MASTER

The value of real options valuation
a case study

Mooren, P.J.H.

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The Value of Real Options Valuation: A Case Study

By P.J.H. Mooren (Pieter)

BSc Industrial Engineering - 2009
Student identity number: 0569468

In partial fulfillment of the requirements for the degree of

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Supervisors:

Prof. Dr. R.J. Mahieu
Eindhoven University of Technology, ITEM

Dr. M.J. Reindorp
Eindhoven University of Technology, OPAC

Ir. T.J. Paffen
PPM Oost, Investment Manager
TUE. School of Industrial Engineering.
Series Master Theses Innovation Management

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Abstract

This study focuses on the potential added value of a real options valuation approach over a DCF valuation approach for individual high potential start-ups. Throughout literature it is theorized that for valuations of high potential start-ups the real options methodology would outperform the DCF method. However, due to a lack of focused research, empirical evidence for the superior performance of the real options methodology when individual ventures are valued is lacking. In this study, a real options valuation tool is modeled and used to value selected cases within the portfolio of a venture capital firm; the results obtained are hereafter compared with the DCF based valuations and actual stock transactions present for the selected cases. Through this comparison, it is found that the real options method is better able to determine the value of high potential start-ups than the DCF method. This study therefore concludes that a more accurate assessment of the value of high potential start-ups can be obtained by making use of the real options valuation method, these results are in line with claims made in literature and can be seen as the first empirical evidence for these claims on a case level. In this thesis also the performance of various real options methodologies is assessed, it is found that the relatively simple decision tree method performs equally well compared to the quantitatively more complex binomial lattice method.
Management Summary

Introduction
This master thesis project is executed at Participatiemaatschappij Oost Nederland NV (PPM Oost), a publicly funded venture capital firm. The primary task of PPM Oost is to invest public funds in start-up companies which through their activities make a positive contribution to the economy and employment of East Netherlands. Due to this task, the ventures in the portfolio of PPM Oost generally possess a large degree of strategic flexibility. In order to correctly determine the value of these ventures, the correct assessment of strategic flexibility is therefore of the utmost importance.

Research Question
It is often theorized that the real options method should have a superior performance over the Discounted Cash Flow (DCF) method due to the fact that the real options method specifically takes strategic flexibility into account. This is done through the assessment of an investment opportunity over time, as well as by considering strategic opportunities which exist after a project is engaged, such as discontinuing an investment. Although evidence is present on the superior performance of the real options method when a group of ventures is valued simultaneously, no empirical evidence is present on the superior performance of the real options method when individual ventures are valued; therefore the following research question is stated:

*Can a valuation process based upon the DCF valuation method be improved by using real options theory to better determine the value of individual high potential start-ups?*

Design of a Real Options Valuation Model
In order to answer this research question, an analytical framework was defined which could be used as a basis to design the real options valuation model. The analytical framework defines two real option valuation methodologies to be used in the real options valuation model; the “Decision Tree method” and the “Binomial Lattice method”. The analytical framework also defines a set of five characteristics through which a high potential start-up should be defined in the real options valuation model; these characteristics are the “Research Trajectory”, “Success Probabilities”, “Length of Phases”, “Costs and Income of Phases” and the “Commercialization Trajectory” of a venture.

Based on this framework, a real options valuation model was designed and tested which could be used to conduct valuation case studies within PPM Oost.

Execution of the Case Studies
Based on seven selection criteria (Industry Fit, Presence of a DCF valuation, Presence of another valuation, Presence of recent market transactions, Presence of comparables, Type of financing, and Reasons for rejecting), four ventures present in the red and white biotech industry were selected to be valued in the case study.
In Management Summary 1, the valuation results of the executed case studies are shown for each of the four cases\(^1\). The lowest valuation obtained through the real options model is set at 100%; all other valuations are adjusted accordingly. All real options and DCF valuations can be regarded to be current valuations. Moreover all stock transactions, except for the semi-recent stock transaction of RedBIO1 are fairly recent transactions, and can therefore be expected to be an accurate representation of the current value of the ventures; therefore these stock transactions will be used as a proxy for the market value of each venture. The market value of RedBIO1 is expected to be significantly higher than the semi-recent stock transaction, as this stock transaction occurred 1 year and three months ago.

![Management Summary 1: Overview Valuation Results (RedBIO1, RedBIO2, RedBIO3 and WhiteBIO1)](image)

**Analysis**

Through the analysis of Management Summary 1 several observations can be made. Since the actual market value for RedBIO1 is expected to be considerably higher than the semi-recent stock transaction, it can be expected that both the DCF method and the real options method provide wrong results.

- Both the DCF method and the real options method provide a valuation which is far from the actual market value of RedBIO1, the real options valuation is too high, the DCF valuation is too low.

\(^1\) Due to confidentiality companies are made anonymous, and valuations are given in percentages.
Moreover, it can be seen that the real options valuation method provides valuation results very close to the market value for RedBIO2 and RedBIO3 whereas the DCF method produces valuation results which are very far from the market value.

- The real options method provides valuations which are very close to the actual market values of RedBIO2 and RedBIO3, whereas the DCF method provides a valuation which is either far too high or unrealistically low (negative).

For WhiteBIO1, the DCF valuation and the real options valuation are similar. Although no actual market value is present it can therefore be stated that none of the two valuations will provide a more accurate result than the other.

- Both the DCF method and the real options method provide a similar valuation.

**Results & Practical Relevance**

Based on the analysis of the four case studies conducted, it can be stated that for all cases conducted, the real options valuation method provides a valuation result which is as close as, or closer to the actual market value than the valuation obtained through the DCF valuation method. Therefore the research question stated in the beginning of this management summary can be answered by: Yes, a valuation process based upon the DCF valuation method can be improved by using real options theory to better determine the value of individual high potential start-ups.

Besides answering the main research question, multiple related questions were answered. The other major findings in this report are:

- The Decision Tree method and Binomial Lattice method provide identical results in most cases. Since the Decision Tree method is more transparent in usage and easier to implement, this method is most appropriate.
- The high potential start-up characteristics defined in the analytical framework are able to capture the most relevant characteristics to consider when adapting a valuation process. It is unclear whether industry specific characteristics have to be considered when start-ups outside of the biotech industry are valued.

The practical relevance of this study is:

- Investment managers are better able to appropriately determine the value of high potential start-ups in which already is, or might be invested. This promotes a better allocation of scarce funds.
- Implementing a real options approach heightens the awareness of practitioners for options present in an investment; this awareness is one of the most important contributions of the real options model since valuable options are not discarded without consideration.
- The real options model requires less input than the DCF method, but an investment manager is still required to determine key sales and development numbers, requiring him to consider the assumptions underlying the most important numbers.
- The real option valuation model requires practitioners to quantify risk and provides an insight into the actual effect of risk on the value of the venture.
“Price is what you pay. Value is what you get.”

Warren Buffet, American Investor & Entrepreneur
Preface
This report is the result of my Master thesis project which I have conducted at PPM Oost. This project represents the last part of my Master Innovation Management at the Eindhoven University of Technology. Moreover, completing this Master is the final step in my education towards becoming an Industrial Engineer.

In the process of becoming an Industrial Engineer I was supported by a large number of people, here I would like to take the opportunity to specifically mention some of these people.

During my internship at PPM Oost, I had the pleasure of having Tom Paffen as my company supervisor. His insights into the venture capital industry, his entrepreneurial spirit, and his ability to not take things too serious made my internship a very pleasant and insightful experience. Who also made my internship worthwhile were all my other colleagues at PPM Oost who kept a continuous interest in my research, made time to answer my questions and above all were pleasant colleagues to work with, thank you all.

I would also like to thank my University supervisor, Mr. Mahieu, who always made time to review my work, discuss difficulties I had, and provide me with thorough feedback. His continuous support and enthusiasm were a great support during the project and helped me lift my work to a higher level. Also I would like to thank Mr. Reindorp, my second University supervisor, who showed a sincere interest in the project from the start on forward and contributed to the quality of this report greatly.

Last but certainly not least, I would like to thank my parents, sister and the rest of my family for their love and support throughout the years, without them I certainly would not be where I am today. Also I would like to thank all my friends, for making my time as a student in Eindhoven such a fun and enjoyable time. I could not have finished my studies without the (well timed) distractions from your part!

Pieter Mooren

Arnhem, September 2011
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1. Introduction

1.1 Introduction to the Problem

Since the emergence of Mesopotamia (3100 BC), money has been used to pay for assets and goods. How much money a person was willing to pay for a certain asset was determined upon his assessment of the value of the asset, this assessment is called valuation. The way asset value is assessed has evolved over time, the underlying motivation for valuation however has stayed the same: determining an appropriate value for the asset to be acquired.

The importance which is placed on accurate valuation techniques nowadays might be best illustrated by the fact that in 1997, the Nobel memorial Prize in Economic Sciences was awarded to Myron Scholes and Robert Merton for their contribution to the development of a derivatives valuation method, the Black-Scholes-Merton model (1973).

Like any asset, also companies can, and are valued. One of the hardest classes of companies to value are young start-up companies (High-tech start-ups, Internet companies, Biopharmaceutical companies, etc.). Due to their short operating history, high probability of failure and often negative current earnings, conventional valuation methods often do not suffice (Damodaran, 2009). Nonetheless, there is an unremitting need for accurate valuation techniques for young start-up companies. This need is particularly well illustrated by the large discrepancies between valuations and actual transaction prices for the recent IPO of LinkedIn, and acquisition of Skype by Microsoft.\(^2\)

A fairly recent (mid 1990's) development in valuation, is the use of the Black-Scholes-Merton model, and other valuation techniques initially intended to value derivatives, to determine the value of young start-up companies. It is theorized that the various possibilities present in the development and commercialization trajectory of a high potential start-up (strategic flexibility) add value to the start-up. The valuation method specifically taking this strategic flexibility into account is called real options valuation.

Real options valuation in theory is a superior valuation method compared to the Discounted Cash Flow (DCF) method, which is currently the most widely used valuation method (Luerhman, 1997). The real options valuation method is said to be superior for two reasons. First, investments opportunities are considered over a period of time, rather than being a now or never decision. Second, real options explicitly value strategic flexibility, such as the option to abort or to expand an investment. The DCF method in contrast, considers investments as a full commitment from the start on forward. It is therefore assumed that the real options valuation technique should outperform more frequently used methods such as the DCF valuation method. Moreover, it was stated by Triantis & Borison (2001) that possibly the most important contribution of the real options method is the heightened awareness by users of the real options valuation method that an investment can include options, the so called real options thinking (McGrath, 1997).

\(^2\) On 27-05-2011, LinkedIn closed at $88.32 a share for a total market capitalisation of $8.346 billion. At its IPO, a week earlier it was offered for $32 to $35 a share. Skype was acquired by Microsoft on 10-05-2011 for $8.5 billion; it was valued to be worth between $3 billion and $4 billion by valuation experts at that time. Both companies where founded in 2003.
Due to the more realistic assessment of investments and the heightened awareness of options by practitioners, it is argued that real options valuation should provide better valuation results; therefore papers were sought throughout literature providing evidence for this claim. Mooren (2011a) found that while evidence is present which shows that real options valuation performs superior on a group level (Joos & Zhdanov, 2008), (Paddock et al.; 1988), (Seppä & Laamanen, 2001), no empirical evidence on the superior performance of real options valuation is present when individual cases are considered. The question whether real options valuation actually provides beneficial results when individual high potential start-ups are considered is therefore a gap in current research.

1.2 Main Goal of the Master Thesis
As was stated in the previous section, it is unclear whether real options valuation actually provides beneficial results when individual high potential start-ups are considered. Answering this question will be the main goal of this master thesis.

1.3 Content of this Report
In this chapter, the main problem and the main goal of this master thesis were introduced. Here it will be discussed how the rest of the report is structured in order to answer the question whether real options valuation actually provides beneficial results on a case level.

First of all, in Chapter 2, the research questions, and how these where obtained from literature will be discussed, this discussion will serve as a theoretical basis for the following empirical study. In Chapter 3, the methodology for conducting this research will be discussed. In Chapter 4, the research scope will be defined both through the company setting in which the research will be conducted, as well as through the specific data which will be used.

In Chapter 5, the analytical framework will be defined through the selection of an appropriate real options valuation methodology and through the definition of key characteristics of high potential start-ups. In Chapter 6, the valuation tool will be designed making use of the analytical framework defined in Chapter 5. This valuation tool will hereafter be used in Chapter 7 to conduct several case studies.

After conducting the case studies, the data obtained from these case studies will be analyzed in Chapter 8. In Chapter 9, the research questions stated in this report will be answered by discussing the results obtained from the analysis of Chapter 8; also the limitations and relevance of this research will be discussed. Finally, in Chapter 10 the main conclusions which can be drawn from this report will be stated.
2. Research Question

Prior to this master thesis, a real options literature study was conducted by Mooren (2001a), this literature study was intended as an exploration of the real options research field and resulted in a research question which was specified further in the research proposal (Mooren, 2011b). This chapter will provide the theoretical background for this thesis and will introduce the research question to be answered in this report.

2.1 Theoretical Advantages of Real Options

There are two major drawbacks of the DCF valuation method; first that an investment opportunity is considered at a single moment in time (now or never) rather than over a period of time, which would be more realistic (Luerhman, 1997). Second, the DCF method considers investments opportunities as a full commitment from the start on and therefore does not consider any strategic opportunities that still exist after the project is engaged (Dixit & Pindyck, 1995).

The real options method considers the strategic flexibility of an investment, and thus specifically considers the timing of an investment as well as the value of the option of discontinuing or expanding an investment. It is therefore theorized that the real options valuation method should have a superior performance over the DCF valuation method.

On a more conceptual level, it is stated by Triantis & Borison (2001) that using the real options valuation method increases the awareness by practitioners that an investment can include options. Real options thinking enables people to also consider the positive elements of uncertainty, and lets people appreciate the value of costly information more. Moreover, people are triggered to keep considering all options available in a project, including less obvious options such as abandonment options.

2.2 Empirical Advantages of Real Options

As the theoretical advantages of the real options method over the DCF method are clear, multiple attempts within literature have been conducted to find empirical evidence for the theorized benefits offered by real options theory.

Research has hereby focused on two related research fields. On the one hand the ability of real options theory to represent reality was investigated, on the other hand evidence which concerns the performance of real options valuation compared to more conventional methods, such as the DCF method was investigated. Both research fields will be discussed hereafter.

2.2.1 Representation of Reality by Real Options

Throughout literature clear evidence was found that real options theory indeed represents reality, this became clear by looking at various characteristics of real options theory.

Bulan (2004) and Bulan et al. (2002) found that uncertainty present in an investment reduced the incentive of firms to commit to an investment and increased the incentive to delay an investment. Charitou et al. (2008) found that the ability to shut down operation or to grow increased the equity value of firms in financial distress. Moreover, situations with a considerable amount of options, such as investment decisions in pharmaceutical
R&D, the prices and development of land and the opening and closing of a mine can all be predicted correctly using real options theory (Cunningham, 2006), (McGrath & Nerkar, 2004), (Moel & Tufano, 2002).

A point of critique offered by Copeland & Tufano (2004) is that due to the fact that in reality real options are often executed too early or too late, real options theory does not represent reality as well as predicted. This indicates that when an investor is able to make use of the right “carrots and sticks”, the real options theory would represent reality even better.

2.2.2 Performance of Real Options
The research regarding the performance of real options valuation compared to more conventional methods such as the DCF method can be split into two distinctly different sections. On the one hand, research on performance was conducted on a group level where a group of companies was valued simultaneously; on the other hand research was conducted on a case level, where companies where valued individually. The outcomes of both types of research will be discussed below.

2.2.2.1 Performance on a Group Level
When considering investments on a group level, research shows that real options valuation indeed outperforms valuation methods such as the DCF method. Joos & Zhdanov (2008) found that real options valuation outperformed DCF valuation in predicting market equity values for 301 ventures in the biotechnology sector. Paddock et al. (1988) found that real options valuation better predicted the transaction prices of offshore petroleum leases than a DCF valuation did. And Seppä & Laamanen (2000) found that real options valuation had a better fit than DCF based valuations when considering the prices of 429 US VC transactions and 178 IPO's.

2.2.2.2 Performance on a Case Level
When considering investments on a case level, no conclusive evidence on the superior performance of real options valuation over other methods such as the DCF method can be found. In three case studies in which stylized cases are used, the real options method actually outperforms the DCF method (Copeland & Tufano, 2004), (Hall & Nicholls, 2007), (Varila & Sievanen, 2005), however these were not real life cases and therefore no binding conclusions can be drawn from these case studies. Kellogg & Charnes (2000) and Damodaran (2000) use real case studies; both papers value a biotechnology firm using real options valuation. The results of Kellogg & Charnes (2000) are pretty accurate during the first two phases compared to the actual equity value of the firm under consideration. However, in this paper the authors do not provide any DCF valuation with which the real options valuation can be compared. Damodaran (2000) found that for a number of selected cases the real options valuation values an investment with an option to delay higher than the static NPV of the investment; however no actual equity value or outcomes of other valuation methods are given to determine whether these higher values obtained for these cases are actually correct.

2.3 Research Questions
As became clear from the literature discussed in the previous section, the real options method provides a clear theoretical advantage. Real options are able to represent reality in a good way; however the practical advantage of using a real options approach is only partially supported by empirical research. On a group level empirical evidence for the
superior performance of the real options method was found, on a case level however no evidence is present on the superior performance of real options valuation compared to more widely used valuation methods such as the DCF valuation method.

The absence of empirical evidence concerning the beneficial performance of real options theory on a case level was identified as a gap in literature. In order to fill this gap, two research questions where stated (Mooren, 2011b) which are aimed at determining whether a real options approach actually has superior performance on a case level.

The first research question is concerned with determining whether a DCF based valuation model can be improved through the use of real options theory in order to be better able to determine the value of individual high potential start-ups. Specific focus areas are the real options valuation methods which are chosen to research this question, which factors specific to the venture which is valued and the industry in which the venture is situated should be considered in order to adapt the valuation model correctly, and which organizational factors will promote usage of the new valuation tool.

The second research question is contingent upon a positive answer to the first research question, and seeks to determine the actual impact, of specifically taking the characteristics of a high potential start-up into account, on the preciseness of a valuation. Below the two research questions, including sub questions are stated.

1) Can a valuation process based upon the DCF valuation method be improved by using real options theory to better determine the value of individual high potential start-ups?

   A. If so, which methodology / technique is most appropriate?
   B. Which factors specific to the venture which is valued, or the industry in which the venture is situated should be considered when adapting the valuation process?
   C. Which factors should be considered in order to promote usage of the new valuation tool and maximize commitment?

2) How does the fact that the characteristics of a high potential start-up are explicitly taken into account during the valuation impact the preciseness of the valuation?

The rest of this report will be focused at answering these research questions.
3. Research Steps

In the previous chapter the research questions to be answered in this report were introduced. In this chapter the steps, which need to be taken in order to answer the research questions stated in the previous chapter, are described in more detail.

**Step 1: Define the Research Scope**
Prior to starting with the actual research, a research scope has to be defined. Therefore, first the company setting within which this research takes place is chosen and described. Hereafter, based on the company setting, the specific type of data used in this report will be chosen, and also a description of this data will be given. This scope will serve as a boundary for this research.

**Step 2: Define the Analytical Framework**
After the research scope has been defined, an analytical framework will be defined. Here both the real options methods to be used as well as the characteristics of a high potential start-up will be defined.

**Step 3: Design the Valuation Model**
Based on the analytical framework, a valuation model will be designed. The model will be built by first defining the goal of the model and the assumptions underlying the model. Hereafter the actual valuation model will be designed and built, through testing the model will be adapted and corrected. Besides creating the model, also an approach towards creating commitment for the new model amongst employees will be discussed.

**Step 4: Execute the Case Studies**
Once the valuation model has been designed and tested properly, a case study will be executed. Prior to executing this case study, first appropriate cases to be used in the case study should be selected based on solid selection criteria. Hereafter, each case will be valued as a part of the case study, and the data obtained per case will be presented.

**Step 5: Analysis of the Results**
After the case study has been completed, the data resulting from this case study is analyzed. First the effect of the analytical framework on the results will be assessed, in order to assess whether the analytical framework has been defined properly. Hereafter the results of the case study will be analyzed.

**Step 6: Discussion**
After the analysis is completed, the results obtained from the analysis will be discussed. This discussion should result in the answering of the research questions stated in the beginning of this thesis as well as a discussion on the meaning of these results.

**Step 7: Conclusions & Recommendations**
In this chapter, the main conclusions which can be drawn from this report are stated. Also possible recommendations for further research will be made.

Above the various steps needed to conduct this research are discussed. The execution of these steps is discussed throughout this report. In Figure 1, the setup of the rest of
this report is shown; moreover, it is shown in which chapter each of the steps described in this chapter are treated in the report.

**Figure 1: Steps in Research**
4. Research Scope
As was stated in Chapter 3, prior to starting the actual research, the scope of this research should be defined, this is done in this chapter. Defining the scope of this research is done by first choosing an appropriate company setting in which the research should take place, hereafter the specific type of data to be used is defined in order to demarcate the scope of this research.

4.1 Company Setting
It is chosen to conduct this research within a venture capital firm (VC). A VC is the ideal setting for this type of research for two reasons.

First of all, it is the core business of a VC to invest in young start-up ventures. These ventures will typically possess a large amount of strategic flexibility and are therefore ideal cases to be used for this research, as this research investigates the value of strategic flexibility.

Second of all, due to regulation as well as due to the nature of a VC’s business, ventures in the portfolio of a VC are valued periodically, which creates multiple valuation data points. Moreover, other events which can serve as an indication of the value of a venture, such as additional stock transactions, occur quite frequently for young ventures, when compared to more mature ventures. As a typical VC also has a large number of ventures in its portfolio, there is typically quite some data available which can be used in research.

In the next section, the VC where this research will be conducted will be described. Also the current valuation practices of this VC will be described.

4.1.1 Description of PPM Oost
The specific venture capital firm which was chosen to conduct the research at is Participatie Maatschappij Oost Nederland NV (PPM Oost). PPM Oost was created when two development institutes, the “Gelderse Ontwikkelingsmaatschappij” and the “Overijsselse Ontwikkelingsmaatschappij” merged into “Ontwikkelingsmaatschappij Oost Nederland NV” (Oost NV) in 2003.

Oost NV is a development institute partially owned by the Dutch ministry of economic affairs (57,62%) and partially owned by both provinces, Gelderland (33,56%) and Overijssel (8,82%). Oost NV is the majority shareholder of PPM Oost (94,5%). Besides Oost NV, the other two shareholders of PPM Oost are University Twente (3,2%) and the foundation Saxion (2,3%) (See Figure 2).

PPM Oost is headquartered in Arnhem and has a second office in Enschede. As of the beginning of 2011, the workforce consists of a 2 person board, 12 investment managers, 2 controllers and 4 secretaries. The 12 investment managers present within PPM Oost are either “Management” or “Acquisition” investment managers. The management investment managers are responsible for the management of investments already in the PPM Oost portfolio; they are also responsible for possible exits. The acquisition investment managers are responsible for screening new investment proposals and to process the acquisition of new participations.
PPM Oost participates in new ventures through the acquisition of a minority share in ventures and by granting (subordinated) loans. Whenever PPM Oost participates in a venture, PPM Oost requires a second investor to participate under the same conditions as PPM Oost, PPM Oost can invest up to € 2.5 million in a single venture. PPM Oost manages multiple funds through which these kinds of investments can be made. As of the beginning of 2011 PPM Oost had a portfolio of investments which contained 102 investments. These investments had a combined revenue stream of € 285 million in 2010; the stake of PPM Oost in these ventures is valued to be currently worth approximately € 39 million. This value is obtained making use of the valuation principles used by PPM Oost, which will be discussed hereafter. A large part of the portfolio of PPM Oost is invested in certain sectors, indicated as focus areas; these are food, health and technology.

As PPM Oost is a regionally focused and publicly funded venture capital firm, the primary task of PPM Oost is to invest public funds in companies which through their activities make a positive contribution to the economy and employment of East Netherlands. Because of this primary task, which does not solely considers the profitability of a venture, but also takes the economic development of the region into account; PPM Oost is able to invest in seed and start-up phase companies, which due to their risk-return profiles might be unattractive to commercial investors. The companies in the portfolio of PPM Oost will therefore generally possess a larger degree of strategic flexibility than the portfolio of other VC investors. Therefore PPM Oost possesses a unique portfolio of investments which is suited extremely well for investigating the value of strategic flexibility.
4.1.2 Valuation at PPM Oost

The main research question within this thesis is concerned with determining whether real options theory is better able to determine the value of startups than the DCF method. In order to be able to answer this research question actual DCF based valuations must be present for companies within the portfolio of PPM Oost.

Therefore, in this section the valuation practices at PPM Oost are described. Based on this description it is determined whether enough DCF based valuations are present for PPM Oost ventures to conduct this research at PPM Oost.

There are two distinct reasons for an investment manager at PPM Oost to value a venture; first, a venture can be valued in order to determine the value of the firm during the acquisition process. Second, a venture can be valued in order to determine the value of a firm already present in the portfolio of PPM Oost, as part of the management process. Hereafter, both reasons will be discussed in more detail.

4.1.2.1 Acquisition Process and Valuation

Whenever a new investment opportunity arises, the investment opportunity has to be assessed prior to investing in it. This assessment is a stepwise process, during which the value of the investment opportunity is determined; this is done using ValuePlan, an Excel driven tool which is primarily intended to monitor the performance of a venture, but is also able to produce a DCF based valuation (See Appendix 1). Here the five steps taken during the assessment are outlined.

1. Application and intake
   A complete business plan is delivered and an initial intake with an “acquisition” investment manager from PPM Oost is scheduled.

2. Assessment of application
   After the intake meeting, the application is reviewed based on a set of six criteria; hereafter the application is accepted or rejected.

3. Search for a second investor
   Once the investment has been approved, a second investor is sought; the entrepreneur might also introduce a second investor himself.

4. Approval of finance proposal
   A finance proposal is drafted, detailing the method of financing and conditions.

5. Formal Settlement
   Once the terms of the participation deal are agreed upon by both parties, a civil law notary will make the agreement official.

From interviews held at PPM Oost it became clear that often the value of a venture is determined through an educated guess by the investment manager, hereafter ValuePlan is used to check whether the projected cash flows support the estimated value by the investment manager. The fact that small adjustments in various parts of the valuation model, such as the growth of cash flows of the firm in the future, or the cost of capital against which is discounted, can cause enormous fluctuations in the outcomes of the valuation, cause investment managers not to rely solely on ValuePlan when making a valuation.
4.1.2.2 Management Process and Valuation

Each venture in which is invested is managed by an investment manager within PPM Oost. Through advice and use of his network, this investment manager will try to add value to the venture; moreover the investment manager will also act as a controlling agent, making sure no breach of covenants occurs.

Part of the management process is periodically valuing each venture in its portfolio in order to determine whether the value creation of each venture is developing according to plan. How this is done depends on the length of time the venture is in the portfolio of PPM Oost.

If a company is in the portfolio of PPM Oost for less than two years, the value for which the venture was acquired is used as a base for the current value. Based on the fact if the venture is developing according to plan or not, the acquisition value can be adjusted by either: 0%, -25%, -50%, -75% or -100%. After two years, the acquisition value can no longer be used due to international financial reporting standards (Private Equity Valuation, 2010) (PPM Oost, 2009), which state that possessions held by a firm should reported based on fair market value instead of acquisition value. At PPM Oost the fair market value is determined by doing a DCF analysis, making use of ValuePlan.

4.1.3 Conclusion on Company Setting

In the previous two sections, the company setting (PPM Oost) and the valuation practices present at PPM Oost were discussed.

It was concluded that due to the fact that PPM Oost does not solely consider the profitability of the ventures it invests in, but also takes the economic development of the region into account, the ventures in the portfolio of PPM Oost generally possess a larger degree of strategic flexibility than the ventures in the portfolio of a conventional VC. Therefore the portfolio of PPM Oost is suited extremely well to be used for a study regarding the value strategic flexibility. Moreover, it was concluded from looking at the valuation practices present at PPM Oost that frequently a DCF based valuation is made for each of the ventures within the PPM Oost portfolio.

Since both the right type of ventures are present within the PPM Oost portfolio, and the right type of data is available on these ventures, it can be concluded that PPM Oost is an appropriate setting for this research.

4.2 Selection of Research Focus

In the previous section PPM Oost was selected as the company where this research will be conducted. As PPM Oost has a portfolio of over a 100 investments, a primary research focus should be chosen in order to maintain a manageable scale for this research. Moreover as one of the research questions is concerned with the industry specific factors that should be considered when adapting the valuation process, also a control group should be chosen.

4.2.1 Selection of Primary Focus

The aim of this thesis is to investigate whether a real options based valuation is better able to determine the value of ventures with a large amount of strategic flexibility present, therefore cases should be selected which have a large degree of strategic
flexibility and in theory should therefore benefit from a real options based valuation approach.

Moreover, as was stated previously, PPM Oost has three investment focus areas; food, health and technology, 87% of the value of the PPM Oost portfolio could be attributed to these three focus areas. In order to be able to collect a sufficient amount of high quality data, selected cases should lay inside one of these three focus areas.

4.2.1.1 Selection of Biopharmaceuticals as Primary Focus
The specific primary focus area selected is the biopharmaceutical industry. As was discussed by Mooren (2011b), biopharmaceutical ventures are ideal cases to be valued using a real options approach. Due to the large amount of uncertainty caused by rigid gates, and the staged type of investments present in the biopharmaceutical sector, a large amount of strategic flexibility is present within these ventures and the correct assessment of this strategic flexibility is vital for determining an appropriate value of the venture. A clear indication of the appropriateness of choosing biopharmaceutical companies for this research can be seen throughout literature, where biopharmaceutical companies are a frequently used type of company for real options valuation studies (Damodaran, 2000), (Joos & Zhdanov, 2008), (Kellogg & Charnes, 2000), (McGrath & Nerkar, 2004).

Biopharmaceuticals also clearly matches the “health” focus area of PPM Oost. Given these two factors, biopharmaceutical ventures are chosen as a primary focus for this case study. In the next section a short description of the biopharmaceutical industry will be given.

4.2.1.2 Description of the Biopharmaceutical Industry
Biopharmaceutical companies are involved in drug development; drug development is unique in the sense that it is a process with very clear phases. Due to the rigid gates at the end of each phase; the different phases can be distinguished particularly well. These rigid gates can be attributed to the fact that prior to starting in-vivo trials (animal trials) and clinical trials (human trials) approval has to be granted by a regulatory body (i.e. FDA or EMA). After completion of each stage of clinical trials, approval to advance to the next stage has to be granted; moreover procedures to be followed during these clinical trials are also very strictly monitored (Bogdan & Villiger, 2010). The staged approach of a typical drug development process can be seen quite clearly in Figure 3.

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3 The US Food and Drug Administration (FDA) and European Medicines Agency (EMA) are involved in approving the research and commercialisation trajectory in the USA and Europe respectively.
The drug development process is also known for its high hazard rates, estimation are that 1 in 10,000 to 1 in 32,000 screened compounds becomes an approved drug (Cassimon, et al.; 2004), (Claassen, 2010). On the other hand, drugs are also known for having a clear blockbuster potential (i.e. annual sales of over $ 1 Bln.), this creates explosive growth opportunities.

Due to the fact that drugs can be copied quite easily, patents are needed to protect sales. In general, sales are lost rapidly after the core patents have expired. Since sales are lost after patent expiration, the option to postpone investing in drug R&D is generally not considered, as postponing investments only limits future revenues (Bogdan & Villiger, 2010). Moreover, drug development suffers from technical uncertainty, which only decreases when investments are made (McGrath, 1997). Considering these two facts, we can state that the option to postpone investments can be ignored when dealing with biopharmaceutical products.

Due to the high amount of uncertainty and the staged type of investments present in the biotech sector, the DCF method is likely not the most appropriate valuation method to be used, since it considers an investment to be a full commitment from the start on forward (Mooren, 2011a), this is certainly not the case for investments in the biopharmaceuticals sector.

### 4.2.2 Selection of Control Group

A second aim of this study is to determine which industry specific factors should be considered when conducting a valuation. A control group, composed of ventures situated outside the biopharmaceutical industry should therefore be chosen in order to compare the valuation process among industries.

This control group should be a logical extension to the biopharmaceutical industry, but still be distinctively different. Like was stated earlier, the control group should also lie within one of the three focus areas defined by PPM Oost and a considerable amount of strategic flexibility should be present within the ventures in the control group.

#### 4.2.2.1 Selection of Industrial Biotech as a Control Group

Based on the selection criteria defined, industrial biotech is selected as a control group. The biopharmaceutical industry (Red Biotech) and the industrial biotech industry (White Biotech) are two of the three most important biotech areas (Biotechnology Industry...
All biotech innovations are similar in the sense that they involve the use of bioprocesses in their research and development process. They are however distinctively different when the products of each type of biotech are considered; red biotech produces health solutions such as medicines, while white biotech produces sustainability solutions such as fuel. Moreover, white biotech clearly fits within the focus area “technology” of PPM Oost. Therefore white biotech is chosen as the control group for this research. In the next section a short description of the industrial biotech industry will be given.

4.2.2.2 Description of Industrial Biotech

White biotechnology is involved in the application of biotechnology to industrial processes. An example of this is the design or adaptation of an organism to produce a useful chemical. Another application is the use of enzymes as a catalyst in industrial processes. It is often said that white biotechnology can be spoken of when biotech makes an industrial process cleaner, cheaper or more sustainable (Wit, 2004).

Compared to the average biopharmaceutical innovation, industrial biotech has the potential to be applied to a wider range of products and processes; it therefore provides a diversification of risk (Schneider, 2009). In addition, the development process is considerably shorter than that of red biotech, and the regulatory requirements are lower than for red biotech innovations (Schneider, 2009). On the other hand, it is not always clear whether there already is a market when a product is ready for commercialization.

From this description it can be concluded that real options theory is very suitable for valuing industrial biotech investments. Different scenarios may occur after completion of the innovation process, due to the fact that a market can be more or less prepared for an innovation. The real options method is able to model these scenarios; this provides a better insight into the value of a white biotech investment than when a single scenario would be considered.
5. Analytical Framework

In Chapter 2 the research questions to be answered in this thesis were defined. As could be seen, the research questions stated are concerned with “real options valuation” and with “high potential start-ups”.

In order to be able to answer the research questions, in this chapter an analytical framework concerning “real options valuation” and “high potential start-ups” will be defined, based on the actual company setting chosen in the previous chapter (PPM Oost), as well as the type of data to be used from the portfolio of PPM Oost (Red and White Biotech).

This analytical framework will be defined by first selecting an appropriate real options valuation methodology; hereafter high potential start-ups will be characterized. The analytical framework defined in this chapter will serve as a basis for the construction of the real options valuation model in the next chapter.

5.1 Description of the Real Options Methodologies

As was stated, as part of the analytical framework, first a real options valuation methodology will be selected. There are various real options methodologies which can be used to determine the value of an investment. As we are interested in determining which real options methodology is most appropriate to be used (See Chapter 2.3), two or more appropriate methodologies should be selected to be used for the design of the valuation model at PPM Oost. Therefore a qualitative analysis of a selection of real options methodologies was made. The analysis was made based on literature as well as insights obtained through crowd sourcing amongst life science valuation experts.

Throughout literature an abundance of methods are suggested. Mooren (2011a) identified some methods which were used quite frequently throughout literature. The most frequently mentioned methods will be discussed here and their potential beneficial contribution will be assessed.

5.1.1 Real Options based Decisions Tree

One of the major points of critique regarding the DCF method is that it considers all investments to be full commitment investments from the start on forward (Dixit & Pindyck, 1995). The real options based decision tree enables investors to consider the impact of having the option to stop investing at a certain moment in time, for instance because research has failed.

In the decision tree, flexibility is taken into account by modeling certain so called “milestones”. These milestones are moments in time where there are two or more distinct possible scenarios, each one delivering a distinctly different cash flow. All cash flows past a certain milestone are conditional upon the outcome at that specific milestone. The real options based decision tree therefore discounts each cash flow by the probability of it occurring. Biopharmaceutical ventures can be described particularly well using a decision tree due to the very clear milestones which are present during

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4 Multiple discussions in expert groups on life science valuation on LinkedIn where initiated, and discussions with valuation experts at PPM Oost where held.
development. Figure 4 below shows part of a decision tree which was used to determine the value of a biopharmaceutical company (Kellog & Charnes, 2000). In Figure 4 it can be seen that once a drug reaches the NDA (Approval) phase, there is a chance of $\rho_7$ that the drug is approved, and a chance of $\rho_6$ that the drug fails to be approved. In case the drug is not approved, only cash outflows (DCF) from year 1 until year T, the year that development fails, are considered and discounted against the discount rate of the year in which they occur. In case the drug is approved, multiple sales scenarios can occur. Scenario 1 occurs with probability $q_1$, scenario 2 occurs with probability $q_2$. Each scenario has the same generic cost structure (DCF), but can have different incomes; respectively $CCF_{2t}$ and $CCF_{3t}$ in this case. All these cash flows should be discounted against their respective discount rates, $r_d$ and $r_c$.

In literature (Bogdan & Villiger, 2010), (Blommaert & Van den Broek, 2010) it is stated that the decision tree technique might be specifically useful for modeling flexibility in practice, due to the fact that the technique can be incorporated into the DCF based valuation tools used by many companies. Moreover, according to a survey by Biostrat (Nielsen, 2010), this method which is also called the rNPV method, is the preferred method by most biotech valuation experts (see Figure 5). Venture capital investors which have a strong focus on biopharmaceutical investments however primarily make use of comparables to value an investment.\(^5\)

![Figure 4: Part of Decision Tree. Source: Kellogg & Charnes (2000)](image)

5.1.2 Binomial Lattice Method (Binomial Tree)
The binomial lattice method is used often in financial options pricing. It is assumed that the price of an asset follows a random walk; each period, the price of the asset can go

\(^5\) This was indicated by the following venture capital firms, involved in biopharmaceutical investments: Thuja Capital, Life Science Partners & Aglaia Biomedical Ventures.
up (or down) with probability “p” (or 1-p), moreover the magnitude of an upward and downward move are quantified by u and d. After a binomial tree is created (See Figure 6) backward induction can be used to determine a correct price for the option on the asset at time zero (Hull, 2009). In Figure 6, \( R_0 \) is the price of the asset at time 0, at time 1 the price of the asset is either \( R_0 u \) or \( R_0 d \), the same goes for period 2. In period 2 the value of the option can be determined for each of the branches (\( f_{uu} \), \( f_{ud} \) or \( f_{dd} \)). Hereafter, through backward induction the option price for each branch at time 1, and the option price at time 0 can be determined.

![Figure 6: Example of a two period Binomial Tree](image)

Two major mistakes have frequently been made when using the binomial tree for real options valuation of biotech projects, the first is the usage of a risk free discount rate, the second is the fact that attrition rates, i.e. success rates, were excluded from the calculations due to the assumptions by practitioners that attrition rates where modeled by the volatility of the sales estimate (Avance, 2009).

The risk free discount rate can be used in quantitative finance for valuing options due to the fact that the risk in an option can be hedged away by taking a position in the underlying and in the option, this position must be adjusted each period (Hull, 2009). In the field of real options in most cases the underlying is future revenues, which are usually not tradable. Therefore risk cannot be hedged away and investors will not be satisfied with receiving only a risk free rate of return, since they could have gotten this by investing in a riskless portfolio.

The success and fail probabilities are not taken into account by some authors (i.e. Schockley, et al.; 2003), since the author assumes that this is modeled by the random walk of the binomial tree. This is inherently wrong, since the binomial tree simply models the sales estimate in a success scenario. For example, a cancer medicine might gain sales potential due to a growing number of cancer patients, but might still not reach the market due to failed clinical trials. It is believed by leading practitioners in life science valuation (Villiger, Yule), that when applied correctly, this approach could deliver qualitatively good valuations.

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6 For a more comprehensive discussion of the binomial tree approach, see: Mooren (2011b)
7 This was concluded by analysing multiple discussions on the LinkedIn forums “Biotech Valuation” and “Valuation in Life Sciences.”
5.1.3 Black-Scholes Method

The Black-Scholes method is based upon the Nobel-Prize winning work of Black & Scholes (1973). Cox et al. (1979) provided evidence that the Black-Scholes method is a limiting case of the binomial tree method; when the length of each time step in the binomial tree goes to zero, or the number of time steps goes to infinity, the value that the binomial model provides for European style options converges to the value determined by the Black-Scholes model. The Black-Scholes method was intended to determine the price of European (no early exercise) financial put and call options. The real options approach is based on seeking real life parameters within a project which resemble the parameters of a financial option (See Table 1) using these parameters the value of a real option can then be determined.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Financial Option</th>
<th>Real Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_0$</td>
<td>Stock price at time 0</td>
<td>Present value of project, if project would be successfully executed.</td>
</tr>
<tr>
<td>$K$</td>
<td>Strike price of the option</td>
<td>Expenditure required when project is successfully executed</td>
</tr>
<tr>
<td>$r$</td>
<td>Risk-free rate</td>
<td>Risk-free rate</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Stock price volatility per period</td>
<td>Standard deviation of value of assets per period</td>
</tr>
<tr>
<td>$T$</td>
<td>Time to maturity of option</td>
<td>The length of time until project is executed</td>
</tr>
</tbody>
</table>

Table 1: Comparison of Financial and Real Options Variables

The Black-Scholes method is not suited for valuing drug development projects for multiple reasons. One is the fact that multiple embedded options are present in a drug development program, while the Black-Scholes method can only value one option at a time. This problem was tackled by Cassimon, et al. (2004) by using a 6-fold compound option. This approach however, is much too complex to be used by most valuation practitioners, as it creates a black box, of which the working cannot be explained to colleagues. Moreover in this approach available attrition rates are not used in the calculation, not using this data is foregoing very valuable information.

Another reason why the Black-Scholes method is not suited to be used when valuing real options is the fact that it considers European style options. In finance it is never profitable to exercise a (non-dividend paying) long call option prior to maturity, since one would rather sell the option than exercise it, prior to maturity. For real options, it is very likely that the opportunity is not tradable; therefore the Black-Scholes value will not capture all value present in a real option.

A third reason why the Black-Scholes method is inappropriate for valuing real options is the fact that the method uses risk free discounting. As we discussed during the section on the binomial tree, the usage of the risk free rate for discounting is not realistic for real options, therefore this approach cannot be used.

5.1.4 Simple Least Squares Approach (Simulation)

Longstaff & Schwartz (2001) presented a powerful simulation technique which could be used to approximate the value of American style and non-plain-vanilla options, called the simple least squares approach. The technique simulates forward paths using Monte
Carlo simulation, hereafter backward iterations are performed, while doing a least squares approximation at each step (Choudhury, et al., 2007). The objective of the technique is to approximate the optimal stopping rule for each path, which maximizes the value of the option, the technique is said to do this very well. This approach relies on the insight that the conditional expectation of the payoff obtained when the option is kept alive, can be estimated using least squares regression (Longstaff & Schwartz, 2001). Schwartz (2004) proposed this technique as a usable approach when one wants to value R&D projects and patents using a real options approach.

A disadvantage of this technique is the fact that specific simulation software is required and that the rationale behind the model might not be easy to explain to non-users, like it is for the binomial tree.

5.2 Method Evaluation & Selection

Based upon literature, discussions with practitioners both in real life, via email and via internet forums, and discussions with employees of PPM Oost, various criteria which have to be considered when implementing a valuation model where determined. The five criteria specifically considered are: whether or not the valuation method can be understood by outsiders (is it a black box?), the ease of use with which a valuation can be made (much effort required for making a valuation?), the fact whether the method is appropriate for valuing a biotech venture, the ease of implementation and adaptation (can the method be implemented and updated easily?), the possibility of implementing and using the method at PPM Oost given the resources available at PPM Oost. The methods determined in the previous sector are now assessed on these criteria, an overview of this evaluation can be found in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Decision Tree</th>
<th>Black-Scholes</th>
<th>Binomial Lattice</th>
<th>Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Box?</td>
<td>++</td>
<td>--</td>
<td>+</td>
<td>+/-</td>
</tr>
<tr>
<td>Ease of use?</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Appropriateness?</td>
<td>+</td>
<td>--</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Ease of implementation?</td>
<td>+/-</td>
<td>++</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Feasible at PPM Oost?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Total</td>
<td>+</td>
<td>+/-</td>
<td>+</td>
<td>Not Possible</td>
</tr>
</tbody>
</table>

Table 2: Evaluation Valuation Methodologies

5.2.1 Black Box

As was discussed in the previous section, the decision tree and binomial lattice method are both intuitively appealing methods due to clear set of assumptions needed to create a decision tree (attrition rates, length and costs of phases and possible payoffs), therefore these score the highest in this category (the random walk of peak sales for the binomial lattice method might be slightly less intuitive). The assumptions of the simulation method will generally be quite clear, but the simulation itself will not be understood by everyone, therefore this method scores a +/- . Moreover, the Black-Scholes model consists of only a single formula and therefore can be considered to be a total black box, receiving a --.
5.2.2 Ease of Use
All methods considered are fairly easy to use when making a valuation. A considerable amount of time and effort has to be invested in all methods, except the Black-Scholes method for which only five key variables will have to be determined, but none of the methods require an extreme amount of effort in use, therefore all methods are graded +, and the Black-Scholes method is graded ++.

5.2.3 Appropriateness
In the section above where the various methods where discussed, an analysis of the appropriateness of each method was given. It was stated that all methods except the Black-Scholes method are appropriate when applied correct, but none of the methods provide perfect results.

5.2.4 Ease of Implementation
Due to the fact that the usage of the Black-Scholes method only requires a single formula to be calculated, this method is easiest to implement. Other methods require more work, but implementation is still doable for the other three methods.

5.2.5 Feasible at PPM Oost
The decision tree method, the Black-Scholes method and the Binomial lattice method can all be modeled in Excel, this tool is available at PPM Oost, and therefore these methods are feasible at PPM Oost. The simulation method requires a Monte-Carlo simulation package such as "@RISK" or "Crystal Ball" to be present at the organization to use for simulation. These simulation packages are fairly expensive\(^8\) and are currently not present at PPM Oost, therefore this method is considered not to be feasible at PPM Oost.

5.2.6 Selection of Methods
Based upon the evaluation of all methods on the criteria mentioned, two methods were selected to implement within PPM Oost, and two methods were rejected. First of all, the simulation method was rejected due to the fact that the method could not be implemented given the resources currently available at PPM Oost. Second of all, the Black-Scholes method was rejected because of the fact that the calculations which the method relies upon lead to a so called “Black Box” and the method is not appropriate for valuing biotech ventures, due to the multiple options present within a biotech venture and because these options are American-style options.

The “Decision Tree” and “Binomial Lattice” method both where appropriate methods for valuing biotech ventures, where quite clear as they did not suffer from being a black box, where both fairly easy to use, and can be implemented at PPM Oost, therefore these two methods are selected to be used in the design of a valuation tool at PPM Oost.

5.3 Characteristics of a High Potential Start-up
As a second part of the analytical framework, a high potential start-up is characterized. Based upon literature (Bogdan & Villiger, 2010), (Kellog & Charnes, 2000), (Joos &

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Zhdanov, 2008), interviews at PPM Oost and crowd sourcing, five sets of characteristics were defined which are assumed to be able to characterize a high potential start-up. These sets of parameters are the Research trajectory, Success probabilities, Costs and income of phases, Length of phases and Commercialization. Each of these sets of parameters will be discussed hereafter.

**Research trajectory:**
As could be seen from both the description of Red Biotech (Cassimon, et al.; 2004), as well as White Biotech (Schneider, 2009), high potential start-ups have various development phases. For a correct understanding of a high potential start-up, it is of vital importance to understand the steps required prior to commercialization, the so-called research trajectory.

**Success probabilities:**
As became clear from the description of Red Biotech (Bogdan & Villiger, 2010) (Claassen, 2010) as well as White Biotech (Schneider, 2009), at the various development phases of a high potential start-up, there is a possibility that the project fails. Therefore a high potential start-up has a success probability for each development phase.

**Length of phases:**
As can be deducted logically, each research trajectory has its own duration. Within each research trajectory the length of particular phases can differ as well. Therefore the length of each development phase should be stated.

**Cost and income of phases:**
Like the length of a phase, it can also be deducted logically that for each high potential start-up the costs and potential income per phase can differ (Bogdan & Villiger, 2010). Therefore the cost and income of each development phase should be stated.

**Commercialization:**
Like for any company also a commercialization phase is present for high potential start-ups. The duration, sales and costs of the commercialization phase is expected to be different for each high potential start-up. Moreover, in knowledge intensive industries, the end of a patent might cause a loss of the remaining sales (Bogdan & Villiger, 2010).
6. Design of the Valuation Model

In the previous chapter the analytical framework was defined, by selecting two appropriate real options valuation methodologies and by characterizing high potential start-ups. In this chapter this analytical framework will be used to design a valuation tool which can be used to value high potential start-ups.

Several steps will be taken in order to design this valuation tool. First, the goal of the valuation model will be defined. Second, the assumptions underlying the valuation model will be discussed. Third, through the introduction of a case, the formulas underlying the valuation model will be introduced. Finally the valuation model will be tested and organizational commitment will be created.

6.1 Goal of the Valuation Model

As was stated in Chapter 2.1, the DCF method is used frequently because it is easy to apply and not extremely complex (Smit & Trigeorgis, 2006). Due to the fact that the DCF considers investments opportunities as a full commitment from the start on, it does not consider strategic opportunities that still exist after the project is engaged (Dixit & Pindyck, 1995). In the case of biotech investments the largest pitfall of the DCF method is not considering the value of terminating a project, once it has failed to reach a certain milestone.

Real Options regard the strategic flexibility to abort or expand a project as a real option; R&D expenses are in this sense regarded as the costs of acquiring an option on executing a project further (Oriani & Sobrero, 2008). The goal of the PPM Oost valuation model should therefore be to enable people to specifically consider the option of discontinuing an investment during the assessment of the value of an investment.

6.2 Assumptions of the Valuation Model

In order to be able to craft an appropriate valuation model, the assumptions underlying the model will have to be stated explicitly; in this section the three most fundamental sets of assumptions underlying the valuation model will be defined.

- The model should identify strategic flexibility within the investment trajectory
  As was discussed in the previous section, the main goal of the real options model is to be able to specifically take into account strategic flexibility. The second source of additional value real options theory is said to address, the ability to postpone an investment (Luehrman, 1997), is not a point of focus of the model, since it was discussed in Section 4.2.1.2 that postponing an investment in the biopharmaceutical industry is generally not an option.

- The value of a venture is determined by its core technology
  The value of a venture will be determined by valuing the core technology platform present within the venture. If multiple non-related technology platforms are present within a venture which all determine a significant amount of value, each technology platform will have to be valued separately in order to determine the value of the venture as a whole.
- **The model requires input**

In Chapter 5.3 the characteristics of a high potential start-up where described, it was stated that these characteristics differed per high potential start-up. Since every venture is unique; company specific input is always required to obtain a substantiated opinion on the value of the venture. Moreover, it should be noted that almost all input is subjective in a sense that experts might disagree on the specific value of a parameter. As was stated by Damodaran (2009), it is still useful to think about these parameters as thinking about them confronts the user with uncertainty in the project. The aim of this model therefore is to be a tool which aids the investment manager in valuing a company and spark discussion among investment managers regarding the characteristics of the venture which is valued. In order to have a clear overview of all input parameters, the five sets of parameters defined in Chapter 5.3 are specified further in Appendix 2.

### 6.3 Case Introduction

In this section a case will be introduced which will be used to illustrate the formulas introduced throughout the rest of this chapter. A company is considered which is focused on developing a single product “Q”. It still has to go through two stages of testing prior to being able to sell the product. In this case, product Q is licensed to a large manufacturer which will handle production and marketing and will pay a royalty % of sales. In Table 3 the main input is given. Moreover the expected sales curve of product Q is given in Table 4; miscellaneous parameters are given in Table 5.

<table>
<thead>
<tr>
<th>Research Trajectory</th>
<th>Success Probabilities</th>
<th>Length</th>
<th>Cash Flow (Costs)</th>
<th>Annual Peak Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>50%</td>
<td>2 Years</td>
<td>-6</td>
<td>-</td>
</tr>
<tr>
<td>Test 2</td>
<td>50%</td>
<td>1 Year</td>
<td>-10</td>
<td>-</td>
</tr>
<tr>
<td>Sales</td>
<td></td>
<td>10 Years</td>
<td>-20</td>
<td>100</td>
</tr>
</tbody>
</table>

**Table 3: Main Input Product Q**

<table>
<thead>
<tr>
<th>Year</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>25%</td>
<td>50%</td>
<td>80%</td>
<td>100%</td>
<td>80%</td>
<td>50%</td>
<td>25%</td>
<td>5%</td>
<td>0%</td>
<td></td>
</tr>
</tbody>
</table>

**Table 4: Sales Curve Product Q**

<table>
<thead>
<tr>
<th>Volatility (σ)</th>
<th>30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Royalties</td>
<td>10%</td>
</tr>
<tr>
<td>COGS</td>
<td>0%</td>
</tr>
<tr>
<td>Costs of Capital</td>
<td>15%</td>
</tr>
</tbody>
</table>

**Table 5: Miscellaneous Parameters Product Q**

As can be seen from Table 3, two tests will have to be conducted prior to being able to sell any products. The probability of successfully completing test 1 is 50%, once Test 1 is successfully completed and Test 2 has begun, the chance of successfully completing test 2 is 50%. Also the time it costs to conduct each test as well as the annual costs of conducting a test is given. Moreover, the annual income obtained from sales is given, and milestone payments, which will be received once a certain phase is reached, are given. In Table 4 the expected sales curve of product Q is given, here the % of peak sales which is expected to be sold in a particular year is given. Moreover, in Table 5 some miscellaneous parameters are given.
6.4 Formulas in the Model

In Section 6.1, the main goal of the valuation model was described; enable people to specifically consider the option of discontinuing an investment during the assessment of the value of an investment. In order to reach this goal, general formulas regarding the probability and magnitude of (discounted) cash flows have to be defined, also formulas specific to the decision tree method and the binomial lattice method have to be defined. These formulas will be introduced using the case defined in Section 6.3. First the general formulas will be described, hereafter the formulas underlying the two methodologies chosen in Section 5.2 are described, and finally the macros incorporated in the model will be described.

6.4.1 General Formulas

There are some general calculations, not specifically related to any of the real options methods, which provide necessary input to the method specific calculations, these calculations will be discussed here.

The likelihood that a cash flow occurs \( P(CF_j) \) is determined by multiplying the transition probabilities \( TR_i \) of each of the years leading up to year \( j \) with each other.

\[
P(CF_j) = \prod_{i=1}^{j-1} TR_i
\]  

The likelihood of a cash flow occurring in year 3 for instance: \( P(CF_3) \) is equal to the transition probability of year 1 to year 2 \( (TR_1) \) multiplied by the transition probability of year 2 to year 3 \( (TR_2) \). As the project is in the Test 1 phase for 2 years, \( TR_1 = 100% \), as the chance of reaching the Test 2 phase is 50% and this phase is reached after 2 years, \( TR_2 = 50% \). Therefore \( P(CF_3) = TR_1 \times TR_2 = 100% \times 50% = 50\% \). Following the same logic, it can be determined that \( P(CF_4) = 25\% \).

The commercialization cash flow for any given year \( (i) \) is contingent upon a number of factors; the peak sales level expected, the % of peak sales to be obtained in year \( (i) \), the % of royalties received and the % of sales retained after costs of goods sold are subtracted.

\[
CF_{Sales\ Year_i} = Peak\ Sales \times %\ Sales\ Curve \times %\ Royalties \times (1-COGS)
\]  

The commercialization cash flow in year 7 for instance is determined in the following way. First the peak sales are determined, in Table 3 it can be seen that these are 100. Then the % of peak sales for year 7 is determined, from it can be seen that this is 80%. Hereafter the % of royalties received and the % of sales retained are determined, from Table 5 it can be seen that these are 10% and 0%. Now we can calculate that the commercialization cash flow in year 7 is:

\[
CF_{Sales\ Year_7} = 100 \times 80\% \times 10\% \times (100\% - 0\%) = 8.
\]
The annual R&D cash outflow during phase \((y)\) can be determined by taking the total R&D expenses during phase \((y)\) and dividing this number by the number of years phase \((y)\) lasts.

\[
CF_{R&D \ phase(y)} = \frac{\text{Costs Phase}(y)}{\text{Length Phase}(y)} \quad (3)
\]

The annual R&D cash outflow during phase Test 1 for instance can be determined by dividing the cash flow of the phase \((-6)\) by the number of years the phase lasts \((2)\). This produces annual cash flow of \(-3\). Likewise, the annual cash flow during the Test 2 phase are \(-10\).

Each year has its own discount factor \((DF_j)\) which is determined by calculating the single year discount factor based on the Cost of Capital \((CoC)\): \(\frac{1}{(1 + CoC)}\). This single year discount rate should hereafter be taken to the power of the number of years a cash flow is in the present \((Y_j - Y_0)\). This leads to the following formula:

\[
DF_j = \frac{1}{(1 + CoC)} \quad \text{For } j \in S \quad (4)
\]

The discount factor for year 3 for instance can be determined by taking the CoC, which is 15% (See Table 5), and filling the formula. \(DF_3 = \frac{1}{(100\% + 15\%)} = 0.6575\).

In this section, general formulas were defined. In the next two sections, these formulas will be used as input for the formulas of the decision tree and binomial lattice method.

**6.4.2 Formulas of the Decision Tree Method**

In this section the formulas underlying the decision tree will be described in detail. The basic theory underlying the decision tree is the fact that all annual cash flows \((CF_j)\) are discounted by the likelihood that the cash flow occurs \((P(CF_j))\), this creates so called risk-adjusted cash flows \((rCF_j)\), this is done for the entire set of cash flows \((S)\).

\[
rCF_j = P(CF_j) \bullet CF_j \quad \text{For } j \in S \quad (5)
\]

The risk-adjusted cash flow of year 3 for instance can be determined by determining the likelihood that a cash flow occurs in year 3 and the annual cash flow in year 3; these are 50% and -10 respectively (See Section 6.4.1). So \(rCF_3 = 50\% \bullet -10 = -5\).

Once the annual risk-adjusted cash flows \((rCF_j)\) are determined, they are discounted by a discount factor \((DF_j)\), in order to determine the risk-adjusted net present cash flow \((rNPV_j)\), this is done for the entire set of cash flows \((S)\).
\[ r\text{NPV}_j = rCF_j \cdot DF_j \quad \text{For } j \in S \quad (6) \]

The risk-adjusted net present cash flow of year 3 for instance can be determined by taking the risk-adjusted cash flows of year 3 and multiplying this with the discount factor for year three. This becomes: \[ r\text{NPV}_3 = -5 \times 0.6575 = -3.2875 \] (See Section 6.4.1 & 6.4.2).

Once all risk adjusted discounted cash flows are determined, the current value of the investment, the rNPV can obtained by summing these cash flows.

\[ r\text{NPV} = \sum_{j=1}^{s} r\text{NPV}_j \quad (7) \]

### 6.4.3 Formulas of the Binomial Lattice Method

The binomial lattice method relies on the same formulas as the decision tree method, as the basic theory for obtaining annual risk adjusted discounted cash flows is identical to the decision tree for the binomial lattice method. These cash flows however can only be used for cash flows incurred prior to commercialization.

\[ rCF_j = P(CF_j) \cdot CF_j \quad \text{For } j \in S \quad \text{(see 5)} \]

\[ r\text{NPV}_j = rCF_j \cdot DF_j \quad \text{For } j \in S \quad \text{(see 6)} \]

The unique feature of the binomial lattice method is the fact that this method takes into account variability in future sales. The variability of future sales is captured through the usage of an extra parameter namely volatility (\( \sigma \)) of sales. Making use of the volatility (\( \sigma \)) of future sales, we can determine the magnitude of up and down movements (\( u \) and \( d \)), with these two parameters the probability of an up or down movement can then be determined (\( p \) and \( p-1 \)). The formula for an upward movement can be simplified by assuming that dividend yield (\( q \)) equals the risk free rate (\( r \)) (Hull, 2009). These parameters together can be used to create a binomial tree as shown in Figure 7.

\[ u = e^{\sigma} \quad (8) \]

\[ d = \frac{1}{u} \quad (9) \]

\[ p = \frac{e^{(r-q)\Delta t} - d}{u - d} = \frac{1 - d}{u - d} \quad (10) \]

The volatility for the sales of product Q are said to be 30% (See Table 5). This would mean that the magnitude of an upward movement is: \( u = e^{0.3} = 1.350 \) the magnitude of a downward movement is: \( d = \frac{1}{1.350} = 0.741 \). The probability of an upward movement is \( p = \frac{1 - 0.741}{1.350 - 0.741} = 0.426 = 42.6\% \), the probability of a downward movement is \( 100\% - 42.6\% = 57.4\% \). Using this information, a simple binomial tree can be made,
which depicts all possible sales scenarios after three years of testing (See Figure 7). In
Figure 7, for all periods the magnitude of each possible sales scenario is depicted, also
the probability of that scenario occurring is given. For instance when in all periods an
upward movement is made, sales will be 246 in period 3, this scenario occurs 8% of the
time. Since after three years the sales phase begins, the various year 3 scenarios and
their probabilities are used as input to determine the value of future cash flows.

Figure 7: Binomial Tree for Product Q

6.4.4 Simulation of Commercialization
Since commercialization often lies in the future for start-up companies involved in the
biotech sector, cash flows obtained through commercialization are highly uncertain. In
order to model this uncertainty, users of the valuation model are enabled to determine
multiple unique sales scenarios and determine the likelihood of each of these scenarios
occurring. An Excel based macro is programmed in order to simulate and save the
valuation results resulting from each individual sales scenario; based on the likelihood of
each commercialization scenario occurring, the macro hereafter determines an expected
value of the venture.

6.5 Testing & Building Commitment
After the design of the model, the model was tested. The testing of the model happened
in two separate stages. First the validity of the model was tested, second the usability
was tested. Both tests will be discussed hereafter.

6.5.1 Validity Testing
After the basic model was completed, multiple validity tests were performed in order to
investigate the correct working of the model. Three types of validity tests were
conducted, namely stress testing, logical testing and case testing, all three types of tests
will be discussed hereafter.

6.5.1.1 Stress Testing
At first, stress testing was used to determine whether the model would still behave
properly in case of an extreme value for one or more of the variables. This testing
included setting parameters at 0% and 100%, giving parameters extreme values such as
0 or 999, and testing the model when starting in the first or last phase. Through this
approach multiple errors in the model such as reference errors, calculation errors and
mathematical impossibilities (division by 0), where detected. The detection and correcting of errors in this phase was an iterative process, all these errors where handled instantaneously, after which testing was started once again. In this sense, the stress testing can also be regarded to be a part of the modeling.

6.5.1.2 Logical Testing
A second approach to validity testing is logical testing. In this testing round, fairly straightforward scenarios are modeled; the results obtained by the decision tree and binomial lattice method are hereafter compared. One of the more important conclusions which could be inferred from this stage early on was that in most cases the answers obtained through the decision tree method as well as through the binomial lattice method where identical.

For each scenario, the answers obtained by the decision tree and binomial lattice method where analyzed to see whether an intuitively logical answer was obtained, and whether both answers where identical. In case of non-intuitive outcomes or deviations among the two methods, the calculations where checked in order to explain the outcomes found. In some cases a logical constraint would cause differing or non-intuitive answers, in other cases, an error in the model was found, in these cases the error was fixed.

6.5.1.3 Case Testing
Through stress testing and logical testing, the abundance of errors was removed from the model. In order to test for remaining errors, it was chosen to model two, more complex, real life cases. This was done by valuing two companies for which an external valuation expert had already made a valuation in the past.

It was analyzed whether the assumptions made by the valuation expert could be introduced into the model. After all input was placed in the model, all calculations where checked, hereafter it was checked whether the valuation outcomes resembled those obtained by the valuation expert.

Through this approach, some functionalities where added to the model. Moreover a few small numerical inconsistencies where removed from the model. Also the model was adapted to be more flexible, adding phases and increasing the length of the binomial tree.

The final model will still result in an error in two specific situations:

**Time required till commercialization > 28 years**
When the time required to reach the commercialization phase is longer than 28 years, the binomial tree method produces an error. As the binomial tree is only 28 steps long, the model is unable to consider investments requiring more than 28 years in development. As it is extremely unlikely that an investment will remain in the development phase for longer than 28 years, this error is neglected.

**Length of certain phase ≤ 0**
When a phase lasts 0 years an error in the model occurs due to the fact that the annual R&D costs are determined by dividing the R&D costs per phase by the number of years a phase lasts. Moreover, when a phase lasts a negative number of years, costs are divided by a negative number, turning costs into income; this is a clear error in the
model. However, to investment managers it should be clear an input of a negative number of years is clearly wrong.

6.5.2 Usability Testing

To test the user friendliness of the model, and to stimulate organizational buy-in of the model, a small and comprehensive test-case was designed (See Appendix 3) alongside with a user manual (See Appendix 4). Both the valuation model and the user manual of the model were tested by asking investment managers to complete the test-case.

Through monitoring the thought process of the investment managers involved in the test-case, as well as through observing whether it was recognized that some vital data was missing, an insight into the usability of the tool was obtained. The test eventually led to the adoption of the model in two ways:

**Grey cells as main input:**
To investment managers, it was unclear that for the original model, in some instances the grey cells were used for direct input and in other cases, the grey cells could be used to make adjustments to another cell. The model was therefore adapted so that the grey cells are the main input in all instances. Advised inputs, for instance obtained by choosing a certain disease category are still given, but are no longer a direct input into the model.

**Explicitly including licensing scenarios:**
To investment managers, it was unclear how to incorporate various licensing scenarios into the model. As licensing deals are very common in case of biopharmaceutical investments, a more intuitively clear approach towards incorporating various licensing scenarios was created.

6.5.3 Creating Commitment

The actual utility of the tool is completely dependent on the adoption of the tool amongst investment managers; therefore a great focus is placed on creating commitment amongst investment managers. Commitment is created by creating ownership amongst investment managers, through formal and informal discussions as well as through the usability tests discussed in section 6.5.2. Moreover by explicitly involving investment managers regarded as authorities in the valuations field by other investment managers, it is intended to positively influence opinion leaders. Finally, as was discussed earlier, through the introduction of a test case and a user manual, it was attempted to lower the barrier of using the valuation tool.
7. Case Studies
In the previous chapter, a real options based valuation tool was designed. In this chapter, this valuation tool will be used to value a selection of red and white biotech cases from the PPM Oost portfolio (See Chapter 4).

In this chapter, first the specific red and white biotech cases to be used for the case study are selected. Hereafter the actual case studies are conducted and the results obtained from these case studies are presented.

7.1 Preconditions
Prior to the actual selection of appropriate cases, some preconditions have to be determined. First, the number of case studies to conduct in total and the number of case studies to conduct per focus area is determined. Hereafter, the selection criteria which will be used in the selection of specific cases will be stated.

7.1.1 Number & Type of Cases
Two of the goals of this study are to determine whether real options valuation is better situated to determine the value of high-potential start-ups, and to determine whether the specific industry in which the venture which is valued is situated is of importance for the valuation model.

In order to determine whether real options valuation is better situated to determine the value of high-potential start-ups a set of moderately different cases should be analyzed. In order to determine whether the specific industry in which a venture is situated influences the valuation model, a case situated in a significantly different industry should be compared to the moderately different set of cases.

Given the two demands stated above, in a dialogue with all thesis supervisors, an analysis of 3 red biotech cases as well as 1 white biotech case was chosen. Here the 3 red biotech cases will act as moderately different cases to be used in answering the first research question; the white biotech case can be used to determine the influence of another industry on the valuation model.

7.1.2 Selection Criteria
In order to obtain the greatest utility from this case study, information oriented sampling is used to select appropriate cases (Flyvbjerg, 2006). Information oriented sampling is focused at selecting cases based on the expectation of their informational content. Therefore selection criteria are specified which are indicators of the informational content of each case.

Since this study has a focus on determining the added value of a real options valuation approach over other DCF-based valuation approaches, the appropriateness of cases are evaluated on the presence of possible indicators of the company value; the evaluation criteria are whether a DCF valuation is present, whether other valuations are present, whether recent substantial stock transactions have taken place which is a clear indicator of the current market value, and whether there are any clear publicly traded comparable firms available (Criteria 2, 3, 4 and 5).
Moreover, two criteria which are indicators of the quality of available valuations are used to simplify the decision of which cases to be used; the fact whether the company fits the description of either a red or white biotech case and whether PPM Oost actually holds an equity stake in the venture, or that financing was provided through a (convertible) loan (Criteria 1 and 6).

Moreover, a final check was included to make sure that cases which for any reason should not be included in the case study where filtered out (Criterion 7). Below, all criteria are explained in some more detail.

1) **Industry fit**
The industry fit is an analysis of the degree to which the pre-selected companies fit the description of a standard red or white biotech venture.

2) **Presence of a DCF valuation**
Here a check is performed whether a DCF valuation has been made by PPM Oost for the company. The fact whether a DCF valuation is present is highly dependent on the length of time a venture is present in the PPM Oost portfolio.

3) **Presence of other valuations**
Here it is considered whether external parties have provided a valuation rapport or any other opinion on the value of the venture in the near past is present.

4) **Presence of recent market transactions**
For this criterion it is considered whether a market transaction has occurred recently which involved the acquisition of a substantial amount of stocks, this would be a clear indication of the current market value of the venture.

5) **Presence of comparables**
Whether financial data is available on companies with similar techniques in similar stages of development (either because a company is publicly traded or an undisclosed stock transaction has taken place), which can be used to determine a value for the venture considered.

6) **Type of financing by PPM Oost**
The type of financing, considers whether PPM Oost participates in the venture through an equity stake, a subordinated (convertible) loan or an alternative financing method.

7) **Are there reasons for rejecting the venture as a case study candidate**
Finally, it is considered whether there are any reasons, why not to use a venture in our case study. Exclusion from the case studies might have an economic reason such as bankruptcy, a strategic reason such as the lack of a clear development path by the key company stakeholders, or a pragmatic reason such as the fact that a subordinated loan has been repaid fully.

7.2 **Case Selection**
In this section, a selection of the cases to be used for the case studies is made. In order to make this selection, first a general selection of 12 ventures fitting either the red or

---

9 For confidentiality reasons, the specific reason per company will not be disclosed.
white biotech sector was made based upon a scan of the PPM Oost portfolio (PPM Oost, 2010), as well as by an inquiry among investment managers.

Based upon the seven criteria defined in the previous section, the information available in the 12 selected ventures was evaluated. Hereafter, an overall evaluation was used to determine the ventures which will be used in this research (See Appendix 5). During this evaluation, the availability of a DCF valuation by PPM Oost as well as the availability of either a recent market transaction or another representative valuation where considered to be the most decisive criteria.

This evaluation led to the selection of three red biotech ventures, and one white biotech venture; from here on forward these ventures will be called RedBIO1, RedBIO2, RedBIO3 and WhiteBIO110.

7.3 Conducting the Case Studies

For each of the four cases selected, a case study was conducted. Each case study was conducted by first analyzing the company data available within the dossier of PPM Oost. Based on this analysis, the main research trajectories of each venture were determined.

Hereafter, an open interview with key stakeholders in each of the ventures selected for the case studies was conducted. In each interview, the main research trajectories determined prior to the interview where either confirmed or adjusted, moreover for these research trajectories the key variables were determined. By using the data obtained from the starting analysis and the interviews as input for the valuation model which was designed in Chapter 6, a valuation of each venture was obtained.

7.4 Individual Case Study Results

In the previous section, a stepwise description of the execution of all case studies was given. The case studies and resulting valuations were documented fully for each venture in Appendix 6. In this section, the valuation results for each case will be given.

Prior to discussing the individual results, it should be noted that all results obtained were expert approved by the investment manager responsible for the venture which was valued. Moreover for all case studies conducted, the two valuation methods used in the real options valuation model, the binomial lattice method and the decision tree method, delivered identical valuation results, this result will be discussed more extensively during the analysis phase. However, it will not be mentioned separately for each case during the presentation of the case study results in this chapter.

Where available, also a recent stock transaction is shown. The price paid for a specific part of the stocks can be used to determine an indication of the price which should be paid for 100% of the stocks company. The price determined in this way can be regarded to be a proxy of the actual market value. In reality the value of a company is influenced by multiple factors such as the value of control, expressed through the control premium (Dyck & Zingales, 2004), the illiquidity discount in case of a private market (Damodaran, 2005), and other factors. As these considerations are beyond the scope of this research, we will assume that by using the price paid for a certain portion of the stock, a good proxy of the company value can be obtained.

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10 Due to confidentiality reasons, the identity of each venture is disguised.
Due to confidentiality reasons discussed earlier, no actual valuations in Euro’s will be disclosed; the valuations will rather be disclosed as percentages. It is chosen for all valuations to let the lowest valuation obtained by making use of the real options valuation represent the 100% mark; all other percentages are determined based upon this valuation.  

7.4.1 Valuation Results RedBIO1

In Figure 8, the valuation results for RedBIO1 can be found. The real options valuation as well as the DCF valuation are valuations which assess the current value of RedBIO1, as these were made recently. The semi recent stock transaction stems from about 1 year and 3 months ago. As was discussed in Appendix 6, if a stock transaction should take place at this point in time, a considerably higher valuation of RedBIO1 is expected due to the development of RedBIO1 during the last year and three months. The magnitude of this increase could not be estimated by the investment manager responsible for RedBIO1.

7.4.2 Valuation Results RedBIO2

In Figure 9, the valuation results for RedBIO2 can be found. The real options valuation as well as the DCF valuation are valuations which assess the current value of RedBIO2, as these were made recently. The external valuation was made about one year ago and as explained in Appendix 6, can be regarded to be a pretty conservative estimate of the current value of RedBIO2. Moreover, the recent stock transaction stems from half a year ago and can be considered to be a little conservative, but still a quite accurate representation of the value of RedBIO2.

In Appendix 6, the monetary valuation for each of the discussed cases can be found.
7.4.3 Valuation Results RedBIO3

In Figure 10, the valuation results for RedBIO3 can be found. All valuations, as well as the recent financing round, can be regarded as assessments of the current value of RedBIO3, as both the valuations and the recent financing round occurred recently. The recent financing round is expressed as a range rather than as a point estimate due to the fact that the financing is provided through a convertible loan, for which the conversion rate is subject to whether or not certain milestones are achieved by RedBIO3.
7.4.4 Valuation Results WhiteBIO1

Rather than an entire company, WhiteBIO1 can be regarded to be a project about to start at a larger company within the portfolio of PPM Oost. In Figure 11, the valuation results for WhiteBIO1 can be found. In addition to the real options valuation, also a DCF valuation is made specifically for WhiteBIO1, as no project specific DCF valuations are made within PPM Oost\(^\text{12}\). As PPM Oost usually finances a company rather than a project within a company, no stock transactions are present for WhiteBIO1. The investment manager responsible for this venture indicated that the fact that both valuation methodologies arrived at almost identical results could be regarded to be a clear sign of a viable business case.

![Figure 11: Valuation Results WhiteBIO1](image)

\(^{12}\text{In Appendix 6 details on the construction of this DCF valuation can be found.}\)
8. Analysis

In the previous chapter four valuation case studies were conducted using the real options valuation model. In this chapter, the data obtained from these case studies will be analyzed. First the effect of the analytical framework underlying the valuation model on the valuation results will be analyzed; hereafter the performance of the real options method compared to the DCF method will be analyzed.

8.1 Analysis of the Analytical Framework

In this section, the analytical framework defined in Chapter 5 will be analyzed. First, an analysis of the impact of the two different real options methodologies on the results will be made. Second, an analysis of the impact of the characteristics of high potential start-ups on the results will be made.

8.1.1 Analysis of the Impact of Real Options Methodologies

In the previous chapter it was mentioned that the binomial lattice method and the decision tree method delivered identical valuation results for all case studies conducted.

This might seem like a surprising result at first; however by applying logical reasoning, this result can be regarded to be a logical consequence of correctly implementing both the binomial lattice method and the decision tree method in the valuation model. In order to reason that identical valuation results are logical, the binomial tree introduced in Figure 7 is considered once again. As can be seen when the weighted average off all potential sales states and their respective probabilities are determined, the sum of the weighted averages for all potential states is equal for any period, moreover this sum is equal to the starting sales determined for period $t = 0$ (See Figure 12).

![Figure 12: Weighted average of Sales for Binomial Tree](image)

Like most high potential start-ups, the ventures involved in this case study typically have commercialization cash flows which are extremely high compared to the costs involved...
with development, in order to compensate for the development risk involved. Due to these high commercialization cash flows, even an extremely negative scenario in the binomial tree, in which only down movements have occurred, will often still result in a commercialization cash flow which is so high that continuing with development is the optimal decision. So when for all possible sales scenarios commercialization is continued, it can be concluded that the weighted average sales equal the sales of period \( t = 0 \). Since the sales of period \( t = 0 \) are equal to the sales which are the input for the decision tree method, it can be concluded that, in case that for all possible sales scenarios commercialization is continued, the binomial lattice method and the decision tree method use the same input and therefore should lead to the same output. The results obtained in this analysis are supported by Steffens & Douglas (2007) who showed in their paper that the valuation resulting from the decision tree method and the real options method based on quantitative finance techniques only differed marginally.

### 8.1.2 Analysis of the Impact of Start-Up Characteristics

In Chapter 5, an analytical framework regarding the characteristics of high potential start-ups was defined. From the case study conducted in Appendix 6, it can be concluded that since all venture characteristics which were considered to be important could be imputed into the valuation model, the five parameters defined in the analytical framework are able to capture the most significant start-up characteristics. In order to determine if no superfluous parameters were defined, here the individual impact of each of these five sets of parameters will be analyzed.

#### 8.1.2.1 Impact of the Research Trajectory

In Appendix 6, it can be seen that each case has its distinctively different research trajectory; even the three RedBIO cases have significantly different research trajectories. Although the impact of the research trajectory itself cannot be defined, it can be stated that due to the fact that for each case an individual research trajectory can be defined, the unique features of each venture can be expressed fully.

#### 8.1.2.2 Impact of the Success Probabilities

From the case studies discussed in Appendix 6, it can be seen that each case has its own unique success probabilities for each development phase. In the RedBIO2 case it is shown that an increase of the success probability causes the value of the venture to increase. This effect is as expected, as a heightened success probability means that the likelihood of receiving commercialization cash flows is increased.

#### 8.1.2.3 Impact of the Length of Phases

From the case studies discussed in Appendix 6, it can be seen that each development phase within each research trajectory has its own distinctive length. Moreover, as can be seen from the RedBIO1 and RedBIO2 case a decrease of the length of a development phase causes an increase in value of the venture. This effect is as expected, as a shortened development trajectory means that commercialization cash flows are received sooner and therefore have a higher present value.

#### 8.1.2.4 Impact of the Costs and Income of Phases

As can be seen in Appendix 6, each case has its own unique costs structure per development phase, moreover the presence and height of milestone payments is also case and phase dependent. It can be seen from all cases that when costs per phase
increase the value of the venture declines, and as milestone payments increase, the value of the venture increases. This effect is intuitively logical.

8.1.2.5 Impact of the Commercialization
As can be expected, for each of the cases discussed in appendix 6, the value of the venture is impacted when commercialization cash flows are in- or decrease. This effect is similar to a DCF based analysis, and can be considered to be intuitively logical.

8.1.3 Conclusion on the Analytical Framework
From the analysis of the impact of the start-up characteristics defined in Chapter 5, it can be concluded that all five parameters defined have a profound and logical impact on the valuation and are able to capture all significant start-up characteristics. It was also concluded that both real options methodologies deliver the same results, which was reasoned to be a logical result of correct implementation of both methodologies.

When both results are assessed simultaneously, it can be argued that the analytical framework chosen is correct, since all relevant high potential start-up characteristics are taken into account, and both real options valuation methods are able to assess these characteristics in the appropriate manner.

8.2 Analysis of the Case Study Results
Since it is argued that the analytical framework used is correct, the results obtained in the case study in Chapter 7 can be used to determine the performance of the real options valuation model. This will be done by comparing the real options valuation results for each case with the DCF valuation and the market value for that particular case. In Table 6 an overview of this analysis can be found, hereafter an analysis per case is provided.

<table>
<thead>
<tr>
<th>Case</th>
<th>Real Options Method</th>
<th>DCF Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>RedBIO1</td>
<td>Very High</td>
<td>Very Low</td>
</tr>
<tr>
<td>RedBIO2</td>
<td>Accurate</td>
<td>Extremely High</td>
</tr>
<tr>
<td>RedBIO3</td>
<td>Accurate</td>
<td>Extremely Low (Negative)</td>
</tr>
<tr>
<td>WhiteBIO1 (No Stock Transaction)</td>
<td>Equal to DCF method</td>
<td>Equal to Real Options method</td>
</tr>
</tbody>
</table>

Table 6: Results per valuation methodology compared to price actual stock transaction

8.2.1 Analysis Results RedBIO1
Prior to the analysis of the results obtained from RedBIO1 (See Figure 8), it should be considered that the semi recent stock transaction occurred about one year and three months ago. Since RedBIO1 has evolved satisfactory since this stock transaction, it is expected that a current stock transaction would result in a higher company valuation. This expectation is shared by an expert in the form of the PPM Oost investment manager responsible for RedBIO1.

8.2.1.1 Real Options Valuation RedBIO1
The mean value for RedBIO1 obtained through the real options valuation (116%) is 395% of the value implicated by the semi recent stock transaction (29%). It is reasonable to assume that even though a current stock transaction is expected to lead to a higher valuation, the real options method values RedBIO1 too high.
8.2.1.2 DCF Valuation RedBIO1
The current DCF valuation obtained for RedBIO1 (21%) is 72% of the value implicated by the semi recent stock transaction. Since a current stock transaction is expected to lead to a higher valuation, it is reasonable to assume that the DCF method values RedBIO1 too low.

8.2.1.3 Overall Analysis RedBIO1
Considering the fact that the real options method values RedBIO1 too high, and the DCF method values RedBIO1 too low, no conclusive statements on the relative performance of the real options method and the DCF method can be drawn.

8.2.2 Analysis Results RedBIO2
When the results obtained for RedBIO2 (See Figure 9) are assessed, it should be noted that the recent stock transaction stems from half a year ago, it can therefore be regarded to be a little conservative representation of the value of RedBIO2.

8.2.2.1 Real Options Valuation RedBIO2
The mean value for RedBIO2 obtained through the real options valuation (117%) is 131% of the value implicated by the recent stock transaction (89%). When it is considered that a current stock transaction might be a little higher than the 89% obtained half a year ago, we conclude that the real options method produces an accurate valuation for RedBIO2.

8.2.2.2 DCF Valuation RedBIO2
The current DCF valuation obtained for RedBIO2 (356%) is 399% of the value implicated by the recent stock transaction (89%). A current stock transaction might be a little higher than the 89% obtained half a year ago, but certainly not close to the DCF valuation obtained for RedBIO2. It can therefore be concluded that the DCF method values RedBIO1 much too high.

8.2.2.3 Overall Analysis RedBIO2
Considering the fact that the real options method produces an accurate valuation for RedBIO2, and the DCF method values RedBIO2 much too high, it can be stated that the valuation of RedBIO2 is improved by using real options theory.

8.2.3 Analysis Results RedBIO3
All valuations for RedBIO3 (See Figure 10) as well as the recent financing round occurred recently.

8.2.3.1 Real Options Valuation RedBIO3
The mean value for RedBIO3 obtained through the real options valuation (115%) is 78% of the mean value implicated by the recent financing round (147%). We therefore conclude that the real options method produces an accurate valuation for RedBIO3.

8.2.3.2 DCF Valuation RedBIO3
The current DCF valuation obtained for RedBIO3 produces a value of -44%. This is clearly a wrong valuation, as currently an investment is made in RedBIO3, whereas a venture with a negative valuation would implicate that no further investment should be
made in the venture. Therefore it can be stated that the DCF method values RedBIO3 too low.

8.2.3.3 Overall Analysis RedBIO3
Considering the fact that the real options method produces an accurate valuation for RedBIO3, and the DCF method values RedBIO3 much too low, it can be stated that the valuation of RedBIO3 is improved by using real options theory.

8.2.4 Analysis Results WhiteBIO1
The valuation of WhiteBIO1 (See Figure 11) is limited in the sense that no recent stock transaction is available to compare the obtained valuations with, due to the fact that WhiteBIO1 is a project rather than an entire company. Therefore, the real options valuation and DCF valuation will only be compared to each other.

8.2.4.1 Comparison Real Options and DCF Valuation WhiteBIO1
As can be seen, the real options valuation is almost identical to the DCF valuation. When the mean value of the real options valuation (106%) is compared to the DCF valuation (112%), we see that the DCF method values WhiteBIO1 at 106% of the value determined through the real options method. Since both methods produce a similar valuation, it can be concluded that the real options method does not perform better than the DCF method; on the other hand the DCF method also does not produce better results than the real options method.

8.2.5 Performance of the Real Options Valuation Model
When the overall results, presented in Table 6 are considered once again, it can be seen that for all four cases, the real options valuation method is able to determine the value of a high potential start-up equally good, or better than the DCF method. Moreover, for the two cases where the real options valuation method provides a valuation very close to the value implicated by a recent stock transaction, the DCF method results in values which are either extremely high or extremely low.

8.3 Preciseness of Valuation Methods
In the previous section it was argued that for all cases, the real options valuation method is able to determine the value of a high potential start-up equally good, or better than the DCF method. In this section the preciseness of both valuation methods will be assessed. In order to determine how the preciseness of valuation is affected when the characteristics of a high potential start-up are explicitly taken into account, first a way to measure the preciseness of each valuation method will be discussed; hereafter the preciseness of both the real options method and the DCF method will be evaluated.

8.3.1 Measurement of Valuation Preciseness
The preciseness of both the real options valuation method and the DCF valuation method should be determined by first considering the preciseness of both methods for each individual case, hereafter the overall preciseness per methodology should be determined.

The valuation preciseness can be determined by determining the discrepancy between the market value and both the real options valuation method and the DCF valuation method as a percentage of the market value. This method is fair in the sense that both
an under- and overvaluation of an asset are weighed equally, as each percentage point expresses the same monetary value. Moreover, also negative valuations can be assessed appropriately by this method.

The overall preciseness of each method should be determined by determining the average discrepancy of all case studies conducted from the market values for each case study. In this case a lower average discrepancy means a higher preciseness.

### 8.3.2 Measuring Preciseness

In the previous section, it was described that preciseness should be determined by determining the average deviation of each valuation methodology from the market value. In this section this analysis was performed, in Table 7 the results of this analysis are shown.

<table>
<thead>
<tr>
<th>Case study</th>
<th>Difference RO – Actual</th>
<th>Difference DCF – Actual</th>
<th>Difference other valuation – Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>RedBIO1</td>
<td>295%</td>
<td>28%</td>
<td>-</td>
</tr>
<tr>
<td>RedBIO2</td>
<td>31%</td>
<td>299%</td>
<td>25%</td>
</tr>
<tr>
<td>RedBIO3</td>
<td>22%</td>
<td>130%</td>
<td>-</td>
</tr>
<tr>
<td>WhiteBIO1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Average Deviation</strong></td>
<td><strong>116%</strong></td>
<td><strong>152%</strong></td>
<td><strong>25%</strong></td>
</tr>
</tbody>
</table>

*Table 7: Deviation per valuation methodology*

As can be seen from Table 7, the real options method on average has a deviation of 116% of the actual market value. The DCF method on average has a deviation of 152% of the actual market value. The deviation of the third method “other valuations” is only 25%. However, since this method is dependent upon only a single external valuation, it will not be considered further.

As can be seen from Table 7, the extremely high difference between the real options method and the actual value (295%), is responsible for a large part of the average deviation of the real options methodology. It was stated in section 7.4.1, the market transaction of RedBIO1 dates from more than a year ago. As the development since then has been according to plan, it can be expected that compared to one year and three months ago, the market value of RedBIO1 has increased.

In order to determine the effect of an increased market value of RedBIO1 on the preciseness of both valuation methods, a scenario analysis is performed. The effect of an increased market value on the preciseness of the various valuation methods was determined (See Table 8). Hereafter, the effect on the overall preciseness of the various valuation methodologies was determined (See Table 9). In order to execute this scenario analysis, three different scenarios were defined; these scenarios assume a current market value of either 125%, 150% or 200% of the market value implied by the semi recent stock transaction.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Difference RO-Actual</th>
<th>Difference DCF-Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market value RB1 = 125%</td>
<td>216%</td>
<td>42%</td>
</tr>
<tr>
<td>Market value RB1 = 150%</td>
<td>163%</td>
<td>52%</td>
</tr>
<tr>
<td>Market value RB1 = 200%</td>
<td>97%</td>
<td>64%</td>
</tr>
</tbody>
</table>

*Table 8: Deviation per Valuation Methodology for the RedBIO1 Valuation per Scenario*
As can be seen from Table 9, a higher current market value of RedBIO1 has an extreme impact on the preciseness of both the real options and the DCF valuation. In case the actual market value is equal to the stock transaction which occurred one year and three months ago, the real options method on average has a deviation of 116% of the actual market value while the DCF method on average has a deviation of 152% of the actual market value. In case the actual market value is 200% of the original stock transaction, the real options method on average has a deviation of 50% of the actual market value while the DCF method on average has a deviation of 164% of the actual market value.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Average Difference RO-Actual</th>
<th>Average Difference DCF-Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market value RB1 = 100%</td>
<td>116%</td>
<td>152%</td>
</tr>
<tr>
<td>Market value RB1 = 125%</td>
<td>90%</td>
<td>157%</td>
</tr>
<tr>
<td>Market value RB1 = 150%</td>
<td>72%</td>
<td>160%</td>
</tr>
<tr>
<td>Market value RB1 = 200%</td>
<td>50%</td>
<td>164%</td>
</tr>
</tbody>
</table>

Table 9: Average Deviation per Valuation Methodology for Different Scenarios
9. Discussion

In the previous section, the data obtained through conducting the case study was analyzed. In this chapter the resulting analysis will be used to answer the research questions stated in the beginning of this report. Moreover, the robustness and limitations of the findings will be discussed and finally the practical and scientific relevance of the findings will be discussed.

9.1 Research Questions

In this section the research questions stated in Chapter 2.3, will be answered and a discussion regarding the results will be held.

9.1.1 Research Question 1

The first research question stated was:

*Can a valuation process based upon the DCF valuation method be improved by using real options theory to better determine the value of individual high-potential start-ups?*

In the previous chapter, it was concluded that the real options method and high potential start-up characteristics defined in the analytical framework were able to assess the value of a high potential start-up in a correct manner. Moreover it was concluded that for all cases executed the real options valuation method is able to determine the value of a high potential start-up equally good, or better than the DCF method. Therefore research question 1 can be answered as follows: Yes, a valuation process based upon the DCF valuation method can be improved by using real options theory, in order to better determine the value of individual high potential start-ups.

The answer to this research question is as expected, since stylized case studies by Copeland & Tufano (2004), Hall & Nicholls (2007) and Varila & Sievanen (2005) already showed this result. As this study provides the first empirical data for real life cases, supporting an effect which up to this point was only theorized to exist, this study can be regarded to be a significant step forward in the research field of real options theory.

9.1.2 Research Question 1A

Research question 1A stated:

*Which real options methodology / technique is most appropriate?*

As was stated during the analysis of the results provided by the two real options methodologies in the previous chapter, both methodologies provided identical results. Therefore no preference for any methodology exists based upon the valuation results provided by each methodology. However, when the evaluation of the various real options methodologies in Chapter 5.2 is assessed once again (See Table 10). It can be seen that the Decision Tree method is somewhat more transparent than the Binomial Lattice method in its calculations (Black Box). Moreover the decision tree method is easier to implement and adapt than the binomial lattice method (Ease of Implementation). Since both methodologies provide identical results, but the Decision Tree method has two slight advantages when user perception is concerned, the answer to research question 1A is: The Decision Tree method is the most appropriate
methodology to be used when designing and implementing a real options valuation model.

<table>
<thead>
<tr>
<th></th>
<th>Decision Tree</th>
<th>Binomial Lattice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Box?</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Ease of use?</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Appropriateness?</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Ease of implementation?</td>
<td>+/-</td>
<td>-</td>
</tr>
<tr>
<td>Feasible at PPM Oost?</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Total</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 10: Evaluation selected Real Options Methodologies

The answer obtained for this research question is supported by the paper of Steffens & Douglas (2007), who found that the valuations resulting from the decision tree method and from a real options method based on quantitative finance techniques were only marginally different. Hereafter, Steffens & Douglas (2007) also concluded that the decision tree method was preferable due to the fact that the decision tree method is a more intuitive and simpler method.

As was discussed in Chapter 5.1 and by Mooren (2011a) a large variety of real options methodologies exist. As could be seen, a large number of authors preferred a real options methodology derived from the field of quantitative finance, such as the binomial lattice method (Hull, 2009) (Copeland & Tufano, 2004) (Bulan, 2004), and the Black-Scholes method (Cassimon, 2004) (Luehrman, 1997 & 1998) (Damodaran, 2000). Due to the fact that non-skilled practitioners were often unable to handle these methods, or used them in the wrong way, many practitioners discarded real options valuation as being too complex and theoretical (Avance, 2009). The fact that the decision tree method, a relatively simple real options method which is also very transparent (See Table 10), is able to deliver results which are identical to more complex, quantitative finance methods, such as the binomial lattice method, might lead to a more wide adoption of the real options methodology in the future.

9.1.3 Research Question 1B

Research question 1B stated:

Which factors specific to the venture which is valued, or the industry in which the venture is situated should be considered when adapting the valuation process?

From the analysis of high potential start-up characteristics in the previous chapter, it could be concluded that all characteristics defined in the analytical framework had a profound effect on the valuation. Moreover, as during the execution of the case studies no characteristics were felt to be missing, and from the analysis of the valuation results it turned out that all real options valuations resulted in an equal or better valuations than the DCF valuations, it can be concluded that all the high potential start-up characteristics defined in the analytical framework should be considered when adapting the valuation process.

When the high potential start-up characteristics defined in the analytical framework are considered, it can be seen that none of these characteristics are industry related. Since from the analysis of the valuation results it turned out that all real options valuations resulted in an equal or better valuations than the DCF valuations, and no industry
specific characteristics were considered, it might be expected that no industry specific characteristics have to be considered when adapting the valuation process. However, since all cases assessed are biotech cases, no general statements on this subject can be made.

Considering the discussion provided above, the following answer to research question 1B can be given: When adapting the valuation process, the research trajectory, success probabilities, costs and income of phases, length of phases, and commercialization of a venture should be considered, it cannot be determined with certainty whether industry specific parameters have to be considered when ventures in different industries are assessed.

This research question presents a clear and high level framework of high potential start-up characteristics, which can be used as an input to design a valuation model. This valuation model can be used for red and white biotech ventures, as the selection of the five sets of high potential start-up characteristics was made based upon a literature review which primarily included papers on red and white biotech ventures (Bogdan & Villiger, 2010) (Schneider, 2009). As no specific biotech characteristics seem to be present in the high potential start-up characteristics defined, the framework might be expected to work in non-biotech industries as well; however due to the fact that this framework was only tested for biotech cases, no general statements on this subject can be made.

It is claimed by Triantis & Borison (2001) that the single most important contribution of implementing a real options approach is the heightened awareness by people involved in a project that an investment can include options. Through the answering of research question 1B, a clear and high level framework of high potential start-up characteristics is defined. Besides aiding as an input for designing a valuation model, this framework can also help practitioners to increase their awareness of options present in an investment.

9.1.4 Research Question 1C
Research question 1C stated:

| Which factors should be considered in order to promote usage of the new valuation tool and maximize commitment? |

In order to promote usage and commitment, several factors were considered. First, in Chapter 5.2.5 the feasibility of each real options valuation method was considered. By making sure a feasible and user friendly method is chosen, commitment will be increased. Second, in Chapter 6.5.2 a usability test was performed amongst future users, this test introduced PPM Oost investment managers to the valuation model and created commitment. Third, by explicitly involving investment managers regarded as valuation authorities by other investment managers, it was tried to positively influence opinion leaders. Fourth, by providing a user manual for the valuation tool, the barrier of using the valuation model was lowered.

As the tool is not yet introduced on a full scale at PPM Oost, no data on the actual usage of the tool is currently present, and therefore no definitive answer to this research question can be given. It is however expected that important factors in creating
commitment for the new valuation tool will not differ substantially from findings on the creation of commitment in literature.

### 9.1.5 Research Question 2

Research question 2 stated:

*How does the fact that the characteristics of a high-potential start-up are explicitly taken into account during the valuation impact the preciseness of the valuation?*

In the previous chapter, the preciseness of each valuation method was determined by determining the average deviation of a valuation method from the actual market value. As could be seen from this analysis, due to the fact that the most recent stock transaction for RedBIO1 has occurred one year and three months ago, no accurate current market value for RedBIO1 could be determined with certainty, therefore a scenario analysis was performed. Based on this scenario analysis (See Table 9), a range of both the preciseness of the real options method as well as the DCF method was defined. It could be seen that the average deviation of a valuation by the real options method is between 50% and 116%, while the average deviation of the DCF method is estimated to lie between 152% and 164%. Considering the large deviation caused by altering the market value of a single case, the answer to research question 2 is: The specific increase in preciseness which is obtained by specifically taking the characteristics of a high potential start-up into account cannot be determined due to the fact that not enough data is present. Considering the analysis of the data which was available it can however be stated that the valuation preciseness is improved by specifically taking the characteristics of a high potential start-up into account.

It is concluded that the impact of a single case can be extremely large, as the average deviation of the real options method varies from 50% to 116% dependent upon the actual market value of RedBIO1. Given this large impact, it can be concluded that a much larger number of cases should be studied in order to obtain an accurate estimation of the actual increase in preciseness obtained by using the real options valuation method.

### 9.2 Robustness of findings

In order to determine the relevance of the findings in this report, the robustness of the valuation model is assessed. This is done by determining the change of the valuation answers obtained when a single variable in the model is varied.

Due to the fact that the valuation model is intended to value high potential start-ups, the characteristics of high potential start-ups defined in the analytical framework are the most appropriate to be analyzed when robustness is assessed. As the valuation tool designed is already able to simulate three of the characteristics defined; Length of Phases, Costs and Income of Phases and Commercialization. And the Research Trajectory cannot be simulated due to the fact that it concerns a fixed and unique trajectory for each venture; it is chosen to determine the impact of altering success probabilities in order to obtain an insight into the robustness of the valuation model.
9.2.1 Success Probabilities

In Appendix 7, five (sub) valuations performed throughout the four case studies discussed in Appendix 6 were randomly selected, and for each of these five valuations, the initial success probability was either increased or decreased by 10%. Hereafter the effect of a change of the success probability on the valuation under consideration was considered. As can be seen in Figure 13, the effect of a 10% in- or decrease of the success of a phase can have a varying effect, in this case anywhere from 10,2% to 29%.

<table>
<thead>
<tr>
<th>Valuation</th>
<th>Effect on Value for success probability -10%</th>
<th>Effect on Value for success probability +10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valuation 1</td>
<td>-10,2%</td>
<td>+10,2%</td>
</tr>
<tr>
<td>Valuation 2</td>
<td>-11,3%</td>
<td>+10,8%</td>
</tr>
<tr>
<td>Valuation 3</td>
<td>-11,1%</td>
<td>+11,1%</td>
</tr>
<tr>
<td>Valuation 4</td>
<td>-23,1%</td>
<td>+23,1%</td>
</tr>
<tr>
<td>Valuation 5</td>
<td>-29,0%</td>
<td>+29,0%</td>
</tr>
</tbody>
</table>

Figure 13: Robustness test of Success Probabilities

When the results from Figure 13 are analyzed, several statements on the robustness of the valuation model can be made.

First of all, it is logical that success probabilities have a varying effect. Due to possible milestone payments paid during the development trajectory as well as due to different phases which can be adapted, earlier or later in the development trajectory, it is highly unlikely that a constant alteration of a success probability of a phase would always result in the same effect; this expectation is correct as the effect on the value varies from 10,2% to 29%.

Second, the absence of extreme effects, such as effects larger than 100% might be an indicator of the fact that the model is robust. It is reasonable to assume that a 10% in- or decrease of the success probability of any phase might have a profound effect on the company value, but it is hard to imagine a case where all value is lost, or the venture doubles in value. An exception might be a venture which is worth very little, as for such a venture, a small decrease of the success probabilities might cause a venture to lose its remaining value. In that case a small in- or decrease of the success probabilities can have a large effect on the value of the venture. As none of the ventures in this case study is worth very little, the absence of extreme effects is an indicator of the robustness of the model.

Third, the fact that for all cases the positive effect of a 10% increase of the success probability of a phase is almost equal to the negative effect of a 10% decrease is a clear indicator that the model is robust. A valuation model which would value a venture 30% higher in case of a 10% increase, but only 10% lower in case of a 10% decrease is expected to be wrong.

From the discussion of the alterations of the success probabilities above, it can be concluded that our findings are robust.

9.3 Limitations of findings

There are three main limitations to this research; each of the limitations will be discussed in this section.
9.3.1 Amount of data available
Due to a limited time frame, and the research set-up of a case study required to investigate the research question, only a limited amount of data could be collected during this study. As could be seen during the answering of research question 2, each individual case can have an enormous impact on the performance of the real options valuation model; therefore it is impossible to make an accurate estimation of the actual improvement in preciseness of the real options method based on four cases.

9.3.2 Diversity of data considered
During this study, it was chosen to have a focus on biotech ventures. As other types of industries are not considered, it cannot be stated with certainty that no industry specific parameters have to be considered when ventures in different industries are assessed. However, like was discussed during the answering of research question 1B, due to the fact that none of the high potential start-up characteristics defined is industry related it is deemed likely that no industry specific parameters have to be considered when adapting the valuation process.

9.3.3 Market Value
Recent stock transactions were used to determine a market value for the entire company. As was discussed in Chapter 7.4, a stock transaction can only be regarded to be a proxy of the actual value of a company, since multiple factors such as the control premium (Dyck & Zingales, 2002) and illiquidity discount (Damodaran, 2005) are not considered. Due to the fact that a venture has a different value to each stakeholder, no single true value exists; therefore a stock transaction can be regarded to be as good of a proxy as possible.

9.4 Relevance of findings
In this section the relevance of the research findings will be discussed. First the practical relevance will be discussed; hereafter the scientific relevance will be discussed.

9.4.1 Practical Relevance
Due to the fact that research is conducted at PPM Oost, it is possible to employ a research technique called participative observation (Savage, 2000). Through interaction with investment managers at PPM Oost on a daily basis, the possible practical relevance of this research could be determined.

It could be seen at PPM Oost that valuations were performed frequently, for instance when assessing a new venture or when a venture already in the portfolio of PPM Oost applies for additional financing. The motive for valuation was however not solely the determination of an appropriate value. One investment manager was quoted saying: “The most valuable part of a tool like the DCF valuation tool is the fact that you are forced to consider the assumptions which lie behind the actual numbers”, this statement is supported by Damodaran (2009), who stated that it is highly valuable for a user to be forced to specifically consider the values of input parameters. In this sense the real options valuation tool designed is extremely relevant. The tool still requires an investment manager to quantify development expenditures and expected sales, but unlike the DCF tool does not require an investment manager to quantify all accounting data, hence the real options model lets the investment manager focus on the important determinants of value.
Another fact which was noticed through participative observation is the relatively low entrepreneurial spirit and high risk averseness of Dutch VC firms, which by some is attributed to the fact that most Dutch venture capital professionals have their roots in the banking industry. Since risk is quantified explicitly in the real options model, a good insight in the effect of a decrease of risk on the value of the venture can be obtained. This insight will help venture capital professionals to view risk in the correct perspective.

As was stated by Triantis & Borison (2001), one of the most important contributions of implementing a real options approach is the heightened awareness by people involved in a project that an investment can include options, the so called real options thinking (McGrath, 1997). As the real options valuation model designed in this report forces practitioners to specifically consider the options present within an investment, real option thinking is enforced.

One of the outcomes of this study indicates that the decision tree method, which is regarded to be one of the simpler real options techniques, in most cases provides similar results to the more complex binomial lattice method; this result is supported by Steffens & Douglas (2007) who have presented similar findings. This result is highly relevant in practice, as most VC firms will be able to understand and implement the decision tree method and might therefore be inclined to actually use this method.

Obviously the fact that the value of high potential start-ups can be determined more precisely is highly relevant as a better estimation of the value of ventures will in the long run contribute to a better allocation of scarce funds.

9.4.2 Scientific Relevance
As was stated in Chapter 2.2, although theorized, no empirical evidence for the performance of real options theory on a case level was present. As such, this study provides the first empirical evidence on the improved valuation results obtained through the usage of real options theory. This study can therefore be regarded to be the first step in closing an important gap in real options theory.

Throughout literature, various authors have propagated different real options valuation techniques. This study showed, by using two real options techniques in parallel, that the two valuation methodologies deliver the same results for most cases. It might be interesting to investigate whether the valuation methodologies not considered during this report would produce the same results.

Research question 1B resulted in a set of characteristics defined for high potential start-ups which were able to capture the most important venture specific characteristics when red and white biotech ventures were valued. As such, a framework for high potential start-ups is obtained; by valuing ventures in other industries the validity of this framework should be assessed.

As was discussed, prior to this case study no similar case studies had been conducted. The data obtained during this study might therefore be the first step in building a larger database in order to be able to make statistically valid claims on the improvement in preciseness obtained through the usage of the real options methodology.
10. Conclusions & Recommendations

In this chapter the conclusions which can be drawn from this research will be summarized. Moreover, recommendations for further research will be made.

10.1 Conclusions

The goal of this study was to answer the research questions stated in Chapter 2.3. In order to answer these research questions, an analytical framework concerning “real options valuation” and “high potential start-ups” was defined, and based on this framework; a real options valuation tool was designed. This valuation tool was used to conduct four valuation case studies. The valuations which were obtained from these case studies can be seen in Figure 14. Each of these valuations shows how the valuation obtained by the real options valuation model compares to the DCF valuation and a (semi) recent stock transaction, which can be regarded to be proxy for the market value.

![Figure 14: Overview valuations obtained through case studies](image)

The valuation results obtained through the case studies (See Figure 14) where hereafter analyzed. Through this analysis answers to the research questions stated in Chapter 2.3 were obtained. The answer to each research question will be stated below.
Can a valuation process based upon the DCF valuation method be improved by using real options theory to better determine the value of individual high potential start-ups?

From an analysis of the case study results it turned out that for all cases considered the real options method is able to determine the value of individual high potential start-ups equally good or better than the DCF method. Therefore it is stated that the valuation process can be improved by using real options theory to better determine the value of individual high potential start-ups.

Which real options methodology is most appropriate for determining the value of a high potential start-up?

Through reasoning it could be explained that the identical case study results of the decision tree method and the binomial lattice method were a logical result of the correct modeling of both methodologies. Since the decision tree method is argued to be more transparent and easier to implement and adjust than the binomial lattice method, it can be stated that the decision tree method is the most appropriate method. These findings are supported by Steffens & Douglas (2007).

Which factors specific to the venture which is valued, or the industry in which the venture is situated should be considered when adapting the valuation process?

By analyzing the impact of the characteristics of high potential start-ups defined in the analytical framework, it could be argued that all characteristics defined had a profound effect on the valuation results and should therefore all be considered. As no characteristics were felt to be missing during the usage of the valuation tool for the case study, it could be stated that the research trajectory, success probabilities, costs and income of phases, length of phases and commercialization of a venture should be considered when the valuation process is adapted. Due to the fact that all cases involved were biotech ventures it cannot be determined with certainty whether industry specific factors should be considered when adapting the valuation process.

Which factors should be considered in order to promote usage of the new valuation tool and maximize commitment?

As the valuation tool has not been introduced on a full scale at PPM Oost yet, no information on the actual usage of the valuation tool could be obtained. Therefore this research question cannot be answered. It is expected that through checking for feasibility, testing for usability, involving opinion leaders and providing background materials such as a manual, commitment is increased and thereby usage is promoted.

How does the fact that the characteristics of a high-potential start-up are explicitly taken into account in the valuation impact the preciseness of valuation?

Due to the fact that individual cases have an extremely large impact on the measure of preciseness, currently no accurate estimation of the improvement in preciseness can be determined. It can however be seen that when the preciseness is measured as an average deviation of the valuation method from the actual market value, the average deviation of the real options method for the four cases considered is considerably lower than the average deviation of the DCF method. Therefore it can be stated with reasonable certainty that the preciseness of the real options method is considerably higher than that of the DCF method.
10.2 Recommendations for Future Research

Based on the discussion held in the previous chapter as well as the conclusions drawn in this chapter, some recommendations for future research can be presented.

**Usability of the analytical framework across industries**

From the discussion of research question 1B it became clear that it cannot not be stated with certainty that no industry specific factors have to be taken into account, due to the fact that the characteristics of high potential start-ups defined in the analytical framework, were based upon red and white biotech literature (Bogdan & Villiger, 2010) (Schneider, 2009). It would be interesting to see whether the analytical framework is also valid across industries.

**Performance of other real options methodologies**

From the analysis of the decision tree method and the binomial lattice method it became clear that both methodologies produce identical valuation results for the case studies conducted. It would be interesting to research the performance of other real options methods such as the Black-Scholes method, as it theoretically should lead to identical results as the binomial lattice method (Cox et al., 1979), and is extremely easy to use.

**Build a valuation database to determine preciseness**

As this study was the first to collect data on the improvement of the real options valuation method over the DCF valuation method for high potential start-ups on a case level. Only the four case studies conducted in this study could be used to determine the improvement in preciseness obtained when high potential start-up characteristics were specifically taken into account. As can be seen from the analysis of the preciseness (See Chapter 8.3), due to the small data set, individual cases have an extremely large effect. It would be interesting to obtain more data in order to make reliable claims on the improvement in preciseness obtained.
References


PPM Oost (2010) Jaarbericht 2010, PPM Oost

PPM Oost (2009) Rapportage: Waarderingen- & Voorzieningensystematiek


Appendices

Appendix 1: ValuePlan, FactSheets
Appendix 2: Overview of all Input Parameters
Appendix 3: Case PPM Oost Employees
Appendix 4: User Manual of the Excel Valuation Tool
Appendix 5: Evaluation of Case Study Candidates
Appendix 6: Case Studies Conducted
Appendix 7: Robustness Testing
Appendix 8: Scientific Poster

The Value of Real Options Valuation
A Case Study

Introduction
The real options valuation method, a valuation method specifically intended to value high potential start-up companies, it is argued that the real options valuation method should outperform the DCF valuation method as the real options method unlike the DCF method specifically considers strategic flexibility present within an investment opportunity such as the option to abort or expand an investment (Dixit & Pindyck, 1995). Empirical advantages for this claim are only partially available in literature, on a group level it is proven that the real options model outperforms the DCF model (Jonas & Zhadanov, 2008), for individual cases however, no empirical evidence of the relative performance of the real options method and DCF method is present. Therefore the following research question is stated:

Can a valuation process based upon the DCF valuation method be improved by using real options theory to better determine the value of individual high potential start-ups?

In order to answer the research question first the research scope was defined. A venture capital firm was chosen to conduct the research at (FPM Cost), and a focus area within the portfolio of FPM Cost was chosen (Red and White Biotech ventures).

Research Method
Three steps are performed in order to obtain the data needed to answer the research question stated above:

1) Definition of the Analytical Framework
   ➢ Choice of Real Options Valuation Techniques
   ➢ Definition of High Potential Start-Up Characteristics
2) Design Valuation Model
   ➢ Defining of Goal & Assumptions of the model
   ➢ Defining & Implementing the formulas in the model
   ➢ Testing and Improving the model
3) Case Studies
   ➢ Choice of Appropriate Cases
   ➢ Execution of Case Studies
   ➢ Collection of Comparable Valuations Data

Results Case Studies
In Figure 1, the results from the case study can be seen.

Figure 1: Overview all case study valuations
Description: For each case study conducted, the lowest real options valuation is presented as a 100% mark, all other valuations are adjusted accordingly. Both real option valuation techniques selected in the analytical framework provide identical results.

Conclusions
From an analysis of the case study results shown in Figure 1, the following conclusions can be drawn:

A valuation process can be improved by using real options theory to better determine the value of individual high potential start-ups.

The Decision Tree method and Binomial Lattices method provide identical results in most cases. Since the Decision Tree method is more transparent and easier to implement, this method is most appropriate.

The high potential start-up characteristics defined in the analytical framework (Research Trajectory, Success Probabilities, Length of Phases, Costs and Income of Phases, Commercialization) are able to capture the most relevant start-up characteristics to consider when adopting a valuation process.

References: