options theory and decision trees. The original model was intended to be applied in order to value corporate growth using real options theory.

The breakthrough carried by inserting the real options theory into investment analysis is that investments are tackled as opportunities to grow. Thus, firms may either buy or not buy (wait) a growth opportunity. The contribution of this model is enhanced when analyzing multi stage investments in the context of executing a mid to long term investment plan aligned with a corporate strategic planning.

The model provided in chapter five serves for valuing a firm growth if three investment projects to be evaluated for adoption in three consecutive investment period are considered. Apart from direct investment costs, the model inputs include inflation, weighted average cost of capital, projected sales (or revenue) increase, projected change in the working capital and last but not least a joint variable incorporating uncertainty and a variable denoting the firm decision to either buy a growth opportunity or wait. The joint uncertainty value is a function of the assumed market demand volatility and two factors denoting demand going up and demand going down, with two respective probabilities.

The model consists of constructing a decision tree, where every node is a combination of the buy or wait decision and the event of demand going up or down. The decision tree is provided in table form, in order to facilitate calculations and is provided in three forms. Initially, the projected revenue is calculated for every node. The second form consists of calculating the project future cash flows, while the latter form consists of calculating the present value of the corporate growth at every node.

It is worth mentioning that the future cash flows have been discounted to their present values using the risk free rate indirectly. Essentially, the weighted average cost of capital has been used a risk measure, incorporating the risk free rate, given the model developed is fictionary.

More extentions of the proposed model, such as optimizing the corporate growth, have not been realized due to computational difficulty but also because this dissertation aims have been fulfilled at the point that the corporate growth has been valued for all the tree nodes.

Finally it is worth mentioning that the data analysis has been performed using Microsoft Excel.

5 Real options valuation application

The proposed real options valuation model has been implemented in order to determine the optimal corporate growth investment decisions in this chapter.

5.1 Introduction

An actual valuation model was provided by the Kleemann Financial Department. Although the model was in depth, only a few figures have been utilized in order to allow for the model implementation. More specifically, the model applied and presented in this chapter assumes entering a new market with acquiring a subsidiary in order to increase the pre investment sales. The firm has been selling goods in this market directly, from the mother firm, achieving a €5 million annual revenue and is expecting to increase the sales revenue upon undertaking three investments in three consecutive periods.

5.2 Assumptions and figures

The set of assumptions and model inputs are provided below;

Table 1: Investment options, projected sales revenue increase and respective change in working capital

	Period 1	*Period 2*	*Period 3*
Investment costs	250.000 €	400.000 €	300.000 €
Projected sales revenue increase	15%	10%	30%
Change in working capital	10.000,00 €	10.000,00 €	15.000,00 €

The demand – sales volatility is assumed equal to 20%, while each period is assumed to be split in 150 sub-periods, according to Gennady (2008) suggestions, so as to achieve a standard normal distribution (Gennady, 2008). Moreover, the following inputs have been fed to the model;

Table 2: Inputs

Inflation	0,5%
Risk free rate	1,0%
WACC	7,8%

Tax rate	24,0%
Demand – sales increase probability	0,50
u	1,02
d	0,98
Investment 1 increase factor	115%
Investment 2 increase factor	110%
Investment 3 increase factor	130%

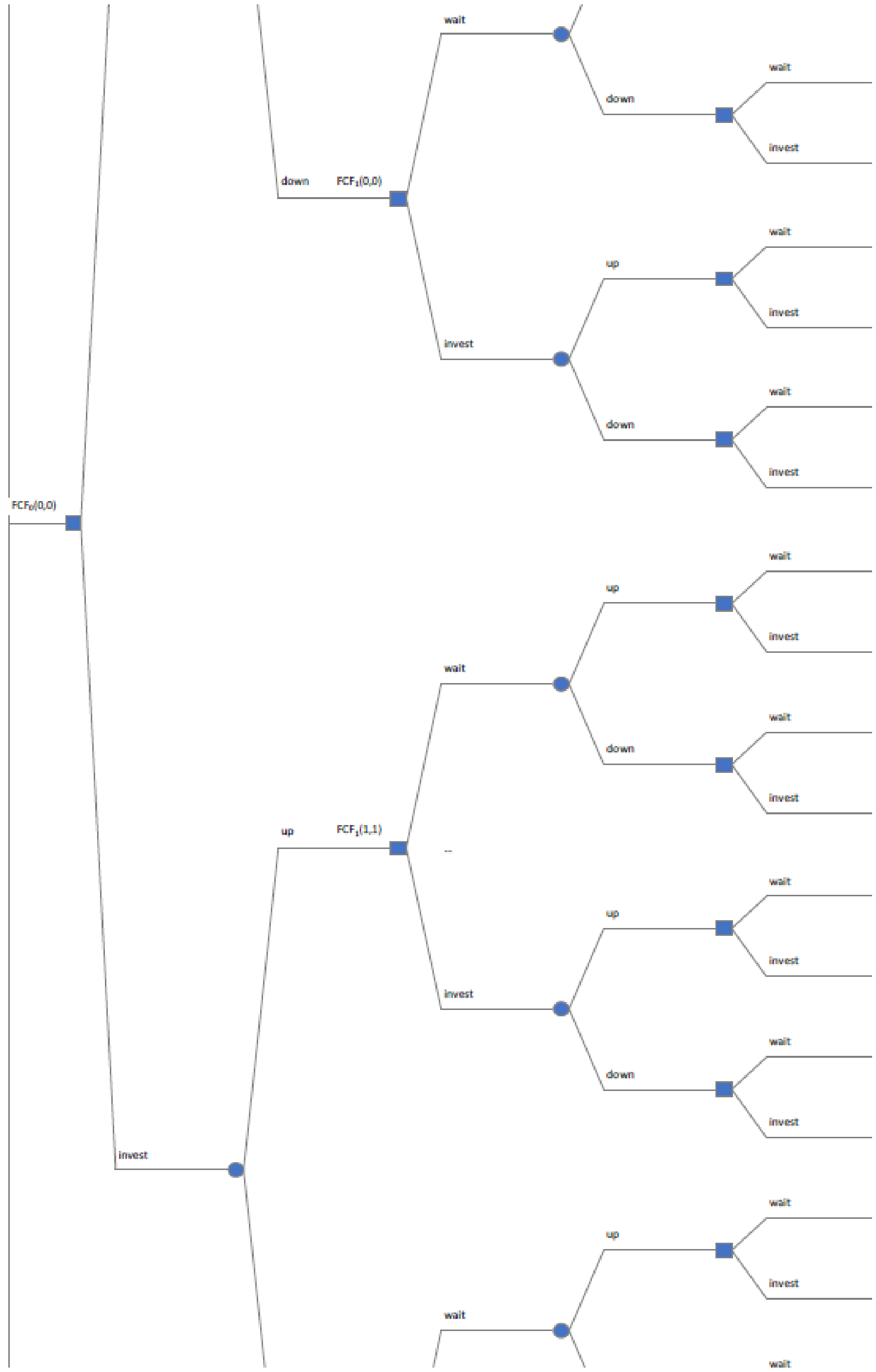
5.3 Analysis

$$u = \exp\left(\sigma\sqrt{\mathrm{k}^{-1}}\right) = \exp\left(0{,}20\sqrt{150^{-1}}\right) \approx 1{,}02$$

$$d = {}^{1}\!/_{u} = \frac{1}{1{,}02} \approx 0{,}98$$

$$p = \frac{1+\mu/k-d}{u-d} = \frac{1+0{,}05/150-0{,}98}{1{,}02-0{,}98} \approx 0{,}5$$

Having calculated the model inputs, three decision trees have been produced in Microsoft Excel· one for the projected sales revenues, one for the projected, future cash flows and one for the corresponding present values. A partial screenshot of the tree created by the author is provided below;



Picture 4: Part of the tree created by the author

The notation follows the notation proposed in chapter 3, where q denotes the investment/reinvestment or wait decision, and j denotes the joint uncertainty. The joint uncertainty is produced by mixing the uncertainty factors; sales increasing and sales decreasing variables u and d respectively. The uncertainty factors are expressed with probabilities p and (1-p) which depend on the steps per investment period, u and d factors and inflation, according to equation 3.8.

Table 3: Projected sales revenues

Year 0		Year 1		Year 2		Year 3	
$S_0(0,0)$	5.000.000,00 €	$S_1(1,0)$	5.056.908,37 €	$S_2(2,0)$	5.114.464,45 €	$S_3(3,0)$	5.172.675,62 €
		$S_1(1,1)$	5.815.444,62 €	$S_2(2,1)$	5.881.634,12 €	$S_3(3,1)$	5.948.576,96 €
		$S_1(0,0)$	4.894.418,33 €	$S_2(2,2)$	6.469.797,53 €	$S_3(3,2)$	6.543.434,65 €
		$S_1(0,1)$	5.628.581,08 €	$S_2(1,0)$	4.950.125,00 €	$S_3(3,3)$	8.506.465,05 €
				$S_2(1,1)$	5.692.643,75 €	$S_3(2,0)$	5.006.465,71 €
				$S_2(1,2)$	6.261.908,13 €	$S_3(2,1)$	5.757.435,56 €
				$S_2(0,0)$	4.791.066,15 €	$S_3(2,2)$	6.333.179,12 €
				$S_2(0,1)$	5.509.726,08 €	$S_3(2,3)$	8.233.132,86 €
				$S_2(0,2)$	6.060.698,68 €	$S_3(1,0)$	4.845.596,50 €
						$S_3(1,1)$	5.572.435,98 €
						$S_3(1,2)$	6.129.679,58 €
						$S_3(1,3)$	7.968.583,45 €
						$S_3(0,0)$	4.689.896,40 €
						$S_3(0,1)$	5.393.380,86 €
						$S_3(0,2)$	5.932.718,94 €
						$S_3(0,3)$	7.712.534,63 €

The respective EBIT has been calculated for every node, in order to reach the future cash flows calculations, applying equation 3.5, while the depreciation has been added back.

Table 4: Projected future cash flows

Year 0		Year 1		Year 2		Year 3	
$FCF_0(0,0)$	1.140.000,00 €	$FCF_1(1,0)$	1.152.975,11 €	$FCF_2(2,0)$	1.166.097,89 €	$FCF_3(3,0)$	1.179.370,04 €
		$FCF_1(1,1)$	1.054.161,37 €	$FCF_2(2,1)$	1.069.252,58 €	$FCF_3(3,1)$	1.107.569,85 €
		$FCF_1(0,0)$	1.115.927,38 €	$FCF_2(2,2)$	774.537,84 €	$FCF_3(3,2)$	851.268,29 €
		$FCF_1(0,1)$	1.011.556,49 €	$FCF_2(1,0)$	1.128.628,50 €	$FCF_3(3,3)$	997.392,39 €
				$FCF_2(1,1)$	1.026.162,78 €	$FCF_3(2,0)$	1.141.474,18 €
				$FCF_2(1,2)$	727.139,05 €	$FCF_3(2,1)$	1.063.989,61 €
				$FCF_2(0,0)$	1.092.363,08 €	$FCF_3(2,2)$	803.330,03 €
				$FCF_2(0,1)$	984.457,55 €	$FCF_3(2,3)$	935.072,65 €
				$FCF_2(0,2)$	681.263,30 €	$FCF_3(1,0)$	1.104.796,00 €
						$FCF_3(1,1)$	1.021.809,71 €
						$FCF_3(1,2)$	756.932,13 €
						$FCF_3(1,3)$	874.755,38 €

$FCF_3(0,0)$	1.069.296,38 €
$FCF_3(0,1)$	980.985,14 €
$FCF_3(0,2)$	712.025,11 €
$FCF_3(0,3)$	816.376,25 €

Taking for example the node $FCF_3(1,3)$, meaning that the firm has undertaken all three investment decisions up to year 3 and that sales have increased during every preceding period, the future cash flows are projected to be equal to 874.755,38 €.

The present values per node are calculated upon incoprorating the weighted average cost of capital, according to equation 3.11;

Table 5: Present values calculation

$PV_0(0,0)$	1.140.000,00 €	$PV_1(1,0)$	1.063.495,20 €	$PV_2(2,0)$	1.075.599,56 €	$PV_3(3,0)$	1.081.717,77 €
		$PV_1(1,1)$	1.017.943,89 €	$PV_2(2,1)$	1.030.955,65 €	$PV_3(3,1)$	1.048.619,20 €
		$PV_1(0,0)$	1.046.416,88 €	$PV_2(2,2)$	895.097,57 €	$PV_3(3,2)$	930.468,90 €
		$PV_1(0,1)$	998.303,82 €	$PV_2(1,0)$	1.058.326,85 €	$PV_3(3,3)$	997.829,42 €
				$PV_2(1,1)$	1.011.092,04 €	$PV_3(2,0)$	1.064.248,48 €
				$PV_2(1,2)$	873.247,60 €	$PV_3(2,1)$	1.028.529,52 €
				$PV_2(0,0)$	1.041.609,16 €	$PV_3(2,2)$	908.370,24 €
				$PV_2(0,1)$	991.866,69 €	$PV_3(2,3)$	969.101,16 €
				$PV_2(0,2)$	852.099,72 €	$PV_3(1,0)$	1.047.340,51 €
						$PV_3(1,1)$	1.009.085,35 €
						$PV_3(1,2)$	886.981,66 €
						$PV_3(1,3)$	941.296,01 €
						$PV_3(0,0)$	1.030.975,84 €
						$PV_3(0,1)$	990.265,98 €
						$PV_3(0,2)$	866.280,35 €
						$PV_3(0,3)$	914.384,31 €

Without digging deeper into the optimization algorithm, and avoiding the nodes ,0, where no investment is undertaken, the optimal investment decision is identified in year

3 at node $PV_3(2,1)$, where the firm has undertaken all three investment decisions and the sales have increased for three years in a row.

All the ,0 nodes, where the firm is led by not making any investment decision correspond to continuous waiting decisions. The FCF and PV calculated at these nodes are reasonably higher than those corresponding to either one investment decision or to one investment decision followed by one or two reinvestment decisions, since the horizon of the presented model is limited to only three years for simplification reasons. The investments under consideration are not expected to pay fruits within three years only, due to the high investment costs, which should be expected to be paid back on a longer time frame. In fact, this is the confirmation of the literature suggestion that the real options valuation models are highly complex· indeed expanding the proposed model to a five year horizon would end up to a decision tree comprising of sixty four nodes, which is evidently harder to solve than a typical DCF model.

Conclusions

The literature around investments analysis has been reviewed thoroughly for producing this dissertation. The major driver for picking and addressing this research topic was the distance between the theoretical and the real business world setup when it comes to valuating investments. This dissertation suggests that in real business setups, investments have variable uncertainty, which varies for different pay off periods. A major conclusion is that uncertainty comprises of various factors. Incorporating every uncertainty component in valuation methods would increase the accuracy but would have a detrimental cost on applicability. Under the proposed valuation method, multiple uncertainty components have been incorporated into one joint variable, which essentially changes in every investment period.

Moreover, it is worth noticing that the proposed model applies best for valuing multiple investments in multiple investment periods, but could also be applied for one sole investment, if the firm would have to invest new capital on a periodical basis, other than changes in the working capital.

The proposed model can be a useful tool for analysing multiple investments under the strategic investments planning, since managers may come up with a decision tree, which can be read both forward and backwards. Such a decision tree can facilitate the decision-making process by exploring every potential path to achieving a desired corporate growth, but it can also facilitate decision making by comparing the projected revenue, future cash flows and present values with the actualized ones.

Focusing back on the research questions provided in chapter one, the author may provide the following answers;

When weighting the advantages and disadvantages of the DCF method and the proposed ROV[2] model, the DCF method is a far better solution if the uncertainty is not expected to vary largely among different investment periods. Moreover, the proposed ROV model prove be more handy if planning a mid to long term investment strategy.

---

[2] Real Options Valuation

Taking into consideration the applicability of the proposed ROV model, the author states that its application proved to very hard, especially if compared against a traditional DCF valuation. Yet, it is worth mentioning that adopting a set of assumptions and simplifications allowed for finally running the model.

The results produced by the proposed ROV model are rather handy since they comprise of various paths, based on different demand – sales uncertainty. Moreover, the provided (in table form) decision tree can be read forward and backwards and allow for examining potential deviations from projected revenue, using historical cata. That said, the proposed model can prove to be very handy for making a mid to long term investment planning.

The major contribution of the real options theory incorporation into the investment analysis theory is the ability to insert different discount factors for investments with multiple paying off periods, as well as the ability to break the decision analysis to multiple nodes, where the firm may decide to either buy (or sell) a growth opportunity or wait.

The major restriction faced during producing this dissertation is the ROV models complexity. Moreover, despite the author intended to dig into potential machine learning application for investment analysis, no significant literature findings were identified. The complexity did not allow for running the proposed model against a DCF valuation provided by Kleemann, but some of the figures provided were used in order to add up to the scenario analysed reality.

When it comes to providing future research propositions, the author suggests running the Least Squares Monte Carlo Simulation in order to allow for simplifying the application of the real options theory.

This dissertation concludes that the real options valuation methods do have potential but are not mature enough for broad implantation especially when it comes to substituting the discounted cash flow model, but they could work well as a supplementary method either for multi stage investments or for strategic planning.

Bibliography

Amram, M. & Nalin, K., 2000. Strategy and Shareholder Value Creation: The Real Options Frontier. *Journal of Applied Corporate Finance,* 13(1), pp. 89-99.

Arnold, T., Crack, T. F. & Schwartz, A., 2007. Valuing real options using implied binomial trees and commodity futures options. *The Journal of Futures Markets,* 27(3), pp. 203-226.

Barton, K. & Lawryshyn, Y., 2011. Integrating Real Options with Managerial Cash Flow Estimates. *The Engineering EconomistFlow Estimates,* 56(3), pp. 254-273.

Brandão, L., Dyer, J. S. & Hahn, W. J., 2005. Using Binomial Decision Trees to Solve Real-Option Valuation Problems. *Decision Analysis,* 2(2), pp. 69-88.

Cassia, L., Plati, A. & Vismara, S., 2007. Equity valuation using DCF: A theoretical analysis of the Long Term hypotheses. *Investment Management and Financial Innovations,* 4(1), pp. 91-107.

Cifuentes, A., 2016. The Discounted Cash Flow (DCF) Method Applied to Valuation: Too Many Uncomfortable Truths. *SSRN Electronic Journal.*

Copeland, T. E. & Antikarov, V., 2003. *Real Options: A Practitioner's Guide.* 1st ed. New York: Texere.

Copeland, T., Koller, T. & Murrin, J., 2000. *Valuation: measuring and managing the value of companies.* 3rd ed. New York: Wiley.

Copeland, T. & Tufano, P., 2004. A Real-World Way to Manage Real Options. *Harvard Business Review,* 82(3), pp. 90-99.

Cruz Rambaud, S. & Sánchez Pérez, A., 2016. Assessing the Option to Abandon an Investment Project by the Binomial Options Pricing Model. *Advances in Decision Sciences,* Volume 2016, pp. 1-12.

Damodaran, A., 2001. *Corporate finance: theory and practice.* 2nd ed. New York: Wiley.

Damodaran, A., 2002. *Investment valuation: tools and techniques for determining the value of any asset.* 2nd ed. New York: Wiley.

Damodaran, A., 2005. *The Promise and Peril of Real Options NYU Working Paper No. S-DRP-05-02,* New York: New York University.

DePamphilis, D., 2018. Relative, Asset-Oriented, and Real Option Valuation Basics. In: D. DePamphilis, ed. *Mergers, Acquisitions, and Other Restructuring Activities.* San Diego: Elsevier, pp. 277-311.

Gennady, L., 2008. Valuing Corporate Growth Using Real Options. *Kyoto Economic Review,* 77(2), pp. 173-205.

Geroski, P. A., Machin, S. J. & Walter, C. F., 1997. Corporate Growth and Profitability. *The Journal of Industrial Economics,* 45(2), pp. 171-189.

Harikae, S., Dyer, J. S. & Wang, T., 2021. Valuing Real Options in the Volatile Real World. *Production and Operations Management Society,* 30(1), p. 171–189.

Jafarizadeh, B. & Bratvold, R. B., 2009. Taking Real Options Into the Real World: Asset Valuation Through Option Simulation. *SPE Annual Technical Conference and Exhibition.*

Jiang, S., 2021. *Using Decision Trees in Finance.* [Online] Available at: https://www.investopedia.com/articles/financial-theory/11/decisions-trees-finance.asp

[Accessed 21 October 2021].

Jorion, P., 2021. Hedge Funds vs. Alternative Risk Premia. *Financial Analysts Journal,* 77(4).

Keming, L., 2021. The effect of option trading. *Financial Innovation,* 7(65).

Koller, T., Goedhart, M. & Wessels, D., 2005. *Measuring and Managing the Value of Companies.* 4th ed. New Jersey: Mc Kinsey .

Lin, C.-M. & Smith, S. D., 2007. Hedging, Financing and Investment Decisions: A Simultaneous Equations Framework. *The Financial Review,* Volume 42, pp. 191-209.

Luehrman, T. A., 1998. Investment Opportunities as Real Options: Getting Started On the Numbers. *Harvard Business Review,* Volume 76, pp. 51-67.

Mason, S. & Merton, R., 2019. The role of contingent claim analysis in corporate finance. *World Scientific Reference on Contingent Claims Analysis in Corporate Finance,* pp. 123-168.

Mun, J., 2002. *Real Option Analysis – Tools and Techniques for Valuing Strategic Investments and Decisions.* New York: Wiley.

Myers, C. S., 1977. Determinants of corporate borrowing. *Journal of Financial Economics,* 5(2), pp. 147-176.

Pivoriene, A., 2015. Flexibility valuation under uncertain economic conditions. *Procedia - Social and Behavioral Sciences,* Volume 2013, pp. 436-441.

Schwartz, E., 2013. THE REAL OPTIONS APPROACH TO VALUATION. *Latin American Journal of Economics,* 50(2), pp. 163-177.

Smith, J., 2005. Alternative approaches for solving real-option problems. *Decision Analysis,* 2(2), pp. 89-102.

Smith, J. E. & McCardle, K. F., 1999. Options in the real world: Lessons learned in evaluating oil and gas investments. *Operations Research,* 47(1), pp. 1-15.

Trigeorgis, L. & Brennan, M. J., 2000. *Project flexibility, agency, and competition : new developments in the theory and application of real options.* 1st ed. New York: Oxford University Press.

Van Horne, J. C. & Parker, G. G. C., 1967. The Random-Walk Theory: An Empirical Test. *Financial Analysts Journal,* 23(6), pp. 87-92.

van Putten, A. B. & MacMillanIan, I. C., 2004. Making Real Options Really Work. *Harvard Business Review,* Volume 150, pp. 134-141.

Wang, T. & Dyer, J. S., 2010. Valuing Multifactor Real Options Using an Implied Binomial Tree. *Decision Analysis,* 7(2), pp. 151-233.

Zhao, L. & Huchzermeier, A., 2015. Operations–finance interface models: A literature review and framework. *European Journal of Operational Research,* 3(1), pp. 905-917.