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Valuation methods & models – Valuating biotechnology companies

Arvonmääritysmenetelmät ja -mallit – Bioteknologiayhtiöiden arvonmääritys

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ABSTRACT

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Biotechnology as an industry is described as a risky one with long investing periods, high degree of research & development dependency and with a lot of uncertainty in the final payoffs. Because of the characteristics of biotechnology firms and the industry as a whole, valuating biotechnology companies can be a difficult and challenging task where many different aspects of the firm have to be taken into account. This thesis' objective is to review and study different valuation methods and models to determine the optimal way to valuate biotechnology companies. The methods include real options model and discounted cash flow model with decision tree approach. The thesis also presents the theory behind the methods and how to use them in practice. The study is conducted with quantitative and empirical methods.

According to the scholars in the respective research field the most optimal valuation method for biotechnology company valuation is the real option method. Its advantages are that it can take options to for example abandon or expand into account and that it offers flexibility. The second-best alternative is the decision tree approach of traditional discounted cash flow model. The empirical study shows that the weakness of both of the valuation models is that they depend largely on the initial estimates of the needed valuation parameters for the models and therefore sensitivity analysis is required to judge the impact of different estimates. Gathering the needed information of a company is a hard task for an outsider. On the other hand, the models offer a great tool for company management to valuate their own company with full information and accurate estimates.

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Bioteknologia-alalle on luonteenomaista pitkät investointijaksot, korkea riippuvuus tutkimuksesta ja tuotekehityksestä sekä epävarmuus lopullisten tuottojen suhteen. Näiden piirteiden takia bioteknologiayhtiöiden arvonmääritys on haastava tehtävä jossa monia eri yhtiön ja alan erityispiirteitä tulee ottaa huomioon. Tämä tutkielma tutkii erilaisia arvonmääritysmenetelmiä sekä malleja, ja selvittää mitkä niistä ovat parhaimpia bioteknologiayhtiöiden arvonmääritykseen. Tutkielmassa esitetään myös teoria metodien takana ja miten malleja pystyy käyttämään käytännön arvonmääritystilanteessa. Tämän lisäksi esitetään malleihin tarvittavien arvojen johtaminen alan keskiarvoista ja tutkitaan bioteknologia-alan erityispiirteitä. Tutkielmassa käytetään hyväksi määrällisiä ja empiirisiä menetelmiä.

Optimaalisin bioteknologiayhtiöiden arvonmääritysmalli on reaalioptio-malli. Sen etuja ovat joustavuus, ja mahdollisuus ottaa projektin hylkääminen tai laajentaminen huomioon. Seuraavaksi parhaimpana vaihtoehtona pidetään diskontatun vapaan kassavirran päätöspuu-mallia. Tämän tutkielman empiirinen osa näyttää, että molemmat mallit kärsivät niiden riippuvuussuhteesta alkuperäisiin parametreihin. Nämä arvioidut parametrit vaikuttavat malleihin suuresti ja käytännössä määrittävät kuinka luotettavina lopullisia tuloksia voidaan pitää. Tämän takia arvonmäärityksessä käytetään yleisesti hyväksi herkkyysanalyysiä, jonka avulla eri parametrien muutokset voidaan ottaa huomioon. Tarkan informaation kerääminen voi olla yhtiön ulkopuoliselle henkilölle hankalaa, mutta tutkielmassa esitetyt mallit tarjoavat yrityksen johdolle parhaimman tavan määrittää yrityksen arvo.

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Appendices

1. Introduction

Biotechnology ("Biotech") is defined by the OECD (2009) as "the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services". Biotechnology techniques cover DNA/RNA techniques, proteins and other molecules, call and tissue culture and engineering, process biotechnology techniques, gene and RNA vectors, bioinformatics and nanobiotechnology. Biotechnology as an industry has had a big part in shaping the modern society and has drastically increased our quality of life. OECD (2009) defines biotech firm as a firm that is "engaged in biotechnology by using at least one biotechnology technique to produce goods or services and/or to perform biotechnology R&D." Some of the largest enterprises in the industry are Johnson & Johnson with a market cap of 316 billion, Pfizer (198 billion) and Merck & Co (181 billion). The largest Finnish biotechnology company is Orion which has a market cap of 6,55 billion. (Yahoo finance, 2017)

The biotech industry is described as a R&D dependent industry with highly uncertain payoffs and long investment cycle. (Joos & Zhdanov, 2008) Because of the characteristics of biotech firms and the industry as a whole, valuating biotechnology firms can be a difficult and challenging task, where many different aspects of the firm have to be taken into account. The purpose of this paper is to look into different valuation methods and models and evaluate which of them are most suited for valuation of biotechnology companies.

The methods researched in detail in this paper are discounted cash flow model and its variants like decision trees and real option models and theory behind them. In addition, other aspects contributing to the value of a biotech company, such as clinical success rates, will also be reviewed as they are a vital part of biotechnology valuation. After the advantages and drawbacks of different methods and their suitability for biotech firm valuation are researched, these methods will be tested in practice on a listed Finnish biotechnology company. The calculated valuations are then compared to the market value of the company to find out how accurate the estimations are.

1.1 Methodology, limitations and research questions

The research in this study is based on literature and researches done by other scholars in the field. The study is conducted with quantitative and empirical methods. The first part of this paper will be focused in reviewing literature on the subject, theory behind the valuation methods researched and discussion considering the results of the review and expected results and hypothesis of the empirical analysis part which is the latter part of this paper.

Limitations set for this paper are that it studies only the valuation of companies in the biotechnology industry. Because the literature is largely centered in the drug industry, the thesis will also have its main focus in it. The case company is listed in the stock market and is a new drug developing typical early-stage biotechnology company. The industry overview considers the whole world, mostly developed countries and areas such as North America, Europe and East Asia since the majority of biotechnology business is located in these regions.

The main research objective of this thesis is to find out "How to valuate listed biotech companies?" The sub-questions of the study are: "How the biotechnology firm valuation methods can be used in practice?", "What is the theory behind the valuation methods?", "How biotech firms' valuation methods differ from valuating companies in other industries?" and "How to make reasonably accurate estimations of the needed parameters in valuation?" The aforementioned questions are mostly addressed in the literature review and theoretical study part of the thesis. In the empirical part the valuation methods will be used to value a listed Finnish biotech firm after which the results are compared to the stock price of the company.

1.2 Biotechnology as an industry

The modern biotechnology industry started in the United States in the 1980s after which Europe and rest of the world followed with a 10-15-year delay. (Tekes 2006) According to the OECD (2016) statistics, today there are over 23 000 biotechnology companies in the world, almost 6000 of them being solely dedicated to biotechnology. Most of the firms are based in the USA (49%), Spain (12%) and France (8%). It should be noted though that only 8,1% of the biotech firms in the USA are dedicated only to biotech. As for the size of the firms, 70% of them are small firms with fewer than

50 employees which is because characteristically especially early stage biotech firms don't have any sales departments or large scale manufacturing and only employ R&D specialists and management. In figure 1 the geographical segments are displayed according to their value in the global biotechnology industry. United states are the major leader in market size, followed by the Asia-Pacific region and Europe.

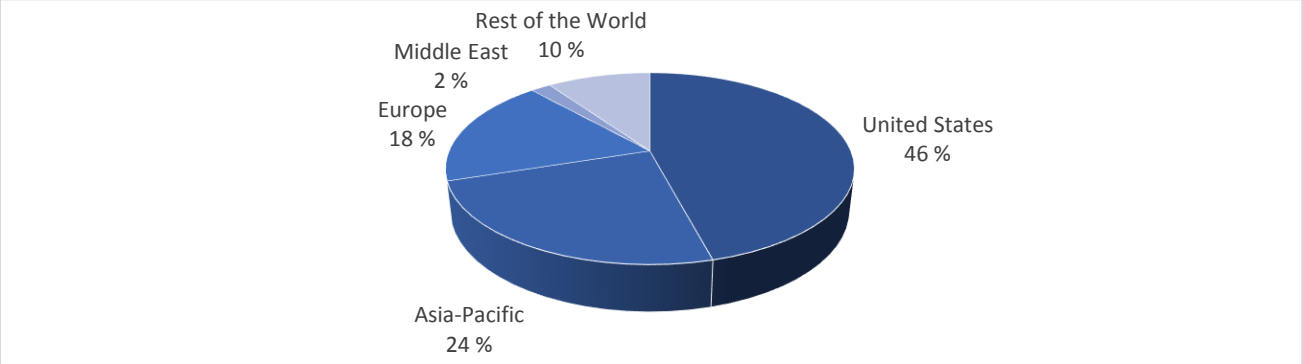

Figure 1. Global biotechnology industry geography segmentation % share, by value (Marketline 2016)

Biotechnology industry in itself covers several different sub-industries. These are medical and healthcare, food & agriculture, environment & industrial processing, service providers and technology services. According to the Marketline (2016) statistics the largest sub-industry in biotechnology is by far medical and healthcare industry with its 58% value share of the global markets.

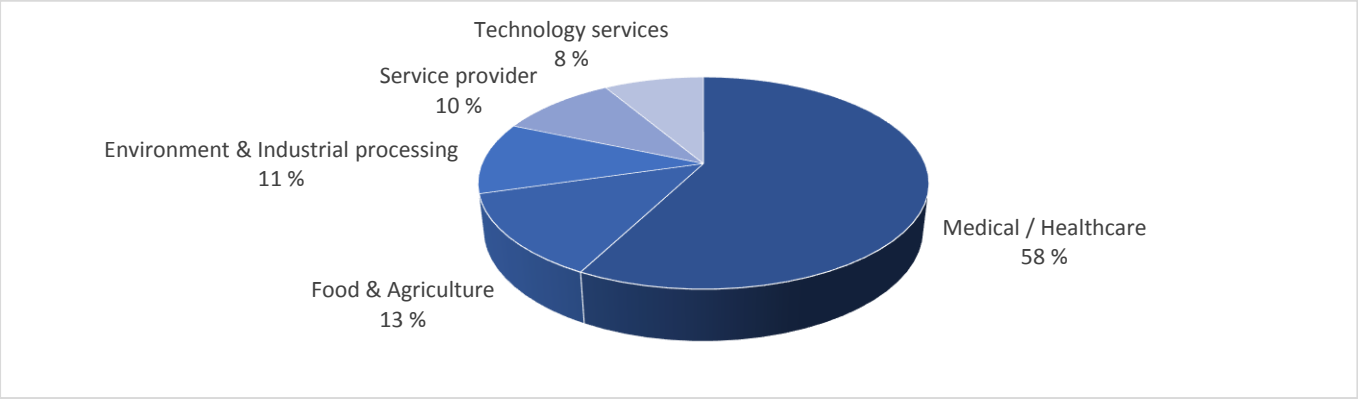

Figure 2. Global biotechnology industry category segmentation % share, by value (Marketline 2016)

The statistics supplied by the OECD show that the overwhelming majority of research and development expenditures are created in the United states, France being second and Switzerland the third. The OECD statistics also show that the most R&D intensive biotechnology companies when compared to the size of the business sector are in Switzerland, Denmark and the United States, as in these countries the companies use 0,85%, 0,78% and 0,34% respectively of the value added in the industry on research and development. On the other hand, the largest expenditures made by the state government are in Germany, Korea and Russia. When the expenditures of companies in different countries is compared to the number of biotechnology patents announced it can be seen that Australia, Japan and Canada are the most cost effective countries. Of course the patent number does not unambiguously mean that the patents registered are all useful or commercially viable. (OECD 2016)

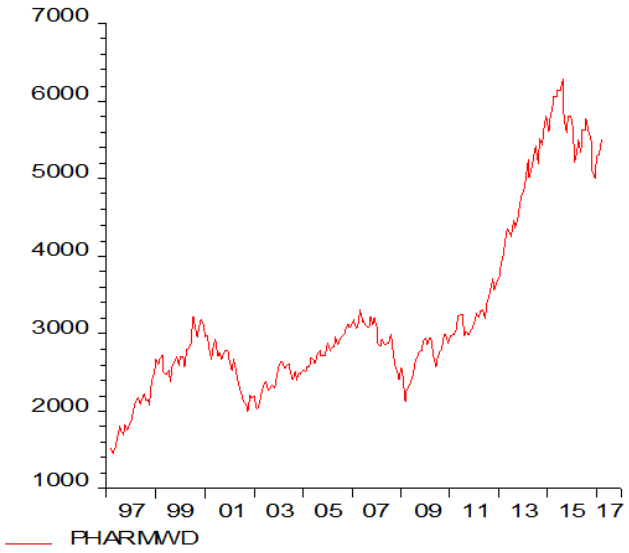

Figure 3. Price index of worlds Pharmaceutical and biotechnology companies from the last 20 years (Datastream)

As we can see from figure 3, the development of biotechnology industry has been rapid as it has approximately doubled in size in the last decade. The whole market cap of the pharmaceutical and biotechnology companies at the moment is 3200 billion euros. The price index growth has been fastest since the financial crisis in 2007 but has dwindled in the past few years. Marketline (2016) study suggests that "The biotechnology companies have been boosted by the expected medical advances and speculations on the potential benefits provided by genetically modified crops."

Most notable characteristic of biotechnology industry is its strong intellectual property (IP) dependence. Intellectual properties are a crucial component for any firm's success and raise barriers for entering the industry for new companies. Most of the young biotechnology start-ups are spin-off companies based on discoveries in academic research. This kind of companies have long periods with minimal profit and with high R&D costs. Therefore, acquisitions are common in the industry as large and stable companies acquire smaller companies with new innovative research projects. Another barrier for entry is the government regulations which in most countries are extremely strict. Clinical trials are lengthy and costly and are a requirement for a biotech firm to get their product to the market. They also pose a significant risk for business because only a minority portion of the products which enter the trials are finally approved for sale. (Marketline 2016)

1.3 Biotechnology in Finland

When the Finnish biotechnology industry grew in the later half of 1980, it had a lot of hype around it and high hopes for a success story. The Academy of Finland institute (2002, 11) stated that "Finland had a very real chance to become one of the most successful small countries in biotechnology". Several research centers were constructed around biotechnology research and public funding was increasingly guided towards biotech industry. The industry development was promising but after the ICT bubble in the beginning of 2000 the public funding dried up in expectation that there could be a bubble in the biotech industry as well. This had also an impact in private investors behavior which resulted in that the growth declined for couple years. Even despite the hard-ships in funding the sentiment towards biotech remained positive trough the turbulent years. (Kotiranta, Kulvik, Maijanen, Tahvanainen, Trieste, Turchetti & Tähtinen 2015) Nowadays Finland has an extensive and internationally highly appraised network of companies which derive their success from biotechnology research institutes and their studies. These companies operate in several different industries and sub-industries as more and more traditional companies use biotechnology to streamline their production. There is also a thriving field of solely biotech dedicated companies in Finland. (Tekes 2006)

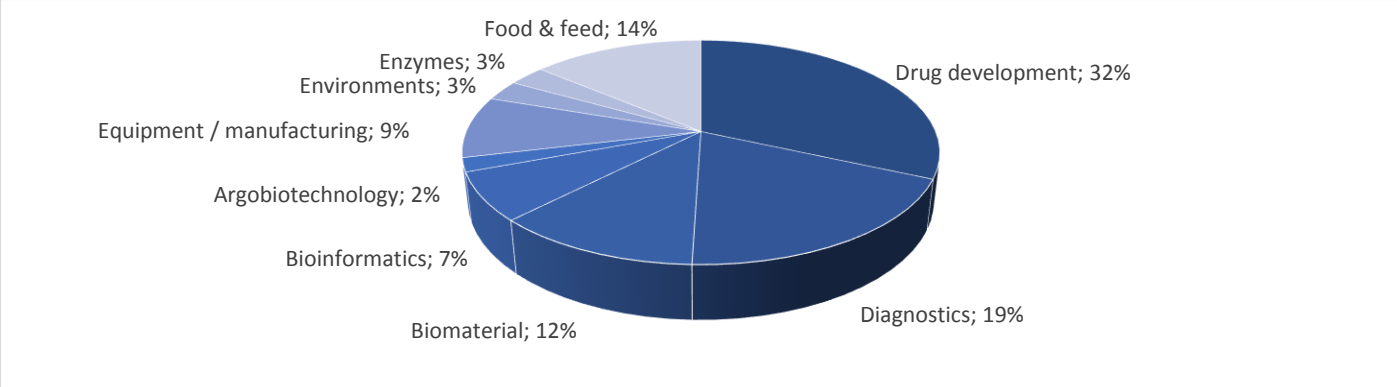

Figure 4. Companies in different biotechnology sectors in Finland (Nikulainen, Tahvanainen & Kulvik 2012)

The portions of companies in different sectors in Finnish biotechnology industry are displayed in figure 4. The statistic is not in market share or value but in the number of firms. Compared to the rest of the world's sector distribution it can be observed that the drug and pharmaceutical sector in Finland is smaller in proportional size.

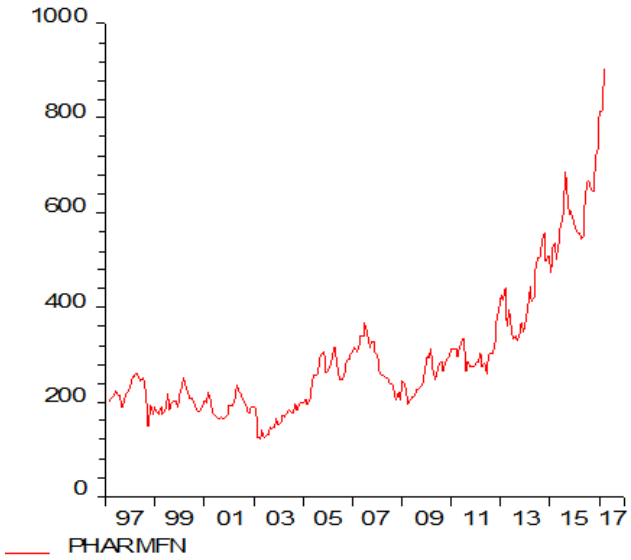

Figure 5. Price index of Finnish Pharmaceutical and biotechnology companies from the last 20 years (Datastream)

The price index of Finnish biotechnology and pharmaceutical companies has followed the equivalent index of the world fairly closely, but instead of dwindling down in the past years it has skyrocketed instead. Before 2011 the development was relatively stale as the index did not majorly

grow in the past decade, but now, even the growth of the past 12 months has been over 60%. Currently the market cap of Finnish biotechnology and pharmaceutical companies is nearly 7 billion euros. Compared to the whole market cap of the world Finland's share is only couple of per mills.

The Finnish biotechnology and life sciences related research is internationally compared very high quality when it is measured by the number of publications and the number of citations as Finland is the sixth in publications per inhabitants and the first in citations per research paper. (Piispanen 2011) This combined with public support and funding gives an excellent basis for success in the international competition. Kotiranta et. al. (2015) describes Finland as the "banana state for experts in Europe" as the supply of biotechnology professionals is almost excessive. Considering these facts, it is not a surprise that the price index of Finnish biotech companies has surged in the near past years.

1.4 Approval and developing process of new drugs

In the thesis' empirical part a new drug company is valuated with the use of the valuation methods reviewed in the thesis. To understand what the valuation is based on, it is important to have knowledge of the development process and especially the approval process of drugs, pharmaceuticals and other biotechnology products. As the case usually is, private or even public companies R&D costs or product approval rates are not publicly available information. For the ones valuating companies this means a need for estimation. Usually the costs and probabilities are derived from industrial averages (Keegan 2008, 39).

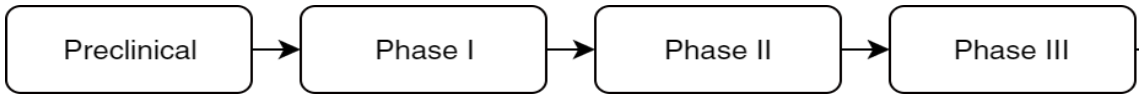

Figure 6. The drug developing and FDA approval process for new drugs

The usual standard of the drug approval process is the USA's Food and Drug Administration's (FDA) new drug application (NDA) process. When developing a new drug, the approval process is split into multiple phases from 1 to 3 (Jägle 1999, 280). Sometimes the preclinical phase of the drug development and the regulatory phase is also included in the approval process.

Author	Phase I	Phase II	Phase III
Kellog & Charnes (2000)	14 %	20 %	30 %
Dimasi & Grabowski (2007)	22 %	22 %	31 %
Abrantes-Metz, Adams & Metz (2004)	49 %	10 %	5 %
FDAreview (2017)	30 %	14 %	9 %
Keegan (2008)	15 %	25 %	60 %
Average	**26 %**	**18 %**	**27 %**

Table 1. The approval rates for each phase of the process

Author	Phase I	Phase II	Phase III
Kellog & Charnes (2000)	1	2,28	6,46
Jägle (1999)	1	2,66	3,16
Dimasi, Grabowski & Hansen (2017)	1	2,59	11,56
Average	**1**	**2,51**	**7,06**

Table 2. The growth-rate of expenses

The most important information about the FDA process for valuation purposes are the probabilities for passing the different phases. In table 1 the different passing rates are displayed. As it can be seen there is some dispersion in the results but for the most part the estimates are consistent with each other. The cost-growth is displayed in the table 2, where phase I is the reference point for the other two phases. According to Kellog and Charnes (2000) the time it takes to pass the phases is one, two and three years respectively. In the case study the averages introduced in the tables will be used as the estimated probabilities and growth rates of the expenses to compensate the lack of accurate information.

2. Valuation in general

"Valuation is as much an art as a science and is composed of reaching a judgement regarding a company's growth prospects and related financial projections. As such it is a blend of subjective and objective assessments of all aspects of the company, including the management team" (Keegan 2008, 11). Modern valuation methods' objective is to determine the company's value from its economic status. The company is assessed on the basis of its status at the moment but also especially by its future expectations. The value determined by these methods can majorly differ from the company's value in its financial statement. (Kallunki & Niemelä 2007, 13) Boer (1999) mentions that "The most common valuation approaches determine the values of the operating

businesses based on their earnings or cash flow, subtract the liabilities, and add back the value of any nonoperating assets."

The valuation methods can be categorized into three groups: asset-based, income-based and relative-based methods. In the relative valuation method, a company is evaluated by comparing it to its similar peers. For example, one can compare a firm's value-to-asset ratio over an equivalent ratio of another similar listed company and then compare the companies' values. (Guo, Lev & Zhou 2005) Income approach calculates the business' value by its present value of expected future cash flows, and in the asset approach company's value is calculated by the fair value of the company's assets minus the fair market value of its liabilities. (Bratic, Blok & Gostola 2014)

In this thesis the emphasis is placed on the income approach. That is because biotech firms usually do not have substantial assets and are often different from each other. This rules out some of the usefulness of asset and relative based valuation methods. These methods are more commonly used for companies in their mature state or in more stable industry. As mentioned later in the literature review, the aforementioned methods were not used at all and the most preferred method in biotechnology company valuation was the real option method which tries to predict future cash flows. In this section of the paper the theory of different valuation methods is researched and explained. The focus is mostly on real options methods but also discounted cash flow model and other methods will be discussed for comparison.

2.1 Why valuation is important

The reasons why one would want to estimate a value for a company are numerous: mergers, sale transactions, company bankruptcy and liquidation, taking over or comparing companies and building an investment portfolio are just some of the reasons Dzyuma (2012) lists. When merging, it is vital for the seller and the buyer to get a numeric value for the company for the transaction to happen. When companies go bankrupt and their assets need to be liquidated, realistic value is also needed. In addition, everyone who invests in stocks also has to have some kind of idea what is the value of a company and how it creates value for the stockholders to make intelligent and well-grounded decisions.

Kuttner (1989) also emphasizes valuation's importance in mergers and acquisitions as does Kissin and Zulli (1988), who also mention its importance in obtaining financing, determining taxes, buy-sell agreements, employee stock ownership plans, charitable contributions and property settlements. Fernandez' (2007, 1-3) list of purposes for valuation includes company buying and selling operations, valuations of listed companies to obtain share price, public offerings, inheritances and wills, compensation schemes, identification of value drivers and strategic planning.

According to Kallunki and Niemelä (2007, 9) valuation has become one of the most essential issues in today's free market economy. Companies' values have to be estimated by many different market participants such as professionals and private investors, financiers, merger and acquisition consultants, business owners and business managers. Kallunki and Niemelä also highlight the importance of valuation for the whole economy.

Company valuation is especially important in the biotech industry where thousands of small firms operate and whose identities change as companies merge and are acquired. In the biotech industry mergers and acquisitions are used as an exit strategy for smaller firms who often have financial difficulties or have insufficient distribution or manufacturing channels for the products they have developed or are developing. These can then be attained by merging into a larger company. (Bratic, Blok & Gostola 2014)

2.2 Discounted cash flow model

The discounted cash flow model is an essential tool for valuation of any asset when a part of its returns are attained in the future. When valuating financial instruments like loans or obligations with stationary returns the valuation is quite straightforward. On the other hand, valuation of R&D projects and R&D dependent companies is considerably more complex and challenging procedure. In fast growth situations, most of the economic value is most likely obtained from the terminal value, not from short-term cash flows. (Boer 1999, 96-97)

The concept of the discounted cash flow method is to estimate future cash flows and then discount them to present value with a discount rate (WACC). The most common cash flow model is the free

cash flow (FCF) model. (Kallunki & Niemelä 2007, 110) Free cash flows are the cash available for distribution to investors after all planned capital investments and taxes. It is suggested that the future cash flows should be estimated by constructing a financial model of the company made up of complete set of financial statements: income statements, balance sheets and cash-flow statements to assure that the assumptions about the individual line items of the forecast are consistent each other. (Arzac 2005, 9) Free cash flow calculation is shown below in table 3.

	Earnings before interest and taxes
+	Depreciation
-	Taxes
=	Operating cash flow
-	Net capital spending
-	Change in net working capital
=	Free cash flow

Table 3. How to calculate free cash flow (Ross, Westerfield & Jordan 2008, 33-35)

After the free cash flows have been calculated and estimated they are discounted and summed into a value representing the value of a company or a project. The discount rate used is usually the weighted average cost of capital (WACC) which is calculated for each company or project individually. The formula for DCF valuation is showed below.

$$Value = \sum_{n=1}^{\infty} \frac{FCF_n}{(1+i)^n}$$

Where CF = Free cash flow, i = Discount rate and n = Time period.

2.2.1 Calculating WACC

Possibly the most important part of the discounted cash flow model in addition to the free cash flows is the discount rate. Weighted average cost of capital (WACC) which is used as the discount rate is calculated from the cost of the capital, weighted on the ratio of equity and debt the company has. The tax benefits of the debt are also taken into account. The formula for WACC is the following:

$$WACC = \left(\frac{E}{V}\right) \times R_E + \left(\frac{D}{V}\right) \times R_D \times (1 - T_C)$$

Where E = Equity, D = Debt, V = D + E, R_E = Cost of equity, R_D = Cost of debt, T_C = Corporate tax rate.

As there is no way to directly asses the cost of equity a company has. Ross, Westerfield and Jordan (2008, 481-485) give two different approaches to determine it. The first one is dividend growth approach which calculates the rate from the value of the company's share, dividend per period and the growth rate of dividend:

$$R_E = \frac{D_1}{P_0 + g}$$

Where R_E = Cost of equity, D_1 = Dividend, P_0 = Price per stock, g = Growth rate of dividend.

This is an easy way to estimate the equity cost but cannot be applied to companies that do not pay dividends. Also, the dividend growth rate is in many times difficult to estimate and not all valuated companies are listed so the real share value is unknown. Security market line (SML) approach is based on the modern portfolio theory. It uses the risk-free rate, market risk premium and beta coefficient to estimate the cost of equity:

$$R_E = R_f + \beta_E \times (R_M - R_f)$$

Where R_E = Cost of equity, R_f = Risk-free rate, β_E = Estimated beta, R_M = Market risk premium.

The drawbacks of the approach are that it requires two things (market risk premium and beta) to be estimated. If the estimates are poor the outcome will also be inaccurate. Both models rely on the past too which is not necessarily a good guide for the future. The cost of debt for WACC can be estimated from information in the financial statement or from the SML approach.

2.2.2 Decision trees

Decision trees are a tool for modelling and visualizing situations in which there are several subsequent decisions or options with uncertain and different probabilities (Keegan 2008, 119). They are a way to use the DCF model in situations in which there is uncertainty with the payoffs.

For example, for a drug company a decision tree looks like the one in figure 7 where a drug has to pass subsequent clinical trials before it is approved for commercial use in the markets. At the beginning the discovered potential drug candidate is evaluated if it is suitable for the phase 1 trials. The drug can fail or pass the evaluation and depending on it the drug moves onto the phase 1 trials or fails, in which case the project is completely abandoned or potentially licensed or put into hibernation.

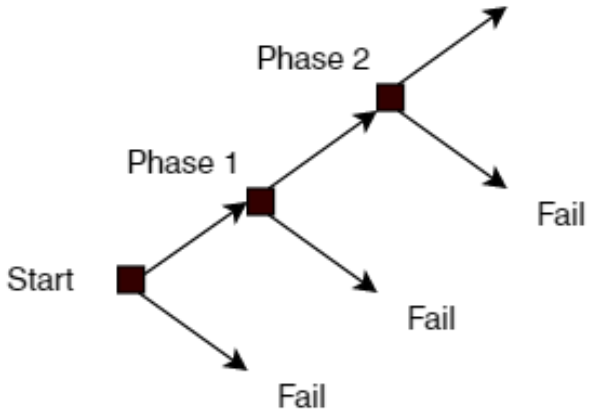

Figure 7. An example of a pharmaceutical company's decision tree

A decision tree has a point of start from where it deviates into for example two paths. The probabilities of different paths are estimated as are the costs, profits and the time it takes to pass a phase. In drug development industry, we can estimate the possibilities of passing a phase from industrial averages. The payoffs of drugs can be estimated with the size of the market the drug will be in and the with other characteristics of the drug, for example if it is a curing one or a treatment for symptoms. With this information, we can estimate the value of a project.

The value of a project is calculated with a decision tree by estimating the negative and positive cash flows associated with the project, adjusting them by their probabilities and then discounting them. The NPV derived by this method is the value of the project, and if a company has many projects, their net sum is the value of the company. Compared to the real option analysis, decision trees do not take different options such as option to abandon into account which means the real value is larger than the method shows. (Kodukula & Papudesu 2006, 26-33)

2.3 Financial options

To understand real options and the theory behind them it is vital to understand the mechanics associated with financial options. Both real and financial options share many characteristics but there is also some key-differences between them. Option is a contract made by two parties that gives the contract holder the right but not the obligation to buy or sell an underlying asset for a specified price before the expiration date of the option. The price the asset is sold or bought is called strike price or exercise price. Call option gives its holder the right to purchase the asset and put option gives its holder the right to sell the asset. The purchaser of the option has to pay a price for the writer of the contract called the premium which represents the compensation which the holder of the option has to pay for the right to exercise the option. (Bodie, Kane & Marcus 2005, 698)

As the holder has the choice to decide if he or she wants to exercise the option or not it is essential to know in which situations exercising is viable. For example, if the holder has a call option for company ABC stock for a price of 20€ the holder has the right to buy the stock for 20€ at any time up to and on the expiration date. If the company ABC's stock price exceeds the 20€ mark the option holder can profit the amount of the spread between the stock price and the exercising price. If the stock price rises to 25 euros, the option has made a profit of 5 euros. On the other hand, in the case of a put option the contract holder benefits when the underlying asset's price decreases since the owner of the contract has the right to sell the asset for a price higher than the current price.

Option's value can be divided into its intrinsic value and time value. The value of a call option at expiration or its intrinsic value before the expiration = Stock price - Exercise price. For put options the value at expiration or its intrinsic value before the expiration is Exercise price – Stock price. The final profit is calculated as the difference of the Final value – Option contract price. If the option is unprofitable before and at the date of expiration, it will not be exercised and will expire as worthless. In some cases, the option can only be exercised on the expiration date. These options are known as European options. If the option can be exercised at any point before and on the exercising date it is known as American option. (Brealey & Myers 1996, 558-561)

2.3.1 Option pricing

The way to calculate a price of an option at its expiration or its intrinsic value before the expiration was displayed in the end of the previous chapter. Now, if we consider an option which is at the moment out of the money (for example a call option's exercise price is higher than the underlying asset's price) but there is still time before its expiration there can be and usually is a value larger than zero for the option. This is because of the time premium or so called time value the option has. The value comes from the chance the option has to make it on the money in the time before expiration. Therefore, the value of the option is not in most cases equal to its intrinsic value, especially when there is a lot of time left to its date of expiration. (Bodie, Kane & Marcus 2005, 746)

The longer time it is until the option expires, the more time value it has and so forth the higher the whole value of the option is. This is because the more time there is until the expiration, the higher the probability for the underlying asset's price is to develop favorably. This means that to estimate an option's value correctly the time value of the option has to be taken into account. (Fabozzi, Modigliani & Jones 2010, 577) This can be done with different option valuation models. The models reviewed here are the Black and Scholes model and binomial pricing model as they can be useful also in real option valuation.

2.3.2 Black and Scholes model

There are several models developed for the calculation of theoretical prices of options. The most popular one is the Black and Scholes formula developed in 1973 for valuing European call options. (Fabozzi, Modigliani & Jones 2010, 579) The general concept of the formula is that a risk-free portfolio consisting stocks and options has to be in balance with the risk-free rate. Black and Scholes state: "If options are correctly priced in the market, it should not be possible to make sure profits by creating portfolios of long and short positions in options and their underlying stocks." (Black & Scholes 1973) And also in other words, as Brealey and Myers (1996, 574) describe, the trick is to set up an option equivalent with the use of common stock investments, borrowing and lending.

The model makes three assumptions for the assets for the formula to work: 1. The underlying stock does not pay dividends to its owner before the option's date of expiration, 2. The interest rate and the standard deviation of the stock are constant and 3. The stock prices are continuous. The assumptions for markets are that there is no possibility for arbitrage, there is no transaction fees, it is possible to borrow or lend money at the risk-free rate and it is possible to buy or sell any amount of the stock. Although the mentioned conditions cannot be completely implemented in the real world, the model still performs well. (Bodie, Kane & Marcus 2005, 752-761) The Black and Scholes model is the following:

$$\text{Value of call option} = [\text{Delta} \times \text{Share price}] - [\text{Bank loan}]$$

$$[N(d_1) \times P] - N(d_2) \times PV(EX)$$

Where $d_1 = \frac{\log[P/PV(EX)}{\sigma\sqrt{t}} + \frac{\sigma\sqrt{t}}{2}$, $d_2 = d_1 - \sigma\sqrt{t}$, N(d) = cumulative normal probability density function, EX = exercise price of option, t = number of periods to exercise date, P = price of the stock and σ = standard deviation per period of rate of return on stock.

The effects of variables' changes to the value of a call or put option are presented below in table 4. As it can be seen the effects are in correlation with the Black and Scholes formula.

Variable increases	Value of a Call option	Value of a Put option
Price of underlying asset	Increases	Decreases
Strike price	Decreases	Increases
Volatility of the underlying asset	Increases	Increases
Time to expiration	Increases	Increases
Interest rate	Increases	Decreases
Anticipated cash payments (Ex. Dividends)	Decreases	Increases

Table 4. The determinants of call and put option values (Fabozzi, Modigliani & Jones 2010, 577)

2.3.3 Binomial option pricing model

In addition to the Black and Scholes' model, there is also another widely used method for valuing options called the binomial option pricing model which was originally developed by Cox, Ross and Rubinstein in 1979. The idea behind the model is to use the basis of arbitrage argument to calculate the fair value of an option. Arbitrage argument determines that the price of the option is at most the payoff you can acquire by purchasing the underlying asset of the option and borrowing funds.

In other words, it is not possible to achieve oversized profits from arbitrage. (Fabozzi, Modigliani & Jones 2010, 579-580)

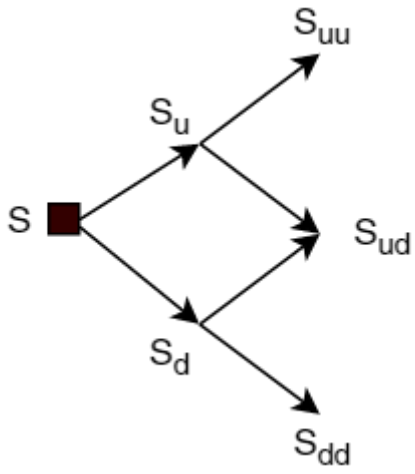

Figure 8. An example of a two-step binomial option pricing model

The aim of the model is to build a replicating portfolio using combination of risk-free borrowing and/or lending and the underlying asset of the option to replicate the same cash flows as the option which is being valued. As there is no possibility for arbitrage, the option must have the equal value as the replicated portfolio. (Damodaran 2005) The model is based on an assumption that at each stage of the event tree the asset can only move in to one of two possible destinations. In figure 8, S means the price of the asset. The price can only move to S_u with a probability of p or to S_d with a probability of 1-p and further from S_u to S_{uu} or S_{ud}, or from S_d to S_{ud} or S_{dd}. The formula to calculate the hedge ratio H of the options is the following:

$$H = \frac{S_u - S_d}{uS - \mathrm{dS}}$$

Where S_u or S_d is the call option's value whether the price goes up or down, and where uS and dS are the prices of the asset in similar stages. With the hedge ratio, it is possible to calculate the price of the option if other values such as the risk-free rate are known. For example, if the hedge ratio H = 0.5, dS = \$50, S = \$100, a portfolio made up of one share would be worth 0.5 x \$50 = \$25 in the end of the period with certainty. If the risk-free rate is 8% the present value of dS is \$23.15. When the value of the hedged position is set to the present value of the certain end-of-

period value (0.5 x S – C = $23.15) we find out that the option value C is $26.85 ($50 – $23.15). (Bodie, Kane & Marcus 2005, 752-755)

2.4 Real Options

Leppard and Morawitz (2001) describe real option "a tactical or strategic decision that can be made at some future date, and will be made in response to changes in prevailing market conditions. A tactical option is an embedded option, which often characterizes the operational flexibility of a business." In other words, real option is, like financial option, a right but not an obligation to exercise an option in the future. Valuation with real options combines the usage of decision trees with the theory and insight developed for financial options valuation. Real options are an answer for a situation in which the company has prominent growth opportunities and shareholder value creation possibilities like biotechnology companies have. Whereas financial options' underlying assets are stocks or other financial instruments, real options' underlying variable is free cash flow. Also, when compared to financial options, real options usually have a much longer time span. (Keegan 2008, 126-127)

Real options can be used as a tool to for stock analysts to valuate companies with no current revenue or for companies' financial managers to valuate projects for information in capital-budgeting purposes. Companies' top management can use them for strategical purposes or to decide for example if a price of an acquisition is too high, low or suitable. (Kellog & Charnes 2000, 1) Real option methods give the possibility to include flexibility, high risks of profit realization, waiting for new information and different strategical choices into the value of a project or a company. Real options are especially useful in valuating intangible assets which makes them a valuable tool for biotechnology valuation. (Dzyuma 2012)

Ljumovic, Cvijanovic and Lazic (2012) argue that biotechnology companies should be valued as the sum of their existing values, opportunities in the market and future prospects. The problem is how to valuate existing opportunities as they consist only of projects that are not real products yet but have chances to generate profits in the future. For this purpose real options offer a great tool as the future prospects can be taken into account.

2.4.1 Categories of real options

Leppard and Moravitz (2001) categorize real options into four different categories: Growth options, Contraction options, Flexibility options and Learning options. Growth options are possibilities to expand or scale-up an ongoing operation. Call options are growth options that can be used for future investments, such as R&D. Contraction options include for example scaling down or mothballing a business, or completely abandoning it. Abandonment options are effectively put options with an exercising price equal to the salvage value of the asset or operation. Flexibility options are options to "switch between different states of operation (Call, put, spread, basket of compound options). For example, a possibility to run a station plant during the day and shut it at night is an example of a spread option." Learning options are, as the name suggests, options to learn from experience.

Keegan (2008, 129) provides six categories for real options: Option to defer, to expand, to contract, to abandon, to switch and to grow. The fundamental idea which characterizes these possibilities is that flexibility has value. The categories intersect with Leppard's and Moravitz' ones but are categorized more specifically. Option to defer is a situation where deferring an investment is the best course of action while for example waiting until further data is available. In biotechnology, this option can be valuable since the industry has high uncertainties and long investment cycles. Option to expand can provide a strategic advantage for a biotechnology company which can for example direct more of its capital to expand an on-going project to collect a larger payout. Option to contract means the company has the possibility of for example licensing one of their drug assets. Abandonment option is considered especially valuable in biotech by Keegan since after every clinical trial, company should have the option to abandon a drug developing project. Switching option can refer to the cost of restarting activities. Lastly, the growth option is deemed also important especially in biotech industry because the products can have multiple potential applications.

2.4.2 Real option pricing

Valuation of real options has some differences and similarities with pricing of financial options. Damodaran (2005, 21) argues that the Black and Scholes model is not the best solution for real option valuation, because when financial options' underlying assets are always traded, real options underlying assets are not. This means that as the model is based on a premise that building a replicating portfolio is possible, applicating the model into real options is not optimal or sometimes even possible. Damodaran also argues that with real options there are issues with the assumption that the underlying asset's price is continuous and with the variance needed for the Black and Scholes model. In addition, Ljumovic et. al (2012) state that the Black and Scholes model is only applicable for the valuation of European style options and therefore cannot always take the flexibility of real options into account, as real options can more than usually be exercised before the expiration date. Trigeorgis (2002, 15) reminds that the Black and Scholes model does not take into account the embedded options a project may have. In example exercising an option in a project may affect another option the project has. This is why determining the values of option independently and them summing the values together can be inaccurate.

Simkins and Kemper (569-570) argue that the use of binomial trees is the simplest approach and most in line with the needs of managers. The method can also valuate projects which have embedded options within them. They also argue that with the Black and Scholes model the biggest difficulty is to quantifying the volatility. According to Keegan (2008, 129) the most useful method to valuate real options is the use of binomial trees. This is mostly because of their ease of implementation. Binomial lattices can also be solved with two techniques: risk-neutral probabilities or market replicating portfolios. From these two the risk-neutral probability method is easier to apply. In their article, Kellog and Charnes (2000) also used the decision tree and binomial lattice as the pricing method. Considering the literature, the binomial option pricing approach will be used in this thesis instead of the Black-Scholes model.

2.4.3 Binomial trees

Binomial lattices are the most commonly used lattices in real option valuation. The binomial lattice is consisted of several steps where two possible paths are available at every step. The logic is the same as in the binomial option pricing model displayed in chapter 2.3.3. The last values in the end of the binomial tree are the range of possible assets values in the end of the option's life. It is important to note that at the end, the highest and lowest values in the tree have the lowest probabilities to appear and the values in the middle of the tree have the highest probabilities to appear. (Kodukula & Papudesu 2006, 70-71) In addition to binomial lattices, there are also trinomial, quadranomial, hexanomial and so on, lattices that are different in that they have more possible paths in every step (Brous, 2011).

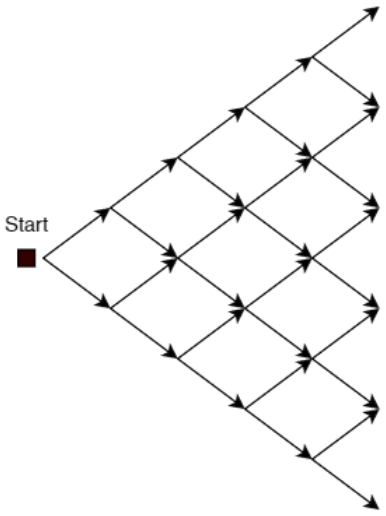

Figure 9. Binominal lattice

The binomial lattices can be solved by using market-replicating portfolios or risk-neutral probabilities. Judging from the literature, the latter method is more common and suitable in biotechnology valuation and is what this thesis will also use. The risk-neutral probabilities approach adjusts the cash flows with risk-neutral probabilities and discounts them at the risk-free rate. (Kodukula & Papudesu 2006, 72-74)

The key values that are needed for the binomial tree valuation are 1. The current value of assets, S_0 2. Standard deviation of the asset, σ 3. Risk-free rate, R_f 4. Amount and timing of exercise price

and 5. The probability of proceeding to next stage of development. The values u (up movement) and d (down movement) represent the volatility of the underlying assets. They can be calculated with the following formula:

$$u = e^{\sigma\sqrt{\Delta t}}$$

Where σ = is the volatility and Δt is the time period for each step of the model. After we have the value for u, the value of d can be calculated as the inverse of u (d = 1/u). (Keegan 2008, 130-131) The risk-neutral probability of an up-step is then calculated with the following formula:

$$p = \frac{e^{r\Delta t} - d}{u - d}$$

Where r = risk-free rate. The probability for a down-step is 1 – p. The value of the option at one step can be calculated with the following formula:

$$\frac{Value\ if\ up \times p + Value\ if\ down \times (1 - p)}{Risk - free\ discount\ rate}$$

The way the option's final value is calculated is that first the binomial lattice for the underlying asset is constructed with multiplying the expected NPV of the asset with the up-step (u) and down-step (d) values working from left to right. After we have the end values for each path, we work backwards with the previous formula from right to left until we have the value of the option. If there is decision to make, for example after clinical trials, if the management wants to invest the developing costs needed for the next phase, the costs are subtracted from the option's value. The Value is also adjusted with the technical probability of success in moving onto the next phase. (Keegan, 2008, 137-139) (Shockley, Curtis, Jafari & Tibbs 2002, 50-53)

The challenges of the binomial model are similar as in other models. The biggest difficulty is how to estimate the NPV of the positive and negative cashflows, especially the final payoff. Keegan (2008, 136) also describes the estimation of the underlying asset's volatility a key-hurdle in real option valuation. Though, as Shockley et al. (2002, 54) show, the volatility of the underlying asset has much more smaller effect on the value of the option than the value of the cashflows. In their article, doubling the volatility of the assets produced 28% change from the initial value. On the

other hand, higher market penetration and higher market share resulted in a much larger difference in the option's value. In any case, the results of any valuation model have to always be taken with a grain of salt and should be judged in their context. There is no possibility to accurately predict uncertain cashflows which is the core reason for the inaccuracy. This is why calculations such as sensitivity-analysis are commonly used when making decisions and valuating companies.

2.5 Literature review

The valuation of biotech firms has been researched by many scholars. The studies can roughly be divided to ones that research listed biotech firms and the ones that have their focus on early stage firms. The main difference between these two is that early stage firms have much more uncertainty in their payoff and since are more difficult to value. This section will review and summarize essential articles and literature considering biotech companies and their valuation.

Ljumovic et al. (2012) argue in their article about real option based valuation of biotechnology companies that biotech companies do not have a standard format and therefore simple techniques such as financial statement analysis or discounted cash flow model cannot be used. Intangible assets' effect on the value of the company must be taken into account especially in biotech because of their large impact on the future sales and value of the company. The real options model is much more flexible and useful in valuating biotech companies than the traditional methods because it takes possibilities to for example abandon, delay or expand an investment project into account.

Article written by Kellog and Charnes (2000) notes that many biotechnology companies have significant valuation even though they have no revenue and their products are still in early stages of development. In the article they used real option valuation (decision-tree and binomial-lattice methods) to value a biotechnology company and then compared the calculated values to the company's stock prices. The results showed that the stock prices were higher than the calculated values, which might have been partly because of political pressure towards accepting a drug the company was developing. The conclusion was that real option based valuation techniques are a great tool to calculate a value for a biotechnology company, especially when it is at its early stages.

When the drug development projects proceed into further phases than phase I, the real option method becomes more inaccurate.

In an article about valuation of early-stage biotech companies, Bratic, Blok & Gostola (2014) give an overview of the inherent risks in the pharmaceutical industry. They also list three different approaches to valuation: Asset approach which focuses on company's assets and liabilities, Income approach that includes calculating the present value of expected future cash flows and Market approach which uses publicly traded companies as a comparison. The article identifies ten risks in the pharmaceutical industry: underestimating cost and risk in the drug development process, risk of overestimating the patient population, reimbursement risk, risk of litigation, human resources risk, risk of outsourcing, risk of counterfeit drugs, risk of parallel trade, supply chain and distribution risks and the risk of biosimilars. The risks listed should all be taken into account when valuating a biotechnology firm.

Joos and Zhdanov (2008) research price-earnings relation in biotech industry by constructing a real options based valuation model in their article about earnings and equity valuation in the biotech industry. They believe that DCF method is not optimal for the valuation of biotech companies because most of the value comes from the company's growth options. They also add that real options have the advantage to abandon or expand a project and are more flexible because of that. In the paper they showed that earnings and equity value have a V-shaped relation and that the negative relation between earnings and equity value is "primarily caused be the fact that R&D investments are positively correlated with market equity value and negatively correlated with earnings."

In an article named Pitfalls of valuation in biotech, Villiger and Bogdan (2005) go through common flaws in biotech valuation. They argue that the DCF model is insufficient in valuating biotech firms because it takes the future cash flows for granted and expects they will not change in any circumstances. It does not take the abandonment of a project into account either. The article studies real options and showcases a binomial based model. The setback with real options compared to DCF is that they are more demanding and complex. On the other hand, they have many advantages such as the option to abandon or to expand a project, they attribute value to

good management and they have the possibility to construct nested options: options of options. The conclusion of the article is that real options should be used to valuate biotech firms rather than the DCF model.

Jägle's (1999) article about shareholder value, real options and innovation in technology-intensive companies compares the advantages of option tree approach compared to the traditional DCF tree approach. In their binomial option tree approach for new product development (NPD) each phase can be considered as a real call option on the next phase of the product's development process. The cash flows are weighted using risk-neutral probabilities calculated by using option pricing. The DCF tree they describe is a binomial tree that weights cash flows by actual success probabilities and discounts the flows to the present using a risk adjusted rate discount rate. The case company valuation in the article was completed by valuating each project in the company's R&D pipeline individually with option tree approach. Conclusion of the paper was that the real option model should be used to valuate technology-intensive growth companies such as biotechnology firms. The advantage compared to DCF model is that the real option model is less dependent on Free cash flows which are difficult to forecast for a fast-growing company.

In his article about valuation of internal growth options, Ottoo (1998) constructs a model of the interaction between current real options and future growth opportunities. He considers R&D investments as real options on the value of a completed manufacturing project as the underlying asset. The results show that the real growth option model can be conveniently applied to value intangible assets and R&D investment projects. The model can be a useful tool for valuating a biotech company if all the necessary parameters can be estimated.

2.5.1 Discussion

The following table summarizes the articles referenced in the literature review. At least deduced from the articles summarized, there seems to be a consensus amongst the research field: the real option models are the most suitable valuation tool for biotechnology companies. Discounted cash flow model suffers from its stiffness and its dependency in predicting the future cash flows. It does not have the options to expand, switch or abandon a project either. Also, asset-based or relative-

based valuation methods were not mentioned as a viable tool. That leaves us with the option of only focusing on income-based models such as the real option model and the DCF model.

Author	Name of the article	Methods	Summary
Ljumovic, Cvijanovic & Lazic (2012)	Valuation of biotechnology companies: Real options approach under uncertainty	Real options,	The real options model is much more flexible and useful in valuating biotech companies than the traditional methods
Kellog & Charnes (2000)	Real-Options Valuation for a Biotechnology Company	Real options (binominal lattice, decision tree)	Real option based valuation techniques are a great tool to calculate a value for a biotechnology company, especially when it is at its early stages.
Bratic, Blok & Gostola (2014)	Valuation of early-stage companies in the biotechnology industry	NPV	Lists different risk that should be taken into account when valuating biotech companies
Joos & Zhdanov (2008)	Earnings and Equity Valuation in the Biotech Industry	DCF, Real options	DCF method is not optimal for the valuation of biotech companies, real options method should be used
Villiger & Bogdan (2005)	Pitfalls of valuation in biotech	DCF, rNPV, Real options	Real options should be used to valuate biotech firms rather than the DCF model
Jägle (1999)	Shareholder value, real options, and innovation in technology-intensive companies	DCF and real options trees	Real option model should be used to valuate technology-intensive growth companies such as biotechnology firms
Ottoo (1998)	Valuation of internal growth opportunities: The case of a biotechnology company	Real options model	Real growth option model can be conveniently applied to value intangible assets and R&D investment projects. The model can be a useful tool for valuating a biotech company if all the necessary parameters can be estimated

After considering the insight the literature review has given, it can be seen that the most important valuation method in this paper is going to be the real option model. Even though the real option based valuation is most suitable for biotech based on the literature, this study will use the discounter cash flow based decision tree model as well to find out how the two models' results vary from each other.

3. Case firm

The company chosen for this case study is Herantis Pharma which is a relatively small new drug development company with a market capitalization of 15,4 million euros. Its focus is in regenerative medicine and in indications of unmet clinical needs. The company has practically no turnover since it does not have any existing final products. Herantis Pharma's business strategy is to develop drugs with promising results in clinical trials. After a drug project has proved its potential it can be licensed to a larger company through commercialization agreements. The larger pharmaceutical companies can then develop the drug further and/or manufacture it. The company itself can also be a subject of an acquisition for a larger company as it is reasonably small and has some valuable research projects. The company is a good subject for this thesis' valuation case since it is a typical small biotechnology firm with research projects that have high uncertainty in their payoffs. The difficulty in valuation of any company is that all the information of for example the R&D costs is not available openly. This means that some of the values have to be estimated which in turn causes some flaws in the final results. (Herantis Pharma 2016a)

Herantis Pharmas objective is to develop new innovative breakthrough drugs for complicated diseases. At the moment there are three significant drugs in the research and development pipeline: CDNF (Cerebral dopamine neurotrophic factor) for Parkinson's disease, CDNF for ALS and Lymfactin. Lymfactin is a treatment for lymphedema which means chronic, progressive swelling of affected tissues which is associated with some breast cancer treatments. The markets for all of these drugs have substantial potential. Herantis Pharma also recently secured a rare disease research grant of 6 million euros for its Parkinson's disease medicine study. (Herantis Pharma 2016a)

The company has been listed in the NASDAQ OMX Helsinki First North stock exchange since June 2014 when the initial public offering price for the stock was about 10 euros. The price has fallen after failed clinical trials of a drug for dry eye treatment. The stock is traded for 4,2 euros at the moment (14.5.2017) while the average price for it in 2016 was 1.25 euros. As Herantis Pharma's financials go, the firm has a debt heavy balance as its equity ratio of 2016 is 15.4%. It has no substantial turnover and all the capital it has acquired through emissions, loans or grants is

forwarded into the R&D projects. This means that the company has not yet made profit in its existence.

3.1 Estimates for the valuation

Before constructing the actual valuation models, we need to estimate the needed variables. These variables include the negative and positive cash flows of the company, information of the drugs that are being developed, the probabilities of the drugs being approved, cost of equity and debt etc. The estimations affect the final results significantly and can have even more effect in the results than the model itself.

The final payoff of the drug developed is maybe the most important piece of information needed in valuation. As the companies do not usually disclose any accurate assumptions of the payoff, investors have to use variety of information to make approximations. Herantis Pharma has three drugs in the pipeline: CDNF for Parkinson's, CDNF for ALS and Lymfactin. The three projects are independent from each other so they do not share risks. (Herantis Pharma 2016a, 16) The company estimates the market potential for CDNF for Parkinson's disease to be worth of over 3 billion dollars. Unlike the drugs sold at the moment, Herantis Pharma's drug candidate does not treat symptoms but aims for curing the disease. For the ALS drug's market potential the firm does not give other information than the yearly new patient number which is 140 000. As of now, the common treatment for ALS is a drug names Rilutek, which usage can be as much as €10 000 per year it is justified to presume that the payoff for Herantis Pharma's drug could be somewhere between 1-1,4 billion, if the development succeeds. For Lymfactin the market potential according to Herantis Pharma (2016b) is 200 million euros with no existing competition.

Herantis Pharma's yearly R&D, salary and other costs have been approximately 3,7 million euros in 2016 and 6,7 million in 2015. The difference is explained by the clinical trial cost for the Eye drop drug. The drug's development has been hibernated after the trials produced unsatisfactory results. Because the company does not specify the costs for single development projects accurately enough, the projects' costs are targeted by dividing all of the company's operating costs according

to the final payoff of the drug developed. For example, if drug A's payoff would be 20% of all of the possible payoffs, its costs would be 20% of all operating costs.

The equity cost for Herantis Pharma are calculated with the security market line approach described in the chapter 2.2.1. The parameters for the calculation are the following: Risk-free rate = 0.35% (Investing 2017), Estimated beta = 1.40, which is the industrial average of drug developing biotechnology firms (Nyu Stern, 2017a) and Market risk premium = 8%. These values give us 11.06% for the cost of equity. The cost of debt is calculated with the information from the company's financial statement where the costs of interest and other financial expenses were approximately €77 300 and the long and short term debt was about €8 million. This gives us 0.96% for the cost of debt. With these parameters, the WACC for Herantis Pharma is 2.547%.

The projects that are valuated are CDFN for Parkinson's disease, CDNF for ALS and Lymfactin. The probabilities for the drugs to enter the markets are estimated with the averages of the industry. For Herantis Pharma's projects the industry's average probabilities might be somewhat high since the drugs it has in development are all for diseases which do not yet have any existing cures. This obviously means that the possible cures are extremely hard to develop. This implies that the values acquired with the calculations have to be considered in this context. Also, there is a sensitivity analysis with different passing rates for the drugs.

3.2 Decision tree model

The discounted cash flow decision tree model starts from estimating the operating costs of the firm. For this case the all operating costs, excluding financial expenses are included in the costs for the drugs developed. This is because the firm's only business is to develop drugs and every resource is directed to development. The future costs are calculated with the growth-rates from the chapter 1.4. This means that for example that the second phase's costs are €3 215 491 * 2,51.

Costs per year		Phase I		Phase II		Phase III
All costs	-	3 215 491 €	-	8 070 882 €	-	22 701 368 €
CDNF for Parkinson's	-	2 206 710 €	-	5 538 841 €	-	15 579 370 €
CDNF for ALS	-	882 684 €	-	2 215 536 €	-	6 231 748 €
Lymfactin	-	126 098 €	-	316 505 €	-	890 250 €

Table 5. Costs per year for each phase and allocated costs per each drug project

For the discount rate, the company's WACC (2,547%) is used at first but in the sensitivity analysis the calculations are completed also with higher rates to demonstrate the cost of debt in the future when the cost of debt will most likely increase. The assumptions made in the model are that the cost-growth during different phases follows the same progress as the industry on average, the phases have the average length of the industry and that the company has the option to abandon the project on the entry spots for each phase.

The calculations also assume that the final payoff is a onetime amount at the start of the launch which can be acquired from licensing or selling the rights of the drug or from another company which is acquiring the firm. Any more advance assumptions would not necessarily be reasonable because there already is a large amount of uncertainty regarding the payoff. The ambiguity of the payoff is taken into account with sensitivity analysis which is completed with a variety of final payoff values.

Year	1	2	3	4	5	6
Phase	Phase I	Phase II	Phase II	Phase III	Phase III	Phase III
Probability of success	0,26		0,18			0,27
Cost per year	-2 206 710 €	-2 769 421 €	-2 769 421 €	-5 193 123 €	-5 193 123 €	-5 193 123 €
Discounted costs	-2 151 901 €	-2 633 559 €	-2 568 148 €	-4 696 094 €	-4 579 456 €	-4 465 714 €

Table 6. Probabilities of moving on to next phase, CDNF for parkinson's disease project's cost per year, discounted costs with the rate of 2,547%

In table 6. the needed parameters with the exception of discount rate and final payoff are displayed. The costs are discounted with the earlier calculated WACC. The costs for the drug are calculated by weighting its payoff and then allocating the costs for it accordingly.

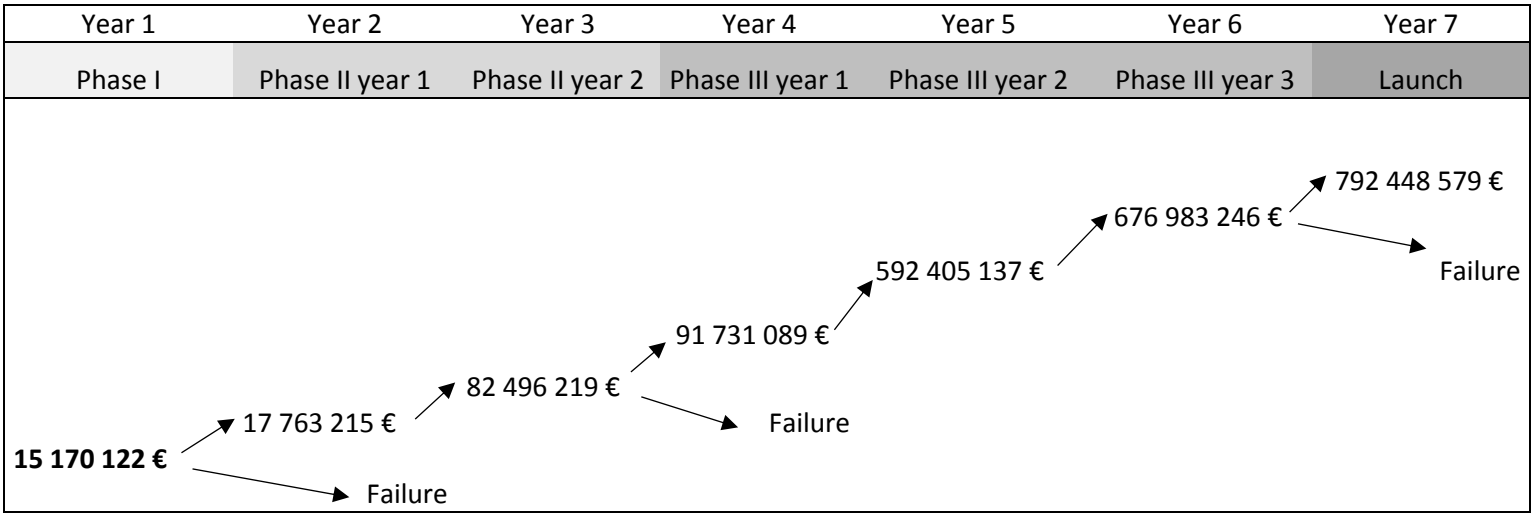

Table 7. The DCF decision tree for CDNF Parkinson's drug

The table 7. showcases the decision tree method in practice for the drug development of CDNF for Parkinson's disease. The expected payoff for this tree is €3,5 billion which gives us €15,2 million valuation for the drug. In the tree, it is assumed that the drug can fail only in the boundaries between the phases. The costs are discounted to year zero as is the expected payoff. The three is constructed from right to left, first multiplying the payoff by its probability and then subtracting the phase costs needed for the development. The same decision three is built for all three drugs. In the sensitivity analysis, the expected payoff is divided into high = 125%, medium = 100% and low = 75%. The discount rates in the analysis are the originally calculated WACC 2,547%, 5% and 10%.

Payoff / Discount rate	2,547 %	5 %	10 %
High (125%)	20 637 446 €	8 037 889 €	- 1 271 370 €
Medium (€3,5 billion)	15 170 122 €	5 217 446 €	- 2 038 065 €
Low (75%)	9 702 798 €	2 397 003 €	- 2 804 760 €

Table 8. Sensitivity analysis for CDNF for Parkinson's drug

Table 8 displays the sensitivity analysis for Parkinson's disease drug. Both, the expected payoff and discount rate have large impacts on the value the project receives. The sensitivity analysis and decision tree tables for the other two drugs are displayed in the appendix part in the end of the thesis.

Payoff / Discount rate	2,547 %	5 %	10 %
High (125%)	30 071 707 €	11 712 352 €	- 1 852 568 €
Medium	22 105 035 €	7 602 564 €	- 2 969 752 €
Low (75%)	14 138 363 €	3 492 776 €	- 4 086 936 €

Table 9. The valuation of Herantis Pharma with decision tree analysis

Finally, in the table 9 the valuations for Herantis Pharma are displayed. The values are the sums of the three drugs projects' respective values. As it can be seen the cost of capital has a large effect on the valuation, as does the expected payoff. When compared to the market valuation at the moment (€17,3 million), the closest value was the with the low payoff and with the same WACC as originally calculated. What is also notable is that all the valuations for the company with 10% WACC are negative. This shows that the projects for Herantis Pharma most likely cannot be sustained if the rate levels or cost of equity increase in the future.

Payoff / Probability	Original	Low (80%)	Lower (60%)
High (125%)	30 071 707 €	11 282 069 €	104 303 €
Medium	22 105 035 €	7 203 133 €	- 1 616 499 €
Low (75%)	14 138 363 €	3 124 197 €	- 3 364 293 €

Table 10. Valuation of Herantis Pharma with passing rate sensitivity analysis

In addition, in table 10 the company value is estimated with different passing rates. As the drugs Herantis Pharma is developing are completely new cures and treatments for illnesses it can be argued that the industry average passing probabilities for the phases are too high. In the analysis, the respective rates are lowered by 20 and 40 percent of the original rates. This obviously results in much lower valuations for the company. The originally calculated WACC was used as the discount rate.

3.3 Real options model

The real option model in this thesis will attempt to estimate a value for Herantis Pharma from its drug developing projects. The model is constructed with the same principles as Kellog & Charnes' (2000), Keegan's (2008, 129-139), Shockley's et. al. (2002) and Brous's (2011) models. This means constructing a binomial lattice and using binomial option pricing model to valuate it, which is described in the chapter 2.4.3.

Because the available information is very limited, the model has to be simplified. The assumptions made in it are partly same as in the decision tree mode. These are that the cost-growth during different phases follows the same progress as the industry on average, the phases have the average length of the industry, the volatility of the underlying assets is the industry average, the costs for one drug is a share equal of the weight of the drugs payoff of all the salary, R&D etc. costs of the company and that the company has the option to abandon the project on any given year before and at the launch. The same assumption regarding the payoff is also made.

U	1,9739	Volatility	0,68
D	0,5066	Risk-free rate	0,035
p	0,3605		
1-p	0,6395		
Risk-free discount factor	1,0356		

Table 11. Parameters calculated for real option model

The parameters are calculated by the instructions given in the chapter 2.4.3. The volatility is assumed to be that same as the industry average which is approximately 68% (Nyu Stern, 2017b). The risk-free rate is the same as in earlier calculations.

Year	1	2	3	4	5	6	7
Phase	Phase I	Phase II year 1	Phase II year 2	Phase III year 1	Phase III year 2	Phase III year 3	Launch
							342 647 580 926 €
						173 591 166 291 €	
					87 944 274 794 €		87 944 274 794 €
				44 554 084 371 €		44 554 084 371 €	
			22 571 866 546 €		22 571 866 546 €		22 571 866 546 €
		11 435 296 372 €		11 435 296 372 €		11 435 296 372 €	
	5 793 318 105 €		5 793 318 105 €		5 793 318 105 €		5 793 318 105 €
2 934 994 737 €		2 934 994 737 €		2 934 994 737 €		2 934 994 737 €	
	1 486 918 886 €		1 486 918 886 €		1 486 918 886 €		1 486 918 886 €
		753 298 719 €		753 298 719 €		753 298 719 €	
			381 634 106 €		381 634 106 €		381 634 106 €
				193 342 411 €		193 342 411 €	
					97 950 596 €		97 950 596 €
						49 623 459 €	
							25 140 099 €

Table 12. Binomial tree of the underlying values of CDNF for Parkinson's disease, payoff 100%, Discount rate = 2,547%

First, the binomial tree for the underlying values for the drug is constructed. The tree begins from discounting the expected value of the drug and then multiplying it with the up-tick or down-tick parameters displayed in the table 10. The binomial tree is displayed in the table 12.

Year	1	2	3	4	5	6	7
Phase	Phase I	Phase II year 1	Phase II year 2	Phase III year 1	Phase III year 2	Phase III year 3	Launch
							92 514 846 850 €
						46 864 421 775 €	
					23 734 746 563 €		23 744 954 194 €
				2 162 619 560 €		12 024 409 657 €	
			1 091 607 526 €		6 084 196 336 €		6 094 403 967 €
		142 424 364 €		553 046 463 €		3 082 336 897 €	
	68 996 884 €		276 170 072 €		1 553 988 257 €		1 564 195 888 €
33 023 825 €		35 014 553 €		139 931 804 €		787 255 455 €	
	14 581 224 €		66 879 070 €		391 260 468 €		401 468 099 €
		7 446 642 €		33 901 377 €		198 197 531 €	
			13 162 229 €		92 833 577 €		103 041 209 €
				6 687 501 €		47 009 328 €	
					16 239 029 €		26 446 661 €
						8 205 210 €	
							6 787 827 €
Cost	- 2 206 710 €	- 2 769 421 €	- 2 769 421 €	- 5 193 123 €	- 5 193 123 €	- 5 193 123 €	
Probability		0,26		0,18			0,27

Table 13. Binominal lattice with costs and probabilities for CDNF for Parkinson's disease, payoff 100%, Discount rate = 2,547%

After the tree for the underlying values is completed, the end values are imported into the binominal lattice tree after weighting them with the respective passing probability. After the end values are calculated the tree continues by working from right to left with the method described earlier in the thesis. For CDNF for Parkinson's the estimated value is €33million with the payoff of €3,5 billion and the discount rate of 2,547%.

Payoff / Discount rate	2,547 %	5 %	10 %
High (125%)	42 295 473 €	35 225 472 €	24 305 895 €
Medium (€3,5 billion)	33 023 825 €	27 367 824 €	18 632 162 €
Low (75%)	23 752 176 €	19 510 175 €	12 958 429 €

Table 14. Sensitivity analysis for CDNF for Parkinson's disease drug

The sensitivity analysis for Parkinson's CDNF is presented in the table 14. The values are remarkably higher compared to the equivalent ones in the decision tree analysis.

Payoff / Discount rate	2,547 %	5 %	10 %
High	61 630 546 €	51 328 544 €	35 417 161 €
Medium	48 120 430 €	39 878 829 €	27 149 722 €
Low	34 610 314 €	28 429 113 €	18 882 283 €

Table 15. The valuation of Herantis Pharma with real option analysis

Lastly, in the table 15 the valuations for Herantis Pharma calculated with real option model is displayed. First thing to notice is that the valuations are significantly higher than the ones

calculated with decision tree model. This is at least partly because real option models take option to abandon the project into account. That means the option value is always equal of above zero. The closest figure compared to the market value at the moment is the one with low expected payoffs and 10% discount rate. With the medium payoffs and the original WACC the company's value is almost three times its corresponding value in the market.

Payoff / Probability	Original	Low (80%)	Lower (60%)
High (125%)	61 630 546 €	29 371 646 €	14 409 053 €
Medium (€3,5 billion)	48 120 430 €	22 454 467 €	10 571 467 €
Low (75%)	34 610 314 €	15 537 287 €	6 864 300 €

Table 16. Valuation of Herantis Pharma with passing rate sensitivity analysis

When the passing probabilities are lowered for the projects the valuations decrease as they did with the decision tree analysis also. When compared to the market valuation, it can be seen that market's view on the passing rates is more pessimistic than the industry average or that the payoffs of the drugs are overestimated. The closest figure compared to the market value of the company is with low (75%) payoff and low (80%) probability.

3.4 Summary

When comparing the results with the market value of the case company, it can be seen that both of the models, decision tree and real option model, produce a variety of different results, some differing substantially from the market value of the company. The main trend with the decision tree analysis was that the results were below the current market valuation. This could mean that the market valuation includes the embed options the company has and since values the company higher. The trend with the valuations calculated with real option analysis was that they were throughout much more higher than the market value of the company. This is because the value a single drug project can take in the real option analysis is always equal or more than zero. If the expertise of the scholars in the field is trusted the real option model's results should be more reliable and trusted than the decision tree model's, even though they exceed the market valuation by a large margin.

Though, the market value of the company is a combination of numerous investors' views and represents the average view of the market. Some investors are more pessimistic or optimistic about the chances the company has and other external factors such as the general sentiment of the market contribute to the value of the company as well. This means that the market can over or underestimate the value of a company. This can be the case especially with small, R&D dependent firms like Herantis Pharma which are probably the hardest type of firms to valuate credibly. This means that even though the valuations gotten in this thesis differ from the market value it does not necessarily mean that they are incorrect. Also, some of the figures calculated are quite close to the market value at the moment. If the estimates behind the models are accurate, according to the real option model it is reasonable to think that the case company is undervalued at the moment.

When comparing the usage of the two different models it can be said that the decision tree model is much more straightforward than the real option model. The real option model requires more expertise and effort in using it, and also more parameters, like for example volatility of the underlying asset. This comes as a trade-off as the real option model is thought to be the best one in biotechnology valuation. In any case, both of the models are not overly hard to use in themselves and the difficulty mainly comes from estimating the parameters needed for the models.

4. Conclusions

This thesis researched how to valuate listed biotechnology firms. The conclusions that can be drawn from the theory and the case parts, is that valuation of any company is a demanding and complicated task. This is the case especially with biotechnology companies which have high amount of risks and volatility. If the person doing the valuation is someone outside the company with no inside knowledge of the project costs and other details of the firm, many estimations and assumptions must be made even before the actual valuation models can be built. This means that the valuations depend largely on the initial estimates made by the valuator. Going forward this creates a need for sensitivity analysis and ability to interpret the results in the correct context.

When using the industry averages the results can be misleading as might be the case with this thesis' case company as well. A firm developing completely new cures for serious illnesses obviously has a smaller chance to come up with a working drug than a firm working on treatments for symptoms. Regardless, the probabilities for the drugs' passing rates are extremely hard to determine for an individual firm. Accurate estimations would require professional knowledge and inside information of the project which is an unreasonable requirement for a valuator working outside the firm. The conclusion from these facts is that valuation of biotechnology companies requires a lot of information to be accurate. Private investors rarely have enough data needed for a precise and reliable valuation. On the other hand, this means that for example real option method is a useful tool for management to valuate their own firm's project or the whole company value as they have the all information of the company and can make more accurate estimations. This thesis showcases the best-case scenario of valuating a biotech company as a private valuator.

The main objective of this thesis was to find out what are the best valuation methods to valuate biotechnology companies and how to use them. The results of the thesis were that the best option according to the research field is real option valuation. It takes different options to for example abandon or expand into account and offers a flexibility. In this thesis the binomial lattice with binomial option pricing model was determined to be the most suitable implementation of the real option method. Alternatively the Black & Scholes' pricing model could be used to valuate the option also.

The second-best model after real option analysis was the decision tree variant of the traditional discounted free cash flow valuation model. The disadvantages of the DCF model compared to the real option model are that it is more stiff and rigid. The advantage of the DCF tree model compared to the real option model is that it is more simple to use and does not require all the information real option model does. Valuating companies in industries with high degree of uncertainty rules out the usage of asset-based and relative based methods which are more suited for valuation in stable industries with more mature companies.

In the second section the theory behind the methods was reviewed, and in the third part the methods were put into practice. These sections give an answer for the second and third questions

of this thesis which were “How the biotechnology firm valuation methods can be used in practice?” and “What is the theory behind the valuation methods?”. Anyone who is interested in the earlier mentioned matters should have a good picture of biotechnology valuation and valuation methods and their theory after reading this thesis. Shortly put, the theory behind real option analysis relies heavily on financial options theory. Also, the DCF decision tree model has its roots deep in the traditional DCF model.

Some of the future research objectives could be to look into rainbow options and other more advanced real option models and see if the attained results are more accurate. Also, subjects like patent valuation or drugs potential market valuation could be interesting and supplement the models built in this thesis.

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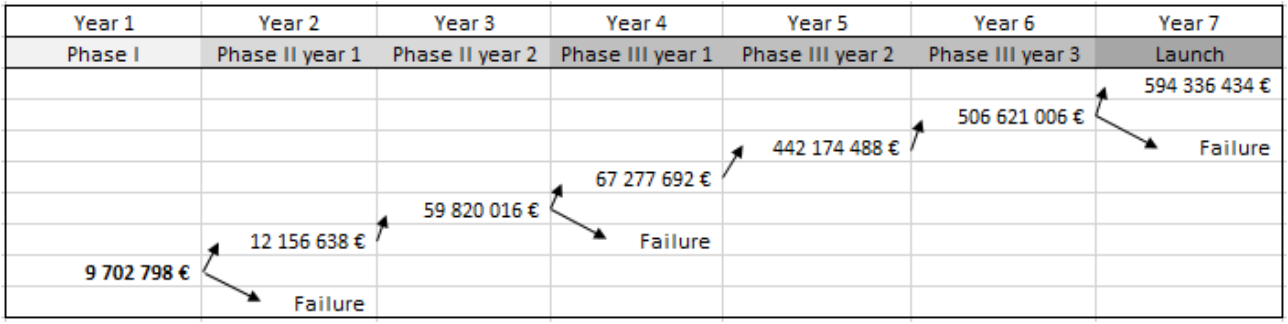
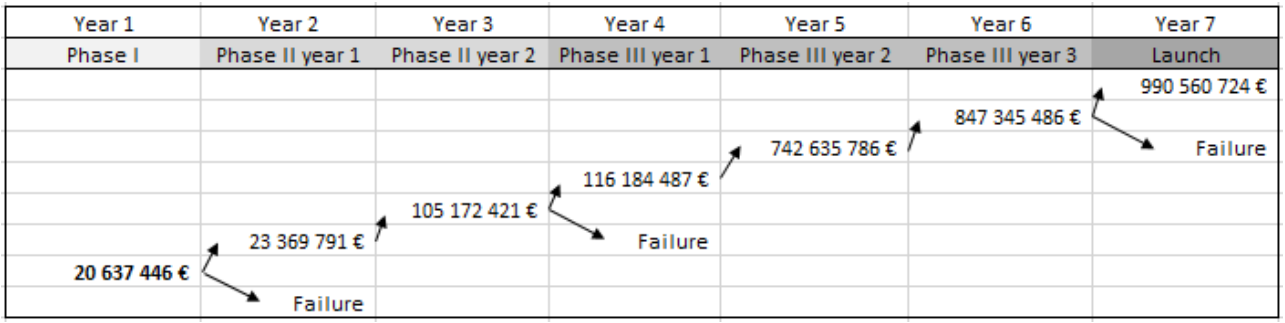
Appendices

Appendix 1. Decision tree, CDNF for Parkinson's disease, payoff 75%



Appendix 2. Decision tree, CDNF for Parkinson's disease, payoff 125%



Appendix 3. Decision tree sensitivity analysis for Lymfactin

Payoff / Discount rate	2,547 %	5 %		10 %
High (125%)	1 179 283 €	459 308 €	-	72 650 €
Medium (€200 million)	866 864 €	298 140 €	-	116 461 €
Low (75%)	554 446 €	136 972 €	-	160 272 €

Appendix 4. Decision tree sensitivity analysis for CDNF for ALS

Payoff / Discount rate	2,547 %	5 %		10 %
High (125%)	8 254 978 €	3 215 156 €	-	508 548 €
Medium (€1,4 billion)	6 068 049 €	2 086 978 €	-	815 226 €
Low (75%)	3 881 119 €	958 801 €	-	1 121 904 €

Appendix 5. Binomial lattice real option analysis, CDNF for Parkinson's disease, payoff 75%

Year	1	2	3	4	5	6	7
Phase	Phase I	Phase II year 1	Phase II year 2	Phase III year 1	Phase III year 2	Phase III year 3	Launch
							69 386 135 137 €
						35 147 018 051 €	
					17 798 508 014 €		17 808 715 646 €
				1 621 287 435 €		9 017 008 962 €	
			817 359 348 €		4 560 595 344 €		4 570 802 976 €
		106 300 263 €		414 107 613 €		2 310 454 392 €	
	50 695 792 €		205 781 257 €		1 162 939 285 €		1 173 146 916 €
23 752 176 €		25 742 904 €		104 271 618 €		589 143 311 €	
	9 884 047 €		48 813 005 €		290 893 443 €		301 101 074 €
		5 066 971 €		24 748 798 €		147 349 867 €	
			8 525 375 €		67 073 275 €		77 280 906 €
				4 338 391 €		33 958 715 €	
					9 627 364 €		19 834 996 €
						4 855 627 €	
							5 090 870 €
Cost	- 2 206 710 €	- 2 769 421 €	- 2 769 421 €	- 5 193 123 €	- 5 193 123 €	- 5 193 123 €	
Probability		0,26		0,18			0,27

Appendix 6. Binomial lattice real option analysis, CDNF for Parkinson's disease, payoff 125%

Year	1	2	3	4	5	6	7
Phase	Phase I	Phase II year 1	Phase II year 2	Phase III year 1	Phase III year 2	Phase III year 3	Launch
							115 643 558 562 €
						58 581 825 500 €	
					29 670 985 111 €		29 681 192 743 €
				2 703 951 685 €		15 031 810 352 €	
			1 365 855 705 €		7 607 797 328 €		7 618 004 959 €
		178 548 465 €		691 985 314 €		3 854 219 402 €	
	87 297 976 €		346 558 887 €		1 945 037 229 €		1 955 244 860 €
42 295 473 €		44 286 201 €		175 591 990 €		985 367 600 €	
	19 278 400 €		84 945 134 €		491 627 492 €		501 835 124 €
		9 826 313 €		43 053 957 €		249 045 194 €	
			17 799 084 €		118 593 879 €		128 801 511 €
				9 036 611 €		60 059 940 €	
					22 850 694 €		33 058 326 €
						11 554 794 €	
							8 484 783 €
Cost	- 2 206 710 €	- 2 769 421 €	- 2 769 421 €	- 5 193 123 €	- 5 193 123 €	- 5 193 123 €	
Probability		0,26		0,18			0,27

Appendix 7. Binominal lattice real option model sensitivity analysis for Lymfactin

Payoff / Discount rate	2,547 %	5 %	10 %
High (125%)	2 416 884 €	2 012 884 €	1 388 908 €
Medium (€200 million)	1 887 076 €	1 563 876 €	1 064 695 €
Low (75%)	1 357 267 €	1 114 867 €	740 482 €

Appendix 8. Binominal lattice real option model sensitivity analysis for CDNF for ALS

Payoff / Discount rate	2,547 %	5 %	10 %
High (125%)	16 918 189 €	14 090 189 €	9 722 358 €
Medium (€1,4 billion)	13 209 530 €	10 947 129 €	7 452 865 €
Low (75%)	9 500 870 €	7 804 070 €	5 183 372 €