START-UP VALUATION OF BIOTECH COMPANIES WITH REAL OPTIONS

A case study of the start-up Organovo Holdings, Inc.

Master Thesis HEC Paris

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Abstract: This master thesis examines several valuations methods for young companies. Start-ups are generally characterised by negative earnings, pure equity financing and binary business models. Traditional valuation methods, such as the Discounted Cash Flow, valuation multiples or comparable transactions, cannot be applied due to start ups' high degree of uncertainty, short histories, volatile discount rates and little publicly available data on financials, comparable companies or comparable transactions. Consequently, new valuation methods, e.g. the Venture Capital method, the First Chicago method, the Damodaran approach and Real Option valuation, will be presented and directly applied to the 3D bioprinting start-up Organovo. The new valuation methods take the uncertainty of start-ups into account and allow more flexibility regarding timing and investment decisions. On top of this, the valuation of intangible assets is shortly discussed, as it is especially important for start-ups with a strong intellectual property portfolio. This master thesis also highlights non-financials factors in valuation, since the personal skills and experience of the founder and management team can have a large impact on the start-up's value. The author concludes by proposing several areas of further research which will help to improve the current understanding of start-up valuation.

Key words: Start-up valuation, biotech start-ups, new valuation approaches, start-up value, start-up discount rate, Damodaran valuation, First Chicago Method, Venture Capital Method, Real Option valuation, 3D bioprinting, Organovo

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1. Introduction

Everything that can be counted does not necessarily count;
everything that counts cannot necessarily be counted.
- Albert Einstein

Especially due to the skyrocketing valuations of young companies, such as Uber ($62.5bn), AirBnB ($25.5bn) and Palantir ($19.6bn), many start-ups have been chasing billion-dollar "unicorn" valuations. Venture capitalist are searching for innovative ideas, excellent management skills and great business models to make their investment the next huge success. Start-ups in the areas of financial technology, the Internet of Things and digital health are trending at the moment, as more and more graduates are inspired by the infamous growth stories of start-ups like Facebook, Dropbox and Snapchat. However, veterans, such as Bill Gates, warn to be cautious with unicorn valuations, because young companies, like payment provider Square and cloud storage company Box, just to name a few examples, have been disappointing investors with high stock market fluctuations.

Determining the financial value of the company becomes an inevitable question for founders and investors, when agreeing on giving away a specific percentage of the founders' start-up for a specific amount of investment. Several websites, such as YouNoodle, claim to predict the start-up value through an algorism, which allocates a certain value after answering a number of questions online. But is start-up valuation that simple? Clearly, assessing the value of an early stage growth company is not easy, mainly due to the short financial history, uncertain growth potential and little comparability to listed companies or past transactions. Therefore, more and more investors as well as founders are wondering: How can a start-up actually be valued adequately? The aim of this research paper is to assess which methods are most applicable for start-up valuation and come up with a valuation method for biotech companies through a case study of the American 3D human tissue bioprinting start-up Organovo.

The first part of this thesis will highlight current research, existing literature and several valuation techniques. After first introducing general characteristics of start-ups, including life stages and financing, the traditional valuation methods will be discussed. Since these methods cannnot be used for start-ups, alternative methods for valuing young companies will be presented. These new methods will take the shortcomings and main characteristics of start-ups, i.e. no history, negative earnings and fully equity finance, into account. Different valuation methods, such as the venture capital method, the Damodaran approach and the real options approach, will be discussed and their limitations highlighted at the end of each section. To make this thesis as practical as possible, the new valuation methods will be directly applied to the case study of Organovo. After introducing the company, its strategy, financing and market, Organovo will be valued on the basis of the proposed methods. Other important non-financial factors will be discussed before concluding about start-up valuation and proposing future research for this field.

2. Start-up characteristics and development stages

Start-up companies are difficult to value for a number of reasons. A start-up is characterised by having little or no revenue, negative cash flows, being mostly loss making, having short histories, a binary business model and being dependent on equity financing (Damodaran, 2009). Generally, start-ups are facing extreme volatility of capital employed, as most of the economic model still has to be built (Vernimmen, 2014). This leads naturally to a lot of volatility and uncertainty regarding the valuation of a particular start-up, especially since most of the start-ups fail in the primary business phase and only a little percentage of start-ups survive.

Knaup and Piazza (2007) have published a study on the longevity of start-ups in different sectors that shows on average only 44% of start-ups survive through the fourth year and 31% through the seventh year. The rate of failure decreases at a decreasing rate, meaning that the longer a start-up survives, the better the chances of growth in sales and employment. The following table (Knaup & Piazza, 2007) gives an overview of the statistics of start-up survival as a proportion of firms that survived through the year with 1998 as a base year.

Sector	First year (1999)	Second year (2000)	Third year (2001)	Forth year (2002)	Fifth year (2003)	Sixth year (2004)	Seventh year (2005)
Natural resources	82.3%	69.5%	59.4%	49.5%	43.4%	39.9%	36.6%
Construction	80.7%	65.8%	53.6%	42.6%	37.0%	33.4%	30.0%
Manufacturing	84.2%	68.7%	57.0%	47.4%	40.9%	37.1%	33.9%
Transportation	82.6%	66.8%	54.7%	44.7%	38.2%	34.1%	31.0%
Information	80.8%	62.9%	49.5%	37.7%	31.3%	28.3%	24.8%
Financial activities	84.1%	69.6%	58.6%	49.3%	43.9%	40.3%	36.9%
Business services	82.3%	66.8%	55.1%	44.3%	38.1%	34.5%	31.1%
Health services	85.6%	72.8%	63.7%	55.4%	50.1%	46.5%	43.8%
Leisure	81.2%	65.0%	53.7%	43.8%	38.1%	34.6%	31.4%
Other services	80.7%	64.8%	53.3%	43.9%	37.0%	32.3%	28.8%
Total start-ups	**81.2%**	**65.8%**	**54.3%**	**44.4%**	**38.3%**	**34.4%**	**31.2%**

Table 1: Start-up survival probability per industry

While it takes some time until start-up companies grow into established businesses, the young companies go through different stages. The early stages of the life cycle of start-ups can be illustrated as follows (Damodaran, 2010):

- Idea companies: During the first phase, the founders start working on their idea, which needs to be tested to see whether further investments are worthwhile. No revenues are generated, since the product first needs to be fully developed. The development and testing costs a lot of money, which is why the company incurs high operating losses. Without doubt, this is the riskiest investment period, since the product still needs to be fully developed, tested and launched on the market.
- Start-up companies: At this point the start-up is able to launch their product and have its first paying customers. Although some revenue is generated,

losses are increasing due to higher cost of development, marketing and growth. At this stage, start-ups have proven to be able to market their product, however, still need to become profitable in order to survive in the long term.

- <u>Second stage companies:</u> In this stage the company is able to further increase their revenues and finally reach the point of making profits. The company is characterized by an established operating history and business model, being able to further decrease their losses. Second stage companies tend to look for access to capital markets through an Initial Public Offering (IPO) in order to further expand their business.

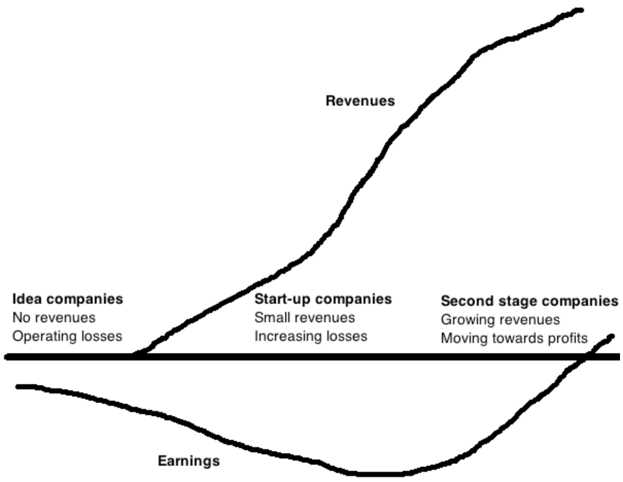

Figure 1: Different stages of start-up development (Damodaran, 2010)

Investments in start-up are generally illiquid, because the investment are mostly privately held and during several rounds different terms negotiated. Depending on the risk profile, investors demand a different return. At each financing round, the start-up needs to be valued and dilution of existing investors carefully dealt with. From the founders' perspective, the goal is to get as much funding from new investors to rapidly increase the growth, while giving away as little ownership as possible. From the investors' perspective, the goal is to invest at a relatively low price for a relatively large stake in order to sell their stake at a higher price in future.

Damodaran (2012) identified several types of risk which can be associated with start-up companies. First, small companies have a lot less information available than large public companies, thus investors in start-ups face information risk. Furthermore, since most of the value will be generated in future, start-ups face a lot of uncertainty and the value is mostly determined on the expected growth potential. However, in most of the cases, the start-up faces problems during their initial phases and investors face unpredictable growth risk. Third, investors can mostly only invest or divest during financing rounds and cannot freely choose when to buy or sell part of their stake. Most of these investments are very illiquid, since they are privately held, which makes the investment process even more difficult. Therefore, start-ups often have to apply an illiquidity discount, since investor face liquidity risk. Because of information, growth and illiquidity risk, venture capitalists require a higher rate of return of around 20% - 30% for start-up companies (Damodaran, 2012). Dealing with uncertainty and the aforementioned risks are some of the key challenges in start-up valuation. Several traditional models might not be applicable, while new methods to value start-ups have to be discovered. In the following chapter the limitations of traditional valuation techniques will be discussed.

3. Limitations of traditional valuation techniques for start-ups

First of all, valuation of start-ups is difficult due to the uncertainty of the business model, which translates into uncertainty of future revenues, cost and earnings. In addition, since the ideas or technologies created within the start-up are relatively new, it is hard to estimate the future growth, cash flows and investment requirements. The value is captured in several intangible assets, which sometimes might not even appear on the balance sheet. Moreover, due to the loss making nature of start-ups, most of the value lies in the terminal value, which again the longer the time horizon, the more uncertain the forecasts. But even more important, due to negative earnings and negative cash flows, both enterprise as well as equity multiples cannot be applied, unless projected future values are used. The study of Black (2003) has shown that earnings do not provide significant information for valuation of start-ups, but become more important once the firm picks up growth. Eventually, information asymmetry exists between the company's founder and the investors, because the investor is looking for information that allows him to pay as little as possible for a potential share, while the owner is aiming to convince the investor of his high growth prospects in order give as little ownership as possible away.

Thus, the characteristics of start-ups, e.g. loss making, short history, only equity financed and binary business model, make it especially difficult to use valuation methods, normally applied to value a company. The following section will quickly explain why certain methods, such as the discounted cash flow method (DCF), trading multiples and transaction multiples cannot be used and why the discount rate needs special attention for start-up valuation.

a) The discounted cash flow method

The Discounted Cash Flow (DCF) method values the company as a whole by discounting the free cash flows to the firm (FCFF) with the company's weighted average cost of capital (WACC). The shareholders' equity is calculated by deducting the net debt from the enterprise value of the DCF. The enterprise value can be calculated as follows:

$$Enterprise\ Value\ (EV) = \sum_{t=0}^{\infty} \frac{FCFF_n}{(1 + WACC)^n}$$

$$WACC = k_E\ x\ \frac{V_E}{V_D + V_E} + k_D\ x\ (1 - t)\ x\ \frac{V_D}{V_D + V_E}$$

with k_E being the cost of equity, k_D the cost of debt, t the tax rate, V_D the net debt value and V_E the equity value.

The cash flows are projected for a certain number of n years, depending on the industry. For the cash flows generated after the forecasted period, a terminal value (TV) will be calculated. The value of the company is the sum of the present values of after-tax cash flows for a specific amount of n years and the terminal value at the end of the forecasting period (Vernimmen, 2014). The free cash flows are calculated as follows (Beneda, 2003):

$$\begin{gathered}\boldsymbol{Free\ Cash\ Flow\ to\ the\ Firm\ (FCFF)} = \\ Operating\ income\ (EBIT)\ x\ (1 - Tax\ rate) \\ - Capital\ Expenditures \\ + Depreciation\ and\ Amortization \\ - Change\ in\ Net\ Working\ Capital\end{gathered}$$

The terminal value at the end of the forecasting period can either be calculated with the terminal multiple method or the perpetuity growth method. The terminal multiple method uses an average multiple from selected companies' trading multiples and multiplies the multiple with the projected financials of the last forecasting period:

$$TV = Terminal\ Multiple\ x\ Corresponding\ Financials\ for\ final\ forecasting\ period$$

These are mostly enterprise value multiples, such as EV/Sales or EV/EBITDA, since the DCF method values the whole company and not only the equity, which will be the case for equity multiples, such as the Price-Earnings-Ratio (P/E).

The terminal value based on the free cash flow at the end of the forecasting period assumes that the company will growth continuously and generate FCFF for perpetuity. The perpetuity growth rate g is typically the historic inflation rate or the historic GDP growth (Vernimmen, 2014). In case the growth rate is bigger than one of the two values, the company is expected to outgrow the economy forever. The formula for the terminal value with free cash flows to the firm is calculated as follows:

$$TV = \frac{FCFF_t\ x\ (1 + g)}{WACC - g}$$

Especially in case most of the cash flows are generated after the forecasting period, the terminal value of the company makes up a big part of the valuation. A DCF valuation is based on the past company history, its weighted average cost of capital and future growth assumptions. For start-ups, however, the intrinsic valuation applied in the DCF method cannot be used due to several reasons:

- No history: Young companies with a limited history mostly only have one or two years of data available. The basis of a DCF is to forecast the growth, but with no information from the past, this growth forecast becomes very subjective (Damodaran, 2009). Especially with regards to existing and growth assets, start-up companies face problems coming up with an accurate and realistic reinvestment and growth rate.

- Little or no revenue: In the first years, most start-ups generate significant operating losses and negative cash flows, which are mainly associated with the cost of setting up the business. Establishing a useful operating pattern and thereby growth rate for the DCF is therefore impossible, especially since small changes in the input parameters can lead to significant changes in the overall values (Kotova, 2014).

- Binary business model: A lot of uncertainty regarding the future of the business exists, with up to 56% of businesses failing in the first three years (Knaup & Piazza, 2007). The DCF mostly only takes one scenario into account, which does not fit the binary business model of start-ups. Therefore, the valuation method used for start-ups has to be as flexible as possible, allowing the investor to take different scenarios into account.

- Timing: The DCF approach is very sensitive to the time to market of start-up companies. High-tech or pharmaceutical development projects have long time horizons of up to 30 years. With the valuation of the DCF approach none of these project would be started due to the high uncertainty and long period without positive cash flows (van Schootbrugge & Wong, 2013). The DCF approach fails to include value generate in far future and therefore is not suitable for start-up companies.

- Rigid model: Van Schootbrugge and Wong (2013) reveal that the DCF approach does not include enough flexibility for optional expansion strategies. In case a start-up learns from it initial mistakes, the market strategy can be significantly changed and investment reallocated to other products which have proven to be successful. The option to reallocate, expand, contract or delay investments has actually a large value, which will be discussed in detail during the later sections.

- Discount rate: The greatest challenge with the DCF model is to set one discount rate for the whole model, which is nearly impossible for start-ups with varying degrees of risk through the different development stages (van Schootbrugge & Wong, 2013). Furthermore, regarding the calculations of the discount rate, the beta of equity is usually estimated by regressing the returns of a stock against the market index and cost of debt by comparing market prices of the publicly traded bonds (Damodaran, 2009). Since start-ups are mostly not publicly traded and have not publicly traded bonds outstanding, it becomes difficult to estimate a discount rate. In addition, most start-up companies are only equity financed, with equity coming from several source with different terms leading to several cost of equity depending on the investors. Because estimating the discount rate poses several challenges, this issue will be investigated into detail at a later stage.

- Terminal value: For well established companies the terminal value accounts already for a large proportion of the overall value, thus for a start-up it can happen that the terminal value accounts up to 90% or 100% of the value (Mills, 1998). The assumptions of the timing of stable growth and the growth rate itself have a substantial impact on the terminal value of the start-up. It remains, however, questionable whether the start-up will reach a stable growth rate, when the start-up will reach a stable growth rate and how the start-up will look like in stable growth. Due to the high failure rate of start-ups, estimating the probability of survival is more vital than the stable growth rate it may reach. Furthermore, depending on competition, the timing of reaching the stable growth rate can vary significantly. It is therefore important to make the right assumptions for their stable growth rate, which will be very subjective, taking into account that start-ups lack historical data (Beneda, 2003).

- Allocation of equity value: For public companies, with one or very few classes of shares, the equity can be easy divided on a proportionate basis. Start-up companies, however, face several issues when allocating the equity claims: Multiple rounds of financing from private investors, contrary to the public market, can result in different terms and priority agreements for later financing rounds. Equity claims on cash flow and control of the start-up may differ with regards to preferential rights for primary investors. Eventually, the investors mostly demand rights protecting their interest in new financing round or investment decision, making it hard for the management of a start-up to maintain flexibility regarding the future of the company. Eventually, the illiquidity of equity in start-ups impact the difficulty of measuring the right value of equity attached.

b) The multiples method

Next to the direct valuation methods, such as the DCF method, several relative valuation methods exist. Relative valuation methods rely on multiples, which are financial ratios that have been calculated through a sample of comparable companies. Two basic categories of multiples exist (Vernimmen, 2014):

- Price multiples: These multiples are used to calculate the market capitalisation of a company directly. The most common multiples are the price-to-earnings ratio (Equity value/PER) or the price-to-book ratio (Equity value/PBR).

- Enterprise multiples: These multiples don't consider the capital structure of a company and are used to calculate the entire value of the company, the enterprise value (EV). The most popular multiples are the EBIT multiple (EV/EBIT), Sales multiple (EV/Sales) or EBITDA multiple (EV/EBITDA).

It is important that the sample of comparable companies to calculate the multiple is carefully selected and matches the company that needs to be valued. Since the intrinsic valuation methods, such as the DCF, cannot be used for start-up valuation due to reasons mentioned above, the following passage will investigate whether comparable methods are more helpful. The following factors explain why the valuation of start-up companies using multiples will be equally difficult:

- Comparable companies: Relative valuation techniques are used to value a company with publicly traded comparable companies of equal size in a similar industry. Start-up companies should therefore be compared with other small companies, which are usually not publicly traded. The computation of multiples will be difficult, partially due to very limited access to financial information and non existent market prices. As an alternative, start-ups can be compared with publicly traded companies in the same sector, but for this it is important to take into account that these firms have different risk, growth and cash flows compared to the start-ups.

- Common measure: The multiples computed from a set of comparable companies need to be scaled to a common measure in order to value a target company. For larger companies this does not pose a large problem, for start-ups, however, common measure such as EBITDA, EBIT or P/E ratio are mostly negative. In addition, the book value is very small compared to the capital invested, cash flows negative and revenues very small, thus, multiples for negative measures will not result in a meaningful valuation.

- Risk adjustment: In relative valuation market based risk, e.g. beta or standard deviation of equity returns, are used as a proxy for risk (Damodaran, 2009). For start-up companies the risk measurement is difficult. Standard deviation of financials could be used, but due to the short histories an objective risk adjustment is hard to estimate.

- Probability of survival: Start-up companies have a high probability of failure, adding more risk to the transaction. When comparing large public companies with start-ups for a multiple valuation, this risk needs to be taken into account. Start-up companies should therefore be valued substantially lower, since they have a smaller chance of surviving compared to bigger companies with an established product portfolio. An idea would be to lower the multiple by a certain threshold, but depending on the likelihood of the start-up this needs to be assessed on an individual basis.

- Timing: The development of a start-up to a comparable listed company will take time. By the time the start-up reaches that stage, the market may have completely changed and so may the multiples have changed (van Schootbrugge & Wong, 2013). Therefore, the start-up should be valued on forward looking multiples, but since the start-up might need approximately ten years to fully develop, these forward looking multiples might not exist.

- Illiquidity and equity claims: Difference in cash flow and control claims can have an effect on the value of the equity claims each investor is entitled to. When valuing a start-up with a relative valuation method, the illiquidity issue and equity claims based on different term from various financing rounds still need to be taken into account.

The arguments above show that the multiples method not appropriate for start-up valuation. In order to overcome the challenges mentioned, venture capitalists should use forward revenues or earnings when valuing start-ups. For this, however, multiples for same time period as the forward revenues or earnings need to be considered. This leads to even more complexity and uncertainty when forecasting both financials as well as multiples for the start-up valuation. To conclude, despite the ease of the comparable method, this valuation technique does not seem very applicable for start-ups, mainly due to the difficulty in comparison with regards to comparable companies, common measures, risk adjustment and equity claims (Damodaran, 2011).

c) The transaction method

The transaction method uses a sample of recent transactions to calculate the average multiple which can be used to attain the enterprise or equity value of the target. Contrary to the methods mentioned before, the multiples calculated through the transaction method include the control premium the acquirer had to pay to obtain control of the target (Vernimmen, 2014). Therefore, the price paid includes the anticipated synergies and premium paid for the company. Although both conventional methods above have proven to be hard to use for start-ups, the following paragraphs will investigate the usefulness of the transaction method for start-up valuation:

- Private transaction multiples: Before going public, start-ups are valued and shares purchased through private instead of public transactions. In theory, Damodaran (2009) emphasises that start-ups need to be valued on the basis of private transaction multiples of private companies similar to the company in question. The following challenge about data availability will highlight why this is nearly impossible.

- Availability of data: Start-ups are mostly financed by private investors, such as private equity, family, friends or founders. During the financing rounds, the data is only available for the investors and not to the general public. Well-known databases consequentially do not have access to this sensitive information. Therefore, getting access to comparable private transactions is very difficult. Furthermore, financing is very subjective and depends on the financing round, as for various rounds, different terms are attached to the investments. The lack of organised databases makes it impossible to use private transactions to value start-ups.

- Transaction specific information: Especially transaction multiples often contain very specific information, which is not at arm's length. Consequentially it will be hard to compare the private transaction multiples and establish a meaningful multiple for valuation from it. For instance, an acquirer might pay more because the key person decides to stay for a transition period instead of leaving the company. Thus, this company sensitive information is hard to compare when taking the private transaction multiples into account.

- Time lag: Private transactions do not take place very often. It is hard to find several transactions taking place in the same time frame. Establishing meaningful multiples which can be applied to other start-up companies is therefore difficult.

- Geography: Most comparable private transactions in big databases only cover transactions taking place in the United States. This could be due to an absence of data in other places or due to a transaction concentration in the US. When a start-up from an emerging market needs to be valued, this data base is of little value. Unfortunately, the geographic concentration of private transactions taking place in the United States further limits the transaction method.

- Comparable measures: For publicly traded companies comparing transaction on basis of EV/Revenues, EV/EBITDA or PE ratio is relatively easy since the multiples simply reflect the value of a comparable transaction. For start-ups, however, these measures are not meaningful, since revenues are non existent, EBITDA mostly negative and PE ratios do not exist. The current financials are simply not a good indication for the future potential of a company, consequentially using multiples on the current financials will not provide powerful results. Furthermore, for start-up companies the accounting principles might not be as comparable as for bigger companies. Thus, the bottom line will show different results, depending on which accounting standard is used, leading to greater difficulty in comparing the results.

- Equity proportion: For start-up companies the equity claims are depend on the cash flow, control claims and illiquidity (Damodaran, 2009). Consequently, the equity price of one start-up may not be compared to the equity of another start-up. Thus, for the reason for the premium or discount paid needs to be considered when valuing a start-up with comparable transactions.

Private transaction multiples have proven to be very difficult to use for an objective valuation of a start-up company. There are several remedies and other valuation methods, which will be described in the subsequent section. Before that, however, the author will take a closer look at the difficulty of estimating the discount rate for start-ups.

d) The discount rate

A crucial part of the valuation process is discounting the future cash flows with the discount rate. For mature companies, the discount rate corresponds to the weighted average costs of capital, which consists of two parts, the cost of equity k_E, which is calculated with the capital asset pricing model (CAPM) and the cost of debt k_D:

$$WACC = k_E \ x \ \frac{V_E}{V_D + V_E} + k_D \ x \ (1-t) \ x \frac{V_D}{V_D + V_E}$$

with t being the tax rate, V_D the net debt value and V_E the equity value.

$$Capital \ Asset \ Pricing \ Model \ (CAPM) = k_E = r_f + \beta_{security}(r_m - r_f)$$

with r_f being the risk free rate, r_m the expected return of the market.

$$k_E = r_f + \beta_{security} x MRP = r_f + ERP$$

with MRP being the market risk premium and ERP the equity risk premium.

When the debt to equity ratio of the company is expected to change over time, the levered beta β_L will also change. The beta will, therefore, first need to be unlevered β_U and then re-levered with the appropriate debt to equity ratio:

$$\beta_U = \frac{\beta_L}{1+(1-t)x\frac{D}{E}} \text{ and } \beta_L = \beta_U x \left[1 + (1-t)x\frac{D}{E}\right]$$

The traditional approach of calculating the discount rate, however, cannot be used due to several reasons:

- Cost of equity: First of all, most start-ups are not publicly traded companies, therefore estimating the start-up's beta through stock prices will not work. Moreover, young companies are often held by undiversified owners. Thus, the cost of equity should include both the market risk and the firm specific risk.
- Cost of debt: Most start-up companies are fully equity financed, because they will not have the possibility to take out a loan or issue bonds to the public. Therefore, no bond ranking will be available, which measures the default risk of a start-up. Furthermore, banks will probably charge a premium on any synthetic ranking a start-up can gain, simply because the young companies are mostly loss making, have no guarantees and no proven business model.
- Debt-Equity ratio: Young start-ups which are not traded do not have market data on debt and equity available that can be used to calculate the debt equity ratio. Even more important van de Schootbrugge and Wong (2013) is convinced that start-ups have changing levels of risk and therefore changing

cost of capital during the different the development stages. Due to permanent risk shifting the discount rate needs to be adjusted over the years contrary to the DCF method (Sahlman, 1987).

For venture capitalists, discount rate should correspond to the rate of return that is required. Since higher risk requires higher return, this rate is different for start-ups compared to mature companies. The following paragraphs about financing will give an overview of the required rate of return demanded by investors at the different stages. Furthermore, throughout the different stages of start-up development, there are different sources of financing used. Generally, start-ups are dependent on private equity, since no banks will be willing to offer loans due to the low probability of being paid back, when no revenues are generated. Therefore, in the initial phase, most start-up companies are privately owned or funded, usually by their founder, family or friends and business angles. In the seed stage, the company is conducting market research, developing their idea into a product and spending their funds on R&D. Generally, only small investments of between €25,000 and €300,000 are made in order to support the entrepreneurs explore their ideas, write a business plan and recruit key management (Sahlman, 1987). However, investors apply discount rates of over 80%, mainly due to the high risk and little development. Seed investors, however, provide basics business advice to ensure their money is not completely lost.

During the next stage, the start-up starts generating first revenues, but increasing losses. Since high expenses are incurred and the business model has not been fully developed yet, the start-up is entering in the valley of death, where survival is very unlikely. During the start-up stage the company has been able to enter the market with their product and generate the first revenues, even though it has not been profitable yet. Careful market research, detailed business plan and all necessary documentation will allow the start-up to break even at the end of this phase. Start-up financing includes more significant funds in order to finance operations and properly bring the product on the market. Discount rates of investors range between 50% and 70% (Sahlman, 1987).

To continue, during the early growth stage the start-up will need more external funds to finance their growth. This is mostly supported by venture capitalists, who will invest during one of the financing rounds. First-stage investors are often more involved, by monitoring closely the start-up's sales levels and headcount ratio, filling key management positions and searching for new staff. Discount rates are between 40% and 60% (Sahlman, 1987). Moreover, second-stage investors are more involved in expansion. Their capital is needed to improve products, tap new markets, establish new operations and finance working capital requirements. Due to higher amount of assets and lower risk, the required rate of return decreases slowly to 30% to 50% for second-stage investments (Sahlman, 1987).

At a later stage, the start-up is growing further, even though at a lower rate than before. Debt and mezzanine financing becomes available, as the start-up is generating stable revenues and has developed a history of increasing financials. Venture capitalists exit the company at the stage where the start-up is taken public through an IPO. Usually, this takes between five to ten years from their initial investment. Bridge financing will help the start-up to overcome the phase until the IPO, which is generally only suitable at the right market timing with regards to the performance and size of the start-up. Bridge investors are generally passive investors with a discount rate of 25% to 30% (Sahlman, 1987).

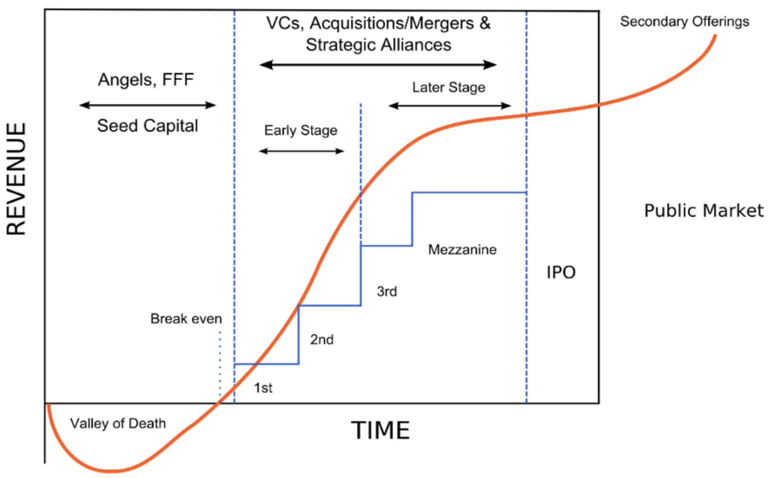

Figure 2: The start-up financing cycle

The DCF approach has shown not to be flexible enough for varying discount rates and venture capitalists are using too high discount rates through their required rate of return. Since finding the discount rate of a start-up is a crucial point in the present value calculation, the exact approaches for start-up valuation will be discussed in the next valuation part in detail. These new approaches suggested for start-up valuation need to take the flexibility, uncertainty and varying level of risk of start-ups into account.

To conclude traditional valuation techniques cannot be directly used to value start-up companies. Often times, traditional methods do not consider the value of intangible assets, unrecorded assets or self-created assets, which are key to start-ups. The start-up valuation will therefore focus on the estimation of future earnings instead of relying on historical financial statements. Furthermore, other non-financial parameters will also be considered, as the management team can add substantial value to the start-up, with most venture capitalists being very concerned about the power of the founders to succeed with their ideas (Goldman, 2008). The following paragraph will therefore first introduce the start-up that will be valued before going into depth regarding new valuation methods suitable for start-ups.

4. Introduction of the case study Organovo Holdings, Inc.

In order to put theory into practice, the methods used for start-up valuation will be directly applied to a case study. Due to limited data availability of unlisted companies before the IPO, a listed company with the characteristics of a start-up, e.g. loss making, short history, solely equity finance and uncertain business model, was selected. Due to the authors sincere interest in ground-breaking biotechnology, Organovo Holding, Inc., a start-up from the US that designs and creates functional human tissues using proprietary three dimensional bioprinting technology, will be studied in the next paragraphs. To begin with, a quick overview of the company and its strategy will be presented. Afterwards, the author will analyse Organovo's financials and market before introducing several valuation techniques that can be used for start-ups.

a) Company overview and strategy

The following part will first describe Organovo's business activities, afterwards the different products, the company's milestones and its strategy for the future. To start with, Organovo has developed a 3D bioprinting technique for human tissue that can be used in drug discovery, development, biological research and regenerative medicine. The main aim is to reproduce living human that that accurately functions like native tissue. Organovo holds a lot exclusive commercial rights to patented 3D bioprinting technology, which was derived from research led by Dr. Gabor Forgacs, a professor of biophysics at the University of Missouri. As part of their business strategy, the start-up intends to pursue collaboration agreements with drug development companies to further develop their 3D bioprinting technology. The patented printing process can be described according to the company's website as follows:

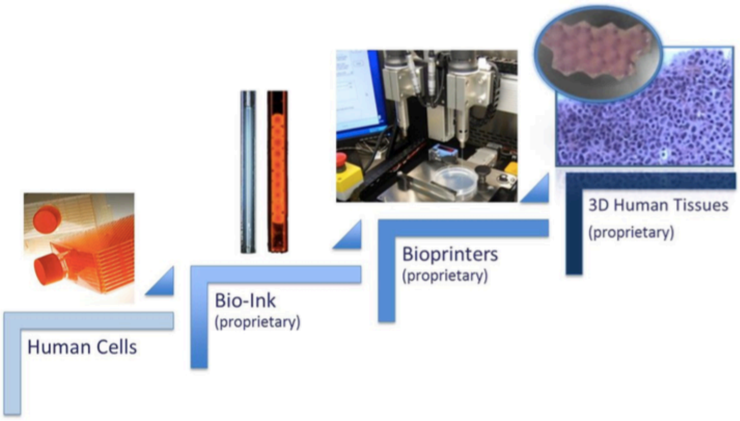

Figure 3: Organovo's bioprinting process

These milestones highlight the development of Organovo:

- **2007: Foundation:** Organovo, Inc. is officially incorporated intending to use the patent of Professor Gabor Forgacs for their 3D bioprinting
- **2008: Funding:** The start-up manages to raise $3m in angle financing
- **2009: Bioprinter:** Organovo opens its first laboratory in San Diego, United Staes and completes together with Invetech their first bioprinter
- **2010: Blood vessels:** The start-up manages to create their first blood vessel, by only using primary human cells

- **2011: Partnerships**: Organovo starts first partnerships on drug discovery
- **2012: Public:** The start-up goes public through a $15m financing round and issues two new patents
- **2013: NYSE:** Organovo is listed on the New York Stock Exchange and closes a $47m secondary public offering
- **2014: Liver:** The start-up successfully launches the the exVive3D™ Human Liver Tissue and collaborates with Yale University to develop 3D organ tissues for transplantation research
- **2015: Skin:** L'Oreal partners with Organovo to create 3D bioprinted skin tissue for their R&D, at the same time Organovo closes a $40m secondary public offering
- **2016: Kidney:** Organovo is looking to bring its 3D bioprinted kidney tissues to market in September 2016

Organovo operates in an attractive and growing market, where they managed to gain the first mover advantage with their innovative technology and strong portfolio of intellectual property (IP). Customers include major pharmaceutical companies and academic institutions, such as Merck, L'Oreal or Harvard Medical School. With Organovo's products, these companies will be able to validate more predictive tissues for disease modelling, test drugs on functional human tissues without administering the drug on a living human and implant three dimensional tissue into the human body in order to replace damaged or diseased tissue. Clinical tests have revealed that drugs failed mostly due toxicity, i.e. unknown adverse effects of chemicals on living organisms and lack of efficacy. Organovo's products will therefore address the gaps in pharmaceutical in vitro - tested in a laboratory - and in vivo - tested in living organisms - preclinical research, lower the development costs for drugs significantly and provide new ground-breaking techniques which can fill the high demand for human implants.

Organovo's core business is focused on recreating 100% cellular native tissue architecture for in vitro and in vivo applications. Their business established from the need for more predictive preclinical tissue models, for tissue that replaces or repairs organ functions and the need for lowering the high R&D cost of pharmaceutical companies. The focus areas are skin, liver and kidney with efficacy models leading to decreased cost, increased predictability and quicker drug discovery through partnerships and revolutionizing "tissue-on-demand" 3D printing of implants for clinical and educational use. These three 3D bioprinted tissues have been brought to the market and the preclinical human tissue system successfully launched. So far the products have been excellently matching the human tissue by correctly revealing the toxicity of a drug. According to Pfizer's annual report, this is very critical for huge pharmaceutical companies, as Pfizer itself had to pay $750m in legal cost and $136m in market withdrawal cost for their toxic Troglitazone drug, known for prevalence of adverse liver effects. Therefore, several opportunities arise for Organovo, which will be discussed in the market analysis.

The strategy of the young start-up is to use their unique 3D bioprinting technologies to print first, 3D human tissue for preclinical assessment of drugs in a commercial approach, second, print highly customized disease models of human tissues for drug discovery through partnerships and third, print on demand tissue for clinical application and implants. Their strong intellectual property portfolio is key to the company's success. Organovo owns or exclusively licenses over 25 patens world wide, with more than 80 patent applications pending. These patent filings relate mainly to bioprinting technology and its various uses in tissue creation, use in drug discovery and specific tissue construct. Organovo's key objectives is therefore to strengthen its position in its core business activities and further expand by developing new human tissues, contracting new partnerships for cost saving efficacy models and creating successful collaborations with research institutions for 3D bioprinted implants.

Although Organovo unique technology for 3D bioprinting has disrupted the market, several competitors are trying to recreate their technology. On the one hand, large pharmaceutical companies, such as Eli Lilly, Abbott Laboratories, Sanofi and Pfizer, are main competitors, not necessarily specialized in 3D bioprinting, however, with bigger financial and technical resources than Organovo. On the other hand, innovative start-ups focused on 3D bioprinting exist across the world, with Japanese Cyfuse Biomedical, American BioBots and Russian 3D Bioprinting Solutions being direct competitors of Organovo.

b) Financial and market analysis

Financial analysis

Revenues increases almost 50% from 2014, mainly due to the increase of \$0.3m in commercial revenues since the product launch in 2014 offset by the \$0.1m decrease in revenues after the company's completion of one of the research agreements. Operating expenses increases by \$9.9m or 47% from 2014 to 2015, which can be split in a \$5.0m increase in selling, general and administrative (SG&A) expenses and \$4.9m increase in investment in R&D expenses. The increase in R&D expenses is mostly attributed to the increase in research staff from 32 full time employees (FTE) in 2014 to 54 FTS in 2015. SG&A expenses increased mainly due to additional staff to support the infrastructure collaborative relationship and preparation for commercialization of products and services. As most other start-ups, Organovo has large operating losses, i.e. \$25.8m in 2014 and \$30.1m in 2015.

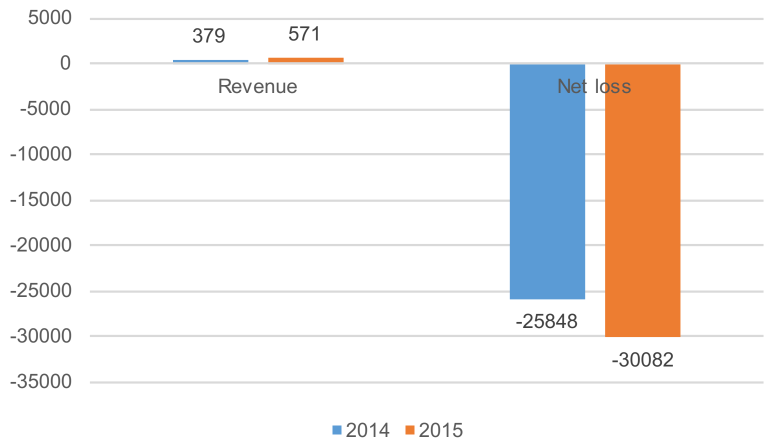

Figure 4: Organovo's revenue and net loss for 2014 and 2015 in $k

Since its inception the company has been loss making, with losses per share of $0.35 in 2014 and $0.38 in 2015. Organovo's ROE has been slightly increasing from -78% in 2014 to -62% in 2015. This is typical for a start-up company, where investors invest not in order to make short term returns, but hope that their investment will gain substantial value over the long term.

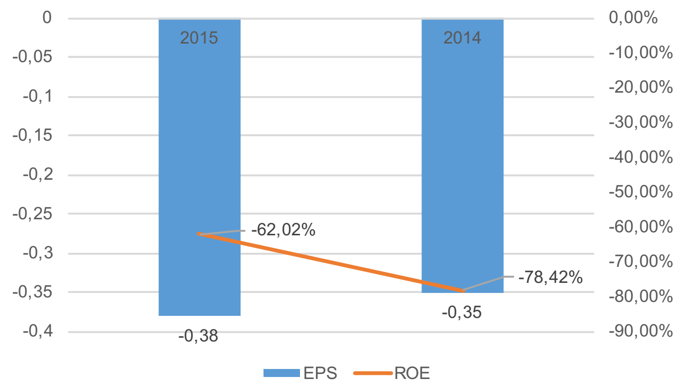

Figure 5: Organovo's EPS and ROE for 2014 and 2015 in $ and %

Organovo's assets are made up of largely cash and only a small proportion of fixes assets, e.g. $0.9m fixed assets (1.7%) of $50.2m total assets in 2015 and $2.0m fixed assets (3.8%) of $53.5m total assets in 2015. The detailed overview of fixed assets is depicted in Appendix 4. At the end of 2015, Organovo has a cash balance of $50.1m compared to $48.2m in 2014. Through several financing rounds as mentioned above Organovo has been seeking new cash to finance their operations. Working capital is largely positive, showing that customers have huge bargaining power over Organovo. So far the start-up has largely financed its operating losses and working capital requirements through the sales of convertible notes, private placements of equity securities, common stock, revenues from products and services, grants and collaborative research agreements. The cash balance of $50.2m at the end of 2015 will allow Organovo to finance their operations at least for another one year before significant investments are required again.

Selected Consolidated Statement of Operations Data:		Year Ended March 31, 2015		Year Ended March 31, 2014
Revenue	$	571	$	379
Operating loss	$	(30,297)	$	(20,649)
Net loss	$	(30,082)	$	(25,848)
Loss per share, basic and diluted	$	(0.38)	$	(0.35)
Weighted average shares outstanding, basic and diluted		79,650,087		73,139,618

Selected Consolidated Balance Sheet Data:		Year Ended March 31, 2015		Year Ended March 31, 2014
Working capital (deficit)	$	46,501	$	47,268
Total assets	$	53,489	$	50,186
Long-term liabilities	$	32	$	9
Stockholders' equity (deficit)	$	48,696	$	48,284

Table 2: Selected financial data of Organovo in 2014 and 2015

Market analysis and growth opportunities

The market of Organovo can be divided into the following segments. The data has been collected through the Pharmaceutical Industry Profile of Pharmaceutical Research and Manufacturers of and Organovo's website.

Segment	Market size and trend	Competition	Organovo
Liver Toxicology	$1.3bn 6,500 annual programs	Gaps in 2D and animal models Some start developing 3D models	Project runs every 9 month Average contract $150k
Kidney Toxicology	$2.1bn 6,500 annual programs	Gaps in 2D and animal models Too advanced for other companies without crucial patents	Higher prices compared to liver Average contract $250k
Efficacy Models	$50bn annual R&D Every new drug costs around $2.6bn and takes 10-15 years Only 12% finally approved after entering clinical trials	Gaps in 2D and animal models Competition behind the innovation of Organovo 3D printers	Significant revenues expected due to shorter R&D process and significnat savings in
Implants	More than 120,000 patients on the waiting list in the US Only 30,000 transplants yearly	No competition, only small start-ups in the development phase, but behind Organovo	Partnerships with well regarded hospitals and universities Clinical trials for products

Table 3: Organovo's market and competitive dynamics according to Organovo's website

Growth opportunities exist in various human tissues, as the 3D bioprinting technology can ideally be expanded to any type of organ. So far, the three main tissues developed by Organovo are skin, liver and kidney, with many more opportunities for other tissues, e.g. lung, bone, blood vessels and heart. Furthermore, Organovo sees strong royalty opportunities from partnerships for early cancer discovery. For breast cancer, an initial model has already been bioprinted with defined multi-cellular composition and architecture. The valuation of diseased tissue will be dealt with in detail in the real options approach.

Risk analysis

However, especially, since Organovo is still a start-up several risks exist. First of all, with its limited operating history and high operating losses, Organovo is expected to incur additional operating losses in future. The strategy has not been proven so far and as a start-up Organovo may never achieve profitability. Furthermore, wrong expectations and additional R&D requirements may force the start-up to raise more capital in another round of financing. Although the technology developed by Organovo has been successful so far, the long term effect and potential challenges have not been fully discovered yet. In addition, the success may largely depend on market demand, successful strategic relationships and competitors, who mostly have larger financial and technical resources than this start-up. Lastly, regulations and restrictions from the government can severely harm Organovo's business, as they largely depend on regulatory approval to bring their product on the market.

Stock price analysis and ownership overview

The following chart will give an overview of Organovo's stock price performance since its listing on the stock exchange on February 15, 2012. The highest stock price has been $12.50, while the lowest has been $1.24. After the highest peak in November 2013, Organovo's stock has been decreasing to $1.88 in January 2016 and recently grew to $2.55. The chart has been recorded from Yahoo! Finance on May 23, 2016.

Figure 6: Organovo's stock price development in $

The stock price has been largely fluctuating over the past. Due to the negative earnings no dividends have been declared. The P/E Ratio is negative and therefore, as discusses above, is not meaningful for multiples valuation. The number of shares is increasing as Organovo is issuing new common to finance their loss making operations. The stock market capitalisation of Organovo has almost halved since 2014, because of the large fluctuations in the stock price.

Year	2014	2015
Highest stock price ($)	13.65	9.25
Lowest stock price ($)	3.27	3.29
Last price as of 31/03/N ($)	7.64	3.54
Number of outstanding shares as of 31/03/N (m)	78.11	81.54
Earnings per share ($)	-0.35	-0.38
Price-Earnings-Ratio (x)	-21.83	-9.32
Dividend per share ($)	0.00	0.00
Payout ratio (%)	0%	0%
Stock market capitalization ($m)	596.79	288.64
Shareholders' equity ($m)	48.28	48.70
Price Book Ratio (x)	12.36	5.93

Table 4: Stock price data analysis for Organovo in 2014 and 2015

The second chart compares the performance of a $100 investment in Organovo with the performance of the NASDAQ Composite Index and the NASDAQ Biotechnology Index, assuming all dividends are reinvested. Although Organovo outperforms both indexes until mid 2015, the stock price largely fluctuates and eventually underperforms the NASDAQ Biotechnology Index. Although this graph has no indication for the future performance of the stock, Organovo reveals typical start-up behaviour with its highly fluctuating stock price history. The chart has been generated on May 23, 2016.

Figure 7: Organovo compared to the NASDAQ Composite and the NASDAQ Biotechnology Index

In Appendix V, the consolidated statements of stockholders' equity or deficit highlights the issuance of common stock and the net loss from year 2011 until 2015. The net losses of $16.1m, $25.8m and $30.1m in 2012, 2013 and 2014 respectively, need to be financed by issuance of common stock. Since the company is still loss making, Organovo is fully equity financed, which means that the shareholders fund the operations of the company. Despite the loss-making nature of the business, investors seem very confident in Organovo, as the CEO Keith Murphy announced that the $46m capital increase was two times oversubscribed and the full green shoe exercised.

According to Thompson One data dated May 23, 2016, Organovo has 92,413,951 shares outstanding and a free float of 84,710,011 (92%). The following table will give an overview of the top five current shareholders of Organovo, which currently has a market capitalization of $235.6m:

Name	% Ownership
Keith Murphy (Chairman and CEO)	6.97%
BlackRock Institutional Trust Company	4.84%
The Vanguard Group, Inc.	3.35%
State Street Global Advisors	1.47%
Northern Trust Investments, Inc.	1.03%

Table 5: Top five % ownership of Organovo's investors

c) Valuation approach

Disclaimer: The aim of this case study is not to reach the IPO or fair value of Organovo, but apply different approaches used for start-up valuation. Due to limited publically available financial information, the listed 3D bioprinting start-up Organovo has been selected. Any of the forward looking estimations and calculations are based on the current financials and authors assumptions, which are subject to a number of risks and uncertainties. Therefore, the valuation of the start-up should not be viewed as an investment recommendation, but merely as putting theory into practice when applying different start-up valuation approaches directly to the case study of Organovo.

In the next chapter alternative valuation methods for start-up valuation will be discussed. These will be applied directly to the case of Organovo. First of all, the Venture Capital method will be presented. Due to its limitations, the First Chicago method will be described and applied to the case of Organovo. Moreover, in the next step, the Damodaran approach will illustrate how to forecast future cash flows, discount rates and terminal value for start-ups. Since this approach does not include the flexibility and uncertainty a start-up has to deal with on an everyday basis, the real option approach will value Organovo's potential with the Cox-Rubinstein and Black-Scholes formula. This approach will focus on the valuation of diseased human tissue, since the DCF approach only takes Organovo's current developments and growth opportunities in healthy human tissue into account. Eventually, the author will present different methods for valuation of intangible assets, especially interesting for start-ups with strong IP portfolios, before verifying the valuation methods presented for start-ups in particular.

5. Alternative valuation methods for start-ups applied to Organovo

The study of Black (2003) has proven that instead of using earnings, a better measure for start-up valuation are cash flows in the pre-growth start-up stage. However, analyst need to be careful, since the value relevance of earnings, cash flow and book value of equity is likely to change over the life cycle of a start-up (Black, 2003). As a result, most valuation methods used for start-ups try to circumvent the issues described above and therefore focus on the following:

- Little financial information: Since it is difficult to estimate the exact items of a start-up, mainly due to the short history and the high reinvestment rate, most venture capital valuations only include revenues, the top line or earnings, the bottom line (Damodaran, 2009).

- Short time horizon: Due to the uncertainty of future development of the start-up company, setting up a long term business plan has been proven difficult, e.g. DCF valuation. Therefore, most start-up valuation methods focus on the short term, taking only three to five years into account.

- Mix of relative and intrinsic valuation: As mentioned before, estimating cash flows for long time periods can be very arbitrary. That is why the exit multiple of a start-up is often estimated using multiples of publicly traded companies. Therefore, next to the intrinsic business plan valuation for a short term period, the terminal value is determined by relative valuation methods.

- Risk and discount rate: Most start-ups have a low probability of surviving the initial stages of their business (Knaup & Piazza, 2007). This risk needs to be taken into account when choosing the discount rate. Therefore, start-ups face not only earnings volatility, sensitivity to the macroeconomic environment or pressure through a lack of economies of scales, but also risk of running out of funds, bankruptcy or even death. The higher risk will lead to a higher discount rate, which will be very important when investing into the business.

a) The Venture Capital method

i. Principles of the Venture Capital method

The venture capital method is an alternative method used to value start-up companies. As seen before, traditional valuation techniques are hard to apply, which is why many private investors use the venture capital method. Sahlman (1987) describes the venture capital approach, which is based on the idea that at a certain point an investor wants to exit the investment. The method combines the DCF and multiples approach and depending on the projected cash flows, the value is calculated using multiples of comparable companies. This method is based on the following principles:

- Expected earnings or revenues: The first step consists of estimating the expected earning and revenues in the future year, with a time range between two and five years. The forecast period is set to the time when the investor plans to sell the start-up company in the future. The scenario chosen is the success scenario, in which the company attains its sales and margin projections (Sahlman, 1987).

- Terminal value: The second step consists of estimating the terminal value by multiplying the future earnings with the price earnings ratio of other comparable publicly traded companies in the same industry. The PER has to match the success of the company, e.g. it should correspond to the economic characteristics of the target company (size, profitability, growth, capital intensity and risk). Alternatively, in case other companies have been sold recently, the multiple of these transactions can be used. In case earnings are not available, revenue multiples can be used in an equal approach. This is mostly used for companies that are not profitable in the short term, but will only have positive earnings in the long term. The chosen multiple will be applied to the projected earnings or cash flow in order to arrive at the terminal value (Goldman, 2008).

- Discount rate: In the next step, the discount rate is calculated. For this several risks need to be considered, e.g. riskiness of the business, probability of survival and the macroeconomic environment. The terminal value calculated in the previous steps is then discounted with the rate capturing all risks in order to arrive at the present value of the target. Generally, the required rate of return of venture capitalist is much higher than for publicly traded companies, mainly due to the high risk perceived for start-ups. According to Sahlman (1987) this rate can be typically between 35% and 80% depending on the development stage.

- Equity share: In the final step, the equity share based on the money brought into the company will be estimated. The post money valuation will amount to the valuation calculated during the third step plus the new capital the venture capitalists will inject. The proportion of equity investors think they will be entitled to is simply their capital injected divided by the post money valuation.

According to Damodaran (2009), the venture capitalists' target rates of return depending on the stage in the life cycle are as follows:

Development stage	Venture capitalists' target rate of return
Start-up stage	50% - 70%
First stage	40% - 60%
Later stage	35% - 50%
Bridge/IPO stage	25% - 35%

Table 6: Target rate of return per development stage

As an example, a venture capitalist thinks about investing $2m into Organovo that expects to require no additional capital in the next five years with -$5m of earnings in the fifth year of the investment. Comparable companies have a forward looking PER multiples of around 15x (Appendix VI). However, since the author assumes that Organovo will still have negative earnings in year five, the venture capital method will be calculated through the EV/Sales multiple as suggested above. The revenue in year five is expected to be $15m and the EV/Sales multiple of comparable companies 4.1x (Appendix VII). The venture capitalist expects to sell his stake to the acquiring company at the end of year five. Furthermore, the venture capitalist requires a 30% rate of return due to the risk of Organovo. Normally the venture capitalist would require a higher rate, but since Organovo has already proven their business by launching products and going public, the discount rate is significantly lower.

Assumptions	
Investment (in $m)	2.0
Duration (in years)	5.0
Dilution	None
Earnings (Year 5) (in $m)	-5.0
PER Multiple (Year 5)	15.0x
Revenue (Year 5) (in $m)	15.0
EV/Sales Multiple (Year 5)	4.1x
Required rate of return	30.0%

Table 7: Assumptions Venture Capital method

After estimating the future earnings at the end of year five and the average of the PER of several comparable companies, the venture capitalist can estimate the terminal value of Organovo by calculating:

$$\text{Terminal value (Year 5)} = Earnings\ (Year\ 5)\ x\ PER\ Multiple\ (Year\ 5)$$
$$\text{Terminal value (Year 5)} = Revenue\ (Year\ 5)\ x\ EV/Sales\ Multiple(Year\ 5)$$

In the following step the TV needs to be discounted to todays value, which will be:

$$\text{Present Value of Terminal Value} = \frac{Estimated\ terminal\ value\ (Year\ 5)}{(1+IRR)^{years}}$$

Assuming that the capital invested will be in addition to the current value of Organovo, which is the present value of the terminal value, the proportional share of equity is:

$$\text{Share of equity} = \frac{Investment}{Pre-money\ value+Investment}$$

Calculations (Additional capital)	
Terminal Value (Earnings) (in $m)	-75.2
Terminal Value (Revenue) (in $m)	61.1
PV of TV (Revenue) (in $m)	16.4
Investment (in $m)	2.0
Share of Equity	10.8%

Table 8: Calculations Venture Capital method with investment as additional capital

Assuming that the money invested will be used to for R&D expenses, the final ownership will be 10.8%. Alternatively, in order to guarantee 30% return, the investor can calculate the required future value of his investment and terminal value as follows:

$$\text{Required future value (Investment)} = (1 + IRR)^{years}\ x\ Investment$$
$$\text{Terminal value (Year 5)} = Earnings\ (Year\ 5)\ x\ PER\ Multiple\ (Year\ 5)$$
$$\text{Terminal value (Year 5)} = Revenue\ (Year\ 5)\ x\ EV/Sales\ Multiple(Year\ 5)$$

In order to arrive at the required return at the end of year five, the venture capitalist has to own at that point the following percentage:

$$\text{Final ownership required} = \frac{Required\ future\ value\ of\ the\ investment}{Total\ terminal\ value} = \frac{(1+IRR)^{years} x\ Investment}{PER\ x\ (Terminal\ earnings)} = \frac{Investment}{TErminal\ Value\ /\ (1+IRR)^{years}}$$

Calculations (No additional capital)	
IRR	30.0%
Required future value	7.4
Terminal Value (Earnings)	-75.2
Terminal Value (Revenue)	61.1
Required ownership	12.2%

Table 9: Calculations Venture Capital method with invest capital paid out to current investors

Assuming that the money invested will be used to pay out current owners, the final ownership will be 12.2%, so the $2m will not be in addition, but part of the total value.

ii. Limitations of this valuation method

Although the venture capital method is taking the weaknesses of traditional approaches into account, there is hardly a perfect method to value high risk investments. Critics may argue that the method is overly simplistic, not taking the company's business plan and strategy into account, however, due to the high degree of uncertainty, anyone could argue that a model for start-up valuation is either too complex or too simply. The following arguments are the most relevant limitations of the venture capital method:

- Focus on revenues and earnings: Since the venture capital method solely focuses on revenues or earnings, start-ups will do everything possible to push up the forecasted revenues or earnings. Therefore, they will lower items, such as capital investment, to make sure the earnings are high enough to reach their valuation goal. This will have a substantial impact on the future of the business. Venture capitalists, however, will try all possible to push down the estimates. Due to the short history, the venture capital method becomes more of a bargaining method than an objective valuation tool.

- Uncertainty and multiples: The multiple used to calculate the terminal value is based on comparable companies trading today. Firstly, using a multiple of trading companies without applying a discount to that multiple assumes that the start-up has successfully reached the stage where it is worth as much as a traded company. Furthermore, the multiples of a current period might be especially high due to investor preferences to invest in a specific sector. Therefore, the multiple may be more of an indication of investment tendencies than the intrinsic value of the traded company. In order to correctly estimate the multiple, the valuation should be based on the cash flows at the point where the multiple is used. Since cash flows are still uncertain for that period, the level of uncertainty is not decreased by the venture capital method (van Schootbrugge & Wong, 2013).

- Discount rate: In the venture capital method, the target rate is based on the required rate of return demanded by the investors. Their required rate of return will include the likelihood that the business will fail, which is why the discount rate demanded by venture capitalists is a lot higher than what the discount rate should normally be (Damoradan, 2009). The discount rate needs to be based on the cost of capital, not on the rate demanded by equity investors. When discounting the future value of equity, venture capitalists could use their required rate, not however, when discounting the value calculated through revenue or enterprise value multiples. Furthermore, having a discount rate that includes the probability of failure, venture capitalists assume that the rate will not change within the business cycle, which is not correct (Damodaran, 2009).

- Calculation of equity share: The new capital is added to the value in order to calculate the amount of equity for the investors as a proportion of the post money value. Depending on what the money is used for, the calculation needs to be adjusted. In case part of the freshly invested capital is used to pay other investors, the part needs to be removed from the post money value. This has been illustrated in the second example of the calculations (Damodaran, 2009).

- Dilution: Most importantly, when additional capital is injected, the new investors might be diluted in the following financing rounds. Despite the fact that special anti-dilution clauses exist, which prohibit new investors to acquired large shares which dilute old investors, this dilution still needs to be taken into account. The current formula does not account for dilution and therefore needs to be modified. In addition, the discount rate used per round will differ, mainly due to the fact that the future investors will requires lower rates the further developed a start-up will be. The difference in discount rates that investors will require per round needs to be estimated, which adds another limitation to this method.

- Additional cash flows: The venture capital method fails to take additional cash flows, such as dividends, into account. It simply assumes that between the initial investment and the exit no money will be returned. This need to be adjusted, namely, because with such a high risk in the early stage of a company, the investor is more likely to invest in case he receives dividends or is able to get his investment paid back. These scenarios will be discussed in the First Chicago method (Sahlman, 1987).

- Probability of success and liquidation pay out: Most venture capitalists use the same discount rate for a group of investments, when applying the venture capital method, assuming that each investment has the same probability of success or failure and that in all different cases each investment has the same relative pay-out ratio (Sahlman, 1987). This, however, does not take the capital intensity of each investment into account, which will have a significant impact on the cash flow of each scenario of different start-ups. Investments in capital intensive industries, such as a manufacturing start-up, are likely to pay out more in case of failure than investments in asset light industries, such as an ecommerce middleman. In case of liquidation the capital intensive business will be able to gain some money from their existing assets to pay back a part to their investors, while in the asset light business, liquidation will not recover a lot of cash. These different pay-out scenarios need to be carefully considered in the method used for start-up valuation.

Although the uncertainties for valuing start-up companies are larger than for mature companies, the short comings of the venture capital approach do not overcome the problems laid out before. Instead, investors should use an approach, which systematically values start-ups and helps reduce uncertainty.

b) The First Chicago method

The probability of success and pay-out has not yet been taken into account in the venture capital method. The aforementioned method simply assumes that every start-up has the same relative cash flow, especially under the liquidation scenario.

Depending on the capital intensity of the start-up the discount rate used by the venture capitalist should vary.

i. Principles of the First Chicago method

In order to take the survival of a start-up properly into account, venture capitalists should make two scenarios, one, in which the start-up is financially healthy, and another, in which in which the start-up will not survive. Damodaran (2009) suggests three approaches to assess the probability of failure:

- Several publications exist which measure the probability of survival for start-ups in specific sectors over a period of time. Depending on the existence, the likelihood of failure decreases and can be assessed on a year by year basis. The study made by Knaup and Piazza (2007) shows that on average only 44% of start-ups survives through the fourth year and 31% through the seventh year.

- Since the data sources depend on data from the past, a more sophisticated approach would be to build a model that will be able to predict the probability of the start-up's survival. Characteristics could include the amount of start-up established before, the amount of cash, the age of the founders and the amount of capital available. Before using, this model should be tested and verified.

- Alternatively, a specific simulation can be created. This could entail details about at which stage the company will fail, e.g. no fresh capital while development cost exceeds forecast by more than 50%. Using such concrete examples will help to estimate the overall probability of failure of a start-up.

The First Chicago method takes the different pay-out ratios depending on each scenario into account. It assigns different probabilities of success and failure to different ventures and consequently applies a lower expected discount rate (Sahlman, 1987). This method was first applied at First Chicago Corporation's venture capital group with three scenarios being weighted by their probability in order to value the average of the expected cash flow of the start-up.

- The success scenario (IPO): In the venture capital method this is the only scenario considered. The First Chicago method assumes that the investor will receive a dividend over the years and also sell his share when the start-ups is listed. However, due to several financing rounds as mentioned in the Venture Capital method, the percentage of final ownership cannot be fully determined yet. During the final year, the venture capitalist will gain:

$$Accrued\ dividends + Terminal\ value\ x\ \%\ of\ ownership$$

- <u>The sideways scenario:</u> In this scenario the investor only receives a yearly dividend, since the start-up has not been overly successful so it would be able to launch an IPO. For the investor it is important to make sure at least some part of his investment is returned in case no IPO takes place. The investment can be paid back in another financing round in the future or through a straight light redemption. The assumptions have to be made until when the dividend is paid and from which point onwards the investment will be fully repaid.

- <u>The failure scenario (Liquidation):</u> In the worst case scenario the start-up needs to be liquidated. Depending on the capital intensity of the start-up the probability to recover some of the capital will vary greatly. The assumption on the percentage of money left after liquidation has to be made on basis of available cash, value of assets and working capital requirements.

The probabilities of each scenario have to be estimated so that the total expected cash flow can be calculated. The discount rate applied should be significantly lower than in the Venture Capital method, since the First Chicago method already takes the lower expected cash flow into account. Furthermore, in the Venture Capital method, the future value of the investment had to be equal to the proportion of terminal value. For the First Chicago method, however, the investor needs to include both the dividends and components of expected cash flow to value his investment correctly.

$$FV\ (Expected\ cash\ flow) = FV(Investment) = \\ Prob.of\ Success\ x\ \%\ final\ ownership\ x\ Terminal\ Value + FV\ (Non\ IPO\ Cash\ Flows)$$

Therefore, the required final ownership can be defined as follows:

$$Required\ final\ ownership = \frac{FV\ (Investment) - FV\ (Non\ IPO\ Cash\ Flow)}{Probability\ of\ Success\ x\ Forecasted\ Terminal\ Value}$$

Compared to the Venture Capital method, the First Chicago method takes dividends and potential payments between the investment and the exit into account. In the formula above the future value of the intermediate cash flows and expected future value from the terminal value will yield the future value of the total investment. Furthermore, the Venture Capital method does not distinguish between the forecasted and the expected terminal value. The forecasted terminal value is calculated by multiplying the forecasted earnings with the PER ratio from comparable companies and later discounted with a high rate to adjust for uncertainty. The expected terminal value, however, is equal to the forecasted terminal value multiplied by the probability of the success scenario.

Take the example of Organovo valued with the First Chicago method mentioned above and adjust it to the new First Chicago method. A venture capitalist thinks about investing \$2m into Organovo that expects -\$5m of earnings in the fifth year. Comparable companies have a PER of around 15. The revenue in year five is expected to be $15m and the EV/Sales multiple of comparable companies 4.1x (Appendix VII). Should everything go as planned, the venture capitalist expects to successfully sell his stake at the end of year five. Dividends for this start-up are 5%, only from year 2 onwards, since currently Organovo is making too high losses. In case of the sideway scenario, the investor assumes to receive dividends only in year 3 and from year 4 onwards a straight-line repayment of four years which yields 9% return in total. Under liquidation, the assumptions are that only 15% of the invested capital will be recovered and 30% of the expected dividend will be paid in the third year. Furthermore, the venture capitalist discounts the expected cash flow at the expected portfolio average discount rate of 20%.

Assumptions	
Investment (in $m)	2.0
Duration (in years)	5.0
Earnings (Year 5) (in $m)	-5.0
PER Multiple (Year 5)	15.0x
Revenue (Year 5) (in $m)	15.0
EV/Sales Multiple (Year 5)	4.1x
Dividend (in %)	5.0%
Straight line repayment (in years)	4
Repayment return (in %)	9%
Liquidation recovery (in %)	15%
Liquidation dividend payment (in %)	30%
Required rate of return (in %)	20.0%

Table 10: Assumption for the First Chicago method

The following probabilities are typical for venture capital investors (Sahlman, 1987):

Probability	
Success	25.0%
Sideway	50.0%
Failure	25.0%

Table 11: Typical scenario probabilities for the First Chicago method

Instead of personally evaluating the factors that lead to success or failure, Goldman (2008) suggest using websites, such as BizMiner (bizminer.com), which have a database of three-year failure rates for small businesses by industry and geography. After estimating the future earnings in each scenario the venture capitalist can estimate expected cash flow in each scenario:

Szenario	Probability	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Success	**25.0%**	0.000	0.100	0.100	0.100	X+ 0.100	0.000	0.000
Sideway	**50.0%**	0.000	0.000	0.100	0.680	0.635	0.590	0.545
Failure	**25.0%**	0.000	0.000	0.330	0.000	0.000	0.000	0.000
Average	**100%**	**0.000**	**0.025**	**0.158**	**0.365**	**0.25X+ 0.343**	**0.295**	**0.273**

Table 12: Expected cash flows for Organovo using the First Chicago method

With X being the percentage of final ownership times the terminal value. The Net Present Value of the non IPO cash flows will be calculated as follows:

Net Present Value	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Discount factor	0.83	0.69	0.58	0.48	0.40	0.33	0.28
Cash Flow (in $m)	0.000	0.017	0.091	0.176	0.138	0.099	0.076
Net Present value	**0.597**						

Table 13: NPV of Organovo's cash flows using the First Chicago method

Since some cash flows will only be received in year six and seven, the present value will be multiplied by the required rate of return to the power of five in order to arrive at the future value at year five. The required final ownership is therefore:

$$Required\ final\ ownership = \frac{FV\ (Investment) - FV\ (Non\ IPO\ Cash\ Flow)}{Probability\ of\ Success\ x\ Forecasted\ Terminal\ Value}$$

Required final ownership	
FV Investment (in $m)	5.0
FV Non IPO Cash Flow (in $m)	1.5
Probability of success (in %)	25.0%
Forecasted Terminal Value (in $m)	61.1
Required final ownership	22.9%

Table 14: Required ownership for 20% return using the First Chicago method

Under the assumptions and different scenarios mentioned above the investors need to acquired 22.9% in order to succeed at their required rate of return of 20%.

ii. Limitations of this valuation method

The First Chicago method includes several scenarios, which is very useful for start-ups with different cash flows per scenario. In case a company is able to generate substantial value during liquidation, the First Chicago method is able to adjust the discount rate and take different cash flows per scenario into account. The First Chicago method therefore truthfully reveals if an investment is more valuable due to higher liquidation value. Although the First Chicago method overcomes a substantial part of the weaknesses of the Venture Capital method, limitations still exist:

- Multiple rounds of financing: The investors need to repeat the calculation for each financing round that is expected in order to maintain their rate of return.. The discount rate used in the First Chicago method will remain approximately the same, since the discount rate does not depend on the financing round anymore, but more on the riskiness of the portfolio. After each investor's required ownership is estimated, the retention rate, the required current ownership, the number of shares and the share price need to be calculated in order to tackle current challenges (Sahlman, 1987).

c) The Damodaran approach

Although the Discounted Cash Flow method has proven to be difficult to use for start-up valuation, Damodaran (2009) came up with systematic process to adjust this method for start-up companies. The approach suggested by Damodaran will be complemented by other literature in order to arrive at a well-reasoned and clear-cut approach. In a first step, the cash flows will be estimated with the top-down or bottom-up approach. Afterwards, the author will highlight important aspects for estimating the discount rates for start-ups. Eventually, the terminal value will be approximated, using the case study of Organovo as an example.

i. Estimation of future cash flows

As a first step in the adjusted valuation method, Damodaran (2009) highlights the top-down approach to estimate future cash flows:

- Estimation of future cash flows: For the top down approach it is important to first analyse the potential market for the product or service, by defining the product or service the company is offering and estimating the market size through trade publications and professional forecasting services (Mills, 1998). More importantly, databases, such as Gartner Group, provide forecasts into the future, which will be necessary to estimate the total market value and future cash flows of the start-up. Furthermore, Goldman (2008) highlights that the growth also depends on the market acceptance of the product, competition, financing and risk.

- Market share: In order to correctly measure the potential market share in future, it is useful to compare the product and market share of the biggest players with the quality of the product of the start-up. Furthermore, the capacity of the management of the start-up to delivery the promised results is a very important dimension when valuing young companies. Brilliant ideas do not necessary lead to a successful business, it is more that great management and business skills are inevitable when turning an interesting idea into a great success. Additionally, when estimating the potential market share, the resources start-ups can get in order to reach the desired market share are very important.

- Operating expenses: For the steady state, the operating margin of mature companies can be compared in order to find a suitable estimate for the start-up company in the later stage. Mils (1998) suggests to estimate future earnings by relating the final forecast to current peer group earnings. Once this target margin has been set, the start-up has to define the pathway to this rate. Depending on the competition, fixed cost and R&D cost, this pathway can be more or less difficult. The level of detail should decrease into the future, as more and more items become uncertain (Damodaran, 2009).

- Investment for growth: Neither revenue, nor margin improvement will be successful without substantial investments. However, investment will require cash outflows, which mostly result in a negative cash flow and thus require new capital infusion. Goldman (2008) mentions that the biggest mistake in start-up business plans is revenue growing at much greater rates than assets and expenses, which are needed to generate the revenues. Founders of start-ups tend to use to low reinvestment rates, while venture capitalists are afraid that to high investment will dilute their shares due to fresh capital needed. Examples of reinvestments include R&D, expansion of production capacity, human resource development, expansion into new markets or development of new technologies (Goldman, 2008). Generally, as an estimation of the reinvestment, the revenue to capital invested ratio based on publicly traded companies in that specific sector should be used in order to determine how much money needs to be reinvested. The reinvestment will need to be made with a one-year lag between reinvestment and generation of additional revenue.

- Taxes: Start-ups will benefit from negative earnings by carrying losses forward to shelter positive earnings in future. Therefore, in the first couple of years, start-ups will not pay any taxes until the net operating losses carried forward is exhausted. Afterwards the company should move to the marginal tax rate of the average effective tax rate used by healthy companies in the same sector and country (Damodaran, 2009).

- Internal consistency: Damodaran (2009) proposes to check for internal consistency by comparing the operating income and reinvestment rate by calculating the imputed return on capital as the expected operating income after tax divided by capital invested in the firm. Afterwards, the imputed return on capital should be compared to the industry average in order to secure that the company has not a too high or too low return.

$$Imputed\ Return\ on\ Capital = \frac{Expected\ Operating\ Income\ after\ tax_t}{Capital\ invested\ _{t-1}}$$

$$Imputed\ Return\ on\ Capital = \frac{Expected\ Operating\ Income\ after\ tax_t}{Capital\ invested\ _{t=0} + \sum_{n=1}^{n=t-1} Reinvestment\ _n}$$

The second approach highlighted in Damodaran (2009) is the bottom up approach, which builds up on firm specific elements before reaching revenue and cash flow estimations:

- Capacity and investment: To start with, an estimation of future capacity and capital needed for the expansion should to be made. For most start-ups, however, at the initial stage, either financial or human capital is the limiting factor in the expansion process.

- Revenues: Once the capacity has been determined, the estimate of sales for each year can be made. Equally to the top down approach, at this stage the market and competition needs to be taken into consideration. The pricing decision should also be made at this stage.

- Operating costs: With an estimation of revenues sold per period, the operating cost can be estimated. These cost should be as detailed as possible, at least for the initial periods and get less detailed for future periods.

- Taxes: Taxable income will be estimated on the operating cost and revenues estimated in the steps before. In addition, depreciation and amortization as well as financial expenses need to be estimated to calculate the cash flows. Equally as in the top down approach, the net operating losses carried forward have to be deducted before income tax will be paid.

- Additional reinvestment: Some business need high working capital requirements, which is why additional investments might be necessary. In order to outgrow capacity constraints, additional investments might help to increase growth, assuming that the market for the product or services provided by the start-up is there.

Generally, the bottom up approach will lead to a more conservative approach, because capacity constraints are taken into account. Damodaran (2009) suggests using this approach for companies that face either financial or human capital constraints, e.g. personal service businesses. Since Organovo as a bioprinting company has a huge capacity and especially, since the start-up will be able to produce enough printers, bio ink and R&D facilities over the next years, the top down approach will be used to estimate future cash flows of Organovo:

Revenue: To put theory into practice, the revenue and cash flows for Organovo will be estimated and the assumptions for the calculations described in the following. The revenues in 2015 were made up of product and services of $314k (55%), collaborations of $134k (23%) and grants of $123k (22%). As pointed out by Goldman (2008), the growth also depends on market acceptance, competition, finance and risk. As it can be seen from the growth opportunities listed in the table below, so far Organovo has reached the targets which are circled. Since the product has already attracted several collaborations with little competition and successful financing rounds to finance Organovo's activies in future, the following assumptions will be made for Organovo's revenue growth. These assumptions will merely be made for the healthy tissue models, since unhealthy partnership tissue models will be valued separately with the real option approach.

Tissue Research Programs	Preclinical Safety (Product/Service)	Efficacy Models (Partnerships)	Simple Tissues for Therapy (Clinical)
Liver	✓ (Launched C4Q14)	✓	✓
Lung		✓	✓
Kidney	✓ (Expected launch C3Q16)	✓	✓
Cancer		✓	
Bone		✓	✓
Blood Vessel		✓	✓
Heart	✓	✓	✓
Skin	✓	✓	✓

Key Focus Areas

Table 15: Overview of Organovo's activies and growth opportunities

- <u>Products and Services:</u> Only due to the new commercial launch of its exVive3D™ Human Liver Tissue in November 2014, Organovo was able to generate its first commercial revenue. According to Organovo's press releases, the start-up is looking to bring its 3D bioprinted kidney tissues to market in September 2016 following the launch of its preclinical Human Liver system.

  - <u>Liver:</u> In their earnings report, Organovo emphasised that the exVive3D Human Liver Tissue product and services have a $100m+ revenue potential in the future, part of a total addressable market of over $1bn. Currently, Organovo assumes average contract revenue of $150k.
  - <u>Kidney:</u> The exVive3D Human Kidney Tissue will only be introduced in the calendar third quarter of 2016, with a market of at least the equal size of the 3D printed liver tissue. However, the average size of the kidney contract will be $100k larger, namely $250k per contract, with the market almost being double the size. Therefore, once the kidney will be launched the growth will accelerate.
  - <u>Skin:</u> Currently, these models are only related to cosmetic use and still has huge potential for commercialisation as well as expansion in other markets, such as dermatological and pharmaceutical uses.
  - <u>Other:</u> The table above indicates that there are several areas Organovo is still looking to expand into. So far, the biggest markets are liver, kidney and skin tissue, however, other 3D printed human tissue, such as hearts, blood vessels and lungs might especially become useful for therapy use.

As limited public information is available regarding the size of all human tissue markets for this new technology, the author took arbitrary assumptions of growth of the market, only considering the commercialisation of healthy human tissues. The author therefore assumed that due to the kidney tissue launch the revenues will grow by 200%, 150% and 100% the next three years and then slow down to 10% until year 10. This growth rate is still relatively high, mainly due to the excellent IP portfolio Organovo has to offer and its further growth opportunities in new 3D printed tissue, such as lungs, hearts or blood vessels.

- Collaborations: The growth rate of collaborations has been greatly fluctuating, especially, lately from 2014 to 2015 it has been declined by 50% since two big collaborations were successfully terminated. With the new introduction of the kidney tissue, we assume that more collaborations will arise. Revenue from collaborations is lower, however, for the future great growth opportunities of around 40% in the first four years exist, with a slow down to 15% in the year 10. No market data on collaborations regarding Organovo is available. This is a mere assumption of the author based on the current interest of big companies and research centres in collaborations.

- Grants: According to Organovo's annual report, two types of grants exist: Cost reimbursement based grants, which are received to cover specific cost in the development process, and fixed price grants, which are received upon achievement of specific milestones. Since the overall allocation is not given and the grants are only a small part of the revenue generated by Organovo, the author made the following assumptions: The more mature the company gets, the less grants it will receive. Therefore, the author assumes that Organovo will receive only 80% of the grants of in 2016, 50% in 2017, 40% in 2018 and from then nothing onwards.

Revenue 31/03 in $k	2014A	2015A	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Products and Services	0	314	942	2,355	4,710	8,814	15,362	24,799	36,844	50,003	61,432	67,576
% growth			*200.0%*	*150.0%*	*100.0%*	*87.1%*	*74.3%*	*61.4%*	*48.6%*	*35.7%*	*22.9%*	*10.0%*
Collaborations	248	134	188	263	368	515	699	921	1,174	1,448	1,725	1,984
% growth		*-46.0%*	*40.0%*	*40.0%*	*40.0%*	*40.0%*	*35.8%*	*31.7%*	*27.5%*	*23.3%*	*19.2%*	*15.0%*
Grants	131	123	98	49	20	0	0	0	0	0	0	0
% growth		*-6.1%*	*-20.0%*	*-50.0%*	*-60.0%*							
Total Revenue	**379**	**571**	**1,228**	**2,667**	**5,097**	**9,329**	**16,062**	**25,720**	**38,018**	**51,451**	**63,158**	**69,560**

Table 16: Organovo's estimated revenue growth 2016 - 2025

EBIT: In the next step, the EBIT margin of Organovo will be estimated. From the comparable financials in Appendix VIII only comparable mature companies have reached a positive EBIT margin, the comparable listed start-ups still have negative EBIT, just like Organovo. On average, the comparable companies with a positive EBIT margin have reached 20% on the trailing twelve-month basis. At the end of the forecasting period, the author assumed that Organovo will only reach 15% EBIT margin, due to its high development cost and lower economies of scale. According to the quarterly earning calls of Organovo, both the CEO Keith Murphy and CFO

Barry Michaels suggest that a lot of costs will also be for additional sales representatives. When commercialising the product, more full time employees need to be added to the sales force, since the 3D bioprinted tissue is a relatively complex product that needs to be directly marketed and explained to potential customers.

In the fiscal year of 2015, however, Organovo has a EBIT margin of -5306%, due to revenues of $571k and EBIT of -$30.3m. Because of its high developmental cost and forecast of market trends, the author assumed that Organovo will only reach profitability in year 2021. Until then it will linearly improve its EBIT margin every year. Organovo's CEO Keith Murphy highlighted during their earning reports that earnings will be negative of around $30m for year 2016 and thereafter improving steadily. From 2021 onwards, the author assumed that the EBIT margin will grow to 15%. The steep increase in EBIT margin can be justified by the fact that most of Organovo's costs are fixed cost, such as R&D and SG&A. Thus, a quick increase in revenues will trigger a sharp increase in EBIT margin.

EBIT 31/03 in $k	2014A	2015A	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
EBIT	-20,649	-30,297	-30,700	-20,001	-12,743	-9,329	-4,015	0	1,426	3,859	7,105	10,434
% margin	*-5448.3%*	*-5306.0%*	*-2500.0%*	*-750.0%*	*-250.0%*	*-100.0%*	*-25.0%*	*0.0%*	*3.8%*	*7.5%*	*11.3%*	*15.0%*

Table 17: Organovo's estimated EBIT for the years of 2016 - 2025

Investments: Especially due to its innovative products and increasing demand in various tissue models, Organovo will need to reinvest in order to generate more revenues. The CEO Keith Murphy highlighted that the 3D skin models, for instance, are currently funded via their partnership with L'Oréal. However, these models are only related to cosmetic use and therefore 3D printed skin tissue will require a larger R&D budget for other uses, such as commercialisation and making it ready for dermatology use. In addition, after the capital increase, Organovo mentioned that a large part of the $46m raised will be used to finance capacity expansion for liver and kidney tissues, investment in new tissue build outs for commercial uses and building powerful new drug discovery models. This R&D expenses will be expensed directly and not part of capital expenditures. After launching the 3D bioprinted liver tissue and soon the kidney tissue, Organovo expects significant increase in demand which will require capacity expansion. Organovo's CEO announced in their press release that a second manufacturing facility will need to be opened in near term.

For the reinvestment rate, Damodaran (2009) suggested to compare other publicly listed companies' sales to R&D spending, since the start-up ratio will mostly be too high due to the little revenues. Data provided from Statista on the top 50 global pharmaceutical companies' sales to R&D spending in 2014, suggests a median of 5.31x revenue to R&D spending. However, since these are very established pharmaceutical companies, we will look at another data set. As an alternative, New York Stern collected a dataset of reinvestment rates per sector in which the reinvestment rate is defined as:

$$Reinvestment\ rate = \frac{\text{Net Capital Expenditures} + \text{Change in WC}}{\text{EBIT}\ (1 - \text{t})}$$

$$Reinvestment\ rate = \frac{\text{Expected growth rate}}{\text{Return on capital}}$$

The dataset provided uses a 138% reinvestment rate for biotechnology companies. Since the first rate only includes big pharmaceutical companies, the average of both rates will be used, arriving at 3.35x reinvestment rate. The reinvestment will need to me made with a one-year lag between the investment and growth. The table below shows reinvestments that Organovo needs to make in order to increase their revenue.

Reinvestment in $k	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Revenue growth	1,413	2,355	4,104	6,548	9,437	12,045	13,159	11,429	6,143	6,758
Reinvestment rate	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35
Reinvestment	422	704	1,227	1,957	2,821	3,601	3,934	3,417	1,837	2,020

Table 18: Organovo's reinvestment for the years of 2016 - 2025

Taxes: Organovo is incorporated in Delaware, known for its favourable tax rules. According to PWC a Delaware corporation is subject to state income tax at a rate of 8.7% on its taxable income, which is calculated from the income generated from business activities within the state. However, due to the economic nexus doctrine, any other state can claim taxes from the corporation which has a sufficient economic footprint in that state. Therefore, this doctrine severely limits the tax advantages created through the incorporation and Dyreng, Lindsey and Thornock (2012) found a Delaware-based state tax avoidance strategy lowers state effective tax rates by between 0.7 and 1.1 percentage points, on average. Assuming a generate corporate tax rate of the US of 35%, we assume a tax rate of 34% for Organovo. Furthermore, it is important to mention that losses generated in previous periods will be carried forward, e.g. Organovo will only be paying taxes once the profit has been larger than the losses generated. According to the Generally Accepted Accounting Principles (GAAP), tax losses can only be carried forward for seven years. The following table calculates the Net operating profit after taxes (NOPAT), the starting point for the cash flow calculations:

$$NOPAT = EBIT\ (1 - tax\ rate)$$

NOPAT 31/03 in $k	2014A	2015A	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Losses carried forward	-20,649	-50,946	-81,646	-101,647	-114,391	-123,720	-127,735	-107,086	-75,364	-40,805	-13,698	0
Tax expense	0	0	0	0	0	0	0	0	0	0	0	-3,223
NOPAT	-20,649	-30,297	-30,700	-20,001	-12,743	-9,329	-4,015	0	1,426	3,859	7,105	7,211

Table 19: Organovo's NOPAT for the years of 2016 - 2025

Consistency check: Damodaran (2009) suggests to check the consistency of the approach by comparing the return on capital of Organovo with the industry average return of capital. The return will be calculated by dividing the current operating income after taxes (NOPAT) by the current capital invested at the beginning of the period. According to the Deloitte report (2015) R&D returns for pharmaceutical companies range between 4.2% and 10.1% over the past 6 years. Therefore, a return of capital of maximum 10.6% for Organovo does not seem to unrealistic.

Return on Capital Invested in $k	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
NOPAT	-30,700	-20,001	-12,743	-9,329	-4,015	0	1,426	3,859	7,105	7,211
Reinvestment	422	704	1,227	1,957	2,821	3,601	3,934	3,417	1,837	2,020
Capital Invested BOY	48,728	49,150	49,854	51,081	53,039	55,860	59,461	63,395	66,812	68,648
Capital Invested EOY	49,150	49,854	51,081	53,039	55,860	59,461	63,395	66,812	68,648	70,668
Return on Capital Invested	-63.0%	-40.7%	-25.6%	-18.3%	-7.6%	0.0%	2.4%	6.1%	10.6%	10.5%

Table 20: Organovo's return on capital invested for the years of 2016 - 2025

Therefore, the total cash flow to Organovo over an expected time period of 10 years can be calculated as follows:

Free Cash Flow in $k	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
NOPAT	-30,700	-20,001	-12,743	-9,329	-4,015	0	1,426	3,859	7,105	7,211
Less: Capex	-422	-704	-1,227	-1,957	-2,821	-3,601	-3,934	-3,417	-1,837	-2,020
Free Cash Flow	-31,122	-20,705	-13,970	-11,287	-6,837	-3,601	-2,508	442	5,269	5,191

Table 21: Organovo's expected cash flow for the years of 2016 - 2025

ii. Estimation of the discount rate

The discount rate exists of two parts, the cost of equity and the cost of debt. These can be estimated in different ways. Since traditional methods are not suitable and venture capital target return rates not adaptive enough for start-up companies, Beneda (2003) suggests calculating the WACC for a young company as follows:

- Cost of Debt: The cost of debt for a start-up company can be calculated by adding the default risk spread to the risk-free treasury security yield. For the risk free rate, the yearly average of the treasury bond, e.g. 30-year treasury bonds, yields should be used. Regarding the default risk spread, reports by Standard & Poor's or Moody's for companies with the same credit rating can be used. In case the start-up does not have a rating, Beneda (2003) suggests to approximate the rating of the company in order to estimate a default spread.

- Cost of Equity: The cost of equity can be computed with the capital asset pricing model (CAPM) with a weight of two and the bond yield plus market risk premium approach with a weight of one (Beneda, 2003). Again, for the risk free rate, the yearly average of the treasury bond, e.g. 30-year treasury bonds, yields should be used. Furthermore, the average market excess return can be approximated by using the historical average excess return for small companies over the long term government bond rate. For the beta, Beneda (2003) suggests using the average of betas reported by different platforms, e.g. Value Line and Compustat, from similar start-up companies, which have recently been IPOed. For the second part of Beneda's equation, the bond yield of similar start-ups in the same sector should be used, adding a market risk premium on top.

- Market risk premium: Beneda (2003) mentions that the excess return for a start-up can be calculated through the historic average market excess return for small companies over the long-term government bond rate. This data is available on databases such as Value Line and Compustat.

- Market value of debt: The market value of debt can be approximated with the book value of debt obtained from the most recent balance sheet (Beneda, 2003).

- Market value of equity: The market value of equity can be computed as the number of outstanding shares times the average weekly stock price for mature companies, however, for start-ups the equity should be calculated through the latest balance sheet book value or in case the information is not available through the equity value calculated in the last financing rounds (Beneda, 2003).

To estimate the discount rates, Damodaran (2009) suggests using the following approach: Since start-ups are mostly owned by undiversified owners, the cost of equity should both include the market and firm specific risk. Cost of debt cannot be measured by rating, because start-ups usually do not have bonds outstanding. Due to the riskiness of the company, banks usually charge a premium on the interest rates, which resembles the cost of debt. Target rates of venture capitalists are not suitable, since these rates are too high and take the risk of going bankrupt into account.

- Beta approximation: When no data of beta through public companies or other sources is available, HEC Finance Professor Patrick Legland suggested using five criteria as an approximation for the beta. Depending on the characteristic of the company, each criterion assigns a beta value between 0.5 and 2.5 to the start-up. The average of all five factors will comprise the estimated beta:

    1. Fixed cost: A high amount of fixed cost will require a high level of financing. The breakeven point will be relatively high and earnings more volatile to little revenue changes. Companies with high fixed cost will have a high beta.
    2. Debt to equity ratio: A high level of debt will result in high financing cost and especially a lot of risk due to high leverage. This will therefore lead to a high beta compared to an equity financed company.
    3. Cyclicality of the business: Cyclical businesses tend to be riskier businesses, since they are depended on the high period to be really successful to reach their estimated earnings. The more cyclical a business, the higher the beta compared to a less cyclical business.
    4. Earnings growth: Higher growth will result in a higher beta, because the quicker the company growths, the more likely the situation that the company will lose momentum and underperform the expectations of the market.

5. Business model: High quality of the business model, competent management and sufficient analyst coverage will all lead to lower betas and less uncertainty about the future of the business.

In order to estimate the unlevered ß of Organovo, the following five criteria will be used. As mentioned before, since Organovo is evolving over the time horizon of ten years, the beta will change over time. The beta will be decreasing over time, mainly because of the cost structure, business model and earnings growth. On the one hand, we assume that in future less and less R&D cost will be required, Organovo's growth will slow down and the business model will be proven after being listed on the stock exchange for many years. This will all have a decreasing effect on the beta of Organovo. On the other hand, the debt to equity ratio will be slightly increasing, but this will not have a major impact, especially since Organovo is only expected to be profitable in six years:

Beta estimation	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Fixed cost	2.00	1.94	1.89	1.83	1.78	1.72	1.67	1.61	1.56	1.50
Debt to equity ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.10	1.20
Cyclicality	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Earnings growth	2.50	2.50	2.50	2.31	2.13	1.94	1.76	1.57	1.39	1.20
Busines model	2.00	1.89	1.78	1.67	1.56	1.44	1.33	1.22	1.11	1.00
Average beta	1.70	1.67	1.63	1.56	1.49	1.42	1.35	1.28	1.23	1.18

Table 22: Organovo's beta estimation for the years of 2016 - 2025

- Beta through sector averages: When using the beta of young companies that successfully passed the early stage and are publicly traded in the same industry as the start-up, venture capitalists can estimate the market risk associated with the business. The beta needs to be unlevered using the average debt to equity ratio for the firms used in the sample or if possible each beta unlevered before calculating the average unlevered beta. Beneda (2003) calculated the beta as the historic average betas of small companies through platforms like Compustat and Value Line. The beta then needs to be relevered with the start-ups debt to equity ratio to arrive at the estimated levered beta:

$$\beta_L = \beta_U x \left[1 + (1 - t) x \frac{D}{E}\right]$$

According to Infinancials the 1-year unlevered beta data of Organovo's comparable companies has been gathered and summarised in the table below.

1-Year Beta	Levered	Unlevered
Eli Lilly	0.33	0.32
Abbott	0.99	0.95
Sanofi	0.98	0.92
Merck & Co	0.74	0.69
Pfizer	0.50	0.47
Johnson & Johnson	0.71	0.75
Mabvax Therapeutics	1.08	1.06
Stellar Biotechnologies	1.42	1.26
Sarepta Therapeutics	1.44	1.77
Prothena	2.11	2.03
Average	**1.03**	**1.02**

Table 23: Beta average for comparable companies of Organovo

- Beta adjustments: Owners of start-ups tend to be less diversified than those of more established companies. In case of little diversification, the beta needs to be adjusted and reflect a higher market beta, which also includes the company specific risk. The more diversified investors, the smaller the cost of equity. Since Organovo is reasonably diversified with 92% free float and a broad range of different investors, the author decided not to adjust the beta.

- Cost of debt: Although start-ups do not have ratings, their rating can be estimated by using financial ratios, such as interest coverage ratio. Depending on their estimated rating, the cost of debt should resemble the average cost of debt of companies in that industry with the same rating. On top of this, a spread for the small size of the business needs to be added, because banks will charge more interest to a loss making start-up with little revenues than to a large company with the same ranking and established revenues.

- Expected changes: When moving through the life cycle the risk and cash flow characteristics will be changing (van de Schootbrugge and Wong, 2013). These changes also need to be considered for the discount rate. Cost of equity will decline with more diversified investors contributing capital and on top cost of capital will decline with debt becoming an available source of financing at a later stage of the start-up.

For the US based start-up Organovo the risk free rate will be based on the long term U.S. treasury bill rate (Damodaran, 2008). Beneda (2003) used the 73-year average of the 30-year treasury bond yield as a risk free rate, which was 5.5%. When comparing the dataset of 30-year treasury bonds provided by the Federal Reserve, we reach an average of 3.78% over the past 10-year basis. As an alternative, the risk free three-month rate could be used. According to forecasts of the Federal Reserve Open Market Committee and Seeking Alpha the risk free will rise from its current 0.30% to 0.479% in one year and to 3.044% in ten years. Damodaran (2008), however, highlights that the duration of the risk free rate should match the duration of the cash flows. Therefore, the average of the past 10 years 30-year US government treasury yield of 3.78% will be used.

For the average market risk premium, the excess market return for small companies over the risk free rate of different sources will be compared. Beneda (2003), for instance, used a 73–year historical average of the excess average market return for small companies of 12.1%. Leach and Melicher (2015) found an excess return of 10.3% of small companies over long term government bonds between 1926 and 2008. According to Grabowski, Harrington and Nunes (2015) the average risk premium over the risk free rate for the portfolio comprised of the smallest companies was 14.30%. For the calculations of Organovo the average of the three rates will be used for the market risk premium, thus 12.2%. Thereafter the cost of equity can be calculated:

$$k_E = r_f + \beta_{ONVO}\ x\ MRP$$

In Organovo's case finding an artificial rating through the interest coverage ratio is not applicable, because Organovo is still fully equity financed. Therefore, the approach of Beneda (2003) will be used to calculate the cost of debt. As such the 10-year average of the 30-year treasury bond yield was used as a risk free rate of 3.78% on which a default risk spread will be added on top. According to New York Stern, for smaller non-financial service companies with small market caps the spread would be around 2.5% for a A3 or A- rating. Therefore, we assume a total cost of debt of 6.3%. This cost of debt can be validated with the data set for cost of capital per sector in the US provided by New York Stern. Since Organovo operates in several sectors, the average cost of debt of 4.62% or 6.5% for biotechnology companies validate the 6.3% assumed above.

Industry Name	Number of firms	Average Beta	Cost of Equity	Cost of Debt	Cost of Capital
Drugs (Biotechnology)	411	1.28	9.96%	6.52%	9.20%
Drugs (Pharmaceutical)	157	1.02	8.37%	4.52%	7.72%
Healthcare Products	254	1.03	8.43%	4.02%	7.45%
Healthcare Support Services	127	1.05	8.57%	4.02%	7.20%
Heathcare Information and Technology	126	1.11	8.93%	4.02%	7.95%
Average	**215**	**1.10**	**8.85%**	**4.62%**	**7.90%**

Table 24: Cost of capital by sector in the US according to New York Stern's database

Over the years the WACC decreases, mainly due to the decline in beta and the use of debt in the last two years of the forecast. This correctly resembles the decrease of risk, when Organovo moves through the life cycle (van de Schootbrugge and Wong, 2013).

WACC	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Risk free rate	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%
Beta	1.70	1.67	1.63	1.56	1.49	1.42	1.35	1.28	1.23	1.18
Market risk premium	12.2%	12.2%	12.2%	12.2%	12.2%	12.2%	12.2%	12.2%	12.2%	12.2%
Cost of equity	24.6%	24.2%	23.8%	22.9%	22.0%	21.2%	20.3%	19.5%	18.8%	18.2%
Tax	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%
Cost of debt	6.3%	6.3%	6.3%	6.3%	6.3%	6.3%	6.3%	6.3%	6.3%	6.3%
% Debt	0%	0%	0%	0%	0%	0%	0%	0%	10%	20%
% Equity	100%	100%	100%	100%	100%	100%	100%	100%	90%	80%
Debt to equity ratio	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.25
WACC	24.58%	24.17%	23.76%	22.90%	22.04%	21.17%	20.31%	19.45%	17.37%	15.40%

Table 25: Organovo's estimated WACC for the years of 2016 - 2025

Having successfully estimated the free cash flows to the firm and the discount rate for a forecasting period of ten years, the sum of the discounted free cash flows can be calculated as follows:

Discounted Cash Flows in $k	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Period	1	2	3	4	5	6	7	8	9	10
Free Cash Flow	-31,122	-20,705	-13,970	-11,287	-6,837	-3,601	-2,508	442	5,269	5,191
WACC	24.6%	24.2%	23.8%	22.9%	22.0%	21.2%	20.3%	19.5%	17.4%	15.4%
Discount Factor	0.80	0.65	0.53	0.44	0.37	0.32	0.27	0.24	0.24	0.24
Present Value FCF	-24,983	-13,429	-7,370	-4,947	-2,526	-1,137	-687	107	1,247	1,239
Sum of Discounted FCF										**-52,487**

Table 26: Organovo's estimated discounted cash flows for the years of 2016 – 2025

Apart from this, Goldman and Goldman (2009) suggest that the discount rate can be significantly lowered by venture capitalists taking option positions on a start-up and thereby limiting the downside of their investment. The higher the put price relative to the stock price, the grater the downward adjustment of the target required rate of return according to Goldman and Goldman (2009). This, however, is a more specific approach and was mentioned merely to show how broad and complex the process is to determine the discount rate for a start-up.

iii. Estimation of the terminal value

In the next step, the terminal value of a start-up will be approximated. First, regarding the terminal value of the start-up, Damodaran (2009) highlights that the terminal value is an even bigger part for start-up than regular companies, mainly due to the high level of uncertainty and biggest part of earnings being in future. Since relative valuation multiples for the terminal value are hard to apply to start-ups, Damodaran (2009) suggests three different ways that can be used to determine the intrinsic terminal value:

- Perpetual growth: Use the perpetual growth rate and excess returns to calculate the cash flows which will be growing in perpetuity. This approach can be best used for start-ups aiming for acquisitions of publicly traded companies or IPOs.

$$TV = \frac{FCFF_t \, x \, (1+g)}{WACC - g}$$

- Growth assumptions: Make assumptions about the length of expected cash flows, in case perpetual growth is too ambitious or the start-up very dependent on a key person. The terminal value can be calculated by adding the present value of the cash flows of the estimated survival period. This approach can be best used for start-ups, whose success is defined by surviving the initial stage.

- Liquidation: Assume that at the end of the forecasted period the company will be liquidated and the terminal value will consist of the salvage value of the assets of the start-up. This approach should be best used for companies with limited operating licenses or set up agreements.

For Organovo the first case scenario with perpetual growth will be calculated, because Organovo is neither based on a model with limited operating licences nor dependent on key persons in management. Organovo's technology is very innovative and might only be successful in a couple of years, when companies accept the futuristic approach Organovo is taking in printing 3D human tissue. After year ten, the author assumes a slightly higher growth rate of 3.8% than the perpetual growth rate of 3% as suggested by Damodaran (2009). This is because the author assumes that with its innovative technology, Organovo will be able to cut a lot of cost of big pharmaceutical companies, enable new ways of drug discovery and maybe even overcome the scarcity of implants through 3D bioprinted human tissue. Since the Organovo is still at the beginning of its development, risk and cash flows will be fluctuating, leading to a change in WACC over time (van de Schootbrugge and Wong, 2013). Therefore, for the perpetual WACC, the author used the New York Stern database for cost of capital by sector in the US dated January 2016. The average from the following sectors, in which Organovo is all active, is built. The dataset shows the amount of companies in each sector that have been investigated in order to build an average for each sector in the US.

Industry Name	Number of firms	Cost of Equity	E/(D+E)	Cost of Debt	D/(D+E)	Cost of Capital
Drugs (Biotechnology)	411	9.96%	87.50%	6.52%	12.50%	9.20%
Drugs (Pharmaceutical)	157	8.37%	88.49%	4.52%	11.51%	7.72%
Healthcare Products	254	8.43%	83.68%	4.02%	16.32%	7.45%
Healthcare Support Services	127	8.57%	77.75%	4.02%	22.25%	7.20%
Heathcare Information and Technology	126	8.93%	84.96%	4.02%	15.04%	7.95%
Average	**215**	**8.85%**	**84.48%**	**4.62%**	**15.52%**	**7.90%**

Table 27: Sector averages for cost of capital according to New York Stern's database

Thus, with all data collected and assumptions made above, the terminal value and total value of Organovo can be calculated. Notice, however, that the overall value of $8.8m is still very low compared to the market capitalisation of $235.6m. The terminal value in Organovo's case makes up all of the value created, since the cash flows generated for ten years still have a negative value. This is very typical for start-up companies, since currently, especially due to Organovo's high R&D expenses, the company is generating a lot of losses and profits are only generated in future. It is important to mention that this approach only includes Organovo's expansion possibilities in healthy human tissue, because unhealthy human tissue will be valued separately with the real options method.

Total Value Organovo	
Final cash flow 2025	5,191
Perpetual growth rate	3.8%
WACC Future	7.9%
Terminal Value 2025	**131,290**
Discount Factor 2025	0.47
Discounted Terminal Value	61,356
Discounted FCF	-52,487
Total Value	**8,869**

Table 28: Terminal value of Organovo

d) The real option approach

As most valuation methods mentioned above have proven to be too rigid and not really applicable to start-ups, the ideal valuation technique is supposed to be flexible enough to adjust for the uncertainties in start-ups, but at the same time value the potential the start-up may have in future. Therefore, instead of using short cuts in the valuation, investors should rather use a well reasoned, systematic approach to value start-up companies. The real option approach embeds the option to expand, defer, reallocate or contract an investment and allows more flexibility successfully complementing tradition approaches, such as the discounted cash flow model, which does not account for volatility or investment timing of cash flows (Baduns, 2013).

Alexander and Chen (2012) highlight that is is important to include the managerial flexibility of the decision making and the uncertainty of cash flow in real options, because the value increases with the frequency of decision opportunities. Benaroch (2001) reveals that real options are especially valuable, because they allow management to take rational, value adding actions by being able to change the timing, scale and scope of the investments. Research by Baldi (2005) has shown that even the valuation of LBO may be strongly enhanced by adding real options for the flexibility for the acquirer's managerial course of action taken to improve the target's operations.

Especially in the case of Organovo, an agile biotechnology company, the DCF approach is too static and fails to capture the value from R&D options. Banerjee (2003) highlights that the concept of real options can successfully be applied for valuing R&D investments, since in his study only 39% of the pharmaceutical companies' market capitalisation could be explained by the DCF approach. That is because the market has already priced in the growth options, e.g. options from growth through new drug discovery, new joint ventures or new distribution platforms. Furthermore, Banerjee (2003) showed that for companies with high R&D costs, the underlying value of the R&D investment is best captured in the option pricing model presented in the following.

i. Principles of the real option method

Especially for start-ups the option to expand is a very useful method to account for flexibility in case a specific innovation is very successful. This may in return lead to another successful innovation, which needs to be taken into consideration. For instance, the success of Organovo's 3D bioprinted human skin led to the development of new 3D bioprinted human tissue, such as Organovo's printed liver or kidney, simply because the customers needed this human tissue to better estimate the toxicology of their developed drugs. Furthermore, success in one market may lead to success in another market, with customers who are looking for a similar product. For example, Organovo is already right now looking to sell their 3D bioprinted human tissue not only in the US, but also in Europe and Asia. Thus, Organovo hopes to expand to several countries after they have once successfully set foot in their home country. To conclude, Eichner, Gemünden and Kautzsch (2007), emphasize that the real option is only complementary to the DCF valuation and two conditions need to be fulfilled: First, a high degree of uncertainty about future cash flows and second, a high degree of flexibility for management to adjust the strategy to external changes and time.

The strategic value of real options is highlighted in the table by Leslie and Michaels (1997), who claim that by managing real options proactively the following advantages can be obtained:

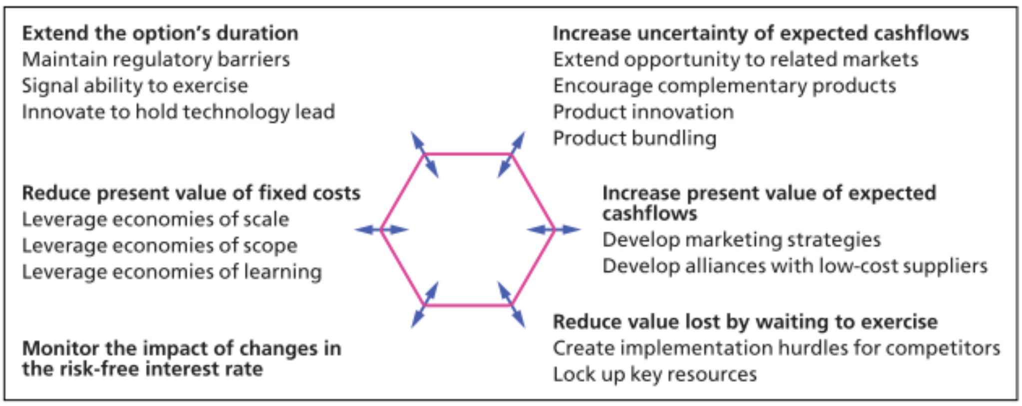

Figure 8: Advantages of real options (Leslie and Michaels, 1997)

<u>Basics of Options</u>

An option gives the holder the right, but not the obligation, to buy or sell an amount of the underlying asset at a fixed price, the strike or exercise price, before or at the expiration date (Damodaran, 2012). The payoff of the two types of options, the call and put option will be discussed in detail.

- Call: A call option gives the buyer the option to buy an underlying asset for a predetermined price. If at expiration this price is lower than the strike price, the option will not be exercise and the buyer simply needs to pay the price for the right (Damodaran, 2012). If the value of the underlying asset is great than the exercise price, then the buyer of the call option makes a profit.

- Put: A put option gives the buyer the option to sell an underlying asset for a predetermined price. If at expiration this price is higher than the strike price, the option will not be exercised and the buyer simply needs to pay the price for the right (Damodaran, 2012). If the value of the underlying asset is lower than the exercise price, then the buyer of the put option makes a profit.

- American/European: Two different categories of options exist, American and European options. American options can be exercised prior to the expiration date, whereas European option can only be exercised at the expiration date. Since American options can be exercised earlier, these are more valuable, but also more difficult to value.

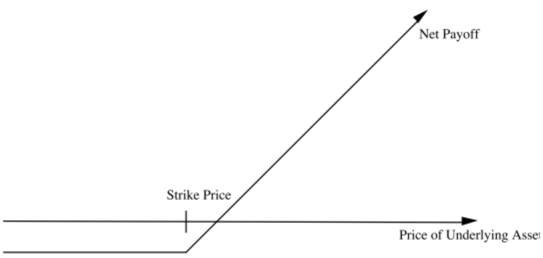

Figure 9: Call option payoff diagram

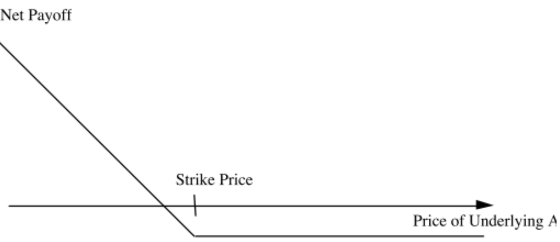

Figure 10: Put option payoff diagram

At expiry the call and put value equals: $Call = Max\ (0; S^{*} - K)$; $Put = Max\ (0; K - S^{*})$ with S being the price of the underlying at expiry and K being the strike price.

Take Organovo as an example, which after successfully launching skin, liver and soon kidney tissues, will expand into another 3D bioprinted tissue. After raising \$40m the company stated in their press release that this money will be used for expanding on the total number of 3D printable tissues types to be offered commercially. The current cash flow forecast only take the strong growth opportunities of skin, liver and kidney into account. In the official press statement, Organovo sees the growth opportunities in the following matrix:

Tissue Research Program	Toxicology Assays (Product/Service)	Disease Models (Partnerships)	Simple Tissues for Therapy (Clinical)
Liver	✓	✓	
Lung		✓	✓
Kidney	✓	✓	
Cancer		✓	
Bone		✓	✓
Blood Vessel		✓	✓
Heart	✓	✓	✓
Skin	✓		

Table 29: Organovo's expansion possibilities for real option analysis

Organovo's CEO Keith Murphy mentioned in the press release that he sees tremendous growth opportunities not only in healthy 3D printed liver and kidney tissues, but especially in diseased tissue. Organovo wants to expand their 3D cancer model, for which a lot of capital, not only for the development, but also for the commercialization, will be needed. Furthermore, Organovo is looking into developing diseased tissues, for instance, unhealthy kidney tissues with polycystic disease or unhealthy liver tissues with fibrosis disease. The expansion in other tissue areas for product, services and partnerships has already been taken into account in the DCF method. The main problem with this investment, as Berg, Green & Naik (2004) correctly describe, is that firms only learn about the potential profitability of the project throughout its life, but that the uncertainty about the R&D effort is only resolved through additional investments. Therefore, the real option method will focus on the expansion possibilities in the field of diseased 3D bioprinted human tissue.

When measuring the value of the investment, the net present value (NPV) approach is very useful. The NPV measures the amount of value created through the investment by taking both the positive, e.g. revenues and negative, e.g. investment, cash flows into account, discounted at the rate of return required by the market (Vernimmen, 2014). An investment with a positive NPV is worth to invest, while a negative NPV is expected to destroy value. The internal rate of return (IRR) is the rate of return of the investment, meaning that if the IRR is higher than the required return it is worth to invest in, if it is lower than the required rate, then the project should not be undertaken (Vernimmen, 2014):

$$NPV = -C_0 + \frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} + \cdots + \frac{C_t}{(1+r)^t}$$

with $-C_0$ being the initial investment, C the cash flows, r the discount rate and t the time in years. Take the example of Organovo, were we can assume the following cash flows per year with an initial investment of \$80m and a discount rate of 9.2% for biotechnology companies according to New York Stern's cost of capital database per industry:

Net Present Value (in $m)	2015A	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Year	0	1	2	3	4	5	6	7	8	9	10
Initial Costs	-80										
Expected Revenues		0.5	2	4	8	16	24	30	35	40	50
Expected Cost		-10	-8	-8	-6	-6	-4	-4	-2	-2	-2
Cash Flows	-80	-9.5	-6	-4	2	10	20	26	33	38	48
Discount factor at rate 9.2%	1	0.92	0.84	0.77	0.70	0.64	0.59	0.54	0.49	0.45	0.41
Discounted Cash Flows	-80	-8.7	-5.0	-3.1	1.4	6.4	11.8	14.0	16.3	17.2	19.9
NPV	**-9.7**										

Table 30: Organovo's NPV for investments in 3D bioprinted unhealthy human tissue

As we can see the simple approach leads to a negative NPV, therefore, using this simple approach, Organovo should not invest in the diseased tissue project. The real option approach, contrary to the NPV approach, allows more flexibility, a key element of a start-up. It is easiest to understand real options by thinking of a decision tree. Take the example below, where Organovo can, for instance, invest $80m in R&D for specifically diseased liver tissue and make a profit of $157m, thus $77m in earnings or in the other case make no profit and $80m loss due to the costs it had. The simply decision tree has to include the probability for each scenario, e.g. 50% for the first scenario and 50% for the second scenario. The expected value of the decision tree with this investment decision can be calculated as follows:

$$Expected\ value = 50\% * \$77M + 50\% * (-\$80M) = -\$1.5M$$

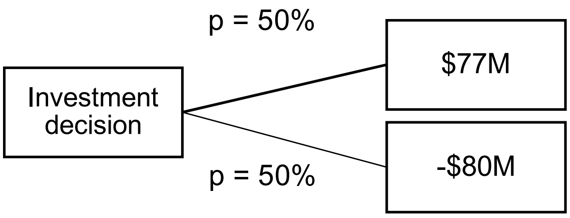

Figure 11: Exemplary investment decision of Organovo

However, two issues still persist when taking the value of these options into account. First, the potential of a new product or market expansion can only be accounted for with big uncertainty. Organovo had not imagined their potential success with other 3D bioprinted tissues or in other markets before actually expanding. However, in case a start-up tries a small investment first, it can benefit from the learning before investing a lot of money. Second, only after launching a new product or expanding into the new market, the lessons learnt from a potential failure will help to be more successful in future. Start-ups mostly adapt their behaviour after learning from a previous experience. Therefore, the option to expand allows a start-up despite potential failure to be more cautious and reflective in future.

Therefore, the decision tree below illustrates how initial phases of learning and testing can help to avoid losses at the first stage. Only at the later stage, once it becomes clear how high the risk of the investment is, i.e. lower probability of failure, the start-up should invest more money. Both the total profits and losses are identical and the cumulative probabilities improve in stage two. However, the total expected value is higher due to the option to delay the investment after initial testing.

$$Expected\ value = 50\%(-\$20M) + 50\%[\$19M + 55\%\$58M + 45\%(-\$60M)] = \$1.9M$$

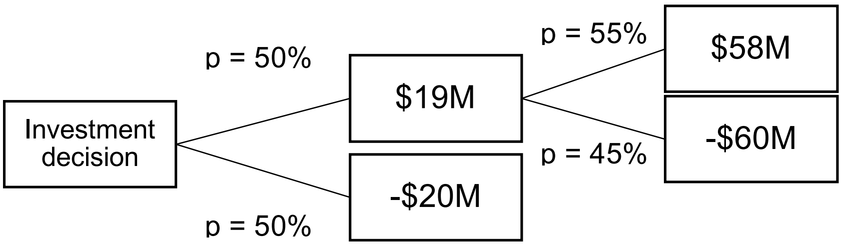

Figure 12: Exemplary decisions to delay Organovo's investment

This shows that the investment in the second place is better, not only due to the learning from the first phase, but also being able to adapt the behaviour in case the first phase has been negative. Depending on the decision from the first case, the company can choose their following steps. Generally, there are three options to consider: the option to expand, the option to abandon or the option to delay (Benninga & Tolkowsky, 2002). The option to expand offers a company the possibility to grow in a certain business area. In case first market surveys and testing have showed that customers are especially excited about a certain product, the option can help introduce the product into the market in a quicker way. The option to abandon on the other hand offers the possibility to scale down an investment after noticing that the product is badly perceived by the market. It helps a start-up to decrease their losses in case their investment has gone wrong. Lastly, the option to delay helps to postpone an investment, in case market research has shown that it might be better to invest into the project at a later stage, when customers are more ready (Benaroch, 2001).

ii. Valuation of options

The main weakness of the DCF model is that it only takes the present value of fixed costs and the present value of expected cash flows into account. It does not account for flexibility or project risk depending on the different scenarios. Contrary to the net present value approach, the real option valuation is determined by several key factors:

- Underlying asset: The higher the increase of the asset, the more expensive the call option. The steeper the decrease, the more expensive the put option.
- Variance of the underlying asset: The higher the variance, the greater the value of the option. For both put and call options the buyer will have the potential to earn higher returns, as the maximum loss is minimised to the option price.
- Dividends: The call option value will decrease and the put option value will increase with increasing dividend payments.
- Strike price: For call options, the higher the strike price, the cheaper the option. For put options, a higher strike price leads to a more expensive option.

- Expiration date: The longer the time until expiry, the more valuable are put and call options. The value will increase, because with a larger time frame the underlying asset is more likely to move and result in higher payoffs.
- Interest rate: An increase in interest rates will increase the value of the call and decrease the value of the put.

Increase in	Value effect on call option	Value effect on put option
Underlying asset	Increase	Decrease
Variance of the underlying	Increase	Increase
Dividends	Decrease	Increase
Strike price	Decrease	Increase
Expiration date	Increase	Increase
Interest rate	Increase	Decrease

Table 31: Overview of value effects on call and put options

Several option pricing theories have been developed with Black and Scholes (1972) being one of the pioneers with their replicating portfolio theory. When valuing the option to expand, Damodaran (2009) suggests using the following four steps:

1. Estimation of value and cost of expansion: To start with, the potential present value of future cash flows needs to be estimated. Although this step might seem counterintuitive it rightly forces the company to think about how much value and how many cost will be delivered or needed for the expansion. Eichner, Gemünden and Katzsch (2007) highlight that the volatility, the present value and the cost of the underlying are the most critical values for real option valuation and despite the uncertainty have to be approximated accurately.

2. Estimation of uncertainty: In the second step, the start-up needs to assess the probability of successful expansion, both from the process perspective, as well as from the cash flow perspective. The uncertainty can be measured by the standard deviation of cash flows and the project as a whole. The standard deviation of publicly traded companies in the same industry can be used as a proxy (Damodaran, 2009). Alternatively, a simulation can help to derive the specific standard deviation for the expansion project. Eichner et al. (2007) used the historic volatility in equity returns of six listed peer companies to estimate their start-ups volatility. The table below suggests the estimation of volatility with or without market data (Eichner et al., 2007):

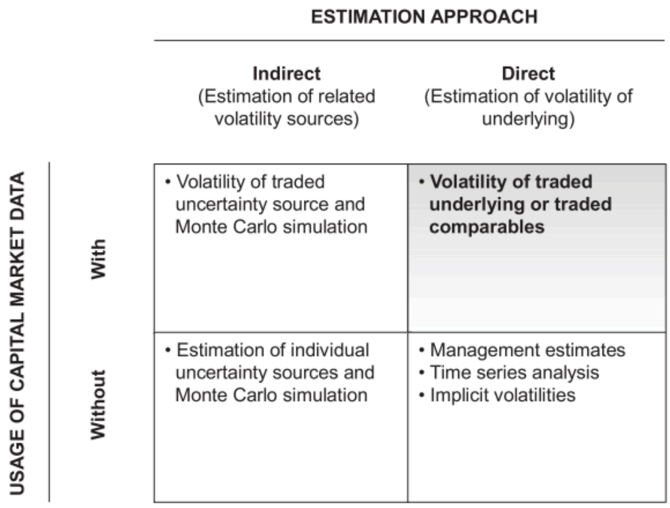

Figure 13: Market consistent determination of the volatility parameter (Eichner et al., 2007)

3. Determination of the timing: The option to expand has to be for a specific time period. This may be for a specific time period, i.e. expiration of a patent or renewal of building contract. The time period has to match the projects time line.

4. Valuation of the option: The present value of expected cash flows from the option to expand becomes the value of the underlying asset and the cost of expansion become the strike price. The standard deviation depends on the volatility of the underlying asset and the life of the option is the time by which the option has to be exercised latest. For the valuation either the binominal option pricing model or the Black-Scholes model can be used.

Generally, there are to methods to value start-ups using real options, namely the Cox-Rubinstein formula or the Black-Scholes formula. The former assumes a discrete distribution, while the latter assumes a continuous distribution. Both valuation methods will be explained with examples in the following part.

1. The Cox-Rubinstein formula

As a first approach, the Cox-Rubinstein formula, also known as the binominal option pricing theory or binominal lattice, is probably the simplest model for the valuation of options. It assumes that during any time period the asset can move in two directions only. The stock with the underlying value S will move either up to S_u, value at the up state, with the probability p or decline to S_d, value at the down state, with the probability 1-p (Arnold & Crack, 2004). The stock and the call can take the following values:

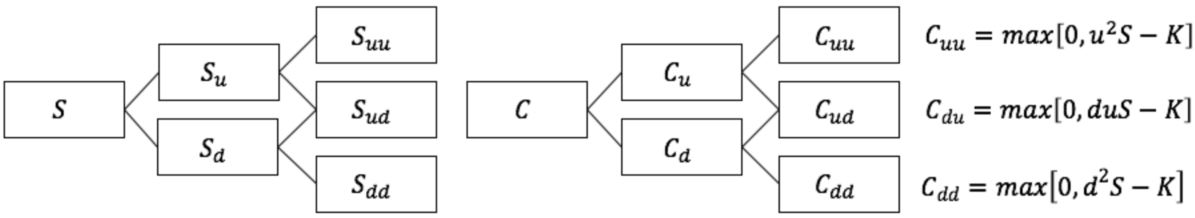

Figure 14: Stock and call value using the binominal lattice

Therefore, the underlying has two possible outcomes at the time t=1, either $S_1 = S_u = S_0(u)$ or $S_1 = S_d = S_0(d)$ with u and d being multiplicative growth factors for the underlying asset's value. These growth factors are given as $u = e^{\sigma\sqrt{\Delta t}}$ and $d = e^{-\sigma\sqrt{\Delta t}} = \frac{1}{u}$ with σ being the annual volatility of continuously compounded returns to the underlying assets and Δt the length of the time period in years (Arnold & Crack, 2004). The probability p that the value goes up is defined as $p = \frac{e^{r\Delta T}-d}{u-d}$ with r being the risk free rate (Cox, Ross & Rubinstein, 1979).

The principle of the binomial option pricing model (Cox et al., 1979) is to create a replicating portfolio with risk free borrowing or lending of B dollars, paying $e^{r\Delta t}$ interest at the end of the period, and the underlying asset to create the same cash flows as the option. Cox et. al (1979) base their model on a portfolio containing Δ shares of stock and the dollar amount B in riskless bonds.

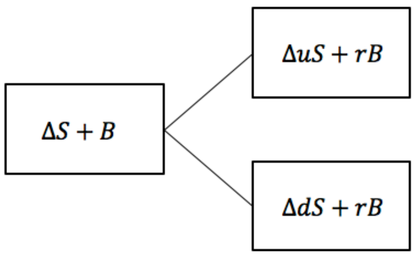

Figure 15: Replicating portfolio consisting of Δ shares and the dollar amount B in riskless bonds

The parameters Δ and B have to be chosen so that the two portfolios are equal. The value of the option must therefore be equal to the value of the replicating portfolio (Damodaran, 2012). Cox et al. (1979) consider the portfolio long Δ shares and short one option with two cases:

$$\Delta uS + rB = C_u \text{ and } \Delta dS + rB = C_d$$

Solving the two equations, Δ and B can be found. In order to replicate a call with a strike price of K, B needs to be borrowed and Δ of the underlying asset acquired:

$$\Delta = \frac{C_u - C_d}{S_u - S_d} = \frac{C_u - C_d}{S(u-d)} \text{ and } B = \frac{uC_d - dC_u}{r(u-d)}$$

with C_u being the value of the call if the stock price rises to S_u and C_d being the value of the call if the stock price drops to S_d (Damodaran, 2012). This approach can be used for several periods with each step being valued separately:

$$(S_{uu}\Delta) - (1+r)B = call\ value \text{ and } (S_{ud}\Delta) - (1+r)B = call\ value$$

These two formulas have to be plugged into each other and solved for Δ and B for each step. The valuation should start with the last period moving backwards until the current time. The value of the call consists of:

$$C = e^{-r\Delta t}[pC_u + (1-p)C_d]$$

This value will be pugged into the formula $(S_{uu}\Delta) - (1+r)B = Call\ value$ in order to arrive at the overall call value at the current point in time. In fact, this theory shows that the option value is determined by the current price, not by the expected price (Damodaran, 2012).

Take the example of Organovo, the value of the option will be estimated through the following steps. First, a binominal tree will be built with the evolution of the underlying asset value at each step. Second, the payoff, meaning the present value of the cash flows minus the cost of expansion, are calculated for each step. Third, using the backward method, the expected present value of each period are calculated backward to arrive at the option value. At each step, the project's value will be assessed by the cash flow from the underlying minus the R&D cost. In case the value is negative, the project will not be continued and Organovo can save further cost, thus avoiding additional losses. This is a great way to demonstrate the additional flexibility the real option valuation has to offer.

The input parameters for Organovo were set as follows: For the risk free rate the author took a bond with the same time to maturity as the option, i.e. a US government bond with a 10-year maturity yielding 3.78% as used earlier. Furthermore, the author assumed it will cost Organovo $80m to develop new diseased tissues in 10 years' time. This includes the cost of R&D, production and commercialisation. Regarding volatility, the annualised standard deviation in the stock price of Organovo is 76.9% according to their annual report. Alternatively, this could be measured with the volatility of the price of comparable listed companies.

Cox-Rubinstein assumptions	
u	11.38
d	0.09
r	3.78%
K	80.0
T	10
nb time steps	10
dt	1
p	0.08
σ	76.90%

Table 32: Real option assumptions using the Cox-Rubinstein formula

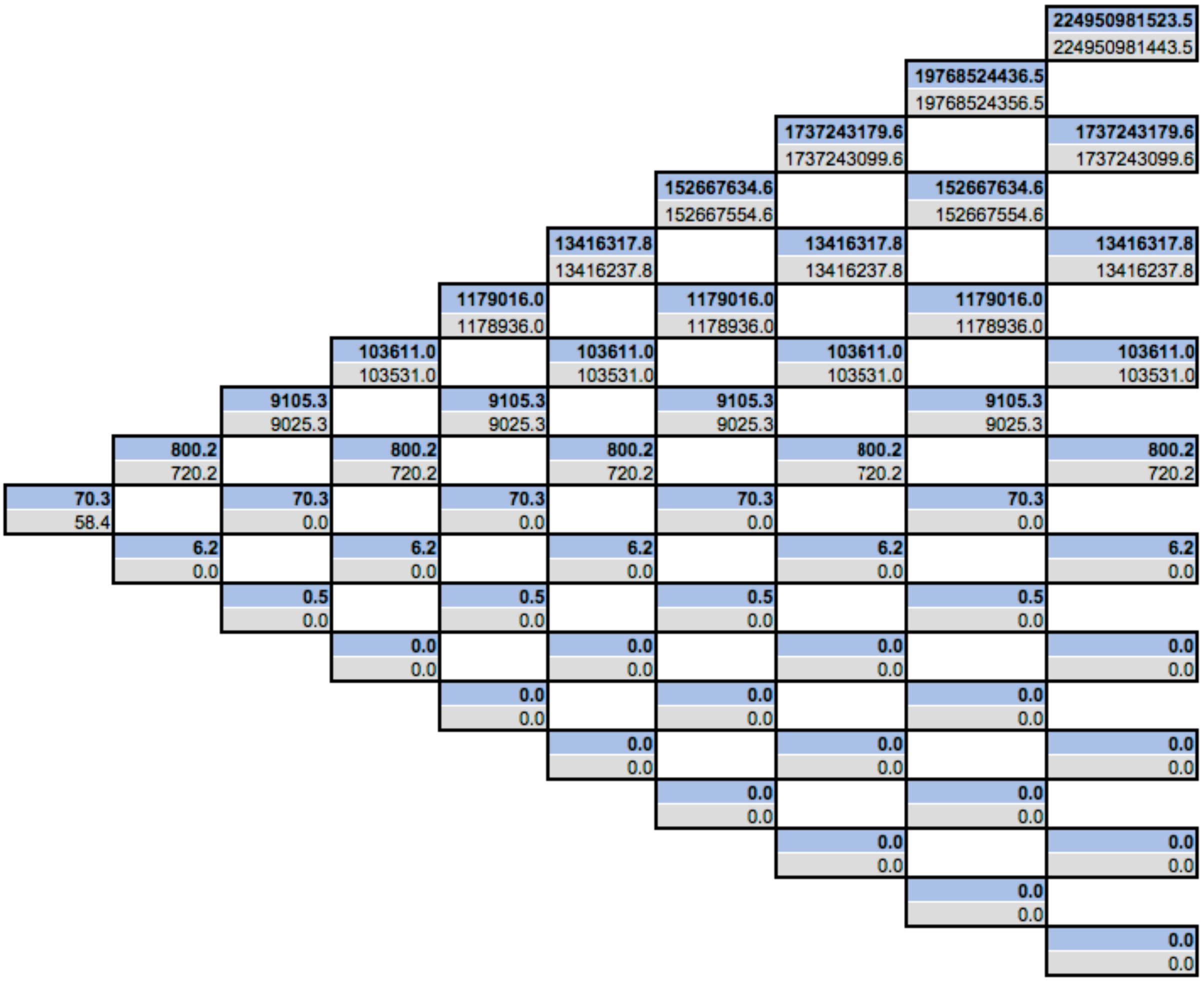

Figure 16: Organovo's real option valuation using the Cox-Rubinstein formula

Compared to the Black-Scholes formula, which requires less information, the Cox-Rubinstein formula is very helpful for projects which have several stages of different outcomes where information is available. Alternatively, for a biotechnology company with more information about the exact stages and the potential revenues per stage, Kellog and Charnes (2000) and Benninga and Tolkowsky (2002) suggest using a decision tree method calculating the expected net present value (ENPV) of a product. Take the example of a drug company, Kellog and Charnes (2000) suggest the following R&D stages and conditional probabilities of success:

R&D Stage	Total cost (in $k)	Years per stage	Probability of success
Discovery	2200	1	60%
Preclinical	13800	3	90%
Clinical			
Phase I	2800	1	75%
Phase II	6400	2	50%
Phase III	18100	3	85%
FDA filing	3300	3	75%
Postapproval	31200	9	100%

Table 33: R&D stages and probabilities of success (Kellog & Charnes, 2000)

In case this detailed information is available for a company, mostly companies with repetitive innovation, which data is available on, the following formula can be used to calculate the valuation of the binominal lattice method (Kellog and Charnes, 2000):

$$ENPV = \sum_{n=1}^{N} p_n \sum_{t=1}^{T} \frac{DCF_{i,t}}{(1+r)^t} + p_N \sum_{m=1}^{M} q_j \sum_{t=1}^{T} \frac{CCF_{j,t}}{(1+r)^t}$$

With i being the number of stages from discovery to post approval, p the probability of success at each stage, t the time in years. The second part of the equation sums up the probability of reaching the last stage p_N and adding the probability of the success of the drug and its commercial cash flows (CCF), in order to arrive at the expected net present value. The decision tree for a pharmaceutical development like this can be illustrated as below:

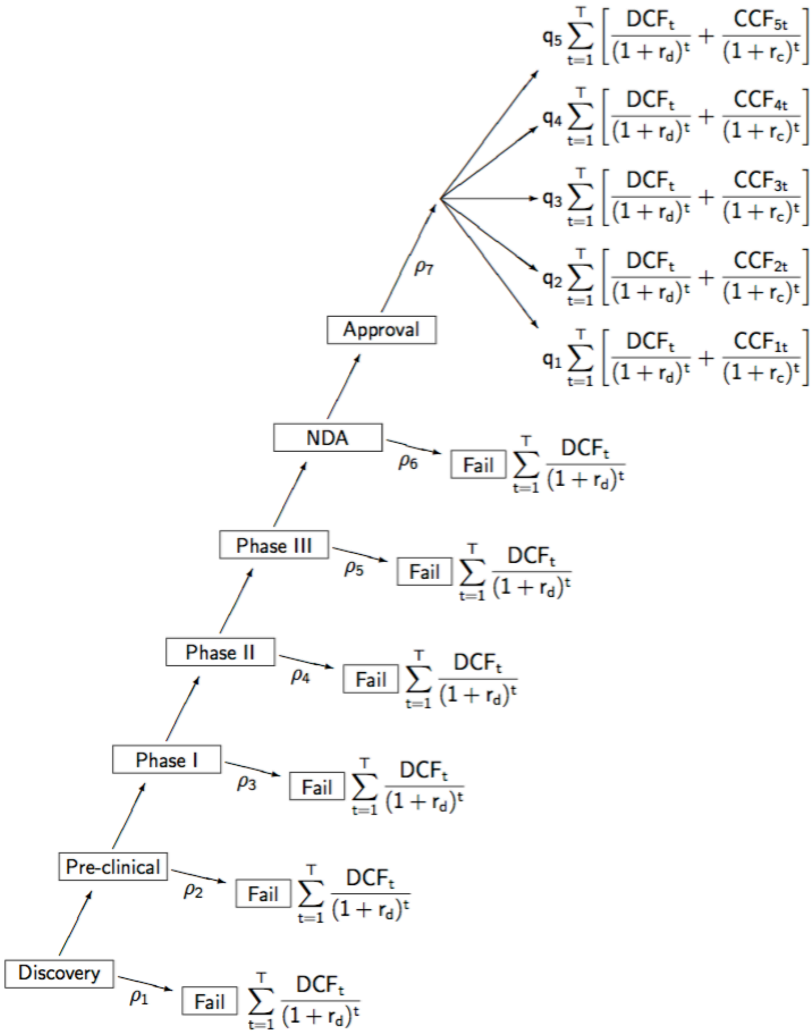

Figure 17: Decision tree for a pharmaceutical development (Kellog and Charnes, 2000)

Since this method is too detailed for the innovative technology of Organovo, it is just presented as an alternative for R&D development projects, which are detailed and can be broken down into different steps. This can be very helpful for start-up valuation, which rely on repetitive procedures.

2. The Black-Scholes formula

Since the binominal pricing model is a discrete model with several time intervals between price movements, this approach is limited to the point where the time intervals gets smaller and smaller. Alternatively, Black and Scholes (1972) have come up with a continuous approach for valuing European options, assuming the the prices keep changing under a normal distribution. Due to its flexibility, ease of understanding and risk neutral probability based model, the Black-Scholes model is one of the most-widely accepted real option valuation methods (Baduns, 2013). The value of the call option under Black and Scholes (1972) is calculated with the present value of all future cash flows of the underlying (S), which requires an initial investment (K), the strike price, to generate future cash flows in T years with a volatility (σ) and the risk free rate (r). The estimate d_1 and d_2 are calculated with the inputs of the option:

$$d_1 = \frac{\ln\left(\frac{S}{K}\right)+\left(r+\frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}; \; d_2 = d_1 - \sigma\sqrt{t}$$

Afterwards the cumulative normal distribution function $N(d_1)$ and $N(d_2)$ are estimated. The present value of the exercise price is approximated using the formula Ke^{-rt}. Black and Scholes model assigns the value of the call:

$$C = S\,N(d_1) - Ke^{-rt}N(d_2).$$

The first part of the formula resembles the number of shares (option delta) which need to be bought $S\,N(d_1)$ and the second part resembles the amount that needs to be borrowed $Ke^{-rt}N(d_2)$.

For put options, the put value P can be calculated through the put call parity which assumes a call with the same strike price and expiration date:

$$C - P = S - Ke^{-rt}$$

The put call parity is based on the assumption that the holder sells a call and buys a put with exercise price K and the same life time t and buys the stock at the current price S. The payoff is riskless and always yields K (Damodaran, 2012). This relationship can be substituted into the Black-Scholes model with the value of the put:

$$P = Se^{-yt}\,(N(d_1) - 1) - Ke^{-rt}(N(d_2) - 1)$$

$$\text{with } d_1 = \frac{\ln\left(\frac{S}{K}\right)+\left(r-y+\frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}; \; d_2 = d_1 - \sigma\sqrt{t}$$

While the approach suggested by Damodaran takes Organovo's current operations and expansion in 3D bioprinted human tissues into account, there is a probability that the start-up can use its customers base and partnership to expand in the diseased human tissue. The following parameter are assumed for the Black-Scholes formula:

- Investment: It will cost Organovo $80m to develop new diseased tissues. This includes the cost of R&D, production and commercialisation.
- Cash flows: Based on the information Organovo has today, the start-up expects to stepwise reach around $50m in after-tax cash flows at year 10.
- Cost of capital: The cost of capital for comparable biotechnology companies is 9.2%, as suggested in the database of New York Stern provided earlier.
- Volatility: The annualised standard deviation in the stock price of Organovo is 76.9% according to their annual report. Alternatively, this can be measured through the volatility of the market value of comparable listed companies.
- Risk free rate: For the risk free rate the author took a bond with the same time to maturity as the option, i.e a US government bond with a 10-year maturity yielding 3.78% as discussed earlier.

In order to value the option to expand into diseased tissue, we derive the option inputs from the value provided above:

- S = Current value of the underlying: Present value of expected cash flows from expanding into the 3D bioprinted diseased human tissue is $70.3m

Present Value of Cash Flows (in $m)		2015A	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Year			1	2	3	4	5	6	7	8	9	10
Expected Revenues			0.5	2	4	8	16	24	30	35	40	50
Expected Cost			-10	-8	-8	-6	-6	-4	-4	-2	-2	-2
Cash Flows			-9.5	-6	-4	2	10	20	26	33	38	48
Discount factor at rate	9.2%		0.92	0.84	0.77	0.70	0.64	0.59	0.54	0.49	0.45	0.41
Discounted Cash Flows			-8.7	-5.0	-3.1	1.4	6.4	11.8	14.0	16.3	17.2	19.9
Present Value of Cash Flows		**70.3**										

Table 34: Present value of Organovo's cash flows for diseased human tissue

- K = Strike price = Cost of entering the diseased tissue market = $80m
- t = Time until expiration in years = Life time of the option = 10 years
- r = Risk-free rate = Derived from the US 10-year government bond 3.78%
- σ = Volatility of the underlying asset = The annualised standard deviation in the stock price of Organovo is 76.9% according to their annual report

Afterwards, d_1 and d_2 will be computed:

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}} = 1.32$$

$$d_2 = d_1 - \sigma\sqrt{t} = 1.32 - 0.769\sqrt{10} = -1.11$$

However, the value for the $N(d_1)$ and $N(d_2)$. When including all these parameters in the Black-Scholes model, the following call value is obtained:

$$C = S\,N(d_1) - Ke^{-rt}N(d_2) = 70.3\,(0.91) - 80e^{-(0.0378)10}(0.13) = \$56.5m$$

Black-Scholes assumptions	
So	70.3
K	80.0
r	3.78%
σ	76.9%
T	10
d1	1.32
d2	-1.11
N(d1)	0.91
N(d2)	0.13
Call value	**56.5**

Table 35: Organovo's option value using the Black-Scholes formula

This is a classical example of real option value. Note that the previous NPV would not have allowed to develop the diseased tissue, because the development costs were higher than the present value of cash flows. The following two factors are key in the expansion: First, Organovo can flexibly adjust its diseased tissue investment, i.e. expand, contract, defer or reallocate the investment. Second, Organovo can learn from the market and decrease the uncertainty through gathering information about additional costs and revenues. The value derived from the real option calculation has to be added to the value from the discounted cash flow from Damodaran's approach. Therefore, the total value of Organovo is:

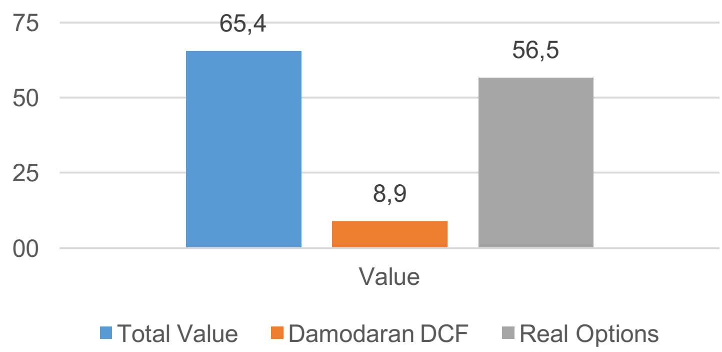

Figure 18: Valuation of Organovo with the Damodaran DCF and Real Options approach

iii. Limitations of this valuation method

Despite the strengths of the real option valuation in taking managerial flexibility and cash flow uncertainty into account, there are several limitations of the theory that will be discussed in the following. It is important to mention that the key factor of the real option theory is the exclusivity of the learning and adaptive behaviour of the start-up. Adding a growth option for the diseased tissue would not be possible in case any company would be able to easily expand in this new niche. The option has to be restricted to the company and cannot be open to the rest of the market. In the case of Organovo, due to its 3D bioprinters and special technology patented by their strong IP portfolio, Organovo is able to use their technology in another way and instead of creating healthy tissue, create diseased one. It is important to mention that due to its unique customer base and especially trust established in the industry, Organovo will have the exclusivity and therefore can use real option valuation.

Furthermore, the real option approach is limited to growth opportunities, which are not already priced into the current discounted cash flow. Many analysts mistake this feature and add options to any kinds of company that has growth opportunities. This growth potential, however, shall not be double counted, it has to be either in the discounted cash flow or in the option premium. Damodaran (2009) adds that real options should only be used in the case, where the expected expansion opportunities cannot be adequately captured in the expected cash flows and where the company in question has significant competitive advantage over the competition. In the case of Organovo, only the healthy 3D bioprinted human tissue is valued in the DCF approach, while the diseased expansion opportunity is added to the option valuation.

Moreover, van Putten and MacMillan (2004) argue that many CFOs do not see the practical use of real options, because managers using real options overestimate the value of uncertain projects. Therefore, managers might overinvest in those projects, which might allow overambitious managers to misuse shareholders' money on an excessively optimistic real option valuation (van Putten and MacMillan, 2004). This is also partially due to model risk, the case, in which the model does not accurately represent reality. The gap between the model and the true outcome can happen due to necessary simplification, lack of information or long time periods. Managers should nevertheless be careful not to take too much risk and accurately estimate the parameters in the real option valuation.

Benninga and Tolkowsky (2002) highlight that an accurate estimation of the volatility has a large impact on the value of real options, since the value from the option comes from the uncertainty about the cash flows of a project. The main difficulty is to find a suitable volatility for a specific start-up and the right arguments for the chosen value. This is especially difficult, because volatility between different companies in the same industry varies by around 80%, contrary to the WACC, which only varies by around 15%. Volatility is a key variable in the real option calculation, which determines the value in the up or down scenario: $u = e^{\sigma\sqrt{\Delta t}}$ and $d = e^{-\sigma\sqrt{\Delta t}} = \frac{1}{u}$. Little changes in volatility can have a big impact on the valuation and therefore need to be estimated as accurate as possible.

iv. Applicability for start-up valuation

Although the option calculation is not widely used yet, the argument of its complexity does not fully apply. Compared to the DCF method, the real option approach is surely more technical, however, not difficult to apply. It is very important to understand that the option value only arises from this exclusivity, since growth might be counted double otherwise. The expected growth of a start-up is already taken into account in the discounted cash flow, the growth of an exclusive option to expand has to be treated separately in the option premium (van Putten & MacMillan, 2004).

In fact, real options are a powerful tool for companies to assess the potential value of a start-up. This tool, however, needs to be selectively used only in those cases, where the expansion cannot be adequately captured in the normal cash flow growth (Damodaran, 2009). Furthermore, the real option approach allows to account for the probability that a start-up can decide not to stop with a project half way through. The Net Present Value approach on the other hand does not take the investor's exposure to risk into account and assume that the project is irreversible. The real option approach allows investors to calculate the necessary flexibility if market or project conditions change significantly. For more product driven start-ups, Bollen (1999) developed a real option framework for products that are characterised by a stochastic product life cycle. This approach should be used, because the standard technique for valuing real options ignore the development stages and only use a constant expected growth rate for demand or price (Bollen, 1999).

Furthermore, the real options approach decreases the probability of overlooking a future profitable investment opportunity. Lin and Herbst (2003) have shown that using real options is especially useful for valuing start-ups with pending patents that are associated with high growth. Since start-up companies operate with a higher degree of uncertainty compared to mature companies, the management tends to change their decisions during the development stages (Banerjee, 2003). Therefore, the flexibility allowed in the real options valuation is necessary to account for the change of plans, as Banerjee (2003) has proven the importance of real options for big R&D investments, which are still uncertain. But in fact, real options are not only limited to the healthcare investments, Benaroch (2002), for instance, presented a new approach in his paper to exploit real options in order to optimally configure IT investments in light of its risk. Furthermore, Zarzecki (2010) confirmed the use of DCF combined with real options for internet companies. Van Zee and Spindler (2014) researched a different field by looking at the applicability of real options approach for valuing public-sector R&D projects, while Schwartz (2013) focuses on the valuation of natural resource investments with real options. The research has shown that this method can also be used for public technology projects and more importantly generate potential tax payer savings while investing in a stepwise binominal lattice approach. Consequently, it can be said that the real option approach is universally applicable to any kind of start-up or project with uncertain investments, where the investment flexibility to expand, contract, defer and reallocate need to be taken into account.

e) Valuation of intangibles

Nowadays, many start-ups, especially in technology and ecommerce, have little assets on their balance sheets, as they try to use as little capital as possible in order to successfully launch their idea. Therefore, contrary to capital intensive manufacturing start-ups, several start-ups are characterized by little asset value on their balance sheet apart from the cash they raised. However, having a low intrinsic value measured by the discounted cash flow analysis and a low asset value on the balance sheet does not mean that the start-up is not worth a lot. Most start-ups in fact have a lot of intangible assets, which are not recorded on the balance sheet. In order to recognize intangible assets on the balance sheet, these three characteristics have to be met: identifiability, control over a resource and existence of future economic benefits (Kothari, Ranka and Sharma, 2013).

Kothari et al. (2013) divide intangibles in the following categories: marketing related intangibles (names, internet domains), customer related intangibles (customer lists and relationships), artistic related intangible assets (lyrics, advertising jingles), contract based intangibles (royalties, broadcasting rights), technology based intangibles (software, secret processes), patents, copyrights, trademarks, franchise licenses, government licenses and goodwill. Intangibles can generally be divided in two categories, whether they have been purchased or internally developed with a finite or indefinite life. For start-ups most intangibles assets are internally developed, which often add a lot of value to the young company. These include new innovative technology, cost-saving business processes or creative business models. However, since these intangibles are in their development phase and still need to prove to bring future economic value, they are mostly not recognized on the balance sheet.

Thus, start-ups have a lot of intangible assets that are not recorded on their balance sheet, which makes the valuation even more difficult. Goldman (2008) highlights a couple of factors, such as exclusivity, ownership rights, degree of development, competition, cost of substitution and ability to generate revenues or reduce cost, which make intangible assets valuable. Instead of looking at the intangibles only, it is more important to focus on the value drivers of a company. The following paragraphs take a closer look at the valuation of innovative technology with the market based, cost based and income based methods. Afterwards potential challenges in valuing intangibles for start-ups will be pointed out.

i. Market based valuation method

In the market based valuation approach, transactions are analysed for comparability, for instance, licensing agreements, which can be investigated to benchmark an appropriate royalty rate (Kothari et al., 2013). Market based valuation of assets is especially difficult, because even for tangibles of established companies it is hard to find a comparable company. Let alone for intangible assets, finding comparable transactions is nearly impossible. However, not only due to the lack of comparable transactions, but especially due to the fact that intangibles are mostly not developed to be sold on their own, but more as part of the company, the valuation with the market method is very difficult. Data for those transactions where only specific intangible assets have been sold, is mostly not available, because the price is kept confidential. But most importantly, the intangible assets that make a start-up especially valuable, e.g. innovative technology, will not exist on the market, so it will not be possible to find an equivalent with a comparable value. Therefore, using the marked based valuation method will mostly not be applicable for start-ups.

In the case of Organovo, valuing the IP portfolio on a market based approach will be especially difficult to the reasons mentioned above. First of all, no comparable patents exist, second the price Organovo paid to hold the exclusive licence of the patent developed by Professor Gabor Forgacs is unknown and also the value created from the resulting patents is not disclosed. Therefore, the market based valuation method does not help in determining the intangible asset value of Organovo.

ii. Cost based valuation method

The cost based approach calculates the "cost to create" or the "cost to replace" in order to value an intangible asset. Kothari et al. (2013) highlight, that the cost of recreating an intangible asset needs to be taken into account with the historic cost of the initial creation. The method assumes that the acquirer only pays the amount it will cost to produce the technology themselves. The "cost to create" approach refers to the historic cost approach, which adds up the cost that have been incurred in developing the intangible asset. These costs include both direct costs, e.g. material and labour costs, and indirect costs, e.g. design, marketing and overhead costs. However, the historic cost approach does not consider, that special know how had to be available in order to come up with the idea to create the innovative technology, as an example of an intangible asset. Therefore, the "cost to replace" approach focuses on the value another company had to incur in order to recreate the same technology. The difficulty with both methods is, however, that they ignore the value of the intangible asset will create over time, e.g. potential growth and the usefulness of innovative technology created by a start-up for the future of a mature company (Goldman, 2008). Since this approach does not take into consideration the intrinsic value of the intangible asset, van Schootbrugge and Wong (2013) suggest that this approach is only useful for small projects and the stage where start-ups are out of cash and need to accept any kind of deal.

In the case of Organovo it is hard to estimate how many costs were incurred to develop the patents, the basis of their business. On Organovo's website it says that in 2004 a $5m National Science Foundation Frontiers in Integrative Biological Research (FIBR) grant has been awardee to the team led by Professor Gabor Forgacs of the University of Missouri-Columbia. The author assumes that the $5m only covered a part of the cost the university needed to develop the patent and therefore assumes that at least another $3m had been raised earlier to develop the technology. Therefore, in total, using the cost based approach, the intangibles of Organovo can be valued at additional $8m, which needs to be added to the total value.

iii. Income-based valuation method

The income based valuation method uses future earnings that are attributable to the intangible asset that are forecasted over the useful life and discounted to the present value in order to value the intangible asset (Kothari et al., 2013). The "relief from royalty" method, for instance, adds up the potential royalties a purchaser would be willing to pay and afterwards the royalty stream is capitalized in order to reflect the risk return relationship when investing in such an intangible asset. For this approach, market trends and competitive dynamics need to be estimated in order to correctly assume how much income can be made with the innovative technology of a start-up.

This method is mostly used for intangibles businesses, since it is most comparable with the true value of free cash flows generated by the intangible asset. The forecasted cash flows, however, need to be carefully reviewed and double counting avoided, since some intangible assets may generate the same cash flows. Goldman (2008) suggests estimating the income and cash flows of the intangible asset by looking at the following factors:

- Loyalty of customers
- Degree of value added and attractiveness of the product
- Size, growth rate and competition in the market
- Capital requirements and barriers to entry
- Efficiency and comparable advantages
- Available resources and potential constraints
- Expected time of sale and profitability
- Seasonality and cyclicality
- Regulatory, tax and economic environment

The value of the intangible can be calculated as follows (Goldman, 2008):

$$Value = Potential\ revenues * Probability\ of\ success$$
$$-Potential\ costs * Probabiltiy\ of\ failure$$

Since in the case of Organovo, the income and future cash flows generated have already been taken into account through the DCF approach suggested by Damodaran, the author sees no need to recalculate potential income through the strong IP portfolio of Organovo. The author will however add the value of the patents calculated in the cost based approach to the total value of Organovo.

iv. Challenges of valuing intangible assets

Despite not having any physical value, intangible assets can have an immense value for a start-up. The difficulty lies not only in valuing the intangible assets, but also in finding a good balance between having value created through DCF and tangible assets on the one side and intangible assets on the other side. Companies that have too many intangibles on their balance sheet run risk to being insolvent when the value of the intangibles is written down. This has happened in many cases, where investors lost all their money they put in a start-up, simply because the level of intangibles was more than double the value of book equity. For these young companies, it is hard to understand, how intangibles are valued that high, especially, in case the start-up is still loss making.

The study of Block, de Vries and Schumann and Sander (2014) has shown that the number and breadth of trademark applications have inverted U-shaped relationships with the financial valuations of start-ups. The different valuation methods have proven that for start-up valuation the income based method is most appropriate, especially in case significant revenues can be generated and the DCF approach showed little value. However, as a very interesting insight, Block et al. (2014) found that in later funding rounds, the value of trademark applications decreases, as the growth of the start-up becomes more important during later development stages. Therefore, in the case of Organovo, the valuation from intangibles will only be added through the cost based approach. Surely, the value from its strong IP has helped Organovo in the primary financing rounds, but at this stage, the author assumes that the focus has shifted from the IP portfolio to how high revenues Organovo is actually able with it. The income based method should therefore be used only for very young companies as an add-on to the Damodaran approach and real option approach mentioned in the previous sections. To conclude, together with the patent value of the cost based method the total value of Organovo will be a total of $m:

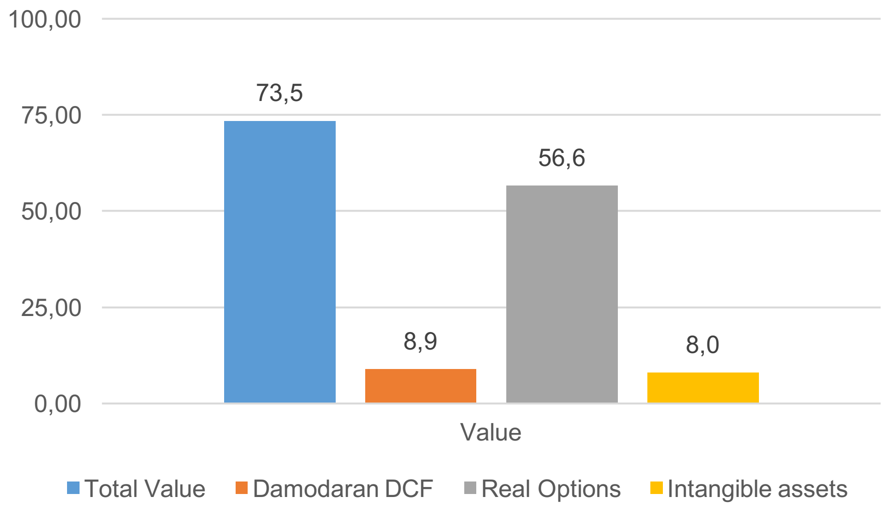

Figure 19: Valuation of Organovo with the Damodaran DCF, Real Options and Intangible assets

6. Verification of the valuation methods

Following Eichner, Gemünden & Kautzsch (2007) the next table gives an overview of the principles, difficulty and applicability of all valuation methods discussed above. It aims to show which start-up valuation methodology has proven most useful during the valuation of Organovo. In this master thesis several valuation techniques have been considered. Their complexity and applicability to Organovo are indicated below:

	Relative valuation (Multiples or Transactions)	Discounted Cash Flow (DCF)	Venture Capital/ First Chicago Method	Damodaran Appraoch	Real options	Intangible asset valuation	Hybrid models
Principle	• Valuation based on capital market or transaction data of comparable companies • Transaction or price multiples	• Valuation of future cash flows generated by the assets of the firm	• Mixture of previous methods for quick valuation of investors' equity share	• Valuation based the DCF approach, including a variation of discount rate and better FCF approximations	• Value comes from options which allow managerial flexibility and learning • Possibility to expand/defer/ contract or reallocate	• Valuation based on market, transaction or forecasted revenue data of comparable intangibles	• Valuation based on previous approaches • DCF, real option and market like approach
Difficulty	• Lack of data • No history • Difficult to find comparable listed start-ups • Difficult to compare young with mature companies	• Lack of historic data and detailed financials • Difficult to estimate FCF and discount rate	• Not very precise, mostly too optimistic • Focus on revenues or earnings only • Too high discount rates	• Terminal value too high, but great adaptation to characteristics of start-ups	• Seemingly too technical, but easy to apply • Volatility has large impact on the value	• Lack of data • Difficult to find comparable intangibles • Expertise of start-ups for intangibles mostly unique	• Needs to be verified for different industries and start-ups
Applicability for start-ups							

Table 36: Different valuation methods and their applicability for start-ups

As stated in the disclaimer at the beginning of the valuation, this master thesis is not trying to value the company so the market value is reached, but instead use the valuation methods proposed for start-up and apply them to the case of Organovo. The possible sources of missing value will be discussed in the following.

First of all, the market price of a start-up can be different, because a larger company aims at acquiring the young companies and this premium for a strategic acquisition is already priced in. Fujiwara (2014) found that especially biotech start-ups build their business models based on strategic partnerships, since big pharmaceutical companies see these investments as a quick, low cost alternative to R&D and venture capitalist see a mismatch between long term basic research and short term financial markets. In case of Organovo, there is no doubt that big biopharmaceutical companies are interested in a start-up, which has a very strong IP portfolio and innovative technology which may significantly shape the future. Currently, Organovo has several partnerships, for instance, with Merck or Roche. However, in case the price gap is too big between the calculated value of the company and the market value, a rational buyer will not pay this big surplus. Nevertheless, in recent years several unicorn valuations have been critically scrutinised, as some people do not believe that their real value is as high as the value it has been assigned.

Another possible explanation of the value gap could be the uniqueness of the technology in question. Organovo's 3D human tissue bioprinting, if proven as successful, as forecasted, has huge growth opportunities in foreign markets. The company is based on a strong IP portfolio, which might not be easily replicable in other countries, but can reach great success once all regulatory requirements have been passed. Thus, it might be helpful to add another real option approach on top, valuing the expansion of Organovo's technology to other countries and continents.

Cornell and Damodaran (2014) add in their studies about rapid stock price increase of young companies with the example of Tesla that the stock price might also be driven by momentum-stoked investor sentiment. Within one year, Tesla's stock price had risen over 590% to $253.00, showing that Cornell and Damodaran's (2014) arguments of investor sentiment are highly probable, especially in the time of incredibly high unicorn valuations. Although Organovo's stock price is on a comparable low level with the highest point being around $12, the start-up is prone to fluctuations in its stock price, because investors sentiment has a significant impact on the market value. To conclude, the study has shown that due to several reasons the stock prices can differ significantly from other valuation methods, as presented in the case of Organovo.

a) Alternative approaches to consider

The study of Gavious and Schwartz (2010) shows that during the technology bubble in the early 2000s, the market did not rely on accounting information for valuing start-ups. Mainly too many start-ups had been overvalued and therefore after the bubble burst, the market turned more conservative, relying predominantly on book value of equity and earnings (Gavious and Schwartz, 2010). Bratic, Blok and Gostola (2014) mention that understanding the several risk in the biotechnology sphere is key to successfully forecast revenues and cost. Risks, such as risk of biosimilars, risk of litigation or risk of decreasing demand, therefore need to be considered in the valuation process (Bratic et al., 2014). Zhen, Liu and George (2010) looked at the dynamic impact of innovative capability and inter firm network on valuation and found that for biotechnology start-ups the relative value of network status declines while the value of innovative capability increases with firm age.

However, due to the high degree of uncertainty, other important variables in start-up valuation need to be taken into account. Non-financial information, especially for start-ups, has proven to be powerful and complementary to financial information in explaining pre-money value (Sievers, Mokwa and Keienburg, 2013). Maxwell, Jeffrey and Levesque (2011) found that the value and decision to invest in a start-up is based on the founders' industry experience, management ability and team experience. Regarding venture capitalists, Miloud, Aspelund and Cabrol (2012) found that investors are especially interested in the attractiveness of the industry, the quality of the founder and top management team as well as the external relationships of a new venture. Zarzecki (2010) suggests that investors' expectations and emotions have a great impact on stock value. These studies have all shown that several subjective factors have a great impact on start-up valuation and therefore need to be taken into consideration when valuing young start-up companies.

Furthermore, since only limited financial, market and operational information is available for start-ups, Goldman (2008) suggests to take a broader set of factors into account. After several forecasts, calculations, comparisons and methodologies, the value of a start-up also depends on the managers' and founders' ability to perform. The future growth potential can, for instance, be assessed through the competences of the management team and the ability to successfully expand the operations. Goldman (2008) therefore suggests to focus on the following management traits when valuing a start-up: Focus on cash flow, ability to admit mistakes and adjust a business plan, ability to adhere to a detailed action plan with timetables and performance benchmarks. Furthermore, Goldman (2008) suggests to define responsibilities, communicate in a timely and effective manner with all stakeholders involved and organise data in a structured way in order to attract more attention of investors. Management competences, such as being creative and taking the lead, understanding potential risks of the start-up, motivating employees, providing guidance and setting an example are key to succeed. Goldman (2008) also highlights the ability to set clear goals, utilise strong functional or technical expertise and reach out to relevant contacts in order to establish a strong network.

Because the success of a start-up can be very dependent on the owner or a key person in management, the value of the company can change significantly in case a key person leaves the company. Damodaran (2009) suggests that one way to access the importance of the key person is to survey existing customers and suppliers to see how their behaviour changes in case the key person leaves. This is a very subjective value, however, it needs to be taken into account, in case one of the key persons is leaving. Consequently, two scenarios, one being with the key person and one without the key person, can be created which will lead to the net worth of the key person. To minimise the effect, often times the key person stays for a transition period until the new owner of the business can fully take control of the important relationships.

7. Conclusion and recommended research

"Price is what you pay, value is what you get"
– Warren Buffet

Low survival rates, fluctuating free cash flows, changing discount rates and a lack of financial data make start-up valuation a challenging task. After a short introduction in the characteristics of start-ups, i.e. loss making, equity financed and binary business model, this master thesis highlights the main limitations of traditional valuation models, such as the DCF, multiple method, transaction method with a specific focus on the discount rate. Therefore, five alternative methods to value start-ups have been proposed, namely, the Venture Capital method, the First Chicago method, the Damodaran approach, the real options approach and the valuation of intangible assets. Based on the theoretical framework, the biotechnology start-up Organovo has been valued. Under the assumptions made in this master thesis, Organovo was valued at $73.5m, compared to a current market capitalisation of $235.6m.

In reality, start up valuation is also determined by the willingness of the entrepreneur and the investor to agree on a price for the amount of cash in the deal and the percentage of equity (Ochse, 2014). Therefore, in the last section of this master thesis, the importance of non-financial information complementary to financial information has been highlighted. The value and the decision to invest in a start-up in based on the the quality of the founder, founders' industry experience, management ability and team experience (Goldman, 2008; Maxwell, Jeffrey and Levesque, 2011). Although there is hardly any method that makes it possible to accurately value high risk, uncertain investments, any attempt to raise questions that acknowledge the inability to predict the future with certainty will improve the decision making process.

For future research the author recommends to investigate whether the methods proposed also fit for start-ups in different industries. Real options, for instance, have proven to be applicable especially for mining, pharmaceutical and technology companies. New research could investigate the applicability of the real options approach in, for instance, automotive, engineering or fashion start-ups. In addition, start-ups have different capital requirements. Thus, one start-up might require multiple rounds of start-up financing, while others are almost self financed. Future research should investigate whether this has an impact on the valuation of start-ups. Furthermore, the relative importance of each valuation technique compared to the other methods proposed needs to be reviewed more in detail. So far it is not apparent, depending on which variable, a certain valuation technique might be more important than another valuation technique especially designed for start-ups. Moreover, in the last part of the thesis the author highlighted a couple of non-financial parameters which have an impact on the valuation. The relative importance of each of these non-financial factors should be investigated in future in order to get a clear overview, which factor is most important for investors. This can again depend on the industry or the type of investor, which needs to be investigated.

To conclude, valuing start-ups is a very challenging task, especially due to start-ups' high operating losses, short histories and restricted financial data. The approaches suggested in this thesis help modify traditional methods into valuation approaches which can be used for start-ups. Although these methods still have to be proven in different contexts and industries, carefully selected assumptions and accurate estimations will allow investors to arrive at a structured and well-reasoned start-up value.

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Abbreviations and Acronyms

β_L	Levered beta
β_U	Unlevered beta
CAPM	Capital asset pricing model
CCF	Commercial cash flows
DCF	Discounted cash flow
EBIT	Earnings before interest and taxes
EBITDA	Earnings before interest, taxes, depreciation and amortization
ERP	Equity risk premium
EV	Enterprise value
FCFF	Free cash flows to the firm
g	Growth rate
IP	Intellectual property
IRR	Internal rate of return
K	Initial investment or strike price
k_E	Cost of equity
k_D	Cost of debt
MRP	Market risk premium
NOPAT	Net operating profit after taxes
NPV	Net present value
NWC	Net working capital
PBR	Price book ratio
PER	Price earnings ratio
r_f	Risk-free rate
r_m	Return of the market
S	Present value of all future cash flows of the underlying
t	Tax rate
TV	Terminal value
V_D	Net debt value
V_E	Equity value
WACC	Weighted average cost of capital
σ	Volatility

9. Appendix

Appendix I

Organovo's consolidated balance sheet for the years 2014 and 2015
(in thousands except per share data)

	March 31, 2015	March 31, 2014
Assets		
Current Assets		
Cash and cash equivalents	$ 50,142	$ 48,167
Inventory, net	66	63
Prepaid expenses and other current assets	1,054	931
Total current assets	51,262	49,161
Fixed assets, net	2,042	857
Restricted cash	79	79
Other assets, net	106	89
Total assets	$ 53,489	$ 50,186
Liabilities and Stockholders' Equity		
Current Liabilities		
Accounts payable	$ 1,387	$ 326
Accrued expenses	2,257	822
Deferred rent	759	345
Deferred revenue	227	13
Capital lease obligation	5	10
Warrant liabilities	126	377
Total current liabilities	4,761	1,893
Deferred revenue, net of current portion	32	4
Capital lease obligation, net of current portion	—	5
Total liabilities	$ 4,793	$ 1,902
Commitments and Contingencies (Note 8)		
Stockholders' Equity		
Common stock, $0.001 par value; 150,000,000 shares authorized, 81,536,724 and 78,113,639 shares issued and outstanding at March 31, 2015 and March 31, 2014, respectively	82	78
Additional paid-in capital	170,909	140,419
Accumulated deficit	(122,295)	(92,213)
Total stockholders' equity	48,696	48,284
Total Liabilities and Stockholders' Equity	$ 53,489	$ 50,186

Appendix II

Organovo's consolidated income statement for the years 2014 and 2015
(in thousands except per share data)

	Year Ended March 31, 2015	Year Ended March 31, 2014
Revenues		
Product and service	$ 314	$ —
Collaborations	134	248
Grants	123	131
Total Revenues	571	379
Selling, general, and administrative expenses	17,947	13,054
Research and development expenses	12,921	7,974
Loss from Operations	(30,297)	(20,649)
Other Income (Expense)		
Fair value of warrant liabilities in excess of proceeds received	—	—
Change in fair value of warrant liabilities	196	(5,120)
Financing transaction costs in excess of proceeds received	—	—
Loss on inducement to exercise warrants	—	—
Loss on disposal of fixed assets	(12)	(84)
Interest expense	(1)	(13)
Interest income	32	18
Other income (expense)	—	—
Total Other Income (Expense)	215	(5,199)
Net Loss	$ (30,082)	$ (25,848)
Net loss per common share—basic and diluted	$ (0.38)	$ (0.35)
Weighted average shares used in computing net loss per common share—basic and diluted	79,650,087	73,139,618

Appendix III

Organovo's consolidated cash flow statement for the years 2014 and 2015
(in thousands)

	Year Ended March 31, 2015	Year Ended March 31, 2014
Cash Flows From Operating Activities		
Net loss	$ (30,082)	$ (25,848)
Adjustments to reconcile net loss to net cash used in operating activities:		
Amortization of deferred financing costs	-	-
Amortization of warrants issued for services	557	323
Depreciation and amortization	472	387
Loss on disposal of fixed assets	12	84
Amortization of debt discount	-	-
Interest accrued on convertible notes payable	-	-
Fair value of warrant liabilities in excess of proceeds	-	-
Change in fair value of warrant liabilities	(196)	5,120
Loss on inducement to exercise warrants	-	-
Expense associated with warrant modification	-	12
Stock-based compensation	7,020	4,600
Increase (decrease) in cash resulting from changes in:		
Grants receivable	-	101
Inventory	(3)	25
Prepaid expenses and other assets	(389)	(392)
Accounts payable	1,061	(315)
Accrued expenses	1,435	312
Deferred rent	270	75
Deferred revenue	242	(45)
Net cash used in operating activities	(19,601)	(15,561)
Cash Flows From Investing Activities		
Deposits released from restriction (restricted cash deposits)	-	9
Purchases of fixed assets	(1,517)	(277)
Purchases of intangible assets	-	-
Net cash used in investing activities	(1,517)	(268)
Cash Flows From Financing Activities		
Proceeds from issuance of common stock and exercise of warrants, net	22,752	48,016
Proceeds from exercise of stock options	351	402
Principal payments on capital lease obligations	(10)	(10)
Repayment of convertible notes and interest payable	-	-
Deferred financing costs	-	(40)
Net cash provided by financing activities	23,093	48,368
Net Increase in Cash and Cash Equivalents	1,975	32,539
Cash and Cash Equivalents at Beginning of Period	48,167	15,628
Cash and Cash Equivalents at End of Period	$ 50,142	$ 48,167
Supplemental Disclosure of Cash Flow Information:		
Interest	$ —	$ —
Income Taxes	$ 4	$ —

Appendix IV

Organovo's detailed overview of fixed assets for the years of 2014 and 2015
(in thousands)

	March 31, 2015	March 31, 2014
Laboratory equipment	$ 1,951	$ 1,207
Construction in process	529	—
Computer software and equipment	274	191
Furniture and fixtures	135	33
Leasehold improvements	155	—
	3,044	1,431
Less accumulated depreciation and amortization	(1,002)	(574)
	$ 2,042	$ 857

Appendix V

Organovo's consolidated statement of stockholders' equity for 2011 until 2015
(in thousands)

	Common Stock		Additional Paid-in Capital	Accumulated Deficit	Total
	Shares	Amount			
Balance at December 31, 2011	**22,445**	**$ 22**	**$ 4,835**	**$ (6,692)**	**$ (1,835)**
Issuance of common stock in connection with the merger	6,000	6	(6)	—	—
Issuance of common stock through private placements in connection with reverse merger	13,723	14	13,709	—	13,723
Cost associated with merger	—	—	(13,723)	—	(13,723)
Issuance of common stock through conversion of notes payable and accrued interest in connection with the merger	1,525	2	1,524	—	1,526
Issuance of warrant	—	—	890	—	890
Issuance of common stock from warrant exercises, net	13,424	14	10,977	—	10,991
Warrant liability removed due to exercises of warrants	—	—	23,321	—	23,321
Stock option exercises	224	—	18	—	18
Issuance of restricted common stock	1,380	1	(1)	—	—
Restricted stock forfeitures	(186)	—	—	—	—
Stock-based compensation expense	—	—	1,435	—	1,435
Loss on inducement to exercise warrants	—	—	1,904	—	1,904
Net loss	—	—	—	(43,553)	(43,553)
Balance at December 31, 2012	**58,535**	**$ 59**	**$ 44,883**	**$ (50,245)**	**$ (5,303)**
Issuance of common stock from warrant exercises, net	6,131	6	3,718	—	3,724
Issuance of restricted common stock	55	—	—	—	—
Restricted stock forfeitures	(34)	—	—	—	—
Stock-based compensation expense	—	—	848	—	848
Expense related to modification of warrants	—	—	65	—	65
Warrant liability removed due to exercises of warrants	—	—	23,869	—	23,869
Warrant liability reclassified to equity	—	—	1,886	—	1,886
Net loss	—	—	—	(16,120)	(16,120)
Balance at March 31, 2013	**64,687**	**$ 65**	**$ 75,269**	**$ (66,365)**	**$ 8,969**
Issuance of common stock from warrant exercises, net	2,713	3	1,098	—	1,101
Issuance of restricted common stock	60	—	—	—	—
Restricted stock forfeitures	(215)	—	—	—	—
Issuance of common stock from public offering, net	10,684	10	46,905	—	46,915
Stock-based compensation expense	—	—	4,600	—	4,600
Expense related to modification of warrants	—	—	12	—	12
Warrant liability removed due to exercises of warrants	—	—	10,874	—	10,874
Warrant liability reclassified to equity	—	—	767	—	767
Stock option exercises	184	—	402	—	402
Issuance of warrants to consultant	—	—	492	—	492
Net loss	—	—	—	(25,848)	(25,848)
Balance at March 31, 2014	**78,113**	**$ 78**	**$ 140,419**	**$ (92,213)**	**$ 48,284**
Issuance of common stock from warrant exercises, net	211	—	445	—	445
Restricted stock forfeitures	(190)	—	—	—	—
Issuance of common stock from public offering, net	3,198	4	22,303	—	22,307
Stock-based compensation expense	—	—	7,020	—	7,020
Warrant liability removed due to exercises of warrants	—	—	55	—	55
Stock option exercises	205	—	351	—	351
Issuance of warrants to consultant	—	—	316	—	316
Net loss	—	—	—	(30,082)	(30,082)
Balance at March 31, 2015	**81,537**	**$ 82**	**$ 170,909**	**$ (122,295)**	**$ 48,696**

Appendix VI

Organovo's comparable companies: Market data & price multiples
(in millions, except for price data)

This data das been collected from Thompson One and Capital IQ.

Market Data & Price Multiples (in $m)								
Name	**Ticker**	**Last Period End Date**	**Price**	**52 Week Low**	**52 Week High**	**Dividend Yield TTM**	**Shares Outstanding**	**Market Cap - Consolidated**
ORGANOVO HOLDINGS, INC.	**ONVO-US**	**12/31/2015**	**2.55**	**3.29**	**9.25**	**0.00%**	**92**	**235.60**
ELI LILLY AND COMPANY	LLY-N	03/31/2016	74.08	67.88	92.85	2.73%	1,104	81,820.81
ABBOTT LABORATORIES	ABT-N	03/31/2016	37.37	36.00	51.74	2.77%	1,469	54,902.21
SANOFI	SAN-FR	03/31/2016	80.00	75.71	115.21	4.12%	1,287	102,942.32
MERCK & CO., INC.	MRK-N	03/31/2016	54.92	-	-	3.34%	2,768	152,019.80
PFIZER INC.	PFE-N	04/03/2016	33.67	28.25	36.46	3.56%	6,065	204,203.40
JOHNSON & JOHNSON	JNJ-N	04/03/2016	112.16	81.79	115.00	2.84%	2,751	308,512.10
MABVAX THERAPEUTICS HOLDINGS, INC.	MBVX-5	12/31/2015	0.64	0.41	2.82	0.00%	31	19.70
STELLAR BIOTECHNOLOGIES, INC.	SBOT-O	12/31/2015	3.87	2.63	10.39	0.00%	8	32.72
SAREPTA THERAPEUTICS, INC.	SRPT-O	03/31/2016	17.48	8.00	41.97	0.00%	46	800.15
PROTHENA CORPORATION	PRTA-O	03/31/2016	44.19	28.20	76.42	0.00%	34	1,517.89

Eli Lilly, Abbott, Sanofi, Merck, Pfizer and Johnson & Johnson are all established companies, whereas Mabvax Therapeutics, Stellar Biotechnologies, Sarepta Therapeutics and Prothena Corporation are start-ups. This is also visible in the high stock price volatility of the star-tup companies compared to the mature ones and the 0% policy.

Market Data & Price Multiples (in $m)			
Name	**P/E TTM**	**P/E FY1**	**P/E FY2**
ORGANOVO HOLDINGS, INC.	**NEG**	**NEG**	**NEG**
ELI LILLY AND COMPANY	34.06	20.79	18.68
ABBOTT LABORATORIES	23.44	16.93	15.15
SANOFI	20.99	12.71	12.47
MERCK & CO., INC.	33.60	-	-
PFIZER INC.	27.58	13.80	12.86
JOHNSON & JOHNSON	20.45	16.98	16.03
MABVAX THERAPEUTICS HOLDINGS, INC.	NEG	NEG	NEG
STELLAR BIOTECHNOLOGIES, INC.	NEG	NEG	NEG
SAREPTA THERAPEUTICS, INC.	NEG	NEG	NEG
PROTHENA CORPORATION	NEG	NEG	NEG
Mean	26.69	16.24	15.04
Median	20.45	5.86	5.75
High	34.06	20.79	18.68
Low	20.45	12.71	12.47

Due to their negative earnings, start-up companies have a negative P/E multiple. Therefore, only the forward looking P/E multiple of the established companies can be used for the Venture Capital method. For the valuation the author used the forward looking P/E multiple of around 15x, since the multiple of the trailing twelve month is very high compared to the future outlook.

Appendix VII

Organovo's comparable companies: EV multiples

This data das been collected from Thompson One and Capital IQ.

EV Multiples			
Name	EV/Sales TTM	EV/Sales FY1	EV/Sales FY2
ORGANOVO HOLDINGS, INC.	**140.87**	**133.59**	**27.99**
ELI LILLY AND COMPANY	4.31	4.17	4.01
ABBOTT LABORATORIES	2.89	2.82	2.67
SANOFI	2.78	2.65	2.58
MERCK & CO., INC.	4.17	-	-
PFIZER INC.	4.40	4.28	4.13
JOHNSON & JOHNSON	4.16	4.07	3.89
MABVAX THERAPEUTICS HOLDINGS, INC.	12.33	42.33	-
STELLAR BIOTECHNOLOGIES, INC.	50.68	11.28	3.83
SAREPTA THERAPEUTICS, INC.	543.72	59.49	15.16
PROTHENA CORPORATION	815.98	112.16	24.55
Mean	144.21	37.68	7.60
Median	4.40	7.78	4.07
High	815.98	133.59	15,618.16
Low	2.78	2.65	2.58

For the Venture Capital method, a EV/Sales multiple of 4.1x has been chosen, since it is closed to the median and compared to the more mature companies the start-ups have an inflated multiple due to their little sales and high valuation.

EV Multiples			
Name	EV/EBITDA TTM	EV/EBITDA FY1	EV/EBITDA FY2
ORGANOVO HOLDINGS, INC.	**NEG**	**NEG**	**NEG**
ELI LILLY AND COMPANY	19.95	14.66	13.47
ABBOTT LABORATORIES	14.12	11.45	10.56
SANOFI	10.28	8.27	8.13
MERCK & CO., INC.	13.12	-	-
PFIZER INC.	14.05	9.83	9.24
JOHNSON & JOHNSON	12.57	11.73	11.01
MABVAX THERAPEUTICS HOLDINGS, INC.	NEG	-	-
STELLAR BIOTECHNOLOGIES, INC.	NEG	-	-
SAREPTA THERAPEUTICS, INC.	NEG	NEG	NEG
PROTHENA CORPORATION	NEG	NEG	NEG
Mean	5.65	4.47	3.81
Median	10.28	9.05	8.69
High	19.95	14.66	13.47
Low	10.28	8.27	8.13

Data one EV/EBITDA multiples for start-ups is not available, because negative EBITDA will not create a meaningful multiple.

EV Multiples			
Name	**EV/EBIT TTM**	**EV/EBIT FY1**	**EV/EBIT FY2**
ORGANOVO HOLDINGS, INC.	**NEG**	**NEG**	**NEG**
ELI LILLY AND COMPANY	29.96	18.38	16.49
ABBOTT LABORATORIES	21.60	14.73	13.22
SANOFI	17.67	10.38	10.33
MERCK & CO., INC.	26.39	-	-
PFIZER INC.	21.07	11.63	10.77
JOHNSON & JOHNSON	14.98	13.56	12.68
MABVAX THERAPEUTICS HOLDINGS, INC.	NEG	NEG	NEG
STELLAR BIOTECHNOLOGIES, INC.	NEG	NEG	NEG
SAREPTA THERAPEUTICS, INC.	NEG	NEG	NEG
PROTHENA CORPORATION	NEG	NEG	NEG
Mean	10.01	4.67	2.45
Median	14.98	4.76	4.81
High	29.96	18.38	16.49
Low	14.98	10.38	10.33

Data one EV/EBIT multiples for start-ups is also not available, because negative EBIT will not create a meaningful multiple. Therefore, the author used the EV/Sales multiple for the Venture Capital method.

Appendix VIII

Organovo's comparable companies: Key financials and effectiveness

(in millions, except for margin data)

This data das been collected from Thompson One and Capital IQ.

Key Financials & Effectiveness (in $m)							
Name	**Sales TTM**	**EBITDA TTM**	**EBIT TTM**	**EBIT Margin TTM**	**Net Income TTM**	**Net Margin TTM**	**EPS TTM**
ORGANOVO HOLDINGS, INC.	**1.20**	**(37.30)**	**(38.00)**	**-3161%**	**(38.00)**	**(3,161.48%)**	**(0.43)**
ELI LILLY AND COMPANY	20,179.10	4,358.80	2,903.10	14%	2,319.00	11.49%	2.17
ABBOTT LABORATORIES	20,393.00	4,179.00	2,731.00	13%	2,447.00	12.00%	1.59
SANOFI	38,629.58	-	5,943.89	15%	4,958.18	12.84%	3.81
MERCK & CO., INC.	39,385.00	12,529.00	6,230.00	16%	4,614.00	11.72%	1.63
PFIZER INC.	50,992.00	15,974.00	10,652.00	21%	7,601.00	14.91%	1.22
JOHNSON & JOHNSON	70,182.00	23,231.00	19,489.00	28%	15,381.00	21.92%	5.49
MABVAX THERAPEUTICS HOLDINGS, INC.	1.27	(18.08)	(18.11)	-1429%	(18.11)	(1,428.95%)	(1.82)
STELLAR BIOTECHNOLOGIES, INC.	0.53	-	(12.70)	-2376%	(12.73)	(2,380.04%)	(2.12)
SAREPTA THERAPEUTICS, INC.	1.25	-	(218.63)	-17449%	(218.24)	(17,417.48%)	(5.02)
PROTHENA CORPORATION	1.28	(91.40)	(92.32)	-7218%	(92.93)	(7,265.91%)	(2.90)
Mean	21,796.93	7,515.63	4,324.48	20%	3,358.20	(2,869.91%)	0.33
Median	20,179.10	4,268.90	2,731.00	14%	2,319.00	11.49%	1.22