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Valuation of Biotechnology Company

Based on Real Options Approach

Author: Darius Ramoska

Student Number: 432961

Thesis Supervisor: Drs Hans Haanappel

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PREFACE AND ACKNOWLEDGMENTS

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ABSTRACT

There is an increasing necessity to account for the uncertainty of the future cash flows. That becomes even a bigger problem when a significant investment has to be made in the future. This is exactly the issue with which the conventional NPV method cannot deal, since it may estimate a project to be of a negative value even if it is not. Therefore, to account for the misestimates, an auxiliary method needs to be considered. The thesis considers several techniques for that purpose, such as Monte Carlo simulation, risk-adjusted NPV, and Decision tree analysis. However, the tool selected to value a biotechnology company is Real Option approach. Even though, the Real Options valuation as a technique is highly debatable amongst scholars and practitioners, more often than not it is considered as an appropriate tool. The analysis made within the thesis confirms and proves that. Especially since the method used within this thesis is improved as proposed by Kellogg et al (2000) and Tan et al (2012) to account for the success probabilities and phase investments at different time steps. The resulting ROV lattice tree method is applied to the provided DCF estimates to compute the values of drugs separately within the portfolio of the company. Afterwards, the values are combined together to arrive at the final value of 786.7 million EUR. In addition to value estimation, I prove within the thesis that ROV lattice tree can indeed facilitate the conventional NPV method by adjusting not only for the risk factors of passing the stages but also from managerial point of view, where strategic capital budgeting decision can be made by observing the progress of the lattice tree. As a final step, the ROV is compared to the risk-adjusted NPV method. The results provide grounds to conclude that ROV lattice tree approach is a more conservative tool not only because it produces lower estimate of the value than rNPV but also because it is less sensitive to the movements in success probabilities.

Keywords: **Real Options, Lattice tree, Biotechnology**

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1. INTRODUCTION

In the past, the possibility of accurately valuing companies was relatively high since the value was assigned to everything that is tangible and already produced. Additionally, all the future cash flows and returns were valued as a base case scenario and uncertainty about the movements was not priced in. However, in the recent decades, new types of businesses started to grow where lion's share of the total value was no longer present in the assets in place, but rather in the intangible factor, such as the market movement, the growth opportunities, and potential.

As a result, the necessity to account for these determinants has increased. This resulted in the conventional net present value models being less accurate and reliable: the future cash flows are discounted and the method itself does not provide any information for managerial decisions and does not adjust for the assumed market movements that bring high uncertainty of the future (Brandao et al. 2005; Tan et al. 2012). Consequently, it may value a project negatively even if it may have a positive value (Myers and Howe, 1997; Smit and Trigeorgis, 2003). There were some attempts to price companies so that the uncertainty about the future market movements could be implemented. The very first of those attempts was the ground-breaking model by Black and Scholes (1973) that was designed to price the options and was adapted to pricing the companies. This produced a relatively accurate value, though, only at the end of the research and development phase. Therefore, there was no room for managerial decision in regard to the timing of the launch (Copeland and Tufano, 2004). The model was later improved by Cox et al (1979) who proposed a lattice tree approach where managerial decisions could have been made at any point in time. The approach was a breakthrough auxiliary methods to the conventional net present value technique and facilitated the capital budgeting decisions more often than the Black-Sholes-Merton model (Mun, 2006; Schwartz, 2013).

Even more so, the lattice tree approach can be improved to account for the success probabilities and phase investments at different time steps which makes the model applicable to the valuation of biotechnology company (Kellogg et al, 2000; Tan et al 2012). Ergo, the resulting Real Option approach aims to value a Dutch-based biotechnology company *Nucleos Human Health* (thereafter *Nucleos*) via valuation of its portfolio of drugs, Joxeline and RX. Both drugs target different indications and opposite markets, and both are in different stages of the approval process. As a result, the company sees no synergies and the valuation of the company itself can be done by simply adding the values of both products (Damodaran, 2006). The resulting value is then tested against the risk-adjusted NPV approach via sensitivities too see which of the methods is more likely to be dependent on certain factors.

Therefore, the **objective of the thesis is to value *Nucleos* based on the Real Option valuation framework.**

The valuation within the thesis aims to answer the following questions:

1) What are other auxiliary valuation tools and how Real Option approach is different from those, thus, how applicable it can be in valuing biotechnology company?
2) Can Real Option approach be applied to biotechnology company that has multiple yet different success probabilities and phase investments?
3) Can Real Option approach facilitate the valuation by providing information that would facilitate the management in timely capital budgeting decisions, given market conditions and uncertainty that governs it?
4) Can Real Option approach be more superior than the risk-adjusted net present value approach in its dependency on other factors, such as success probabilities or discount rate?

The thesis is organized in a way so that after literature review any reader or user would be able to implement ideas and derivations, or use it as the handbook while doing an ongoing valuation. In the first part of the thesis I substantiate the topic by providing examples, reviews, and proofs: I review the literature and build a story around it to further substantiate what are the side effects of the NPV approach, what are the alternatives and why Real Option approach will be used as an auxiliary tool. What follows then is the methodology part where I provided a complete guide to the Real Option valuation: from the free cash flows and the discount rate, to the Real Option approach and its framework. After methodology, the valuation case takes place where the biotechnology industry is presented with the protagonist being introduced and value. The aftermath of the valuation includes the sensitivity analysis and the comparisons between the Real Option valuation and the risk-adjusted net present value approach. Lastly, I summarize the thesis with a conclusion, provide recommendations to the managers who may consider implementing the Real Option approach into their capital budgeting decisions, and generate ideas for what I think can be worth researching further.

2. THEORETICAL SUBSTANTIATION AND LITERATURE REVIEW

In this part of the thesis I will overview the basic concepts of valuation and more advanced techniques that aim to improve these models. As a result, I will discuss the Discounted Cash Flow (thereafter DCF) valuation that results in the Net Present Value (thereafter NPV) and will present its flaws. Afterwards, I will introduce the valuation techniques that ought to diminish these issues and will present one of these methods – the Real Option Valuation (thereafter ROV) – in more dept. All of this analysis will be made via thorough literature review and will aim to answer one of the objectives of the thesis: what are other auxiliary valuation tools and how Real Option approach is different from those, thus, how applicable it can be in valuing biotechnology company?

For the correct interpretation of the text when considering the terminology next to the number of the transactions or valuation, the following concepts have to be defined:

- **Value** can be defined as a single number that represents the future profitability for the investor discounted at a time-sensitive expected rate of return (Mun, 2006);
- **Price** is the amount of money a party is willing to pay for the acquisition of the business.

In finance, the value is what you get and the price is what you pay. The price can be determined by industry-specific standards and criteria, usually, some sort of multiples (Kaplan and Ruback, 1996). It always varies and is hardly the same for the distinctive industries. For instance, the social media industry might use the number of users as a multiple, while a price of a company from biotechnology sector is decided on the peak year sales figure. The price usually deviates from the value due to the fact that the buyer perceives the value differently and understands the risks of the business and its relation to the market differently. Moreover, even if both the price and the value are perceived in the same manner, the transaction value usually differs, since it can include a control premium for the purpose of full control of the company, or any other premium that might be aimed at triggering the incentive to sell the business in the first place (Kaplan and Ruback, 1996; Finnerty and Emery, 2004).

For valuation, however, the future cash flows of the business have to be forecasted. If precise enough, the value of the company can be estimated correctly and would represent a true worthiness. For value determination, above all, DCF valuation method suffices as superior and most popular one (Hartman and Hassan, 2006). It is relatively easy to adapt, requires basic mathematical knowledge and involves only a couple of steps. Mainly so, because the DCF itself is researched and utilized to the maximum there are only a few aspects that can go wrong with it, regardless of the type of the company that is being valued:

1) The incorrect method to discount both the cash flows and the investments costs with the same rate. The major investment costs that are associated with platform investments can only be discounted at a risk-free rate since it represents the scenario as if the money would have been put

aside at the opportunity cost of capital, namely, the risk-free rate (Mun, 2006). Whereas, the smaller investments can be discounted at the same rate as the cash flows because these are treated as an incremental capital expenditure and presents the part of the company's operation activities already.

2) The DCF does not take into account the flexibility of the investment decision. The DCF values all cash inflows and outflows accordingly, though, cannot facilitate the user in terms of managerial and strategical initiation of the investment decision. Therefore, the model not only provides no additional information other than the numerical one but also fails to account for the timing value of investment decision (Brandao et al. 2005; Tan et al. 2012).

Therefore, in some cases it is merely enough to use DCF alone to arrive at the value of company. For instance, in standard accounting, a treatment of platform investment is usually regarded as R&D and is being expensed from the operations of the company. As a result, it underestimates the true value of the assets and, in turn, overestimates the rate of return (Myers and Howe, 1997). Whereas, in order to arrive at NPV of the company that is ready to do an expansion-related investment, the platform investment value has to be subtracted from the DCF value and represents a static nature of the investment (Smit and Trigeorgis, 2003).

That being said, one can infer that DCF method alone cannot accurately value biotechnology company. Even more so, as I will explain later, the static NPV is also flawed as a tool for value estimation due to the fact that it stems from the DCF and adjusts for the platform investment at $t = 0$, regardless of the economic outlook. The following sections within the literature review shall reveal that Real Options Valuation as an add-on tool can provide the managerial flexibility and improve the aforementioned valuation techniques.

2.1. Literature review on valuation

The DCF as a tool of valuation can be well representative of the value if the company holds an investment opportunity that would not result in a game-changing technology and there is no flexibility in regard to the investment timing. However, if the company indeed possess the opportunity to invest in a technology that would redefine its position and has an option to trigger the investment based on its preference, then static NPV alone fails to incorporate these values appropriately (Myers, 1977; Smit and Ankum, 1993). In other words, corresponding timing of the investment largely depends on the availability of the information of the future opportunities. If the latter has a substantial uncertainty, then DCF fails to incorporate it too (Myers, 1977; Smit and Ankum, 1993). Therefore, DCF is a very sensitive to certain industries or companies, ergo, cannot accurately value a company if the following conditions associated with it prevail:

1) The business is a relatively new one with limited historic performance and belongs to the industry that requires early phase investments such as R&D (research and development) or FDA (food

and drug administration) approval process, generates unstable current profit, and might have a chance at the high growth opportunities (venture capital, biotechnology, pharmaceuticals, etc.);

2) The investment is a sunk cost that cannot be taken back;
3) The outcome of the investment is highly uncertain and can be approximated via probabilities, or volatilities, at best; and
4) The timing of the investment is highly dependent upon the asset holder. In such case, one can defer the investment opportunity once more information is at hand, though, there is a chance that the other way round happens and an opportunity that was fairly plain previously does not look like that anymore (Smit and Ankum, 1993; Dixit and Pindyck, 1994).

Since the DCF valuation technique is unable to capture these strategic decisions and cannot incorporate them into valuation, there is a rising need to solve the analogous issues and quantify them in accordance. A timely executed capital budgeting decision can bring more added value to the company (or the asset) than it would be accounted for within the DCF framework. Therefore, in reality it requires a flexible investment decision and a way to account for its flexibility (Smit and Trigeorgis, 2003; Hartman and Hassan, 2006). The corresponding value is regarded as the *flexibility value* of the company and can be added to the generic *static NPV* to arrive at the new NPV – the *expanded NPV.* In addition, a timely strategic decision that brings value to the assets in place is also regarded as *growth opportunities*. This represents the value of opportunities initially inherited in the assets the company owns that can be triggered only by a timely executed strategic investment decision. Therefore, the *growth opportunities* and the *flexibility value* in essence resembles same idea of valuing the company (or assets) for which the additional worthiness can be excelled due to its link to the possibility of value provided by the investment execution (Meyer, 1977).

The literature suggests tree main ways to facilitate the capital decision making (as well as the DCF method) in order to appropriately account for the uncertainty of the investment outcome: (1) Decision Tree Analysis (thereafter DTA), (2) Real Option Valuation (thereafter ROV or ROA), and (3) Monte Carlo Simulation (thereafter MCS). All these models use the DCF valuation as an input and provide with the end-point figure that includes both static and flexibility values. As a result, it happens that sometimes these techniques positively value the projects that initially demonstrate negative NPV (Smit and Trigeorgis, 2003).

2.1.1. Monte Carlo simulation

The Monte Carlos Simulation method is made by running a software to produce a several thousand possible price scenarios in the future. Each scenario is a distinct price path from the other one and is affected by the stochastic process. The technique is widely considered to be useful for capital budgeting and cash flow forecasting (Gamba, 2002; Mun, 2006; Tan et al. 2012) and may be convenient

in doing so for the public companies where the simulations of the market can be executed. However, the simulation is not advisable to use in forecasting cash flows of smaller projects or the companies about whom only some degree of private (inside) information is known. The latter can be a building block in the forecast and would provide much more ground than the simulation itself. Another extent to which the MSC does not suffice is when it comes to convenience, time efficiency, and relevance. The simulation provides no insight into the strategic investment decision and is computationally heavy: the time it takes to run all the simulations may be consuming, especially for the smaller businesses (Hartman and Hassan, 2006). The simulation only provides the value of the option at a specific future time ($t = n$) by following a Brownian motion that is based on the random process of normal distribution, the drift, and the diffusion terms. Due to the fact that the simulation is a forward-looking technique, the backward induction necessary to value the option at a current time ($t = 0$) cannot be implemented (Gamba, 2002). Whereas, the other two approaches (DTA and ROV) can provide more than numerical information for the user and attain both the value of the option in specific time ($t = n$) and in current time ($t = 0$). As a result, the Monte Carlo Simulation is not user friendly, possess challenges in its computation and implementation, and provides no additional value into the strategic planning (Hartman and Hassan, 2006).

2.1.2. Decision tree analysis

The Decision Tree approach is done by constructing a tree to depict a discrete time managerial flexibility so that each nodes represents a distinct decision the manager can make in order to optimize the value of the project (Brandao et al. 2005). On the other hand, maximizing value at each node effectively changes the expected cash flows, in turn, shifting the characteristics of risk (Brandao et al. 2005). That may seem like a problem, though, it can be diminished by incorporating the market information for the risk input (Brandao et al. 2005). Ergo, the DTA can be a valid tool and is already widely used by practitioners in industries that entails substantial uncertainty and probabilities to solve them, such as biotechnology or pharmaceuticals (Amram and Kulatilaka, 2000; Hartman and Hassan, 2006). Interestingly enough, the DTA usage is very limited and is the lowest in usage between the three when looking from the perspective of a healthcare divisions of an investment bank or a consulting firms (Hartman and Hassan, 2006). However, the overall popularity of the method provides no grounds for a real challenge in its application and presents many similar qualities to the risk-adjusted NPV, therefore, will not be analysed in detail within the thesis.

2.1.3. Real Options approach

The ROA is still debatable and presents mixed feelings amongst practitioners (Copeland and Tufano, 2004). Moreover, Hartman and Hassan (2006) summarized a vast array of surveys made by numerous scholars, academics, and consulting agencies, concluding that ROA is rarely used in practice

(9% of the participants in 2000 said to use the ROA), though, nearly a third of respondents acknowledged the importance of incorporating the abandonment of the project into the valuation and were using its rate (32% of respondents in the same survey). The reasons for that were twofold: either the practitioners were not fully familiar with the concept to fully employ it in day-to-day activities, or the structure of the ROA was not trustworthy due to it being a new way of computing uncertain projects (Hartman and Hassan, 2006). Consequently, it stands as a challenge waiting to be tackled.

Consequently, there are many auxiliary methods to facilitate the DCF methodology, the most used ones being the conventional risk-adjusted NPV (thereafter rNPV) technique, the MCS, the DTA, and the ROA. As you will see in the upcoming section, the comparison of these methods reveal that ROA is very vague in its application, albeit because it is being associated with two completely different approaches. One of the approaches, the lattice tree[1] (or referred to as CRR) shares the top spot with DTA as the most fitting tool for the valuation of biotechnology company when it comes to comparing them with one another (Table 2). Here, the CRR ticks almost all of the boxes and fails only to be trustworthy amongst practitioners and managers in a way that it is usually problematic to explain the how it really computes the values (Hartman and Hassan, 2006). On the other hand, it incorporates the true volatility of the cash flows or the market, while DTA only assumes market movements in terms of probabilities. On the other hand, partial differential equation (referred to as BSM) which is the other ROA, is ranked as one of the least feasible techniques, alongside MCS and the NPV. The main faults with the MCS and the BSM models are the advanced mathematics resulting computational challenges that also makes smaller companies almost unable to efficiently generate values. Furthermore, these approaches do not facilitate the managers with the timing of the strategic investment decision.

2.2. Literature review on ROV

The consensus regarding the applicability of ROV is unthinkable due to the differences between lattice tree and partial differential equation approaches. Ergo, in this section I will touch upon the main differences between the two approaches and what makes the lattice tree a more feasible solution in valuing biotechnology companies.

The term real options stem from the idea that company has an option to proceed with an investment in the future at any time of its choice (Dixit and Pindyck, 1994; Amram and Kulatilaka,

[1] *Following Brandao et al (2005) remarks, the thesis will not reflect on the lattice tree (or binomial lattice) as a synonym to the binomial tree. According to Brandao et al (2005), lattice tree (or binomial lattice) is a Real Option tree where a number of pairs of branches, except for the extreme ones, meet at distinctive points (e.g., upward and downward scenarios result in the same value as downward and upward scenarios). In turn, either the product or the sum of probabilities result in 1. Therefore, the number of nodes increase at an arithmetic progression (by 1 at each time step). Meanwhile, the binomial tree represents a Real Option tree where all the branches are independent, therefore, the number of branches never meet and the resulting number of nodes increases at a geometric progression (by a factor of 2 at each time step).*

2000). The underlying of such option is the assets in place. However, the value of both underlying and the option itself may deviate due to various reasons. Most of those reasons are more or less inherited and perceived by the market. However, in the ROV framework the deviation is attributed to the firm's ability to grow that is perceived to be caused by the actual assets in place. As a result, the difference between the price of the option and the real value of the assets in place is regarded as the *growth opportunities*. Therefore, such option is comparable to that of call option in the world of finance.

The first applications of the ROA were due to the ground-breaking option pricing model by Black and Scholes (1973). It allowed for option-related valuation model to be applicable on the valuation of liabilities of the company. The technique was based on the equilibrium arguments and later updated by Merton. This model stood as the backbone for almost every area of finance, though, the term "Real Options" itself was applied later on by Myers (1977). The inputs within the model were applied for corporate usage and reflected the optionality that the companies have on their investment decisions (Table 1). Afterwards, Cox, Ross and Rubenstein (1979) were able to make another useful and accurate model that did not require such a heavy math as it was the case with the original BSM (Black-Scholes-Merton) model. Cox et al. (1979) designed the lattice approach which was initially based on the arbitrage arguments. It was the same theory and technique that is used to this date to price the options by drawing a lattice tree. The method used algebra instead of calculus and provided an easy way for the practitioners to value their real options (Copeland and Tufano, 2004).

Table 1.

Comparison of the inputs within both Call and Real Options

Call Option with stock as underlying asset	**Real Option with project as underlying asset**
Current value of the underlying asset	Static NPV
Strike price	Investment cost
Time to maturity	Life of project opportunity
Volatility of the underlying asset	Uncertainty of the project
Risk-free rate	Risk-free rate

Aside from the computational characteristics, the aspects that set the two approaches apart are: (1) BSM model is slightly more accurate in pricing assets, especially when more steps (time periods) are involved, though, can only value the asset as if it is based on European option (exercised only at the expiration); (2) CRR (Cox-Ross-Rubenstein) or lattice tree model is slightly less accurate when more steps are used, though, applicable in valuing options that can be exercised at any point in time. The CRR can also be tailor-made to incorporate the changes in volatility or adjusted to reflect multiple investment decisions (Copeland and Tufano, 2004). It means that the CRR method facilitates the valuation so that managers could use probabilities instead of approximated volatilities, the value of the company can be observed at any stage of the process, and the timing of the option can be based on the market conditions.

To summarize, only lattice tree approach of the ROV technique will be used in valuing the biotechnology company as it possesses the highest number of advantages not only compared to BSM methods, but also to other auxiliary tools. Biotechnology company of any size can implement it, it also incorporates uncertainty and fluctuations of the market as well as properly discounts the investment costs. Furthermore, the method is time-efficient, mathematically feasible, and most importantly, provides information for managerial decision making.

Table 2.

The comparison of considered valuation techniques (MCS – Monte Carlo simulation; DTA – decision tree analysis; CRR – lattice approach introduced by Cox, Ross and Rubenstein; BSM – partial differential equation of Black, Scholes and Merton; rNPV – risk-adjusted NPV)

	CRR	**BSM**	**DTA**	**MCS**	**rNPV**	**NPV**
	9/10	5/10	9/10	5/10	7/10	5/10
Easy-to-generate for small companies	☑	☒	☑	☒	☑	☑
Easy-to-generate for big companies	☑	☑	☑	☑	☑	☑
Time-efficient	☑	☑	☑	☒	☑	☑
Mathematically/computationally feasible	☑	☒	☑	☒	☑	☑
Provides information for managerial decisions	☑	☒	☑	☒	☒	☒
Trustworthiness by practitioners/managers	☒	☒	☑	☑	☑	☑
Applicability for biotechnology valuation	☑	☒	☑	☑	☑	☒
Incorporates uncertainty	☑	☑	☑	☑	☒	☒
Incorporates volatility of the market/cash flows	☑	☑	☒	☑	☒	☒
Correct way of discounting the investment	☑	☑	☑	☒	☑	☒

2.2.1. Types of Real Options

This section will discuss the types of Real Options and how these can be applicable to the specific case of biotechnology company.

CRR initially developed a call-based option that essentially was an *Option to defer* since the observer is able see the value at each node and decide whether to continue with the current flow of business or halt it. Ever since then, numerous other types of options were made (Table 3).

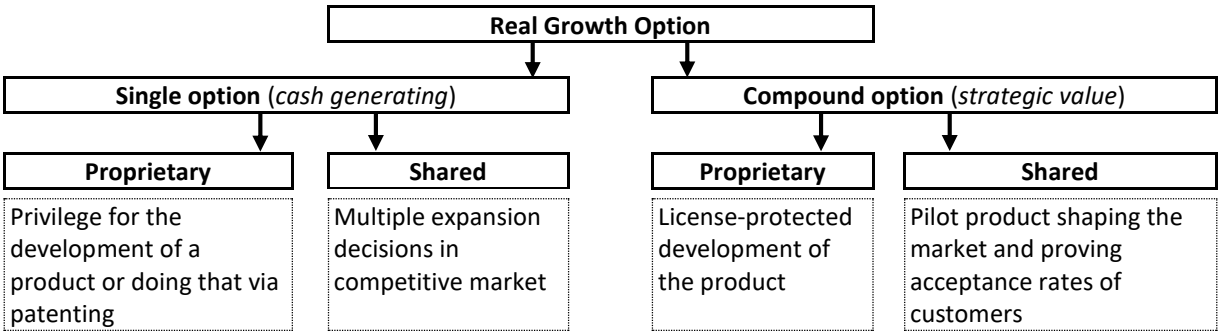

Figure 1. *Types of Real Growth Options.*

Source: Smit and Trigeorgis (2004) "Strategic Investment. Real Options and Games"

The main ones that are used the most are *Option to defer, Option to wait-and-see, Option to abandon, Option to expand, Option to contract,* and *Option to expand or contract.* There are other

types of options that have limited applications and were less talked about amongst academic, however, neither of them shed such a degree of importance to practice as the listed ones.

Table 3.

Types of Real Options

Option to	Type	Description
Defer (Simple)	Timing	Option to defer gives management the opportunity not to invest if the outcome seems to be dissatisfactory. In a sense it is the European call option which provides downside protection by not exercising the option.
Wait and See	Timing	The option that provides the management with the ability to decide on the time and the execution of the investment decision. The option is similar to the American call option in a sense that it provides the management with the right to execute the option at any point in time. Generally, it is used to "wait-and-see" until more relevant information is known about the market/industry outlook that might influence the execution or timing of the investment (Dixit and Pindyck, 1994). E.g., *biotechnology company decides pause the drug development since it believes that the market conditions will be more favourable in the future*.
Abandon	Timing	The option that gives the management the opportunity to abandon the operations if the market/industry outlook looks pessimistic for future investments. The option provides the choice between the 'normal' state and the 'abandonment' which accounts for the value of equipment in case it was sold. The latter is the main difference between the *Option to Defer* and the *Option to Abandon*. E.g., *it is more profitable for mining company to close the mine and sell the equipment rather than keep extracting*.
Expand	Size	The option giving the holder a right to expand the business or operating activities given the financials, market/industry outlook, and the possible costs of expansion. The option holder can choose between staying on the same track or expanding the business.
Contract	Size	The option providing the holder with a right to contract in size or operations by taking into account the costs of contractions, financial conditions of the company, and the market/industry outlook. E.g., *company acknowledges the reduction in demand and wants to respond to changes accordingly by cutting down the output.*
Expand or contract (Switching option)	Size	A compound option that provides with the ability to dynamically switch the binary operating activities: on or off. At the different time steps, the management can choose to either continue (call option, expand) or switch off the production (put option, contract). It is incorporated at any production facility where a vast array of production depends on the demand or the decisions of the management. The execution is binomial (binary): either expansion or contract.

Therefore, a combination of several options can be used in combination to provide an ultimate package, e.g. a biotechnology company that expects to finish developing a patented ground-breaking drug and already looks for commercialization opportunities might be holding a *compound proprietary option to expand* or *compound proprietary option to wait-and-see*. This provides companies with selective and concrete managerial flexibilities that are absent in other forms of techniques. Therefore, the ROV framework can be essential when management can undertake an identification of strategic investment decisions under uncertain future business outlook; when valuating strategic decision at distinct times and reflecting it in terms of financial resources; in prioritization of decisions based on certain qualitative and quantitative criteria; in optimization of value by identifying the investment consequences and financial viability at each path or determining what paths have to be undertaken in

order to arrive at the optimal capital budgeting strategy; and in optimization and management of optimal timing of investment decision (Mun, 2006).

Consequently, the literature on Real Options and its applicability to the projects largely driven by uncertainty, provides much ground to proceed with the ROV applications for companies within the biotechnology and/or pharmaceutical industry.

2.2.2. ROV in biotechnology industry

It is debatable whether the ROA is an appropriate tool to estimate the value of a company within the biotechnology and/or pharmaceuticals industries (Jacob and Kwak, 2003). Myers and Howe (1997) alongside Amram and Kulatilaka (2000) state that the estimation of the true profitability and the valuation of biotechnology company is hard, noisy, and biased in itself, regardless of the valuation method, and that there are no traded asset resembling the project value reasonably well. In addition, Amram and Kulatilaka (2000) declare that the private risk is persistent all the time and goes away only before commercialization, ergo, all operating decisions are only driven by the considerations of private risk. Lastly, the information is of the highest value in a drug development process and the ROA cannot incorporate it into the valuation (Amram and Kulatilaka, 2000). More to these points, quite a lot of practitioners are sceptical about the implementation because they regard it as complex, unacceptable, or lacking transparency, thus, resulting in a low usage of such technique within the biotechnology industry (Hartman and Hassan, 2006).

However, as mentioned previously, the majority of reports, usually refers to both CRR and BSM approaches as Real Option valuation techniques. That is a correct way to treat it, albeit, as the analysis suggest, the partial differential equation method is flawed in many regards, while the binomial lattice method not only suffices as the appropriate tool, but can be considered as superior in regard to other auxiliary methods (Table 2). In support of that, a more recent survey, completed by Hartman and Hassan (2006) found that the ROA is a relatively popular valuation method when the drug is past the pre-clinical phase (*for clinical phases, see 4.1. Biotechnology industry*) and is also already in-use by the healthcare divisions of investment banks and consulting firms when valuing biotechnology companies. According to the same paper, out of the two popularly used ROV methods, the lattice tree approach is used more when pricing the R&D projects and/or FDA phases. Therefore, the ROA is applicable in any situation (whether it is a clinical trial, or valuation of the company) and can vary between both approaches. In accord to that, Mun (2006) and Schwartz (2013) unveils the advantages that make the ROA applicable within the biotechnology industry:

1) The type of the investment that may be unprofitable at first but create compound options in the future can be dismissed by the DCF approach, but validated via usage of ROA;

2) The ROA enables management to see the intrinsic strategic values within the R&D phase and quantify it. As a result, the investor has the ability to spread a single investment into the multiple-stage injections and to observe the conditions at each time phase. Therefore, the management can wait-and-see, abandon or defer the injection into the project if the costs are too high. These managerial decisions provide an opportunity to invest only if the investment can generate value;

3) Due to the high costs related to the R&D or FDA phases, the importance of options such as the abandonment of the project has even more value and must be included in the valuation technique.

Therefore, a biotechnology company constitutes uniqueness when compared to other industries and cannot be tackled by usual techniques, hence, possess perfect characteristics for the ROV case (Kellogg and Charnes, 2000; Schwartz, 2013). Moreover, the ROA provides a holistic project analysis that may be preferential and would foster its application in the real-life decisions within either biotechnology/pharmaceutical sector or healthcare division of banks and consulting firms. However, the lattice tree approach will be used as an auxiliary technique to the DCF for the valuation of the biotechnology company. The reasons for that are listed in the previous sections, though, also the overall tendency of both academia and consultancy firms to lean towards the binomial lattice approach is appealing in choosing the method (Copeland and Tufano, 2004; Hartman and Hassan, 2006).

In conclusion, during the course of the chapter I touched upon the flaws of the DCF technique arising in valuing companies that require multiple investments and possess uncertainty about the future cash flows and the success rates. As a result, the auxiliary methods that aim to eliminate these issues were introduced and compared. Monte Carlo simulation and the BSM approach had the least amount of characteristics applicable to valuation of selected company, while DTA ticked almost all the boxes. All of the models, expect for the CRR approach, lacked an aspect or two to make it applicable in valuing the biotechnology company. Meanwhile, the CRR method stood out since it provides the flexibility to managers in terms of timing of strategic investment decision, ability to oversee the life of the project and to halt it or proceed with it depending on the size of the investment and market conditions. It also incorporates the uncertainty, success rates and the investment outlays, as well as presents little computational challenges. This answers my first research question and confirms that the lattice tree approach of ROV is applicable in valuing biotechnology company in question.

3. METHODOLOGY

In this part of the thesis I will cover the derivations, equations, and the formulas that are necessary for the valuation. In all instances I will provide simple examples to make it more understandable. I will start with the conventional NPV approach, then introduce the risk-adjusted NPV. Lastly, I will explain the BSM and CRR approaches that are under the umbrella of the ROV technique, I will then present its calculation, and at the very end will introduce the ROV framework that will be used to value biotechnology company.

3.1. Net present value

In this section, I will explain how to derive the Net Present Value (NPV) of the company which includes deriving the free cash flows and estimating the discount rates. The first major input, the free cash flows, will be derived from the Income statement and the balance sheet of the company. Then, it will be discounted at the cost of capital via DCF method to generate the NPV value. The latter is estimated by adding a collection of time series of free cash flows discounted at time-specific discount rate. The resulting formula is as follows:

$$NPV = Planning\ Value + Residual\ Value \tag{1}$$

$$Planning\ Value = \sum_{t=1}^{n} \frac{FCF_t}{(1+r)^t} \tag{2}$$

Where FCF_t are the cash flows at the time t, while the r is the discount rate (WACC). The sum of these discounted values represents the planning value of the company. Meanwhile, the residual value represents the value of the company after the planning period, or, the perpetual value of the company. Its calculation highly depends on the positioning the company is expected to have after the planning period. Since the competitive advantage in biotechnology industry is established via the protection of patent, the exclusivity of the product will end once the patent expires. Ergo, the expectation is that the return on investment will converge to the required cost of capital during the perpetual period. For that reason, the residual value is calculated based on the convergence model, as suggested by the McKinsey & Co. (Koller et al, 2010). It is calculated by dividing the NOPAT of last year within the planning period by the discount rate of the last period.

$$Residual\ Value = \frac{NOPAT_{last}}{(1+r)^{last}} \tag{3}$$

Therefore, the NPV is composed of two main building blocks: the planning value and the residual value. The debt will only be subtracted at the end of the complete valuation. Thus, the interim NPV will be unaffected and therefore, will be used as an input within ROV framework.

The valuation horizon for the planning period is initially set at 20 years from the date when the application for the patent was issued. Therefore, based on the differences in the launch dates, the length of the planning period itself can vary for different drugs, though, the end date of planning period will be the same for all products, 2036 (*see 4.3.3. Drug Assumptions*).

3.1.1. Free cash flow

The FCF is free cash available to investors that company can generate after accounting for all the expenditures necessary to sustain normal course of the business. It is essentially the Operating Cash Flow minus the Capital Expenditures. However, in order to arrive at this conclusion some important intermediary steps need to follow.

First, the Operating activities of the business have to be evaluated by arriving at the Net Operating Profit after tax (NOPAT). It is derived from the income statement and is the first building block in arriving at the free cash flow. The line of calculus is as follows (where OP is Operating Profit):

$$NOPAT = Revenue - Costs - Operating\ Expenses - Taxes\ over\ OP \quad (4)$$

Where $Costs$ are costs of goods sold (COGS) that are directly attributed to the producing goods or delivering services. Therefore, the line items for the COGS will be Production and Packaging Costs.

$$Costs = Production\ costs + Packaging\ costs \quad (5)$$

The $Expenses$ include other types of costs that indirectly affect the business. This category can be split into operating and financial expenses. Since NOPAT concerns only operations, the latter type of expense will be taken out. Meanwhile, the $Operating\ Expenses$ includes Selling, General and Administrative (SG&A) expenses, Depreciation and Amortization (D&A), and other Research and Development (R&D) expenses that are associated with improvement of current line of products or add-ons and cannot be regarded as a platform investment or enlargement within the production line.

$$Operating\ Expenses = SG\&A\ expenses + D\&A \quad (6)$$

Within the valuation, SG&A will take into account:

- **Sales and Marketing** expenses referring to all costs associated with advertising campaigns, articles, and other costs incurred via sales and marketing department;
- **Personnel** expenses that include fees necessary for the management of the business, such as salaries, advisory and legal fees, bonuses, insurance costs, holiday and travel allowances;
- **Distribution** expenses that include the costs associated with logistics and delivery of the product to the customer, such as fees for postal services and/or physical delivery of the goods to the partners;
- **Other** expenses that take into account costs associated with premises rent, utilities, car rental, fuel costs, and other overhead expenses.

The $D\&A$ (Depreciation and Amortization) is the charge associated with fixed or intangible asset that is capitalized for a specific time period, where the value of the asset is represented by the price it was purchased rather than market price.

Afterwards, the NOPAT is being adjusted by several line items within the balance sheet and income statement to arrive at the FCF:

$$FCF = NOPAT - \Delta NWC - \Delta Capex + \Delta Provisions + D\&A \quad (7)$$

$$\Delta NWC = \frac{NWC_{t-1} + NWC_t}{2} \quad (8)$$

$$NWC = Stocks + AccRec + Prepayments + CCE - AccPay - Other\ Payables \quad (9)$$

Where ΔNWC is the change in Net Working Capital. For the estimation of this input will be based on the line items from the balance sheet: the NWC takes into account the average difference of two-year period of Current Assets (thereafter *CA*) and Current Liabilities (thereafter *CL*). The inputs for each of the line items are as follows:

- **Stocks** (CA) or inventory include the outstanding number of products that are already manufactured and ready to be sold or everything that is still in the process of making. The value is calculated based on the price of their purchase or manufacturing cost;
- **Accounts Receivables** ($AccRec$ of CA) are the outstanding unpaid amounts from the buyers for the goods or services provided;
- **Prepayments** (CA) are the payments that is paid by the buyers in advance for the goods or services provided;
- **Cash & Cash Equivalent** (CCE of CA) is the amounts of liquid and ready-to-use money that company has either in cash, or on its bank accounts;
- **Accounts Payables** ($AccPay$ of CL) are outstanding unpaid amounts that the company owes to suppliers or other parties that provide services;
- **Other Payables** (CL) are other outstanding unpaid amounts that the company owes to other parties or employees.

$$\Delta Capex = \frac{Capex_{t-1} + Capex_t}{2} \quad (10)$$

$$Capex_t = (FA_t + IA_t) - (FA_{t-1} + IA_{t-1}) \quad (11)$$

$$\Delta Provisions = \frac{Provisions_{t-1} + Provisions_t}{2} \quad (12)$$

The $\Delta Capex$ is Capital Expenditures that is derived from the balance sheet and represents the average two-year investments in both fixed and intangible assets. The line items that are taken into account are **Fixed Assets** (FA) that include hardware, software, and laboratory equipment and

Intangible Assets (IA) which takes into account patents or goodwill. Input of $\Delta Provisions$ is only concerned about the change in Provisions that include deferred taxes, pension and social security contributions, and other provisions such as credits to pay or medium-term interest.

3.1.2. Discount rate

The Weighted Average Cost of Capital (WACC) will be used as a discount rate. It represents the risk profile of the company and will be used as a proxy for the required rate of return. The same discount rate will be used for the cash flows of all the regions and all the drugs regardless of their FDA phase that are in the portfolio of the company (Myers and Howe, 1997).

$$WACC = \frac{E}{V} \times k_e + \frac{D}{V} \times k_d \times (1 - T) \tag{13}$$

In the equation, k_e is the cost of equity, whereas k_d is the cost of debt. The other inputs, are straightforward so that E is equity, D is debt, and V is the total value of the company. As a result, $\frac{E}{V}$ is the weight for equity, while $\frac{D}{V}$ is the weight for debt in retrieved from the economic value of the company, since *Nucleos* is a relatively young private entity, it entails rather distorted balance sheet values. The economic value of the company will be estima will be extracted from the dataset compiled by Damodaran (2016). Since *Nucleos* has more than one drug (*see 4.2. Description of the company*), the discount factor will be weighted across the drugs and used as one for the whole valuation (Myers and Howe, 1997).

3.1.3. Cost of equity

The first component of the WACC is k_e, the cost of equity. It represents the required rate of return at which the investors expect to be compensated for the risk they take for holding the stock of the company. Therefore, cost of equity can sometimes be regarded as the only discount rate when the company is private or has no debt on its books. The base upon which the cost of equity will be used is the Capital Asset Pricing Model (CAPM):

$$k_e = r_f + \beta \times (r_m - r_f) \tag{14}$$

Where r_f is the risk-free rate, r_m is the return of the benchmark market index or any similar point of reference, and β is the sensitivity of the company to the movements in the market and is called the systematic risk. The resulting difference between the return of the benchmark and the return of the risk-free rate is referred to as risk premium.

Risk-free rate is the rate that represents the return on virtually riskless investment opportunity. It is represented by the German government bond since the *Nucleos* already has presence of operating activities in Europe, is a European company, and denominates its cash flows in Euro. The yield of the bond will be taken as the return and the time to maturity of 20 years matches the valuation horizon.

Risk premium is the premium that market participants expect to receive for the risk of investing in the market portfolio, or at least its proxy. In this case, the proxy will be the *iShares Nasdaq Biotechnology (IBB),* an exchange-traded fund (ETF) that follows an index comprised of biotechnology companies' stocks (Myers and Howe, 1997). Therefore, the annualized stock returns of 20 years will be used as market returns.

Beta will also be taken from the same benchmark index to facilitate the computation. If the index does not have its beta, this issue can be tackled in the following way:

$$\beta = \frac{Cov(R\,, R_M)}{\sigma_M^2} \tag{15}$$

Where β is factor of a systematic risk associated with the specific asset, while R is return of the benchmark stock, R_M is return of the benchmark market and σ_M^2 is variance of a market return. In this way, the beta of a stock can be approximated in regard to wanted market benchmark.

3.1.3. Cost of debt

The cost of debt is based on the approach, developed by Damodaran (2016). In such case, the risk-free rate is added to the default risk premium (credit spread premium), the r_{DP}. The default risk premium is estimated by arriving at the interest coverage ratio ($EBIT/Interest\ Expenses$), then converting it to the bond rating and eventually to the default risk premium (Table 4). Since the current interest coverage ratio of *Nucleos* is distorted, the industry average interest estimate is applicable. The cost of debt is estimated in the following way:

$$k_d = r_f + r_{DP} \tag{16}$$

Table 4.

The derivation of default spread based on the interest coverage ratio.

Interest Coverage Ratio (market cap or book value < 5 billion USD)	Rating	Default Spread
> 12.50	AAA	1.25%
9.50 – 12.50	AA	1.75%
7.50 – 9.50	A+	2.25%
6.00 – 7.50	A	2.50%
4.50 – 6.00	A-	3.00%
4.00 – 4.50	BBB	3.50%
3.50 – 4.00	BB+	4.25%
3.00 – 3.50	BB	5.00%
2.50 – 3.00	B+	6.00%

Source: Damodaran (2016)

3.4. Risk-adjusted NPV

Risk-adjusted NPV method is the simplest way of accounting for the success probabilities and FDA phase investment. It uses the NPV as a starting point and, then at each time period it adjusts for the success probability and the investment costs. The latter is discounted to the present time at the risk-free rate, therefore, eliminating the downside of the conventional NPV method where the

investment costs are subtracted from the cash flows and the resulting values are discounted at the discount rate, namely WACC. The process of arriving at the rNPV is as follows:

$$rNPV_1 = NPV(q_1) - \frac{K_1}{(1+r_f)^1}$$
$$rNPV_2 = rNPV_1(q_2) - \frac{K_2}{(1+r_f)^2} \quad (17)$$
$$\dots$$
$$rNPV_t = rNPV_{t-1}(q_t) - \frac{K_t}{(1+r_f)^t}$$

Where q is success probability that adjusts the NPV at certain time periods, K is the phase investment outlay at the same time step, and r_f is a risk-free rate. The last estimate, which is $rNPV_t$ in this case is deemed to be the final value of the project.

To better understand this method, assume that the current expected NPV of the drug is 100 million EUR, there is two phases left with an investment outlay (K) y required at 10 and 5 million EUR, respectively. Assume, that the company considers that the chances of passing these stages are equal at 50% (q) and that the risk-free rate (r_f) is 1%. The conventional NPV technique would have taken these investments into the DCF and would have discounted at the same discount rate without adjust for any risk, resulting in the value of approximately 90 million EUR. Meanwhile, for the rNPV estimation, the phase investments are discounted for the present time via risk-free rate, the NPV is then adjusted for the success probabilities and the present values of investments. Therefore, at $t = 1$, the 100 million EUR is adjusted for 50%, leaving 50 million and then the PV of investment is subtracted, arriving at 40.1 million EUR. The resulting rNPV of the project is 15.1 million EUR, hence, reducing the value, estimated by the NPV by approximately a factor of 6. The complete derivation of the value can be seen below.

Table 5.

The example of the practical implementation of rNPV approach.

	$t = 0$	$t = 1$	$t = 2$
Cost of the phase investment (million EUR)		10.0	5.0
Risk-free rate		*1%*	*1%*
Present value of the phase investment (million EUR)		9.9	4.9
Success probabilities		*50%*	*50%*
Unadjusted NPV (million EUR)	100.0		
Risk-adjusted NPV (million EUR)	**15.1**	**40.1**	**15.1**

This small example then confirms the importance of adjusting the values for risks and the necessity of properly discounting the costs of phase investments.

3.5. Real Option valuation

As discussed, the ROV can be made in two completely different ways (*see 2.2. Literature review on ROV*). One way is to rely on the partial differential approach, the other is to use the lattice tree

method. Both methods use the estimated NPV as a starting point and treats it as underlying asset value. With the same NPV as underlying asset value and the same investment cost, applied properly and executed only at the maturity, both techniques provide almost identical outcome (Cox et al., 1979).

In the following two sections I will explain each method on the technical level and provide a practical implementation.

3.5.1. Partial differential approach

This approach was developed by Black and Scholes (1973; *see 2.2. Literature review on ROV*). Using this method, the drug value can be calculated in the following way:

$$f_0 = S_0 N(d_1) - K e^{-r_f T} N(d_2) \tag{18}$$

$$d_1 = \frac{ln\left(\frac{S_0}{K}\right) + \left(r_f + \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}} \tag{19}$$

$$d_2 = \frac{n\left(\frac{S_0}{K}\right) + \left(r_f - \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T} \tag{20}$$

The inputs that can be easily applicable to both financial and real options are listed in the table 5, while probability factors $N(d_1)$ and $N(d_2)$ follow normal distribution with mean of 0 and standard deviation of 1 ($\sim N(0,1)$), therefore both d_1 and d_2 are independent and identically distributed. The $N(d_1)$ can be regarded as the upward probability, representing the possibility of the project ending up in the money, while $N(d_2)$ can be regarded as the downside probability.

Table 6.

The comparison of the inputs within the frameworks of financial and Real Options

Call Option with stock as underlying asset	Input	Real Option with project as underlying asset
Current value of call option	f_0	Current value of real option
Current value of the underlying asset	S_0	Static NPV
Strike price	K	Investment cost
Time to maturity	T	Life of the project
Volatility of the underlying asset	σ	Uncertainty of the project
Risk-free rate	r_f	Risk-free rate

Source: Black, Scholes, Merton (1973); Schwartz (2013).

To make this method more feasible, assume the same inputs that were used in the rNPV example, hence, the S_0 equals the unadjusted NPV of 100 million EUR and the r_f is 1%. However, since the BSM model works as European option, the application of more than one stage investment would require slightly advanced example. To neglect this issue, the assumption is that only one phase investment (K) at 10 million EUR is and the success probability is the same at 50%. Furthermore, additional input is required to account for the uncertainty of the future movements (σ), hence, the volatility is assumed to be at 25%. Given these inputs, the BSM model results in the outputs that make the adjust the phase investment costs to 9.9 million EUR, while the static NPV value adjusted for the

success probability results in 50 million EUR. The final value, therefore, is 40.1 million EUR. The estimation and the BSM model outputs are listed below.

The resulting value provides almost exact outcome as the one produced by the risk-adjusted NPV method (difference of only 525 EUR). However, the values may differ significantly if more phases would be included with more success probabilities or if investment costs would be higher than the unadjusted (static) NPV itself.

Table 7.

The example of the practical implementation of BSM approach.

Assumptions		**BSM model outputs**	
Cost of the phase investment (million EUR)	10	d_1	4.8752
Uncertainty of the project (volatility)	*25%*	$N(d_1)$	1.0000
Risk-free rate	*1%*	d_2	4.3752
Success probability	*50%*	$N(d_2)$	1.0000
Lifetime of the project (time to maturity)	1		
Unadjusted (static) NPV (million EUR)	100		
NPV via Black-Sholes model (million EUR)	**40.1**		

3.5.2. Lattice tree

The other approach was developed by Cox-Ross-Rubenstein to value financial option Cox et al. (1979; *see 2.2. Literature review on ROV*). The valuation is made by using the generic lattice approach of binomial tree with two opportunities at each node (Figure 2).

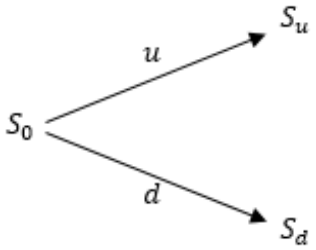

Figure 2. *Generic one-step lattice tree approach*

The construction of the tree going forward consist of NPV as S_0 at $t = 0$. Then, at each time period NPV can increase by a probability of an upward movement, u, and decrease by an opposite probability of a downward movement, d. The movements result in S_u or S_d at the second node, the values, resulted from positive and negative market impact, respectively.

$$u = e^{\sigma\sqrt{t}} \tag{21}$$

$$d = e^{-\sigma\sqrt{t}} = \frac{1}{u} \tag{22}$$

The σ is volatility (standard deviation) and t is the number of steps within life of the project, T. For instance, if the lengths between nodes are 1 year and the $T = 2$, then the $t = \frac{2}{1} = 2$. This is a continuous process and only stops once the option is at maturity, or, in this case, the company decides whether to invest or not. At that point the value of each node is compared with the value of investment

and if the value of the assets is higher, then the company chooses to invest, if not, the investment opportunity is deferred. At the last and upward-most node, such decision is depicted by the following:

$$f_u = \max[S_u - K, 0] \tag{23}$$

Where f_u represents the value of the option at the S_u node after taking into account the cost of investment decision. The same procedure is followed at each node and then the tree is worked back via backward induction (Figure 3).

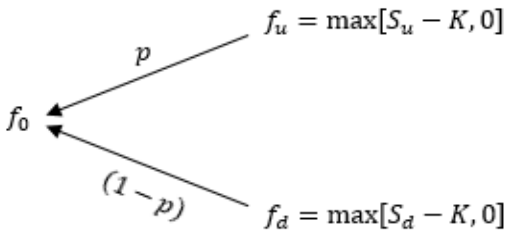

Figure 3. *Generic valuation of the option at end nodes and the implementation of backward induction to arrive at the real option value*

The backward induction can be done with the risk-neutral probability, p, and the values of the drug at different nodes. Therefore, the value of the option can be estimated given the value of the nodes at up and down states (f_u and f_d, respectively):

$$p = \frac{1 + r_f - d}{u - d} \tag{24}$$

$$f_0 = \frac{p f_u + (1-p) f_d}{1 + r_f} \tag{25}$$

Here, the risk-free rate, r_f, is used as a discount factor in order to eliminate the risk attitude of the investor so that no arbitrage opportunities would exist. The key insight is that because the option values are independent of investors' risk preferences, the same valuations will be obtained even when we assume that everyone is risk-neutral (Schwartz 2013). Such an assumption is a cornerstone of the ROV and is commonly referred to as risk-neutral valuation.

However, the fundamental lattice tree method does not have adjustments for success probabilities and multiple phase investments, therefore, it has to be adjusted to account for that. The model that do just that will be introduced in the following section, therefore, the practical application of such method in valuating biotechnology company will also be presented in there.

3.6. ROV framework

The following section will provide ROV framework since fundamental CRR approach has to be improved to account for success probabilities and phase investments. Ergo, the ROV framework that this thesis will be following is based on the paper by Kellogg et al (2000) and on the extension of Tan

et al (2012) that sets out the guidelines for the basic lattice tree method of *Option to defer* that includes probabilities and R&D investments at various stages. The basic concept and the formulas will be used, though, will be adjusted for the FDA phases. The tree itself will then incorporate the success probability at each phase and will account for the investment outlays. Therefore, the value at each node will be reduced by a fraction that is set out as a success probability and by the cost of the phase investment. In case of a positive number, the tree will continue to take shape, in case of a negative scenario, the *Option to wait-and-see* will be executed. As a result, the calculus of the possible payoff at the one-step end node is as follows:

$$fu = \max[Su(q) - K, 0] \tag{26}$$

Where q is the success probability. Ergo, incorporating this framework into the ROV means that such managerial decisions exists not only at the end node, but also at each node that represents certain drug approval stage and requires investment outlay:

$$\alpha_1 Su = \max[Su(q) - K, 0] \quad \text{or} \quad \alpha_1 Sd = \max[Sd(q) - K, 0] \tag{27}$$

Where α_1 is the first node value adjustment for success probability and the investment outlay. In turn, the simplistic picture of the adjusted lattice tree approach would look like this:

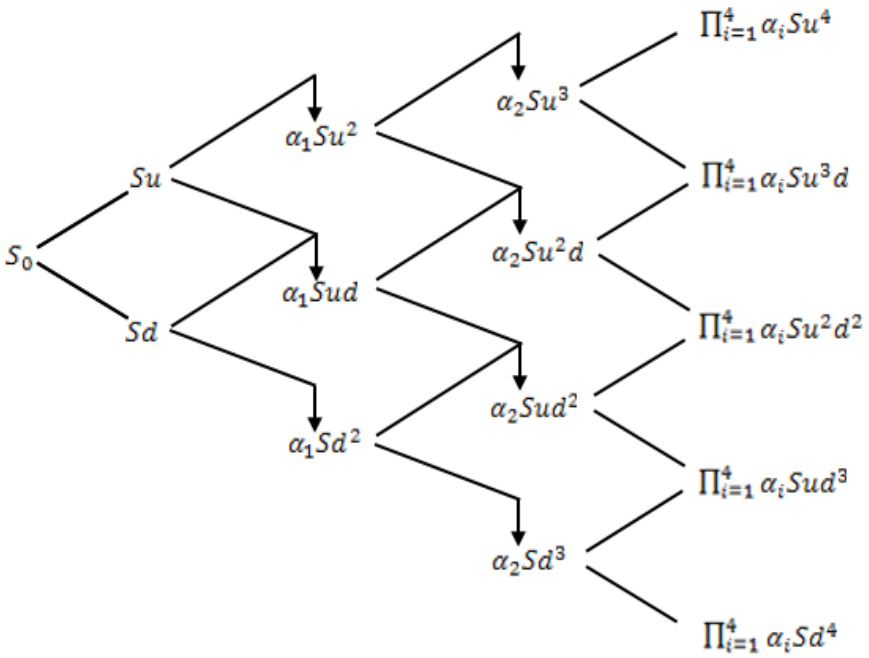

Figure 4. *The Real Options Valuation framework*

Source: Kellogg et al (2000) and Tan et al (2012)

Figure 4 depicts a lattice tree where the first phase commences after the first year and lasts for at least two remaining years. As a result, the investment carries the uncertainty for the remaining time period until the approval stage is over. The backward induction, necessary to arrive at the option value will be the same as for the generic ROV.

To put this in perspective, the assumptions for the practical application are the same as for rNPV and BSM techniques: the unadjusted NPV is 100 million EUR, the costs of phase investments are 10 and 5 million EUR, both of which have 50% in probability of success, the risk-free rate is 1%, and the volatility is 25%. The resulting lattice tree values can be seen in the chart below. Meanwhile, the Real Option value become 40.1 million EUR, when implementing only one phase investment (same as BSM method). Therefore, the value becomes identical to the values generated by BSM and rNPV techniques.

Table 8.

The practical implementation of the one-step ROV lattice tree approach.

Static NPV (million EUR)	100			**Lattice tree inputs**	
Investment (million EUR)	10			Upward movement	1.28
				Downward movement	0.78
		64.2		Volatility	25%
Asset Value (million EUR)	100.0	54.2		# of steps	1
Option Value (million EUR)	40.1	38.9		Risk-neutral probability	0.458
		28.9		Risk-free rate	1.0%

When assuming two phase investments (exactly like for rNPV) approach, the value provided by the lattice tree becomes 14.3 million EUR, making it less than the value estimated by rNPV approach (which was 15.1 million EUR). This is expected due to the fact that with larger amount of steps, ROV lattice tree approach produces more conservative (lower) estimates since upward and downward probabilities are affected, by the time horizon, in turn, affecting the risk-neutral probability. For example, in this case, the risk-neutral probability reduces from 0.458 to 0.426. Therefore, higher weight is given to the lower values.

Table 9.

The practical implementation of the two-step ROV lattice tree approach.

1st Investment (million EUR)	10				**Lattice tree inputs**	
2nd Investment (million EUR)	5			44.6	Upward movement	1.42
			61.2	39.6	Downward movement	0.70
Asset Value (million EUR)	100.0		23.6	18.9	Volatility	25%
Option Value (million EUR)	14.3		25.1	13.9	# of steps	2
			7.6	9.8	Risk-neutral probability	0.426
				4.8	Risk-free rate	1.0%

According to Kellogg et al (2000), the standard deviation of the company can be taken out of the volatility of the commercialization cash flows at the time of the launch. However, since *Nucleos* is in the business for a very small time and even the future free cash flows themselves cannot be forecasted with a precise degree, an annualized yearly volatility will be taken from benchmark, the *iShares Nasdaq Biotechnology (IBB) index*. Meanwhile, the usage of success probabilities is based on the probability that the drug will proceed to another phase of FDA approval process (*see 4.1. Biotechnology industry*). These probabilities are assigned to different phases and are different based

on the rule of thumb, management overview, and the fact that *Nucleos* already was successful in passing most of the stages with their other product.

That concludes the methodology part where NPV derivation and the ROV techniques were introduced and discussed. In addition to that, the examples of practical application for each of the methods were also presented. Lastly, the lattice tree of ROV framework that is adjusted to be applicable in valuing the biotechnology companies was introduced and explained. Hence, such a framework provides an answer to the second research question and confirms that indeed the Real Option approach be applied to biotechnology company that has multiple yet different success probabilities and phase investments.

4. VALUATION CASE

In this section I will provide all the necessary information regarding the biotechnology industry, the drug approval process, and the company itself. Afterwards, I will indicate the assumptions regarding drugs and accompanying aspects, operational activities, discount rate, and the ROA. Then, using these inputs and indications I will evaluate the potential value of the company via DCF approach and will adjust for risk and market uncertainty via ROV methodology. Lastly, I will display sensitivity analysis and compare the values provided by the Real Option and risk-adjusted NPV approaches.

4.1. Biotechnology industry

Primarily, the tag of biotechnology is a self-explanatory mixture of biology (as a science) and technology (as an art of engineering) that aims at the production or improvements of currently available drugs or medical devices by using the methods based on the living surroundings – bacteria, microbes, plants, or even animals (Ranade, 2008).

The development of such a drug takes a long way, requires considerable resources at the early stages, includes a research-intensive and a high-risk path that has many barriers, eventually resulting in high uncertainty (Kellogg and Charnes, 2000; Jacob and Kwak, 2003). Typically, one in approximately 5000 compounds end up being marketed, while about 20% of drugs that enter clinical trials end up being commercialized (Kellogg and Charnes, 2000; Jacob and Kwak, 2003). Each development stage has to be done in precise and standardised manner ultimately leading to the last phase of the approval from the FDA. The chronological order of the stages as based on Kellogg and Charnes (2000) and the FDA report (2016) and is exactly the same and unavoidable for the development and has to be done sequentially one after the other:

1. **Pre-clinical trials.** The stage includes tree other major sub-stages:
    a. The drug development and application for the FDA's approval in case of success;
    b. The testing of a drug on animals for toxicity. For such purpose, multiple species of animals are used to gather the most reliable set of data;
    c. The application for the Investigational New Drug (IND) has to be filled.
2. **Clinical trials.** The whole stage is divided into very autonomous phases within:
    a. Phase I: the testing is done with a small number of people, approx. 20 to 80, who volunteer for the tests. The aim is to see how the drug is absorbed, distributed, and eliminated within human's body as well as to find out the safe dosages and possible side effects.
    b. Phase II: the drug is tested on a larger scale with more than 100 patients for whom the drug is intended to work. The side effects are still being monitored and in some trials

some of the patients are given placebo for the comparison purposes. Usually, after this point the discussion about the size of the next stage is held between the FDA and the inventor (biotechnology company or sponsor).

c. Phase III: the final pre-marketing phase where the drug is tested on much bigger scale in order to compare the usage for more diverse sample (e.g., different dosages, different population, and effectiveness in combination with other drugs). The primary reason for the large sample size is purely based on the potential effectiveness of the drug during the marketing phase (e.g., whether it benefits more patients and results in infrequent side effects).

3. **FDA filling and review.** The biotechnology company meets the FDA representatives and submits the New Drug Application (NDA) that is followed by the review of the both the application and the drug labelling as well as the inspection of the facility where the drug is being made.

4. **Commercialization.** The drug is launched into the market with high uncertainty about the future cash flows. Compulsory provision of periodic safety updates to the FDA is mandatory.

4.2. Description of the company

Due to the privacy purposes, the real name of the company will not be revealed and will be changed to a fictional one. The same routine will be done with products that the company is making, though, the indications that these products aim to heal will stay as they are. The name of the company is changed to *Nucleos*, while the names of the products are chosen to bear the names of Joxeline and Rx. The latter is actually the generic name for any drug that is still in the FDA approval process and that is yet to be named.

The company was established in 2012 and is based in the Netherlands. It is a private entity and it has passed 2 full financial years. It operates as biotechnology company and currently has operations in Europe (commonly referred to as EU5) and Rest of the World (thereafter RoW) region. As of the time of valuation, the company holds patents for 2 products:

1) Already finished medical device called Joxeline. The product is already for sale in Europe and RoW region and is set to have optimistic sales within several approaching years. Furthermore, the company aims to introduce the product to the USA market in 2019, meaning that before that the registration and platform investment phases has to take place. The Joxeline will be applicable for the usage of 4 indications, namely, Acne, Atopic Dermatitis (*thereafter Eczema*), Rosacea, and Skin Irritation (*thereafter SI*). The product is aimed towards the over-the-counter (OTC) market, which is when the product can be bought at the pharmacy or similar outlet without prescription. The size of the target

market and other assumptions for revenue derivation will be discussed in the following chapter (*see 4.3. Assumptions*).

2) Another product is called RX and is about to start the FDA approval process. The RX is a prescription drug and therefore, targets the market that is the opposite of the OTC. In such a way, the company expects to fully capture the whole market of medicine usage. The exact expected time periods and success probabilities for each step are discussed in the next section (*see 4.3. Assumptions*). The product is to be released in Europe, the USA, and RoW region in the same year. The RX will be applicable for 4 indications, such as Atopic Dermatitis (*thereafter Eczema*), Diabetic Wound Infection (*thereafter DWI*), Folliculitis, and Rosacea with respective market launch years of 2022, 2023, 2022 and 2023.

Due to the differences in the compounds used for the medical device and the drug, as well as different bottling and labelling, the company does not expect to gain any synergies over the course of the valuation period.

Table 10.

Main line items from income statement and balance sheet of full years of 2015 and 2016 (in EUR)

For complete income statement and balance sheet for 2015 and 2016, see Appendix 1

Income statement	**2015**	**2016**
Revenue	663,393	699,695
COGS	177,352	45,421
SG&A expenses	2,957,177	2,927,286
EBIT	(2,591,178)	(2,413,605)
Net profit	(2,652,882)	(2,500,891)

Balance sheet	**2015**	**2016**
Fixed Assets	759,987	1,473,393
Current Assets	245,863	421,169
Equity	(6,437,519)	(11,037,847)
Liabilities	7,443,368	12,932,409
Balance	*1,005,850*	*1,894,562*

4.3. Assumptions

In this section of the thesis I will provide the assumptions for the input fields that will lead to the generation of NPV. The assumptions will be provided for WACC, operational activities that will help to produce the free cash flows, also for the revenue determination that is highly dependent on the assumptions regarding the market sizes, shares, and all sorts of prevalence rates regarding each indication. Lastly, assumptions governing the inputs of ROV framework will be also presented.

4.3.1. WACC

For the estimation of **cost of equity**, the risk-free rate (the yield of German government bond with 20 years to maturity) is 0.746%, market risk premium, reflected as annualized returns from *iShares Nasdaq Biotechnology (IBB)* index, is 11.33%, while beta that will be used is taken from the same index and is 1.27. As for **cost of debt**, since the average interest coverage ratio within the biotechnology industry is within 4.5x to 6x (Damodaran, 2016), the corresponding default risk premium is 3.0% (Table 3), while the risk free rate is same as for the cost of equity, 0.746%.

4.3.2. Operations

The values of operational inputs in regard to the margins, growth rates, and other ratios are assumed by the management of the company who has the best insight into the activities of the business. In addition to that, they are the ones that are expected to execute the managerial decisions and theoretically possess the ability to manage the company to the best of their abilities so that the expected cash flows would be projected in a relatively detailed manner.

Revenue is accurately derived for the vocal regions, Europe's 5 (*thereafter EU5*) biggest markets, namely, Germany, United Kingdom, France, Italy and Spain, and the USA. The management team assumes that the RoW region will generate roughly 25% of the combined sales of other regions each year. The derivation of the revenue for both EU5 and USA is done in the following manner: firstly, the assumptions about the population sizes and growth rates are made based on the report by the Huron Consulting Group[2] (*see Appendix 2*); then, the following estimates are made after accounting for the opinion of the CMO (Chief Medical Officer), the members of the management team, the report of Huron, and the online market research survey executed by the third party on behalf of the company:

1) Prevalence rates. What proportion of the total population have any degree of specific indication, e.g., Acne or Rosacea;
2) The proportions of prevalence pool that have mild, moderate, and severe conditions;
3) The assumed ratio of treated people via either OTC (for Joxeline) or prescription (for RX) markets out of all people with indication;
4) The ratios related to the peak years: years to reach the peak, expected share of either OTC (for Joxeline) or prescription drug (for RX) market during the peak;
5) The number of years of stable income once the peak is reached and the rate at which the revenue is expected to decline after the stable income years;
6) Compliance rates, adjusting for the fact that customers do not use the product at all times;

The prices of a yearly treatment that takes into account the average price, the expected usage and the recurring behaviour (*see Appendix 3*). It is assumed that prices will be 1.(6) higher in the US rather than EU5 and the prices for products aimed at adults will be twice as pricier, as the products for paediatric. Identically, recurring patients are expected to spent twice as much money as the customers who would buy for the first time.

Operational assumptions are the compromise of what the management thinks of both income statement and balance sheet items going forward (Table 7; *for detailed assumptions see Appendix 4*). As a result, the given inputs are based on their opinion and are deemed to be subjective and representative of the expected operating margins of the products.

[2] The report made detailed analysis about the market size and population at the request of company itself

Table 11.

The Operational Assumptions of Joxeline and RX products

Input field	**Margins for Joxeline product (% of Revenue, unless stated otherwise)**	**Margins for RX product (% of Revenue, unless stated otherwise)**
COGS	*US: 5%; EU5: 7%; RoW: 10%*	*US: 35%; EU5: 45%; RoW: 55%*
Production	*83% of COGS*	*75% of COGS*
Packaging	*17% of COGS*	*25% of COGS*
Sales and Marketing	*Starts at 35%, gradually declines until reaches 10% and stays at that level*	*Starts at 5%, increase until reaches 17.4%, then goes down gradually*
Personnel Expenses	*Starts at the level of 2016, grows by 5% YoY*	
Distribution Expenses	*Starts at 9.5%, goes to 10% and stays there*	*Starts at 3 million EUR and stays when no product is launched; once launched, increases during the whole period of valuation*
Other Expenses	*Premise Expenses starts at 30%, goes down to 10% and stays there; General Expenses stays at 1% during the whole valuation horizon*	
R&D Expenses	*Starts at 3%, increases to 6% and stays there*	
Depreciation	*20% of Tangible Assets*	*Starts at 3%, increases to 5% and stays at that level*
Amortization	*5% of Intangible Assets*	
Capital Expenditures	*Sum of both investments into the Tangible and Intangible Assets*	
Tangible Assets	*10% of the previous' year level*	*5% of the total value of Platform Investment for all RX line drugs*
Intangible Assets	*7% of the previous' year level*	
Prepayments	*10% of the Revenue*	*Not assumed since these line items are regarded as having minor effect on total valuation and it is hard to guestimate these especially when the product is not for sale*
Days Sales Outstanding	*Starts at 20 days; gradually goes to 10 days*	
Stock Days	*Starts at 75 days, gradually goes to 50 days*	
Cash and Cash Equivalent	*2% of NOPAT (if NOPAT is positive)*	
Days Payable Outstanding	*Starts at 900 days, gradually goes to 300 days*	
Other Payables	*33% of COGS*	
Provisions	*Same absolute level as in year 2016; increases at the risk-free rate annually*	

4.3.3. Drugs

Approval phases. The assumptions regarding the drug approval phases are valid for both RX and JOXELINE. RX is a drug and will start its FDA process in 2017, therefore, all the phases are applicable. Joxeline, on the other hand, is already present in Europe, though, need FDA registration to comply with the regulations governing the medical devices in the USA. Therefore, it is also applicable to the approval phases only in the USA (Table 8). The success probabilities of passing each stage and respective costs associated with it are computed after discussions with the management team (Table 9). Note that, it is assumed that both phase 1 and phase 2 are expected to be done within the same year, therefore, are combined together. Other phases are assumed to take at least 1 year to complete.

Planning period. Since (a) the application for the patent was filled at different times for Joxeline and RX (for Joxeline in 2014, for RX in 2017), and (b) the valuation horizon should be the same for both products – the planning period should be long enough to capture the development years, launch, and the peak years for the RX product and short enough to still capture the adequate cash flows from the Joxeline product. Therefore, the planning period is 20 years and finishes at the end of 2036.

Table 12.

Chronological sequence of drug approval phases for Joxeline and RX products

	2017	2018	2019	2020	2021	2022	2023
JOXELINE							
USA	*Registration*	*Platform*	*Market*	*Market*	*Market*	*Market*	*Market*
EU5	*Market*	*Market*	*Market*	*Market*	*Market*	*Market*	*Market*
RoW	*Market*	*Market*	*Market*	*Market*	*Market*	*Market*	*Market*
RX							
DWI	*Pre-clinical*	*Phase 1/2*	*Phase 3*	*Phase 3*	*Registration*	*Platform*	*Market*
Eczema	*Phase 1/2*	*Phase 3*	*Phase 3*	*Registration*	*Platform*	*Market*	*Market*
Folliculitis	*Pre-clinical*	*Phase 1/2*	*Phase 3*	*Phase 3*	*Registration*	*Platform*	*Market*
Rosacea	*Phase 1/2*	*Phase 3*	*Phase 3*	*Registration*	*Platform*	*Market*	*Market*

Table 13.

Success probabilities (in percentages) and costs of each FDA phase (million EUR)

	Pre-clinical 100%	Phase 1/2 90%	Phase 3 55%	Registration 90%	Platform 100%
JOXELINE					
USA	-	-	-	1.2	5
EU5	-	-	-	-	-
RoW	-	-	-	-	-
All costs	***-***	***-***	***-***	***1.2***	***5***
Cumulative probability	-	-	-	*90%*	*90%*
RX					
DWI	0.1	5	6	2	2.5
Eczema	3	6	15	10	6
Folliculitis	-	4	4.5	2	2
Rosacea	2	3	6	4	3
All costs	***5.1***	***18***	***31.5***	***18***	***13.5***
Cumulative probability	*100%*	*90%*	*49.5%*	*44.55%*	*44.55%*

Table 14.

Main sales assumptions for Joxeline and RX products (for remaining assumptions, see Appendix 5).

	Years to the peak	**Years at the peak**	**market share during the peak**	**Price per year of treatment (EUR)**	**Decline rate after the peak**
JOXELINE					
Acne	*5*	*5*	*3%*	*104 (US); 62 (EU5)*	*5% (40%)*
Eczema	*5*	*5*	*Pediatric: 6%* *Adults: 5%*	*Pediatric: 242 (US); 145 (EU5)* *Adults: 484 (US); 291 (EU5)*	*5% (40%)*
SI	*5*	*5*	*1st occurrence: 0.3%* *Recurrent: 0.3%*	*1st occurrence: 113 (US); 68 (EU)* *Recurrent: 339 (US); 203 (EU5)*	*5% (40%)*
Rosacea	*5*	*5*	*10%*	*404 (US); 243 (EU5)*	*5% (40%)*
RX					
DWI	*5*	*5*	*30%*	*1,420 (US); 852 (EU5)*	*5% (20%)*
Eczema	*5*	*5*	*Pediatric 15%* *Adults: 5%*	*Pediatric: 1,562 (US); 937 (EU5)* *Adult: 3,125 (US); 1,875 (EU5)*	*5% (20%)*
Folliculitis	*5*	*5*	*1st occurrence: 10%* *Recurrent: 50%*	*1st occurrence: 379 (US); 227 (EU5)* *Recurrent: 1,136 (US); 682 (EU5)*	*5% (20%)*
Rosacea	*5*	*5*	*5%*	*4,545 (US); 2,727 (EU5)*	*5% (20%)*

4.3.4. Real Options Valuation

The main ROV inputs are the value of the underlying asset, platform investment, investments for corresponding phases, success probabilities, launch year, risk-free rate, number of steps, and volatility. All but the last 2 inputs were already discussed and assumed. The underlying asset value will be known once the NPV value of each product is estimated. Platform investment and investments for corresponding stages, success probabilities, and the launch years are taken from the previous section (*see 4.3.3. Drugs*). The number of steps is estimated as the number of years, necessary to commercialize the product. Here, the assumption is that a year of platform investment is fully occupied by the establishment of the platform and the following year is expected to be the launch year (Table 15). Same as the market risk premium, the annualized 20-year volatility of 24.38% is taken from the benchmark, the IBB Index. Due to the fact, that the number of steps (years), launch years, and the volatilities are the same for all Joxeline products, the resulting upward and downward movement ratios within its lattice tree are also identical. Due to the same reason, a couple of RX products share the same probabilities (Table 15).

4.4. NPV estimation

In this section, the NPV will be determined by performing the DCF valuation technique. All estimated values will be used as underlying assets for the ROV and, therefore, do not account for success probabilities or phase investments. Ergo, these are yet to be adjusted for the risk factors. For this reason, each drug and corresponding product has to have its own lattice (binomial) tree.

WACC. The cost of equity is estimated at 16.0% since risk-free rate is 0.75%, market risk premium is 12.75%, and beta is 1.27. The after-tax cost of debt becomes 0.93% after incorporating the same risk-free rate, default spread of 3.0%, and the tax rate of 25%. The weights for equity and debt according to the economic value are 99.4% and 0.6%, respectively. Consequently, the WACC results in 14.1%. The same discount rate is used for the NPV determination of both Joxeline and RX products.

Free Cash Flows. The residual value is calculated based on the convergence model (*see 3.1. Net present value*). The NPVs for Joxeline product are determined separately for each region. Both Rosacea and Skin Irritation products generate the biggest value, each just over 100 million EUR, followed by Acne with 59.1 million EUR, and Eczema with 43.6 million EUR (Table 11). Meanwhile, the distribution of planning and residual values are very similar for all regions and, as expected, much bigger share is composed by the value of planning period: 92.3% in contrast to the 7.7% of the residual value (Table 12). The reason for that is because (a) the planning period of 20 years is a relatively long period of time, and (b), the convergence model reduces the residual value (as opposed to other techniques). However, all of that is very realistic since the products brings limited profits after expiration of the patent.

Table 15.

NPV estimates of Joxeline products amongst regions (million EUR)

	Acne	Eczema	Rosacea	Skin Irritation	**Totals**
United States	34.2	21.2	51.4	54.5	**161.3**
European Union	14.5	11.7	33.7	27.8	**87.8**
Rest of the World	10.4	10.7	19.3	20.8	**61.1**
Totals	**59.1**	**43.6**	**104.4**	**103.1**	**310.2**

Table 16.

NPV distribution between the building blocks of Joxeline drug amongst regions (million EUR)

	Planning Value	Share of total	Residual Value	Share of total	**Totals**
United States	149.1	*92.4%*	12.3	*7.6%*	**161.3**
European Union	81.3	*92.7%*	6.4	*7.3%*	**87.8**
Rest of the World	56.0	*91.6%*	5.2	*8.4%*	**61.1**
Totals	**286.4**	***92.3%***	**23.9**	***7.7%***	**310.2**

The NPVs of RX products are also divided by regions and indications. Eczema is expected to bring more than half of the total RX NPV (856 million EUR of 1.565 billion EUR), while the NPVs of DWI, Rosacea, and Folliculitis are more conservative at 351 million EUR, 228 million EUR, and 130 million EUR, respectively (Table 13). The lion's share of these cash flows, similarly to the Joxeline product, is comprised by the value of the planning period (83.5%), leaving a small portion to the residual value (16.5%) (Table 14). The total unadjusted NPV of RX product is therefore much bigger than that of Joxeline. However, the value is expected to be reduced as a result of FDA phases and accompanying success probabilities and investment costs.

Table 17.

NPV estimates of RX products amongst regions (million EUR)

	DWI	Eczema	Folliculitis	Rosacea	**Totals**
United States	238.4	466.2	78.8	124.1	**907.5**
European Union	67.6	244.1	35.5	71.6	**419.0**
Rest of the World	44.8	145.9	15.9	32.0	**238.7**
Totals	**350.8**	**856.3**	**130.3**	**227.8**	**1,565.1**

Table 18.

NPV distribution between the building blocks of RX drug amongst regions (million EUR)

	Planning Value	Share of total	Residual Value	Share of total	**Totals**
United States	755.9	*83.3%*	151.7	*16.7%*	**907.5**
European Union	351.7	*83.9%*	67.3	*16.1%*	**419.0**
Rest of the World	198.7	*83.3%*	40.0	*16.7%*	**238.7**
Totals	**1,306.2**	***83.5%***	**290.8**	***16.5%***	**1,565.1**

4.5. ROV

RX. The ROV of RX drug is done by valuing each sub-product (indication) separately and putting all four together at the end. Since the launch is made globally, no separate trees for different regions

are needed. The years until launch (steps) and the volatility of the benchmark index are incorporate to arrive at the probabilities of upward and downward movements (Table 15).

Table 19.

The distribution of lattice tree inputs amongst products and their respective indications

	Joxeline (US only)				RX (all regions)			
Drug	Acne	Eczema	Rosacea	SI	DWI	Eczema	Folliculitis	Rosacea
Years/steps	2	2	2	2	6	5	6	5
Upward probability	1.41	1.41	1.41	1.41	1.82	1.725	1.82	1.725
Downward probability	0.71	0.71	0.71	0.71	0.55	0.58	0.55	0.58
Risk-neutral probability	0.425	0.425	0.425	0.425	0.361	0.374	0.361	0.375

From now on, the binomial lattice composition is possible. At each node, the value of the underlying asset is multiplied by either upward or downward probability and the necessary investment amount for specific phase is subtracted from the resulted value. For example, at the end of year 2017 (2nd node), the value of DWI drug can be either 637.3 or 192.9 million EUR (Table 16). In case of a positive market movements, the company can expect the value to go upward in the subsequent year. In the same year, Phase ½ will commence with success probability of 90% and an investment of 5 million EUR. Hence, the 637.3 million EUR increases in value by a factor of 1.82 and is adjusted for the success rate and the investment outlay is subtracted, resulting in over 1 billion EUR. At the end node (at the end of year 2022), after adjusting for the platform investment, the backward induction begins.

Table 20.

RX DWI lattice tree (million EUR; green box is the option value, white is the underlying asset value)

DWI VALUATION	**million EUR**						
Platform Investment	2.5						5,539.8
Risk-adjusted NPV	138.5					3,050.2	5,537.3
Real Option Value	114.3				1,866.4	3,009.1	1,619.2
				1,030.5	1,618.2	892.5	1,616.7
			1,037.1	857.9	547.0	851.8	432.3
		637.3	446.9	304.3	438.7	239.3	429.8
Underlying Asset Value	**350.8**	228.3	310.5	220.0	147.6	210.5	91.7
Real Option Value	**114.3**	192.9	107.5	84.5	99.1	51.8	89.2
		51.3	90.6	45.2	32.9	37.4	11.1
			20.1	21.4	15.3	7.5	8.6
				6.2	5.8	3.1	0.0
					1.1	0.9	0.0
						0.0	0.0
							0.0
Years	*Beginning 2017*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*

For the backward induction, the risk-neutral probability is found by incorporating risk-free rate, upward, and downward probabilities. In this case, the risk-neutral probability is 0.36. Now, option value at each time node can be found by adjusting both upward and downward option values for risk-neutral probability and dividing by the risk-free rate. For example, at the beginning node ($t = 0$, year 2017), the value can be found by multiplying 228.7 million EUR by risk-neutral probability of 0.36 and adding to the multiplication of 51.4 million EUR by 0.64, the residual ratio of the risk-neutral probability

$(1 - 0.36)$. The sum of both components is then divided by the risk-free rate. This results in 114.3 million EUR, the final ROV for RX DWI product. Values for other products are found in the same manner.

Table 21.

RX Eczema lattice tree (million EUR)

ECZEMA VALUATION	**million EUR**					
Platform Investment	6.0					5,665.7
Risk-adjusted NPV	338.7				3,288.1	5,659.7
Real Option Value	293.3			2,124.5	3,213.0	1,798.7
			1,240.4	1,801.9	1,046.3	1,792.7
		1,323.3	997.8	680.4	982.0	516.4
Underlying Asset Value	**856.3**	545.1	403.2	530.3	302.9	510.4
Real Option Value	**293.3**	440.8	281.7	201.5	267.3	131.5
		146.7	125.5	136.8	79.7	125.5
			68.0	57.8	60.7	28.8
				27.7	20.1	22.8
					8.4	5.7
						0.0
Years	*Beginning 2017*	*2017*	*2018*	*2019*	*2020*	*2021*

Table 22.

RX Folliculitis lattice tree (million EUR)

FOLLICULITIS VALUATION	**million EUR**						
Platform Investment	2.0						2,024.3
Risk-adjusted NPV	45.7					1,115.2	2,022.3
Real Option Value	30.8				683.2	1,083.4	567.9
				378.4	566.9	313.6	565.9
			383.2	286.7	193.0	281.9	126.8
		236.8	140.2	108.7	131.8	70.9	124.8
Underlying Asset Value	**130.3**	66.6	113.3	59.2	44.6	48.6	8.2
Real Option Value	**30.8**	71.7	25.8	27.0	18.8	5.6	6.2
		11.0	31.5	7.3	4.7	2.2	0.0
			2.8	5.0	0.8	0.0	0.0
				0.3	0.0	0.0	0.0
					0.0	0.0	0.0
						0.0	0.0
							0.0
Years	*Beginning 2017*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*

The total value of all the RX products derived via ROV is 504 million EUR. The Real Option value of RX DWI product is 114.3 million EUR, therefore, goes down to 33% of the original value as a result of risk and investments involved in the FDA phases (Table 16). The Real Option value of RX Eczema product, that is the most valuable drug of all, goes down to 293.3 million EUR, 34% of the original value (Table 17). The ROV of RX Folliculitis is 30.8 million EUR which is 24% of the underlying asset value (Table 18), while ROV of RX Rosacea becomes 65.6 million – 29% of the underlying asset value (Table 19). As a result, RX Folliculitis and RX Rosacea are the riskiest products in a sense that *Option to wait-and-see* can be executed as early as in 2020, if the market conditions are unfavourable. Meanwhile, the *Option to wait-and-see* can be executed as early as in 2021 for both DWI and Eczema. However, the RX Folliculitis product is deemed to be the riskiest amongst all RX indications, since in only 43% of

the cases it can be launched after platform investment phase is finished. The launch is possible for the RX Rosacea in 67% of the cases, for RX DWI it is 71%, and for the RX Rosacea it is the highest, at 83%.

In all cases, the value derived via ROV technique provided lower value than that provided by the rNPV. This distortion can be attributed to the fact that abandonment of the project was initiated for each indication at various points of the process. RX DWI and RX Eczema had one case each in 2021 where the project is advised to be halted, while both RX Folliculitis and RX Rosacea had two of these cases each in the same year. The total value of RX product generated via rNPV approach is 606.5 million EUR, 102.5 million EUR more than the value generated via ROV lattice tree approach.

Table 23.

RX Rosacea lattice tree (million EUR)

ROSACEA VALUATION	**million EUR**					
Platform Investment	3.0					1,482.8
Risk-adjusted NPV	83.6				861.4	1,479.8
Real Option Value	65.6			557.4	829.1	454.0
			326.6	455.4	264.9	451.0
		350.6	244.6	173.2	238.1	117.0
Underlying Asset Value	**227.8**	128.3	103.9	121.9	69.5	114.0
Real Option Value	**65.6**	115.9	60.4	47.4	54.1	22.1
		29.0	30.9	24.5	14.5	19.1
			10.7	11.9	7.1	0.8
				2.6	2.2	0.0
					0.0	0.0
						0.0
Years	*Beginning 2017*	*2017*	*2018*	*2019*	*2020*	*2021*

Joxeline. The ROV for Joxeline products is slightly different: both Europe and RoW regions already have cash flows and entails fairly simple assumptions that do not require any platform investment (Table 15). However, since Joxeline currently has no presence in the USA region, the FDA registration and platform investment stages are required. Therefore, each product within the USA region is valued separately via ROV, while products within Europe and RoW are valued via NPV techniques. Consequently, the NPV of all Joxeline products that are sold within Europe amounts to 87.8 million EUR: Acne is 14.5 million EUR, Eczema is 11.7 million EUR, Rosacea is 33.7 million EUR, and SI is 27.8 million EUR (*see Appendix 6*). Meanwhile, the NPV of all the Joxeline products that are sold within RoW market is 61.1 million EUR: Acne is 10.4 million EUR, Eczema is 10.7 million EUR, Rosacea is 19.3 million EUR, and SI is 20.8 million EUR (*see Appendix 7*). The Real Option values of Joxeline products that are sold to the USA market amounts to 138.8 million EUR. The Joxeline SI product takes the biggest share at 48.2 million EUR which is 88% of the original value (Table 23). Joxeline Rosacea follows with 43.7 million, 81% of the initial value (Table 22). The respective Real Option values of Joxeline Acne and Joxeline Eczema are slightly lower and stands at 29.4 and 17.6 million EUR, both amounting to 83% of the underlying asset values (Tables 20; Table 21).

Table 24.

Joxeline Acne lattice tree (million EUR)

ACNE VALUATION	million EUR		
Platform Investment	1.0		
Risk-adjusted NPV	29.0		
Real Option Value	29.4		60.9
		43.1	59.9
Underlying Asset Value	**34.2**	42.0	30.3
Real Option Value	**29.4**	21.5	29.3
		20.5	15.2
			14.2
Years	*Beginning 2017*	*2017*	*2018*

Table 25.

Joxeline Eczema lattice tree (million EUR)

ECZEMA VALUATION	million EUR		
Platform Investment	1.2		
Risk-adjusted NPV	17.3		
Real Option Value	17.6		37.6
		26.7	36.4
Underlying Asset Value	**21.2**	25.3	18.7
Real Option Value	**17.6**	13.2	17.5
		12.0	9.4
			8.2
Years	*Beginning 2017*	*2017*	*2018*

Table 26.

Joxeline Rosacea lattice tree (million EUR)

ROSACEA VALUATION	million EUR		
Platform Investment	2.0		
Risk-adjusted NPV	43.1		
Real Option Value	43.7		91.5
		64.8	89.5
Underlying Asset Value	**51.4**	62.7	45.6
Real Option Value	**43.7**	32.3	43.6
		30.3	22.9
			20.9
Years	*Beginning 2017*	*2017*	*2018*

Table 27.

Joxeline Skin Irritation lattice tree (million EUR)

SKIN IRRITATION VALUATION	million EUR		
Platform Investment	0.8		
Risk-adjusted NPV	47.5		
Real Option Value	48.2		97.6
		69.2	96.8
Underlying Asset Value	**54.5**	68.3	48.9
Real Option Value	**48.2**	34.7	48.1
		33.9	24.6
			23.8
Years	*Beginning 2017*	*2017*	*2018*

As a result, the total value of Joxeline Acne product is 54.4 million EUR, while Joxeline Eczema is at 39.9 million EUR, Joxeline Rosacea amounts to 96.7 million EUR, and Joxeline SI is the most valuable, at 96.8 million EUR (*see Appendix Joxeline 8*). All of it results in a total value of Joxeline products being at 287.7 million EUR.

On the contrary to the value comparison of RX products, all values of Joxeline products that were generated via ROA were higher than comparable values via rNPV approach. This can be attributed to the fact that there was no point in time where projects were advised to be halted, as it was the case for RX products. Therefore, the total value of Joxeline products sold within US, generated via rNPV is 136.9 million EUR, which then brings the total value of Joxeline rNPV to 285.8 million EUR, a total of 1.9 million EUR less than Joxeline value derived via the ROV lattice tree approach.

By combining the values of both Joxeline (287.7 million EUR) and RX (504.0 million EUR) products and adjusting for the long-term debt expenses (5.1 million EUR), the total value of *Nucleos* estimated via adjusted lattice tree ROV is 786.7 million EUR. In comparison, the rNPV approach gives 100.6 million EUR higher value (Table 27). However, as you can see from the valuation, the ROA lattice tree provides the manager with information that is necessary for strategic decision making process, while rNPV provides only the estimate. The superiority of ROV as a managerial tool is therefore clear, though, the differences in values between the two approaches and the resulting conclusions will be discussed in the upcoming sections.

4.6. Sensitivity analysis

The sensitivity analysis is based on the valuation metrics that are thought to have the biggest influence on the NPV: WACC, share of respective markets during the peak (OTC for Joxeline and prescription market for RX), number of years the products takes to reach the peak, and the cumulative success probabilities of phases. WACC and the amount of years the product takes to reach the peak are identical for all 8 indications. Therefore, such sensitivity analysis is established without any complication for the consolidated value of *Nucleos*. The interval between WACC factors is 1%, while 1 year is selected as an interval between distinct years-to-peak. Given these criteria, the resulted sensitivity analysis reveals that Real Option value of *Nucleos* is much more sensitive to the changes in WACC rather than to the changes in quickness of reaching the peak (Table 24). The value fluctuates between 516.9 million EUR (a span of 7 years to the peak at 16.1% WACC) to 1.15 billion EUR (3 years to the peak at 12.1% WACC).

Meanwhile, the sensitivity analysis that included success probabilities and WACC is different as Joxeline product has only one phase to overcome, whereas RX has to complete the whole FDA process. The selected factor for the sensitivity analysis reflects the cumulative success probabilities of both products (Table 25). Resulting cumulative success probabilities vary from 41.9% to 54.5%, while

the base case is 48.2%. Consequently, the value changes from 420.8 million EUR (at 41.9% probability and WACC of 16.1%) to 1.47 billion EUR (at 54.5% probability and WACC of 12.1%).

Table 28.

The sensitivity of Nucleos Real Option value based on the WACC and the years to reach the peak (thousands EUR)

		WACC				
		12.1%	13.1%	14.1%	15.1%	16.1%
Years to reach the peak	3	1,153,925	1,004,054	877,570	770,017	677,792
	4	1,104,304	954,654	829,019	722,510	632,099
	5	1,057,650	908,397	786,682	678,602	590,419
	6	1,014,037	865,361	741,908	638,396	552,061
	7	973,536	825,689	703,284	601,577	516,937

Table 29.

The sensitivity of Nucleos Real Option value based on the WACC and the cumulative success probabilities, resulting from a product of success probabilities of both drugs (thousands EUR)

				WACC				
	Joxeline	**RX**	**Cum.**	12.1%	13.1%	14.1%	15.1%	16.1%
Success probability	80%	39%	42%	742,398	637,741	551,664	480,917	420,775
	85%	39%	42%	751,990	646,514	559,731	488,368	427,683
	90%	39%	43%	761,582	655,288	567,797	495,819	434,591
	95%	39%	43%	771,174	664,061	575,864	503,269	441,500
	100%	39%	44%	780,766	672,835	583,931	510,720	448,408
	90%	42%	45%	897,523	771,588	666,070	578,330	504,703
	95%	42%	46%	907,115	780,361	674,137	585,781	511,612
	100%	42%	46%	916,707	789,135	682,203	593,231	518,520
	80%	45%	47%	1,038,466	890,850	767,648	663,701	576,602
	85%	45%	48%	1,048,058	899,623	775,715	671,152	583,510
	90%	45%	48%	1,057,650	908,397	786,682	678,602	590,419
	95%	45%	49%	1,067,242	917,170	791,849	686,053	597,327
	100%	45%	49%	1,076,834	925,944	799,916	693,504	604,236
	85%	48%	51%	1,233,136	1,058,917	912,882	789,751	685,127
	100%	48%	51%	1,261,913	1,085,237	937,083	812,103	705,853
	85%	51%	53%	1,444,477	1,241,239	1,070,856	926,687	804,090
	90%	51%	54%	1,454,069	1,250,013	1,078,923	934,138	810,999
	95%	51%	54%	1,463,661	1,258,786	1,086,990	941,588	817,907
	100%	51%	55%	1,473,253	1,267,560	1,095,057	949,039	824,816

Lastly, the value of *Nucleos* is being tested via WACC and weighted combined share of the total drugs and medical devices market. The latter factor is weighted based on the prescription drug sales being at approximately 92% (Pfizer Consumer Healthcare otc pharma sales 8) of the total sales of pharmaceutical companies, while the rest is via OTC market. As a result, the total global market share that *Nucleos* can occupy ranges from 9.5% to 18.9%, while the base case is 14.2% (Table 26; *for indication shares within each drug see Appendix 9*). In turn, the value of the company varies from 370.1 million EUR (at the lowest market share scenario and WACC of 16.1%) to almost 1.444 billion EUR (occupying almost 1/5th of the market in given indications and adjusting for WACC of 12.1%).

Table 30.

The sensitivity of Nucleos Real Option value based on the WACC and the total weighted combined share of both OTC and prescription markets (thousands EUR), resulting in the share of global medical market.

				WACC				
	Joxeline	**RX**	**Total**	12.1%	13.1%	14.1%	15.1%	16.1%
Market share at the peak: OTC (Joxeline) and prescription (RX)	3.8%	10.0%	9.5%	675,117	576,241	494,696	427,643	370,145
	4.3%	10.0%	9.5%	713,284	611,028	526,568	456,978	397,252
	4.8%	10.0%	9.6%	751,451	645,815	558,441	486,314	424,360
	3.8%	12.5%	11.8%	827,170	705,833	604,906	521,210	451,326
	4.3%	12.5%	11.8%	865,337	740,620	636,779	550,545	478,434
	4.8%	12.5%	11.9%	903,504	775,407	668,652	579,881	505,541
	5.3%	12.5%	11.9%	941,671	810,194	700,524	609,216	532,649
	3.8%	15.0%	14.1%	981,316	838,823	720,036	619,932	536,204
	4.3%	15.0%	14.1%	1,019,483	873,610	751,909	649,267	563,311
	4.8%	15.0%	14.2%	1,057,650	908,397	786,682	678,602	590,419
	5.8%	15.0%	14.3%	1,133,983	977,971	847,527	737,273	644,634
	3.8%	17.5%	16.4%	1,136,042	973,164	836,753	721,895	624,300
	4.3%	17.5%	16.4%	1,174,209	1,007,951	868,626	751,231	651,407
	4.8%	17.5%	16.5%	1,212,376	1,042,739	900,498	780,566	678,515
	5.8%	17.5%	16.6%	1,288,709	1,112,312	964,244	839,237	732,730
	4.3%	20.0%	18.7%	1,329,182	1,142,597	986,294	854,082	741,772
	4.8%	20.0%	18.8%	1,367,349	1,177,384	1,018,167	883,417	768,879
	5.3%	20.0%	18.8%	1,405,516	1,212,171	1,050,040	912,753	795,987
	5.8%	20.0%	18.9%	1,443,682	1,246,958	1,081,912	942,088	823,094

Given the fact that factors and intervals for sensitivity analysis were selected objectively, the conclusion is that the WACC has the biggest influence on the value of the company. Other factors look very similar in terms of influence and have to be treated as equally important in value determination. As expected, these sensitivity analysis show that value is generated by reaching the peak sooner, having higher success probability, and occupying higher portion of the market. All of these factors can be highlighted via lower discount rate.

4.7. Comparison to rNPV

Some of the direct comparisons between ROV and rNPV approaches between the products of Joxeline and RX were made in previous section (*see 4.5. ROV*). This section, however, will expand on such comparison. For this purposes, each drug is valued by the rNPV technique that takes the DCF as NPV and adjust it for the yearly success probabilities and phase investments (*for rNPV methodology, see 3.4. Risk-adjusted NPV*) and then the comparison between the two models is brought via sensitivity analysis.

4.7.1. Comparison via NPVs

When considering RX, in all indications the ROV givers smaller value than the rNPV method (Table 27). Therefore, the total value is also smaller by more than 100 million EUR. That can be

explained by the fact that during backward induction, much bigger weight is given to the downward scenario. This phenomenon is also strengthened by the amount of steps.

Table 31.

Comparison of the values derived via ROV and rNPV methods (million EUR)

	Real Option value	Risk-adjusted value
DWI	114.3	138.5
Eczema	293.3	338.7
Folliculitis	30.8	45.7
Rosacea	65.6	83.6
RX	**504.0**	**606.5**

	Real Option value	Risk-adjusted value
Acne	54.4	54.0
Eczema	39.9	39.7
Rosacea	96.7	96.1
Skin Irritation	96.8	96.0
Joxeline	**287.7**	**285.8**

Due to the fact, that Joxeline products have to be adjusted for the risk only within the USA region and only for two stages (FDA registration and platform investment), the differences are not that significant (Table 27). Another reason for that is the absence of necessity to halt any project. Even more so, the ROV gives higher value than rNPV technique for all products. In all, the total value of Joxeline product is approximately only 1.9 million EUR higher when valuing via ROA rather than rNPV approach. The opposite is found for RX products: all of the values derived via lattice tree approach are lower than those generated via rNPV.

4.7.2. Comparison via sensitivity analysis

To understand what might influence the gap between rNPV and ROV, sensitivity analysis is run where the key element is the difference in value between two methods. For this, the WACC is factored in alongside volatility (Table 28) and cumulative success probability (Table 29). Volatility is incorporated in upward and downward probabilities and the estimation of risk-neutral probability, ergo has direct influence on the ROV only. Meanwhile, the cumulative success probabilities are used by both methods.

Table 32.

The sensitivity analysis of the difference between ROV and rNPV approaches (thousands EUR), tested by volatility and WACC

		WACC				
		12.1%	13.1%	14.1%	15.1%	16.1%
Volatility	9.38%	-39,156	-43,772	-47,623	-50,869	-53,627
	14.38%	-58,312	-62,885	-66,619	-69,570	-71,943
	19.38%	-78,904	-83,062	-85,568	-87,625	-89,324
	24.38%	-98,478	-101,475	-100,550	-103,969	-102,807
	29.38%	-116,901	-117,662	-116,108	-113,028	-108,713
	34.38%	-126,153	-123,495	-119,463	-115,837	-112,758
	39.38%	-129,318	-126,164	-122,620	-114,187	-105,038

The sensitivity analysis of the difference in relation to volatility and WACC depicts that ROV value becomes closer to that of rNPV as the volatility decreases (Table 28). It is applicable to most cases within the analysis, and all cases where WACC is either equal or below the benchmark rate of 14.1%.

Meanwhile, the tendency for the difference to decrease is applicable only when the volatility is lower than the benchmark volatility of 24.38%. Therefore, the analysis implies that there is little if any impact on the difference between these approaches if both volatility and WACC are higher than the benchmark estimates.

Table 33.

The sensitivity analysis of the difference between ROV and rNPV approaches (thousands EUR), tested by cumulative success probability and WACC

				WACC				
	Joxeline	**RX**	**Cum.**	12.1%	13.1%	14.1%	15.1%	16.1%
Success probability	80%	39%	41.9%	-87,785	-88,401	-86,824	-82,991	-79,136
	85%	39%	42.3%	-87,644	-88,272	-86,705	-82,881	-79,034
	90%	39%	42.7%	-87,502	-88,142	-86,586	-82,771	-78,932
	95%	39%	43.1%	-87,361	-88,013	-86,467	-82,661	-78,830
	100%	39%	43.5%	-87,219	-87,883	-86,348	-82,551	-78,728
	90%	42%	45.4%	-92,283	-93,827	-94,660	-93,428	-90,791
	95%	42%	45.8%	-92,141	-93,697	-94,541	-93,318	-90,689
	100%	42%	46.2%	-92,000	-93,568	-94,422	-93,208	-90,587
	80%	42%	47.4%	-95,455	-98,645	-100,787	-101,451	-100,417
	85%	45%	47.8%	-95,313	-98,515	-100,668	-101,341	-100,315
	90%	45%	48.2%	-95,171	-98,386	-100,550	-101,231	-100,214
	95%	45%	48.6%	-95,030	-98,256	-100,430	-101,121	-100,112
	100%	45%	49.0%	-94,888	-98,127	-100,311	-101,011	-100,010
	85%	48%	50.5%	-97,158	-101,376	-104,683	-106,803	-107,958
	100%	48%	51.7%	-96,733	-100,988	-104,326	-106,474	-107,652
	85%	51%	53.3%	-98,261	-103,398	-107,601	-110,996	-113,331
	90%	51%	53.7%	-98,120	-103,269	-107,482	-110,886	-113,229
	95%	51%	54.1%	-97,978	-103,140	-107,363	-110,776	-113,127
	100%	51%	54.5%	-97,837	-103,010	-107,244	-110,667	-113,025

Meanwhile, the sensitivity analysis between WACC and the cumulative success probabilities depicts several clear parts when the difference is highest at some point and produces a hump around certain WACC (Table 29). The hump then shifts from right to left, as the cumulative success probability decreases. When success probability is higher than the one used in the valuation, the difference widens with increase in WACC. The effect is significant above the 52% probability mark and relatively mild below it. When the success probability is similar or slightly less than the benchmark of 47.8%, the difference diminishes with WACC that is below 14.1%. Otherwise, it increases and then starts to decrease again at WACC of 16.1%. Therefore, it displays a hump around the 14.1% discount rate. Last part is when the cumulative success probability is significantly lower than the benchmark, ergo, the hump visibly shifts to around 13.1% and then the difference between the approaches decreases with increase in WACC. Thus, within the sensitivity analysis the lowest difference of 78.7 million EUR is reached when the success probability is one of the lowest (43.5%) and the WACC (16.1%) is at the highest, while the highest difference is present at the same WACC (16.1%), though, at one of the highest cumulative success probability (53.3%).

All aspects considered, the ROV can be regarded as more conservative approach when comparing to the conventional rNPV method. Such conclusion can be drawn based on (1) the value derived via ROV technique is sensitive to volatility, therefore, sensitive to the risk factor. Meaning, the ROV adjusts for the uncertainty and the expected movement of the market accordingly. Additionally, and more importantly, contrary to the rNPV method, ROV is less sensitive to the fluctuations in success probabilities: the differences in the success probabilities affects the value produced by rNPV more than it affects the value generated via ROA (Table 29). This is also an advantage of this model since success probabilities are hard to materialize and possess high degree of error in its approximation.

5. CONCLUSION

The literature review finds that DCF, as a valuation method, underestimates the value of companies with certain characteristics. It produces false results when the business requires early phase investments, which carry uncertainty about the future commercialization opportunities. That is the case as the corresponding timing of the investment largely depends on the availability of the information of the future opportunities (Myers, 1977; Smit and Ankum, 1993; Dixit and Pindyck, 1994). It also wrongly discounts both the cash flows and the investment costs with the same rate and does not account for the flexibility of the investment decision (Mun, 2006).

Therefore, I answered the first question of the thesis by introducing the MCS, DTA, and ROV approaches as auxiliary valuation tools, comparing the methods and concluding that the Real Option approach can facilitate the DCF as an auxiliary valuation method. The ROV itself is debatable amongst the scholars and practitioners (Jacob and Kwak, 2003; Copeland and Tufano, 2004) since some are against it (Amram and Kulatilaka, 2000), while others favour it (Mun, 2006; Schwartz 2013). Ultimately, I produce the reasoning that treats ROV method as superior auxiliary method, while the subsequent literature review provides grounds for the feasibility of this technique to be used in valuing biotechnology company.

The ROV framework that I used for that purpose is based on the lattice tree approach of Cox et al (1979) and adjusted in accordance to Kellogg et al (2000) and Tan et al (2002) to account for the success probabilities and phase investments. This, in turn, provided an answer to the second question of the thesis by proving that ROA can be improved so that it would be applicable in valuing biotechnology company that entails multiple phase investments and success probabilities.

As a result, a biotechnology company, *Nucleos*, was valued via ROV methodology by combining separate ROV valuations of its two products, RX and Joxeline. The resulting Real Option value of *Nucleos Human Health* is 786.7 million EUR. In comparison, the value estimated by the conventional rNPV is 887.3 million EUR. The difference is not only in value, but also in terms of communication of information to the manager: ROA improves the valuation by providing information that would facilitate the management in timely capital budgeting decisions, while the rNPV does not provide that sort of insight. Therefore, such a finding answered the third question of the thesis.

Lastly, the sensitivity analysis showed that, as expected, the ROV depends on the market share, success probability, and the amount of years-to-peak. However, discount rate plays a big role in value estimation too. On the contrary, the comparison of rNPV to ROV unveils that the latter is less sensitive to the fluctuation in success probabilities, therefore, making it more conservative auxiliary valuation tool. Consequently, this information fulfils the last question of thesis, confirming the superiority of ROA over the rNPV when the dependencies on success probabilities and discount rate are considered.

6. FURTHER RESEARCH AND RECOMMENDATIONS

The thesis covered the Real Option approach by applying *Option to wait-and-see* to the valuation of biotechnology company. The used ROV framework, that adjusts for multiple phase investments and success probabilities, was an improvement within the conventional lattice tree methodology, therefore, the simplest type of option was used. Given this information, further research may be aimed towards improving or adjusting the model:

1. Different option could be used within ROV framework, depending on the type of the industry, e.g., option to abandon may be used in valuation of the oil wells or mines, while option to switch inputs (similarly to option to expand or contract) may be used in industries that sell elastic products where revenue positively correlates with demand;
2. The estimation of Real Option probabilities used within the model were based on Smit and Ankum (1993), Tan et al (2002) and other, so that upward and downward probabilities would incorporate the volatility and time steps and be exact opposite from one another – the product of both would result in 1. However, other way to account for that is to use the probabilities that are an estimate of up and down scenarios and the sum of which (rather than the product) would result in 1, similarly to the approach used by some other scholars (Dixit and Pindyck, 1994; Smit and Trigeorgis, 2003). That would eliminate the dependencies on the time steps and the volatility, therefore, leaving the assignation of probabilities based on management's viewpoint.
3. The upward and downward probabilities within the thesis were made so that the branches of the lattice tree would come at the same position at each time phase, e.g., the value that goes through upward and then downward probabilities results in the same estimate as if it would go through downward scenario first and then through upward scenario. However, this model can be improved to be a binomial tree so that the number of nodes would increase at geometric progression. That can be made by adjusting the upward and downward probabilities not to be the exact opposite of each other (either the product or the sum would not result in 1). In such a case, the resulting binomial tree model would result in even more outcomes;
4. The ROV can be compared whether it provides more conservative valuation than Monte Carlo simulation, Decision tree analysis or any other popular valuation tool.

The thesis also serves as educational material for managers and other practitioners involved in the management process and supplies them with the insights into the advantages of the ROV methodology as a tool for strategic managerial decision. Therefore, the following paragraphs should be regarded as a set of recommendations for the users of auxiliary valuation techniques.

The thesis provides the calculus and basic examples of practical implementation for 4 types of methodologies: NPV, rNPV, and two of the ROV approaches, namely, BSM (partial differential equation), and CRR (lattice tree). In a nutshell, the NPV should never be used as a sole valuation technique in case the manager thinks any of the following aspects suffice: (1) there are substantial uncertainty about the future cash flows or the market cannot be predicted with without high degree of error; (2) there are success probabilities involved in the development stages; (3) phase investments or platform investments are required for the further development, expansion, or exploration.

If there are more than one phase investment or platform investment event, the BSM technique is also not advisable and should not be used. Even if the model incorporates adjustments to account for multiple stages, I would not advise to use it due to calculation difficulties and lack of information it provides to the manager. Ergo, the estimate provided by the ROV BSM approach would be tough to explain to the management or investors.

The rNPV technique, as auxiliary method, is advised to be used when multiple stage investments are required only. If necessary, the technique can also implement success probabilities, though, value generated is sensitive to the fluctuations in the probabilities. As a result, the model can be used when the management is aware of this dependency or when the probabilities are relatively accurate. On the other hand, the rNPV technique cannot be used when there is a high degree of uncertainty about the fluctuations in the market conditions because it cannot incorporate it. However, the model can be adjusted to account for probabilities of different scenarios, though, it then becomes a sort of decision tree approach rather than conventional risk-adjusted NPV. Due to its similarity to the rNPV, the DTA is advisable to be used cautiously when valuation involves success probabilities. Additionally, the approach uses subjective probabilities, therefore, the model is applicable when uncertainty can be approximated via probabilities and is less likely to depend on outside factors, such as market volatility. This tool is highly advisable, though, the literature review suggests there is equally good model, the ROV lattice tree method. Furthermore, the empirical findings even prove that the binomial lattice technique is superior approach due to its limited dependency on success probabilities.

The ROV lattice tree approach is the most recommended of all tools. The only shortcoming that the model may have is the difficulty of explaining the value derivation to the manager. However, the advantages outweigh it heavily. That is both suggested and proven by the literature review and empirical part where valuation of the biotechnology company was made and where it was compared to rNPV. The managers can use the model whether there are one or multiple investments, when there are market uncertainties, and also with it deals well with success probabilities. Therefore, I advise managers from a vast array of industries to implement this technique as auxiliary method to the conventional NPV technique. The value derivation shall be easy to explain to the investors since the methods does not inflate the value unnecessarily, as the thesis shows, and delivers more conservative

estimation of value than the rNPV approach. Also, this model can be safely used amongst the practitioners who constantly evaluate drugs and medical devices or amongst the oil well valuators since the model is not sensitive to the success probabilities and, ergo, even a higher degree of error can be manageable. The general superiority of the tool is the fact that the managers can observe the progress of the project and see to what extent it is affected by the uncertainty along the way. They can also observe at which points investments make the most sense and how it can be triggered in order to optimize the resulting value, i.e., managers can choose to defer the investment (or invest earlier) so that the option value would be positive, meaning, to avoid abandonment option. All these reasons make it a recommended auxiliary valuation technique not only to practitioners, but also to managers due to its user-friendly interface and basic algebra.

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APPENDIX

Appendix 1a. Balance sheet of full years of 2015 and 2016 (EUR).

BALANCE SHEET (EUR)	2015	2016
	actual	actual
ASSETS		
Fixed assets		
Intangible assets	548,951	1,258,121
Tangible assets	211,035	215,272
Total Fixed assets	**759,987**	**759,987**
Current assets		
Stocks	90,786	130,462
Account receivables	4,508	29,504
Prepayments	94,993	170,810
Cash and cash equivalents	55,576	90,394
Total Current assets	**245,863**	**245,863**
TOTAL ASSETS	1,005,850	1,894,562
EQUITY AND LIABILITIES		
Equity and reserves		
Equity	4,978,123	4,978,123
Reserves	(6,409,763)	(6,524,513)
Retained earnings	(2,352,996)	(6,990,565)
Result for the year	(2,652,882)	(2,500,891)
Dividends paid	-	-
TOTAL EQUITY	(6,437,519)	(11,037,847)
Provisions		
Deferred taxes	(121,578)	68,979
Pension and social security	14,678	(20,182)
Other provisions	114,500	32,000
Total Provisions	**7,600**	**7,600**
Long-term liabilities		
Long-term debt	3,726,105	5,073,000
Total Long-term liabilities	**3,726,105**	**3,726,105**
Current liabilities		
Money owed to group companies	3,435,069	7,448,778
Accounts payable	216,224	136,835
Other payables	58,370	192,999
Total Current liabilities	**3,709,664**	**3,709,664**
TOTAL LIABILITIES	7,443,368	12,932,409
TOTAL EQUITY AND LIABILITES	1,005,850	1,894,562

Appendix 1b. Income statement of full years of 2015 and 2016 (EUR).

PROFIT & LOSS REPORT (EUR)	2015	2016
Revenue	**663,393**	**699,695**
Cost of goods sold	**177,352**	**45,421**
Gross margin	**486,040**	**654,273**
Selling, General & Administrative expenses		
Distribution costs	61,150	61,150
General costs	320,620	320,620
Sales costs	332,568	332,568
Personnel costs	1,448,015	1,448,015
Business premises and office costs	328,057	328,057
R&D costs	436,876	436,876
Total	**2,957,177**	**2,927,286**
EBITDA	**(2,471,137)**	**(2,273,013)**
Depreciation and Amortization	120,041	140,592
EBIT	**(2,591,178)**	**(2,413,605)**
Financing Activities		
Interest income	-	-
Interest expenses	239,820	239,820
EBT	**(2,753,061)**	**(2,653,424)**
Subsidy	152,533	152,533
Tax	0.0%	0.0%
Net profit	**(2,652,882)**	**(2,500,891)**
Dividends	-	-

Appendix 2. Assumptions of population sizes (million inhabitants) and growth rates (percentages, as of 2015) of United States and Europe's 5 biggest countries during the planning period.

Market	Growth	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
USA	0.8%	329.1	331.7	334.4	337.0	339.7	342.5	345.2	348.0	350.7	353.5
EU5	0.3%	320.2	321.0	321.8	322.6	323.4	324.2	325.0	325.8	326.7	327.5

Market	Growth	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
USA	0.8%	356.4	359.2	362.1	365.0	367.9	370.8	373.8	376.8	379.8	382.8
EU5	0.3%	328.3	329.1	329.9	330.8	331.6	332.4	333.3	334.1	334.9	335.8

Appendix 3. Prices of Joxeline and RX products for USA and Europe's 5 biggest countries (EUR).

Joxeline products	USA	EU5	RX products	USA	EU5
Acne	103.64	62.18	**DWI**	1,420.39	852.23
Rosacea	404.27	242.56	**Rosacea**	4,545.24	2,727.14
Skin Irritation *(1st occurrence)*	112.88	67.73	**Folliculitis** *(1st occurrence)*	378.77	227.26
Skin Irritation *(recurrent)*	338.64	203.18	**Folliculitis** *(recurrent)*	1,136.31	681.79
Eczema *(pediatric)*	242.11	145.26	**Eczema** *(pediatric)*	1,562.43	937.46
Eczema *(adults)*	484.21	290.53	**Eczema** *(adults)*	3,124.85	1,874.91

Appendix 4. Detailed operating assumptions of both Joxeline and RX products.

Appendix 4a. Detailed assumptions regarding costs associated with Joxeline product.

Cost Drivers	2015	2016	2017 to 2036
COGS margins (% Revenue)	actual	actual	forecast
USA			5.0%
EU5	26.7%	6.5%	5.0%
RoW			5.0%
Production margin (% COGS)			
USA			83.0%
EU5		83.0%	83.0%
RoW			83.0%
Packaging margin (% COGS)			
USA			17.0%
EU5		17.0%	17.0%
RoW			17.0%

Appendix 4b. Detailed assumptions regarding expenses associated with Joxeline product.

SG&A Expenses Drivers	2015	2016	2017	2018	2019	2020	2021	2022	2023 to 2036
	actual	actual	forecast	forecast	forecast	forecast	forecast	forecast	forecast
Marketing (% of Revenue)	57.9%	47.5%	35.0%	23.0%	20.0%	15.0%	13.0%	11.0%	10.0%
Personnel expenses (% of Revenue)	239.0%	206.9%	54.7%	Stays at 54.7% of the 2017 value and grows y-o-y basis					
YoY Growth			5.0%	Decreases by 0.5% every year					2.0% to 0.0%
Distribution expenses (% of Revenue)	7.5%	8.7%	9.5%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Premises (% of Revenue)	77.4%	46.9%	30.0%	15.0%	10.0%	10.0%	10.0%	10.0%	10.0%
General (% of Revenue)	26.8%	45.8%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%

Appendix 4c. Detailed assumptions regarding investments in assets and research and development associated with Joxeline product.

Capex and R&D Drivers	2015	2016	2017 to 2036
	actual	actual	forecast
Capex of Tangible Assets			10.0%
Depreciation	4.4%	1.4%	1.5%
Capex of Intangible Assets			7.0%
Amortization	11.4%	8.1%	5.0%
USA R&D (% US Revenue)			3.0%
EU5 R&D (% EU5 Revenue)			2.0%
RoW R&D (% RoW Revenue)			2.0%

Appendix 4d. Detailed assumptions regarding other line items associated with Joxeline product.

Other drivers	2015	2016	2017	2018	2019	2020	2021	2022 to 2036
Current Operating Assets	actual	actual	forecast	forecast	forecast	forecast	forecast	forecast
Days Sales Outstanding	2.5	15.4	20.0	18.0	16.0	14.0	12.0	10.0
Stocks days	50.0	68.1	75.0	70.0	65.0	60.0	55.0	50.0
Prepayments (% of revenues)	14.3%	24.4%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
CCE (% of operating Profit)	2.1%	3.6%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Current Operating Liabilities								
Days Payable Outstanding	445.0	1,099.6	900.0	700.0	500.0	300.0	300.0	300.0
Other payables (% COGS)	32.9%	424.9%	33.0%	33.0%	33.0%	33.0%	33.0%	33.0%
Provisions (% of total Liabilities)	0.1%	0.6%	0.6%	Increases y-o-y by risk-free rate of 0.746%				
Financing Activities								
NIPAT to FO (for Interest Income)	0.1%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
IEAT to FO (for Interest Expense)	2.3%	1.4%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%

Appendix 4e. Detailed assumptions regarding costs associated with RX product.

COGS margins (% Revenue)	2017 to 2036
USA	35.0%
EU5	45.0%
RoW	55.0%

Production margin (% COGS)	2017 to 2036
USA	25.0%
EU5	25.0%
RoW	25.0%

Packaging margin (% COGS)	2017 to 2036
USA	75.0%
EU5	75.0%
RoW	75.0%

Appendix 4f. Detailed assumptions sales, general and administrative expenses associated with RX product.

The rest of drivers		2021	2022	2023	2024	2025	2026	2027
Sales and Marketing expenses								
Marketing 1st product (% of Revenue)	starts at 5.5%, increases y-o-y by 1% up until reaches 14.5%; then goes down to 14% and decreases by 1% y-oy-y afterwards)	5.5%	6.5%	7.5%	8.5%	9.5%	10.5%	11.5%
Marketing other products (% of Revenue)	starts at 1.7%, increases inconsistently, reaches the peak at 3.85% and decreases the following years y-o-y by 0.15%	0.0%	1.7%	1.8%	1.8%	2.1%	2.4%	2.9%
General and Administrative (% of S&M)	Fluctuates during the period without no pattern	0.0%	0.0%	2.7%	3.1%	3.7%	4.2%	4.1%
Other Expenses								
Depreciation & Amortization	Increases by 5% of initial D&A, starts at 2.5% of platform investment)	2.5%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Capex (% of platform investment)	Stays at 5.0% and stays at 5.0%	0.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%

Appendix 5a. Detailed assumptions regarding of revenue derivation for both Joxeline and RX.

Joxeline rates				**RX rates**		
Commercialization and compliance rates				**Commercialization and compliance rates**		
Rosacea		*0.65*		Rosacea		*0.65*
Skin Irritation (first occurrence)		*0.75*		Folliculitis (first occurrence)		*0.75*
Skin Irritation (recurrent)		*0.65*		Folliculitis (recurrent)		*0.65*
Acne		*0.65*		DWI		*0.9*
Eczema		*0.6*		Eczema		*0.65*
Sales decline when patent expires	***US***	***EU***		**Sales decline when patent expires**	***US***	***EU***
Acne	*60.0%*	*60.0%*		DWI	*80.0%*	*80.0%*
Rosacea	*60.0%*	*60.0%*		Rosacea	*80.0%*	*80.0%*
Skin Irritation	*60.0%*	*60.0%*		Folliculitis	*80.0%*	*80.0%*
Eczema	*60.0%*	*60.0%*		Eczema	*80.0%*	*80.0%*
Population rates				**Population rates**		
RoW gross-up ratio		*25.0%*		RoW gross-up ratio		*25.0%*
Acne	***US***	***EU5***		**DWI**	***US***	***EU5***
Pediatric				**Pediatric**		
Prevalence (% of population)	*11.0%*	*8.7%*		Prevalence (% of population)	*6.5%*	*4.1%*
Growth of prevalence (%)	*0.6%*	*0.2%*		Growth of prevalence (%)	*0.8%*	*0.3%*
Moderate-to-severe (% of prevalence)	*27.0%*	*27.0%*		Foot Ulcer Infection (% of prevalence)	*2.1%*	*2.1%*
Severe (% of prevalence)	*5.0%*	*5.0%*		Mild (% of Infections)	*75.0%*	*75.0%*
OTC treated (% of moderate)	*70.0%*	*70.0%*		Prescription treated (% of moderate)	*100.0%*	*100.0%*
OTC treated (% of severe)	*41.0%*	*41.0%*		**Adult**		
Adult				Prevalence (% of population)	*6.5%*	*4.1%*
Prevalence (% of population)	*0.6%*	*1.6%*		Growth of prevalence (%)	*0.8%*	*0.3%*
Growth of prevalence (%)	*0.5%*	*-0.8%*		Foot Ulcer Infection (% of prevalence)	*2.1%*	*2.1%*
Moderate-to-severe (% of prevalence)	*10.0%*	*10.0%*		Mild (% of Infections)	*75.0%*	*75.0%*
Severe (% of prevalence)	*5.0%*	*5.0%*		Prescription treated (% of moderate)	*100.0%*	*100.0%*
OTC treated (% of moderate)	*70.0%*	*70.0%*				
OTC treated (% of severe)	*41.0%*	*41.0%*				
Rosacea	***US***	***EU5***		**Rosacea**	***US***	***EU5***
Prevalence (% of population)	*1.9%*	*2.4%*		Prevalence (% of population)	*1.9%*	*2.4%*
Growth of prevalence (%)	*0.8%*	*0.3%*		Growth of prevalence (%)	*0.8%*	*0.3%*
Subtype (% of prevalence)	*19.9%*	*19.9%*		Subtype (% of prevalence)	*19.9%*	*19.9%*
Growth of subtype (%)	*0.8%*	*0.3%*		Growth of subtype (%)	*0.8%*	*0.3%*
OTC treatment (% of subtype)	*70.5%*	*70.5%*		Prescription treatment (% of subtype)	*70.5%*	*70.5%*
Skin Irritation	***US***	***EU5***		**Folliculitis**	***US***	***EU5***
First occurrence and recurrent				**First occurrence and recurrent**		
Prevalence (% of population)	*30.0%*	*30.0%*		Prevalence (% of population)	*0.3%*	*0.3%*
OTC treated (% of prevalence)	*75.0%*	*75.0%*		Prescription treated (% of prevalence)	*75.0%*	*75.0%*
First occurrence (% of OTC treated)	*65.0%*	*65.0%*		First occurrence (% of OTC treated)	*65.0%*	*65.0%*
Recurrent (% of prevalence)	*53.8%*	*53.8%*		Recurrent (% of prevalence)	*35.0%*	*35.0%*
Eczema	***US***	***EU5***		**Eczema**	***US***	***EU5***
Pediatric				**Pediatric**		
Prevalence (% of population)	*15.0%*	*15.0%*		Prevalence (% of population)	*1.9%*	*1.4%*
Growth of prevalence (%)	*0.5%*	*0.5%*		Growth of prevalence (%)	*0.5%*	*0.5%*
Mild-to-moderate (% of prevalence)	*75.0%*	*75.0%*		Mild-to-moderate (% of prevalence)	*93.0%*	*93.0%*
OTC treated (% of moderate-to-severe)	*2.9%*	*2.9%*		Prescription treated (% of moderate-to-severe)	*60.0%*	*60.0%*
Adults				**Adults**		
Prevalence (% of population)	*2.0%*	*2.0%*		Prevalence (% of population)	*0.8%*	*1.0%*
Growth of prevalence (%)	*0.9%*	*0.3%*		Growth of prevalence (%)	*0.9%*	*0.3%*
Mild-to-moderate (% of prevalence)	*75.0%*	*75.0%*		Mild-to-moderate (% of prevalence)	*89.0%*	*89.0%*
OTC treated (% of moderate-to-severe)	*0.7%*	*0.7%*		Prescription treated (% of moderate-to-severe)	*60.0%*	*60.0%*

Appendix 6a. Derivation of free cash flows of Joxeline product within Europe's 5 biggest countries (EU5) region (thousand EUR).

EU5 (kEUR)	2017	2018	2019	2020	2021	2022	2023	2024	2025	…	2035	2036
Revenue												
Acne	1,523	3,049	4,577	6,109	7,644	7,651	7,659	7,667	7,674	…	4,887	4,648
Rosacea	3,458	6,933	10,425	13,935	17,462	17,506	17,550	17,594	17,638	…	11,398	10,855
Skin Irritation	2,854	5,723	8,606	11,503	14,415	14,451	14,488	14,524	14,560	…	9,409	8,961
Eczema	1,158	2,327	3,510	4,704	5,911	5,942	5,974	6,005	6,037	…	4,010	3,830
TOTAL Revenue	8,992	18,031	27,118	36,251	45,432	45,551	45,670	45,789	45,909	…	29,705	28,294
Costs of Goods Sold (COGS)												
Production	373	748	1,125	1,504	1,885	1,890	1,895	1,900	1,905	…	1,233	1,174
Packaging	76	153	230	308	386	387	388	389	390	…	252	240
TOTAL COGS	450	902	1,356	1,813	2,272	2,278	2,283	2,289	2,295	…	1,485	1,415
Gross Profit	8,543	17,130	25,762	34,438	43,160	43,273	43,386	43,500	43,614	…	28,219	26,879
Sales, General & Administrative Expenses (SG&A)												
Sales and Marketing	3,147	4,147	5,424	5,438	5,906	5,011	4,567	4,579	4,591	…	2,970	2,829
Personnel	1,111	1,160	815	724	687	608	545	551	555	…	509	508
Distribution	854	1,803	2,712	3,625	4,543	4,555	4,567	4,579	4,591	…	2,970	2,829
Other	2,788	2,885	2,983	3,988	4,998	5,011	5,024	5,037	5,050	…	3,267	3,112
TOTAL SG&A	7,900	9,996	11,933	13,775	16,134	15,184	14,702	14,746	14,787	…	9,718	9,279
Research & Development	361	361	542	725	909	911	913	916	918	…	594	566
EBITDA	282	6,773	13,286	19,939	26,118	27,178	27,770	27,838	27,908	…	17,908	17,035
Depreciation & Amortization	108	110	76	67	63	55	50	51	52	…	59	60
EBIT	175	6,663	13,210	19,872	26,055	27,123	27,721	27,787	27,857	…	17,849	16,974
Tax rate	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	…	25.0%	25.0%
NOPAT	131	4,998	9,908	14,904	19,542	20,342	20,791	20,840	20,892	…	13,386	12,731
Operating Accruals												
Depreciation & Amortization	108	110	76	67	63	55	50	51	52	…	59	60
Change in Operating Provisions	0	0	0	0	0	0	0	0	0	…	0	0
Operating Working Capital	25	1,965	1,562	3,342	2,403	1,701	1,210	1,221	53	…	(314)	(299)
Capital Expenditures	1,298	166	115	101	96	85	77	79	81	…	101	104
FREE CASH FLOW	(1,084)	2,977	8,307	11,528	17,106	18,612	19,553	19,592	20,810	…	13,659	12,986
Acne	(183)	503	1,402	1,943	2,878	3,126	3,279	3,280	3,479	…	2,247	2,133
Rosacea	(417)	1,145	3,193	4,431	6,575	7,153	7,514	7,528	7,995	…	5,241	4,982
Skin Irritation	(344)	945	2,636	3,658	5,428	5,905	6,203	6,214	6,600	…	4,327	4,113
Eczema	(139)	384	1,075	1,496	2,226	2,428	2,558	2,569	2,736	…	1,844	1,758

Appendix 6b. Derivation of free cash flows of Joxeline product within USA region (thousand EUR).

USA (kEUR)	2017	2018	2019	2020	2021	2022	2023	2024	2025		*2035*	*2036*
Revenue												
Acne	-	-	3,128	6,297	9,506	12,756	16,047	16,150	16,254	…	12,101	11,569
Rosacea	-	-	4,612	9,298	14,059	18,895	23,807	23,997	24,189	…	18,292	17,517
Skin Irritation	-	-	4,889	9,857	14,904	20,031	25,238	25,440	25,644	…	19,392	18,570
Eczema	-	-	1,963	3,947	5,954	7,983	10,034	10,090	10,147	…	7,492	7,157
TOTAL Revenue	-	-	14,593	29,399	44,422	59,664	75,127	75,678	76,234	**…**	**57,277**	**54,813**
Costs of Goods Sold (COGS)												
Production	-	-	606	1,220	1,844	2,476	3,118	3,141	3,164	…	2,377	2,275
Packaging	-	-	124	250	378	507	639	643	648	…	487	466
TOTAL COGS	-	-	730	1,470	2,221	2,983	3,756	3,784	3,812	**…**	**2,864**	**2,741**
Gross Profit	-	-	13,863	27,929	42,201	56,681	71,371	71,894	72,422	**…**	**54,413**	**52,072**
Sales, General & Administrative Expenses (SG&A)												
Sales and Marketing	-	-	2,919	4,410	5,775	6,563	7,513	7,568	7,623	…	5,728	5,481
Personnel	-	-	439	588	672	796	896	911	922	…	982	983
Distribution	-	-	1,459	2,940	4,442	5,966	7,513	7,568	7,623	…	5,728	5,481
Other	-	-	1,605	3,234	4,886	6,563	8,264	8,325	8,386	…	6,300	6,029
TOTAL SG&A	-	-	6,422	11,171	15,775	19,889	24,186	24,372	24,555	**…**	**18,738**	**17,975**
Research & Development	-	-	438	882	1,333	1,790	2,254	2,270	2,287	**…**	**1,718**	**1,644**
EBITDA	-	-	7,004	15,876	25,093	35,002	44,931	45,252	45,580	**…**	**33,957**	**32,453**
Depreciation & Amortization	-	-	41	54	61	72	82	84	86	**…**	**114**	**117**
EBIT	-	-	6,963	15,822	25,032	34,930	44,850	45,169	45,495	**…**	**33,843**	**32,336**
Tax rate	*25.0%*	*25.0%*	*25.0%*	*25.0%*	*25.0%*	*25.0%*	*25.0%*	*25.0%*	*25.0%*	…	*25.0%*	*25.0%*
NOPAT	-	-	5,222	11,867	18,774	26,197	33,637	33,877	34,121	**…**	**25,383**	**24,252**
Operating Accruals												
Depreciation & Amortization	-	-	41	54	61	72	82	84	86	…	114	117
Change in Operating Provisions	-	-	0	0	0	0	0	0	0	…	0	0
Operating Working Capital	-	-	841	2,710	2,349	2,228	1,991	2,017	88	…	(606)	(579)
Capital Expenditures	-	-	62	82	94	111	126	130	134	…	194	202
FREE CASH FLOW	-	-	4,361	9,128	16,393	23,931	31,602	31,813	33,985	**…**	**25,908**	**24,747**
Acne	-	-	935	1,955	3,508	5,116	6,750	6,789	7,246	…	5,473	5,223
Rosacea	-	-	1,378	2,887	5,188	7,578	10,014	10,088	10,783	…	8,274	7,908
Skin Irritation	-	-	1,461	3,061	5,500	8,034	10,617	10,694	11,432	…	8,772	8,384
Eczema	-	-	586	1,226	2,197	3,202	4,221	4,242	4,523	…	3,389	3,231

Appendix 6c. Derivation of free cash flows of Joxeline product within rest of the world (RoW) region (thousand EUR).

RoW (kEUR)	2017	2018	2019	2020	2021	2022	2023	2024	2025	…	2035	2036
Revenue												
Acne	507	1,015	2,149	3,293	4,445	5,097	5,757	5,780	5,803	…	4,045	3,859
Rosacea	1,151	2,309	4,393	6,498	8,624	9,605	10,601	10,654	10,707	…	7,451	7,115
Skin Irritation	1,097	2,199	4,434	6,693	8,975	10,171	11,385	11,446	11,507	…	8,086	7,725
Eczema	564	1,133	2,283	3,444	4,618	5,226	5,840	5,872	5,904	…	4,140	3,955
TOTAL Revenue	3,319	6,656	13,259	19,928	26,662	30,098	33,584	33,751	33,920	…	23,723	22,653
Costs of Goods Sold (COGS)												
Production	138	276	550	827	1,106	1,249	1,394	1,401	1,408	…	984	940
Packaging	28	57	113	169	227	256	285	287	288	…	202	193
TOTAL COGS	166	333	663	996	1,333	1,505	1,679	1,688	1,696	…	1,186	1,133
Gross Profit	3,153	6,324	12,596	18,931	25,329	28,593	31,904	32,064	32,224	…	22,536	21,521
Sales, General & Administrative Expenses (SG&A)												
Sales and Marketing	1,162	1,531	2,652	2,989	3,466	3,311	3,358	3,375	3,392	…	2,372	2,265
Personnel	410	428	399	398	403	402	401	406	410	…	407	406
Distribution	315	666	1,326	1,993	2,666	3,010	3,358	3,375	3,392	…	2,372	2,265
Other	1,029	1,065	1,459	2,192	2,933	3,311	3,694	3,713	3,731	…	2,609	2,492
TOTAL SG&A	2,916	3,690	5,835	7,572	9,468	10,033	10,812	10,869	10,926	…	7,761	7,429
Research & Development	133	133	265	399	533	602	672	675	678	…	474	453
EBITDA	104	2,500	6,496	10,960	15,328	17,958	20,421	20,519	20,620	…	14,301	13,639
Depreciation & Amortization	40	41	37	37	37	37	36	37	38	…	47	48
EBIT	64	2,460	6,459	10,924	15,291	17,922	20,385	20,482	20,582	…	14,254	13,590
Tax rate	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	…	25.0%	25.0%
NOPAT	48	1,845	4,844	8,193	11,468	13,441	15,288	15,362	15,437	…	10,691	10,193
Operating Accruals												
Depreciation & Amortization	40	41	37	37	37	37	36	37	38	…	47	48
Change in Operating Provisions	0	0	0	0	0	0	0	0	0	…	0	0
Operating Working Capital	9	725	764	1,837	1,410	1,124	890	900	39	…	(251)	(239)
Capital Expenditures	479	61	56	56	56	56	56	58	60	…	81	83
FREE CASH FLOW	(400)	1,099	4,062	6,337	10,039	12,298	14,379	14,441	15,376	…	10,908	10,397
Acne	(61)	168	658	1,047	1,674	2,082	2,465	2,473	2,631	…	1,860	1,771
Rosacea	(139)	381	1,346	2,066	3,247	3,925	4,539	4,558	4,853	…	3,426	3,266
Skin Irritation	(132)	363	1,358	2,128	3,379	4,156	4,875	4,897	5,216	…	3,718	3,545
Eczema	(68)	187	699	1,095	1,739	2,135	2,500	2,512	2,676	…	1,904	1,815

Appendix 7a. Derivation of free cash flows of RX product within Europe's 5 biggest countries (EU5) region (thousand EUR).

EU5 (kEUR)	2017	2018	2019	2020	2021	2022	2023	2024	2025		2035	2036
Revenue												
DWI	-	-	-	-	-	-	18,239	36,568	54,990	…	76,542	72,897
Rosacea	-	-	-	-	-	19,437	38,972	58,605	78,335	…	77,689	73,989
Folliculitis	-	-	-	-	-	-	9,574	19,195	28,865	…	40,178	38,265
Eczema	-	-	-	-	-	64,687	129,967	195,845	262,325	…	265,641	253,521
TOTAL Revenue	-	-	-	-	-	84,124	196,751	310,213	424,516	**…**	460,050	438,673
Costs of Goods Sold (COGS)												
Production	-	-	-	-	-	9,464	22,134	34,899	47,758	…	51,756	49,351
Packaging	-	-	-	-	-	28,392	66,403	104,697	143,274	…	155,267	148,052
TOTAL COGS	-	-	-	-	-	37,856	88,538	139,596	191,032	**…**	207,022	197,403
Gross Profit	-	-	-	-	-	46,268	108,213	170,617	233,484	**…**	253,027	241,270
Sales, General & Administrative Expenses (SG&A)												
Sales and Marketing	-	-	-	-	10,309	24,531	38,125	54,227	65,296	…	63,486	60,060
General and Administrative	845	845	845	845	845	845	1,873	2,550	3,234	…	3,716	3,584
TOTAL SG&A	845	845	845	845	11,154	25,375	39,998	56,777	68,530	**…**	67,203	63,644
EBITDA	(845)	(845)	(845)	(845)	(11,154)	20,893	68,215	113,841	164,953	**…**	185,825	177,626
Depreciation & Amortization	-	-	-	190	200	210	220	231	243	**…**	395	415
EBIT	(845)	(845)	(845)	(1,035)	(11,354)	20,683	67,995	113,610	164,711	**…**	185,430	177,211
Tax rate	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	…	25.0%	25.0%
NOPAT	(634)	(634)	(634)	(776)	(8,515)	15,513	50,996	85,207	123,533	**…**	139,072	132,908
Operating Accruals												
Depreciation & Amortization	-	-	-	190	200	210	220	231	243	…	395	415
Capital Expenditures	-	-	-	-	-	190	190	190	190	…	190	190
FREE CASH FLOW	(634)	(634)	(634)	(586)	(8,316)	15,532	51,026	85,248	123,586	**…**	139,277	133,133
DWI	(158)	(158)	(158)	(147)	(2,079)	3,883	4,730	10,049	16,009	…	23,173	22,124
Rosacea	(158)	(158)	(158)	(147)	(2,079)	3,883	10,107	16,105	22,805	…	23,520	22,455
Folliculitis	(158)	(158)	(158)	(147)	(2,079)	3,883	2,483	5,275	8,403	…	12,164	11,613
Eczema	(158)	(158)	(158)	(147)	(2,079)	3,883	33,706	53,819	76,368	…	80,421	76,941

Appendix 7b. Derivation of free cash flows of RX product within the USA region (thousand EUR).

US Entry (kEUR)	2017	2018	2019	2020	2021	2022	2023	2024	2025	…	2035	2036
Revenue												
DWI	-	-	-	-	-	-	49,643	100,079	151,319	…	222,444	213,011
Rosacea	-	-	-	-	-	25,928	52,270	79,031	106,217	…	111,251	106,534
Folliculitis	-	-	-	-	-	-	16,400	33,062	49,989	…	73,486	70,370
Eczema	-	-	-	-	-	99,211	199,704	301,493	404,590	…	417,443	399,146
TOTAL Revenue	-	-	-	-	-	125,139	318,017	513,665	712,116	**…**	824,623	789,060
Costs of Goods Sold (COGS)												
Production	-	-	-	-	-	10,950	27,826	44,946	62,310	…	72,155	69,043
Packaging	-	-	-	-	-	32,849	83,479	134,837	186,930	…	216,464	207,128
TOTAL COGS	-	-	-	-	-	43,799	111,306	179,783	249,240	**…**	288,618	276,171
Gross Profit	-	-	-	-	-	81,340	206,711	333,882	462,875	**…**	536,005	512,889
Sales, General & Administrative Expenses (SG&A)												
Sales and Marketing	-	-	-	-	18,237	43,394	67,442	95,926	115,508	…	112,306	106,245
General and Administrative	1,494	1,494	1,494	1,494	1,494	1,494	3,314	4,511	5,721	…	6,574	6,340
TOTAL SG&A	1,494	1,494	1,494	1,494	19,731	44,888	70,756	100,437	121,229	**…**	118,880	112,585
EBITDA	(1,494)	(1,494)	(1,494)	(1,494)	(19,731)	36,452	135,955	233,446	341,646	**…**	417,125	400,304
Depreciation & Amortization	-	-	-	336	353	371	389	409	429	**…**	699	734
EBIT	(1,494)	(1,494)	(1,494)	(1,830)	(20,084)	36,081	135,566	233,037	341,217	**…**	416,426	399,570
Tax rate	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	…	25.0%	25.0%
NOPAT	(1,121)	(1,121)	(1,121)	(1,373)	(15,063)	27,061	101,674	174,778	255,913	**…**	312,320	299,678
Operating Accruals												
Depreciation & Amortization	-	-	-	336	353	371	389	409	429	…	699	734
Capital Expenditures	-	-	-	-	-	336	336	336	336	…	336	336
FREE CASH FLOW	(1,121)	(1,121)	(1,121)	(1,037)	(14,710)	27,095	101,727	174,850	256,006	**…**	312,682	300,075
DWI	(280)	(280)	(280)	(259)	(3,678)	6,774	15,880	34,067	54,399	…	84,347	81,007
Rosacea	(280)	(280)	(280)	(259)	(3,678)	6,774	16,720	26,902	38,185	…	42,185	40,514
Folliculitis	(280)	(280)	(280)	(259)	(3,678)	6,774	5,246	11,254	17,971	…	27,865	26,761
Eczema	(280)	(280)	(280)	(259)	(3,678)	6,774	63,882	102,627	145,450	…	158,287	151,793

Appendix 7c. Derivation of free cash flows of RX product within rest of the world (RoW) region (thousand EUR).

RoW (kEUR)	2017	2018	2019	2020	2021	2022	2023	2024	2025	…	2035	2036
Revenue												
DWI	-	-	-	-	-	-	15,993	32,174	48,547	…	69,936	66,837
Rosacea	-	-	-	-	-	11,653	23,422	35,307	47,310	…	48,100	45,926
Folliculitis	-	-	-	-	-	-	5,766	11,593	17,482	…	25,029	23,906
Eczema	-	-	-	-	-	52,589	105,752	159,493	213,818	…	218,392	208,608
TOTAL Revenue	-	-	-	-	-	64,243	150,933	238,568	327,157	…	361,457	345,276
Costs of Goods Sold (COGS)										…		
Production	-	-	-	-	-	8,833	20,753	32,803	44,984	…	49,700	47,476
Packaging	-	-	-	-	-	26,500	62,260	98,409	134,952	…	149,101	142,427
TOTAL COGS	-	-	-	-	-	35,334	83,013	131,212	179,936	…	198,801	189,902
Gross Profit	-	-	-	-	-	28,909	67,920	107,356	147,220	…	162,656	155,374
Sales, General & Administrative Expenses (SG&A)												
Sales and Marketing	-	-	-	-	8,067	19,196	29,834	42,434	51,096	…	49,680	46,999
General and Administrative	661	661	661	661	661	661	1,466	1,995	2,531	…	2,908	2,805
TOTAL SG&A	661	661	661	661	8,728	19,857	31,300	44,429	53,627	…	52,588	49,803
EBITDA	(661)	(661)	(661)	(661)	(8,728)	9,052	36,620	62,926	93,593	…	110,068	105,571
Depreciation & Amortization	-	-	-	149	156	164	172	181	190	…	309	325
EBIT	(661)	(661)	(661)	(810)	(8,885)	8,888	36,448	62,745	93,404	…	109,759	105,246
Tax rate	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	…	25.0%	25.0%
NOPAT	(496)	(496)	(496)	(607)	(6,663)	6,666	27,336	47,059	70,053	…	82,319	78,935
Operating Accruals												
Depreciation & Amortization	-	-	-	149	156	164	172	181	190	…	309	325
Capital Expenditures	-	-	-	-	-	149	149	149	149	…	149	149
FREE CASH FLOW	(496)	(496)	(496)	(459)	(6,507)	6,682	27,359	47,091	70,094	…	82,479	79,111
DWI	(124)	(124)	(124)	(115)	(1,627)	1,670	2,899	6,351	10,401	…	15,958	15,314
Rosacea	(124)	(124)	(124)	(115)	(1,627)	1,670	4,246	6,969	10,136	…	10,976	10,523
Folliculitis	(124)	(124)	(124)	(115)	(1,627)	1,670	1,045	2,288	3,745	…	5,711	5,477
Eczema	(124)	(124)	(124)	(115)	(1,627)	1,670	19,170	31,482	45,811	…	49,834	47,797

Appendix 8a. DCF valuation of Joxeline product (thousand EUR).

Value per indication	*USA*	*EU5*	*RoW*	*TOTAL*
Acne	34,182	14,541	10,393	**59,116**
Rosacea	51,423	33,693	19,302	**104,418**
Skin Irritation	54,515	27,814	20,780	**103,109**
Eczema	21,218	11,713	10,650	**43,581**
NPV (kEUR)	**161,337**	**87,761**	**61,126**	**310,224**

Value per period	*USA*	*EU5*	*RoW*	*TOTAL*
Planning period	149,060	81,317	55,966	**286,343**
Continous period	12,277	6,444	5,160	**23,881**
NPV (kEUR)	**161,337**	**87,761**	**61,126**	**310,224**

Appendix 8b. DCF valuation of RX product (thousand EUR).

Value per indication	*USA*	*EU5*	*RoW*	*TOTAL*
DWI	238,355	67,644	44,772	**350,771**
Rosacea	124,122	71,634	32,042	**227,799**
Folliculitis	78,819	35,543	15,942	**130,305**
Eczema	466,220	244,140	145,895	**856,255**
NPV (kEUR)	**907,517**	**418,961**	**238,651**	**1,565,129**

Value per period	*USA*	*EU5*	*RoW*	*TOTAL*
Planning period	755,816	351,681	198,693	**1,306,189**
Continous period	151,702	67,280	39,958	**258,940**
NPV (kEUR)	**907,517**	**418,961**	**238,651**	**1,565,129**

Appendix 9. Market shares of all indications based on the total shares.

Total	RX	DWI	Eczema	Folliculitis	Rosacea
9.5%	**10.0%**	5.0%	2.5%	1.7%	0.8%
9.5%	**10.0%**	5.0%	2.5%	1.7%	0.8%
9.6%	**10.0%**	5.0%	2.5%	1.7%	0.8%
11.8%	**12.5%**	6.3%	3.1%	2.1%	1.0%
11.8%	**12.5%**	6.3%	3.1%	2.1%	1.0%
11.9%	**12.5%**	6.3%	3.1%	2.1%	1.0%
11.9%	**12.5%**	6.3%	3.1%	2.1%	1.0%
14.1%	**15.0%**	7.5%	3.8%	2.5%	1.3%
14.1%	**15.0%**	7.5%	3.8%	2.5%	1.3%
14.2%	**15.0%**	7.5%	3.8%	2.5%	1.3%
14.3%	**15.0%**	8.8%	4.4%	2.9%	1.5%
16.4%	**17.5%**	7.5%	3.8%	2.5%	1.3%
16.4%	**17.5%**	8.8%	4.4%	2.9%	1.5%
16.5%	**17.5%**	8.8%	4.4%	2.9%	1.5%
16.6%	**17.5%**	8.8%	4.4%	2.9%	1.5%
18.7%	**20.0%**	10.0%	5.0%	3.3%	1.7%
18.8%	**20.0%**	10.0%	5.0%	3.3%	1.7%
18.8%	**20.0%**	10.0%	5.0%	3.3%	1.7%
18.9%	**20.0%**	10.0%	5.0%	3.3%	1.7%

Joxeline	Acne	Eczema	Rosacea	Skin
3.8%	2.4%	4.8%	7.9%	0.20%
4.3%	2.7%	5.4%	9.0%	0.22%
4.8%	3.0%	6.0%	10.0%	0.25%
3.8%	2.4%	4.8%	7.9%	0.20%
4.3%	2.7%	5.4%	9.0%	0.22%
4.8%	3.0%	6.0%	10.0%	0.25%
5.3%	3.3%	6.6%	11.0%	0.28%
3.8%	2.4%	4.8%	7.9%	0.20%
4.3%	2.7%	5.4%	9.0%	0.22%
4.8%	3.0%	6.0%	10.0%	0.25%
5.8%	3.6%	7.2%	12.1%	0.30%
3.8%	2.4%	4.8%	7.9%	0.20%
4.3%	2.7%	5.4%	9.0%	0.22%
4.8%	3.0%	6.0%	10.0%	0.25%
5.8%	3.6%	7.2%	12.1%	0.30%
4.3%	2.7%	5.4%	9.0%	0.22%
4.8%	3.0%	6.0%	10.0%	0.25%
5.3%	3.3%	6.6%	11.0%	0.28%
5.8%	3.6%	7.2%	12.1%	0.30%