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Real options for investment analysis of biotechnological startups: The case of North-West Technology Transfer Center portfolio company.

Master's Thesis by the 2nd year student

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Pavel Maslennikov

Research advisor:

Associate Professor, Anna E. Loukianova

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ЗАЯВЛЕНИЕ О САМОСТОЯТЕЛЬНОМ ХАРАКТЕРЕ ВЫПОЛНЕНИЯ
ВЫПУСКНОЙ КВАЛИФИКАЦИОННОЙ РАБОТЫ

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АННОТАЦИЯ

Автор	Масленников Павел Сергеевич
Название магистерской диссертации	Реальные опционы для инвестиционной оценки стартапов в сфере биотехнологий на примере компании из портфеля Северо-Западного Центра Трансфера Технологий
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Научный руководитель	Доцент, Анна Евгеньевна Лукьянова
Описание цели, задач и основных результатов	Целью данной работы является разработка рекомендаций для улучшения процесса инвестиционной оценки стартапов в сфере биотехнологий при помощи реальных опционов. Задачами исследования являются: Обзор существующих методов инвестиционной оценки технологических проектов; Анализ применимости метода реальных опционов для инвестиционной оценки стартапов в технологической сфере и более конкретно в сфере биотехнологий; Формирование методологии для инвестиционной оценки биотехнологических стартапов с применением реальных опционов; Использование разработанной методологии для инвестиционной оценки проекта «PolySeed» из портфеля Северо-Западного Центра Трансфера Технологий; Разработка рекомендации для улучшения процесса инвестиционной оценки стартапов в сфере биотехнологий. Результатами работы является получение практических рекомендаций для менеджеров проекта «PolySeed» и иллюстрация применения метода реальных опционов и его преимуществ для оценки стартапов в сфере биотехнологий.
Ключевые слова	Реальные опционы, инвестиционная оценка, биотехнологии, стартапы

ABSTRACT

Master Student's name	Maslennikov Pavel
Master thesis title	Real options for investment analysis of biotechnological startups: The case of North-West Technology Transfer Center portfolio company.
Faculty	Graduate School of Management
Main field of study	Corporate Finance
Year	2016
Academic Advisor's Name	Associate Professor, Anna E. Loukianova
Description of goal, tasks and results	The goal of this research is to develop recommendations to improve the process of investment analysis including valuation and risk management of biotechnological startups applying the methodology of real options. The objectives are to provide an overview of existing methods of investment analysis of technological and biotechnological projects; To review real options method applicability to investment analysis of technological and biotechnological projects; To formulate methodology for real options analysis of biotechnological startups; To apply the formulated methodology to conduct the investment analysis of NWTTC (RUSNANO group) portfolio project PolySeed; To develop recommendations for improvement the process of investment analysis of biotechnological startups. In the result, the practical recommendations for managers of the PolySeed project were developed and the implementation of real options analysis and its benefits were illustrated.
Keywords	Real options, valuation, risk management, biotechnology, investments, startups

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INTRODUCTION

Today a lot of attention is given to investments in the technological sector, especially in Russia. Such organizations as RUSNANO, FIEP, Skolkovo Foundation, State Corporation Bank for Development and Foreign Economic Affairs (Vnesheconombank), Russian Venture Company, Russian Direct Investment Fund, Agency for Strategic Initiatives, Russian Foundation for Technological Development are contributing to the diversification of the economy. Each of listed companies is dealing with the new ventures, which are creating new high-tech products to compete on the market.

Biotechnology is one of the most attractive technological industries for investors in Russia and all over the world (Russia biotechnology report, 2014). According to the expert analysis biotechnologies that have a beneficial effect on human body and quality of life have the potential to be one of the most profitable industries in the 21st century. The key organization in Russia that invest in biotechnologies are Institute of Human Stem Cells, Bioprocess Capital Ventures, Bind Therapeutics, Selecta Biosciences and HimRar.

Biotechnology is a complex term, which is usually includes three areas of the research: biomedicine, industrial biotechnologies, and agrobiotechnologies. Biomedicine is the development of new pharmaceutical products, vaccines, molecular diagnostics and so on. Industrial biotechnologies include industrial processes with the use of biotechnological reactors, microbial recycling of waste, producing of biofuel and biodegradable plastics. Agrobiotechnologies is the technologies of remediation of soil, increasing the tolerance and productivity of plants and son on. This paper focuses mainly on the evaluation of biomedical startups.

The investment analysis of young firms and especially technological ventures is being one of the most complicated questions in the literature devoted to the investment practices. Those companies have a limited history, no revenues; they operate in the very uncertain environment and sometimes don't even have markets for their products. They require special methods of investment analysis in other words valuation techniques and risk management tools that are different from already existing approaches.

There is a gap today between theoretical literature and real practice in terms of methods that are used for valuation and risk management. Most of the practitioners use classical DCF approach, which has a number of limitations when dealing with technological investments. It fails to capture the value of flexibility of the project and usually doesn't provide an adequate

treatment of risks. There are more complex and sufficient techniques that can be used to value the technological investment.

Real options analysis (ROA) is the extension of the financial options theory. It applies the same methodology to assess the real business problems. Basically, the real option is the opportunity or choice that becomes available within the particular investment. Like a financial option, it gives a right but not an obligation to undertake an investment. This instrument has an advantage over other methods of valuation because it enables to capture the flexibility of managerial decisions and consider multiple sources of risk.

In this paper, the ROA technique is implemented for investment analysis of the particular biotechnological project in order to give recommendations for managers of the particular investment fund. The research also might be interesting for managers who work on similar problems. The *goal* of this paper is to develop recommendations to improve the process of investment analysis including valuation and risk management of biotechnological startups applying the methodology of real options. To reach this goal the following *objectives* should be accomplished:

- Provide an overview of existing methods of investment analysis of technological and biotechnological projects;
- Review real options method applicability to investment analysis of technological and biotechnological projects;
- Formulate methodology for real options analysis of biotechnological startups;
- Apply the formulated methodology to conduct the investment analysis of NWTTC (RUSNANO group) portfolio project PolySeed;
- Develop recommendations for improvement the process of investment analysis of biotechnological startups.

The Research is organized as follows. The first chapter of the paper is devoted to literature analysis of the topic. There is a description of existing methods of valuation the technological projects as well as most important stages of each technology development, it's intrinsic risks and methods of risk management.

Furthermore, in the first chapter the concept of Real Options is presented as well as approach of other authors to the ROA process. There is also the discussion about applicability of real options in technological sphere, observation of common types of real options models and review of other papers that are devoted to ROA in biotechnological sphere.

The second chapter provides the methodology of the research that includes three steps: strategic analysis, risk analysis, and quantitative analysis. The strategic analysis implies the framing of the ROA problem. On the second step, the two broad categories of risks that can be applied to biotechnological startup are analyzed: market risks and technological risks. On the third stage, the three methods of valuation including DCF valuation, decision tree method, and Real Options Analysis are described in order to estimate the value of the project. The chosen method of Real Options Analysis, the process of its implementation, and necessary assumptions are presented in this chapter.

In the third chapter, the methodology is applied to the particular project from the portfolio of North-West Technology Transfer. There is an overview of the project, its external environment, and potential risks. The formulated methodology is applied in the chapter. In the result the certain implications that can give managers more flexibility in the process of investment analysis of biotechnological startups are proposed.

CHAPTER 1. LITERATURE REVIEW

1.1 Investment analysis of technological projects

Everything is pretty much clear with the valuation of firms with well-established operations and long selling history. There are plenty of models and approaches to analyze their market price and sources of the value. Things are getting more complex when we start thinking about young companies and especially about those, which are operating in the technological environment. There are some analysts who argue that such a firms cannot be valued at all.

When valuing a firm or investment project the analysts draw on information from three sources (Damodaran, 2006): The current financial state of the firm or project, the past history of the firm in terms of earnings and market prices, and the firm's competitors or peer group to measure how much better or worse a firm is than its competitors. While you would optimally like to have substantial information from all three sources, it is normal to substitute more of one type of information for less of the other.

In the case of technological startups, an analyst will run into serious information problems. First, these firms usually have not been in existence for more than a year or two, leading to a very limited history. Secondly, these companies usually have very few assets in place and have all value in the growth potential, which is very difficult to estimate due to the highly uncertain environment. Thirdly, this firms often develop the break through innovation products, which don't have any market data or even competitors or peers.

Given all these information constraints its getting obvious that special methods of valuation are required for technological investments. In the next paragraph an overview of existing approaches to financial valuation of technology startups will be given. After that the important issue of stages in new venture development will be discussed. Investment analysis includes not only valuation of the startup but also the consideration of risks so the typical uncertainties of the technological project are also presented in this part of the research.

1.1.1 Valuation methods of technological investments

DCF method

The most common method for investment valuation is DCF approach (Beninnga and Tolkowsky, 2002). In the case of valuation of young technological companies, the method can also be called Venture Capitalist Net Present Value (VC-NPV). Generally, this method takes free cash flows generated in the future by a specific project or company and discounts them to derive a present value. When DCF calculations produce values that are higher than the initial

investment, this usually indicates that the investment may be worthwhile and should be considered.

In the traditional DCF method, the discounting value that is usually used is the weighted average cost of capital (WACC). In the VC-NPV approach the discounting factor is usually very high, 20%-100% (Timmons and Spinelli, 2004), 40%-75% (Westland, 2002, p.136). For example, in North-West Technology Transfer Center (NWTTC) the usual discounting factor for financial models is relatively high because of the higher risk of new venture creation is incorporated in this discount rate.

While the DCF method is widely used by practitioners and there are experts who argue in favor of its applicability for new ventures (Damodaran, 2006, p. 891), it is being criticized a lot in the financial literature. Furthermore, this trend is not new, first attempts were made by Mayers and Tynbull in1977 or Hodder and Riggs in 1985. From more fresh articles on that topic, there are Boer 2000, Benninga and Tolkowskiy 2002, Steffens and Douglas 2007, Schachter and Mancarella 2016. There are two main limitations of DCF analysis: It doesn't explicitly consider multiple scenarios and it doesn't provide a flexible treatment of risk.

The first limitation is derived from the DCF assumption of passive management meaning that investment is made only once at the beginning of the project without the ability to postpone or dynamically make changes to the investment project. Given assumption doesn't satisfy the dynamic nature of technological startups where everything changes very fast. The DCF approach analyses single (most likely) scenario and ignores hidden opportunities and risks. Moreover, in the technological sphere a lot of spendings are irreversible and represent high sunk costs for a firm. So that costs are "locked-in" within a project but will affect future decisions that will be made.

The second limitation is that the only treatment of higher risk in DCF is simply the assigning of a high discount rate so it fails to capture the value created by managerial flexibility in the treatment of risks. The DCF model fails to distinguish between market risk and firm specific risk so in the result it is good only in treatment of the first one but much of the risks associated with a new venture is specific (McGrath and MacMillan, 2000). Furthermore, a time-based penalty (i.e. discount rate) is not appropriate for most specific risks, which largely vary in a lumpy manner at discrete times rather than continuously over time.

Despite all critics the DCF method is still a good benchmark for investment analysis and the base for all other more complicated techniques. The doubtful benefit of this method is simplicity, which prevents analyst from the mistakes and enables to get the solutions very fast.

The Market Comparables method

The given method uses data from public companies and private market transactions to estimate value. It gives adequate indications of what market can pay for the company. There are different ways to use the information from the comparables to estimate the value of the subject property. One approach is to consider each factor one at a time and compare the averages to the subject. A better approach, if sufficient data are available, is to build a statistical model to the data, for example, by using multiple regression. The model can be used to assess the marginal effect of each factor in conjunction with the effects of the others.

The Market Comparables method can be applicable to the valuation of new ventures and it is, arguably, delivers value estimates that come close to what investors are willing to pay, but unfortunately, there are some problems with this approach. It is rather obvious that the method is not working with disruptive technologies but it also may not be applicable to sustaining technologies.

Mostly, because data about comparable companies is difficult to obtain. It's not easy to find companies on the startup market themselves and it is even harder to get access to the deal terms which are usually kept under wraps. Furthermore, if the company and its data would be found it is not necessary that it is at the same stage of the development with our company. Hence, it is highly unlikely that suitable market data is available for establishing a valuation using the market comparables method.

First Chicago method

Rather than limiting the analysis to a success scenario, the First Chicago method (Smith, 2011) uses probability-weighted scenarios to come up with a more reliable estimate of expected (in the statistical sense) cash flows, rather than just the optimistic cash flows used in the VC method. These expected cash flows are then discounted using a more realistic cost of capital, rather than the high hurdle rates used in the VC method. If the scenario probabilities are correctly weighted, the appropriate discount rate is identical to the one that would be used in DCF valuation by the. A benefit of the First Chicago method is that it requires the analyst to think about the range of possible outcomes for the venture and their probabilities.

Typically, three scenarios are used: the "best guess" (most likely, median case); the "best case" (optimistic) and the "worst case" (pessimistic). For each of the three scenarios, management must estimate the subjective probability that the scenario will occur and the cash flows for each scenario are estimated as for VC-NPV method. The valuation is equal to the expected (probability-weighted) NPV of the three scenarios.

The advantages of this approach are that some of the risks associated with the venture are identified and different types of risk are separated and explicitly assessed. As such, this approach acts as a starting point for dealing with the risks in the more flexible manner. An important consequence of dealing with many sources of risk explicitly is a reduction in the sensitivity of the valuation to the discount rate – which is now being used to account for less of the overall risk facing the venture.

However, there are some important limitations of this method. The most crucial is that the method doesn't provide any framework of how to value potential flexibility in managerial decisions.

Decision tree approach

Decision Tree Analysis (DTA) has a long tradition in management science and has been around since the 1960 (Raiffa, 1968). Here we discuss not the full convention of 'decision analysis' that involve constructing (or defining) the utility function of the decision maker, but rather the simple DTA which involves calculating the expected NPV using a decision tree.

Long back the decision trees were the only tool to capture the value of flexibility under uncertainty. However, they use they popularity was limited due to complexity (Diallo, 2000). DTA handles the sequential risk with discrete outcomes while there are difficulties in the situations with a wide range of outcomes. DTA is also good when dealing with firm's specific risk (Steffens and Douglas, 2007) and is not good in terms of assessing the market risk.

According to Dzuma 2012, the classical methods of valuation may give a biased result in the situations like:

– Projects that have the option to delay to collect more precise information about current state of the market;
– Projects the implementation of which gives opportunities to launch another project;
– Projects during the implementation process of which will be needed to make the decisions to change the volume of the production;
– Projects that can be abandoned;
– Multi-stage projects in which implementation of one phase depends on the successful completion of the previous one; This situation is typical for investments with substantial initial costs, for example, to carry out research (pharmaceutical industry, biotechnology, real estate).

1.1.2 Stages of new project development

Every single startup company is going through several stages during its development. Why it matters in the context of valuation? Because the perception of risk, nature of options will change from stage to stage. For example, in the early stages, a startup will be riskier for investors as it has limited operation history without any revenues.

There are usually about five or six stages that are mentioned in the literature (Smith, 2011) (Damodaran, 2006). In this paper, six stages will be discussed: Opportunity stage, research, and development, start-up, early growth, rapid growth and exit. Each stage is characterized by its own options and sources of value.

Figure 1. Stages of new venture development.
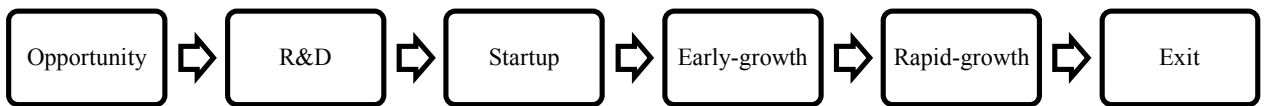
Source: Smith, 2011

Opportunity stage

The main activities on this stage are: to obtain seed financing, assess strategic opportunities, determine organizational structure and form and to prepare the business plan. Opportunity staged is not characterized by the significant capital inflows. The source of value that the company has at this stage is entirely the future growth. The options that the project usually has are to continue to the next stage, modify the concept or abandon the project.

Research and development stage

On this stage the company is obtaining R&D financing, building research team, conducting R&D, assessing and upgrading business plan. The source of value on this stage can be in the form of patent or other intellectual property but not in the form of real revenues. The options for the venture are to continue to the next stage, extend stage financing, modify R&D strategy, abandon the project.

Startup stage

On the start-up stage venture should obtain the financing to initiate revenue generation, to initiate the production, to build sales and marketing team and to acquire facilities and equipment. Beginning from this stage the company can be compared with other companies on the market. On this stage there are options to continue to the next stage, to modify production or financing, to modify marketing and to abandon the project.

Early growth stage

On this stage companies usually obtain financing for further growth, work toward revenue breakeven, expand team and facilities if needed. The main source of revenue still relies on the further growth but already with a portion of existing assets. The options are to continue to the next stage, extend stage financing or to abandon the project.

Rapid growth stage

The only difference with previous stage is that the company on the rapid growth stage is reaching economic breakeven and working towards proven viability to attain investments. On this stage, the operating history of the company can be already used in the valuation. The options of the company continue to the next stage or to extend the financing.

Exit stage

On the last stage companies usually do activities to establish a continuing financing such as IPO, acquisitions, buyouts and so on. The source of valuation on this stage is mainly the existing assets. The only option that the ventures have on this stage is to choose the form of exit.

1.1.3 Risks of a technological project

Every company or project is influenced by the different factors of risk. This influence can be both negative and positive. That is why the process of risk management is so crucial especially for investment projects. Risk management is the process of identification, analysis and either acceptance or mitigation of uncertainty in investment decision-making. The stages of identification and assessment of risk are the important part of this research.

In traditional financial literature, there is a distinction between market and firm-specific risk. Market risk is that part of risk correlated with the market (known as systematic risk), whereas firm-specific risk (known as private or unsystematic risk) is unique to the firm (Copeland et al, 2005). Dixit and Pindyck in their book Investment Under Uncertainty distinguish between two form of uncertainty for the technological project: "technical" uncertainty and "input cost" uncertainty.

Technical uncertainty refers to the probabilities of costs and probabilities of accomplishing technical success; a firm reduces this type of risk only through investment. Technical uncertainty creates pressure on the firm to invest immediately. Delays, at best, incur a discounting penalty and, at worst, expose the firm to the risk of competitive preemption. Input cost uncertainty relates to factors exogenous to the firm. No amount of investment makes a difference in this form of uncertainty, which creates pressure on the firm to delay investment until information is revealed with the passage of time.

In McGrath, 1997 the third type of risk was suggested and called "external" risk. This type of risk is presented when sources of uncertainty are caused by external factors, not technical in nature and can be influenced by the strategic action of a company. These are risks that technological company can hedge and that are consequently influencing the value of a technological option.

Figure 2. Factors influencing the value of technology option.
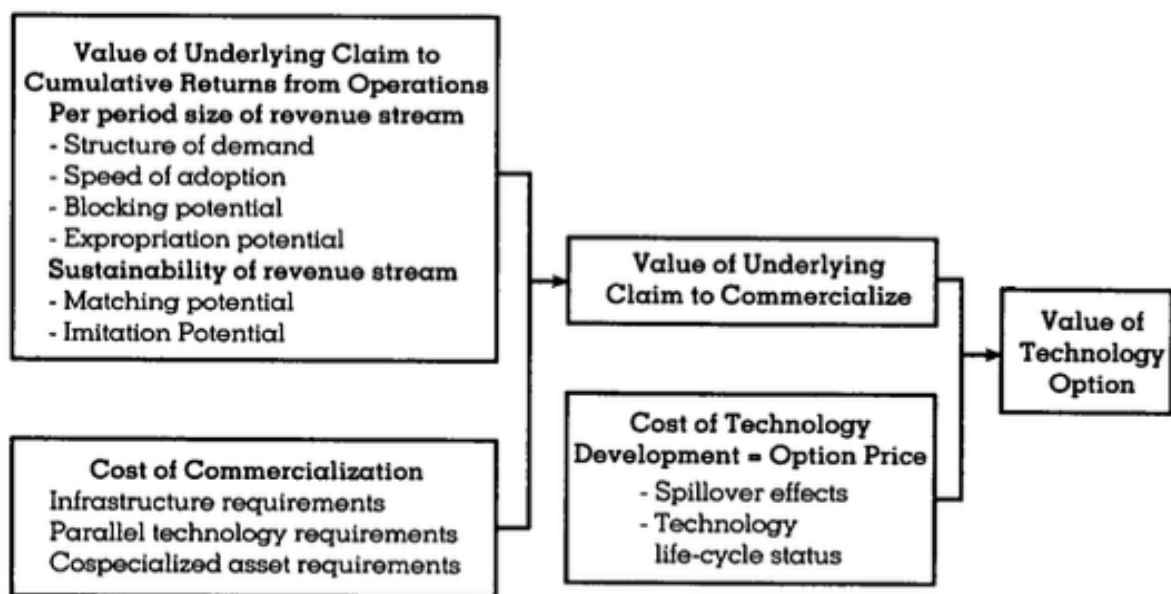
Source: McGrath,1997

The risk associated with the level of demand is related to the market size for the technology (disruptive technologies) and the market share the firm will capture (disruptive and sustaining technologies). These uncertainties are both related to the market factors and actions of the particular firm.

The speed of adoption is the very important factor that affects the size of the revenue stream. People are slow to change their existing, are resistant to making time investments which are necessary to learn the new way of doing things, and reluctant to throw their old assets. So the adaptation usually takes longer that was anticipated in the beginning. When adaptation is slow additional resources are needed to push the product on the market. Moreover, competitors have more time to respond or even leapfrog the idea.

Blocking occurs when the business is preventing from accessing customers, sales channels or other critical resources as the result of actions of the third party that can be competitors, government, etc. Massive regulatory hurdles, for example, affect biotechnology industry, on the stage of R&D. The problem with blocking is that it can either stop the business

or require enormous investments and managerial decisions to continue.

Expropriation is similar to blocking in a way that firm faced a threat from the more powerful external players but it differs in the outcome. When it is blocked, the firm is denied access to critical resources and markets. Under expropriation, however, the firm is required to give away a portion of its cash flows. For instance, such a threat may come from the government, which can increase the tax burden of the firm in the national interest.

The next portion of uncertainties is dealing with sustainability of revenue streams. Duration of competitive advantage influenced by the market response. Matching occurs when after the success in addressing important customer problem, competitors are able to address the same problem but doing it with technology or other recourses proprietary to themselves. Imitation is also an important threat because the product, which is easy to imitate, is more likely be able to preserve price premiums or sustainable market share.

The next big group of uncertainties is related to the cost side. The obvious cost factors include investment to create and distribute the product or service, the creation of production facilities, hiring and organization of staff, and marketing expenses. These investments can be broadly called infrastructure investments and, of course, to the extent that the availability of such infrastructures is uncertain now or in the future, the expected costs of commercialization and their variance will be greater.

Two other categories of costs in the model are more specific and occur when the additional product is needed to support the existing one. This could be in the form of parallel supportive technology or other cospecialized assets. The greater the potential is to deploy existing parallel technologies or uniquely owned cospecialized assets in conjunction with the proposed technology, the greater the value of the technology option will be.

Spillover effect refers to the situation when a company utilizes the developing technology to enter one modest market with the to target other markets when this technology is sufficiently well developed. In this case, technological uncertainties are reduced because the company already have the relevant experience.

Technology life-cycle status matters a lot in terms of risks, as in the periods of incremental changes firms innovate in the context of dominant design. That means that key dimensions of the market have been established, the customers have been educated, and coexisting technologies share a common architecture. In the satiation like this, clearly, the risks, as well as the costs, are lower, while in the periods of disruptive change firms need to make more investments.

1.2 Real options for investment analysis of technological projects

1.2.1 Concept of Real Options

Literally, the real options approach is the extension of financial option theory to options on real (nonfinancial) assets. While financial options are detailed in the contract, real options embedded in strategic investments must be identified and specified. Moving from financial options to real options requires a way of thinking, one that brings the discipline of the financial markets to internal strategic investment decisions (Amram and Kulatilaka, 1999).

The real option is right but not the obligation to undertake certain management initiatives. It can be seen as call or put option on underlying incentive. The connection between vital parameters of a financial call option and a real option are given in table 1.

Table 1

Parameter comparison of a Financial and a Real option

Financial option on the stock	Real option on a project
Current value of the stock	Present value of expected cash flows
Exercise price	Investment cost
Time to expiry	Life of project opportunity
Stock price volatility	Uncertainty of the project
Risk free interest rate	Risk free interest rate

Source: Hull, 2006.

Real options investments are characterized by sequential, irreversible investments made under conditions of uncertainty (Dixit and Pyndyk, 1994). The framework suggests that in the beginning investor purchases the option and then, during the course of the holding period, the value of option changes in response to external events. Normally, when market volatility increases the option price is also increases (Oriani and Sobrero 2008).

As it was discussed previously the NPV approach has a number of important limitations. That was Stewart Mayers who said: "Strategic planning needs finance. Present value calculations are needed as a check on strategic analysis and vice versa. However, standard discounted cash flow techniques will tend to underestimate the option value attached to growing profitable lines of business. Corporate finance theory requires extension to deal with real options» (Mayers, 1984). Moreover, the benefit of real options analysis is that it incorporates volatility, whereas decision trees (which rely on NPV analysis) only compute expected values.

1.2.2 The Real Options Process

In the literature, there are different approaches to illustrate the implementation of the Real Options Analysis. In Morano (2014) the three basic stages of Real Option Process were discussed: Risk analysis, strategic analysis and quantitative analysis.

The path is organized in a "cascade" mode, so the results of each phase form the starting point of the next, the connections between the various steps do not allow a clear separation and give rise to a linear iterative process, which can sometimes require the return on the factors already analyzed, in order to deepen the study or broaden the spectrum of investigation.

In Mun (2002) the three main stages of Real Option Analysis implementation are extended to 8 steps:

Qualitative management screening

On this step management decides which projects, assets or strategic initiatives are viable for further analysis, in accordance with the firm's mission, vision, goal or overall business strategy. The insights are created as management frames to complete a problem. Also on this stage, various risks of the project are identified.

Time-Series and Regression forecasting

The future is forecasted using time-series analysis or multivariate regression analysis if historical or comparable data exist. Otherwise, other qualitative forecasting methods may be used (subjective guess, growth rate assumptions, expert opinions, Delphi method, and so forth).

Base case Net Present Value analysis

For each project that passes the two initial stages, a discounted cash flow model is created. This model serves as the base case analysis, where a net present value is calculated using the traditional approach of using the forecast revenues and costs, and discounting the net of these revenues and costs at an appropriate risk-adjusted rate.

Monte Carlo simulation

Because, the static DCF produces only a single- point estimate result, there is often a little confidence in its accuracy given that cash flows are highly uncertain. To better estimate the actual value of a particular project, Monte Carlo simulation should be employed next.

Real Options problem framing

The next critical step is to frame the problem within the context of ROA. Based on the overall problem identification occurring during the initial qualitative management screening

process, certain strategic options would have become apparent for each particular project. The strategic options may include, the option to abandon, to switch, to contract, to expand and so forth.

Real Options modeling and analysis

Through the use of Monte Carlo simulation, the resulting stochastic discounted cash flow model will have a distribution of values. In ROA, it is assumed that the underlying asset is the future profitability of the project, which is the future cash flow series. An implied volatility of the future cash flows or other underlying assets can be calculated through the results of Monte Carlo simulation. Usually, the volatility is measured as the standard deviation of the logarithmic returns on the free cash flow stream. Using the implied volatility and present value of future cash flows the ROA is performed to obtain the project's strategic option values.

Portfolio and resource optimization

This is the optional step of which analysis is done on multiple projects. This is actual only for companies who have portfolio of projects because there are opportunities for hedging and diversifying risks through the portfolio.

Reporting and update analysis

Real options analysis assumes that the future is uncertain and that management has the right to make midcourse corrections when these uncertainties become resolved or risks become known. Therefore, when it happens, the analysis should be revisited to incorporate the decisions made or revising any input assumptions.

1.2.3 Real options in technological sphere

There is a discussion on whether ROA (Real Options Analysis) is a good instrument to value the investments in the technology in general and more particularly in young technological startup companies. In Adner and Levinthal 2004, it is stated that there are two critical features of the ROA process: 1) The value of the option and and the underlying asset is exogenous to the investor's activity – the investor cannot take steps to make the intrinsic characteristics of the asset more attractive; 2) The market signal of option value is readily observable and is independent of investors' behavior.

These two statements imply that in the industries where market and technological agenda are flexible such as in the most technological industries the implementation of ROA would be problematic. There would be too many degrees of freedom for ruling out success. However, the

firm can have a stricter action mandates, the more formalized milestones, organizational structures that are more tolerant to failure and so on, to cope with these difficulties.

The next portion of criticism comes from the notion that ROA is good at treatment of market risk but not the firm-specific risk, which investors usually want to be compensated for. This comes from the original ROA method that identifies a replicating portfolio of traded securities that match the volatility of the investment. Nonetheless, it is extremely hard to find such a security for any technological investment (Steffens and Douglas, 2007).

Another and more common method for volatility determination is the risk neutral valuation this method is often easier to implement. Both methods build on no arbitrage opportunity and assume that all investors are neutral towards risk, which is the basis for a risk neutral valuation. This allows all assets in the market to be valued regardless of the different individual risk preferences. This assumption is valid in a financial setting under the assumption that risk can be hedged or completely eliminated at every time step by buying and selling the right quantity of shares and options, known as a risk-neutral portfolio (Hull, 2006).

However, since RO are usually not traded assets, a portfolio of RO and shares cannot be traded to hedge an investor's risk, invalidating the risk-neutral assumption (Hugonnier and Morellec, 2007) (Sick, Gamba 2010). In Schachter and Mancarella 2016 it is suggested to use different discount rates depending on the level of risk associated with the cash flow. Possibly this rates may be different at distinctive points in time to reflect the different level of uncertainty while the future unfolds.

The uncertainty estimation is very important part of real option analysis. In the Black-Scholes model one can use either historic volatility or the implied volatility for calculating the option value. The historic volatility of the stock can be computed by estimating the standard deviation of continuous price return of a series of recent stock prices. As an alternative option, the stock's volatility can be derived from the market price of a stock by inverting the Black-Scholes formula. The volatility parameter that is estimated using the latter method is called the implied volatility.

When implementing real option models to the technological projects, estimating the volatility parameter for the underlying asset is much more difficult because the relevant market data is rarely available. In case of technological projects it is more appropriate to estimate the volatility of project value rather than volatility of comparable stock that usually do not exist. Since the underlying asset for a real option is the gross project value it is important that one use the volatility of underlying asset value. There are a lot methods present in the financial literature to estimate the volatility of underlying cash flows.

ROA methods can be classified into three types: Analytical or continuous methods, discrete time or lattice models and simulation models. The basic features of each method and it's applicability to valuation of technological investments will be discussed next in this paragraph.

Analytical methods

All analytical methods are mostly the modifications of the Black-Scholes model which is described below. They allow deducing an analytical price of the option by creating a mathematical expression to value its dynamics over time. Analytical methods are exact, quick, and easy to implement with the assistance of some basic programming knowledge.

$$c = S_0 N(d_1) - Ke^{(-rfT)}N(d_2) \tag{1}$$

$$p = Ke^{(-rfT)}N(-d_2) - S_0 N(-d_1) \tag{2}$$

$$d_1 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(rf + \frac{\sigma^2}{2}\right)T}{\delta\sqrt{T}} \tag{3}$$

$$d_2 = d_1 - \sigma\sqrt{T} \tag{4}$$

Where c is a value of the call, p is a value of the put, S_0 is the price of underlying asset, K is the exercise price, rf – risk free rate, σ is volatility of the asset, T is the time of expiry of the option and finally N is the cumulative probability distribution for a normal distribution.

However, these kinds of methods are criticized a lot in the classical ROA literature and literature devoted to implementation of ROA in the technological sphere. Analytical methods are also called closed-form because they are difficult to explain, as they tend to apply highly technical stochastic calculus mathematics.

They are also very specific in nature, with limited modeling flexibility. Closed-form methods are very precise for European options but can be only approximations for American options. Moreover, many more complex compound and Bermudan options cannot be solved with analytical methods.

The "Black-Scholes" model is by far the most numerically tractable model we have for valuing options, but are its assumptions appropriate for ROA? Almost not, because it assumes continuous trading, constant interest rate, and no exercise before final option maturity. The model is considering only one uncertainty, or at most two correlated once, which limits its implementation on difficult technological projects.

The "Black-Scholes equation" relies on the uncertainty following a stochastic process with constant mean and volatility over time. On technological markets have changing mean and

volatility over long timescales (Brigo, 2007). Again assumption is better suited for operational decisions of technological or engineering companies, as in Kitapbayev, 2013.

Simulation methods

These types of models are based on Monte-Carlo simulations. Implementation of the simulation gives an opportunity to incorporate into the ROA many scenarios and several sources of volatility. Simulation models can price options for any stochastic process with different probability distributions, thus extending the valuation to assets with non-normal or non-lognormal returns too.

The example of simulation approach is the Datar-Mathews method (Datar and Mathews, 2007). The method provides an easy framework to conduct ROA of a project simply by using the average of positive outcomes for the project. The approach can be seen as an extension of the net present value (NPV) multi-scenario Monte Carlo model with an adjustment for risk aversion and economic decision-making.

As it was discussed above the terms $N(d_1)$ and $N(d_2)$ are used in the calculation of the Black–Scholes formula, and are variables related to operations on lognormal distributions. The Datar–Mathews method does not use $N(d_1)$ or $N(d_2)$, but instead typically solves the option problem by means of Monte Carlo simulation applicable to many different types of distributions inherent in real option contexts. When the Datar–Mathews method is applied to assets with lognormal distributions, it becomes possible to visualize graphically the operation of $N(d_1)$ and $N(d_2)$.

However, despite of it's methodological excellence simulations methods are still complicated for practical usage and what is more important they don't provide clear strategic framework for managers.

Lattice methods

To solve the American option problem, Cox, Ross and Rubenstein developed the binomial tree which provides discrete time approximation to the Geometric Brownian Motion process (GBM) and computing the value of exercising an option earlier than at expiry. At every time period, the value from immediately exercising the option (known as the exercise value) is compared with the value from holding this option one extra time period in the future (known as the continuation value which is based on the expected value of the option).

The basic assumption of the binomial model for pricing options is that the options market is the (supposed) efficient, i.e., speculators are unable to obtain excessive profits from the combination with the basic tools and options with the simultaneous buying and selling of both.

Provided that, if known to the base price, the possibility that price changes in one direction or another, risk-free interest rate, you can calculate the price of the option with the set deadlines.

There are generally two types of methods to calculate an option in the lattice framework: replicating portfolio and risk-neutral valuation. The replicating portfolio method is based on finding a security in the market that has the same or very similar cash flow as the project the company is considering undertaking. Based on the law of one price, if the so called twin security and the investment have those characteristics they will have the same value.

Risk neutral valuation is a more common method than the replicating portfolio approach to value real options and often easier to implement. Both methods build on no arbitrage opportunity and assume that all investors are neutral towards risk, which is the basis for a risk neutral valuation. However, in the risk neutral valuation the search for a twin security is unnecessary since the method approaches the valuation from the theory of option pricing.

Lattice methods are convenient, very popular and are analogous to dynamic programming as they rely on backward-recursion through Bellman's optimality principle. However, they have some important limitation such as: difficulty with incorporating multiple volatilities, the underlying asset should follow lognormal distribution and practical flows of replicating portfolio and risk-neutral probability methods.

1.2.4 Common types of real options in the technological sphere

There are plenty of real options types or as they are also called Real Options models. The most common are the Option to defer, Option to expand, Option to contract, Option to abandon and Option to switch. The more complex real options models still exist, including compound options, which are basically the combinations of the five most common options. Compound options are widely used in technological sphere because usually projects in this field have multiple stages depending on the success of previous stage. In this paragraph the main types of real options will be observed.

Option to defer

An option to defer enables a company to defer its investment decision for some period of time or until more information about the project is available. It can be seen as the American call option on the project value. For example, we can imagine a company that has a new product under development and protected by the patent, then there is an option to wait the favorable conditions on the market. This option is widespread in technological project because they operate in the uncertain markets. The value of an option to defer can be denoted as *max(V − I, 0)*, where *I* is initial investments and *V* is the present value of the projects cash flows. When the

value of the project will exceed the value of the investments the company will exercise its option and launch or go ahead with the project.

Option to expand

This option is enables the company to expand its current production. The option to expand can be interpret as an American call on the value of the additional output. In technological sphere the Option to expand is usually involved into compound option. For example, company that has the production facilities is waiting for a patent and wants to expand the production if it will get it. Intrinsic value of an expansion option is denoted as *max(pV-I-V, 0)*, where *V* is the present value of the projects cash flow, *p* is the percent of expansion of the project and *I* is the initial investment cost.

Option to contract

 Is the opposite of the expansion option and enables the company to reduce the output if market conditions turn out to be unfavorable. Option to contract is analogous to American put option on the capacity installed. For example, the company that is operating in an uncertain environment, where demand for its product is decreasing. Then the management has the option to shut down one of their production lines and therefore to decrease their maintenance and production cost. The value of the right to decrease an output is *max(I – pV, 0)* where *I* is the cost saved by contracting, *p* is the percent of reduction of the project and *V* the present value of the projects cash flow.

Option to Abandon

If a project turns out to be unsuccessful the company has the right to close it and may be sell it for a salvage value instead of keeping it going and facing losses. Option to Abandon, can be seen as the American put on the project value and denoted as *max(V-S, 0)* where *S* is the salvage value. In technological industry it is the common case when larger company for salvage value merges one company with the bright R&D but unsuccessful business model.

Option to Switch

This type of option enables the company to switch between either input materials or output products. It is particularly valuable in uncertain environment where prices can fluctuate very frequently. With a switching option it can be possible to choose from one project to another as if the previous project is unsuccessful but has some knowledge that the second project can benefit from. A switching option may give companies a considerable competitive advantage.

Compound option

Compound option analysis refers to the situation when existing of one option generates another. For example, at the R&D stage of a new drug company has several stages of technological development, clinical tests and receiving the final approval. Every step depends on the previous stage because it can be either terminated or continued depending on technological success of the drug.

A compound option derives from the value of another option but not from the value of underlying asset. The first investment creates right but not the obligation to create next investments which in turn gives the possibility to make further investment and so on. A compound option can be sequential or parallel (Kodukula and Papudesuk, 2006). If a company must exercise an option to create another one, it is considered as sequential option and in opposite case the compound option is parallel.

1.2.5 Real options in biotechnological sphere

There are a number of representative studies in the financial literature that were aimed to value the biotechnological firm using the Real Options Analysis (Cassimon 2004, Fujiwara 2015, Kellog 2000, Loch 2002, Wang 2015, Zabolotskij 2008). The given studies apply different approaches to the problem. The approaches mainly differ by the ROA models that are used and the types of options that are estimated.

In Kellog (2000) and Zabolotskij (2008) the binomial lattice method with risk-neutral valuation advocated by Cox, Ross and Rubenstein (1979) was used. The key insight of this approach is that because the option value is independent of investor's risk preferences, the same value will be obtained even when everyone is assumed to be risk neutral. This important assumption simplifies the calculations by eliminating the need to estimate the risk premium in the discount rate. Also, it is important that the method enables to estimate the market value of the project rather than a subjective or private value.

Another approach is to evaluate options with dynamic programming (Loch 2002, Wang 2015). The given method doesn't require asset replication which is beneficial in case of technological projects. The drawback of the dynamic programming approach is that it does not address the question of the correct risk-adjusted discount rate. Dynamic programming requires an exogenously specified discount rate that reflects the decision maker's risk attitude. Moreover, this approach doesn't provide a decision framework for the mangers but rather calculates the final value of an option.

Concerning the nature of Real Options that are applicable for biotechnological projects the most common one is the option to abandon the project. Almost in every case the management have a possibility to close the project and receive a salvage value from selling the patent rights or equipment or other assets. The value of such flexibility is contributing to the present value of the project.

Another model is growth option which is substitutable to the abandon option so they can be presented in the project at the same time. The idea for the growth option is that engaging in the development of the project is similar to purchasing a call option on the value of the subsequent project. By engaging in the development of the biotech product, the company earns the right but not the obligation, to conduct the subsequent development.

The third most common real option in biotechnological sphere is the option to defer the project. For instance, if one of the stages of the development process was not successful management can may not just close the project but try again or wait until the more favorable conditions on the market.

The most accurate way of analyzing multi stage projects within the real options framework is the sequential compound option model (Cassimon 2004). In the given model every step of the development process is described as a European call option. Only after exercising one option the company have a right but not the obligation to continue the next stage. The series of options lattices are considering one after another and it gives more accurate results than creation of only one lattice.

The specify of a biotechnological sphere or even every technological development is the possibility to estimate the Rainbow Option. There is such possibility because technological and market uncertainties are not correlated with each other. The Rainbow Option means that the option has multiple uncertainties in the case of biotechnologies it is the probability of proceeding to the next round of development and possibility to commercialize the technology.

Summary

The given chapter is devoted to the review of existing approaches to investment analysis of technological startups and description of Real Options concept as well as specifics of its implementation in technological area. Such approaches to valuation of technological projects like DCF analysis, First Chicago, market comparables, and decision tree methods do not allow to capture the full flexibility of technological investments. Moreover, these approaches do not value properly the multi-stage projects in which implementation of one phase depends on the successful completion of the previous one, which is typical for biotechnological sphere.

Every technological startup has the number of stages or milestones including opportunity stage, R&D stage, startup stage and other that are different in terms of uncertainties. The risks can be classified as market uncertainties systematic or firm specific and technical uncertainties.

The real options approach is the extension of financial option theory to options on real (nonfinancial) assets. The real option is right but not the obligation to undertake certain management initiatives. It can be seen as a call or put option on underlying incentive. The ROA process includes risk assessment, net present value calculation, real options problem framing and quantitative analysis.

The ROA technique can be applied to technological projects, among three main methods of real options the binomial (lattice) method is most common and convenient for managers as it allows to build a consistent framework of the project. There are several different types of real option types or models such as the option to defer, option to expand, the option to contract, the option to abandon, option to switch and the compound option.

There are a number of papers that were aimed to value the biotechnological firm using the Real Options Analysis. According to these studies, the most accurate method to value the biotechnological development is to use sequential compound rainbow option. The sequential compound option exists when the project has multiple stages and each step depends on the previous. The rainbow option refers to the situation when the project has different uncertainties, for instance, technological and market uncertainties.

CHAPTER 2. METHODOLOGY

The new ventures that are focused on creation of new biotechnological products have the number of common traits. These features can be called the specifics of biomedical startups. They refer to the process of product research and development, specificity of risks and the way of "cashing out" the investments. These specific traits will affect the design of real options and are important in further analysis.

This chapter is devoted to the methodology of real options analysis process of new biotechnological startups. As it was discussed above the ROA process has several required steps. These are Strategic analysis, Risk analysis, and Quantitative analysis. In this chapter the methodology will be described according to given sequence.

2.1 Strategic analysis

In the stage of strategic analysis of biotechnological project management should identify the areas of managerial flexibility, or the strategic opportunities built-in in the project and which the investor could provide. The flexibility is needed to hedge against technical and market uncertainties. Out of the three main steps of ROA process, strategic analysis is the most subjective step. The analysis defines the characters of the options provided, necessary to quantify their value in the later stage of quantitative analysis. In fact, the type and the algorithms that synthesize the condition of exercise are necessary to identify for each option.

First of all, on the strategic analysis stage is important to identify the potential market drivers, for example, unmet customer's needs that influence the process commercialization of the company's product. It is also needed to forecast the information about the future cash flows by making realistic assumptions about the size of the market, the market share, and the price of the product. In some cases, it is possible to obtain the information about similar deals in the industry. The way of exit is also matters, the company may establish manufacturing on its own facilities or it can sell the technology license to the another company which is the most popular case.

When entering into the license agreement the type of the contract is also matters. In some situations, the startup could receive royalty payments during the whole period of the technology being on the market. The other case is when buyer of the license is guaranteeing to finance the R&D stage.

For biotechnological projects, the main source of flexibility is hidden in the R&D stage. The given step of the project can be divided into several phases and the milestone approach is usually used to control its progress. An initial investment is similar to the purchasing of an option on a future investment. The decision makers also have the option to stop or defer the

project at the end of each phase. Therefore, each phase is an option that is contingent on the earlier exercise of other options. If the project is a technical success, then it creates the option to make a significantly larger investment in the continuing project with relatively higher expected net benefit. If the project fails to achieve the technical success, then there is no need to commit any further resources, and therefore, the downside risk is limited to the initial investment cost of the R&D phase. It is also important to mention that if one phase of the R&D process was not successful, managers have the option to defer the project to improve the initial product so that it can pass through that stage.

In the beginning of the strategic analysis, it is useful to build the decision tree of the project that will include the most important milestones. The weighted average value of the project that will be obtained after decision tree analysis is a good proxy for investment analysis. However, one should not forget that decision tree doesn't evaluate the full range of the options of the project.

2.2 Risk analysis

Every technological startup is the subject for a big number of risks that have different nature. Of course, biotechnological startups and more specifically biomedical startups have its own specifics that should be considered. The specifics mainly refer to the process of development and commercialization.

According to Schwartz and Moon (2000), there are three main types of uncertainties in pharmaceutical R&D process: technical uncertainty associated with the success of the R&D process itself, an exogenous chance for obsolescence, during and after the development process and there is uncertainty about the value of the project on completion of the R&D. The former uncertainty refers to firm-specific risk and two latter refer to the risk of commercialization or market risk.

As a result, two broad groups of risks for biotechnological startup company can be identified: technological risks that affect the capability of the project to pass all the development milestones and commercialization risks that are connected with the market success of the product. These two groups of risks are not correlated with each other.

2.1.1 Technological uncertainties

Biotechnology is characterized by the long process of product development. It can take as around a decade to get a new drug on the market in developed countries. In emerging economies such as Russia, this process is not so time consuming but still requires a considerable time. Anyway, there are typical milestones that can be implied to every biotechnological project.

The typical process of new biomedical development includes concept development, analysis of optimal characteristics of products which include computer modeling and toxicity check, pre-clinical studies where new drugs are tested on animals, synthesis of pilot pieces for the clinical studies and the clinical studies that have four stages.

The first stage of clinical studies is the first trials on people, which are aimed to find the optimal dose for the components of the drug. The given trials are aimed to indicate tolerance, safety, and presence of the therapeutical effect on the wholesome body. On the second step, clinical effect is tested on people with the certain disease again to prove the sufficiency of product which is tested.

The third stage is the mass trial of people with the certain disease. It is usually the most time consuming and the most expensive period of clinical study. Before the third stage, the entity which product is being tested should produce the required amount of samples, usually around one thousand. On the results of this stage, the government body that is in charge might confirm or decline the registration of new drug.

The last stage is conducted after obtaining the license when the drug is already on the market. These trials are aimed to determine the difference of the product comparing to other drugs on the market in a particular niche and hidden risk factor that were not described during the previous studies.

To sum up, there are four important technological milestones for the biotechnological project (Table 2). During each step, there is a likelihood to fail and to continue. The probability of failure can be obtained using the Delphi method the anonymous survey of the experts who are working on the project and on the projects with similar characteristics.

The length of the steps of the development process is also matters. The data can be obtained from the web-site of Association of Clinical Trials Organizations (ACTO) that annually publishes the numbers for the duration of the clinical process. The average number of days to obtain the license from 2005 to 2015 is 116 days (Clinical Trials in Russia, 2016).

Figure 3. The process of biotechnological R&D.

Source: Association of Clinical Trials Organizations

2.1.2 Commercialization uncertainties

The biotechnological industry consists of ventures that are using living organisms or molecular or cellular techniques to provide medicines, food and services to meet human needs. There are thousands of small firms in biotech industry, whose R&D activity shapes the overall industry. Mergers and acquisitions happen very frequently in this market and are used as an exit strategy for those smaller biotech firms who often have financial difficulties, such as few or no marketable products and low cash-to-sales ratios.

Early-stage companies in the biotech industry face market uncertainties that should be considered in valuation. Those uncertainties depend not only on the stage of development and the experience of the company, but also the types of drugs being developed. There are several type of main specific risks in biotechnological industry, they were summarized in Bratic et al, 2014 and will be discussed in following paragraph.

Table 2

Commercialization risks in biotechnological industry

The risks	Impact
Government regulation	After the whole technological process there is a risk for biotechnological company in not obtaining the license.
Risk of litigation	The commercianalization of a drug can be blocked by the law.
Risk of estimating the patient population	Can lead to misevaluation of demand.
Risk of biosimilars	There is a risk that another research unit will find a better solution to a problem that addressed by the venture's drug.
Risk of fake drugs	The large amount of fake drugs has a downward effect on commercianalization potential of a new drug.
Risk of different legal environment	If the company selling its products to another country more likely that it will require additional examinations and confirmations.

Source: Bratic et al 2014

Government regulation

A newly created chemical or biological entity in every developed or developing country should overcome numerous regulatory hurdles. In Russian Federation as it was discussed above the procedure of drug approval takes around 120 days and consists of 5 stages including the expertise of all documents and clinical research and ethical expertise.

Moreover, a venture needs to receive a special license, which is given for 5 years only if venture has approved production facilities and certified well-trained personnel. According to open data of Federal Service for Surveillance in Healthcare of Russia only 3% of total amount of licenses that were requested in 2015 were denied but at the same time, 18% of total requests to extend the license were canceled. So there is always the risk not to obtain regulatory approval.

Risk of litigation

Litigation risk is another area for consideration when valuing early-stage biotech companies. In spite of extensive risk management efforts of pharmaceutical companies, there has been a rise in the number of settlements for violations of a variety of laws in the last two decades abroad and in Russian Federation.

Risk of estimating the patient population

The actual number of patients that need to be treated, as compared to an extrapolated estimated prevalence, is often uncertain. The mistakes in estimations can be related to the fact that prevalence studies are usually done in regions of higher prevalence and usually based on hospital data. The misevaluation of the demand, of course, has a significant effect on forecasted revenues.

Risk of biosimilars

The risk of "Biosimilar" drugs is an important factor and should be considered. There is always the uncertainty that another research unit will find a better solution to a problem that addressed by the venture's drug. Moreover, another company may just produce a cheaper generic alternative. This sphere is well regulated in recent time (Brtatic et al. 2014) but there is always back doors for generic producers.

Risk of fake drugs

Ernst & Young observed that as of 2008, counterfeit drugs accounted for approximately 10 percent of the world's pharmaceutical product supply. This problem is very important for emerging markets where there is a lack of normative regulation. Counterfeit biologics are extremely challenging to detect, and they are extremely vulnerable to environmental degradation, more so than other drugs.

Risk of different legal environment

The company from Russia that aims to sell its products for example in   German market will be needed to obtain the commercial license and pass through the whole stages of clinical trials that are needed in the another country. Hanse, there is an additional risk of not obtaining the license and that the procedure of passing through clinical trials will temporize.

2.3 Quantitative analysis

2.3.1 DCF valuation

The first stage of the ROA process is the estimation of the Net Present Value of the project. The estimating of a discount rate is the essential step of DCF analysis. There are some widespread methods of obtaining the discount rate such as WACC or CAPM but they are not suitable for technological startups. One of the few reliable approaches in case of technological projects is the cumulative method (Managarov, 2011) where discount rate is calculated using the following formula:

$$r = rf + I + rp \tag{5}$$

Where, r is the discount rate, rf is the minimal discount factor or risk-free rate, I is the inflation rate, and rp is the coefficient that considers the investment risk of the project. The risk-free rate is needed not only for DCF valuation but also for the real option valuation using the binomial approach so it should be calculated. Russian government bond yield at the time of the research is 9,34% (Moex.com, 2016) but due to the unstable economic situation, the country default spread should be considered. According to Damodaran (2016), the Russia's rating based default spread currently is 2,77%, so the risk-free rate is equal to 6,57%.

The annual inflation rate in 2016 according to the forecasts of Ministry of Economic Development of Russian Federation is estimated to be 12%. The risk premium for innovation development is very high. The risk is increasing when the R&D process is conducted by several organizations, there is an uncertainty about demand, prices and absorption of the technology.

2.3.2 Decision tree analysis

The decision tree method enables to estimate the value of the project with managerial flexibility. The method is basically the graphical representation of the sequential decision making process. Real options approach uses decision trees method as the starting point of the analysis. However, decision tree valuation is discrete in time, and doesn't capture full flexibility of the project.

To estimate the Expected Net Present Value (ENPV) it is needed to determine the present value of all possible end points and then multiply them by the respective cumulative probabilities. Each stage of the R&D process has its probability to pass as well as there are several outcomes of commercialization that have their own distribution. Normally, a constant discount rate is applied to find value of the project using the decision tree method (Steffens, 2007). The estimation of Expected Net Present Value is conducted using the formula 6:

$$ENPV = \sum_{i=1}^{n} \frac{DCF_{i,t}}{(1+r)^t} * p_i + \sum_{j=1}^{n} \frac{CCF_{j,t}}{(1+r)^t} * q_j \qquad (6)$$

Where, i is the index of stages, p_i is the conditional probability to pass the stage i, r is the discount rate for development cash flows, t is the time of the project development, $DCF_{i,t}$ is the expected development cash flow at time t given that i stage is the end stage, j is the index of market state at the time of commercialization, $CCF_{j,t}$ is the expected commercialization cash flow at time time t and the market conditions j, and q_j is the probability that market will be in the state j. The typical decision tree for biotechnological development is presented on the figure

Figure 4. Decision tree for biotechnological development.
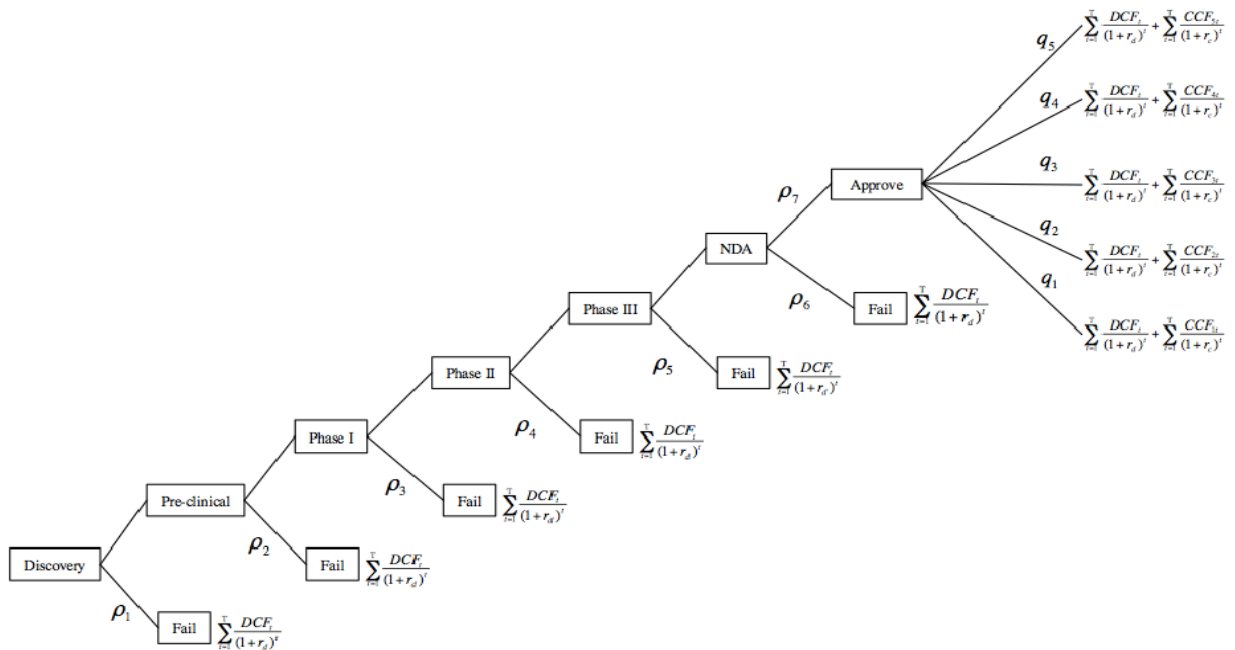
Source: Kellog, Charnes, 2000

2.3.3 Real options analysis

As it was discussed in the previous chapter the binomial real options approach doesn't require sophisticated continuous-time stochastic calculations but allow scenario planning techniques to be integrated to determine possible development paths for the value of the underlying R&D projects. As scenario planning is one of the most common long-term planning

tools in corporate practice, the binomial approach has the potential to be implemented in the practice of investors.

The model by Cox, Ross, and Rubenstein is used to form a binomial lattice. The first step of the binomial model is to form evolution lattice of the underlying asset. It is assumed that in a small time interval Δt the price may change in only two directions: u (u > 1) times if the price will rise and d (d < 1) times if the price will go down. At the end of the first stage, the result is the value of the underlying asset at any period of time. Then, the option is calculated using the process of backward induction. Figure 4 shows the example of binominal tree with the underlying asset S, which is transformed into the tree with option value C:

Figure 5. Binomial trees with evolution of underlying asset and corresponding option values.

```
                    S*u^3                                    C3,uuu
           S*u^2                                    C2,uu
     S*u           S*u^2*d                   C1,u           C3,uud
 S          S*u*d                   C0,0            C2,du
     S*d           S*u*d^2                   C1,d           C3,udd
           S*d^2                                    C2,dd
                    S*d^3                                    C3,ddd
  t=0   t=1   t=2      t=3              t=0    t=1    t=2      t=3
```
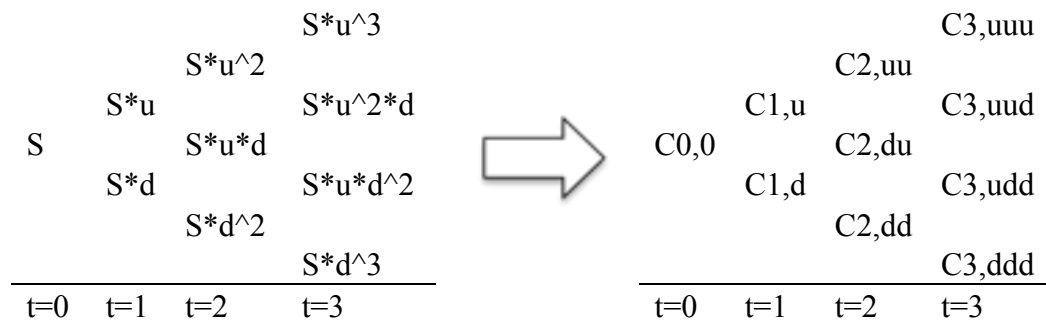
Source: Cox, Ross and Rubinstein (1979)

The initial binomial lattice is building only with up (u) and down (d) factors. The formulas are:

$$u = e^{\sigma\sqrt{\delta t}}; \ d = e^{-\sigma\sqrt{\delta t}} = \frac{1}{u} \tag{7}$$

Where δt = length of binominal period and σ = volatility. As it was discussed in the first chapter, the volatility of the technological project is typically based on its market performance that is affected by the external factors. Following Kellog et al 2000 in this research volatility is estimated using the formula 8.

$$\sigma = \left(\frac{1}{l}\right)\ln\frac{h}{A} \tag{8}$$

Where l is the time period, h is the maximum value for the project cash flows, A is the value of the underlying asset. The idea is that we want the value of the project to grow from A to the maximum value of h after l time intervals. The natural log is used for volatility estimation to make it follow the exponential Brownian Motion stochastic process because the binomial model requires it as a fundamental assumption. The binomial period is the time interval in which the

price of an underlying asset is changing. For example, after the first-month value of the project may either increase or shrink by 10% and so on.

After the lattice for underlying asset is formed we can calculate the option value using the process of backward induction. Values are rolled back using the risk-neutral probability. That are probabilities of future outcomes adjusted for risk, as the assumption of the binomial model is that investors are neutral towards risk. The assumption is needed to price the asset based only on its expected payoffs. The formula for risk-neutral probability is presented below:

$$p = \frac{e^{(r_f - D) \times \delta t} - d}{u - d} \tag{9}$$

Where rf is the risk-free rate, D is the dividend yield, t = length of the binominal period, u is the up state and d is the down state. The binomial model was initially developed for pricing of financial options so the dividend yield was used to properly assess the price of the stock. However, in real options analysis, the dividend yield is not used. Finally, the general formula to find the value of each node of the lattice is:

$$C_{J,i} = \frac{p \times C_{j+1,i} + (1 - p) \times C_{j+1,i}}{e^{r_f \times dt}} \tag{10}$$

Sequential Compound Option

According to the results of the first chapter, the most accurate way to estimate the flexibility value of the biotechnological R&D development is to use the sequential compound rainbow option model. The compound option exists when the project has multiple stages and the latter phases depend on the success of previous ones. To find the value of the project it is needed to find a value of several sequential European options. The first step of building the sequential compound option is not different from any other ROA model. It includes calculation of up and down factors and the underlying asset lattice. On the table below there is the lattice of underlying asset S.

Figure 6. Lattice for the underlying asset.

			S*u^3
		S*u^2	
	S*u		S*u^2*d
S		S*u*d	
	S*d		S*u*d^2
		S*d^2	
			S*d^3
t=0	t=1	t=2	t=3

The underlying asset is typically the present value of project cash flows. After building the first lattice the analysis requires the calculation of the longer-term option first and then the shorter-term options because the value of the option is based on the value of previous one. So there are as many lattices as stages in the project. If for example the project has two stages, the first stage duration is the two time intervals and the second stage start after the realization of the first and lasts the one time interval the following lattices should be estimated:

Figure 7. Example of the lattice for the first stage.

```
                                                        C3,uuu
                                        C2,uu
                        C1,u                            C3,uud
        C0,0                            C2,du
                        C1,d                            C3,udd
                                        C2,dd
                                                        C3,ddd
        t=0             t=1             t=2             t=3
```

Figure 8. Example of the lattice for the second stage.

```
                                        C2,uu
                        C1,u
        C0,0                            C2,du
                        C1,d
                                        C2,dd

        t=0             t=1             t=2
```

The value on each node of the lattice for the first stage depends on the underlying asset but values of the second lattice depend on the values from the previous stage. At the end of each stage, the manager has a choice to continue the project or to defer the investments. So the value of $C_{i,j}$ is the maximum between investing and keeping the option open.

$$C_{i,j} = \max\left[\left(C_{i,(j+1)} - Inv_t\right) * \theta_t; \left(p \times C_{(i+1,j)u} + (1-p) \times C_{(i+1,j)d}\right) * e^{-rf\sqrt{\delta t}} \right] \quad (11)$$

Where $C_{i,(j+1)}$ is the value of the underlying asset taken from the previous lattice, Inv_t are investments that are required at time t and θ_t is the probability to continue to the next stage, p is the risk-neutral probability, $C_{(i+1,j)u}$ is the value of underlying asset in the upper state in the same lattice, rf is the risk free rate, and δt is length of binominal period.

Summary

The goal of this chapter is to present the methodology for real options analysis of biotechnological startups. The ROA process normally includes three steps: Strategic analysis Risk analysis, and Quantitative analysis.

The strategic analysis is needed to identify the areas of managerial flexibility, or the strategic opportunities built-in in the project and which the investor could provide. In the case of biotechnological development, this flexibility is that investor may choose to infuse capital in stages. If the one stage was not successful investor may choose to defer or abandon the project.

The risk analysis is required to properly estimate the uncertainties of the particular project. These uncertainties are then incorporated into the real options model. Each biotechnological development has two main categories of uncertainties: Technological uncertainties and Commercialization uncertainties. There are typically four milestones of biotechnological R&D process: concept development, analysis of optimal characteristics of the product, pre-clinical studies where new drugs are tested on animals, synthesis of pilot pieces for the clinical studies and the clinical studies that have four stages. Every step has the probability to pass that is included in the Decision tree analysis and in the ROA as the parameter.

The commercialization uncertainties are individual for every technological project. Nevertheless, there are common market risks for biotechnological projects such as Government regulation, Risk of litigation, Risk of estimating the patient population, Risk of biosimilars, Risk of fake drugs, Risk of the different legal environment. The given risks, as well as those that apply for each case specifically, influence the cash flow volatility of the project.

The DCF valuation is the first step of real options analysis. To estimate the cost of capital for technological development the cumulative method is used. The decision tree approach is the alternative method to find the value of the technological project. It enables to consider the option to abandon but doesn't treats properly the market risk and doesn't take into consideration the possibility to defer the investment. However, the method is used to build the strategic tree of the project.

To find the real option value the sequential compound rainbow option model is used. The word compound means that the value of one option depends on the previous option. For example, in the case of biotechnological development, the value of the first stage depends on the success of further stage. This model allows finding the value of an option with two sources of uncertainty so it is called a rainbow.

CHAPTER 3. CASE STUDY

The purpose of this chapter is to implement the methodology of real options analysis to the project PolySeed from the portfolio of North West Technology Transfer Center (RUSNANO group) in order to solve the particular managerial problems such as valuation of the project and reducing of risks. The results of given case study can be applicable to other biotechnological projects.

3.1 Description of the project

PolySeed is the fundamentally new technology for manufacturing polymer micro-sources, based on the iodine adsorption effect into polymers. These polymer micro sources can be used in the cancer treatment method called "brachytherapy" and they are better than micro sources that are currently used. The benefits of "PolySeed" micro sources are:

- The simplicity of the production cycle - the developed technology eliminates the complex manufacturing operations while maintaining the physical properties of the mineral;
- Lower cost - there is no need to use expensive materials (titanium housing, gold or silver marker) for the production of micro sources;
- The increased specific activity of micro sources and the ability to make different shapes;
- Expanding the range of measurable LDR-brachytherapy diseases - using PolySeed will lead to the expansion of the number of Diseases treatable by low-dose brachytherapy. Besides prostate cancer, surgery may be the treatment of breast cancer, eye cancer, esophagus, lung, trachea, and bronchus. In the long term option for targeted delivery of drugs can be developed;
- Reduces injury rate of operations - because micro sources used will be manufactured entirely from biodegradable materials, their presence in the patient's body will be limited to a certain period, after which the Micro Source dissolved, while not causing any harm to the body.

3.1.1 Market of brachytherapy

Brachytherapy - is a local form of radiotherapy in which the Micro Source of radiation is introduced into the affected organ for some time (HDR brachytherapy) or placed on a permanent basis in the patient's body (low-dose brachytherapy).

In the treatment of prostate cancer brachytherapy technique has become the most popular and replaced the surgical method and EBRT method because of the similar efficacy, but lower costs and injury rate. The cost of surgical intervention for brachytherapy remains high. According to the Institute for Clinical and Economic Review (ICER), cost of brachytherapy in

the treatment of prostate cancer in the US in 2010 was USD 35.1 thousand, and the cost of external beam radiation therapy - USD 59,5 thousand.

The world medical statistics testifies to the annual increase in the number of new cases of cancer worldwide - around 13 million. Most of the malignant tumors are radiosensitive. Over the past decade, the number of men annually detected with prostate cancer increased by an average of 7.6%. The absolute number of newly diagnosed prostate cancer has increased since 2001, more than 2 times: from 12.8 thousand to 28.6 thousand the case of the time. This type of disease accounts for 12.4% of the total of detected cancers in men.

HDR brachytherapy method has become a primary therapy to be applied for the treatment of localized malignant tumors in remote organs such as the prostate gland, the esophagus, stomach, pancreas, kidney, bladder, uterus, trachea, bronchi, and lungs. In the total volume of newly diagnosed cancers, there are more than 40% that can be cured by low-dose brachytherapy.

Today, the capacity of the Russian market of HDR brachytherapy is estimated at about 3 thousand micro sources sets per year, in Europe 12 thousand in the US -50 thousand. When selling price of micro sources in USD 130, the entire market is estimated at USD 507 million. a year, Russia USD 23 million. per year. The number of micro sources implantation into the prostate gland is growing 2-3% annually.

Figure 9. Market volume for low dose brachytherapy in 2015.
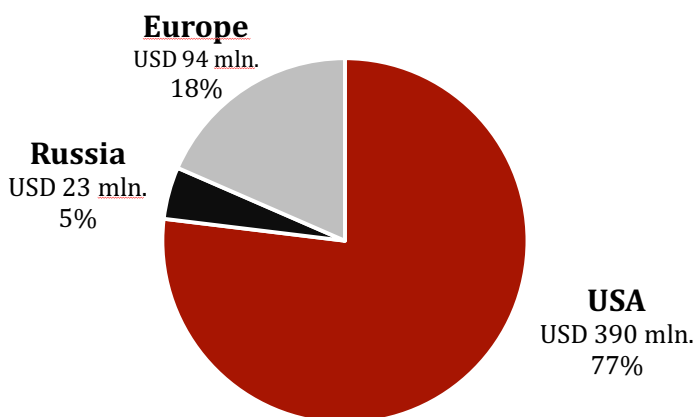
Source: Cancer Treatment Centers of America

In Russia the state allocates quotas for operations: in 2013, the number of quotas for low-dose brachytherapy was 737, an increase of 100 quotas than in 2012. Thus, the state provided about 25% of the potential demand. According to the Association of Russian Brahitherapists, there are 17 medical centers in our country that have brachytherapy services, with leading clinics

in the segment of low-dose brachytherapy is FGUZ KB №8 FMBA of Russia (Obninsk) and the Clinical Hospital №122 them. LG Sokolova FMBA of Russia (St. Petersburg).

Figure 10. Allocation of low dose brachytherapy surgeries in Russia (2015).
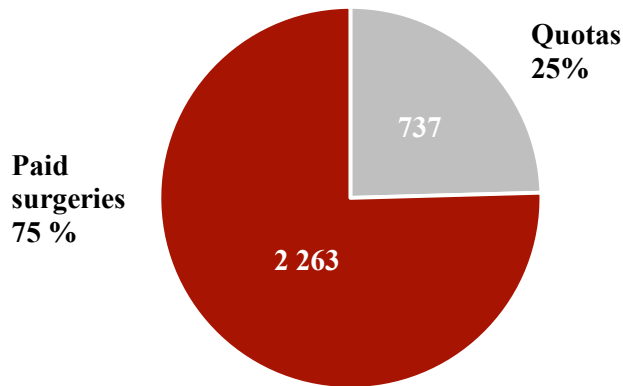
Source: Association of Russian Brahitherapists

3.2 Investment analysis of the project

3.2.1 Strategic analysis of the PolySeed project

In the case of the PolySeed project as well as in the case of almost each biotechnological development the investors have the option to infuse capital in stages. To consider the given option, the project development process was divided into stages according to a methodology that was presented in the second chapter. The typical structure of the biotechnological development includes four main stages: analysis of optimal characteristics of products which include computer modeling and toxicity check, pre-clinical studies where new drugs are tested on animals, synthesis of pilot pieces for the clinical studies and the clinical studies that have four stages. In this particular case, the following structure is applied. The project aims to develop the micro sources to carry the nuclear materials for cancer treatment, so the second stage includes the research with nuclear materials.

The crucial part of the strategic analysis of the biotechnological project is to split the costs between stages of the development as well as estimate the duration of every step. In this case, the duration of clinical tests was taken from the ACTO database. According to the database, the average duration of clinical tests in Russia is 130 days. The durations of other stages was obtained from the interviews with the investment managers of NWTTC that have experience of conducting the similar projects. The probabilities to succeed on every step was derived from interviews with experts group who are working on this or similar projects The results summarized in the table above.

Table 3

Stages of the PolySeed project

Stage	Duration (month)	Costs (In thousand roubles)	Probabilities
Research of technology's optimal parameters	8	-2850	0,7
Research with materials	6	-4000	0,7
Production of necessary amount of materials for clinical trials	2	-300	0,9
Clinical trials	4	-1850	0,6

Source: Interview with experts from NWTTC

The full range of real options that are typical for biotechnological development is presented in the PolySeed project. For the NWTTC, the project clearly embraces the growth option. There is a possibility to abandon the project at every stage. The equipment is supposed to be rented through the life of the project so the proyect doesn't have any salvage value. Managers also have an option to defer the project in case of any technological stage will not be successful. In this scenario rather than shutting down the project, it is more sensible to make adjustments in technology and continue the development.

3.2.2 Risk analysis of the PolySeed project

The probability of passing every step was assessed by the survey of technical experts who are in charge of the process realization. The another source of risk is the volatility of project's cash flow. Commercialization of the technology is planning to be achieved through the sale of Russian and international patent rights on the production technology to create polymer radioactive sources and for utility installation model to interested strategic investors. The leading manufacturers of micro sources in Russia and worldwide are:

- Russian manufacturer of micro sources JSC "NanoBrahiTek" Dubna (shareholders: OJSC «RUSNANO», Eckert & Ziegler BEBIG s.a, NADEX MAX LTD, OOO "Santis");

– The world's largest manufacturers: Eckert & Ziegler BEBIG, Varian Medical Systems, Nucletron (Elekta), GE Healthcare.

One of the main risks of PolySeed project is the threat from similar technologies. In table 4, the competitive position of the project is summarized. There are two rival technologies on the market are IsoSeed® I-125 and Oncoseed. Their main advantage is they already well established on the market. However, PolySeed technology has an advantage in terms of price as it uses cheap polymer materials instead of titanium.

Table 4

Competetive position of the PolySeed project

Name of technology	Manufacturer	Stage	Material	Shape and size	Radiactivity (mCi)	Price
IsoSeed® I-125	Eckert & Ziegler BEBIG	On the market	Ti, Ag, Au	Cylinder Length: 4.5 mm ± 0.2 mm; Diameter: 0.8 mm ± 0.04 mm	0.203-1.687	On request
Oncoseed	Oncura (GE Healthcare unit)	On the market	Ti, Ag, Au	Cylinder Length: 4.5 mm; Diameter: 0.8 mm	0.191-1.016	On request
PolySeed	**Project's group**	**Start of the development**	**Medical polymer**	**Sphere, cylinder and so forth. Typical size: 0.5-0.8 mm**	**0.10-2.00**	**Lower than price of competitors**

Source: North West Technology Transfer Center

The commercialization of the technology is planning to be achieved through the disposal of patent rights in Russia and abroad. The capacity of the Russian market of low-dose brachytherapy is estimated at about 3 thousand sets (1 set = 15 micro sources) per year in Europe - 12 thousand in the US - 50 thousand. The commercialization of the technology to foreign countries is impeded by the fact that technology should overpass the whole medical control. Moreover, the international companies will be ready to use the technology if it will recommend itself on the market. Nevertheless, the main goal of the project is the disposal of patent rights to international companies.

The assumptions about the price of the technology are based according to realistic market data that are:

– Developed polymer micro sources have no analogs on the market;
– Developed micro sources will have a number of competitive advantages, from the lower cost of production, ending with the increased specific activity of micro sources;
– In 2009 JSC "NanoBrahiTek" acquired the Eckert & Ziegler BEBIG license to manufacture successfully passed clinical trials titanium brachytherapy sources for the USD 2 000 000;
– Low-dose brachytherapy market is growing at a pace of 3.2% in real terms (According to estimations of Russia's brachytherapy center).

The assumption about the price of the technology was made based on the interview with managers of NWTTC and the analysis of the market. The most likely scenario is that PolySeed will obtain 15 millions of rubles for the technologic patent, also there is a possibility to get 60 millions of rubles in the case of the favorable market conditions and 0 in the case of the failure in the market.

Table 5

The revenue assumption

Revenue assumption	
In thousands rubles	
Probability	Revenue from selling the patent rights
0,6	15000
0,25	60000
0,15	0

Source: Interview with managers of NWTTC, market analysis

3.2.1 DCF valuation of the PolySeed project

As it was discussed in the second chapter the discount rate was found following the cumulative method. The annual inflation rate was assumed as 13%, the risk-free rate is 6,5% and the project risk premium is 30% that can be explained by the high risk of the project and internal norms of the NWTTC. The discount factor that was used in the analysis is equal to 50%. The tax rate is assumed to be 20% for the entire life of the project. The revenue of the project was taken from the most likely scenario. The process of Net Present Value calculation is presented in the table below. The detailed table with computations is in Appendix 1.

Table 6

DCF valuation of PolySeed project

Starting date of the project	01.10.16			
Expected duration	20 month			
In thousands rubles	2016	2017	2018	Total
Contractor's fee	-1 775,00 ₽	-5 475,00 ₽	-1 800,00 ₽	-9 050,00 ₽
Administrative cost	-60,00 ₽	-240,00 ₽	-60,00 ₽	-360,00 ₽
Patent registration			-200,00 ₽	-200,00 ₽
Salary budget and the social tax	-17,00 ₽	-68,00 ₽	-23,00 ₽	-108,00 ₽
Operating expenditures	**-1 852,00 ₽**	**-5 783,00 ₽**	**-2 083,00 ₽**	**-9 718,00 ₽**
Rent and following acquisition of equipment	-23,00 ₽	-90,00 ₽	-1 388,00 ₽	-1 501,00 ₽
Capital expenditures	**-23,00 ₽**	**-90,00 ₽**	**-1 388,00 ₽**	**-1 501,00 ₽**
Income from selling the patent rights			**15 000,00 ₽**	**15 000,00 ₽**
Income tax (1,7% month)	-93,75 ₽	-1 174,60 ₽	923,55 ₽	
FCF	-1 843,13 ₽	-5 684,69 ₽	11 529,61 ₽	
DCF	-1 228,75 ₽	-3 158,16 ₽	4 702,27 ₽	
NPV	**316,27 ₽**			
IRR	**51%**			

Source: Made based on the previous analysis and data provided by NWTTC

The discounted cash flow analysis shows that present value of the project is slightly above zero. The internal rate of return is just on the same level with what investors want to gain from such types of projects. After such results, the project is at risk of not being approved by the investment committee so the flexibility of the project should be taken into the account.

3.2.2 Decision tree analysis of the PolySeed project

The decision tree method was used to estimate the Expected Net Present Value of the project. The main advantage of the method comparing to DCF is that it captures managerial flexibility. It estimates the value of the option to abandon the project in case of technological

failure. The method implies that the revenues occur only in case of passing all the technological stages

To calculate the ENPV of the PolySeed project the data obtained during the strategic analysis was used. The project was divided into four stages. Probabilities to pass each stage were derived from a survey of experts who had the experience of launching the similar projects. The overall costs of the project were split between the stages. On the table below there are inputs and results of the decision tree analysis. The decision tree itself is presented in Appendix 2.

Table 7

Decision tree analysis

Stage		Cumulative probability of negative result	Probabilities of CCF	NPV	P*NPV
In thoussands roubles					
Research of technology's optimal parametrs		0,3		-2 807,83 ₽	-842,35 ₽
Research with nuclear materials.		0,21		-4 597,45 ₽	-965,47 ₽
Production of necessary amount of materials for clinical trial.		0,0245		-4 808,00 ₽	-117,80 ₽
Clinical Tests		0,1862		-6 237,06 ₽	-1 161,34 ₽
Approval	Optimistic		0,25	20 429,60 ₽	5 107,40 ₽
	Most likely		0,6	316,27 ₽	189,76 ₽
	Pessimistic		0,15	-6 237,06 ₽	-935,56 ₽
				ENPV	**1 274,65 ₽**

Source: Made based on the previous analysis and data provided by NWTTC

The decision tree analysis gives the higher value of the project than DCF method because it incorporates the option to abandon and make possible to estimate the distribution of project's cash flows based on different scenarios. However, it doesn't capture the full flexibility that investors have.

3.2.3 Real options analysis of the PolySeed project

For the purpose of the analysis, the present value of revenue was taken as the underlying asset for the binomial tree. It was estimated as 6,553 millions of rubles. The volatility of the project's cash flow was estimated using the formula presented in the second chapter where h is 60 millions of rubles – the maximum amount of money that the project can obtain, l is the

duration of the project – 20 months, and A is 6,553 the present value of the project. The volatility of the project was estimated as 27%. The binomial period was taken as 2 so we assumed that the price of the technology will change every two months.

The sequential compound rainbow option captures the flexibility of managers to invest in the next stage or keep the option open. So at each node, there is a choice between investing and waiting. The decision rule is the following:

$$If \left(C_{i,(j+1)} - Inv_t\right) * \theta_t > \left(p \times C_{(i+1,j)u} + (1-p) \times C_{(i+1,j)d}\right) * e^{-r\sqrt{\delta t}} \rightarrow$$

$$The\ investors\ should\ proceed\ with\ the\ project \qquad (12)$$

Where $C_{i,(j+1)}$ is the value of the underlying asset taken from the previous lattice, Inv_t are investments that are required for the stage t and θ_t is the probability to continue to the next stage, p is the risk neutral probability, $C_{(i+1,j)u}$ is the value of underlying asset in the upper state in the same lattice, *rf* is the risk free rate, and δt is length of binominal period. The first part of equation symbolizes the value of investments and the second part the value of keeping the option open.

After building the lattice with the evolution of the underlying asset, the four sequential phases are evaluated using the described above decision rule, starting with the latter stage. The lattices are presented in the Appendices 3, 4, and 5. In Appendix 6, there is a strategic lattice built based on the previous binomial trees. The prices of options for each stage are summarized in the following table. The option price for the first option reflects the flexibility value of the whole project. The extended value of the project according to ROA approach is the value of the compound sequential option, i.e. the option price of the first stage plus the NPV.

Table 8

Option values for the sequential stages of the research (In thousands of rubles)

Stage	First stage: Research of technology's optimal parameters	Second stage: Research with nuclear materials.	Third stage: Production of necessary amount of materials for clinical trial.	Fourth stage: Clinical Tests
Option Value	**132,5**	1399,4	3514,2	2943,6

In the given model such options as growth option, the option to abandon the project and option to defer were incorporated. The real options approach allows receiving the value of the venture at every stage of R&D development. It is the practically useful information because commonly before the initiation of the certain development stage managers need to bear the certain costs for example for patenting or prototyping. The value of the option shows the maximum sum that investors can spend in the beginning of the stage.

Moreover, managers may use the ROA approach in the decision-making process because it uses the volatility of project cash flows that are dependent on the state of the market. So before the initiating of the project, managers may use the binomial lattice to see in what of the market state they should make investments. The strategic lattice is presented in Appendix 6.

3.3 Discussion

In the given research the methodology for investment analysis of the biotechnological project was formulated and applied to the specific project from the North West Technology Transfer Center. The real options model was adopted for the purpose of the analysis. The proposed model suits the process of the biotechnological development because it enables to calculate the value of every stage using information about the future sequential options. The model is also consistent with the risk-free arbitrage method of valuing options. The proposed model may approach not only projects in biotechnological sphere but other technological projects that require several steps of development.

For the investment managers of the particular project, the value of the startup was obtained using three methods, the results are summarized in table 9.

Table 9

The value of the project obtained using different approaches

Method used	DCF	Decision tree	ROA
Value of the project (in thousands of rubles)	316,27	1274	448,77

Apart from the strictly practical result, this paper provides the comparison of valuation methods. The methodology that applied in the paper clearly provides more sophisticated approach to value technological project than simple DCF approach. The usage of the decision tree method and real options approach enables to estimate the flexibility of the project. Moreover, those methods take into account two factors of volatility: technological and market that appear to be more precise in terms of risk management.

In this research, the real options model was implemented for valuation of the project in biotechnological industry. There is a limited amount of works on the given topic in financial literature, especially in Russia. The binomial method was used for valuation of biotechnological development in Kellog 2000 and Zabolotskij 2008. However, the models of real options that were used in this works are slightly different.

The model of the sequential compound rainbow option was used in Cassimon 2004, Herath 2002, and Fujiwara 2015. Nevertheless, there is no the parallel comparison with other methods of valuation and the specifics of the real option implementation is rather different. In this way, the given paper provides a new glance on the problem of real options implementation to the biotechnological industry.

The research illustrated that DCF analysis tends to give undervalued results because it doesn't deal with density distribution of project's cash flows. Hence, application of real option methods may be extremely useful to value the projects with negative NPV. The decision tree approach allows to build a consistent framework of the project and should be used as the first stage of real options analysis. However, it doesn't capture the full spectrum of managerial flexibility implied in the project. In a case of PolySeed decision tree doesn't account for the option to keep the project open.

Both the decision tree and real option methods imply several scenarios for cash flows distribution that are more realistic assumption that DCF model has. However, the decision tree method is rather simplified because it assumes the discrete distribution of cash flows. Like in the case of PolySeed, there are only three scenarios: 60, 15 and 0 millions of rubles. In real options analysis, the continuous distribution of cash flows is used so the result is the stochastic variable. The latter approach appears to be more reasonable but tends to give lower results in terms of valuation. The value of the project obtained with decision tree technique is more than twice higher than those obtained using ROA.

The additional benefit of the sequential compound real options model with multiple volatilities is that it estimates the value of every step of the separate project that gives the most precise understanding of the development scheme for managers.

On the basis of the conducted research, it can be concluded that real option is the tool that most accurately suits the valuation process of biotechnological startups as it allows to estimate the full flexibility of the R&D process. The importance of the tool is obvious for the firms that operate in a very uncertain environment like technological ventures. In this research, the methodology for conducting ROA in the biotechnological industry is presented. The proposed model can be used for projects that have several stages.

At that point, it is important to say about the limitations of the sequential compound model for valuing real options. Despite that the model very well suits the process of biotechnological and other multi-stage developments it is might be problematic to implement in other fields because the nature of real options there is different. Secondly, the process of real options analysis requires rather sophisticated calculations that managers who are limited in time wouldn't approach. Moreover, there are limitations that are aligned with implementation of the binomial model. It was initially developed to work with historic volatilities rather than future estimation of cash flows. Despite the implementation of volatility associated with future projections of cash flows is scientifically sound it may give the small mistake in the results.

CONCLUSION

The goal of given research was to make recommendations concerning the improvement of the investment analysis process of biotechnological projects applying the methodology of real options. In order to accomplish this goal, the certain objectives were solved. First of all, the overview of existing methods of valuation of technological startups and typical risks of such projects were provided. Also, the real option concept and its applicability to the investment analysis of technological and biotechnological ventures was reviewed. Then the methodology for investment analysis of biotechnological ventures with consideration of real options was formulated. Then in order to illustrate the advantages of the method it was applied to the particular project. Finally, we propose some recommendations for improvement the process of investment analysis of biotechnological startups.

In the first chapter, the benefits and limitations of the most common methods of valuation of technological startups were reviewed. Additionally, the typical structure of the technological development and standard risks that are associated with technological companies were discussed. The second part of the first chapter is devoted to the literature overview of the real options concept and its applicability in the technological and biotechnological sphere. The aim of this part was to review the real options models that can be relevant to investment analysis of biotechnological projects.

On the basis of the first chapter, it was determined that the most widespread approaches do not value properly the multi-stage projects in which implementation of one phase depends on the successful completion of the previous one, which is typical for the biotechnological sphere. The risks can be classified as market uncertainties systematic or firm specific and technical uncertainties. ROA process includes three main stages: Strategic analysis, risk analysis, and quantitative analysis. The binomial (lattice) method and the sequential compound rainbow option model are the most accurate to value the biotechnological development.

The second chapter was devoted to the formulation of the methodology for the investment analysis of the biotechnological startups. The strategic analysis is needed to identify the areas of managerial flexibility, or the strategic opportunities built-in in the project and which the investor could provide. In the case of biotechnological development, the typical flexibility is that investor may choose to infuse capital in stages. If the one stage was not successful investor may choose to defer or abandon the project.

The specifics of biotechnological projects were considered in this chapter. There are typically four milestones of biotechnological R&D process: concept development, analysis of

optimal characteristics of the product, pre-clinical studies where new drugs are tested on animals, synthesis of pilot pieces for the clinical studies and the clinical studies that have four stages. The commercialization uncertainties are specific for every technological project. However, there are common market risks such as government regulation, risk of litigation, risk of estimating the patient population, risk of the different legal environment and other. The given risks, as well as those that apply for each case specifically, influence the cash flow volatility of the project.

In the part devoted to the quantitative analysis, three methods of valuation were described such as DCF method that is basically the first part of the ROA, Decision tree method, and real options analysis. The combination of this methods enables to conduct the investment analysis of the biotechnological project in an adequate manner.

Finally, in the third chapter the developed methodology was applied to the real project from the portfolio of North West Technology Transfer Centre (RUSNANO group). The PolySeed project develops the new technology for manufacturing polymer micro-sources that are used in the cancer treatment method called brachytherapy. Strategic and risk analyses included the identification of stages of the project, amount of capital that is needed for each stage and analysis of the external environment of the project in order to identify the cash flow volatility. The quantitative analysis contained the assessment of the project using three abovementioned techniques.

In the result the following recommendations for managers and investors who involved into the investment analysis of biotechnological startups are proposed:

1. The DCF analysis tends to give undervalued results because it doesn't deal either with the flexibility that the project has nor with density distribution of project's cash flows. However, it rather simple to implement and is good to obtain the conservative value of the project. Moreover, the DCF analysis is the first stage of implementation of the ROA.

2. The decision tree method allows to build a consistent framework of the project and to capture the value of the option to abandon. However, it doesn't capture the full spectrum of managerial flexibility implied in the project and uses the simplified assumption of discrete distribution of cash flows.

3. The real option allows estimating the full flexibility of the R&D process. The importance of the tool is obvious for the firms that operate in a very uncertain environment like technological ventures because it incorporates the multiple sources of volatility and provides the appropriate treatment of risks. Application of real options method may be

extremely useful to value the projects with negative NPV because it estimates the value of managerial flexibility.

4. To conduct the real options analysis of the biotechnological venture, the sequential compound rainbow option model was implemented. The given model allows to properly estimate the flexibility that biotechnological project has. Moreover, the model allows finding the value of every stage of the development that represent the marginal expenditures for managers. It also provides the strategic lattice of the project's value that is the useful tool in the decision-making.

There are two main contributions of this papers. First of all, the investment analysis of the PolySeed project was conducted. The paper has a practical information for managers from NWTTC (RUSNANO group). Secondly, the developed methodology might be implemented for investment analysis of projects in the biotechnological sphere and for other multi-staged projects. The implementation of the real options tool and its benefits was illustrated on the example. The assumptions of the method appear to be the most realistic for the companies operating in the uncertain environment among all methods that were described so it definitely should be applied for investment analysis of the biotechnological projects.

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APPENDICES

Appendix 1: DCF valuation

In thousands rubles	01.10.16	01.11.16	01.12.16	01.01.17	01.02.17	01.03.17	01.04.17	01.05.17	01.06.17	01.07.17
Contractor's fee	-592	-592	-592	-456	-456	-456	-456	-456	-456	-456
Administrative cost	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
Patent registration										
Salary budget and the social tax	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6
Operating expenditures	-617	-617	-617	-482	-482	-482	-482	-482	-482	-482
Rent and following acquisition of equipment	-8	-8	-8	-8	-116	-125	0	0	0	0
Capital expenditures	-8	-8	-8	0	1250	1250	0	0	0	0
Income from selling the technology license										
Income tax (1,7% month)	-11	-11	-11	-8	-8	-8	-8	-8	-8	-8
FCF	-614	-614	-614	-474	-474	-474	-474	-474	-474	-474
DCF	-410	-410	-410	-316	-316	-316	-316	-316	-316	-316
NPV	316									

In thousands rubles	01.08.17	01.09.17	01.10.17	01.11.17	01.12.17	01.01.18	01.02.18	01.03.18	01.04.18	01.05.18
Contractor's fee	-456	-456	-456	-456	-456	-600	-600	-300	-300	
Administrative cost	-20	-20	-20	-20	-20	-20	-20	-10	-10	
Patent registration									-200	
Salary budget and the social tax	-6	-6	-6	-6	-6	-8	-8	-4	-4	
Operating expenditures	-482	-482	-482	-482	-482	-628	-628	-314	-514	
Rent and following acquisition of equipment	0	0	0	0	0	-463	-463	-231	-231	
Capital expenditures	0	0	0	0	0	-463	-463	-231	-231	
Income from selling the patent rights										15000
Income tax (1,7% month)	-8	-8	-8	-8	-8	-19	-19	-9	-9	255
FCF	-474	-474	-474	-474	-474	-1072	-1072	-536	-736	14745
DCF	-316	-316	-316	-211	-211	-476	-476	-238	-327	6553
NPV										

Appendix 2: Decision tree of the PolySeed project

		NPV	P cumm
p=0,25		20 429,60 P	0,25
0			
0,5			
p=0,6		316,27 P	0,6
p=0,15		-6 237,06 P	0,15
		-6 237,06 P	0,1862
		-4 808,00 P	0,024
		-4 597,45 P	0,21
		-2 807,83 P	0,3
	ENPV=		1274
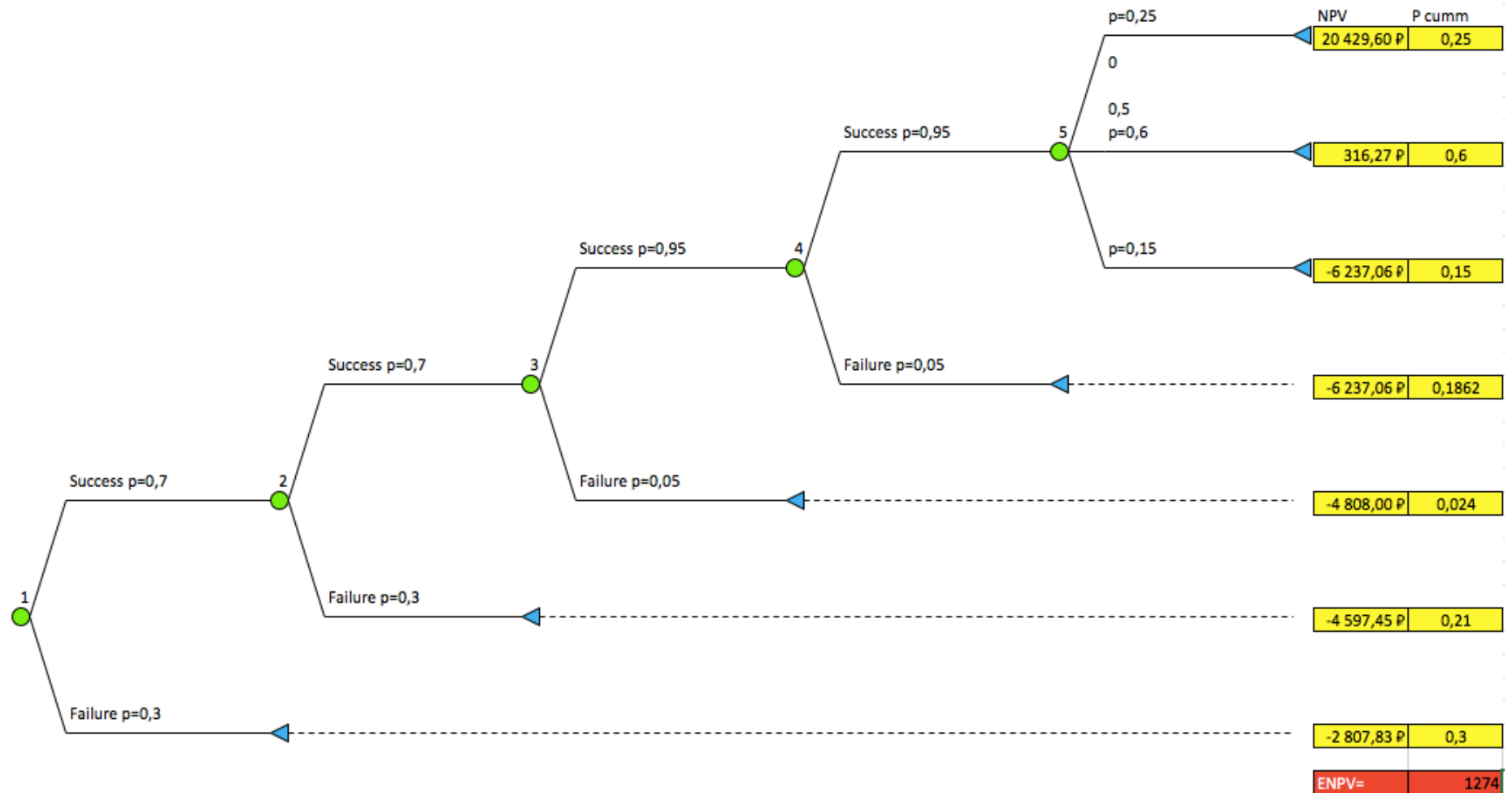
Appendix 3: Evolution of the underlying asset of the PolySeed project

PV	6553,30
Volatility	27%
U	1,46
D	0,68260586
rf	6,53%
e^rf	1,06747922
p	0,49193368
1-p	0,50806632
Bp	2
e^-rf*dt	0,91178766

PV of the underlying

0	1	2	3	4	5	6	7	8	9	10
6553,3	9600,4	14064,4	20603,9	30184,2	44219,1	60000,0	60000,0	60000,0	60000,0	60000,0
	4473,3	6553,3	9600,4	14064,4	20603,9	30184,2	40956,4	60000,0	60000,0	60000,0
		3053,5	4473,3	6553,3	9600,4	14064,4	20603,9	27957,0	40956,4	60000,0
			2084,3	3053,5	4473,3	6553,3	9600,4	14064,4	19083,6	27957,0
				1422,8	2084,3	3053,5	4473,3	6553,3	9600,4	13026,6
					971,2	1422,8	2084,3	3053,5	4473,3	6553,3
						662,9	971,2	1422,8	2084,3	3053,5
							452,5	662,9	971,2	1422,8
								308,9	452,5	662,9
									210,9	308,9
										143,9

Appendix 4: The binomial lattices of the forth and the fifth stages

Step 1 phase 4	0	1	2	3	4	5	6	7	8	9	10
NPV	2943,6	4710,2	7388,6	11312,4	17060,5	25481,5	34950,0	34950,0	34950,0	34950,0	34950,0
		1793,6	2882,0	4391,1	6816,0	10444,6	15791,8	23523,8	26573,8	34950,0	34950,0
			1081,3	1777,3	2879,4	4600,5	7256,1	11312,4	15369,2	23523,8	34950,0
				613,3	1048,6	1761,3	2905,2	4710,2	6846,9	10400,2	15724,2
					308,6	558,3	989,1	1710,7	2879,4	4710,2	6766,0
						125,6	247,4	478,7	904,8	1655,0	2882,0
							31,7	70,6	157,4	350,8	782,1
								0,0	0,0	0,0	0,0
									0,0	0,0	0,0
										0,0	0,0
											0,0

Step 2 Phase 3	0	1	2	3	4	5	6	7	8
NPV	3514,2	5521,2	8023,2	9821,1	14994,5	22573,3	31095,0	31095,0	31095,0
		2240,1	4150,0	7810,1	5864,6	9100,8	13884,4	20811,4	23556,4
			817,3	1396,3	2341,0	3847,9	6202,2	9821,1	13472,3
				412,4	747,6	1327,6	2301,2	3879,2	5802,2
					166,3	328,4	637,8	1211,4	2231,5
						41,0	91,4	203,8	454,4
							0,0	0,0	0,0
							0,0	0,0	0,0
									0,0

Appendix 5: The binomial lattices of the first and the second stages

Step 1 phase 4	0	1	2	3	4	5	6	7	8	9	10
NPV	2943,6	4710,2	7388,6	11312,4	17060,5	25481,5	34950,0	34950,0	34950,0	34950,0	34950,0
		1793,6	2882,0	4391,1	6816,0	10444,6	15791,8	23523,8	26573,8	34950,0	34950,0
			1081,3	1777,3	2879,4	4600,5	7256,1	11312,4	15369,2	23523,8	34950,0
				613,3	1048,6	1761,3	2905,2	4710,2	6846,9	10400,2	15724,2
					308,6	558,3	989,1	1710,7	2879,4	4710,2	6766,0
						125,6	247,4	478,7	904,8	1655,0	2882,0
							31,7	70,6	157,4	350,8	782,1
								0,0	0,0	0,0	0,0
									0,0	0,0	0,0
										0,0	0,0
											0,0

Step 2 Phase 3	0	1	2	3	4	5	6	7	8
NPV	3514,2	5521,2	8023,2	9821,1	14994,5	22573,3	31095,0	31095,0	31095,0
		2240,1	4150,0	7810,1	5864,6	9100,8	13884,4	20811,4	23556,4
			817,3	1396,3	2341,0	3847,9	6202,2	9821,1	13472,3
				412,4	747,6	1327,6	2301,2	3879,2	5802,2
					166,3	328,4	637,8	1211,4	2231,5
						41,0	91,4	203,8	454,4
							0,0	0,0	0,0
								0,0	0,0
									0,0

Appendix 6: Strategic lattice for the PolySeed project

Time	0	1	2	3	4	5	6	7	8	9	10
Decision	OPEN	OPEN	OPEN	OPEN	INVEST	OPEN	OPEN	INVEST	INVEST	OPEN	INVEST
		OPEN	OPEN	OPEN	DON'T INVEST	OPEN	OPEN	INVEST	INVEST	OPEN	INVEST
			OPEN	OPEN	DON'T INVEST	OPEN	OPEN	INVEST	INVEST	OPEN	INVEST
				OPEN	DON'T INVEST	OPEN	OPEN	INVEST	INVEST	OPEN	INVEST
					DON'T INVEST	OPEN	OPEN	DON'T INVEST	INVEST	OPEN	INVEST
						OPEN	OPEN	DON'T INVEST	INVEST	OPEN	INVEST
							OPEN	DON'T INVEST	DON'T INVEST	OPEN	INVEST
								DON'T INVEST	DON'T INVEST	OPEN	DON'T INVEST
									DON'T INVEST	OPEN	DON'T INVEST
										OPEN	DON'T INVEST
											DON'T INVEST