Saint Petersburg State University
Graduate School of Management

Master in Corporate Finance Program

THE ASSESSMENT OF R&D EXPENDITURES VIA REAL OPTIONS

Master's Thesis by the 2nd year student
Concentration – Master in Corporate Finance
Maria Cherepanova

Research advisor:
Alexander V. Bukhvalov, Professor

Saint Petersburg

2021

ЗАЯВЛЕНИЕ О САМОСТОЯТЕЛЬНОМ ХАРАКТЕРЕ ВЫПОЛНЕНИЯ ВЫПУСКНОЙ КВАЛИФИКАЦИОННОЙ РАБОТЫ

Я, Черепанова Мария Леонидовна, студент второго курса магистратуры направления «Менеджмент», заявляю, что в моей магистерской диссертации на тему «Оценка расходов на НИОКР с помощью реальных опционов», представленной в службу обеспечения программ магистратуры для последующей передачи в государственную аттестационную комиссию для публичной защиты, не содержится элементов плагиата.

Все прямые заимствования из печатных и электронных источников, а также из защищенных ранее выпускных квалификационных работ, кандидатских и докторских диссертаций имеют соответствующие ссылки.

Мне известно содержание п. 9.7.1 Правил обучения по основным образовательным программам высшего и среднего профессионального образования в СПбГУ о том, что «ВКР выполняется индивидуально каждым студентом под руководством назначенного ему научного руководителя», и п. 51 Устава федерального государственного бюджетного образовательного учреждения высшего образования «Санкт-Петербургский государственный университет» о том, что «студент подлежит отчислению из Санкт-Петербургского университета за представление курсовой или выпускной квалификационной работы, выполненной другим лицом (лицами)».

Черепанова

08.07.2021

STATEMENT ABOUT THE INDEPENDENT CHARACTER OF THE MASTER THESIS

I, Mariia Cherepanova, second year master student, program «Management», state that my master thesis on the topic « The Assessment of R&D Expenditures via Real Options», which is presented to the Master Office to be submitted to the Official Defense Committee for the public defense, does not contain any elements of plagiarism.

All direct borrowings from printed and electronic sources, as well as from master theses, PhD and doctorate theses which were defended earlier, have appropriate references.

I am aware that according to paragraph 9.7.1. of Guidelines for instruction in major curriculum programs of higher and secondary professional education at St.Petersburg University «A master thesis must be completed by each of the degree candidates individually under the supervision of his or her advisor», and according to paragraph 51 of Charter of the Federal State Institution of Higher Education Saint-Petersburg State University «a student can be expelled from St. Petersburg University for submitting of the course or graduation qualification work developed by other person (persons)».

Черепанова

08.07.2021

АННОТАЦИЯ

Автор	Черепанова Мария Леонидовна
Название ВКР	Оценка расходов на НИОКР с помощью реальных опционов
Образовательная программа	Корпоративные финансы
Направление подготовки	Менеджмент
Год	2021
Научный руководитель	Бухвалов Александр Васильевич, Заведующий кафедры финансов и учета, Профессор кафедры финансов и учета
Описание цели, задач и основных результатов	Целью работы «Оценка расходов на НИОКР с помощью реальных опционов» является предложить модель оценки отраслевых затрат на НИОКР с использованием метода реальных опционов. Задачами исследования являются: 1. Изучить тему оценки НИОКР как реального опциона; 2. Изучить модели, предложенные исследованиями по теме оценки НИОКР; 3. Построить модель для оценки НИОКР; 4. Показать, как работает модель, и проиллюстрировать на примерах. Проведенное исследование состоит из двух основных частей, которые описаны в двух главах соответственно. Были изучены различные методы оценки инвестиционного проекта с указанием их сильных и слабых сторон, также описана суть оценки НИОКР методом Реальных Опционов. Также были рассмотрены различные модели оценки НИОКР с учетом их применимости и ограничений. Для индустриального уровня была выбрана модель, которая может применяться без наличия инсайдерской информации. Для построения модели были рассмотрены параметры, которые можно использовать в качестве величины инвестиции в НИОКР, среди них как те, которые можно найти в финансовых отчетах, так и показатели,

	не относящиеся к отчетности (например, эластичность). Наконец, для оценки НИОКР была построена однопериодная модель, где в качестве инвестиционного показателя были взяты капитальные расходы. Модель была применена к данным, собранным по 25 отраслям и 2145 компаниям за 2019 год. Для каждой отрасли была рассчитана величина НИОКР, которая сравнивалась с реальной с использованием показателя интенсивности (НИОКР/Выручка). Наиболее приближенными к реальным значениям отраслями оказались: Авиакосмическая и оборонная промышленность; Общие промышленные предприятия; Путешествия и отдых; Строительство и материалы. Для иллюстрации были рассмотрены две отрасли: фармацевтика и электронное и электрическое оборудование. Для электроники были взяты компании, производящие процессоры, для фармацевтики была рассмотрена ситуация с производителями вакцины COVID-19. Отрасли, взятые на рассмотрение, были выбраны на основе критерия о наличии в открытом доступе информации о НИОКР и их процессах. Был также рассмотрен случай с COVID, поскольку он является уникальной иллюстрацией быстрого воздействия НИОКР на стоимость компании. Модель, предложенная в исследовании, может быть применена инвесторами, финансовыми менеджерами или консультантами при проведении анализа для оценки стоимости НИОКР. Модель может использоваться в качестве индикатора, позволяющего определить, являются ли инвестиции в НИОКР достаточными или нет. Также на основании модели можно сказать, являются ли инвестиции в НИОКР эффективными.
Ключевые слова	Расходы на НИОКР, Реальные опционы

ABSTRACT

Master Student's Name	Mariia Cherepanova
Master Thesis Title	The Assessment of R&D Expenditures via Real Options
Educational Program	Master in Corporate Finance
Main field of study	Management
Year	2021
Academic Advisor's Name	Alexander V. Bukhvalov, Head of Department, Professor, Department of Finance and Accounting
Description of the goal, tasks and main results	The aim of the work "The Assessment of R&D expenditures using real options" is to propose a model for estimating the costs of industrial expenditures on R&D using the real options method. The research objectives are: 1) Study the topic of treating R&D as a real option; 2) Examine the models proposed by researches on the topic of R&D evaluation; 3) Build a model for evaluating R&D; 4) Show how the model works and illustrate with examples. The research done consists of two main parts, described in two chapters accordingly. Firstly, the different methods of assessment of the investment project were studied, with their strengths and weaknesses, highlighting the point of R&D assessment by the method of Real Option. Secondly, different models of assessing the Research and Development were considered with their appliance and limitations. For the industrial level the one-period model was chosen as the one, which could be applied without internal information. Thirdly, different aspects of the Investment were considered, both ones, which could be found in the Accounting and Non-accounting indicators (for example, elasticity). Finally, the one-period model was built for the assessment of the R&D, where for the investment indicator was taken Capital Expenditures as the

	value from the Report. The model was applied to the data collected for 25 industries and 2145 companies for 2019. For each industry the R&D value was calculated and compared to the real one, applying the Intensity indicator (R&D/Revenue). The industries with the closest to the real value were: Aerospace and defense; General industrials; Travel and leisure; Construction and materials. Later two industries were considered for the case study and illustration: pharmaceuticals and electronic and electrical equipment. For the electronic were companies, which produce processors, for the pharmaceuticals the recent situation with the COVID-19 vaccine producers was considered. Industries taken for the consideration were chosen based on the information criteria: there is the information available on the R&D and its processes. The case with COVID was also taken, since it is the unique illustration of the fast impact of R&D on the company's value. The model suggested in the research might be applied by the investors, financial managers or the consultants when performing the industrial analysis in order to estimate the value of R&D as the real option. This will be beneficial due to the existence of the flexibility of the decision. The model can be used as the indicator for the researcher to identify whether the investments into R&D are sufficient or over-/under- invested. Also the model could show whether the investment in R&D is done effective or not.
Keywords	R&D Expenditures, Real Options approach

Table of Contents

INTRODUCTION

URGENCY OF THE PROBLEM

Research and development (also R&D) is the number of different activities of the company, devoted to the acquisition of innovative products and services. R&D helps the company to compete on the market and also provides advantages, when the company correctly uses the results. Nevertheless, each company has its own level of investment in R&D - the share varies not only by industry, but also by companies within the same industry. According to the latest research, the most R&D intensity companies are: Celgene Corporation (Pharmaceuticals), Roche Holding AG (Pharmaceuticals), Merk&Co (Pharmaceuticals), Intel (Semiconductors), Facebook Inc. (Software and Services) (Jaruzelski, Chwalik, & Goehle, 2018).

Since the competitiveness of a company is determined, among other things, by existing developments that are different from competitors, R&D occupies an important place in the company's activities. For some companies, investment in R&D is critical to their business (for example, pharmaceutical and biopharmaceutical companies). At the same time, R&D is a significant financial investment, the assessment of the potential of which is important for the company. Currently, there are several methods of R&D estimation. One of the most suggested is the value, estimated by the market: this is possible due to the attitude of investors to R&D as a source of future cash flow generation (Eberhart , Maxwell , & Siddique , 2004). This idea is also supported by the research done (Cohen, Diether, & Malloy, 2013) on the topic of market evaluation on R&D capacity via the stock price of the company. Palmon D. and Yezegel A. (Palmon & Yezegel, 2012) also confirmed by their research that R&D is important for assessing the attractiveness of a company to investors. Their approach, however, was focused specifically on how analysts interpret a firm with higher R&D investments (and then provide information to the market). The same approach with market valuation was applied by (Zhang & Toffanin, 2018), but with the focus on the special aspect of the existing information environment of the firm, which has direct influence on the market valuation of the company. However, the limitation of the market value approach is the consideration of only one aspect of uncertainty.

The second approach of evaluation of Research and Development, covers the aspect of existing on the market the high level of uncertainty of the variety of sources– this evaluation is done applying Real Options theory. Many modern academic authors support this method, pointing to its more accurate and at the same time applicable assessment for the company. Nishihara M. identifies three sources of uncertainty - in addition to market, also technological and competitive, which all should be taken into account (Nishihara, 2018). Based on these uncertainties, the author creates the model of R&D estimation, treating it as a real option for the company. The idea of R&D estimation via Real Options is also supported by another research, connected with the deeper analysis of the factors described above – the Real Options approach allows to make a more flexible decision regarding the further development of the company and its projects, and for some companies to abandon the project altogether (Metelski, Mihi-Ramirez, & Arteaga-Ortiz, Research and Development Projects Upon Real Options View, 2014). For some specific cases Real Options application could be the only possible way of assessment of the true value of the project – for the concrete company or industry, since R&D expenditures vary significantly and the formula could not be appropriate with the existence of specific uncertainties (Lynch & Shockley, 2016) and (Hauschild & Reimsbach, Modeling sequential R&D investments: a binomial compound option approach, 2015).

Application of Real Options to the assessment of Research and Development provides significant flexibility to the managers and investors. It is an important part of the investing process. The existing models and proposals on valuation estimate narrow areas and spheres, specific industries, even specific cases of companies. This problem was covered by (Bukhvalov, Loukianova, Nikulin, & Okulov, A Real Options Model for Analysis of industrial R&D Expenditures, 2018) via creating a model that takes into account more general aspects for assessing the intensity of R&D in large companies. The model developed is applicable for the valuing R&D and can be used by managers. Though the work provides an overview of the methodology for assessing the intensity of R&D for industries, the authors identified several limitations related to the specifics of the model itself - a limitation on R&D financing from operating profit was considered. That is why the research in the field of the Real Options model construction with the different sources of financing is acute. What is more, the research done had some limitations on the data, which also would be considered within the study.

THE RESEARCH OVERVIEW

The research goal is to propose the model for the assessment of industrial R&D expenditures via the application of Real Options. While the importance of Real Option application to the valuation of Research and Development is confirmed by researches, there are still some problems with the valuation. One of the problems is connected with the specificity of such aspect as R&D: most researches are done for the selected industries, companies or cases. Other researches focus on the industries, but introduce some assumptions, which made the further research in the field needed. The identified through literature review research gaps demonstrated that there is a lack of models for the all industries. The research will try to fulfill this gap, taking into account the problems, identified by other researches. The model might be applicable by the investors and financial managers in order to estimate the value of R&D as a real option. This will be beneficial due to the existence of the flexibility of the decision.

The research questions are the following:

1) How to apply the method of Real options to the R&D expenditures?
2) How to classify the Real Option models for estimation of R&D expenditures?
3) How to choose the model for estimation of R&D expenditures?

The research objectives are the following:

1) To study the topic of treating Research and Development as a Real Option;
2) To study models suggested by the researches on the Real R&D Option;
3) To build the model for the R&D estimation;
4) To show how the model functions and illustrate on concrete cases.

The research design is the mix of exploratory and explanatory studies, with the investigation of R&D valuation as the Real Option phenomena via covering the existing research gaps, and also with the understanding of relationships between the value of R&D option and various factors that may impact it.

The research consists of two chapters. The first chapter gives the theoretical overview on the aspects of applying the method of Real Options to the case of the assessment of R&D expenditures with the study of different methods, applied by the researches. The first chapter also gives an overview of the specific aspects of investing in R&D in terms of sources of financing and indicators of the value of R&D.

The second chapter is devoted to the theoretical implementation of the Real Options theory towards the case of assessing R&D expenditures; the model for the assessment of industrial R&D expenditures is introduced. The model is illustrated on the examples of two industries. Chapter also describes the limitations of the model applied.

In the last chapter the conclusions are made about the model suggestion based on the Real Options approach, managerial applications are provided and suggestions of further research are made.

CHAPTER 1. THEORETICAL OVERVIEW

1.1. TREATING R&D AS A REAL OPTION

Research and Development is one of the most important parts of the competitiveness of the company, which supports its growth on the market. Each company has its own level of investment in R&D, the share varies from company to company. The R&D expenses can be estimated in different way: from expert and market appraisals to trying on the real options method. For the assessment of the Research and Development companies can apply several methods, that would allow estimate the future value. Among the existing methods are: Net Present Value, Adjusted Present Value, Liquidation price, Market Valuation, Market Comparison, Acquisition price and Real Option (based on (Vriborg & Plenborg, 2012) (Berk & DeMarzo, 2017)) .

Net Present Value (NPV) is the most common way for the assessment of the investment projects, in the basis of the method is the approach of using Discounted Cash Flows (DCF). The Cash Flows that are generated by the project during its lifetime minus the invested funds, discounted by the discount rate, set according to the risk of the project. This method is quite simple when evaluating a project if there are estimated projections of future cash flows. One of the main difficulties when using the NPV method is determining the discount rate and/or growth rate. The usual risk-free rate of the company (which is generally not used in complex projects), the weighted average cost of capital (WACC), the rate for similar projects, the rate of attracted financing, CAPM can also be used as the discount rate. NPV is the useful method for the assessment of the project, however, the criteria of it being positive or negative is subjective, since its only describes profitability of the asset itself (Merlo, 2016). What is more, the NPV rule allows studying some particular cash flows and is inflexible to changes, that is why it is necessary to apply other methods together with NPV (Lidia, 2020). And the last, but not the least, the NPV is applied to the projects with the determined value, the method is not applicable to the methods with high uncertainty (Alexakhin & Zaytsev, 2020).

Adjusted Present Value (APV) method is based on the Net Present Value method with the condition of financing by equity and taking into account all the financial benefits of attracting debt. Among the financial benefits are the tax savings on the interest (tax shield), debt issuing costs, cost of financial distress and etc. APV is used for the consideration of debt financing of the project, comparing the ways of financing. For the assessment of the APV researches apply the unlevered cost of capital discount rate, because of the all-equity financing assumption. However, because of this assumption, many researches criticize this method as the unrealistic and the inaccurate one (Booth, 2002).

Liquidation price (or the value of liquidation) is the sum, that the company will receive after selling the asset. The underlying assumption under this valuation method is that the asset is sold immediately on the market. Therefore, the value could be lower than the actual value. Because of that, the business does not apply liquidation price method for the assessment of the long-lasting or big projects, also with intangible assets. What is more, due to the aspect of selling the asset on the market in limited time frame, the value of the asset could be significantly lower than its real value. Moreover, sometimes the value comes closer to the Salvage value, which is the negative value of getting away the asset (Berk & DeMarzo, 2017, p. 286).

The Acquisition value method is opposed to the method of the liquidation price. The company evaluates an asset or project by how much it will have to pay (invest money) to get the existing asset from the company. A close method to this is the method of evaluating analogues in the market (market comparison). With Market Comparison method, the company evaluates the project that exists on the market and its value from the owner of the project. Typically, these methods are applied to common assets in the industry. However, for the method of market comparison it is applied to the companies with the same procedures of accounting and same structure and position on the market (based on the multiples). These methods are criticized by the researchers, since the comparison between companies/projects is relative and subjective, and provides nor the real value, nor an accurate estimate (Nenkov, 2017), (Agudze & Ibhagui, 2020).

Market Valuation is the approach used by the researches to assess the asset according to the value the market would gave to it. The valuation is mostly done by the investors, who vote by their shares, lowering or increasing the value of the company, and, as the consequence, value of the project. Market valuation is an interesting method of assessing the value of an asset, on the one hand, as it reflects the expectations of investors directly. On the other hand, market volatility shows that investors' expectations quite often do not coincide with the company's ideas. Moreover, management often does not disclose information to maintain competition, especially about new developments and plans (Hussinger & Schwiebacher, 2015).

Real option approach is based on the idea of the right to make a particular business decision (for example, investment) after the appearance of some information (Berk & DeMarzo, 2017). There are several main types of real options:

1) Option to expand (to grow): provides an opportunity to ensure the future development and growth of the company;
2) Option to wait: the opportunity to wait for some period of time in order to get some additional information on the situation without losing preferences;
3) Option to contract: the opportunity to pause or close the project is the situation is unfavorable and return back to operations later;
4) Option to abandon: the opportunity to leave some project without losing investments.

The importance of Real Options introduction into the R&D treatment was underlined, especially because it provides flexibility in the high uncertainty world. The great opportunity to apply Real Options theory for the R&D evaluation was illustrated my many specific company-cases. For example, in the Pharmaceutical and Biotechnological industry, where the R&D may take a lot of time with the aspect of the possible competitors' activities of failure of the drug, the Real Options Approach is very useful. This was illustrated by the cases provided by (Jacob & Kwak, 2003), (Banerjee A. , 2003), (McGrath & Nerkar, 2004) and others. However, Real Options are applicable not only for the Pharmaceutical companies, but for the companies from different industries, countries and of different size, etc. The method is applied in the environmental studies, where the high level of uncertainty goes with the lack of statistics (Kim, Lee, & Park, Evaluation of R&D investments in wind power in Korea using real option, 2014) (Managi, Zhang, & Horie, 2016) (Martín-Barrera, Zamora-Ramírez, & González-González, 2016).

The summary on the valuation methods of Research and Development is provided in the Table 1.

Table 1. Possible approaches for the valuation of R&D

Approach	Application	Limitation
Net Present Value	Assessment of the future cash flows of the project, discounting them to the present value at moment t=0	Applied to the projects with the defined cash flows, where uncertainty is low; inflexible
Adjusted Present Value	Assessment of the future cash flows of the project, financed by the own funds	Applied to the projects with the defined cash flows, assumption of equity

Approach	Application	Limitation
	of the company	financing is not applied to all industries
Liquidation price	Value is defined on the price of the asses/project in the case of selling it immediately	The value assessed by the method is much lower than the actual value
Market Valuation	Value is defined by the stakeholders on the market, mostly shareholders (investors)	For the projects with low uncertainty and determined plan of the project development
Market Comparison	Value is defined based on the comparison with the existing projects on the market	Assumptions are made on the firm size, performance, aim, and development
Acquisition price	Value is determined based on the amount of money needed to acquire the asset on the market	Asset could unique or have unique features
Real Option	Value is defined treating the project as the option	Assumptions are made on the risk-neutrality

Source: done by the author based on the literature review

All the methods of the assessment studied are applied to different situations, with different goals of the researchers and parameters. The provided review is the illustration if the importance of Real Options application to the evaluation of R&D because of high uncertainty and risk. Due to the specificity of an asset, there is a numerous amount of the models suggested for the estimation, starting from the individual cases and going through companies of the industries, size, country, market, etc.

1.2. R&D VALUATION TECHNIQUES VIA REAL OPTIONS

There are different ways of assessment of R&D as it was described, however, in terms of this paper the focus will be on the evaluation of R&D via the application of Real Options approach.

The basic terminology of the Real Options theory is (Berk & DeMarzo, 2017):

1) Real Option: right to make a business decision in the future;
2) Call option: right to buy the particular asset in the future;
3) Put option: right to sell the particular asset in the future;
4) Exercise price: the price of the asset, at which it could be bought or sold;
5) Underlying asset: the asset of the company, on which the decision is made.

The valuation of the option is based on the type of the option: Call or Put. Since the research is focused on the assessment of the R&D expenditures, later only Call option will be considered. The basis models for the valuation of the option are the Binomial Option model and the Black-Scholes Option model. The Binomial Option model is replicating the value of the asset with the replication portfolio; the model could be designed for the one period and for multiperiods. Black-Scholes model also builds the value on the replicating portfolio, however, the model is less flexible compared to the Binomial Option model (Berk & DeMarzo, 2017).

1.2.1. BINARY TREE SINGLE PERIOD MODEL

The single period model for the R&D expenditures in large innovative companies was proposed by Bukhvalov, Loukianova, Nikulin, & Okulov (2018). The research done covers the gap of the model proposal in general (existing studies did that for the cases of specific industries). Among the model assumptions are:

1. Single period model;
2. The companies are mature and large in R&D intensive industries;
3. The budget for the investment is stable due to the affiliation to the mature and large companies;
4. The debt financing policy is stable;

5. The world is risk-neutral (and managers of the studied companies are experienced enough to maintain the portfolio in risk-neutral position);
6. Amount of investments is limited by operating profit.

Bukhvalov A.V. et al. suggest to apply for the R&D estimation as the option the following model (1):

$$RD_{an;ind} = OP_{an;ind}\left(e^{\bar{\sigma}\sqrt{T}} - 1\right)e^{-r\bar{T}} \quad (1)$$

where $RD_{an;ind}$ – R&D expenditures in the industry, $OP_{an;ind}$ – annual Operating Profit of all companies in the industry, $\bar{\sigma}$ – average standard deviation of value of companies in the industry, T – period, r – risk-free rate (was ignored due to the fact of being close to 0 in 2016 for the developed countries) , $\bar{T}$ – average length of the R&D project.

The value of R&D is defined as the result of the positive outcome of the investment in the process of research and development, the investment was defined by Bukhvalov A.V. et al. as the annual operating profit. However, the main problem in taking operating profit as the investment is connected with the fact, that its value could be negative.

For this model the following gaps were identified:

1) The risk free rate is considered to be close to 0, which is not true;
2) The deviation for companies was taken from the A. Damodaran site as the average , which is not accurate;
3) The debt volatility was not estimated, but taken as 40% of equity volatility, what is not true;
4) The correlation between the stocks and bonds was taken as 0,5, what is not true;
5) The R&D are considered to be financed from operating profit.

The deeper analysis have shown, none of the mentioned assumptions was true for the industries studied. Applying the real statistics the model appears less accurate, for some industries the accuracy is insignificant.

The model suggested is done for the risk-neutral world and calculated with the risk-neutral probabilities, so the investments into the assets are made after the R&D completion. The model was applied for the calculation of R&D expenditures and R&D intensity for large innovative companies. Though the research done presents the new idea of R&D valuation for the industries, the research has some limitations, noted by the authors. It is the aspect of the homogeneity of the debt and its limitation by the operating profit.

1.2.2. COMPOUND OPTION MODEL

Choi, Kwak, & Yoo (2016) in their research applied Real Options valuation for the project of seabed manganese nodule mining, this approach is more appropriate for valuation of R&D of such type, since the projects in this sphere are highly important for the economic development, cost a lot and have high level of uncertainty. The authors treat R&D in this case as a growth option (call option). Choi et al. consider the three-stage model, including Initial investment, Additional investment and Start of the production. A more detailed description of the stages of the project is presented in the Figure 1. The first period is three years length and includes the starting amount of investments. The second period is seven years and includes some additional investments on the exploration, mining and transportation. The last period is thirty years with the assumption, that each year the 300 mln tons of manganese nodules each year.

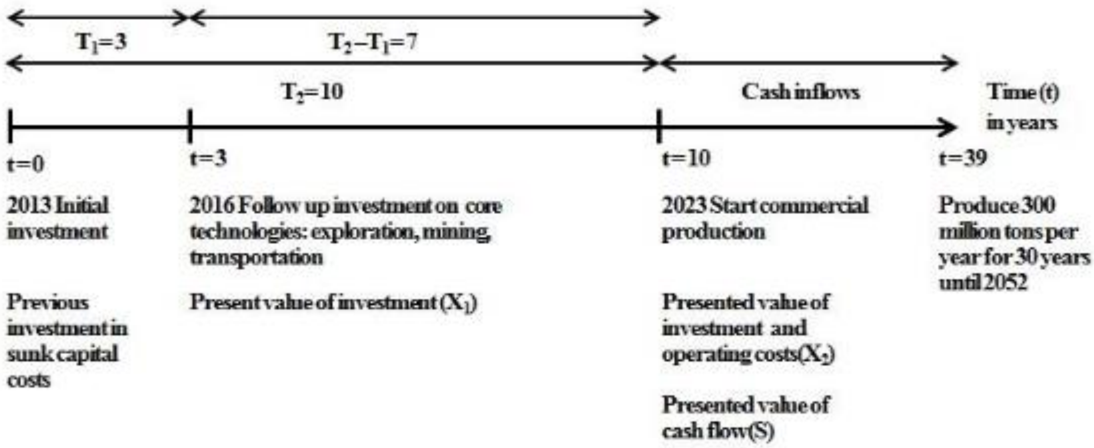


Figure 1. *Structure of the Deep Seabed Manganese Nodule Project, (Choi, Kwak, & Yoo, 2016)*

For the evaluation of a compounded call option, the authors apply Geske's valuation approach:

$$C = SM\left(a_1, b_1; \sqrt{\frac{T_1}{T_2}}\right) - X_2 e^{-rT_2} M\left(a_2, b_2; \sqrt{\frac{T_1}{T_2}}\right) - e^{-rT_1} X_1 N(a_2), \quad (2)$$

where

$$a_1 = \frac{\ln\left(\frac{S}{S^*}\right) + \frac{1}{2}\sigma^2 T_1}{\sigma\sqrt{T_1}}$$

$$a_2 = a_1 - \sigma\sqrt{T_1}$$

$$b_1 = \frac{\ln\left(\frac{S}{X_2}\right) + \frac{1}{2}\sigma^2 T_2}{\sigma\sqrt{T_2}}$$

$$b_2 = b_1 - \sigma\sqrt{T_2}$$

N - Normal distribution function, M(a,b;ρ) – Bivariate normal distribution function, S* – Critical value of the project (the minimum value of the project, under which it is meaningful to do the initial investment), S – Present value of the cash inflows of the commercial production (year T_2), σ – Volatility of the present value of commercial venture, X_2 – Present value of the capital expenditures of the commercial venture as of year, X_1 – Present value of first year capital expenditure of the pioneer venture as of year, r – risk-free rate.

The model implied is based on the Black-Scholes formula and is applicable for the estimation of expenses of R&D into the project. The authors also pay attention to the aspect of volatility, which is a very controversial point for R&D projects, since historical data is not available very often. Choi et al. suggest to go for the data on the commodity market (for example, they have taken data from London Metal Exchange) or apply A. Damodaran average standard deviation.

The procedure of estimation of R&D was divided by Choi et al. in three stages with the particular option to each stage. For the first stage of the project (3 years) was the pilot project and testing as the possible option to abandon the project if it won’t be successful. The stages 2 and 3 also reflect the real option, but since the option to abandon was not exercised, they are treated as the growth option for the company.

Based on the Formula (2) the authors have estimated the value of R&D investments – it is profitable to mine deep seabed in the concrete case. However, it is difficult project from the point of working conditions under the sea, so Choi et al. recommend also do the scenario analysis and estimate the R&D in other probable cases: this will help to avoid some losses or prepare to them.

The approach, suggested by (Choi, Kwak, & Yoo, 2016) is applicable to the projects of R&D estimation, for the multi-period stages, which are common and crucial for many industries and companies. The research done, shown more accurate and reasonable results for the R&D process in the studied industry, that the applied earlier Discounted Cash Flow Method. However, for the formula several assumptions were made and some data used was closed. There are doubts about how appropriate it will evaluate not one, but many companies of various industries, since within the framework of this thesis there is no access to the company's internal information on the timing, investment, investment aspects, etc.

Metelski, Mihi-Ramirez, & Arteaga-Ortiz (2014) also conducted study on the multi-period growth option for the firms of small and medium size and for the blue-chips, applying the compound option model. Though, the authors did the duopoly case study for the two companies: Embraer and Bombardier; they also provided a model for R&D valuation via Real Options, that can be applied to SMC and blue chips. Metelski D. et al. studied R&D as the option to grow, calculated compoundly. The success of the companies studied was identified by the authors based on the success of R&D. This success was identified by Metelski et al. acccording to the following criteria:

1. Amount of patents compared to the industrial average;
2. Conversion ratio (R&D expenditures compared to the amount of patents created).

The data of the research was taken on 385 companies. The hypotheses stated were the following:

1. The R&D performance is explained by the main factors, taken by the authors (sales, share price, capitalization, forecasts on sales, scenario forecast, rents, costs, etc.);
2. R&D costs influence in the positive way the value of R&D for SMC and in the negative way the value of R&D for the Blue Chips;
3. Value of companies depends on the value of R&D;
4. Patents have a different impact on growth opportunity for SMCs and for Blue Chips.

The methodology of the research is the empirical study (on 285 companies within the six industries: Biotechnological, Chemical, Medical, Communication, Programming & Software, Semiconductors, traded worldwide) and the statistical analysis. The value of Real Option on the R&D was presented in general way as follows:

$$Gt = Gt\ (V, P, K, X, \sigma_v, \sigma_k, \alpha, D/A, C/A, CF, GW, N, HH, L) \quad (3)$$

where V – payoff of the Real Option, K – capital expenditures, P – current price, X – exercise price, $\sigma_v -$ variance of the expected return, $\sigma_k -$ variance of the exercise price, D/A – debt to assets, C/A – cash to assets, CF – operating benefit, GW – goodwill, N – number of employees, HH – Herfindhal-Hirschman Index, L – work efficiency.

The authors suggest the following formula for the estimation of the option:

$$GM = V_2 N(d_3) - V_1 N(d_4) \quad (4)$$

where V_1 – exercise price (expected rents),V_2 – price of the underlying asset,

$$d_3 = \frac{ln\frac{V_2}{V_1} + \rho(t_2 - t)}{\rho\sqrt{(t_2 - t)}},$$

$$d_4 = d_3 - \rho\sqrt{(t_2 - t)},$$

$$\rho^2 = \sigma_v^2 + \sigma_2^2 + 2\sigma_{v2}\sigma_v\sigma_2$$

$\sigma_v -$ standard deviation of the expected return, $\sigma_k -$ variance of the exercise price, t – time to expiration of the option.

The value of R&D for the compounded option[1]:

$$GH = \frac{f(X_h)}{f(X_L) + f(X_h) + r}\left(V_1 N(d_1) - K(0)N(d_2)e^{-t(\alpha_h - \alpha_k)} + e^{-rt_2}(V_2 N(d_3) - V_1 N(d_4)\right) \quad (5)$$

where $\alpha_h -$ expected rate of increase of the exercise price, $\alpha_k -$ sum of risk free interest rate and premium, $f(X_h) -$ probability of success of the company of high type, $f(X_l) -$ probability of success of the company of low type, r – risk free interest rate, K – capital expenditures,

Based on the model valuation (Metelski, Mihi-Ramirez, & Arteaga-Ortiz, Research and Development Projects Upon Real Options View, 2014) have supported the hypotheses stated, also providing evidence of the importance of some types of R&D for the opportunity to grow (for example, patents). For the Blue Chips the authors found that it is more meaningful not to develop R&D themselves, but to buy access to the results of R&D. Another situation is for the small and medium companies: for their growth it is better to start R&D by themselves. What is more, the authors came to the result, that Capital Expenditures are closely connected with the successfulness of R&D on both criteria. The model provided by Metelski D. et al. is useful and

[1] Note: this model is based on the duopoly study of two competitors

meaningful, but has some limitations. Firstly, the model is done only for six industries and for the companies with the high R&D investing. Secondly, the specific model proposed is not applicable to the general study, but for the case study of two competitors.

The application of the binomial tree is the focus of the research done by Hauschild B. and Reimsbach D. (2015), the authors used binomial tree for the estimation of R&D investments, option is compounded. The authors demonstrate the quality of the model on the case of new drug application (NDA). Due to the fact of the existence of previous researches on the purpose of NDA with the models suggested, Hauschild B. and Reimsbach D. demonstrate the benefits of their model.

For the biopharmaceutical industry the Research and Development is the crucial element to remain competitive and create revenue. However, this is also extremely risky process, due both to the amount of investment and the timing frame (up to 12 years with no revenues), also the success of competitors in these factors. That is why, it is extremely important to treat R&D expenditures right. Unfortunately, the basic DCF models are not applicable to the case of biopharmaceutical sector, because of their low correspondence to the uncertainty. In order to deal with this, Hauschild B. and Reimsbach D. applied Real Options. For the case of new drug application, the project of R&D consists of several stages. The first stage is connected with the discovery and has a length of one year. The second stage is preclinical phase, which is normally three years. Then, there are three clinical phases for the length of one, two and three years respectively. The last stage is FDA (Food and Grug Administartion) filling, which is 2 years long. The uncertainty appears, since no one knows possible payoffs from the drug and success of the drug.

In the case of researching and developing the NDA, it is appropriate to apply the Real Options method, treating the R&D as the option for growth. The valuation of the call option the authors start from the traditional model on the call estimation (with the replicating portfolio), however, due to the multi-stage project Hauschild B. and Reimsbach D. add several implications into the model. The schematic illustration of the R&D investment is presented by the authors as following (Fig.2):

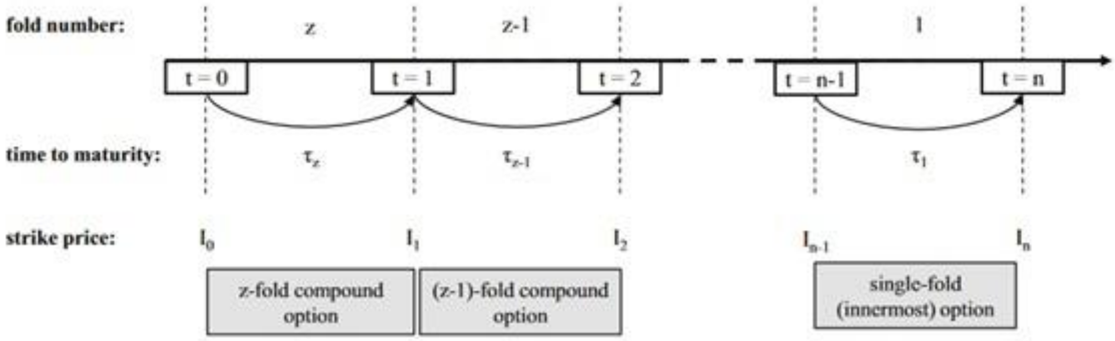


Figure 2. *Valuing R&D as compound option*[2]

Studying the Figure 2, the R&D expenditures ($I_0 - I_n$) is the serie of investment into the project and is treated as the compound option, while z corresponds to the value of option. Because of the copmlex process of NDA with the uncertanties at each period t, the option may also vary – the option to grow or option to abandon. Real options approach hepls to cover the uncertanties within the period of financing new drug. The model for the estimation was suggested by Hauschild B. and Reimsbach D. as follows:

$$C_{z,t} = m^*_{z,t} V_t + B^*_{z,t} \quad (6)$$

where $C_{z,t} -$ value of z-compound option at the moment t, $V_t -$ value of the project at the moment t, $m^*_{z,t} = \prod_{i=1}^{z} m_{i,t}$ – part of investing in the project, $B^*_{z,t} = \sum_{l=1}^{z} B_{l,t} \times \prod_{i=l+1}^{z} m_{i,t}$ – risk free loan.

After the development of the model, the authors have applied it for the calculation of the R&D of the NDA project. With the progress through the stages, the authors noted that the binomial tree is gradually shrinking, as development scenarios become known. This provides some flexibility for the managers, since they can adjust their calculations of the value, if there some inaccuracies.

What adds more value to the research done by Hauschild B. and Reimsbach D. is the debt investments, which are considered flexible and non-fixed. The authors, following the idea of previous researches, come to conclusion, that the proportion of debt is a market-value based consequal R&D estimation. This hepls to decide on the additional investments needed from year to year. The authors suggest the following method for the leverage estimation:

[2] Source: Hauschild B. & Reimsbach D. (2015)

$$L_{z,t} = \frac{|B^*_{z,t}|}{m^*_{z,t} V_t} = \frac{-\sum_{l=1}^{z} B_{l,t} \times \prod_{i=l+1}^{z} m_{i,t}}{\prod_{i=1}^{z} m_{i,t} \times V_t} \quad (7)$$

where $L_{z,t}$ – leverage ratio for compound option at moment t, $B^*_{z,t}$ – risk free loan, , $m^*_{z,t}$– part of investing in the project at moment t, V_t – value of the project at the moment t.

In the model, the leverage amount illustrates the amount of investments made at a certain point of time t. This is how the debt follows the R&D investments. The authors state the application of this model brings the estimated value of R&D closer to the reality. What is more, Hauschild B. and Reimsbach D. underline, that the model they suggested, differs from the previous ones to the point of mathematical complexity reduction, the amount of calculating steps reduction and addition of more flexibility to the managers due to multi-stage binomial approach with leverage estimation and possibility to adjust calculations in progress. However, there might be some limitation to the research, connected with the existance of derivative market assumption (used in the model calcultion), not for all types of assets such markets exist.

Another approach to the estimation technique od Research and Development, though, applying the same idea about the future results of expenditures was suggested by Valdivia et al. (2020). This is also a specific case for the renewable energy and the authors studied the uncertainty of possible outcomes of the investing in R&D in the sector. They decided to evaluate R&D as the source of potential benefit for the organisation (same approach was used by Bukhvalov, Loukianova, Nikulin & Okulov, (2018)). For the study was taken the global company, headquatered in Spain and operating across 70 countries. The project studied was connected with the bioenergy, it was new project for the company and management wanted to estimate the value of it, that’s why the method of Real Options was suggested and applied by Valdivia et al.

The outcome was measured by the simulation modelling of the parameters:

- Voume of gas used
- Ethanol usage per raw material
- Dose of enzyme
- Capital Expenditures

The Monte Carlo simulation was applied to the listed parameters together with the potential number of commercial opportunities (plants amount), ethanol prices and fee on the municipal solid waste (used in the fuel production). The simulation was done based on the historical benchmark data with the relevant assumptions.

It is noteworthy to pay attention to the source of financing of R&D, which was determined by the authors to be equal to the Capital Expenditures. The authors explained this as the reasonable assumption for the cases of renewable energy. Nevertheless, it might be applicable for the other industries as well.

The same approach of the simulation modelling was used by Kim, Lee, & An (2020), the authors applied simulation for the identifiation of R&D technology, which allows to reduce costs of renewable energy. The value of R&D was calculted, using the model of economic value of renewable energy, at the time t if the unit cost of fossil energy power generation increases in i times, the unit price of carbon emission rights increases j times, and there have been r times of R&D investment until the time t.

The decision making process is described on the Figure 3. At each time point the company's management has the opportunity to invest in R&D project, deploy or abandon (options to grow, to wait and to abandon). After the decision to invest is made, the simulation on the possible outcomes of fossil energy costs and emission rights prices was conducted. The time period for data was 14 years, the risk-free interest rate was 3.6% (the average of the interest rate on the 91 day certificate of deposits for the 10 years). The carbon emission was estimated based on the data about the greenhouse gas in the electric power sector.

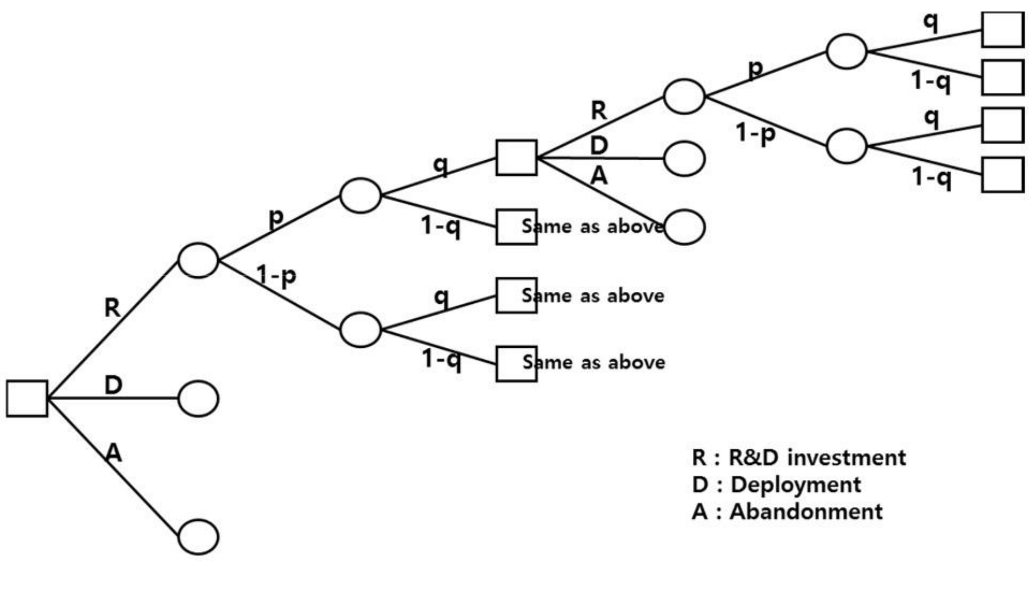


Figure 3. *Decision tree on the case of introduction of R&D project*[3]

[3] Kim, Lee, & An (2020)

The model was applied to the concrete case and the probabilities and uncertainties were clarified for it, and this is the limitation of this approach. However, an application of simulation modeling could be useful on the industrial level, though the further development of the model is needed to be case specific.

The Table 2 presents the main results of the models for R&D estimation investigation, two types of models were found: for the one period and multi period. Both ways have the right to exist and carry the goals and premises of the authors of the study. The models studied all have some limitations, specific assumptions or case conditions, however, the model studied are the good base for the personal model development.

Table 2. Summary on the models of R&D valuation

Author	Limitations
Bukhvalov, Loukianova, Nikulin, & Okulov, (2018)	Homogeneity of the debt, its limitation by the operating profit Application of average debt, equity volatility and correlation to all industries Ignorance of risk free rate
Choi, Kwak, & Yoo, (2016)	Problem of data disclosure
Metelski, Mihi-Ramirez, & Arteaga-Ortiz, (2014)	Model is done for specific industries and case
Hauschild & Reimsbach, (2015)	The aspect of the liquid derivetive market for the studied assets
Valdivia, Galan, Laffarga, & Ramos, (2020)	Specific case is used

Author	Limitations
Kim, Lee, & An, 2020	Specific market is used (renewabe energy)

Source: done by the author based on literature review

Based on the study done, the one-period model was chosen, since it allows to conduct the study for the industries, without studying some specific cases. However, the suggestions from another models described above are being considered.

1.3. INDUSTRIAL SPECIFICITIES

The literature study done on the topic of the assessment of the industrial R&D expenditures has shown urgency of the idea of the model, since most of the researches done and most of the models suggested are case- or industry-specific.

In order to identify the main specificities and features of the industries, the analysis was done. The main results of the analysis are presented below.

1.3.1. SOURCES OF FINANCING R&D

Each company is a unique economic subject and has its own set of rules and policies for the implementation of certain investments. Nevertheless, it is possible to trace the general patterns for certain companies and industries by studying the sample. Investigations about the sources of investments in Research and Development, for the most part, focus on evaluating a particular group of companies belonging to one industry, one country, one market, type of country, etc. There are also studies devoted to specific cases of companies, but they are less applied due to their focus. Since this master's thesis does not imply a consulting project for a specific case, studies, based on a group of companies and not a single company, were taken as a base for the research.

The source of large investments financing is important to the firm, it may provide additional benefits or difficulties. That is why (Lee S. , 2012) studied the impact of R&D investment on company's finance. The author did the research using panel data for the ten years for the Korean firms for the manufacturing industry. The results of the study support the Pecking Order Theory and show the usage of debt for financing R&D expenditure as the primary source. The results also have shown, that the investments in Research and Development are sensitive to the volatility of internal cash flows mostly for the young firms (not for old firms) and this also partly explains the preference of mostly debt financing due to the stable cash flow.

The importance of debt financing and the flexibility of this financing is one of the main arguments of the research done by (David, O'Brien, & Yoshikawa, 2008). The authors state, that the previous researches use the homogenous debt, while it has to be heterogeneous for more appropriate and real results. The sample for the research was for the twenty-year period for the public Japanese companies. The authors applied regression analysis to test the hypotheses of relation on relational debt (debt of extended duration and attributes: private loans) by R&D intensive firms and the high ratios of relational debt over total debt.

Fryges H. et al. provide evidence on the sources of R&D financing for the small firs and start-ups, which depends on the reputation on the market – for the small firms, which already showed their possibility to operate on the market the financing is done mostly via loans, while for start-ups the situation is opposite and financing goes mostly from the founder, sales and third parties (Fryges, Kohn, & Ullrich, 2015). The authors did the analysis for the firms in Germany, without subsidiaries (which may provide additional financing) or de-mergers from ten industries. In the research the regression analysis is used to provide some evidence and identify relations. Fryges H. et al. provide some suggestions to the managers of the small firms, showing that it is better to consider for the first source of financing a bank loan and try to reduce information asymmetry, so to look more attractive and reliable on the market.

The interesting study on the topic of R&D financing for the medium and small firms was done by the (Czarnitzki & Hottenrott, 2011). They studied German companies of eleven industries, applying regression analysis. The authors specifically mention, that their sample is more representative, than for the previous studies. The results show, that for the small and medium firms it is more likely to apply to the internal source of financing (due to the fact of lower debt provisions to the firms thought to be incapable of fulfilling liabilities) , but the authors underline, that this is a limited source, that is why firms may also attract debt. What is more, the authors unidentified the relation with the firm's size: the bigger the firm, the more likely it will go for the debt financing.

To the same conclusion on the sources of financing came (Riding, Orser, & Chamberlin, 2012). The research done shown that small firms, when deciding on sources of R&D financing, will choose the equity financing first and after that debt financing. In the research the logistic regression was used, with the sample of Canadian and American enterprises of small and medium size. The authors admitted that their results are against Pecking Order Theory (choosing the more cheap financing first) and connected that with the founders and leaders of the firms (for example, as equity they can attract family or friends money, which are cheaper than those from other investors). However, one more conclusion was driven from the research: though it is more likely for the firms to apply internal financing, the sources of financing differ for the companies, depending on their goals of financing, sector or other characteristics. That is why, it is more meaning to do the further research, dividing firm into other characteristics, for example, industry.

The source of financing depends on the type of the market: for the emerging markets for the company it is more likely to apply the internal source of finance rather than debt, to this conclusion came (Alam, Uddin, & Yazdifar, 2019) in their research of sources for R&D financing for the firms, that operate in the emerging markets. The authors did the research for the firms from the 20 emerging markets, applying the generalized method of moments (GMM), and defined not only the most common source of finance, but also two factors, that might change it to the debt financing. Alam A. et al. found, that the affiliation with the company or following a bank-based financial system increases the likelihood of using external sources of financing.

The researches have introduced some important aspects of R&D financing. The summary on the paper studied with the limitations is provided in the Table 3.

Table 3. Summary on the sources of R&D financing[4]

Author	Source of financing	Limitations
David, O'Brien, & Yoshikawa, (2008)	Debt financing, application of the heterogeneity of debt	The research is done for Japanese companies
Czarnitzki & Hottenrott,	Preferably – internal financing,	The size of the firms

[4] Done by the author based on the literature review

Author	Source of financing	Limitations
(2011)	with an increase of the size debt financing is more likely	studied is small and medium, firms are German
Lee, (2012)	Debt financing	Korean firms from manufacturing industry
Riding, Orser, & Chamberlin, (2012)	Preferably – internal financing	Appearance of other factors to be important, American and Canadian firms
Fryges, Kohn, & Ullrich, (2015)	For small firms – loans, for start-ups – mostly from founder or sales	The research studies young firms and start-ups, data mostly from German firms
Alam, A., Uddin, M., & Yazdifar, H. (2019)	For the most cases – internal source of financing	The research is done for the emerging markets

Source: done by the author based on literature review

The great illustration of the pecking order theory and debt financing is the pharmaceutical sector, for this industry the investments into Research and Development activity are high, at the same time, the timing horizon from the research to sales could take up to 10 years without any payoffs in between (How Are Vaccines Developed?, 2019). That is why most of the companies in pharmaceutical sector apply for debt financing, for example, leaders of the industry: Johnson & Johnson and Pfizer. The example of the debt raising and also equity raised by Pfizer is presented on the Figure 4. As we can see, debt financing is prevailing in the company's financing policy, equity was issued only once in 2018 compared to the 6 deals of debt acquiring for the same year. For the all cases the financing of R&D was external: by issuing either shares or bonds.

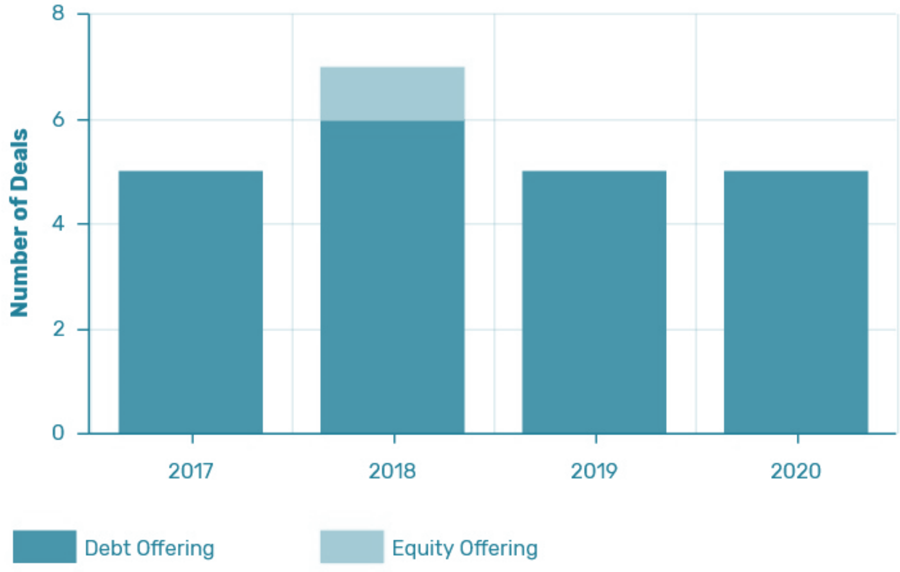


Figure 4. *Debt and Equity offering, Pfizer (Pfizer Inc, 2021)*

An interesting way of financing the R&D activities was presented by Novo Nordisk, Danish pharmaceutical company, which applied Venture Financing (Corporate Venturing , 2021). Venture Capital Financing is quite risky, that is why in the industries with the long development and return on investment companies rare apply it. However, Novo Nordisk considers this the good competitive mood, buying the risky innovation instead of creating them with the existing assets (Our approach to venture investments, 2020).

We can consider that the source of financing deviates and is more likely to be equity for the small firms, and is more likely to be external for the big companies. It is also important, to consider the debt as the heterogeneous one to come closer to the real values of options. One more suggestion on the interpretation of the analysis one is considering the industrial mode or mean value of debt and equity relation for each industry.

1.3.2. Accounting indicators of R&D

In order to identify the most influential or crucial for the Research and Development investments categories, the study of the literature on the topic of performance measurement was done. The indicators considered reported as they appear in one of the financial statements of the organization. One important note for this section is that some indicators, though considered crucial for the analysis of R&D, were not included in the analysis due to their impact (for example, sales amount or amount of people in the organization), also some indicators, which are case-specific and on which there is no information available for the all companies, were not included. One more important notification is that the indicators studied are not considered as the change to R&D, but as the possible measurement of the firm-competing level. The summary on the possible indicators is presented by the end of the section.

1) Operating profit

Operating profit is the profit of the company before interests and taxes. It is calculated by the subtraction from the revenue (sales) cost of goods sold and operating expenses. This indicator reflects the income of the business from its core activities. The idea of using the operating profit as the base for R&D treatment and source of investment was applied by Bukhvalov, Loukianova, Nikulin, & Okulov (2018): the annual operating profit was taken for the estimation of the real option, in the model the summ of all individual operating profits from firms in the industry is taken. The idea is connected with the fact, that some of the companies apply the operating profit as one of the possible sources of finance for some of the projects.

However, by Bukhvalov, Loukianova, Nikulin, & Okulov (2018) mention in their paper, that the situation of taking operating proit is not applicable to the cases when the firm has begative results. This is one of the main constrains of using operating profit as the possible indicator of R&D. Other authors the authors adhere to the idea that operating income may be an example of the efficiency or non-efficiency of an investment in R&D, but not the illustrtation of investment. This was reflected by (Diaconu, 2019), (Amoroso, Moncada-Paternò-Castello, & Vezzani, 2017) and (Blass & Yosha, 2003).

2) Capital expenditures

Capital expenditures are the expenses of the organization connected with the maintenance and support of the assets of the company, it reflects the situation of investing in current and new assets for the expansion of business. Capital expenditures also can be viewed as the indicator of investing into Research and Development. It should not be treated as R&D itself, but as an indicator is acceptable. This was described in the research of Boer F.P. of treating Research and Developmen as an opportuniry with the economic value andmarket value (Boer, 2005). Though, the author argues that R&D is not an expense on its nature, he provides an observation of reporting standards in American and European accounting policies, which treat R&D as an expense, and, more specifically in most cases as capital expense. What is more, Boer F.P. recommend the real option approach for the estimation of R&D more strategic and modern way.

With this idea of wrong-treating R&D agree Czarnitzki D. and Hottenrott H., they pay attention to the fact, that, though, R&D is mostly about acquiring knowledge and some unique skills, while accounting treats it as the cost, reported among all, to the capital expenditure (Czarnitzki & Hottenrott, 2011). What is more, in the models, studies in the part 1.2 R&D valuation techniques of this research, Capital Expenditures were applied for the R&D understanding.

This idea, however, is not supported by Zuoza A. and Pilinkiene V. in their research of company profitability and its markers (Zuoza & Pilinkienė, 2019). The authors did the regression analysis in order to identify the main features, which impact EBITDA of the organization, and the parameters of sums, invested into Research and Development and spent as Capital Expenditures, were divided as two independent costs. It is necessary to mention, that the study was conducted only for some industries, connected with the energy, and Zuoza A. and Pilinkiene V. considered such division of expenditures as reasonable for the sample chosen (44 companies, years 2002-2016).

3) Fixed assets

Fixed assets belong to the category of long-term assets of the company (more than 1 year) that are used for the production of products and services. Fixed assets of the company may be an illustrative example of both R&D performance and the industry specificity. Fixed assets can not be treated as the source of financing R&D (e.g. an investment), but they can be an R&D result. According to Lazzarotti, Manzini, & Mari, (2011) Fixed assets of the company are the illustration of how good the process of investing, researching, development and implementation was done, mostly by showing some equipment as well as laboratories, specific machinery, etc. However, authors point out, that this indicator is too broad and should be used in the cases, when there is a detailed report about which fixed assets company has, how are they used, when did they appear on balance sheet and so on, since the same equipment can be used for several R&D projects, or, on the contrary, might be outsourced. Fixed assets also illustrate some industrial specificities, since some companies require more fixed assets, while some less. The illustrative example of how fixed assets and R&D might be used for the identification of firms leading position as well as belonging to industry was done by Kumbhakar, et al. (Kumbhakar, Ortega-Argilés, Potters, et al., 2012). The authors divided industries in the categories of high- medium- and low-tech, depending on several of parameters. According to the findings, the higher the tech-advanced industry, the more important and similar to the company's performance R&D and Fixed assets are. The idea of Lazzarotti et al. was also later supported by the research of Khalifa, Mansour, & Saci (2017), who studied the firm behavior on the dependence of financing conditions (especially, investing). Among the results of the impact of financing constrains, Khalifa et al. also found the same behavior of investments in fixed assets and R&D, also from competitive perspective. This finding might be also an illustrative example of how the strategic behavior of the firm might be depending on industry, firm size, market position and etc.

However, with the idea of implementation of assets as one of main indicators of R&D disagree Kang & Long (2001). The authors recognize the R&D and the Fixed Assets as two non-descriptive variables, which do have impact on each other (as everything else in the company), but which have different roles in company's performance, liabilities and etc. This idea is supported by the research done by the Ajina, Msolli, & Saidani (2017) in their research of R&D on the example of industries in Japan. The authors divided the investments in Research and Development and in the Fixed Assets as two different investments. Ajina et al. imply, that, though Fixed Assets content some asstes that might be used in researching process, they are independent and used also in the everydaylife activity. What is more, these two accounting provisions have different sighnals to investros and to the market.

4) Intangible assets

Intangible assets do not exist in the physical form in the organization (for example, patents, brand or goodwill). Intangible assets do also describe the industrial specificities and can be viewed as possible reflection for the estimation of Research and Development are. The strong interconnection and origin of one from the other was examined by Pike S et al. in a study of R&D-intensive organizations (Pike, Roos, & Marr, 2005). The authors examined the impact of intangible assets on 5 resources of the organization: human, organizational (created by the organization), necessary for work, physical and financial, and conducted research using the case study method. Research revealed a strong influence of intangible assets on the R&D process, both in terms of preserving the resources already made and in terms of development and implementation of new ones. Studying the impact of owning intangibles and investing in R&D on the firm value and policies during stable and volatile economic environment, Borghesi R. and Chang K. treated Intangible assets as the Result of R&D expenditures (Borghesi & Chang, 2020). The study of data from 1997 to 2015 has shown, that intangibles and R&D tend to have the same impact on the policy of the regulators with regard to investing or supporting the company. The consistency of the Intangible Assets and R&D investments in the role of helping company with the internationalization was also underlined by Bryl L. in his research of companies from USA, Western Europe and Japan with the case study method (Bryl, 2020).

With the idea of treating Intangible Assets as the possible indicator of Research and Development disagrees VanderPal G., pointing, that R&D is much more both risky and beneficial, than Intangibles (VanderPal, 2019). According to the research done by the author for the S&P 500 companies, the impact of Intangible Assets and of R&D on the performance of the company is different both from the reporting perspective as well as investor relations perspective. With this results compromise findings of Datta S. et al. of studying the intangible assets and audit fees of companies, which have reporting according to the US GAAP standards[5] (Datta , Jha, & Kulchania, 2020). The authors point out all the variety of assets included in the concept of Intangible assets, R&D in which takes only a share. Because of that treating Intangibles as the R&D indicator will be the ignorance of all other intangible assets of the organization, which may appear and function without R&D.

1.3.3. Non-Accounting indicators of R&D

When analyzing such an indicator as R&D, one should not rely only on main reports indicators: sometimes non-accounting indicators reflect a more complete picture and at the same time allow taking into account more specificities of a particular industry. To identify possible indicators for the research, the analysis was done.

1) Patent data

Patent is the exclusive right of the inventor or purchaser on the invention done. The invention can be done by the organization itself, but also can be bought. The results of Research and Development activity are often registered as patent to safe the exclusive right on the finding made. Patents also can be a real option for the growth, expansion, to wait. Aruzhan S. et al. suggested using the variable of patent applications as one of the possible indictors of R&D. The idea is either to measure the change of patent applications amount from one year to another or to measure the relation of patent applications per full-time employed in the company researchers. The study on these variables was done for the two industries: biotechnology and information technology.

[5] GAAP - accounting standards adopted by the U.S. Securities and Exchange Commission

However, with the application of only patent variable some specific problems might arise. Firstly, to each industry and sector the patent production timing vary a lot. Secondly, the life of the patent also may vary, and some patents may be useful and reflect R&D for several years, while others will expand in 1 year. What is more, an invention can be produced and registered in two different years or can be produced and not registered at all. This was illustrated by the research of biopharmaceutical industry in the USA, where each company has to do a great procedure of researching, producing, testing, development, approval and registration of a drug, and each patent has its own timing frames, validity and etc. (Li & Rizzo, 2020). Finally, for some products or services several patents are needed to be done, according to the legal prescriptions, the question is how to estimate then such patents: as one for the one good or as several. This problem was studied as the aspect of «patent pool» for the organization by Leveque F. and Maniere Y. with the conclusion on the importance of treating all the patents together, since the lack of one may result in losing competitive advantage (Leveque & Maniere , 2011). The aspect of evaluation of the patent is also under consideration, since it both can be cost method or NPV.

2) Market Value change

Market Value of the firm is the estimation of the price of company's assets from the stakeholders outside, based on the information available and expectancies. Firm's current and future performance is the basis for the market participants to evaluate the company, and Research and Development plays an important role in stating the company's position. The significant impact of R&D expenditures on the market value was studied by VanderPal G. in the research of the companies from different industries (VanderPal, 2019). The analysis done have shown that R&D investments have the greater impact on market. To R&D importance appeal Lee N. (2019) in the study of the effect of R&D on the market value of the companies from more than 10 industries worldwide (Agriculture, Manufacturing, Electricity, Construction, Retail, Transport, Lodging, Communication, Information, Real Estate, Biotech and others) that are listed on Korean Stock Exchange. (Lee N. , 2019). The findings supported hypothesis of positive and negative impact on market value depending on value of R&D, for the biotech firms that were also case-analyzed, the impact is higher, so this could be the indicator of industrial specificity. The same results shown Hai B. et al. in their research of impact of R&D expenditures on the market value among manufacturing firms listed in Shanghai and Shenzhen stock markets with the regression analysis (Hai, Gao, Yin, & Chen, 2020). The study done have shown a strong both positive and negative impact (depending on increase or decrease of R&D) of R&D expenditures on the market value of the company.

There is no doubt that Research and Development plays a significant role in the company's performance and competitiveness. What is more, to some industries it might me crucial for survival. However, market value appear to be the value, that is combined from the more than one factor, even in the studies, mentioned above, there were several factors in each model, that were considered statistically significant. Moreover, Lee J. et al. in their research of the determinants of market value, pointed out, that, though R&D reporting and investments tend to play a great role, investors pay more attention to the operational indicators, since they show how effectively a firm can manage its assets and results of R&D (Lee, Kwon, & Pati, 2019).

3) R&D Elasticity

Elasticity refers to the measurement of the change of one variable as the consequence of another's parameter change; the measurement is usually described in percent. The idea of using elasticity as the possible indicator of Research and Development expenditures was introduces by Coluccia D. et al.in the research of treating R&D elasticity as the positive sign for the market (Coluccia, Dabić, Del Giudice, Fontana, & Solimene, 2020). The authors did the research for the companies listed on Euronext100 index applying the regression analysis with the identification of R&D elasticity with the value driven from the regression-model as beta-coefficient for the R&D expenditures:

$$Ln(Sales) = \beta_0 + \beta_1 + (\beta_1 + \beta_{1i}) \times Ln(Property\ investments_{1t}) + (\beta_2 + \beta_{2i}) \times Ln(Employment\ costs_{it})) + (\beta_2 + \beta_{2i}) \times Ln(R\&D\ Expenditures_{it-1}) \quad (8)$$

According to the statistics, the as beta-coefficient reflects the percentage of change of Sales if the value of R&D expenditures will change by 1%. The authors determined that the R&D elasticity makes an impact on the investment behavior and firm behavior (represented by the Tobin's Q coefficient). The argumentation on the application of such indicator was that the relative parameter is more descriptive from the investment perspective, since it describes the return on the invested unit, and does not simply show a certain amount spent.

R&D Elasticity coefficient appears to be the good example of illustrating the idea of the Real Option approach in the research and development, however, the model could not correct due to the cyclical effect of the formula. It could be a useful tool for the case-analysis and deep study of the company, but is not applicable to the industrial study.

Although, the reported indicators of R&D are quite specific and the description about them could be found in the company's reports, they reflect the company's valuation of the parameter and according to the accounting and taxation policies. To avoid subjective part, some of the non-balanced indicators were studied in order to identify, whether they could be more objective in treating R&D as the real option. The summary on them is provided in the Table 4.

Table 4. Indicators of R&D in the organization[6]

Indicator	Description	Limitations
Accounting indicators		
Operating profit	Operation profit reflects the idea of investing equivalent amount of money into the project of R&D	Operation profit might be negative for some companies; Considered as the non-effective source of finance (studying the cost and alternatives)
Capital Expenditures	Capital Expenditures could possibly describe the amount of money, invested into the R&D and treated as the capital expense, according to the reporting standards	Broad expense, that includes more costs, except R&D expenditures
Fixed Assets	Fixed Assets can be viewed and an illustration of how good the process of researching, development and	Include assets, that are not connected with the R&D activities, and, depending on the industry, may not be an

[6] Source: done by the author based on the literature review analysis

Indicator	Description	Limitations
	implementation was done in the company (i.e. result of R&D)	example of such activity
Intangible Assets	Intangible Assets could also reflect the result of R&D investment, since most of the outcomes of researching activity are then registered as patents, for example	Broad definition of assets, that are the results of R&D – some of the intangibles are acquired, bought or connected with the other activities of the organization
Non-Accounting indicators		
Patent data	The results of Research and Development activity are often registered as patent to safe the exclusive right on the finding made	Reporting issues, connected with the timing as well as existence of complementary patents
Market Value change	Reflects the investors' attitude towards the company's R&D activity as the option	Market Value is a complicated indicator, to which R&D plays a role, but among other parameters
R&D elasticity	Elasticity describes the return on the invested unit of research and development	Mostly case-based parameter

Source: done by the author based on literature review

According to the study of the reported and non-balanced parameters done, the most perspective indicators of the R&D expenditures for the model are the Capital expenditures and

Market Value Change, since they are applicable to the industrial study, reflect industrial specificities, describe the possible outcome of the investment into R&D and are available for the broader audience.

CHAPTER 1 SUMMARY

In the first chapter the introduction to the methods of assessment of different firm projects is done. Among them are the Net Present Value, Adjusted Present Value, Liquidation price, Market Valuation, Market Comparison, Acquisition price and Real Option. The method of Real Options is discussed, which is more appropriate to use, when there is high risk and high level of uncertainty. Research and Development as the Real Option allows company become and stay competitive, increasing revenues and firm value in the ongoing years.

For the assessment of the R&D as the Real Option researches apply several methods from the single period model and compound option. Most of the models suggested, unfortunately, could only be applied to the concrete cases or specific industries, which is not applicable to the most cases. That is why, the most general way to assess was chosen as the most unified one.

For the value of the investment into the R&D several accounting and non- accounting indicators are considered, assessing them on the criteria of the information availability, unity of the cases and research application. Among them the most appropriate ones for the model were defined as Capital Expenditures and Market Value Change, however, Market Value change was identified as more subjective and broad one.

CHAPTER 2. THEORETICAL IMPLEMENTATION

2.1. THE MODEL FOR INDUSTRIAL R&D

The second chapter of this paper will be focused on the model development of the estimation of R&D expenditures. Since the goal of this research is to propose the model for the assessment of industrial R&D expenditures via the application of Real Options, the model suggested further will be more unified for the industries rather than specified for the concrete cases. The model will be based on the one-period model as it was described in Chapter 1.

Since the R&D provides the competitive opportunity and creates value for the shareholders, it will be treated as the option for growth for the company rather than the sunk costs. For the single period, company's value can either grow or decline with the following probabilities (Hull, 2015):

$$p_{up} = \frac{e^{r*T} - d}{u - d} \quad (9)$$

$$p_{down} = 1 - p_{up} \quad (10)$$

where p_{up} – risk-neutral probability of growth, p_{down} – risk-neutral probability of value going down, r –risk-free rate, T – time period, *u* – factor of increase of value, *d* – factor of decrease in value.

The u and d factors are estimated as follows:

$$u = e^{\sigma*\sqrt{T}} \quad (11)$$

$$d = \frac{1}{e^{\sigma*\sqrt{T}}} \quad (12)$$

where e – constant, natural number, r – sum of risk-free rate and 1, σ – variance, T – time period.

By combining formulas (11) and (12) with (9), the risk-neutral probability of growth is:

$$p_{up} = \frac{e^{r*T} - e^{-\sigma*\sqrt{T}}}{e^{\sigma*\sqrt{T}} - e^{-\sigma*\sqrt{T}}} \quad (13)$$

The value of the R&D is based on the possible value of invested amount:

$$\text{R\&D} = Inv * \left(e^{\sigma*\sqrt{T}} - 1\right) \ (14)$$

According to the research done in Chapter 1, for the indicator of the amount of money spent the Capital Expenditures are taken. The Capital Expenditures are the measure of the actual outcome of the investment, so when the value is going up within the time period:

$$CapEx = \frac{Inv * p_{up}}{\bar{T}} \ (15)$$

The value of the Research and Development is estimated as the sum of the outcomes of R&D – its value if the project is successful and 0 if not:

$$\text{R\&D}_{exp} = p_{up} * R\&D + \ p_{down} * 0 \ \ (16)$$

The value of the Research and Development in the moment t=0 is:

$$\text{R\&D}_0 = e^{-r*T} \ * \left(p_{up} * R\&D + \ p_{down} * 0\right) = \text{R\&D}_{exp} * e^{-r*T} \ (17)$$

or

$$\text{R\&D}_0 = R\&D_{industrial} * \bar{T} \ \ (18)$$

Combining the formulas (13) - (18):

$$R\&D_{industrial} = \frac{e^{r*T} - e^{-\sigma*\sqrt{T}}}{e^{\sigma*\sqrt{T}} - e^{-\sigma*\sqrt{T}}} * CapEx * e^{-r*T} \ * \left(e^{\sigma*\sqrt{T}} - 1\right) * \frac{e^{\sigma*\sqrt{T}} - e^{-\sigma*\sqrt{T}}}{e^{r*T} - e^{-\sigma*\sqrt{T}}} \ \ (19)$$

The final model for the assessment of the industrial R&D expenditures present as follows:

$$R\&D_{an;ind} = CapEx_{an;ind}\left(e^{\bar{\sigma}\sqrt{T}} - 1\right)e^{-r\bar{T}} \quad (20)$$

where $R\&D_{an;ind}$ – annual R&D expenditures in the industry, $CapEx_{an;ind}$ – annual Capital Expenditures of all companies in the industry, T – period, r – risk-free rate, taken as real for each company, $\bar{T}$ – average length of the R&D project, $\bar{\sigma}$ – average standard deviation of value of companies in the industry, calculated as on the base of real standard deviation of each company.

2.2. DATA

The collected data was for the 2145 companies globally, the statistics collected was for the 2019. For the industries were chosen only industries, to which Research and Development is crucial and constant in terms of investments. The databases used are Thomson Reuters Database and European Commission Database. The amount of industries is 25:

- Aerospace and defense (38 companies)
- Automobile parts (106 companies)
- Chemicals (82 companies)
- Construction and materials (46 companies)
- Electricity (23 companies)
- Electronic and electrical equipment (227 companies)
- Fixed Line Telecommunications (15 companies)
- Food producers (51 companies)
- Gas, water and multiutilities (13 companies)
- General industrials (82 companies)
- General retailers (10 companies)
- Health Care Equipment and services (86 companies)
- Household goods and home construction (44 companies)
- Industrial engineering (187 companies)
- Industrial metals and mining (51 companies)
- Leisure goods (42 companies)
- Media (19 companies)
- Mobile Telecommunications (13 companies)
- Oil and gas producers (25 companies)
- Personal goods (47 companies)

- Pharmaceuticals and biotechnology (392 companies)
- Software and computer services (255 companies)
- Support services (28 companies)
- Technology hardware and equipment (243 companies)
- Travel and leisure (20 companies)

Companies in the sample are different size, location and geographical coverage. The main countries companies were present are United States, China, Japan, United Kingdom, Germany and South Korea. The distribution for the mentioned countries is present on the Figure 5. The list of the all countries in the sample with the risk-free rates is presented in the Appendix (Appendix 1).

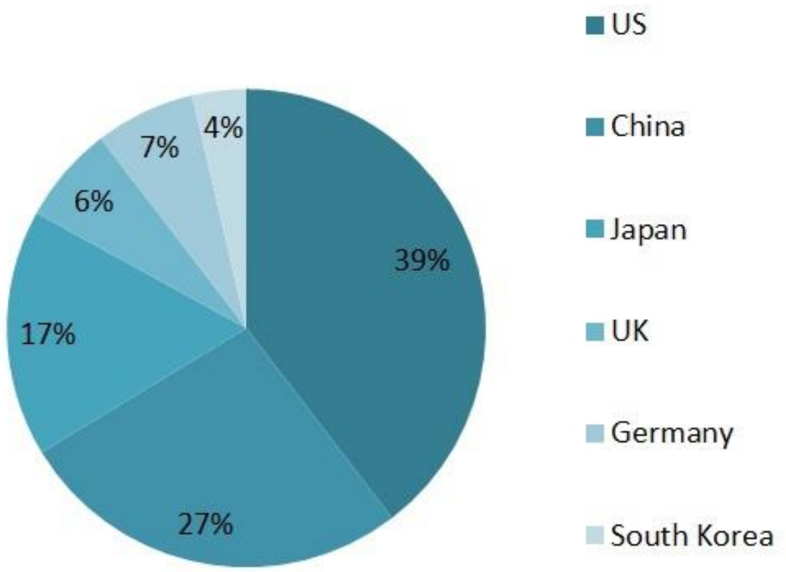


Figure 5. *Main countries in the sample*[7]

The criteria for the companies chosen were:

1) They have to be R&D intensive, the intensity was estimated by the formula (21):

$$R\&D\ Intensity = \frac{R\&D\ expenditures}{Revenue} \quad (21)$$

The company was considered to be not intensive, if its intensity was less that average industrial intensity by 25%

[7] Source: done by the author

2) Their shares are tradable, there is statistics for the year 2019
3) They have bonds allocated, there is statistics for the year 2019
4) R&D has a continuous presence in these companies

The summary on the industrial statistics is presented below in the Table 5, the data is for the year 2019.

Table 5. Industrial data

Industry	**R&D intensity**	$\bar{\sigma}$
Aerospace and defense	4%	31%
Automobile parts	4,5%	25%
Chemicals	2,1%	27%
Construction and materials	1,7%	20%
Electricity	1.5%	27%
Electronic and electrical equipment	4.7%	35%
Fixed Line Telecommunications	3%	41%
Food producers	3.6%	39%
Gas, water and multiutilities	1.21%	26%
General industrials	3.9%	52%
General retailers	8.1%	24%
Health Care Equipment and services	19.6%	34%
Household goods and home construction	3.4%	44%
Industrial engineering	3.8%	39%
Industrial metals and mining	2%	52%
Leisure goods	8%	38%

Industry	R&D intensity	$\bar{\sigma}$
Media	10%	44%
Mobile Telecommunications	14.2%	24%
Oil and gas producers	2.3%	33%
Personal goods	3.2%	28%
Pharmaceuticals and biotechnology	52.7%	57%
Software and computer services	28.8%	34%
Support services	6.8%	38%
Technology hardware and equipment	24%	32%
Travel and leisure	7.7%	30%

Source: Computed by the author based on the data from Thomson Reuters Database and European Commission

The standard deviation was derived from the equation (formula 22):

$$\sqrt{\sigma^2} = \sigma_E^2 \times \frac{E^2}{V^2} + \sigma_D^2 \times \frac{D^2}{V^2} + 2\sigma_E^2\sigma_D^2 \frac{E}{V}\frac{D}{V}\rho_{E,D} \qquad (22)$$

where σ^2 – standard deviation, σ_E^2 - equity's standard deviation, E – equity value, D – debt value, V – company's value (sum of equity and debt), σ_D^2 – debt's standard deviation, $\rho_{E,D}$ – correlation between equity and debt (correlation between stocks and bonds).

The standard deviation of equity was defined from the volatility of the shares of the company traded for the 2019. The standard deviation of the debt was defined from the volatility of the bonds traded for the 2019. The Equity and Debt value were taken from the company's annual reports from the databases. The correlation between debt and equity was defined from the correlation between stocks and bonds for 2019.

A mandatory clause should be made regarding the selected time period T. Each company from the sample has its own project or R&D projects of different duration and with different conditions (for example, some processes take place in parallel, some are sequential, and some are sequentially parallel), most of the information about project deadlines are not in corporate reports, as well as in other open sources (as an exception, case studies for specific projects). In view of this limitation, within the framework of this research work, the assumption is made that T can be equated to 1 since there is lack of statistics on the duration of the particular R&D project for the each company. Such proof can be considered from the point of view of the irrecoverable investment - from the moment of investment and the launch of an R&D project, the funds spent cannot be returned and invested in other projects.

2.3. EMPIRICAL VALIDATION

To empirically test the model (20), the data from 25 industries in 2019 was applied, 2145 companies consisted of companies from different countries and regions, both developed and developing. For the indicator of the model was taken the measure of industrial R&D intensity compared to the industrial R&D intensity, calculated by the model.

R&D intensity reflects the share of investments in Research and Development in the Sales (Revenue). Figure 6 demonstrates the result of comparison of the real (vertical axis) and modelled (horizontal axis) R&D Intensity. The real R&D intensity was taken from the Thomson Reuters Database; the modelled values were calculated from the value of R&D suggested by the Model (20). Each dot on the graph represents one of the 25 industries, taken for the analysis. The slope of the graph is 1.32, coefficient of determination is 0.8889. The results show that the model suggested is appropriate for the valuation and explanation of the industrial values of Research and Development.

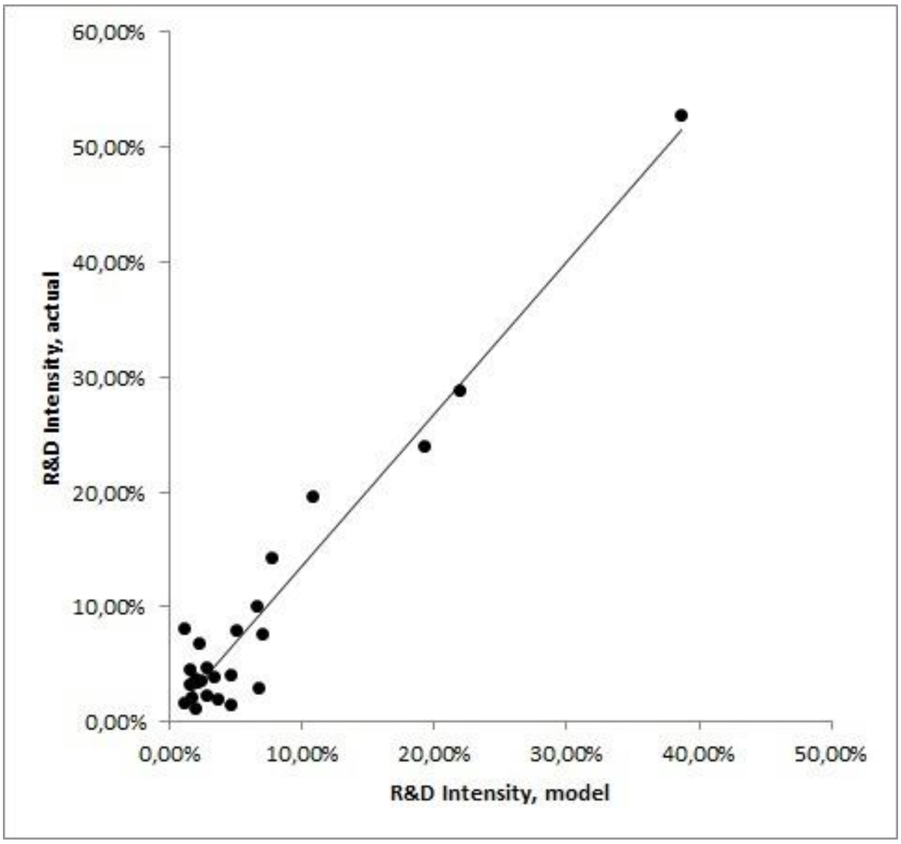


Figure 6. *Comparison of real and modelled values of R&D intensity*

Industries with the minimum difference in the real and modelled values of R&D Intensity were:

- Aerospace and defense;
- General industrials;
- Travel and leisure;
- Construction and materials.

Industries with the maximum difference in the real and modelled values of R&D Intensity were:

- General retailers;
- Pharmaceuticals and biotechnology;
- Healthcare Equipment and Services.

The difference in the values for the listed industries may be connected with the chosen for the calculation time period as 1, it vary from industry to industry and for the healthcare, pharmaceutical and hardware takes longer, from 5 to 7 years (Ker, 2013). What is more, the value of Capital Expenditures, used as the description of the investment into R&D (meaning

R&D facilities and pipelines) could be not an illustrative example for some of the industries, where the most attention is paid to the intangible assets. Because of that it is worthy to suggest the specific models based on the industrial model. In order to test this, the deep analysis on the companies form some of the industries was conducted, for the pharmaceuticals and for the technology.

Pharmaceuticals

Pharmaceutical industry consists of development and production, distribution of drugs for the different therapy areas, for the 2019 it had a value of $1,057.5 billion (MarketLine, 2019). On the pharmaceutical market there are several main players: Johnson & Johnson, Pfizer, Novo Nordisk, Bayer and Novartis, the competition is strong and there are high barriers for new entrants. The leading player for 2019 was Johnson & Johnson and the greatest market was for the USA (ibid.).

Since the competition is strong, pharmaceutical companies invest significant amount in Research and Development, this supports the innovation and leading status on the market. Because of the product specificity (long development and testing process), the timing for the R&D development is crucial for the market players. What is more, the uncertainty of the R&D outcomes and value is high, at the same time costs are great for the company. The outcomes of R&D activities are secured in the form of patents.

For the pharmaceutical companies, the vaccine or drug development procedure lasts for several years and includes several stages (How Are Vaccines Developed?, 2019):

1) Exploratory research: includes both research and testing, has the average duration from 2 to 5 years, depending on the complexity of antigens;

2) Preclinical analysis: includes toxicology, formulation, and development of the process, has the average duration around 2 years of collecting and analyzing data;

3) Clinical analysis: conducted on humans and includes three stages:

Stage 1. Testing on around 100 volunteers to identify the safeness of vaccine and immune response, has the duration of 2 years;

Stage 2. Testing on the larger amount of volunteers, has the average duration from 2 to 3 years;

Stage 3. Testing on thousands of people, conducted randomized and placebo-controlled volunteers, has the average duration from 5 to 10 years.

4) Legal review and approval: for the USA, the vaccine has to have approval from the Food and Drug Administration (FDA), the duration could take up to 2 years;

5) Production: includes manufacturing and distribution, the timing is drug-specific;

6) Quality control.

For some of the stages listed above company has less impact on timing, that is why first two stages, connected with Research and Development are crucial for the competitiveness and success of the vaccine or drug on the market, that is why most of the companies, operating on the pharmaceutical market, have several R&D platforms for the parallel development of several projects and managing in different spheres. What is more, the two stages could be final for the company, since the project could fail at any step, and at the same time costs would still appear. According to the research of (Banerjee A. , 2003), the success percentage of the studies in the drug or vaccine creation is close to 0,01%. The R&D financing could be considered highly risky and uncertain and at the same time, necessary for the consideration.

Usually, the result of investing in the R&D of the particular drug or vaccine is visible only after 12 years or even more. In this point of view, the 2020 and COVID-19 appeared to be the exclusion from all of the standard procedures. Since the 2020 was mostly classified in the pharmaceutical sector by the vaccine from COVID-19 development, within this research the case of vaccine will also be considered. An important remark is that for the purposes of the research the side effects of vaccines would not be considered, by the vaccine will be considered the one having all necessary approvals from Health Institutes (like World Health Organization or Domestic Health Institutions). The leaders in terms of timing and regional coverage the leader companies are Pfizer, Moderna, AstraZeneca and Johnson and Johnson (Landscape, 2021) and based on the experts forecasts these mentioned companies are expected to supply the largest amount of doses (Buntz, 2021). The sources of financing the R&D expenditures on the vaccine development are presented in the Appendix (Appendix

Pfizer published the report on the vaccine development for the emergency case: COVID-19. The U.S. Food and Drug Administration (FDA) have not licensed the produced by Pfizer vaccine in the official way, the authorization was done based on the Emergency Use Authorization (EUA). That is why the phases, which usually require up to 5 years, were done in several months (About Our Landmark Trial , 2021): approximately 12 months, which could be taken as T in this case as 1 year in the Model. Taking into account the Research and Development, the increase in value by $1 billion compared to 2019 was connected with additional spending on the vaccine development (Form 10-K, 2020), total R&D cost accounted for $ 9 405 mln. The R&D intensity of Pfizer for 2020, according to Annual Report, is 21.2%, the real industrial level of R&D intensity is 14.35% (Mikulic M. , 2020). As we can see, the industrial level of intensity is nearly 1.5 times lower than the level of investing in R&D at Pfizer. This is one of the most important aspects why Pfizer was faster in terms of researching and producing the vaccine.

Pfizer is considered to be the leading vaccine (Zimmer, Corum, & Wee, 2021). The value change on the market for Pfizer is illustrated on the Figure 7. As we can see, the value started increasing from April 2020, when Pfizer announced the results of the vaccine second stage testing with the positive effect of 91%. In the June the decrease by 14% happened, however, not connected with the vaccine development, but with the failure on R&D of the breast cancer drug (Orelli, 2020). In the July 2020 we can observe price increase due to the positive news on the vaccine: agreement with the USA government on the vaccine placement (Pfizer and BioNTech Announce an Agreement with U.S. Government for up to 600 Million Doses of mRNA-based Vaccine Candidate Against SARS-CoV-2, 2020). On the 22nd of November the U.S. Food and Drug Administration accepted the Emergency Use Authorization for the Pfizer vaccine (Pfizer-BioNTech COVID-19 Vaccine, 2020), which was announced on the 11th of December with the positive market reaction on the result of the Research and Development of Pfizer. The new decrease of the price happened in March as the reaction in the announcement of the results of the effectiveness of Pfizer and Moderna vaccines for people over 65: prices for both companies decreased, but then recovered with the issuance of the clarifications of the study, which actually showed 94% of effectiveness (Effectiveness of Pfizer-BioNTech and Moderna Vaccines Against COVID-19 Among Hospitalized Adults Aged ≥65 Years — United States, January–March 2021, 2021). Due to the fast research, development and introduction to the market, Pfizer increased the revenue by 45% and also increased the expected sales for the 2021 by 70% (Pfizer’s Covid vaccine revenues hit $3.5bn in first quarter, 2021).

Figure 7. *Pfizer price change, 2020-July 2021*[8]

More illustrative example of the option of investing in Research and Development is the company BioNTech (German biopharmaceutical company, founded 2008 and went IPO 2019), which joined Pfizer in the vaccine development. For such a new company on the market in the beginning of the 2019, BioNTech got the great increase in the value due to the positive investors' reaction on the result of R&D (Figure 8). The effect of the R&D COVID-19 vaccine for the BioNTech turned out to be the value growth by 156%.

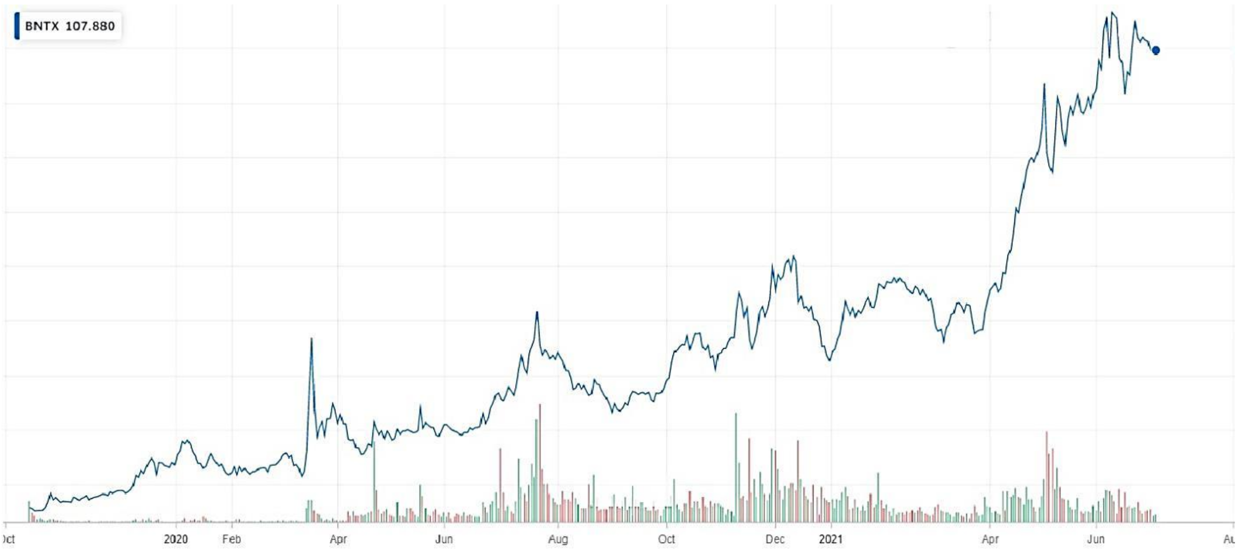


Figure 8. *BioNTech price change, 2020-July 2021*[9]

[8] (Pfizer Inc. (PFE), 2021)
[9] (BioNTech SE (BNTX), 2021)

Not only Pfizer or BioNTech invested into the R&D of vaccine, many companies joined the COVID-19 vaccine market. On the 24th of June there are 18 approved vaccines (globally, like Moderna or Pfizer, or regionally, like Sputnik V) and 86 vaccines are on different stages of the development or testing (COVID-19 vaccine tracker, 2021). This is the chance for any company to reach the greatest market value and see the results of investing in R&D in relatively short-term period (1-2 years compared to 17-20 years). The most widely known and spread ones are the vaccines produced by Pfizer&BioNTech, Moderna, Johnson & Johnson, AstraZeneca, Sinovac, Gamaleya Institute, CureVac and Novavax (Ibid.). The vaccine producers increased their value for the period 2020-2021 (Figure 9). The dark blue line is the Pfizer, while blue reflects to the Moderna, purple to Johnson & Johnson, pink to AstraZeneca, yellow to Novavax and green is CureVac. As we can see, the most dramatic change in price was for the Novavax (by more than 1120%), which CEO Stan Erck claimed about the increase of expected revenue by several $ bln. (Novavax, Inc. (NVAX) CEO Stan Erck on Q4 2020 Results - Earnings Call Transcript, 2021). The first significant value increase appeared in the July of 2020, when US government announced the purchase of Novavax's vaccine (Thomas, 2020), the growth was supported by the UK purchase of vaccine (Novavax to Deliver 60 Million Doses of COVID-19 Vaccine Candidate to UK, 2020). Novavax is another great example of how a not well-known company can boost the value by entering the real option as R&D (option to grow). The peak of the value happened with the announcement of the strong immune response and the efficiency of vaccine (Kotz, 2021). However, with the news on the new COVID mutation in the end of February declined the investors' trust in vaccine and their producers. Company supported the recovery with new studies on the efficiency, but in the April the value dropped again due to the pause in negotiations of the vaccine Amount with UK government (Parliamentary questions, 2021). The ongoing processes on vaccine delivery supported the value growth.

The example of risky R&D investment even for the big market player is AstraZeneca case with the vaccine. The company did great job in terms of timing of the production, but at the same time it appeared, that the quality of the vaccine is lower compared to the other producers, since the vaccine has strong and dangerous side effects, it was prohibited in some countries and defined as the emergency use vaccine in others (AstraZeneca's COVID-19 vaccine: EMA finds possible link to very rare cases of unusual blood clots with low blood platelets, 2021). The value of the company on the market went down by 9% compared to the growth of competitors. Nevertheless, the company still has sales and revenue and is recovering with new researches in vaccine.

Figure 9. *Main vaccine developers price change*[10]

In general, the amount of the inverting into vaccine Research and Development and its effect on the value of the company are described in the Table 6. The detailed structure on the type of financing per each company is presented on the Appendix (Appendix 3). As we can see from the Table, investing in the Research and Development of the vaccine supported the growth of the company's value growth in general. The investment was especially successful for the small companies, which would in normal conditions grow for the longer period, since the result of the R&D in pharmaceutical industry could took up to 20 years. Novavax is even the pioneer, who grew dramatically investing less than the market leaders, but effectively, also operating marketing and sales.

[10] (Comparison to Pfizer Inc., 2021)

Table 6. Vaccine development R&D spending and company value change

Company's name	Amount invested	Value change
Pfizer & BioNTech	$ 11 347 mln	Pfizer + 11% BioNTech +156%
Moderna	$ 3 118 mln	+370%
AstraZeneca	$ 2 632 mln	-9%
Novavax	$ 2 480 mln	+1130%
Johnson&Johnson	$ 1 089 mln	+8%

Source: calculated by the author, based on the information from open sources and (Covid vaccines: Will drug companies make bumper profits?, 2020)

Pfizer or Moderna are great examples of the strong R&D investing policy, which supports the leadership in the industry from year to year. They could allow themselves to diversify portfolio of vaccines and invest even more, than budgeted. Companies have strong sales and market share; however, this is not the case for many players on the pharmaceutical market: there are more than 4800 companies worldwide, specializing on the pharmaceuticals (Mikulic M., Pharmaceutical research and development (R&D) – statistics & facts, 2020), which compete or group against each other to successfully make returns on the projects. R&D spending is large for the pharmaceutical sector, the leaders of the industry could afford it, but small and medium companies usually have limited budget and amount for the investment. For them, the aspect of Research and Development is crucial and at the same time the return on investment could be even smaller that the inflation rate (Mikulic M. , Percentage return on investments in research and development among mid cap biopharma companies from 2013 to 2020, 2021). The overview on the returns on investment in R&D is provided in the Appendix (Appendix 4). For them, the model of the assessment of the R&D expenditures could be the useful tool for planning and budgeting. For example, Intech Pharma, Biopharmaceutical Company, headquartered in Israel, could apply the model to estimate the industrial value of investment and compare it to the budgeted one. According to the Annual report, the R&D process for Intech Pharma is extremely important due to the support of the competitiveness on the global markets and at the same time extremely risky (ANNUAL REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE SECURITIES EXCHANGE ACT OF 1, 2019, p. 18). For 2019 company had net accounting loss due to the intensive investment into research and development, the expenses on the research activities reached $26,7 mln. Applying the model to estimate the industrial level of investment for the 2019, the management would see, that the intensity is much stronger for the industry than for the company, which leads to the weak positions on the market. Since Intech Pharma is financed both governmentally and publicly, they could approach more external investment to keep the company competitive until the results of R&D. The same suggestion on the investing into R&D could be applied to the Immunomedics Inc., American biotechnological company. Their R&D expenses are several times higher than for the Intech Pharma, however, still not intense enough to the market average (Immunomedics Inc (IMMU) SEC Filing 10-K Annual report, 2019). For the 2019 company has initiated several projects as well as proceeded with the ongoing ones, entering new stages of trial and also one FDA approval, aiming at the goal of becoming the strong leader in the market of the USA. In order to achieve the goal set, Immunomedics has to have greater portfolio of drugs rather than it had, which could be done via the enlargement of the R&D closer to the industrial level in the ongoing years, starting with the attracting investments.

Electronic and electrical equipment

Electronic and electrical equipment industry consists of manufacture of electronic supplies and equipment to distribute and use power, like processors, batteries, transistors, motors and etc. The market value for 2020 encountered $1453.67 billion (MarketLine Industry Profile Global Electronic & Electrical Components & Equipment, 2020). The main players on the market are Toshiba Corp., Intel Corp., Schneider Electric SE, Siemens AG, Toshiba Energy Systems and Solutions Corp., Panasonic, Sony Corp., Whirlpool Corp., HP Inc., Apple Inc. and ABB Ltd. (Global Electrical Equipment Market Development Strategy Pre and Post COVID-19, 2021), (Global Electronics Manufacturing Services for Consumer Electronic Market, 2021).

The competitive landscape is strong for the both electrical and electronical equipment markets, main players compete in terms of timing of product development, production and market launch, product quality and characteristics, brand strength and complementary products (MarketLine Industry Profile Global Electronic & Electrical Components & Equipment, 2020). Research and Development is the basis for the mentioned characteristics of competitiveness in terms of both timing and launch – for example, Intel set the strategic priority to remain the leading company via the increase of investing in R&D (Intel Corporation 10-K, 2019) – the R&D spending is increasing from year to year, supporting Intel’s performance (Fig 6.).

Investment in R&D supported the capacity and sales increase of Intel (ibid.) via the improvement of the products and user experience with them.

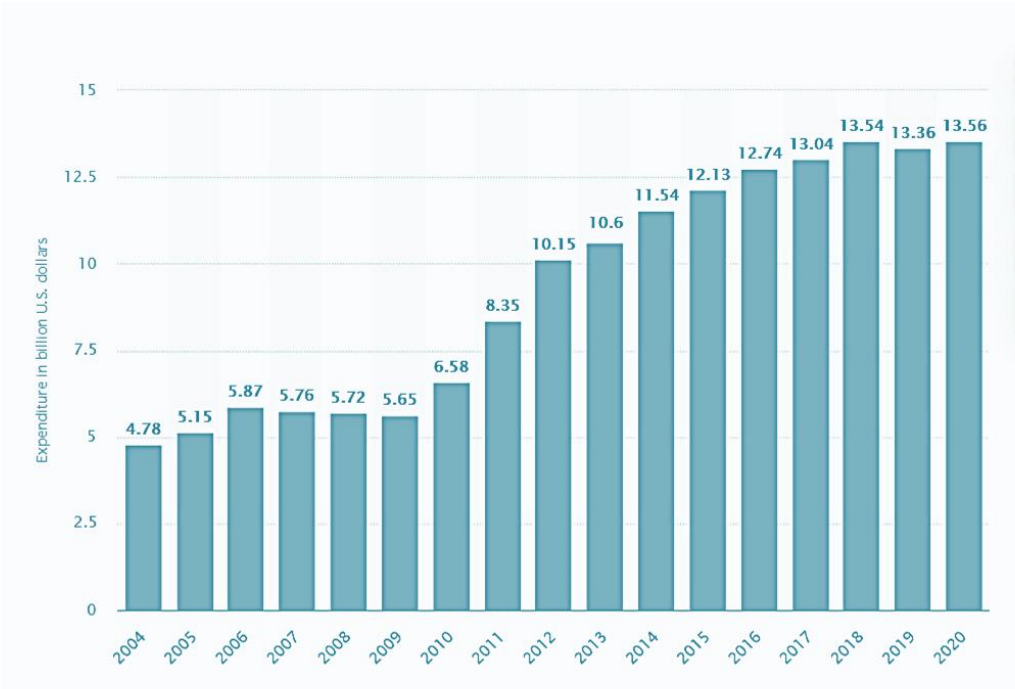


Figure 10.*R&D spending of Intel, in billion U.S. dollars (Intel's expenditure on research and development from 2004 to 2020 , 2020)*

The investment in R&D at Intel is done in all stages of the product development - manufacturing processes, product design, memory and storage, interconnect solutions, security technologies and software (Intel Corporation 10-K, 2019). Intel's Director of Engineering, M. Renduchintala stated that R&D investing, when managed wise, can significantly improve the profitability of the company (Sole). Speaking about the type of R&D investment, Director of Engineering mentioned new processors of Intel, which are costly in R&D expenses, but allow clients lower their expenses and costs being at the same time qualitative, and that's why they are being sold by Intel worldwide. If we will study the production process and introduction of the new products to the market, we can preliminary evaluate the timing of one R&D process. Let's take as an example the processor, which is under development at Intel currently and before and appears as one of the main products. As an assumption, we can assume that Intel will not start developing a new processor until the development of an existing one is completed - thus the process is carried out sequentially, and not in parallel. In general, the speed of development and implementation of the processor has increased compared to the last century - but not significantly. Previously, the process took 3-4 years on average, now it takes 1-2 years on average (Intel Processors Over the Years, 2018) (Microprocessors quick reference guide, 2008). Same timing approaches for the other leader among processors producers – Broadcom (Dubey, 2020) – for the processors of this company the R&D processes could be even conducted in one year for some processors (2020 Annual Report on Form 10-K, 2020), for some processors development and implementation takes 1-1,5 years (Embedded and Networking Processors, 2021). The two companies are competing in the terms of quality, appliance of processors and timing. The R&D intensity of Broadcom is 28.7% for 2020 (2020 Annual Report on Form 10-K, 2020), however for Intel they took only 17% (Intel Corporation 10-K, 2020). The average industrial R&D Intensity for 2020 is 15.1%, which is less that both Intel's and Broadcom's value, because of that companies could allow themselves to compete on the variety and costs. However, for one more market player, which produces processors, Razer Inc. (American technological company), the R&D intensity reaches only 6.4% in 2019 (Annual Report 2019, 2019). At the same time, Razer Inc. has available funds or could attract them on the market – the management could have budgeted a greater amount for the investment into Research and Development. To do so, they could apply the model suggested, to estimate average market value of investing into R&D and then compare to the existing plans on the development of the products to identify the potential to grow.

CHAPTER 2 SUMMARY

In the second chapter of the thesis the model for the assessment of the industrial R&D expenditures was introduced. The model was based on the theory of the Real Options, treating the R&D spending as the option to grow (option to expand), for the industrial level the one-period model was considered. As the investment value, the value of Capital Expenditures was taken.

The model was illustrated on the 25 industries and 2145 companies globally for the year 2019. The industries with the minimum difference in the real and modelled values of R&D Intensity were: Aerospace and defense; General industrials; Travel and leisure; Construction and materials.

The industries with the greatest difference for the real and modelled values of R&D Intensity were: General retailers; Pharmaceuticals and biotechnology; Healthcare Equipment and Services. The difference could be explained by several reasons; among them are the timing (which is crucial for some industries, for example) of the R&D and industrial specificity of Capital Expenditures.

The model was applied to two industries to illustrate how the management could approach the budgeting using the industrial average as the basis. The industries studied were pharmaceuticals and electronic and electrical equipment. For the pharmaceutical industry the recent situation with the COVID-19 vaccine development was considered and the impact of the R&D into vaccine development on the value of the company was illustrated. For the electronic and electrical equipment the case of processors development and its impact on the value was illustrated. The criterion for choosing industries was connected with the availability of data on the timing of Research and Development and main processes of it.

CONCLUSION

The research aim is suggesting the model for the assessment of industrial R&D expenditures via the application of Real Options. The model might be applicable by the investors and financial managers in order to estimate the value of R&D as a real option. This will be beneficial due to the existence of the flexibility of the decision. What is more, the model can be used as the indicator for the researcher to identify whether the investments into R&D are sufficient or over-/under- invested. The research conducted shown that for the case of Real Options the Real Options method of evaluation could be applied, since investing in R&D gives the company right to acquire assets for the competitiveness in the future (for example, patents). Because of the uncertainty about the outcome of the R&D expenditures, companies apply the method on several stages, treating R&D as the option to grow or to abandon. For the assessment it is possible to apply the approach of the single period model, the model of compound option or the simulation of the outcomes of R&D. All methods are useful and applied in different situations, depending on the aim of the evaluation and availability of information. The model suggested within this paper is applied to the cases of the assessment of the industrial level of R&D expenditures, when an overview on the competitiveness within the industry is needed and there is no internal information.

In the first chapter of this research the questions of Real Options method and its application were considered. The real options method is one among different possible ways of the assessment of the project and it is more applicable to the Research and Development, since it allows taking into account uncertainty and high risk. The models suggested by different studies included: one period model, the compound option model. All the models considered are applicable to the cases of concrete companies or industries, since they require additional information, so in this paper the attention was paid to the unity of the model to all industries.

The second chapter of this research described the industrial model for the assessment of the R&D expenditures, which is done applying Real Options theory. As the Real Option to grow the R&D was considered, for the investment amount the amount of Capital Expenditures was taken, since it reflect the result or assets acquired after R&D. For the model testing the study on the real data from 25 industries was done. The studies show that the model is applicable for the assessment of the industrial value of R&D.

Managerial application

The research gives an opportunity to assess the expenditures into R&D on the industrial level. The model built could be used in several ways. Firstly, the model could be applied by the manager to estimate the competitiveness of the company compared to the market players and give an overview whether company should invest more into the R&D activities. Secondly, the model can be applied by the consultants when performing the industrial analysis of the R&D expenditures or of R&D intensity, also to give the client recommendations on the level of investment. Thirdly, the model could be applied by the individual, researcher to identify the industrial differences of the R&D expenditures and identify the cycles in the industries, conduct the study on the market leaders. Finally, the model could be used as the possible decision-making tool, when management does the budgeting: the financial manager could compare the budgeted intensity to the forecasted industrial one to decide, whether they should invest in R&D more.

The possible implementation of this model can be illustrated on the following example, the case study is provided in the second chapter in the part Empirical validation. The company taken for the illustration is Volkswagen – from the industry of Automobiles & Parts. Volkswagen has a stable financial policy to R&D financing and had R&D expenditures for 2019 in amount $13.6 bln[11], filing more than 7.6 thousand patent applications. The R&D intensity, estimated by the company via division of Automotive Division's total research and development costs by Automotive Division's sales revenue, is 6.7%[12]. The R&D intensity for the industry Automobiles & Parts is 4,5%. Comparing these two numbers we can say, that Volkswagen invests more into R&D compared to its competitors' average, which allows the company to win the market share for 2019. This is not the case for one of its main competitors – Daimler AG, which has several times less sales for the studied year with the R&D Intensity of 3.8%. This is not enough for remaining leadership position (also in terms of patents number). Comparing the estimated values of R&D by the model introduces within this research, R&D as the real option for growth, R&D value for Volkswagen is much higher than for the Daimler, since one company takes an advantage of innovation and development, while the other remains on the same level. Applying the model, managers of Daimler AG could forecast the value of the R&D in the industry and compare it to the budgeted one. If the plans on the Research and Development are significantly lower than the market average, managers should think about restructuring investments or acquiring more financing via debt or equity issuance, for example, since the procedure takes time and preparation not only from their side, but also from the third party. Of

[11] Key R&D figures [Electronic source] Volkswagen. URL: https://annualreport2019.volkswagenag.com/group-management-report/sustainable-value-enhancement/research-and-development/key-r-d-figures.html
[12] Ibid.

course, Daimler AG could just take the last year average as the example, but the intensity changes from year to year, so they will be following , but not setting the change. The result received from the model could also be for the managers as the indicator of inefficient investment or internal procedures. For example, the intensity level could appear higher that the average, but at the same time, the competitive position could be weak. This means possibly that either the focus is paid on the wrong research or the quality of the research is low, or the marketing part is not highlighting the best points of R&D.

Limitations

The model suggested is applicable and significant to the industrial level, there are some limitations that could be used as the basis for the further research and model development. First of all, industrial model of R&D expenditures is one-period model – the real R&D life-length varies even inside one company. As it was illustrated by the case of Pharmaceutical industry, the process of R&D could take up to 20 years, and for each industry and company the timeframe will be different. Unfortunately, it's not always possible to identify the specific length of the project, since it's the part of the competitiveness of the organization (how fast they introduce innovation compared to others). However, this limitation is eliminated when managers, knowing the statistics of the industry, directly apply the model.

Secondly, the indicator for investments into R&D could be developed in the specific models to each industry – with the share of debt financing. Also aspects of bond financing or equity issuing could be considered. For example, for the pharmaceutical industry the aspects of governmental grants could be considered instead of only Capital Expenditures.

Thirdly, the indicator of R&D as the Capital Expenditure was measured. Although, it is illustrative and is suggested by the researches (Boer, 2005), (Czarnitzki & Hottenrott, 2011), (Zuoza & Pilinkiene, 2019), the measure does not fully describe the aspect of Research and Development as the Real Option. What is more, Capital Expenditures do not fully reflect the idea of R&D in some industries and more worse for their assessment due to the fact, that the company could not invest a lot in it on the annual basis. To the further studies it is suggested to apply the patent data, which is, though hard to collect, provides more specific illustration of the R&D. The change of Market Value could also be considered as one of the factors of the model, however, requires additional specification or changes.

References

1) 2020 Annual Report on Form 10-K. Retrieved from Broadcom. (2020).

2) About Our Landmark Trial . (2021). Retrieved from Pfizer: https://www.pfizer.com/science/coronavirus/vaccine/about-our-landmark-trial

3) Agudze, K., & Ibhagui, O. (2020). Do fundamentals drive relative valuation? Evidence from global stock market indices. Journal of Financial Managemen, 8(2), 1-42.

4) Ajina, A., Msolli, B., & Saidani, W. (2017, December). Research and Development Investment and Financing Constraints: The Case of Japan. Research in International Business and Finance, 42, pp. 1336-1342.

5) Alam, A., Uddin, M., & Yazdifar, H. (2019). Financing behaviour of R&D investment in the emerging markets: the role of alliance and financial system. R&D Management, 49(1), pp. 21-33.

6) Alexakhin, A., & Zaytsev, I. (2020). Flexibility in Making Decisions for Projects. FAIMA Business & Management Journal, 8(2), 5-15.

7) Amoroso, S., Moncada-Paternò-Castello, P., & Vezzani, A. (2017). R&D profitability: the role of risk and Knightian uncertainty. Small Business Economics, 2, pp. 331–343.

8) ANNUAL REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE SECURITIES EXCHANGE ACT OF 1. (2019).

9) Banerjee, A. (2003). Real Option Valuation of a Pharmaceutical Company. The Journal for Decision Makers, 28(2), pp. 61-73.

10) Berk, J., & DeMarzo, P. (2017). Corporate Finance (4th ed.). Harlow, England: Pearson Education.

11) Blass, A., & Yosha, O. (2003). Financing R&D in Mature Companies: An Empirical Analysis. Economics of Innovation and New Technology, 12(5), pp. 425–447.

12) Boer, F. P. (2005). Research is an investment, not an expense. Applied Catalysis A: General, 280(1), pp. 3–15.

13) Booth, L. (2002). Finding Value Where None Exists: Pitfalls in Using Adjusted Present Value. Journal of Applied Corporate Finance, 15(1), 95-104.

14) Borghesi , R., & Chang, K. (2020). Economic policy uncertainty and firm value: the mediating role of intangible assets and R&D. Applied Economics Letters, 27(13), pp. 1087-1090.

15) Bryl, L. (2020). Intangible assets in the process of internationalization. International Journal of Management and Economics, 56(1), pp. 63–78.

16) Bukhvalov, A., Loukianova, A., Nikulin, E., & Okulov, V. (2018). A Real Options Model for Analysis of industrial R&D Expenditures. Russian Management Journal, 16(3), pp. 393-406.

17) Buntz, B. (2021, February 5). Which companies will likely produce the most COVID-19 vaccine in 2021? Retrieved from Pharmaceutical processing world: https://www.pharmaceuticalprocessingworld.com/which-companies-will-likely-produce-the-most-covid-19-vaccine-in-2021/

18) Choi, H.-Y., Kwak, S., & Yoo, S.-H. (2016). Using Real OptionsPricing to Value Public R&D Investment in the Deep SeabedManganese Nodule Project. Asian Journal of Innovation and Policy(5), pp. 197-207.

19) Cohen, L., Diether, K., & Malloy, C. (2013). Misvaluing Innovation. Review of Financial Studies, 26(3), pp. 635–666.

20) Coluccia, D., Dabić, M., Del Giudice, M., Fontana, S., & Solimene, S. (2020, October). R&D innovation indicator and its effects on the market. An empirical assessment from a financial perspective. Journal of Business Research(119), pp. 259-271.

21) Corporate Venturing . (2021). Retrieved from MarketLine: https://advantage-marketline-com.ezproxy.gsom.spbu.ru/Company/CompanyDeals/novo_nordisk_as

22) Czarnitzki , D., & Hottenrott, H. (2011). R&D investment and financing constraints of small and medium-sized firms. Springer(36), pp. 65–83.

23) Datta , S., Jha, A., & Kulchania, M. (2020). On accounting’s twenty-first century challenge: evidence on the relation between intangible assets and audit fees. Review of Quantitative Finance and Accounting, 55, pp. 123–162.

24) David, P., O'Brien, J., & Yoshikawa, T. (2008). The Implications of Debt Heterogeneity For R&D Investment and Firm Performance. Academy of Management Journal, 51(1), pp. 165–181.

25) Diaconu, M. (2019). Business R&D investments in the EU: Main dynamics and economic effects. Theoretical & Applied Economics, pp. 19-34.

26) Dubey, N. (2020, September). Top 10 Processors Manufacturers. Retrieved from Bisinfotech: https://www.bisinfotech.com/top-10-processors-manufacturers/

27) Eberhart , A., Maxwell , W., & Siddique , A. (2004). An Examination of Long-Term Abnormal Stock Returns and Operating Performance Following R&D Increases. Journal of Finance, 59, pp. 623-650.

28) Embedded and Networking Processors. (2021). Retrieved from Broadcom: https://www.broadcom.com/products/embedded-and-networking-processors

29) Form 10-K. (2020). Retrieved from Pfizer: https://s21.q4cdn.com/317678438/files/doc_financials/2020/ar/PFE-2020-Form-10K-FINAL.pdf

30) Fryges, H., Kohn, K., & Ullrich, K. (2015). The Interdependence of R&D Activity and Debt Financing of Young Firms. Journal of Small Business Management, 53(1), pp. 251–277.

31) Global Electrical Equipment Market Development Strategy Pre and Post COVID-19. Market Reports World. (2021).

32) Global Electronics Manufacturing Services for Consumer Electronic Market. Market Reports World. (2021).

33) Hai, B., Gao, Q., Yin, X., & Chen, J. (2020). R&D volatility and market value: the role of executive overconfidence. Chinese Management Studies, 14(2), pp. 411-431.

34) Hauschild , B., & Reimsbach, D. (2015). Modeling sequential R&D investments: a binomial compound option approach. Business Research(8), pp. 39–59.

35) How Are Vaccines Developed? (2019). Retrieved from Pfizer: https://www.pfizer.com/news/hot-topics/how_are_vaccines_developed

36) Hull, J. (2015). Options, Futures and other Derivatives (9 ed.). Pearson Education.

37) Hussinger, K., & Schwiebacher, F. (2015, May). The Market Value of Technology Disclosures to Standard Setting Organizations. Industry & Innovation, 22(4), 321-344.

38) Immunomedics Inc (IMMU) SEC Filing 10-K Annual report. (2019).

39) Intel Corporation 10-K. (2019).

40) Intel Corporation 10-K. (2020).

41) Intel Processors Over the Years. (2018). Retrieved from Business News Daily : https://www.businessnewsdaily.com/10817-slideshow-intel-processors-over-the-years.html

42) Intel's expenditure on research and development from 2004 to 2020 . (2020). Retrieved from Statista: https://www.statista.com/statistics/263562/intel-expenditure-on-research-and-development-since-2004/

43) Jacob, F., & Kwak, H. (2003). In search of innovative techniques to evaluate pharmaceutical R&D projects. Technovation, 23(4), pp. 291-297.

44) Jaruzelski, B., Chwalik, R., & Goehle, B. (2018). What the top innovators get right. Retrieved from https://www.strategy-business.com/feature/What-the-Top-Innovators-Get-Right?gko=bdbc7

45) Kang, S., & Long, M. (2001). The fixed payment financing decision. To borrow or to lease. Review of Financial Economies, 10(1), pp. 41-55.

46) Ker, D. (2013). Service Lives of R&D Assets:Questionnaire Approach. Office for National Statistics.

47) Khalifa, S., Mansour, W., & Saci, K. (2017). How Do Financing Conditions Impact Firm Behavior?Evidence from the Gulf Zone. Emerging Markets Finance and Trade, 4, pp. 952-967.

48) Kim, K.-T., Lee, D.-J., & An, D. (2020, February). Real Option Valuation of the R&D Investment in Renewable Energy Considering the Effects of the Carbon Emission Trading Market: A Korean Case. Energies, 13(3), pp. 622-639.

49) Kim, K.-T., Lee, D.-J., & Park, S.-J. (2014). Evaluation of R&D investments in wind power in Korea using real option. Renewable & Sustainable Energy Reviews, 40, pp. 335-347.

50) Kumbhakar, S., Ortega-Argilés, R., Potters, L., Vivarelli , M., & Voigt, P. (2012). Corporate R&D and firm efficiency: evidence from Europe's top R&D investors. pp. 125-140.

51) Landscape. (2021). Retrieved from COVID-19 Vaccine tracker.

52) Lazzarotti, V., Manzini, R., & Mari, L. (2011, November). A model for R&D performance measurement. International Journal of Production Economics, 134(1), pp. 212-23.

53) Lee, J., Kwon, H.-B., & Pati, N. (2019). Exploring the relative impact of R&D and operational efficiency on performance: A sequential regression-neural network approach. Expert Systems with Applications(137), pp. 420-431.

54) Lee, N. (2019). R&D accounting treatment, firm performance, and market value: Biotech firms case study. Journal of International Studies, 12(2), pp. 66-81.

55) Lee, S. (2012). Financial Determinants of Corporate R&D Investment in Korea. Asian Economic Journal, 26(2), pp. 119–135.

56) Leveque, F., & Maniere , Y. (2011, December). Patent pool formation: Timing matters. Information Economics and Policy, 23(3-4), pp. 243-251.

57) Li, Y., & Rizzo, J. (2020). Timing and payoff of patent purchases: the role of firm size and composition. Applied Economics, 52(54), pp. 5894-5908.

58) Lidia, V. (2020). The Net Present Value and the Optimal Solution of Linear Programming in Investment Decisions. Economic Science Series, 29(2), 135-145.

59) Lynch , J., & Shockley, R. (2016). Valuation of a Developmental Drug as a Real Option. Journal of Applied Corporate Finance, 28(3), pp. 118-127.

60) Managi, S., Zhang, Z., & Horie, S. (2016). A real options approach to environmental R&D project evaluation. Environmental Economics & Policy Studies, 3, pp. 359-394.

61) MarketLine. (2019). Global Pharmaceuticals.

62) MarketLine Industry Profile Global Electronic & Electrical Components & Equipment. Marketline. (2020).

63) Martín-Barrera, G., Zamora-Ramírez, C., & González-González, J. (2016). Application of real options valuation for analysing the impact of public R&D financing on renewable energy projects: A company′s perspective. Renewable & Sustainable Energy Reviews, 63, pp. 292-301.

64) McGrath, R., & Nerkar, A. (2004). Real Options Reasonong And a New Look at the R&D Investment Strategies of Pharmaceutical Firms. Strategic Management Journal, 25(1), pp. 1-21.

65) Merlo, P. (2016). Consequences of the Absence of Monotonicity of the NPV Function to the Assessment of the Effectiveness of Investment Projects. Engineering Economics, 27(1), 39-46.

66) Metelski, D., Mihi-Ramirez, A., & Arteaga-Ortiz, J. (2014). Research and Development Projects Upon Real Options View. Inzinerine Ekonomika-Engineering Economics, 25(3), pp. 283–293.

67) Microprocessors quick reference guide. (2008). Retrieved from Intel: https://www.intel.com/pressroom/kits/quickrefyr.htm

68) Mikulic, M. (2020). Global pharmaceutical industry - statistics & facts. Retrieved from Statista: https://www.statista.com/topics/1764/global-pharmaceutical-industry/#dossierSummary

69) Mikulic, M. (2020, Aug). Pharmaceutical research and development (R&D) – statistics & facts. Retrieved from Statista: https://www.statista.com/topics/6755/pharmaceutical-research-and-development-randd/

70) Mikulic, M. (2021, Jun). Percentage return on investments in research and development among mid cap biopharma companies from 2013 to 2020. Retrieved from Statista: https://www.statista.com/statistics/825714/randd-returns-among-mid-cap-biopharma-companies/

71) Nenkov, D. (2017). Relative Valuation and Stock-Market Bubbles. Economic Alternatives(3), 363-37.

72) Nishihara, M. (2018). Valuation of R&D investment under technological, market, andrival preemption uncertainty. Managerial and Decisions Economics, 39, pp. 200-212.

73) Palmon, D., & Yezegel, A. (2012). R&D Intensity and the Value of Analysts' Recommendations. Contemporary Accounting Research, 29(2), pp. 621-654.

74) Pazarzi, G., & Sorros, J. (2018). The Effect of R&D Expenses on Earnings and Market Value. SPOUDAI Journal of Economics and Business, 68(2–3), pp. 39–47.

75) Pfizer Inc. (2021). Retrieved from MarketLine : https://advantage-marketline-com.ezproxy.gsom.spbu.ru/Company/CompanyDeals/pfizer_inc

76) Pike, S., Roos, G., & Marr, B. (2005). Strategic management ofintangible assets and valuedrivers in R&D organizations. R&D Management, 35(2), pp. 111-124.

77) Razer Inc. Annual Report 2019.

78) Riding, A., Orser, B., & Chamberlin, T. (2012). Investing in R&D: small- and medium-sized enterprise financing preferences. Venture Capital, 14, pp. 199–214.

79) Sole, R. (n.d.). Intel says that if they were based on something similar to AMD Zen they would reduce their investment in R&D by 50%. Retrieved from Hardwaresfera: https://hardwaresfera.com/en/noticias/hardware/intel-dice-que-si-se-basaran-en-algo-similar-a-amd-zen-reducirian-en-un-50-su-inversion-en-id/

80) Valdivia, M., Galan, J., Laffarga, J., & Ramos, J. (2020, April). A research and technology valuation model for decision analysis in the environmental and renewable energy sectors. Renewable and Sustainable Energy Reviews, 122.

81) VanderPal, G. (2019). Understanding the Nexus of R&D Expenditures and Intangible Assets in Different Asset Types: A Quantile Regression Approach. Journal of Strategic Innovation and Sustainability, 14(6), pp. 117-124.

82) Vriborg, P., & Plenborg, T. (2012). Financial Statement Analysis: Valuation, Credit Analysis and Executive Compensation (2nd ed.). Harlow, England: Pearson Longman.

83) Zhang, L., & Toffanin, M. (2018). The information environment of the firm and the market valuation of R&D. Journal of Business Finance and Accounting, 9-10, pp. 1051-1081.

84) Zuoza , A., & Pilinkienė, V. (2019). Energy consumption, capital expenditures, R&D cost and company profitability: evidence from paper and allied industry. Energetika, 65(4), pp. 197-204.

APPENDIX

APPENDIX 1. COUNTRIES IN THE SAMPLE

Table 7. Description of the countries in the sample

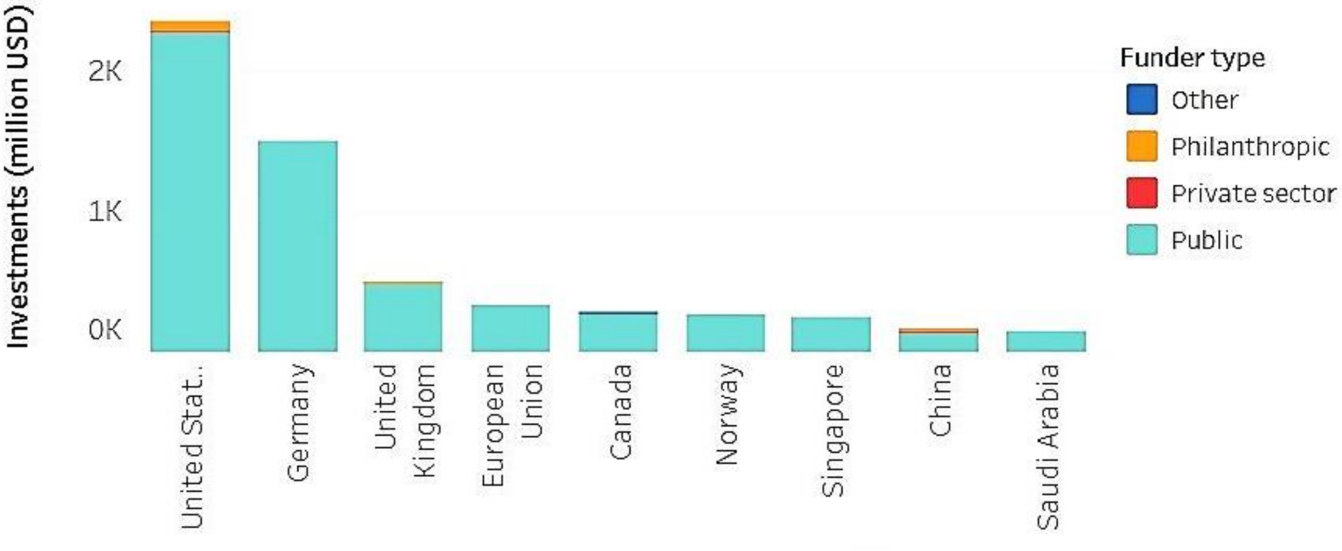
Country	**Share in the sample**	**Risk-free rate**
Argentina	0,04%	10,10%
Australia	0,49%	2,80%
Austria	0,69%	1,30%
Belgium	0,49%	1,20%
Brazil	0,24%	7,20%
Canada	1,13%	2,50%
China	20,48%	4%
Denmark	1,21%	1,20%
Finland	0,69%	1,10%
France	2,75%	1,20%
Germany	5,18%	1,10%
Greece	0,08%	4,30%
Hungary	0,04%	4%
Iceland	0,04%	1,00%
India	1,30%	6,50%
Iraq	,04%	7,20%
Ireland	1,09%	1,40%
Israel	0,89%	2%

Country	**Share in the sample**	**Risk-free rate**
Italy	1,05%	1,60%
Japan	12,79%	1,10%
Liechtenstein	0,04%	0%
Luxembourg	0,16%	1,10%
Malaysia	0,04%	4,30%
Mexico	0,04%	7,10%
Netherlands	1,58%	1,30%
New Zealand	0,12%	3%
Norway	0,40%	1,40%
Poland	,04%	3,10%
Portugal	0,08%	2,60%
Russia	0,04%	8,30%
Saudi Arabia	0,12%	7,20%
Singapore	0,24%	2,60%
Slovenia	,04%	2,40%
South Africa	0,08%	8%
South Korea	2,79%	2,50%
Spain	0,57%	6,40%
Sweden	1,34%	1,30%
Switzerland	,27%	1,10%

Country	**Share in the sample**	**Risk-free rate**
Taiwan	3,60%	1,80%
Turkey	0,20%	11,20%
UK	5,06%	2,10%
Ukraine	0,04%	5,30%
United Arab Emirates	0,04%	8,40%
US	30,35%	2,70%

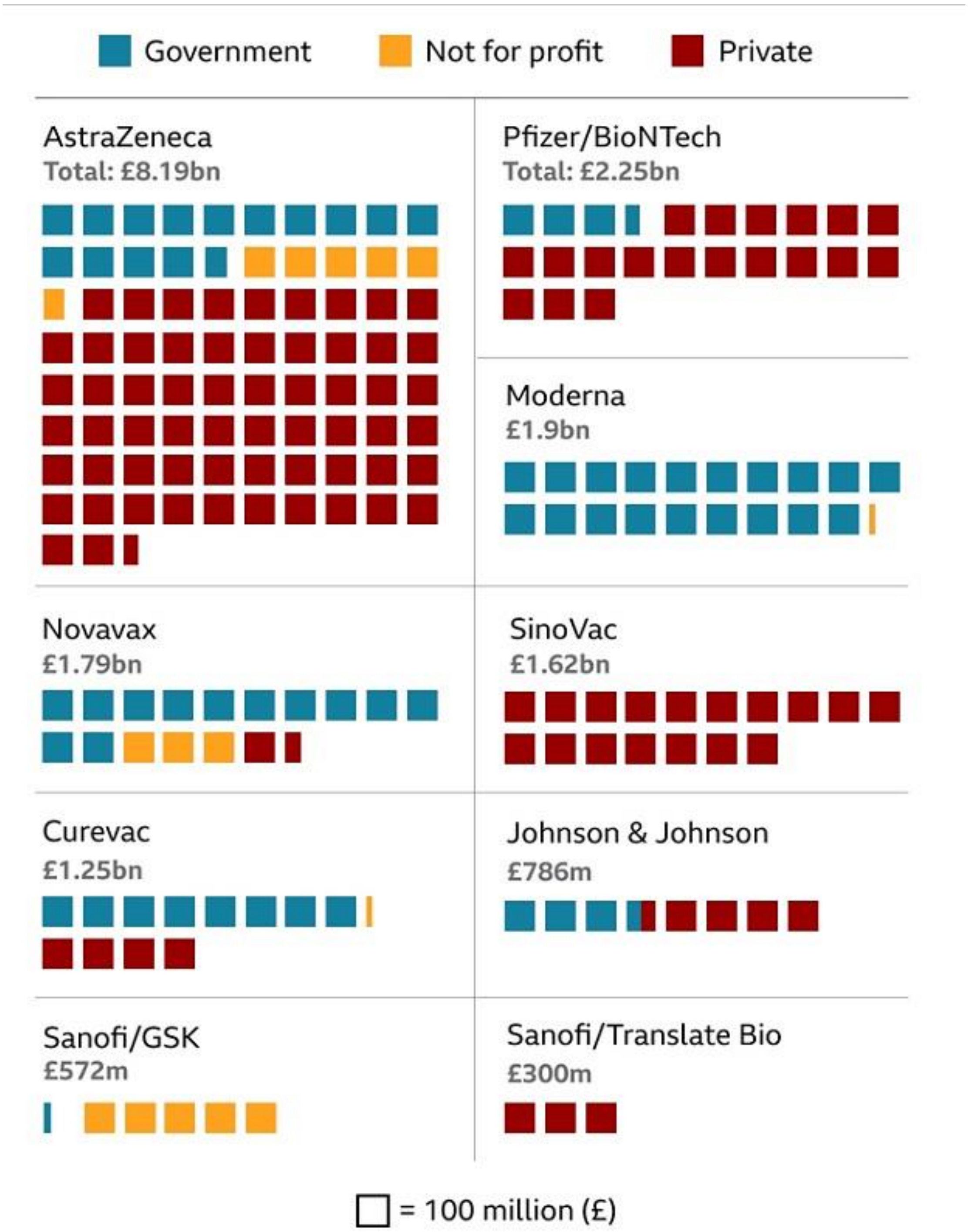
Source: done by the author

APPENDIX 2. SOURCES OF FINANCING THE R&D EXPENDITURES FOR VACCINE PRODUCTION BY COUNTRY



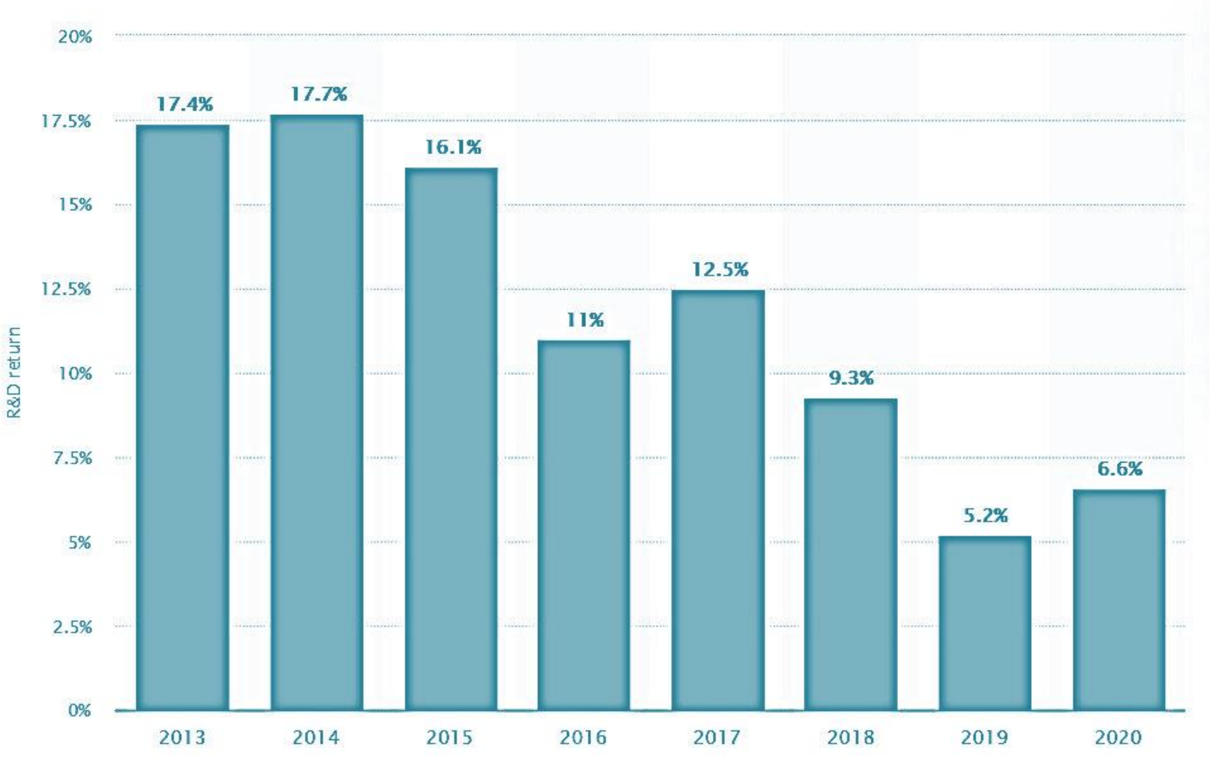
Source: (COVID-19 Vaccine R&D Investments, 2021)

APPENDIX 3. SOURCE OF THE INVESTMENT IN R&D FOR VACCINE PRODUCTION



Source: (Covid vaccines: Will drug companies make bumper profits?, 2020)

APPENDIX 4. RETURN ON INVESTMENTS IN R&D AMONG COMPANIES WITH MIDDLE CAPITALIZATION WITHIN PHARMACEUTICAL INDUSTRY



Source: Mikulic M., Percentage return on investments in research and development among mid cap biopharma companies from 2013 to 2020, 2021