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Regulating Robo Adviser Algorithms: Possible, Sensible, Necessary?

Examiner:	Prof. Dr. jur. Philipp Maume S.J.D
	Assistant Professorship of Corporate Governance and
	Capital Markets Law
Course of Study:	TUM WITEC (Management with Technology)
Submitted by:	Katharina Birgmeir
	Bazeillesstraße 9a
	81669 München
	Matriculation Number: 03683477
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Table of Contents

List of Figures and Tables

List of Appendices

List of Abbreviations

AuM	Assets under Management
AI	Artificial Intelligence
BaFin	Bundesanstalt für Finanzdienstleistungsaufsicht (engl.: federal financial advisory authority)
bn	billion
BGH	Bundesgerichtshof
CEO	Chief Executive Officer
cl.	clause
DAX	Deutscher Aktienindex
e.g.	for example (lat.: exempli gratia)
ESMA	European Security and Markets Authority
Et seq.	and what follows
ETC	Exchange Traded Commodity
ETF	Exchange Traded Fund
EU	European Union
FINRA	Financial Industry Regulatory Authority
fintech	Financial Technology
FinVermV	Finanzanlagenvermittlungsverordnung
GewO	Gewerbeordnung
i.e.	in other words (lat.: id est)
InsurTech	Insurance Technology
IT	Information Technology
IVA	Institut für Vermögensaufbau (engl.: Institute for wealth development)

KWG	Kreditwesengesetz
MiFID	Markets in Financial Instruments Directive
MiFID II	Markets in Financial Instruments Directive II
mn	Million
no.	Number
PropTech	Property Technology
UK	United Kingdom
US	United States
USD	US Dollar
VaR	Value-at-Risk
vs.	Versus
vzbv	Verbraucherzentrale Bundesverband (engl.: customer protection agency)
WpHG	Wertpapierhandelsgesetz

1. Introduction

1.1 Motivation

'Regulation needs to catch up with innovation',

stated Henry Paulson, former treasury secretary of the United States (US) and former *Goldman Sachs* CEO, in 2008 when deregulation was declared part of the problem of the global financial crisis.[1] Larry Page, CEO of *Google*, on the other hand has a different picture in mind when talking about technological innovations. When asked the question about how to make the world more positively inclined towards technological change, he replied:

'There's many, many exciting and important things you could do that you just cannot do because they're illegal, or they're not allowed by regulation'.[2]

These two quotes give a good impression of the trade-off that exists between introducing new regulations while potentially hindering innovation versus the lack of regulation, leading to higher innovation potential but also higher risks.

The same trade-off exists when talking about regulating robo adviser algorithms in Germany which is the topic of this thesis. Simplified, robo advisers offer digital portfolio management using algorithms. In July 2018 the customer protection agency (vzbv)[3] demanded that robo adviser algorithms should be regulated.[4] This demand was covered by the media,[5] bringing the topic robo adviser algorithms to the attention of the public. The reason such regulation demands came up was that robo advisers were, and still are, growing. Assets under Management (AuM) of German robo advisers at the end of 2017 were at approximately €1.8bn while they more than doubled to an estimate of €4bn AuM at the end of 2018.[6] *Google* search queries further show the continuing growth of robo advisers. In 2016 the search word 'robo-advisor' produced 423.000 results on

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[1] Nutting, 2008.
[2] Yarow, 2013.
[3] In German: Verbraucherzentrale Bundesverband.
[4] Verbraucherzentrale Bundesverband e.V., 2018.
[5] See for example La Motte, 2018; Kannenberg, 2018.
[6] Statista, 2019a.

Google.[7] In November 2018 the *Google* search result number was already at 6.2mn[8] and in April 2019, just five months later, at 7.4mn[9] search results.

As robo advisers are growing in popularity, the topic of regulation naturally started coming up. A few research papers dealt with the overall regulation of robo advisers[10] but the regulation of algorithms behind robo advisers was mostly left untouched or brushed aside as a 'future regulatory challenge'[11].

Robo adviser algorithms potentially pose risks to investors and markets. Such risks for example include the malfunctioning of algorithms, thus the risk for the investors of losing their money and the risk of influencing markets. Supporters of regulating robo adviser algorithms point out these risks when advocating for a regulation. On the other hand, strict regulations can hinder innovation which is extremely important for young sectors such as robo advisers. This trade-off leaves us with the following questions, which will be answered through an extensive research and analysis by this thesis:

(1) Is it necessary and sensible to regulate robo adviser algorithms?
(2) What possibilities exist to regulate robo adviser algorithms?

The thesis will focus on the German market as other markets and regulations differ, but the results could possibly be transferred to other markets as well. In order to answer the two research questions, knowledge about robo advisers, algorithms and regulation in general as well as the regulation of robo advisers and algorithms is needed. As some of these topics are rather new, additional information was needed, complimenting the information gained from literature research. This need led to expert interviews being the main source of information. Chapter 1.3 will give a complete overview of this thesis' methodology. The following chapter will now provide an outline and structure of the thesis.

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[7] Deloitte, 2016b, p. 1.
[8] See Appendix 5.
[9] See Appendix 6.
[10] See Maume, 2018; Baumanns, 2016; Möslein & Lordt, 2017; Oppenheim & Lange-Hausstein, 2016; Weber & Baisch, 2016.
[11] Möslein & Lordt, 2017, p. 802; Weber & Baisch, 2016, p. 1071.

1.2 Structure

Chapter 2 starts by providing detailed information about the robo adviser market in Germany, its history, target groups and future development expectations. Further, the chapter defines the word robo adviser according to this thesis and gives insights into the different investment strategies used by robo advisers and their overall chances and risks.

Following, chapter 3 focuses on algorithms and explains the different parts of robo adviser algorithms in detail. It also gives insights into the complexity of the different parts of the algorithms with information gained from expert interviews. Having a good understanding of the algorithms used in robo advisers is especially important when trying to answer the research questions as the answers strongly vary for differently complex algorithms.

In chapter 4 the focus is on regulation. First, the duties of regulators in general and the role of financial market regulation is discussed. Next, the current regulation of robo advisers is explained from a theoretical and a practical perspective. Lastly, the regulation of algorithmic trading is discussed in detail as it plays a big role in the answering of the second research question. Other relevant articles from directive 2014/54/EU (MiFID II) are also highlighted in order to get a comprehensive few of the regulation of robo advisers.

After covering robo advisers, algorithms and regulation, the next chapter transforms the gained knowledge into concrete answers to the research questions. Chapter 5 therefore answers whether it is sensible and necessary to regulate robo adviser algorithms and points out possibilities to regulate them. Before answering the question of necessity, the portfolio management part of the algorithm is categorized into different classes. The answers of whether a regulation is necessary and how it is possible to implement a solution differ between the two parts of the algorithm and within the second part for the different classes of algorithms. Lastly, concrete recommendations for the regulation of the different parts and different complex algorithms are provided. Especially this chapter is strongly based on my own opinion formed through extensive research and input from expert interviews.

Next, the methodology used in this thesis will be explained in detail.

1.3 Methodology

Robo advisory in general, the regulation of them and especially the regulation of their algorithms is a relatively unexplored topic. Therefore, only limited research papers exist. As already stated, the regulation of the algorithms was mentioned as a 'future challenge' for regulators by researchers and was just brought to the attention of the public in July 2018.[12] This novelty of the topic led to expert interviews being the main method used in this thesis to answer the research questions. Such one-on-one interviews with experts fall under the definition of a qualitative research method. Qualitative research aims to explain the world 'from the inside out' by looking at the point of view of the people who participate in it.[13] Qualitative research approaches analyze open research questions in detail with a limited number of examination units, using unstructured or semi-structured data collection methods.[14] The decision to use a qualitative research methodology was made because the question of whether and how robo adviser algorithms should be regulated is open, complex and different opinions and viewpoints about the topic exist. Further, the usage of quantitative methods is not given as there are no quantitative variables that can be defined as a basis, the sample size of people who have knowledge about robo advisers, their regulation and their algorithms is small, and there are no statistical analyses that could be done.[15]

The gathering of information through expert interviews was further accompanied by extensive literature research and fact research in law[16]. The literature review included papers, articles and further documents about the functioning of robo advisers in general, the regulation of robo advisers with a focus on the European and German market, and the possibilities of regulating algorithms. Since the topic is new, often newspaper articles and internet documents in general were used as sources of information. Fact research in law includes regular

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[12] For more information see Verbraucherzentrale Bundesverband e.V., 2018.
[13] Flick, Kardorff, & Steinke, 2004, p. 3.
[14] Döring & Bortz, 2016, p. 184.
[15] Lamnek & Krell, 2016, p. 16.
[16] In German: Rechtstatsachenforschung.

legal research and reviewing laws and additionally comprises the observed implementation of laws in practice.[17]

Expert Selection

Experts can be defined as people who have deep theoretical knowledge in a well-defined area but also know how to apply that knowledge into practice, which includes the structuring of certain information or problems for others.[18] The interviews for this thesis were conducted with experts in the field of robo advisers, their regulation and/or their algorithms. As the number of experts is often limited and they are difficult to reach[19], it was not possible to find only experts that have knowledge in robo advisers in general, their regulation and algorithms. Most experts were either focused on a regulatory perspective or had deep knowledge in the functioning of the algorithms and robo advisers in general. Nevertheless, a general understanding of all aspects was given at all interviews. It must be noted that the statements and opinions of the experts are subjective and do not always represent the opinions of others or the opinion of the company they work for.

Overall, eleven interviews were conducted. Seven of these interviews were with representatives from different robo advisers, three of the interviewees were independent of robo advisory firms and one interview was with representatives from *BaFin*.[20] It was important to get insights from different robo advisers about the algorithms used, the current regulation in practice and overall opinions on possible regulations of robo adviser algorithms. All, except one, of the interviewed robo advisers were portfolio management firms, the other one has the broker license according to § 34f GewO. The distribution of 6:1 (portfolio management : broker) seems uneven but is actually a fairly good representation of the German robo advisory market in general, as the number of portfolio management firms outnumbers broker licenses as well.[21] Still, the information gained from only one interview with a broker has to be viewed more carefully. The other

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[17] For more information see Nussbaum, 1940.
[18] Bogner, Littig, & Menz, 2014, pp. 12–15.
[19] Döring & Bortz, 2016, p. 375.
[20] See overview of interviews in Appendix 1.
[21] For a detailed overview of all robo advisers considered in this thesis including their license type see Appendix 3.

six robo advisers included one start-up company and five robo advisers that came out of banks. A more even distribution between start-ups and banks would have been preferred but most start-ups were not willing or did not have the time to do an interview. Apart from robo advisers, one interview was with a representative from the consumer protection agency Baden-Württemberg, one with an employee of *PwC* working in the fintech area and one with a representative of the institute for asset development who had a background in working at robo advisory firms. Further, an interview with Ulf Linke, head of consumer protection, and three other representatives of *BaFin* was conducted. The overall selection of experts was found to be very helpful to answer the research questions.

Expert Interview Design

Before each interview, guideline questions[22] were sent to the interviewee to better prepare for the upcoming interview and to show that deeper knowledge of the topic already exists, hopefully leading to an in-depth interview going below the surface. This is also a way to be observed as a 'co-expert' rather than an amateur[23] which is preferred as it leads to more detailed answers and the elimination of topics that are considered basic knowledge.[24] These guiding questions were slightly adjusted depending on the interviewee but remained the same content wise to be able to better compare answers. During the interviews the questions were adjusted including the addition of new questions when necessary and the elimination of questions that were already answered or not relevant anymore. The existence of guideline questions and the freedom to adjust questions throughout the interview defines it to be a half-structured interview.[25] All questions were open questions, meaning no answer options were provided and the interviewee was able to answer freely about the topic.[26] The questions in the guideline were structured by topic.

The average duration of the interviews was 44 minutes. Ten of the interviews were done through phone due to location differences and to save time and

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[22] See Appendix 2
[23] Kaiser, 2014, p. 54.
[24] Bogner et al., 2014, p. 52.
[25] Mayring, 2016, p. 67.
[26] Mayring, 2016, p. 66.

travelling expenses. Further, phone interviews suggest a sense of anonymity which can lead to more open answers to critical questions.[27] In the beginning of each interview, the interviewee was informed that the conversation will be recorded and asked whether he wants to anonymize his interview. Six out of the eleven interviewees decided to anonymize it.[28] Further, a verbal explanation of the goals of the interview and the thesis in general was provided beforehand to minimize the risks of getting off topic.

Analysis and Evaluation of Interviews

After having conducted all interviews, it was necessary to summarize and analyze the statements and opinions. For this thesis, a partial transcription was chosen which includes a word-for-word transcription of the especially relevant parts for the research but only summarizes less important parts.[29] The advantage of this technique is that it already reduces the huge amount of material in the first step.[30] The partial transcriptions, meaning the written down interviews, are called protocols in this thesis. All interviews were held in German and protocols were therefore written in German as well. For the sake of the master thesis, the analysis was done in English.[31] Of course a high level of detail and concentration was given to the translation, but the very nature of different languages might still lead to slight differences in how some statements were meant to come across.

The second step after finishing the protocols was to evaluate and analyze the gathered material. By reading through the interviews several times, different categories were established and passages of the interviews, relevant for a specific category, were marked as such.[32] The result was a table with categories, subcategories and relevant text passages of all interviews. This process is called a qualitative content analysis.[33] With the result of the analysis it was possible to have a good overview of all the different opinions and statements regarding one topic. Appendix 4 shows the final analysis of all interviews. It must be noted that

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[27] Döring & Bortz, 2016, p. 374.
[28] For details see Appendix 1.
[29] Döring & Bortz, 2016, p. 583.
[30] Mayring, 2016, p. 94.
[31] See Appendix 4.
[32] Kaiser, 2014, p. 99.
[33] Mayring, 2016, p. 114.

statements of the interview with *BaFin* are not included in the analysis in the appendix as the exact wording is confidential. The complete protocols of each interview, including the names and companies of the anonymous interviewees and the analysis of the interview with *BaFin* are only known to the author and the primary examiner.

2. Robo Advisory

2.1 Definition and Explanation of Robo Advisers

Robo advisers are part of the fintech phenomenon which includes new technology-based business models in the financial industry.[34] Companies that are typically online centered start-ups and focus on a specific financial product with the goal of efficient user-friendliness are usually called fintechs.[35] Other definitions of fintechs not only include start-ups but also entities of existing companies that were formed to offer financial services on a technological basis.[36] For the cause of this thesis, the definition of fintechs will not be limited to start-ups and will also include specific entities of existing companies. Robo advisers therefore include both, start-ups, that only focus on robo advisory, as well as bigger, well-established firms (usually banks) which add robo advisory to their existing service.[37] Therefore, when talking about robo advisers as fintechs, the limitation to only start-ups is not timely anymore even though that is where fintechs started – with start-up companies. Finding a legal definition of fintechs is not possible as fintech business models differ widely (see Figure 1) and services and products have different underlying laws.[38]

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[34] Maume, 2017, p. 2.
[35] Baumanns, 2016, p. 1.
[36] Prof. Dr. Gregor Dorfleitner, Jun.-Prof. Dr. Lars Hornuf, 2016, p. 12; Weber & Baisch, 2016, p. 1065.
[37] Weber & Baisch, 2016, p. 1065.
[38] Prof. Dr. Gregor Dorfleitner, Jun.-Prof. Dr. Lars Hornuf, 2016, p. 12.
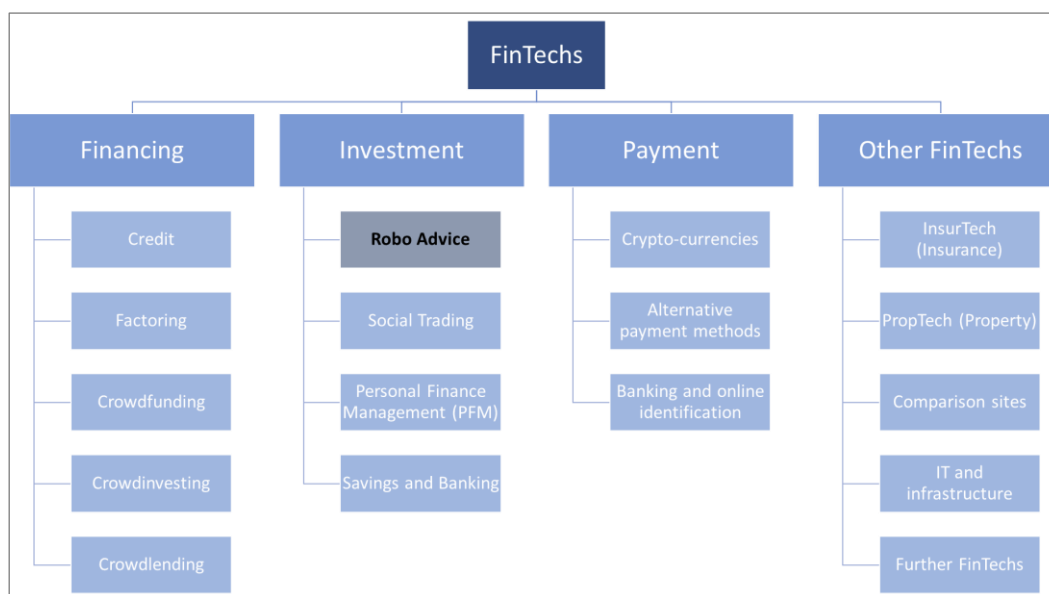
Figure 1: Segments of fintechs and classification of robo advice therein[39]

Definition of Robo Advisers

Even within one fintech segment, a legal one-fits-all definition is sometimes not possible, as can be seen with the example robo advisory. Several definitions for a robo adviser exist. Different public authorities published their own definition of a robo adviser over the past years, which all seem to be held very broad and unspecific, probably to keep their option to regulate and further define robo advisory open. The *US Financial Industry Regulatory Authority* (FINRA) refers to a robo adviser as a 'digital investment advice tool' with the limitation to client-facing tools excluding financial-professional facing software that investment professionals use to better advise their clients.[40] Similarly, *the Joint Committee of European Supervisory Authorities* defines robo advisers as 'automated financial advice tools directly used by the customer'.[41] The German federal financial advisory authority (BaFin)[42] has already published several articles about robo advisers and their regulation in Germany, where they defined robo advisory as

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[39] Own presentation on basis of Prof. Dr. Gregor Dorfleitner, Jun.-Prof. Dr. Lars Hornuf, 2016, p. 19; Fischer, 2017, p. 184; Baumanns, 2016, p. 2.
[40] The Financial Industry Regulatory Authority (FINRA), 2016, p. 2.
[41] Joint Committee of the European Supervisory Authorities, 2015, p. 12.
[42] In German: Bundesanstalt für Finanzdienstleitungsaufsicht.

the 'automated sale of financial instruments'.[43] Further, there are several defini-
tions of robo advisory in published research papers which all include at least
some of the following criteria[44]: investment advice, digital format, algorithm
based, client facing, without human interaction. Some also explicitly include the
management of customers' portfolios, the goal to provide cheaper financial ad-
vice to a broader audience, and the possibility of some human interaction within
the process.

According to this thesis, a robo adviser is an

'automated client-facing online advisory service that uses algorithms to
provide individual and concrete financial advice potentially including portfolio
management'.

This definition includes all necessary differentiations to potential other services.
Further, it does not exclude the management of customers' portfolios which is a
downstream service after the investment advice and is explicitly included in this
thesis as most robo advisers provide portfolio management services.

Different Regulatory Types of Robo Advisers

There are several different business models that are covered under the term robo
advisory, making the word robo advice a description of a phenomenon rather
than a regulatory classification.[45] Robo advisers can be clustered into three dif-
ferent regulatory types.[46] The first layer includes robo advisers that provide in-
formation but not individual financial advice, which can be compared to brokers.
When personal data from the client is used to give financial recommendations,
investment advice is given, and stricter regulation is applied. Thirdly, robo ad-
visers can manage clients' portfolios, as mentioned above, leading to an even
stricter regulatory regime. These three types usually appear in combination with
each other and will be further discussed under 4.2.1. All three layers are included
in this thesis' definition of a robo adviser as most robo advisers have either the

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[43] BaFin, 2017b.
[44] See Ringe & Ruof, 2018, p. 1; Iannarone, 2018, p. 149; Maume, 2018, p. 13; Fisch, Laboure,
    & Turner, 2017, p. 1; Kaya, 2017; Baker & Dellaert, 2018a, p. 3; Baumanns, 2016, p. 3.
[45] Maume, 2018, pp. 14–15.
[46] Maume, 2018, pp. 13–14.

portfolio management or the broker license in Germany. Excluding one of the layers, like some papers do, would also exclude companies that fall under the term robo advisers. Out of the 22 most commonly known robo advisers in Germany, 18 have the portfolio management license, four have the broker license and no robo adviser has the investment advice license.[47] This used to be different in the beginning years of robo advisers when many providers still had the investment advice license[48] which is also why some academic papers discussed excluding portfolio management in their research and focusing on the investment advice part. The investment advice license is included in this thesis as it can be viewed as a part of the portfolio management and is needed to understand all connections. None of the three forms of robo advice are therefore excluded because when answering the question of whether and how algorithmic regulation[49] should be implemented, all forms of robo advisers need to be looked at to get a comprehensive view of the situation.

Business Model of Robo Advisers

The business model of robo advisers is to offer broker services, investment advice or portfolio management to a broader audience at lower costs than human advisers.[50] The process of robo advisers can be divided into three parts.[51]

(1) First, the customer or potential investor fills out an online questionnaire about his personal and financial situation. This initial investor screening typically includes questions about the investor's financial goals (e.g. significant wealth increase vs. maintaining wealth level), the horizon of the investment (the number of years influences the composition of the portfolio), the investor's risk tolerance (e.g. by asking how high the potential short-term loss can be before the investor pulls out or by visually demonstrating the potential losses for a given return to the investor), and the investor's previous experience with the financial

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[47] See Appendix 3.
[48] See Appendix 4, Interview 1.
[49] The term 'algorithmic regulation' often refers to using algorithms for regulation purposes. In this thesis the term means the same as 'regulating an algorithm'.
[50] Iannarone, 2018, p. 148.
[51] Kaya, 2017, p. 2; Baumanns, 2016, pp. 4–5.

market, advisers and portfolio management. Further, the screening almost always includes questions about the net income, the expenses, the liabilities and the liquid and illiquid assets of the investor to make sure that he or she can afford to invest money in the market. This first part is called the suitability assessment and is regulated under Art. 25(2) of MiFID II and the corresponding Art. 54/55 of delegated regulation[52] (EU) 2017/565. All answers are not and cannot be checked for truth, so the recommendation is only as good as the investor's input. Some robo advisers that offer portfolio management let the customer decide whether they want the robo adviser to automatically monitor and adjust their portfolio or to exclude automatic portfolio management and be asked before any changes to the investments are done.[53] Most robo advisers automatically perform portfolio management services, which is indicated to the investor throughout the questionnaire process or when providing the portfolio suggestion. It is necessary to have some basic understanding of the different forms of robo advisers and the possible options to comprehend whether the robo adviser includes automatic portfolio adjustments or not as the displaying of what service the robo adviser offers is not always obvious.

(2) After the investor's screening, the robo adviser provides specific and individual investment advice.[54] This advice or portfolio suggestion is provided by an algorithm which uses the investor's input and a given strategy. The portfolio suggestion by robo advisers is mostly based on Exchange Traded Funds (ETFs).[55] Sometimes Exchange Traded Commodities (ETCs) and saving accounts[56] are used as additional investments. An ETF is an investment vehicle structured as an open investment fund that invests in a specific area of the market, usually either stocks or corporate or government bonds.[57] ETFs have the advantage that they are well diversified as they include several securities, are traded on the stock market and are therefore easily accessible and usually

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[52] Delegated regulations give further details on definitions and interpretation of terms used in the superordinate regulation or directive, see Maume, 2018, p. 16.

[53] e.g. *cominvest*.

[54] For an example of such investment advice see Appendix 7.

[55] See e.g. Kaya, 2017, p. 4; Iannarone, 2018, p. 151; Baumanns, 2016, p. 3.

[56] In German: Tagesgeld.

[57] For more detailed information about ETFs, see for example Hehn, 2005.

cheaper than classic investment funds because they are passively managed.[58]
Depending on the investor's risk profile, the portfolio, including different ETFs,
is chosen. An investor who is more risk averse for example will have a higher
portion of ETFs investing in bonds than in stocks as bonds are less risky with a
lower expected return than stocks. Vice versa, investors more willing and capa-
ble to take risks will have a higher expected return on their portfolio but also a
higher risk, meaning the proportion of ETFs investing in stocks will be higher
than for risk averse investors.

(3) If the investor decides to take the robo adviser's portfolio suggestion,
a depot is opened for the investor and the investment is done automatically. Robo
advisers that are not fully licensed banks itself[59] usually have one bank that they
are cooperating with, where they open the depots for all their customers. On the
other hand, corporate robo advisers that grew as an entity of a fully licensed
bank[60] can open the depots more easily at their own bank. After opening the
depot and making the investment, the design of the ongoing management of the
investor's portfolio depends on the service of the robo adviser. If the service is
limited to brokerage or financial advice, the portfolio is monitored and possible
recommendations to adjust are given to the customer who then can decide
whether he wants to follow the recommendation or not. Rebalancing is per-
formed when the robo adviser algorithm detects drifts from the target asset allo-
cation in a customer's portfolio. For example, an investor's opening portfolio
consisted of 40% stocks and 60% bonds (40/60). As securities perform differ-
ently and change in value, it can happen that at a moment in time the composition
of the portfolio is 43/57 instead of 40/60 as indicated by the investor. Depending
on the pre-defined tolerated deviations, the portfolio is then rebalanced back to
a 40/60 composition by selling stocks and using that money to buy bonds. In this
case, if a deviation of 30 basis points is defined as tolerable by the investor, the
rebalancing would not take place.[61] Some people view the process of rebalancing

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[58] Baumanns, 2016, pp. 3–4.
[59] All start-up robo advisers that only offer portfolio management, e.g. *Scalable Capital* and *gin-mon*.
[60] E.g. *cominvest* (*Comdirect Bank*) and *ROBIN* (*Deutsche Bank*).
[61] Kaya, 2017, p. 7.

as part of the investment advice assuming no portfolio management license would be needed for it.[62] Since there are no robo advisers on the German market (as of May 2019) that only have the investment advice and not the portfolio management license, this categorization of rebalancing is not needed necessarily. According to a robo adviser provider, the companies have all switched to the portfolio management license exactly because of this problem: the legal uncertainty about which services are included in investment advice and which are not.[63] If the robo adviser has the portfolio management license, the algorithm is allowed to manage the portfolio without consulting the investor. For some robo advisers this is limited to rebalancing whereas others use more complex, risk-based approaches (more under chapter 2.4). The following activity diagram shows an overview of the described process.

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[62] Maume, 2018, p. 15.
[63] See Appendix 4, Interview 1.
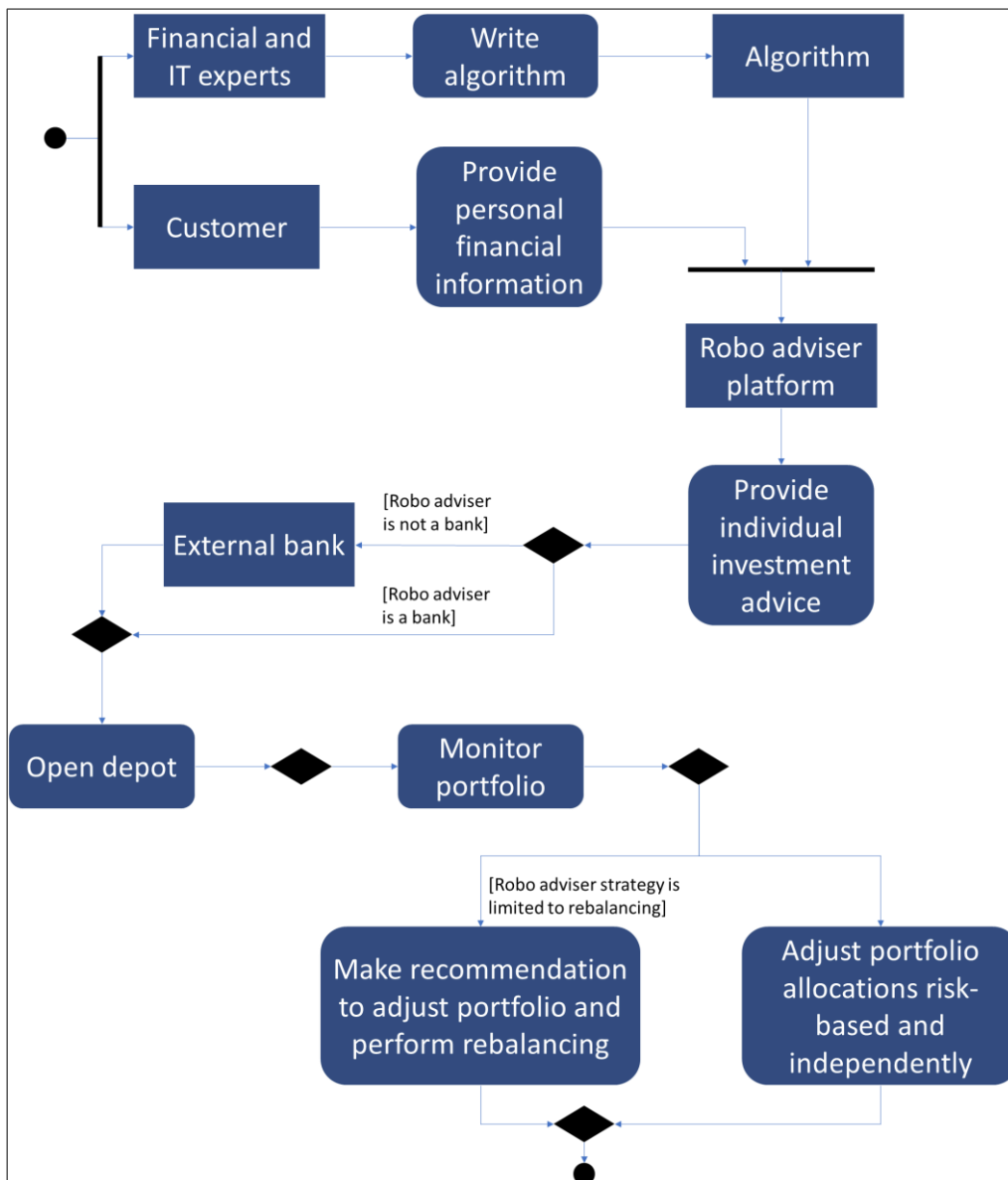
Figure 2: Activity diagram of robo adviser business model. [64]

2.2 Robo Adviser Market Overview

2.2.1 History and Current Market Situation in Germany

The phenomenon robo advisory began, like many other innovations, in the United States (US). In 2010, *Betterment* entered the market and started giving financial advice to a broad audience using algorithms, which is now known as

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[64] Own presentation using a Unified Modeling Language (UML) activity diagram.

robo advisory.[65] Shortly after, *Wealthfront* followed[66] whose goal is to 'help democratize access to sophisticated financial advice'.[67] In the upcoming years, several other companies started offering robo advisory services in the US and in Europe. The companies *quirion* and *Cashboard* were the first German robo advisers entering the market in 2013.[68] The German and the United Kingdom (UK) market are the dominating markets for robo advisory in Europe.
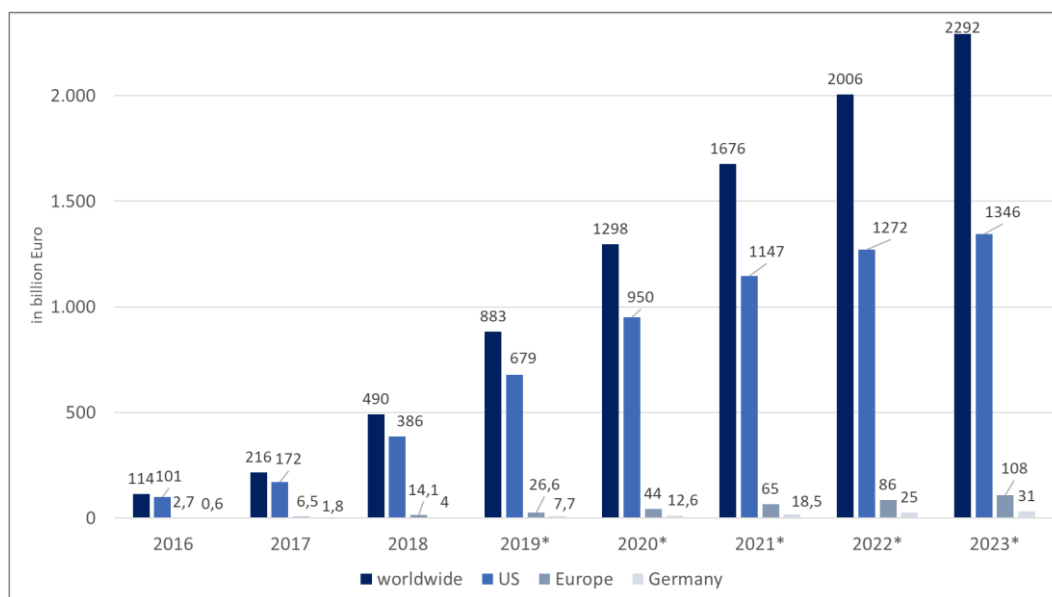
Figure 3: Development of AuM of robo advisers (estimates between 2019-2023)[69]

As shown in Figure 3, compared to the US market with estimated AuM of €172bn in 2017 and €386bn in 2018, the European market had about €6.5bn in 2017 and €14.1bn AuM in 2018[70], showing how far behind it is.[71]

Still, the European market is growing rapidly, says Michael Mellinghoff, managing director at *TechFluence*.[72] According to a survey of fintech experts in 2016, robo advice was the third biggest trend in the fintech industry after mobile payment and crowdfunding,[73] showing the big potential robo advice has. The

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[65] Maume, 2018, p. 12; Möslein & Lordt, 2017, p. 793.
[66] Fisch et al., 2017.
[67] Wealthfront, 2018.
[68] Prof. Dr. Gregor Dorfleitner, Jun.-Prof. Dr. Lars Hornuf, 2016, p. 48.
[69] Own illustration based on data from Statista, 2019b.
[70] See Appendix 11.
[71] See also Appendix 8 for demonstration of dominance of the US robo advisory market.
[72] Mellinghoff, 2017.
[73] See Appendix 9.

main difference of the US and the European market is, that self-directed investing in general and investments in ETFs are more popular in the US than in Europe, according to Shaun Port, chief investment officer of *Nutmeg*, the largest European robo adviser based in the UK. Ulf Linke from *BaFin* stated that Germans in general are not very affine when it comes to investing in the securities market.[74]

Costs of Robo Advisers

Robo advisers in the US offer cheaper products than European robo advisers, partly because ETFs themselves are more expensive in the EU than in the US, says Mr. Pfeiffer from *Solactive*.[75] The average service fee of a robo adviser in the US is 0.4% of capital invested.[76] In Germany on the other hand, the average costs are 1% when investing €20,000, 0.78% when investing €50,000, and 0.73% when investing €100,000, averaging[77] to costs of 0.84% of invested capital.[78] There are only a few German robo advisers that can keep up with the low average fee from the US including *WeltInvest*, *Growney*, *fintego* and *quirion*. On the higher end, with fees above 1%, we find *truevest*, *solidvest* and *Warburg* amongst others.[79]

Assets Under Management in Germany

As of December 2017, the German robo advisory market had an estimate of € 1.8bn AuM.[80] Five months later, AuM were already expected to be above € 2bn.[81] As of December 2018, the market was estimated to have € 4bn AuM[82] leading to a growth of the market of over 100% during 2018. According to a calculation of *Barkow Consulting*, the four biggest robo advisers[83] had about

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[74] See Interview 9.
[75] Cowan, 2018.
[76] valuepenguin.com, 2018.
[77] Due to the lack of data about the distribution of portfolio sizes, the arithmetic mean was taken as an average.
[78] See Appendix 3.
[79] See Appendix 3.
[80] See Appendix 11.
[81] Barkow, 2018.
[82] See Appendix 11.
[83] *Scalable Capital*, *cominvest*, *LIQID*, *quirion*.

74% of total AuM in May 2018.[84] This calculation has to be viewed cautiously though because many robo advisers did not disclose their AuM and those numbers are therefore only guesses. Still, the four biggest robo advisers most likely have a big portion of total AuM, which was also confirmed by *Süddeutsche Zeitung* in February this year.[85]

Current Robo Adviser Providers on the German Market

The first robo advisers were all independent firms i.e. start-ups only offering robo advisory services. In the past years, more and more established banks and asset management firms have entered the robo advisory market, making it harder for start-ups to get established in the market. At the same time, the occurrence of 'big players' helped the growth of AuM. Independent robo advisory firms might potentially be absorbed by or partner with banks looking forward.[86] As of now, there are around 30 robo adviser providers, some of which are very small. In this thesis, a selection of the 22 biggest and most important robo advisers was taken when calculating costs or comparing legal types.[87]

Performance of Robo Advisers

When looking for the performance of robo advisers, many different sources with different performances can be found. The differences occur because of different ways to calculate the performances i.e. different risk profiles of the portfolios, including or excluding taxes, before or after costs. For the sake of this thesis, it is enough to get a broad understanding of where the performance of robo advisers lies compared to a known benchmark index and how big the differences are between the different providers. Therefore, a performance test by *brokervergleich.de* was chosen which seems the least influenced by providers themselves.[88] All following information is based on this study. When talking about the performance, the return or the value development is meant. A return of 10%

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[84] Barkow, 2018.
[85] Freiberger, 2019.
[86] Kaya, 2017, p. 8.
[87] For a complete list, see Appendix 3.
[88] brokervergleich.de, 2019.

over twelve months therefore means that the value of the portfolio one year ago was at a certain level and increased by 10% over the past twelve months.

The study started testing the robo adviser performances about three years ago by investing money in a medium risk portfolio at every robo adviser. Interestingly, the average performance of the robo advisers was lower than the benchmark portfolio[89] for every possible period of time. Sometimes, the average performance was even significantly lower e.g. when comparing the average two-year performance of all robo advisers of 1.9% to the benchmark of 6.9%. Over the past ten months, *fintego*, *WeltSparen*, and *ginmon* are leading the performance ranking with 4.7%, 4.3%, and 3.7%, all still being lower than the benchmark of 6.0%. On the lower end, *SutorBank* and *comdirect* can be found with -1.8% and -7.8%. The performance of robo advisers over the past three months was good as some providers were able to beat, reach or at least get close to the performance of the benchmark portfolio of 8.7%. The average of robo advisers was 7.6% with *ginmon* being able to beat the benchmark with a performance of 9.3%. Though, *ginmon*'s performance over the past six months was -0.1% which was lower than many other providers' performances and lower than the benchmark of 0.5%. This shows that depending on the period, different robo advisers perform the best. For a few robo advisers, performance data exists for the past three years. As the goal of investing in robo advisers is usually to make return in the long run, looking at short- or medium-term returns does not help a lot. Also, past returns do not provide information for future returns. Overall, the performances vary widely between the different robo advisers making it relevant for investors to gather information before making an investment decision.

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[89] Which consists of 50% *MSCI* World (stocks) and 50% *Barclays* Aggregate Bonds (bonds).

2.2.2 Customers and Target Group

Due to low fees and small minimum investments, robo advisers are often said to target millennials, low-income households[90] and less wealthy customers overall[91]. According to *Deutsche Bank Research* though, first estimates indicate that customers of robo advisers are 48 years old on average and that the main target group therefore does not consist of millennials. The report further states that 90% of the customers are male, have an annual median income of €54,000 and invest between €1,000 and €1,500 yearly in their robo adviser accounts.[92] As robo advisers are more accessible to the public due to lower minimum investments, sometimes as low as €1, they automatically target customers with lower income than traditional financial advisers, who sometimes require a minimum investment of €1,000,000.[93] A median income of €54,000 is most probably lower than the median income of an investor going to a traditional financial adviser but can still be seen as a moderate income overall, leading to the conclusion that low income customers are mostly not targeted. Further, the target audience includes people with low financial literacy.[94] This is supported by experts who state that the potential customer does not have a lot knowledge about investing in security markets but should have some knowledge about funds in general in order to be drawn to robo advisers in the first place.[95] The customer group is also comprised of people who respond positively to the word robo adviser and who are online affine in general.[96] Especially the specific amount of knowledge the customer must have about the financial industry (not too much but still a little) paired with a moderate income and internet affinity, makes the target group fairly small. According to Dirk Rathjen from the institute for wealth development[97] (IVA), an independent German institute that helps private investors to increase their wealth

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[90] EY, 2018, p. 1.
[91] medium.com, 2018.
[92] Kaya, 2019, p. 3.
[93] Deloitte, 2016a, pp. 3–4.
[94] medium.com, 2018.
[95] See Appendix 4, Interview 10.
[96] See Interview 9 and Appendix 4, Interview 10.
[97] In German: Institut für Vermögensaufbau.

through scientific approaches[98], targeting a small group of people might be a smart strategy for a start-up but not necessarily for bigger banks.[99]

Given that information, the average investor can be described as follows: Manuel is male, 48 years old with a university degree and an income of €54,000 annually. He is internet affine, likes to read about the financial market in the paper now and then, where he also reads about robo advisers. He was drawn to them due to the low fees and the relatively low minimum investment. He opened an account with €40,000 and saves €1,250 yearly.

2.2.3 Market Growth and Development Expectations

Studies have tried to predict future growth of the robo advisory market. One of the most commonly known studies comes from *Oliver Wyman* dating back to August 2017. The study predicts AuM of robo advisers in Germany of c. €37bn[100] in 2021.[101] *Statista* on the other hand is a little more conservative, predicting AuM of c. €18.5bn for 2021 and c. €31bn for 2023.[102] Only three months ago, *Statista*'s predictions were even lower. AuM for 2021 were forecasted to be c. €10.6bn. *Statista* probably updated their predictions because AuM for 2018 were higher than they had predicted (€4bn vs. €3.2bn).[103] This difference between expectations can also be seen when talking to experts of the robo advisory market. Many have the opinion that the market will continue to grow mostly in line with expectations.[104] Explanations for the future growth include the rising importance of online distribution channels[105] and digitalization in general[106]. Further, a comparison to the US market was done, which is constantly growing, mentioning low costs and good portfolios as future growth factors as well as the trend to move away from actively managed funds and human advisers.[107] Others were a little less confident stating that the market will grow but probably not as

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[98] Institut für Vermögensaufbau (IVA) AG, 2018.
[99] See Appendix 4, Interview 10.
[100] $42bn converted with exchange rate as of March 3rd 2019: 0.88.
[101] Oliver Wyman, 2017, p. 3.
[102] See Appendix 11.
[103] See Appendix 10 and Appendix 11.
[104] See Appendix 4, Interviews 2, 6, 7, 8, 11.
[105] See Appendix 4, Interview 6.
[106] See Appendix 4, Interview 7.
[107] See Appendix 4, Interview 8.

fast as predicted[108] mainly because human advisers are still important and cannot be replaced[109]. One expert mentioned that when predicting technical innovations, short-term predictions are often too high, whereas long-term predictions are too low.[110] When looking at the two mentioned studies, at least the short-term predictions for 2018 were not too high but accurate or even too low. Actual AuM for 2018 of c. €4bn[111] lie exactly in the prediction interval of *Oliver Wyman's* study[112] of €3.2bn - €4.2bn[113] and noticeably above *Statista* predictions of €3.2bn[114]. Predictions for 2017 were more than tripled according to *Investors Inside*.[115]

Further, experts see a consolidation happening in the robo adviser market. *Vaamo*, a pioneer in the robo advisory market in Germany, was recently bought by *Moneyfarm*, a British digital asset manager.[116] This consolidation in the market is seen as a sign that the market is maturing and experts predict that this consolidation will continue as that is was naturally happens in a maturing market.[117] Another possible trend is that robo advisers will increasingly partner with big banks (which is partially already happening) as they are needed as a distribution channel.[118] Further, the product range might widen[119] and there might be a shift towards more individualization, automation and higher complexity overall, as can already be seen in the US[120].

Summarized, no exact predictions can be made about the future of the robo adviser market, but experts agree that the market will continue to grow and mature.

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[108] See Appendix 4, Interview 1, 10.
[109] See Appendix 4, Interview 10.
[110] See Appendix 4, Interview 3.
[111] See Appendix 11.
[112] Oliver Wyman, 2017, p. 3.
[113] $3.6bn - $4.8bn converted with exchange rate as of March 3rd 2019: 0.88.
[114] See Appendix 10.
[115] Investors Inside, 2019.
[116] Investors Inside, 2019.
[117] See Appendix 4, Interviews 1, 2, 11.
[118] See Appendix 4, Interview 1.
[119] See Appendix 4, Interview 4.
[120] See Appendix 4, Interview 8.

2.3 Chances and Risks of Robo Adviser Providers

The fast growing robo advisory market is not a random phenomenon but happening because of the very promising advantages and chances robo advisers offer.

AuM of robo advisers all around the world are constantly growing because potential investors see the advantages the new industry offers. First, robo advisers mostly charge lower, sometimes even significantly lower, fees for their services compared to regular financial advisers[121], as can also be seen in chapter 2.2.1. Additionally, the minimum investment at a robo adviser is usually lower than human advisers' minimums, opening the access to investment advice to a wider range of customers.[122] These advantages for investors are also chances for the robo advisers themselves. Leaving the portfolio decisions and creation to an algorithm without constant human involvement decreases the costs for the robo adviser company[123], which then makes it possible to offer lower fees to customers. Lower fees and lower minimum investments are not only positive for investors but also for the providers of automated financial advice as they get access to a wider range of customers. For example, robo advisers can offer retirement planning for people with lower income that could not afford or do not meet the minimum investment for human advisers or for younger and internet savvy people that would otherwise not use advisers at all.[124] Further, visual input that helps the user to better understand the content can be used when offering services online.[125]

On the other hand, robo advisers offer only little information to customers about how exactly the service works.[126] When talking to a human adviser, interested customers can simply ask how the adviser derives at the portfolio suggestion. The lack of accessible information is also a well discussed topic and led

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[121] Iannarone, 2018, p. 148; Joint Committee of the European Supervisory Authorities, 2016, p. 16; Dapp, 2016, p. 2.
[122] Joint Committee of the European Supervisory Authorities, 2016, p. 16; Dapp, 2016, p. 2.
[123] Joint Committee of the European Supervisory Authorities, 2016, p. 19.
[124] Maume, 2018, p. 20.
[125] See Interview 9.
[126] Joint Committee of the European Supervisory Authorities, 2016, p. 9.

consumer protection authorities in Germany to the conclusion, that further regulation is needed in order to provide better information about the service to investors.[127] Other risks include the appearance of possible legal disputes due to unclear allocation of liability[128] as a direct contact person at a robo adviser is harder to find than when dealing with a human financial adviser. Further, some robo advisers only use little information to derive at the suggested portfolio[129] which could lead to a low-quality service as the investment advice is not individual and not suitable for the investor's personal situation. Also, it could lead to similar suggestions for a wide range of people which misses the point of getting individual investment advice and could, on a large scale, lead to imbalances in the market.[130]

The risks represented by robo adviser providers themselves are small compared to the chances as most risks are posed by the algorithm of robo advisers. This will be discussed in more detail in chapter 3.3 after having gained a more comprehensive understanding of robo adviser algorithms and algorithms in general.

Summarized, robo advisers have many benefits explaining the growth of the market and showing how important it is for regulators to support them. It is important that the industry is not being over-regulated for start-ups and other companies to be able to offer robo advisory services without having to face too many legal obstacles. A functioning, growing and competitive market is best not only for the companies but also for the customers.

2.4 Investment Strategies

Every robo adviser uses algorithms but they differ depending on the robo adviser. One reason explaining why they are different is the chosen investment and portfolio management strategy that robo advisers follow.

What all *BaFin* regulated robo advisers have in common is that they categorize investors into different risk classes and select the optimal mix of higher

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[127] Verbraucherzentrale Bundesverband e.V., 2018.
[128] Joint Committee of the European Supervisory Authorities, 2016, p. 9.
[129] Iannarone, 2018, pp. 154–155.
[130] Maume, 2018, p. 20.

risk securities (e.g. stocks) and lower risk securities (e.g. bonds)[131] for the re-
spective risk category. As of now, this is not done individually but the robo ad-
visers have a specific number of predefined portfolios which the customers are
then assigned to. How the distribution of securities in each risk category is de-
termined is not apparent but could possibly be done through fundamental analy-
sis by using the past returns and risks for predicting the future. The long-term
alignment of the portfolio, meaning the selection of the security classes, is called
strategic allocation and is the most important part of the investment strategy.[132]
Dirk Rathjen believes that many start-ups and also banks do not know how to
correctly do strategic allocation and that there is not much foundation behind
their allocation.[133]

The difference in strategies can especially be observed in how the portfolio
management is executed after the initial investment. Overall, strategies used by
German robo advisers are either passive or active strategies.[134]

Passive Strategies

The passive strategy followed by German robo advisers is called buy-and-hold
strategy, which is the most commonly used amongst German robo advisers.[135]
The main difference of this strategy to an active strategy can not be found in the
first part, the allocation of the investor to the portfolio, but in the second step,
the portfolio management. The goal is to keep the initially determined
stock/bond ratio the same. This process is called rebalancing[136] and was already
discussed in a previous part of this thesis[137].

Active Strategies

Active strategies can further be divided into Value-at-Risk (VaR) and factor in-
vesting.[138]

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[131] handelsblatt.com, 2018.
[132] See Appendix 4, Interviews 1, 10.
[133] See Appendix 4, Interview 10.
[134] See Appendix 4, Interviews 1, 2, 8, 11.
[135] Robo advisers such as *quirion*, *fintego*, *growney*, *investify*, *easyfolio*, *Sutor Bank*, *vaamo*, *VisualVest*, *WeltInvest*, and more are using that strategy.
[136] Baumanns, 2016, p. 3.
[137] See 2.1.
[138] Hilmes, 2017; Naegele, 2017.

VaR was developed in the 1980s and has been used as a financial tool since then. It is a way to quantify risk. VaR defines the yearly loss that will not be exceeded with a probability of 95%.[139] A VaR of 20% for example means that a loss of more than 20% per year will only occur with a 5% probability or in other words, during a 20-year time-period a loss of 20% will occur once. The VaR is a quantitative risk model to create and regulate the portfolio which can lead to significant differences in stock percentages in the portfolio[140], as rebalancing in this case does not mean to bring the portfolio back to a specific stock/bond ratio. Rebalancing when using the VaR method means, keeping the portfolio at a pre-defined risk. In times of a strong market, a VaR-20% portfolio for example can lead to a stock ratio of over 80%[141], whereas the stock ratio can decrease to about 40%, which was the case for the VaR-20% portfolio at *Scalable Capital* in February 2018 when the DAX fell ten percent in only three weeks.[142] This adjustment according to the risk profile can be of advantage as risk is easier quantifiable and manageable than return but can also lead to lower returns than the buy and hold and the factor investing strategy according to a study by IVA.[143] According to that study, *Scalable Capital*'s strategy can explain why their portfolio fell by 8.3% during that timeframe, whereas portfolios of robo advisers using other strategies only fell by 4.3%-6.0%[144]. The VaR strategy leads to higher stock holdings in the portfolio during less volatile ('good') market times and lower stock holdings during more volatile ('bad') market times. Imagine a sudden 'crash' or market downturn happens, which usually does without obvious and previous indications, where the VaR-managed portfolio consists of 80% stocks. The percentage of stocks in the portfolio is only decreased shortly after the downturn when the return of the formerly included 80% stocks was already negatively affected. On the other hand, when the market is low with a high vol-

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[139] Cao Minh Duc, Faseruk, & Hossain, 2018, p. 88.
[140] Ritter & Beck, 2018, p. 1.
[141] As was the case for the VaR-20% portfolio at *Scalable Capital* end of 2017/beginning of 2018 according to Scalable Capital, 2018.
[142] Ritter & Beck, 2018, p. 2.
[143] Ritter & Beck, 2018, p. 3.
[144] brokervergleich.de, 2019.

atility, the stock holding percentage is also low, keeping the risk low. The following upturn of the market would only be participated by the low percentage of the stocks included in the portfolio at that time.

Summarized, the VaR-strategy tends to hold many stocks in a good market which then are all affected by a downturn and the percentage of stocks in the portfolio is usually adapted a little too late. Therefore, the VaR-method can be classified as a pro-cyclical approach, adjusting the portfolios in accordance with the market.[145] German robo advisers that follow this approach are *Scalable Capital*[146] and *Whitebox*. According to Erik Podzuweit, founder of *Scalable Capital*, the advantage for the investor of using VaR as the risk indicator is, that the risk is quantifiable, and customers do not have to interpret what portfolios with the name 'low risk' or 'high risk' mean.[147]

The second active strategy, called factor-investing, is similar to the VaR-method but it follows an anti-cyclical approach, meaning securities are being bought when the price is low and sold when it is high.[148] Most prominently *ginmon* follows this anti-cyclical strategy which is additionally based on the *Fama/French* model.[149] The *Fama/French* model states that the return of a portfolio can be increased by choosing three specific types of investment for the portfolio. First, the model suggests choosing stocks in general, which have higher returns than other asset classes like government bonds for example. Second, small-cap stocks, meaning stocks from smaller companies perform better in the long run than big companies. Third, value companies perform better than growth companies according to *Fama* and *French*. A value company is defined as having a low price-to-book value, meaning their stock is trading at a lower value than their intrinsic or book value, making the company undervalued. Theoretically, in a perfect market, undervalued companies will gain in value on the stock market in order to be priced properly. This then leads to a gain on the

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[145] Hilmes, 2017.
[146] Scalable Capital, 2018.
[147] Scalable Capital, 2018.
[148] Hilmes, 2017.
[149] ginmon, 2018.

investment, if the stocks were purchased at the time of the company being undervalued.[150]

Influence of the Strategy on Algorithms

Neither these strategies nor the service robo advisers offer is something completely new or innovative to the investment world. Simply the way robo advisers offer the service, through an online platform available to a broad audience, is the innovation. Therefore, it makes sense that they also use existing investment strategies, that have proven to be successful, for their service. Still, it is important to understand the differences in the strategies as the algorithms are structured accordingly.

As of now, the three strategies discussed are the most commonly used strategies for robo advisers in Germany. Since more investment strategies exist, potential new robo advisers might offer different strategies. The differentiation between the explicit strategies is less important, whereas the distinction between passive and active strategies is very important for this thesis. Passive strategies are less complex, whereas active strategies have a higher complexity. This complexity is automatically conveyed to the portfolio management algorithms.

By studying the strategies, possible differences in the algorithms can be determined. In the first part of the algorithm, the security selection and allocation, differences are small regarding the investment strategy. Though, when it comes to the portfolio management after the initial investment, the algorithms of robo advisers using a passive strategy are less complex than the algorithms using an active strategy as they 'only' rebalance the stock/bond ratio back to a predefined ratio. Adjusting the portfolio based on the VaR strategy, more complex calculations need to be done in order to keep the risk category stable. When examining the factor-investing strategy, it seems that the portfolio management part of the algorithm must be complex as well, since under- and overvalued titles have to be determined in the first place, if that is even possible[151].

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[150] Fama & French, 1992.

[151] If the efficient-market hypothesis in the strong form is true, it is not possible to find under- or overvalued companies as all information is already reflected in the stock prices, see Fama, 1970.

In the following chapters, the relevance of the difference of the algorithms regarding a potential algorithmic regulation will be examined.

3. Algorithms

3.1 Definition

Commonly and informally the word algorithm is used to describe a computer program. 'A program is an algorithm expressed in a programming language'[152], so the usage of the word algorithm in that sense is correct. Still, a computer program is only one option which an algorithm can be used in.

An algorithm can be defined as 'any well-defined computational procedure that takes some value, or set of values, as input and produces some value, or set of values, as output'[153]. Another definition describes an algorithm to be a 'formula, or formal statement of rules, that guides a process'[154]. Simplifying these definitions, an algorithm is the process of transforming input into output.

The exact procedure or process normally consists of determining a sequence of individual processing steps.[155] For example, the desired result is to bake a cake. The algorithm is the recipe which includes individual steps like inserting flour or putting the cake in the oven. In the case of a robo adviser, the first desired result is a suitable investment portfolio suggestion for the respective customer. The algorithm to get there is a coded computer program which consists of individual steps, for example one part of the code handles the first question of the questionnaire and maps the answer to the corresponding outcome.

As computer scientist Donald Knuth famously stated, 'besides […] being a finite set of rules that gives a sequence of operations for solving a specific type of problem', algorithms fulfill all (or most) of the following characteristics:[156]

(1) Static finiteness: The description of the algorithm has a finite length.

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[152] Räcke, 2017, p. 22.
[153] Cormen, Leiserson, Rivest, & Stein, 2009, p. 2.
[154] Baker & Dellaert, 2018b, p. 734.
[155] Räcke, 2017, p. 10.
[156] Knuth, 1997, pp. 4–6.

(2) Dynamic finiteness: The intermediate results obtained during processing are finite.

(3) Termination: Algorithms that deliver a result after a finite number of steps are called terminating.

(4) Determinacy: If the input data is the same, an algorithm outputs the same result.

(5) Determinism: The next step in the procedure to be applied is always clearly defined.

These five characteristics can be applied to baking a cake as well as to the algorithms of a robo adviser. As an example, we will look at the first part of the robo adviser algorithm (the different parts of the robo adviser algorithms will be discussed in more detail in the next chapter). The first part of the algorithm consists of the evaluation of the questionnaire, the so-called suitability assessment, and the arrival at a suggested portfolio. The algorithm is expressed through software code and based on a model of how to best match the input from the customer with the right portfolio suggestion. It fulfills all five characteristics mentioned above as the algorithm has (1) a finite length, it ends when the portfolio is suggested, and (2) the intermediate results are also finite. After each evaluated question for example concrete and finite intermediate results are conducted and saved which all are brought together in the end to come up with the right portfolio suggestion. Further, the algorithm (3) is terminating as it ends after a finite number of steps and if programmed correctly, (4) the result is always the same when entering the same input data. Lastly, (5) each step of the algorithm is clearly defined and there is only one possible way for the algorithm to move forward.

Artificial Intelligent Algorithms and Machine Learning Algorithms

When talking about algorithms, artificial intelligence (AI) automatically comes up in a conversation nowadays. But what is AI exactly? AI in general means that machines can perform tasks intelligently and are not simply programmed to do one task.[157] Another definition states, AI 'provides computers with the ability to

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[157] Mills, 2018.

make decisions and learn without explicit programming'[158]. There exist several different definitions of AI but as the definition of intelligence itself is a big debate, defining artificial intelligence is as well.[159]

As of now, there are some robo adviser algorithms that use machine learning techniques in their algorithms.[160] Machine learning is a sub-category of AI, meaning every machine learning algorithm is also an AI algorithm but not every AI algorithm is a machine learning algorithm.[161] Machine learning makes programs smarter through training instead of being programmed with specific rules.[162] The machine learning algorithm is fed with training data, where the output is known. After processing the input data, the algorithm comes to a conclusion, if the algorithm's output is not correct, the processing function of the algorithms changes to improve the accuracy of the output. The more training data is inserted, the better the algorithm's output accuracy becomes. Therefore, 'the defining characteristic of a machine learning algorithm is that the quality of its predictions improves with experience'[163]. As an example for such an algorithm, a search engine can be used. If you search for the word 'algoritm', accidentally forget the 'h' in between and search for the correct term "algorithm" immediately after, the search engine algorithm recognizes this and keeps it in mind for others who make the same typing mistake. The algorithm then immediately suggests 'Did you mean *algorithm*?' because it has learned that this is a typical mistake users make.[164] The more the search engine is used and typing mistakes are made, the better the algorithm can react to future typing mistakes, due to its machine learning programming.

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[158] Barnett, Koshiyama, & Treleaven, 2017, p. 2.
[159] For more details see Scherer, 2016, pp. 359–362.
[160] See Appendix 4, Interviews 2, 4.
[161] MMC Ventures & Barclays UK Ventures, 2019, p. 20.
[162] MMC Ventures & Barclays UK Ventures, 2019, p. 6.
[163] MMC Ventures & Barclays UK Ventures, 2019, p. 21.
[164] Bell, 2016.

3.2   Differences in Robo Adviser Algorithms

The name robo adviser does not describe one exact business model or company type, as we have already established. Hence, there are also big differences in the algorithms which are the 'heart' of robo advisers.

Firstly, there are two different parts of the algorithm which must be looked at separately and will be discussed in detail under 3.2.1. Secondly, the complexity of the two parts of the algorithm differs between robo advisers. The suitability assessment algorithms mostly differ because of different interpretations of the regulation.[165] The most important driver of the complexity of the portfolio management algorithm is the investment strategy (see 2.4) robo advisers follow. These differences in complexity are elaborated on under 3.2.2.

3.2.1   Different Parts of Robo Adviser Algorithms

When the press or people in general are talking about a robo adviser algorithm, they are usually only talking about the first part of the algorithm. Academic papers also consider the suitability assessment, which is the first part, the 'key algorithm' of robo advisers.[166] Though, the algorithm not only consists of the first part but can be split into two main parts which mostly function independently:

1) Suitability Assessment
2) Portfolio Management

Suitability Assessment

The suitability assessment consists of a questionnaire which the future investor must fill out and the subsequent suggestion of a portfolio. The questionnaire aims to find out about an investor's risk preferences (What risk is the investor willing to take?) and risk bearing capacity (What risk is the investor able to take?).[167] The risk bearing capacity determines the maximum risk the portfolio is allowed to have. Choosing to take less risk is possible for the customer but taking more

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[165] See Appendix 4, Interview 4.
[166] Baker & Dellaert, 2018b, p. 734.
[167] See Appendix 4, Interview 8.

risk than the risk bearing capacity determined is not possible.[168] In order to find out the risk profile of the investor, several questions are asked and must be answered by the customer. The algorithm is a simple mapping of calculated risk profiles to pre-defined portfolios. All robo advisers as of now have a specific number of portfolios and have their own definition of which risk profile fits which portfolio. How the firms come up with the different portfolios and the associated risk levels is independent of any algorithm. The risk levels of the portfolios can be chosen by the firm in accordance to their strategy. For example, a firm is allowed to only offer portfolios with stocks and differentiate risk levels within this assets class. Another provider might offer portfolios with both, stocks and bonds (as most robo advisers do in Germany), leave the asset allocation within each asset class the same and declare a portfolio with 100% stocks the riskiest. In this case, all offered portfolios of provider A would be as risky as the riskiest portfolio of provider B (if a simplification is used and stocks in general are considered risky and bonds less risky). The regulator checks whether a customer with a given risk profile is matched correctly to a portfolio with a similar risk level, but they do not regulate how the firm comes up with the risk levels as that would include the regulation of the strategy.

The suitability assessment is an important topic for the EU and therefore also for the German regulation. The importance is underlined not only by Art. 25(2) of MiFID II but also by Art. 54 and 55 of the commission delegated regulation 2017/565 which is supplementing MiFID II and by the published *European Securities and Market Authority* (ESMA) Guidelines on the suitability assessment. Art. 25(2) of MiFID II states that in order to assess a client's suitability, the investment firm has to attain specific information about the client including (1) the client's knowledge and experience in the investment field, (2) the client's financial situation including his ability to bear losses and (3) his investment objectives including his risk tolerance. The supplementing delegated regulation and the ESMA guidelines further explain what exact information has

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[168] question answered by the founder of Scalable Capital at an information session, see Scalable Capital, 2018.

to be asked of the customer and how this should be done in detail.[169] This shows not only the importance of the suitability assessment to the regulator but the detailed descriptions also help robo advisers to eliminate the uncertainty about the questionnaire[170]. The market also views the suitability assessment as regulated very detailed and *BaFin* puts a focus on regulating it. The suitability assessment itself is not unique to robo advisers but must be done by every investment firm giving investment advice or offering portfolio management services. The unique thing about the suitability assessment for robo advisers is that it is entirely done through an algorithm, meaning the questionnaire is filled out online by the client himself and the mapping to a suitable portfolio is done by the same algorithm right after. A human adviser usually fills out the questionnaire together with the client but for the mapping of the portfolio he also uses an algorithm. The risk that the inserted data is used incorrectly because wrong connections are being made inside the algorithm is not only applicable for robo advisers but is also prevalent for human advisers, according to an employee of *BaFin*.[171]

Robo advisers that do not have the portfolio management license but the broker license according to § 34f GewO also do a short form of a suitability assessment according to an employee of a robo adviser with such a license.[172] They use the gained information to advise a customer against a non-suitable portfolio if that customer wanted to choose it. The difference to robo advisers with the portfolio management license is, that the customer at a broker can nonetheless choose the portfolio, that does not align with his risk profile. The customer at the other robo adviser cannot choose a portfolio with a higher risk than his own risk profile.

Portfolio Management

The second part of the algorithm covers the portfolio management. Almost all robo adviser providers have the license to do portfolio management and none have the license to only provide investment advice as of March 2019. Some robo

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[169] ESMA, 2018.
[170] See Appendix 4, Interview 7.
[171] See Interview 9.
[172] See Appendix 4, Interview 11.

advisers on the market only have the § 34f GewO license and are not being regulated by *BaFin*. Since they also perform rebalancing according to an interview with an employee of a robo adviser with the § 34f GewO license[173], these robo advisers will be viewed the same as those robo advisers doing rebalancing with the portfolio management license in this thesis. The portfolio management algorithm comes into place after the suitability assessment and the matching of the portfolio with the client. The client gives the financial institute the right to adjust the portfolio without further consultation within the given risk parameters. This is where the former mentioned strategies come into place. There are robo advisers which only do rebalancing and there are robo advisers which use complex risk-based models to adjust the portfolios. When looking at the algorithms it is important to differentiate between these two approaches because the algorithms only doing rebalancing are a lot less complex than the ones with a more mathematical and risk-based approach.[174] The strategies robo advisers follow are not regulated by *BaFin*.[175] Therefore the portfolio management algorithm can be programmed as wished as long as the resulting portfolio changes stay within the results of the suitability assessment. According to the guidelines by *ESMA*, there must be regular checks on whether the suitability assessment about a client is still correct, meaning it is not enough to assess once in the beginning in case of an ongoing relationship.[176]

Summarized, two things must be differentiated. The two parts of the algorithms and within the second part, the different approaches of managing the portfolio. The suitability assessment and the mapping of the customers to the respective portfolios does not have to be differentiated any further because it is done similarly at all providers. These differences will be important in the following parts of the thesis as they are essential when concluding about what and how algorithms should be regulated. The different complexities in robo adviser algorithms will be further discussed in the following chapter.

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[173] See Appendix 4, Interview 11.
[174] See Appendix 4, Interviews 2, 8.
[175] See Interview 9.
[176] ESMA, 2018, p. 45.

3.2.2   Complexity of Robo Adviser Algorithms

The algorithms of robo advisers are not published and no public information can be found about how complex or how costly the creation of them is. By conducting expert interviews, it was possible to get an insight on this topic, which is important to answer the question of a possible regulation as its execution strongly depends on the complexity of the algorithms.

Two main findings can be extracted from the expert interviews in regard to the complexity of the algorithms. First, the algorithm for the suitability assessment is not very complex as it uses a simple mapping mechanism.[177] This means that answers are mapped to a specific portfolio or specific portfolios are excluded due to an answer, e.g. if you are over 50, portfolios with a high stock ratio are excluded. How the answers are considered and influence the outcome is up to each robo adviser and can probably be complicated in the conception phase. Though the programming of the algorithm is not very complex, the suitability assessment itself can be complex because the regulation must be fulfilled.[178] The interviews also showed, that either the complexity of the suitability assessment algorithm is viewed and described differently by robo adviser employees or that the extent to which the complexity of the regulation is considered, differs. So overall, the suitability assessment has concrete regulatory specifications that need to be addressed which can be done through a scoring system, meaning the outcome portfolio suggestion depends on the score a customer gets due to his questions. The programming of this scoring system and the respective portfolio suggestion is not very complex, which is congruent with most of the information received through the interviews.

The second finding about the complexity of the algorithms was, that portfolio management mainly has two types of algorithm complexity. The robo advisers doing rebalancing stated that the portfolio management algorithm is not very complex and easy to program. Others that use risk-based and more mathematical approaches described their portfolio management algorithm as complex.

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[177] See Appendix 4, Interviews 3, 8.
[178] See Appendix 4, Interviews 4, 6.

Erik Podzuweit said that it took almost 24 months to program the algorithm which has over100.000 lines of code and that they have nine to ten programmers constantly working on the algorithm. Especially the tax system in the three different countries they are operating in makes it more complex.[179] Another robo adviser provider stated that the portfolio management is still completely done by humans who then give the order to execute the shifting of the portfolio to a computer program.[180] Therefore this program has no decisive power on its own.

Another topic that has to be covered when talking about the complexity of algorithms is AI. Two out of the seven interviewed robo advisers stated that they are already using machine learning for the purpose of optimizing the algorithm.[181] Another robo adviser provider stated that they are currently thinking about the implementation of machine learning techniques to gather additional market data and use it for the construction of the portfolio.[182] The problem is, that it might happen that the algorithm gets to a point where certain output cannot be explained by programmers anymore as the algorithm learned itself. Still, machine learning is better defined and can better be described than AI in general.

This shows how differently complex the algorithms of robo advisers can be, which will come up again when discussing a possible regulation of the algorithms.

3.3 Chances and Risks of Algorithms and AI

After already having established overall chances and risks of robo advisers, this chapter focuses on the chances and risks of robo adviser algorithms and AI.

An important advantage that algorithms in general, and robo adviser algorithms especially, have compared to human advisers is the absence of behavioral biases.[183] These behavioral biases that human advisers tend to use include things

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[179] See Appendix 4, Interview 2.
[180] See Appendix 4, Interview 6.
[181] See Appendix 4, Interviews 2, 4.
[182] See Appendix 4, Interview 3.
[183] Iannarone, 2018, pp. 154–155.

such as using heuristics or anchoring when giving financial advice or being over-confident and following herding behavior.[184] Using algorithms to give financial advice avoids these behavioral biases if the algorithm is well developed[185] and can lead to objectively correct decisions[186]. Another advantage is that the usage of an algorithm makes it possible for the firms to offer services such as robo advisory more easily and to a broader audience, which are basically the advantages robo advisers in general display.

Despite the advantages algorithms offer, some people argue that the algorithm also poses the largest risks at robo advisers. These risks include possible flaws to the functioning of the system due to errors, hacking or manipulation of the algorithm.[187] Compared to a human adviser, who can make errors as well, a problem in the algorithm would not be limited to a single person but would affect all users of the robo adviser at the same time. [188] In 2016, *Blackrock* already saw potential problems with the algorithms and suggested an algorithmic due diligence and supervision of robo advisers.[189] Another problem is that the algorithm is dependent on the quality of the input that the investors provide. This can be better guided by human advisers who are able to ask and answer questions. Further, humans can use their intuition to assess the customer's answer and ask more detailed if necessary.[190] It is also argued that so far robo advisers only existed in bull markets and markets with a low interest environment, not having experienced drastic downturns or volatile markets yet.[191] Customers therefore cannot know for sure if robo advisers, i.e. algorithms, are prepared for such market conditions and how they will react in this case. This risk is especially important for full-service robo advisers that include active portfolio management as they automatically adjust the portfolio weights according to how the market is performing at the moment. On a larger scale, meaning if robo advisers grow and get more

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[184] For detailed information see Baker, Filbeck, & Ricciardi, 2017, pp. 25–26.
[185] Maume, 2018, p. 20.
[186] See Interview 9.
[187] Joint Committee of the European Supervisory Authorities, 2016, p. 9.
[188] See Appendix 4, Interview 8; Maume, 2018, p. 20.
[189] BlackRock, 2016, p. 10.
[190] See Interview 9.
[191] See Appendix 4, Interview 11 and Kaya, 2017, p. 10.

AuM, this could lead to an influence of markets and a possible downward spiral.[192] High frequency trading algorithms have already shown that it is possible for algorithms to influence markets.[193] Robo adviser algorithms are not high frequency traders but if they gain market share and the algorithm performs erroneous trades, it is possible to imagine that markets are influenced.

As already mentioned, some robo advisers use machine learning in their algorithms and more complex AI algorithms will most probably be used in robo advisers in the future. AI adds further risks to algorithms leading to problems when trying to regulate these intelligent algorithms. These risks include the loss of control of the algorithm, the development of the algorithm in unforeseeable ways and therefore a potential debate about the liability as the algorithm evolved itself.[194] Regulating robo adviser algorithms that use AI will not be the only problem regulators have as AI is constantly evolving in many different areas.

Within robo advisers, different complex algorithms exist. Algorithms that fulfill clear defined tasks only, with little complexity, such as rebalancing, only have a small probability of the mentioned risks happening compared to more complex algorithms. These algorithms might rebalance the portfolio in the wrong way but since the algorithms are not very complex, the chance of it happening is very slim. Making sure that these risks are under control can be done through thorough testing, good documentation of the functioning and changes to the algorithm and other standard procedures, most programmers follow anyways. When algorithms get more complex, for example if they make their own decisions, based market movements, the risks get higher as the chance of the algorithm not functioning properly gets higher because it is more complex and harder to obtain standards. With the usage of AI the complexity grows and it might happen that the programmer cannot even explain the functioning of the algorithm anymore as it has evolved over time.[195] Overall, the risks are the same for differently complex robo adviser algorithms. Though, the probability of them

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[192] See Interview 1.

[193] For more information see U.S. Commodity Futures Trading Commission / U.S. Securities and Exchange Commission, 2010.

[194] Scherer, 2016, p. 359.

[195] See Appendix 4, Interview 7.

happening gets a lot higher the more complex algorithms get because it is harder to control the functioning of them.

The many risks that are imposed by robo adviser algorithms make them the riskiest part about robo advisers, still it is the least regulated one. The risks robo advisers and especially their algorithms pose to investors and markets are significantly different to the risks that regular investment advice and portfolio management has, showing the need for these risks to be addressed by regulators. As robo advisers and the usage of algorithms also offer chances, a trade-off for the regulation between supporting a growing robo adviser market and addressing the risks of it, is very important and a challenge for regulators.

The following chapter covers the regulation of robo advisers. This includes the regulation of financial markets, the current regulation of robo advisers by law and in practice and relevant norms from MiFID II with a focus on the regulation of algorithmic trading.

4. Regulation

4.1 Duties of Regulators and the Role of Financial Market Regulation

The *International Organization of Securities Commissions* has formulated 'objectives and principles of securities regulation', naming the three main objectives to be (1) protecting investors, (2) ensuring that markets are fair, efficient and transparent and (3) reducing systemic risk.[196] As financial markets regulation is done on a national level[197], these objectives are not necessarily applicable in every country. Though, when looking at the objectives on a European and a German level, strong similarities can be found. ESMA is a regulatory body on European level. Its main objective is to enhance investor protection, achieve orderly markets and maintain financial stability.[198] On a German level, *BaFin*'s goals are similar. Its primary goals are to 'ensure the proper functioning, stability and

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[196] International Organization of Securities Commissions, 2010.
[197] Maume, 2018, p. 28.
[198] ESMA, 2019a.

integrity of the German financial system'.[199] The general line of approach for financial market regulation is therefore aligned between Germany, Europe and the world. When discussing the regulation of robo adviser algorithms, the three mentioned objectives are considered. One of the questions asked before answering the research questions is therefore: 'Does the lack of algorithmic regulation of robo advisers negatively influence customer protection, a fair, efficient, and transparent market and systemic risk?'.

Supervisory law works principle oriented, meaning it states general clauses that provide information about what must be done in order to minimize the risk when for example doing financial activities. There is no detailed instruction in the law about what that looks like, leaving it up to the companies to come up with a solution how to put the general principles into practice.[200] Additional to general laws, the regulator often publishes papers in which certain aspects are explained in more detail.[201] Sascha Demgensky from *PwC* stated in the interview that the general statements include everything and therefore there is not really a lack in regulation but only insecurities about how to implement these laws.[202]

The most important development in EU financial market regulation in past years was the introduction and implementation of MiFID II. MiFID II was entered into force in July 2014 and is a directive by the EU with the goal to have better regulated and more transparent financial markets.[203] Starting in January 2018, the rules applied on a national level and Germany introduced the new rules as laws through extensive amendments.[204] MiFID II does not specifically mention its applicability to robo advisers but recital 86 of the commission delegated regulation EU 2017/565 states that, given the market's development, automated and semi-automated systems also fall under the regulation to ensure the same level of investor protection. It is therefore possible to use articles from MiFID II as well as German laws when discussing robo adviser regulation as rules from

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[199] BaFin, 2011.
[200] See Appendix 4, Interview 7.
[201] See Interview 9.
[202] See Appendix 4, Interview 7.
[203] European Commission, 2019.
[204] BaFin, 2017c.

MiFID II are incorporated in German Law already and should be interchangeable.

4.2   Current Regulation of Robo Advisers in Germany

4.2.1   Regulation by Law

When discussing algorithmic regulation of robo advisers, the difference in algorithms must be taken into account. There are several reasons why algorithms differ, see previous chapters. One additional reason the algorithms might differ is due to the different types of robo advisers.

As displayed in Figure 4, according to this thesis, three different types of robo advisers exist. Even though the existing laws are not specifically tailored for robo advisers but are meant for human advisers, they can still be transferred to the digital world in most cases. In the following, an overview of the types will be given and relevant behavioral duties and exceptions will be covered.
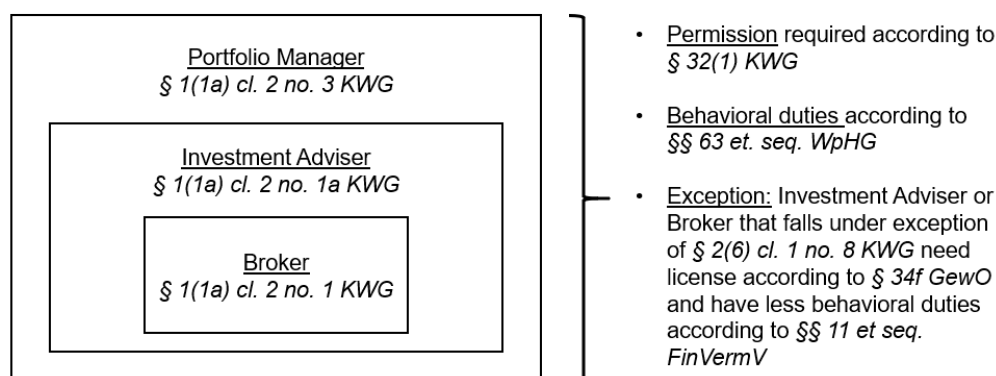
Figure 4: Overview of different legal types of robo advisers and their permission requirements and obligations[205]

Broker

On the lowest tier, a robo adviser can be a broker[206] according to § 1(1a) cl. 2 no. 1 KWG. A broker performs intermediation in transactions relating to the acquisition and sale of financial instruments. This means the broker serves as a

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[205] Own illustration.
[206] In German: Anlagevermittler.

messenger for the investor and is not allowed to give individual investment advice but merely information about possible investment products.[207] The given information must be correct and is usually displayed with a focus on the marketing of the product to increase the probability of the investor 'buying' the product.[208] The customer then decides what he does with the given information and if he wants to invest money in the advertised products. Even though no advice is given, algorithm-based brokers are still referred to as robo advisers in this thesis as well as in the fintech world, the internet and other papers about robo advice. This shows that the word robo adviser is not a legal description but simply a phenomenon covering several (and partly very different) legal entities. The advantage of having a broker license compared to the investment advice and portfolio management licenses, is that lesser behavioral duties occur according to § 63(11) WpHG. Namely, duties including the commensuration and suitability examination mentioned in § 63(10) WpHG are excluded for brokers. Other duties according to § 63 WpHG still have to be fulfilled.

Further it is possible to avoid the extensive *BaFin* licensing for brokers and investment advice firms if the circumstances explained in § 2(6) cl. 1 no. 8 KWG are given. Accordingly, a *BaFin* permit is not required if investment advice or brokerage is offered exclusively in respect of shares or units in open or closed investment funds in accordance with the *German Investment Code*[209] and in respect of asset investments within the meaning of the *German Investment Act*[210].[211] Even if the robo advice firm chooses this exemption, they still need a permit according to § 34f GewO. The process of receiving that permit is easier than getting the *BaFin* license, making this alternative attractive especially for start-up companies in the beginning to be able to start their business operations right away and apply for the *BaFin* license meanwhile.[212]

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[207] Möslein & Lordt, 2017, pp. 796–797.
[208] Oppenheim & Lange-Hausstein, 2016, p. 2.
[209] In German: Kapitalanlagegesetzbuch.
[210] In German: Vermögensanlagegesetz.
[211] Winheller Rechtsanwälte & Steuerberater, 2018.
[212] Möslein & Lordt, 2017, p. 797.

The second form of a broker[213] regulated in § 1(1a) cl. 2 no. 2 KWG is allowed to give a declaration of intent in the name of the client, whereas in the first case, the broker simply receives and transmits the investor's declaration of intent. For this form of a broker, the mentioned exemption of § 2(6) cl. 1 no. 8 KWG cannot be applied. Further, a robo adviser can be a contractually bound broker according to § 2(10) KWG. In that case, the robo adviser works under the liability of another credit institution and therefore does not need its own license. To avoid complexity and as the two additional forms of brokers are less common for robo advisers, when mentioning a broker in this thesis, the first definition according to § 1(1a) cl. 2 no. 1 KWG or a broker with the § 34f GewO license is meant. As of now, no robo adviser has a *BaFin* broker license but a few have the § 34f GewO license.

Investment Adviser

A robo adviser on the second tier performs investment advice[214] according to § 1(1a) cl. 2 no. 1a KWG. According to Art. 4(1) no. 4 of MiFID II, 'investment advice means the provision of personal recommendations to a client, either upon its request or at the initiative of the investment firm, in respect of one or more transactions relating to financial instruments'. Investment advice is therefore provided if (1) individual advice, including concrete product recommendation is given, (2) to the client or a representative, (3) based on provided personal information of the investor and (4) the information is not only distributed to the public via information dissemination channels.[215] *BaFin* emphasizes the fact, that the recommendation has to be concrete[216], meaning specific ETFs have to be recommended with a precise distribution of how much of the invested money goes into which ETF. Providing individual advice on the other hand seems to be less important to *BaFin,* probably because it is more difficult to circumstantiate.[217] Important for the individual advice is the amount and detail of questions asked beforehand. Also the algorithm has to be able to process the information, use it

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[213] In German: Abschlussvermittler.
[214] In German: Anlageberatung.
[215] BaFin, 2017a, p. 1.
[216] BaFin, 2016.
[217] Only briefly mentioned under the „frequently asked questions" section at BaFin, 2016.

to conclude concrete investment advice and consequently do so.[218] Verifying this is almost impossible as the regulator has no access to the algorithm, therefore it is enough if the investor can believe that the information he provided led to the investment recommendations.[219] The introduction of a regulation of the algorithm could potentially solve that problem as the regulator would be able to verify if the algorithm actually uses the personal information to derive the investment advice.

There are currently no robo advisers on the German market with the investment advice license.

Portfolio Manager

The third and most common form[220] of robo advisers are investment firms with a portfolio management[221] license according to § 1(1a) cl. 2 no. 3 KWG. 'Portfolio management means managing portfolios in accordance with mandates given by clients on a discretionary client-by-client basis where such portfolios include one or more financial instruments' according to Art. 4(1) no. 8 MiFID II, meaning portfolio management firms have the right to manage and change their customers' portfolios without consulting them in advance. An important distinction between a portfolio manager and the other two types already mentioned is, that a robo adviser with a portfolio management license has the right to make investment decisions for the investor, whereas with an investment advice or broker license, the final decision of an investment always lays with the customer.[222] Accompanying the portfolio management license, an investment firm also automatically has the broker and investment advice licenses (see Figure 4).

Permission and Behavioral Duties

Broker, investment advisory, and portfolio management services are subject to permission under § 32(1) KWG with possible exceptions according to § 2(6) cl.

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[218] Möslein & Lordt, 2017, p. 796.
[219] BaFin, 2017a, p. 3.
[220] See Appendix 3.
[221] German: Finanzportfolioverwaltung.
[222] Oppenheim & Lange-Hausstein, 2016, p. 2.

1 no. 8 KWG which were already mentioned before. Accompanying one of those permits, the respective company is obligated to follow certain behavioral duties according to §§ 63 et seq. WpHG. The general obligation an investment firm has is to provide their service with the necessary diligence and contentiousness in the interest of the customers (see § 63(1) WpHG). Also, they are obligated to avoid and disclose possible conflicts of interest to the customer (see § 63(2) WpHG). The following paragraphs of § 63 WpHG then further describe behavioral duties that investment firms i.e. robo advisers have. One important obligation these companies have is that they must do exploration, commensuration and suitability examination before giving investment advice to their customer according to § 63(10) and § 64(3) WpHG. The necessary information they must conduct, includes past experiences of the potential investor with financial instruments, the investor's financial situation, and his investment horizon including the risk tolerance, see § 64(3) cl. 1 no.1-3 WpHG. The algorithm must use this information to derive an investment suggestion and only if the algorithm finds suitable investments based on the given information it is allowed to give advice. Subsequently, the investment firm is obligated to transmit the declaration of suitability[223] to the investor before signing the contract according to § 64(4) WpHG. An exception is being outlined in § 64(4) cl. 4 WpHG, which states that the transmission of the declaration of suitability can be delayed to shortly after the conclusion of contract if the consultation was done via distance communication (as is the case for robo advisers) and if the investor approves. Further, the investment firms not only have the obligation to get information from the investors but also to provide information to them. According to § 83 WpHG the investment firm must record and archive information about the customer and their advice to the customer and if demanded, hand over all stored information to the investor (see § 83(7) WpHG). Before giving advice about specific financial instruments, the firm is obligated to give the potential investor standardized information including details about the company, its services, the financial instruments and all accompanying costs according to § 63(7) WpHG. It is important that market material is marked as such and that all information is unambiguous (see § 63(6)

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[223] In German: Geeignetheitserklärung.

WpHG). In § 82 WpHG the so called best-execution rule is outlined. The rule states that the investment firm must achieve the best possible result for the investor when executing their orders. Best-execution was already introduced in 2007 by the first Markets in Financial Instruments Directive (MiFID), was further addressed and extended in MiFID II[224] and then implemented in the newly formed § 82 WpHG (formerly: § 33a WpHG). MiFID II introduced further control mechanisms for this rule including quarterly execution quality reports, annual top 5 execution venue lists and similar controls.[225] Altogether, MiFID II played a crucial role in the adjustment of almost all paragraphs mentioned above (§§ 63 et. seq. WpHG) which used to be displayed under §§ 31 et. seq. WpHG before 02.01.2018. The obligations of investment firms under §§ 63 et. seq. WpHG are relevant for brokers, investment adviser and portfolio management companies, with some exceptions and differences. Robo advisers that fall under the exception of § 2(6) cl. 1 no. 8 KWG have behavioral duties according to §§ 11 et seq. FinVermV, which are less strict than the duties for the other investment firms. A reason for the obligations being less strict is not evident.[226] An expert mentioned during the interview that there are discussions about the § 34f GewO brokers to be potentially regulated by *BaFin* as well.[227] Behavioral duties for investment firms could be discussed further and in more detail. As this would exceed the scope of this thesis, this will not be done.

4.2.2 Regulation in Practice

The current status of how robo advisory regulation is done in practice is important for the result of this thesis because it should be the benchmark when proposing a possible new regulation for algorithms. The way the current laws are implemented will serve as a starting point to work out missing parts of the regulation regarding the algorithms.

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[224] PwC, 2017, p. 1.
[225] PwC, 2017, pp. 2–6.
[226] according to Baumanns, 2016, p. 9.
[227] See Appendix 4, Interview 11.

Expert interviews are the main source of information for this part as they give the relevant insight into robo advisory regulation from a company as well as from the regulator's perspective.

Robo adviser regulation is implemented through a yearly audit done by certified auditors which is summed up in a report and sent to *BaFin* for review.[228] The main focus of the audit is on the suitability assessment part of the robo adviser.[229] The auditors check every wording of the questions[230] and whether the portfolio suggestion in the end coincides with the risk profile of the investor.[231] This black-box testing is executed by taking different scenarios and checking whether the input of the example investor aligns with the output of the robo adviser i.e. the portfolio suggestion.[232] The testing of the suitability assessment was mentioned by almost every interviewee and was also confirmed by *BaFin*[233] and can therefore be seen as a very important part of the regulation. The auditors also check if the advertisement and the communication to the customers are in line with what the robo adviser actually offers.[234] As long as the communication coincides with the offered product, any investment strategy can be pursued.[235] Even though strategies might be discussed with *BaFin*, they do not regulate these strategies as long as they are communicated correctly to the investors.[236] The general risk of investing therefore remains but it is important that robo advisers are transparent about their products and the accompanying risks so that investors can make informed decisions about which strategy they find the best. Current regulation is strongly focused on the suitability assessment and not on the portfolio management part of robo advisers.[237]

According to an employee of *BaFin,* there is no law that states that the code of algorithms needs to be handed over to *BaFin* but there are principles that state

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[228] See Interview 9 and Appendix 4, Interview 2.
[229] See Appendix 4, Interviews 1, 2, 4.
[230] See Appendix 4, Interview 2.
[231] See Appendix 4, Interviews 1, 2, 3, 8.
[232] See Appendix 4, Interviews 1, 6, 8.
[233] See Interview 9.
[234] See Appendix 4, Interviews 2, 7.
[235] See Appendix 4, Interview 2.
[236] See Appendix 4, Interview 2.
[237] See Appendix 4, Interview 4.

how the processes must be set up when using algorithms.[238] Robo adviser providers mentioned that even though there is no concrete regulation, they still provide the auditors with explanations, flowcharts or walk-throughs of the functioning of the algorithm if asked for it.[239] One statement by an employee of a robo adviser was also that if the auditors asked for the source code they would send it to them, even though that request will probably not come as auditors have no use for many thousands of lines of code.[240] Nevertheless, this statement shows that the regulator already has the means to regulate the algorithms directly if they wanted to. In some cases, *BaFin* itself might visit a robo adviser provider to have a closer look at the company. This can happen additionally to the regular yearly audit in case there have been complaints about a company and is called abuse control audit.[241]

Summarized, even though the algorithm itself is not explicitly regulated as of now, the auditor, as a representative of the regulator, or the regulator itself already has the power to check the algorithm if necessary. The suitability assessment is regulated very strictly and is the focus of the regulation. The portfolio management algorithm is not a priority.

4.3   Relevant Norms of MiFID II for the Regulation of Robo Advisers

The division of robo advisers into the different legal categories in chapter 4.2.1 was important to better understand the differences in licenses German robo advisers can hold as it affects the business the firms conduct. The analysis was based on German law which is the relevant one when talking about German investment firms providing robo advisory services. As all MiFID II articles are incorporated in German law as of January 3rd 2018[242], the directive and German law can be used interchangeably. This chapter will give an overview of relevant articles for robo adviser regulation from MiFID II. Potentially these articles

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[238] See Interview 9.
[239] See Appendix 4, Interviews 3, 4, 6.
[240] See Appendix 4, Interview 6.
[241] See Interview 9.
[242] BaFin, 2017c.

might give reason to regulate robo adviser algorithms. This chapter therefore also lays the foundation, to be able to answer the question if there is a legal reason why an algorithmic regulation of robo advisers in German law must be established. In other words, the goal is to find out if the compliance with current laws (represented by articles of MiFID II) can be ensured without an algorithmic regulation.

Firstly, any investment firm needs authorization before starting its business according to Art. 5 of MiFID II. An investment firm is defined as 'any legal person whose regular occupation or business is the provision of one or more investment services to third parties and/or the performance of one or more investment activities on a professional basis', see Art. 4(1) MiFID II. According to section A of annex I, all services that robo advisers offer, including portfolio management, investment advice and brokerage, fall under the definition of investment activities. Therefore, robo adviser providers are investment firms under MiFID II. Art. 7 of MiFID II and commission delegated regulation (EU) 2017/1943 further define the procedures for granting and refusing requests for authorization. According to Art. 6 of delegated regulation (EU) 2017/1943, a firm applying for authorization must provide the regulator with a program of initial operations for the following three years, including activities to be carried out by the investment firm. As the usage of an algorithm is a main component of the operations of robo advisers, the fact that they are using algorithms should be communicated to the authorities when applying for a license. Art. 6(g) additionally states that firms using algorithmic trading have to notify authorities of that. As will be discussed in following chapters, robo adviser algorithms might fall under the definition of algorithmic trading. Though, even if they were not included in the definition of algorithmic trading, Art. 6 should be interpreted so that applicants are obliged to tell authorities about the usage of algorithms anyways as this is a crucial part of the firms' business model. Authorization requirements according to Art. 7 of MiFID II state that authorization is only given if the regulator is fully satisfied that the applicant fulfills all requirements of MiFID II. As MiFID II does not require a detailed description of the robo adviser's algorithm (unless they fall under the definition of algorithmic trading), a review of

the algorithm before receiving the license is not legally required and is not done in practice[243]. Art. 21 of MiFID II states that investment firms must comply with the conditions for authorization at all times, even after receiving the license.

Art. 16 of MiFID II defines organizational requirements investment firms must comply with. These requirements are outlined in paragraphs 2-10 and include the establishment of adequate policies and procedures to ensure compliance, the maintenance and operation of effective organizational and administrative arrangements to prevent conflicts of interest, the introduction of reasonable steps to ensure continuity and regularity in the performance of investment services and activities and the keeping of records of all services, activities and investments. There are no specific requirements outlined which apply to algorithms, but the general requirements outlined in Art. 16 have to be applied to robo advisers using algorithms.

The next relevant article in MiFID II is Art. 17 about algorithmic trading. This article is not like the others discussed in this chapter as it is not applied to robo advisers currently. The next chapter will cover the topic of algorithmic trading and will show, why the article is important for this thesis.

Chapter II of MiFID II regulates the operating conditions for investment firms. The first section of it covers general provisions whereas section II is focused on the provision to ensure investor protection. According to Art. 23, investment firms have to prevent conflicts of interest between any involved parties and disclose possible conflicts to clients. Art. 24 outlines general principles and the information transmission to clients. Investment firms must always act with the best interest of their client in mind and must provide information about their services, their investment strategies and financial instruments, amongst other things. Art. 25 about the assessment of suitability, appropriateness and reporting to clients was already discussed in more detail in an earlier chapter. The obligation to execute orders on terms most favorable to the client (best execution) is outlined in Art. 27.

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[243] See Appendix 4, Interview 1.

Section III, which covers the rights of investment firms includes Art. 34 stating that investment firms have the freedom to provide investment services and activities and that no additional regulation other than outlined in MiFID II should be introduced by domestic regulators. This means that if a new regulation of the algorithm were to be introduced in the German law, it must have a foundation in MiFID II. One possibility would be to conclude that it is necessary for the regulator to check the algorithm to make sure that the robo adviser follows the best execution rule (Art. 27 MiFID II) or appropriately executes the suitability assessment (Art. 25 MiFID II). This will be picked up again in later chapters.

4.4 Algorithmic Trading Regulation and its Linkage to Robo Adviser Algorithms

The only algorithm that is already regulated in the EU is the algorithm used in algorithmic trading. As Recital (59) of MiFID II states, 'the use of trading technology has evolved significantly in the past decade and is now used extensively by market participants'. The increasing usage of algorithmic trading made the *European Commission* decide to regulate the arising risks of algorithmic trading in MiFID II. The regulation is outlined in Art. 17 of MiFID II.

Robo Adviser Algorithms as Algorithmic Trading Algorithms?

Article 4(1)(39) of MiFID II defines algorithmic trading as 'trading in financial instruments where a computer algorithm automatically determines individual parameters of orders such as whether to initiate the order, the timing, price or quantity of the order or how to manage the order after its submission, with limited or no human intervention […]'. At first glance and with the background that Art. 17 is not applied to robo advisers, one might think that the portfolio management of robo advisers does not fall under this definition of algorithmic trading, which is not entirely true. The suitability assessment and the subsequent investment advice do not fall under the definition as the advice given still needs approval from the investor before the order is executed. This contradicts the definition that limited or no human intervention is included. Those robo advisers which also do portfolio management after the investor approved (or more accurately:

went ahead and invested in) the initial portfolio suggestion, need to be looked at further in regard to the definition above. Within the limits of the risk profile of the investor, the robo adviser algorithm does, or at least is allowed to do exactly what is included in the definition i.e. initiate an order or the timing, price or quantity of an order. Other papers that only include investment advice in the definition of robo advisers (and exclude portfolio management) use the argument, that every order, even after the initial one, still needs approval from the investor, to distinguish between robo advisers and algorithmic trading[244], which is correct if only investment advice is taken into account. Since most robo advisers in Germany have the portfolio management license though, this argument cannot be used. More suitably, one can argue that even though robo advisers have the license to do what is included in the algorithmic trading definition, not many robo adviser as of now actually do it. As already mentioned, most robo advisers still only do rebalancing and small changes to ETFs they invest in, with many providers still including human interventions. Some providers trade more often but, to the best of my knowledge, the most a robo adviser in Germany trades is every two to three weeks.[245] They would still fall under the definition of algorithmic trading which is supported by ESMA who answered the question whether simple algorithms can qualify as algorithmic trading with 'yes'.[246] The trading frequency though opposes the every-second-trading a classic high frequency trader does. Still, the definition of algorithmic trading does not include the need to trade high frequently which is merely classified as a subclass of algorithmic trading according to Recital (61) of MiFID II. It is simply assumed by many that the regulation for algorithmic trading is only relevant for high frequency trading which is underlined by a strong focus on high frequency trading in MiFID II.[247] This belief can further be highlighted by the reason the regulation was initiated in the first place, which is to avoid downward spirals in the market leading to potential crashes because of high frequency traders, as had happened

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[244] Maume, 2018, p. 38.
[245] See Appendix 4, Interview 2.
[246] ESMA, 2019b, p. 16.
[247] See Recital (61) and several mentioning of high frequency trading in MiFID II.

in the US in 2010[248]. Robo advisers in the current state do not pose the same risk as their main goal is stable long-term return[249] which leads them to not trade that often. Further, AuM of robo advisers in Germany are fairly small compared to the total money invested and would therefore not even be able to contribute to a market crash, which could change in the future in case of a rapid growth of the robo advisory market.

In conclusion, even though some robo adviser's services might fall under the definition of algorithmic trading, the current evolution of robo advisers does not pose systemic risk and is therefore exempted from the algorithmic trading regulation. This is not a personal opinion but an attempt to explain why robo advisers are not held against the standards of Art. 17 of MiFID II as of now. Possible other viewpoints or conclusions will be discussed when finding a regulatory solution for robo adviser algorithms in chapter 5. Therefore, the concrete regulation of algorithmic trading is highlighted in the following passages.

Art. 17 MiFID II

According to Art. 17(1) of MiFID II, investment firms that engage in algorithmic trading must follow guidelines 'to prevent the sending of erroneous orders or the systems otherwise functioning in a way that may create or contribute to a disorderly market'. The respective firm must have in place effective systems and risk controls suitable to the business it operates to ensure its trading systems are resilient, have sufficient capacity and are subject to appropriate trading thresholds and limits. Further, the investment firm must have in place effective business continuity arrangements to deal with any failure of the trading systems and must ensure its systems are fully tested and properly monitored to ensure that they meet the requirements mentioned above. Summarized, paragraph one of Art. 17 states the goal of the regulation, which is to prevent the creation of a disorderly market, and names principles that must be followed in order to do so. Regarding the algorithm itself, the paragraph orders the firms to fully test and properly monitor their systems. Art. 17(2) then states that an investment firm, that engages

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[248] For more information see U.S. Commodity Futures Trading Commission / U.S. Securities and Exchange Commission, 2010.
[249] See Appendix 4, Interview 2.

in algorithmic trading, must notify the authorities about it. The paragraph further demands the firms to provide the authorities with all necessary controls and documents to prove that the requirements from paragraph one are satisfied. This includes a description of the nature of its algorithmic trading strategies, the key compliance and risk controls and details of the testing of the systems. The provision of information can happen regularly or on an ad-hoc basis. Also, competent authorities may, at any time, request further information about the algorithmic trading and the systems used for trading. Records of everything mentioned above must be kept, enabling the authorities to monitor compliance with the requirements of the directive, see Art.17(2) of MiFID II. The second article that is relevant for algorithmic trading regulation (and potentially for the regulation of robo adviser algorithms) is Art. 48 of MiFID II. Overall, the article aims at establishing system resilience and circuit breakers in electronic trading through different measures. One of them is the flagging of orders (Art. 48(10)) to be able to identify orders made by algorithmic trading and the different algorithms used for the creation of orders. Interestingly, Recital (67) of MiFID II, which talks about the mentioned flagging, points out that this procedure is necessary for the regulator to be able to detect defective algorithmic strategies and to be able to evaluate these strategies. This is a rare mentioning of a regulation of a strategy behind an algorithm.

Commission Delegated Regulation (EU) 2017/589

To supplement Art. 17 and Art. 48, the *European Commission* has released commission delegated regulation (EU) 2017/589 which explains in detail how the controls and requirements must be implemented in practice. For the purpose of this thesis, only articles in the delegated regulation that might have relevance for the algorithmic regulation of robo advisers are discussed. This excludes chapters III, IV and V of the delegated regulation because they deal with direct electronic access, general clearing members, and high frequency trading which are all topics less relevant for the algorithmic regulation of robo advisers. Chapters I and II on the other hand are very relevant and will be examined more detailed. Chapter I describes the general organizational requirements a firm, which engages in algorithmic trading, must comply with. Art. 1 requires the firm to establish and

monitor its trading systems and algorithms through a clear and formalized governance arrangement. Overall, organizational requirements are already regulated in Art. 16 of MiFID II. Art. 17 of MiFID II and Art. 1 of the mentioned delegated regulation further extend these requirements not only to the firm itself but to the systems and algorithms the respective firm uses. The same applies to all articles under chapter I which are designed specifically for firms using algorithmic trading and therefore augment other articles in MiFID II for investments firms. Art. 2 describes the role of the compliance function more detailed and Art. 3 states requirements about staffing including that employees must have necessary skills to manage algorithmic trading systems and trading algorithms which includes regular trainings for example. The last article in chapter I states that an investment firm is still fully responsible for its obligations even when outsourcing (parts of) their IT.

Chapter II of the commission delegated regulation 2017/589 is called 're-silience of trading systems' and is further divided into three sections with section I being about the testing and deployment of trading algorithms, systems and strategies, section II about the post deployment management, and section III about the means to ensure resilience. Especially section I includes relevant insights into algorithmic regulation. Art. 5 describes the general methodology of how the firm should handle changes of the algorithm. Before updating the algorithm, it needs to be tested properly to ensure that it does not behave in an unintended manner, it complies with regulation and continues to work effectively in stressed market conditions. The article further states that one person in the company has to be responsible to release the changes in the algorithm and that detailed records have to be kept about (1) the nature of the change, (2) the person who made and (3) the person who approved the change and (4) the time of the change. The following article emphasizes the need to do conformance testing to make sure that the algorithm complies with the environment at the trading venue. Further, Art. 8 demands firms to deploy the algorithm in a controlled way which includes the introduction of limits on specific things such as the number of financial instruments being traded, the price, value and number of orders and the strategy position.

Next up is section II which includes three articles and deals with post deployment management. Art. 9 states that the investment firm must perform an annual self-assessment and validation process and issue a validation report on that basis. During the assessment, the firm reviews, evaluates and validates its algorithmic trading systems, algorithms and trading strategies, as well as its governance, accountability, and approval framework, its business continuity agreements and its overall compliance with Art. 17 of MiFID II. The risk management function is obliged to draw up the report, inform the compliance function of any deficiencies identified in the report and hand over the report to internal audit and senior management for approval. As part of the annual assessment, the firm shall do stress tests to make sure that their systems and algorithms can withstand increased order flows or market stresses according to Art. 10. Art. 11 then defines what should be done when material changes to the algorithms or systems are applied. This repeated mentioning of the changing procedure of the algorithm shows how important this part is to the regulator.

In section III, the means to ensure resilience are outlined within articles 12-18. These means to resilience include a kill functionality, meaning a firm must be able to immediately delete all outstanding trades in case of emergency (Art. 12). The firm must also have an automated surveillance system to detect market manipulation (Art. 13) and have business continuity arrangements in place to make sure, the firm is able to do business or to stop doing business without creating disorderly trading conditions (Art. 14). Another mean to ensure resilience is the introduction of pre-trade controls on order entry in Art. 15. These controls include price collars, maximum order values and volumes, and maximum messages limits, amongst others. To minimize the risk of mistakes being made, Art. 16 then introduces the necessity for real-time monitoring while trades are being made and Art. 17 states that post-trade controls have to be implemented as well, which includes the continuous assessment and monitoring of market and credit risk of the investment firm amongst other controls. Lastly, Art. 18 defines the necessary IT security and limits to access. This article is completely based on the IT perspective of the systems and displays how exactly the regulator wants the firm to build and maintain their IT systems and algorithms.

The regulation of algorithmic trading is especially important for this thesis as it is the only European regulation of an algorithm so far. The high degree of detail about the articles described above will be important to understand the suggestion of a possible regulation of robo adviser algorithms in the next chapter.

5. Regulating Robo Adviser Algorithms

This chapter will answer the two research questions of this thesis. First, the question about whether the regulation of robo adviser algorithms is necessary and sensible will be answered. Second, possible solutions about the regulation will be displayed. Finally, a concrete solution is presented, considering all information and knowledge gained throughout the analysis. All previous parts of this thesis are important to understand different aspects of the research questions and their answers.

Beforehand it must be clarified what type of algorithmic regulation is discussed in the following parts as different people understand different things when talking about regulating robo adviser algorithms. When bringing up the topic of algorithmic regulation, many interviewees thought about a content regulation, meaning the regulation of the investment strategies of robo advisers. This is what consumer protectors started demanding last year[250] which was prominently covered by the media[251]. In my opinion, this is the reason why people automatically assume that the regulation of investment strategies is meant when talking about algorithmic regulation. An investment strategy cannot be equated with an algorithm though. The algorithm is merely the mean to put strategy into practice. If a strategic regulation was to be implemented, it would have to be done for the whole financial industry as well and not limited to robo advisers or firms using algorithms. The regulation of algorithms, this thesis is talking about in the following parts, is more a technical rather than a strategic regulation. Technical regulations for example ensure, that the strategy (which can be chosen freely) that is being communicated to the customers is implemented properly by

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[250] See Appendix 4, Interview 5 and Verbraucherzentrale Bundesverband e.V., 2018.
[251] See for example RoboAdvisor-Portal, 2018b; Kannenberg, 2018.

the algorithm, meaning there is no technical error or intentional difference between the communicated and the applied strategy. The regulation of investment strategies will also be discussed as an option later. Therefore, when not mentioned otherwise, the following parts will focus on the technical regulation of robo adviser algorithms.

5.1   Regulation of Robo Adviser Algorithms: Sensible and Necessary?

There might be different reasons making a new regulation for robo adviser algorithms necessary or sensible. One reason could be that the implementation of specific principles from MiFID II into German law is not sufficient when taking into account algorithms. Secondly, risks that arise from robo adviser algorithms might not at all have been considered in any directive or regulation so far. Another reason for an algorithmic regulation of robo advisers that was brought up during the interviews is that the regulation of an algorithm is easier and more efficient than regulating human advisers because once the algorithm is checked for correctness, it reacts the same for every customer.[252] On the other hand, possible disadvantages of additional regulation must be taken into account when discussing the need for regulation. One reason against further regulation is the stalling of innovation. Innovations can basically be any future development of the algorithm that one can think of including advanced AI, new programming techniques and progressive data storing methods. With stricter regulation, it might happen that new innovations cannot be expedited anymore, as Larry Page has also realized, see quote in chapter 1.1. Further, if the algorithms were to be overregulated, the whole product robo advice might be 'killed' and it might happen that companies stopped offering robo advisory services as the additional regulation made it unprofitable to offer the product. On a less extreme side, entry-barriers for start-ups could increase, leading to only banks with enough resources offering robo advisory services, again limiting innovation.[253] Arguments against a regulation also include that robo adviser products are not very complex

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[252] See Appendix 4, Interview 5.
[253] Arner, Barberis, & Buckley, 2015, p. 37 and Appendix 4, Interviews 2, 4, 6, 11.

at the moment and do not pose systemic risk and should therefore not be (over)regulated.[254]

The disadvantages of further regulation were always kept in mind when answering the research questions by proposing the least necessary regulation that still deals with the significant risks that occur. Further, when answering the question of whether robo adviser algorithms should be regulated or not, some differentiations need to be made. Most importantly this thesis differentiates between the first part of the algorithm, the suitability assessment, which is the algorithm mostly referred to when talking about robo advisers, and the second part of the algorithm, the portfolio management. As there are large differences in how the investment firms execute their right to manage an investor's portfolio, a classification of algorithms will be provided for the second part of the algorithm which is especially important when suggesting possible algorithmic regulation.

5.1.1 Algorithm Part One: Suitability Assessment

The suitability assessment algorithm maps customers with a specific risk profile to predefined portfolios with similar risk levels. The question is, whether further regulation is needed to make sure, that the algorithm places customers to the right portfolios.

Overall, the suitability assessment is already regulated strictly which can be seen in Art. 25 of MiFID II, the corresponding technical guidelines by ESMA and statements about the strictness of the regulation by robo adviser providers during the expert interviews. Not included in the regulation is a review of the algorithm as the laws are the same for all investment firms independent of the way they offer portfolio management or investment advice services. During the yearly audit at robo adviser providers, auditors test the functioning of the algorithms usually by doing a black-box testing.[255] This black-box testing can already be considered a mild form of testing an algorithm. One interviewee also stated that they provide the auditors with descriptions of the algorithm in form of flowcharts and stated that if the regulator (either *BaFin* itself or the auditors

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[254] See Appendix 4, Interview 11.
[255] See Appendix 4, Interviews 1, 2, 3, 4.

as representatives) was to ask for the source code, they would hand it over to them.[256] As there are more robo advisers on the German market than the seven that were interviewed for this thesis, it is not certain that the audit is done the same way at every firm. On the contrary, as there are already differences of the way the audit is conducted within these seven providers, it is almost certain that it is done differently at all robo advisers. The need for consistency is the first reason, why some change is needed in the execution of the suitability assessment regulation.

Next, relevant articles of MiFID II will be looked at to analyze if further regulation for the suitability assessment algorithm is needed in order to comply with the directive. Starting at the beginning, during the licensing of the robo adviser provider, certain organizational requirements must be fulfilled and detailed information about the services of the firm have to be provided (see Art. 6 MiFID II). As no information about the practice of the licensing can be found on the internet and no details about it were provided during the interviews, I will assume that similar information as during the yearly audits is shared with the regulator during the license application. This leads to the same result as above: some further guidelines for firms using algorithms are needed to make the application process for a license uniform. For the suitability assessment algorithm, the whole process is very well regulated under Art. 25 of MiFID II and other articles of MiFID II are not violated without an algorithmic regulation of the suitability assessment in my opinion. Therefore, further articles from MiFID II are not looked at. There are people demanding an even more concrete regulation of the suitability assessment especially regarding the questions of the questionnaire. The discussion of that would go beyond the scope of this thesis as the focus is on the algorithm of robo advisers.

The only potential risk of the suitability assessment algorithm is that it could possibly mismatch customers to wrong portfolios. This could happen because of wrong programming, errors in the systems that are not detected or customer input scenarios that have not been considered in the program. Systemic

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[256] See Appendix 4, Interview 6.

risk, potentially influencing whole markets, does not appear in this part of the algorithm.

Summarized, there is need for an adjustment of regulation because of differences in the execution of the yearly audit and the licensing procedures regarding the suitability assessment algorithm. Further, the risk of a potential mismatch between customers and portfolios by the algorithm is not addressed by regulation and is up to the firm currently. The answer if a regulation of the suitability assessment algorithm is necessary and sensible is therefore a 'soft yes'. It is called a 'soft yes' because there are reasons that vindicate change, but these reasons are not urgent nor particularly dangerous. Therefore, possible suggestions about what to change will not be drastic. The solution offered by this thesis will be presented in chapter 5.3.

5.1.2 Algorithm Part Two: Portfolio Management

The second part of robo adviser algorithms is the portfolio management. When asked, which algorithm is more complex, interviewees answered very differently. Some said it is without a doubt the portfolio management[257], whereas others said, the first part is more complex[258]. Since the programming of the suitability assessment is similarly complex for every provider, this shows that the portfolio management algorithms are very different. In order to answer the question of whether portfolio management algorithms need to be regulated, a classification of algorithms needs to be done beforehand as the algorithms are too different to give the same answer for all.

Classification of Portfolio Management Algorithms

The need for a classification emerged during the expert interviews when the extend of differences between algorithms was clear. The goal of the classification system is to be able to answer the question of whether regulation of robo adviser algorithms is necessary and sensible and what possibilities for a regulation exist

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[257] See Appendix 4, Interviews 2, 3, 4, 8.
[258] See Appendix 4, Interviews 1, 6.

for each class. The classification as of now is only for robo adviser algorithms and is strongly aligned with robo advisory services. It is based on three criteria:

(1) The complexity and explainability of the algorithm on a scale from 1-10.
(2) The degree of AI used.
(3) The services the algorithm is able to execute.

Complexity and explainability are not exactly the same but explainability is strongly influenced by complexity and has the same number on the scale for each class. Therefore, complexity and explainability make up a category together. The scale starts at one which represents the qualitative statements about the algorithm: 'low complexity/not complex' and 'very easy to explain'. On the other side of the scale, a ten means: 'high complexity/very complex' and 'very hard to explain'. The numbers in between are distributed equally. A scale of numbers which represent qualitative features can sometimes be hard to interpret as everybody understands explanations like 'low complexity' or 'high complexity' differently. Therefore, the classes are also based on the degree of AI used and the services the algorithm can execute. These two categories give further inside into the complexity of the algorithm.

Classification	Complexity/ Explainability Scale 1-10	Degree of AI	Services provided
CLASS A	1	No AI	rebalancing + reinvestment
CLASS B	2	No AI	rebalancing + reinvestment + trading with human input
CLASS C	5	No AI	rebalancing + reinvestment + trading without human input

CLASS D	6	AI - Machine learning	rebalancing + reinvestment + trading without human input
CLASS E	>7	AI	rebalancing + reinvestment + trading without human input

Table 1: Classification of robo adviser algorithms[259]

Class A portfolio management algorithms are not complex, easy to explain and do not use AI. The service they provide is only rebalancing and reinvestment of returns. Typically, robo advisers with the broker license fall under this class of algorithms as they are not allowed to trade within a customer's portfolio after the initial investment. All they are allowed to do (or do anyways) are the two services mentioned above.

Class B algorithms are a little more complex than class A algorithms, do not use AI and besides rebalancing and reinvestment they are also able to trade securities after receiving the necessary input about what to trade from a human. This type of algorithm is used by robo advisers with the portfolio management license. They usually follow a passive investment strategy and do not trade often, instead they only change ETFs sometimes. For this change of ETFs they do not need the approval of the investors which is the big difference to robo advisers with a broker license.

These two types of algorithms do not pose any great risks as they do not make their own decision about buying or selling a security. Still, the correct functioning of rebalancing, reinvestment and trade execution algorithms needs to be ensured.

Class C algorithms differ from class B algorithms as they are programmed to make own investment decisions. They do not need a person to tell them to sell or buy a security, they are programmed to follow a specific strategy and trade accordingly. Often this strategy is a dynamic risk management which has the

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[259] Own table with own classification; some information/inspiration used from Tutt, 2016.

goal to keep the risk of the portfolios the same, by varying the stock and bond rates according to the market situation.

Class D algorithms do the same as class C algorithms. The only difference is that they additionally use machine learning to optimize their performance. What is important to know about class D of robo adviser algorithms is that algorithms already exist that fall under this class, which is a big difference to class E. There are already robo advisers in Germany which use simple machine learning techniques to improve the performance of their algorithms.[260] According to the robo advisers, these algorithms are not very complex and can still be explained. Still, as the algorithms not only consist of rule-based programming anymore, a new class is necessary. Therefore, six was chosen on the scale of complexity and explainability.

Class E is a class that no algorithm belongs to so far. Even though the goal is to define relevant classes for the existing algorithms, the possible (near) future must not be ignored. AI is a big topic these days and it is almost certain that it will become even bigger in the future. Innovations around AI are thriving and it is very likely that robo advisers will start using more complex AI other than simple machine learning techniques in the future. One example of the development of AI in a similar area is the first AI powered equity ETF established by a US company called *EquBot*. The algorithm works completely without human input and chooses investment options just like a person would but only with a lot more data in relation to the processing time it needs.[261] As long as innovations such as this AI powered ETF arise, there is no indication that more advanced AI will not be established within robo advisers as well. Robo advisers in the US are already experimenting with AI. American robo adviser *Wealthfront* for example uses AI for an additional feature called 'Path' which is able to provide answers to questions like when you can retire or which neighborhood you can afford to live in. *Betterment* uses AI for some back-office tasks such as check processing.[262] Class E algorithms are not a main focus of this thesis but are included

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[260] See Appendix 4, Interviews 2, 4.
[261] RoboAdvisor-Portal, 2018a.
[262] Konish, 2018.

anyways to show that it is important to not only look at the current picture when regulating innovations but to also try to have possible future developments in mind.

Class C, D, and E algorithms have potential to pose risks to markets as the trading is done automatically and without human input. These algorithms should be regulated. Further, the usage of machine learning (class D) or even more advanced AI (class E) call for an even higher degree of regulation. These types of algorithms can potentially lead to investment firms not complying with MiFID II articles anymore. For example, it might be possible that the best interest of the customer is not taken into consideration anymore (see Art. 27 MiFID II) as the algorithms are trading wrong products for the investors' risk profiles. This needs to be reviewed.

The overall conclusion that the algorithms should be regulated, is not an isolated opinion. *BlackRock* stated in a paper about robo advice in 2016 that an effective supervisory framework for the supervision of robo adviser algorithms is important and even included some suggestions for such a framework.[263] Other researchers also suggest that algorithms should be regulated, especially once robo advisers reach mass market scale.[264] Demands about the regulation of robo adviser algorithms are increasing and possible solutions are suggested in another paper.[265] Further, the regulation of robo adviser algorithms was called a 'regulatory challenge'[266] and a 'future assignment'[267] by other researchers. These opinions underline the finding of this thesis that further regulation of robo adviser algorithms are necessary and sensible.

Possible ways to regulate suitability assessment algorithms and the different classes of portfolio management algorithms will be discussed in the next chapter, followed by a suggestion of which regulatory possibilities should be established for the different algorithms.

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[263] BlackRock, 2016, pp. 9–10.
[264] Baker & Dellaert, 2018b, p. 734.
[265] Barnett et al., 2017, p. 8.
[266] Weber & Baisch, 2016, p. 1071.
[267] Möslein & Lordt, 2017, p. 802.

5.2   Regulation of Robo Adviser Algorithms: Possible?

The past chapter established that there is need for new regulation of robo adviser algorithms. Since the need for regulation varies between the two parts and within the different classes of portfolio management algorithms, the following part will demonstrate that solutions for the different needs exist.

5.2.1   Ongoing Requirements and Regulation

There are certain guidelines that robo adviser algorithms, or probably any algorithm, should comply with constantly. A good example of such guidelines can be found in Art. 17 of MiFID II. The regulation of algorithmic trading includes standard quality guidelines that can easily be applied to other algorithms as well. Interestingly, many of the guidelines from Art. 17 are also being used in *ESMA's Guidelines on certain aspects of the MiFID II suitability requirements,* which further explain the regulation of the suitability assessment. Paragraph 82 of the final guidelines states that 'firms should regularly monitor and test the algorithms that underpin the suitability of the transactions recommended or undertaken on behalf of clients' to ensure the consistency of the suitability assessment.[268] It further gives concrete minimum requirements that firms have to meet regarding their suitability assessment algorithms. These requirements are:

- Establishing an appropriate system-design documentation including decision trees to show the design, purpose and scope of the algorithms.
- Having a documented test strategy to explain the scope of the testing of the algorithms.
- Having in place appropriate policies and procedures for managing any changes to an algorithm, including monitoring, record keeping and security arrangements.
- Reviewing and updating the algorithms.
- Having in place policies and procedures to detect errors in the algorithms.
- Monitoring and supervising the performance of the algorithms, including having the necessary resources to do so, human and technological.

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[268] ESMA, 2018, pp. 52–53.

- ▪ Establishing an appropriate internal process to ensure these requirements are fulfilled.

This list of requirements considers many relevant aspects a regulation of an algorithm should consider and will be called 'standard guidelines for algorithms' from now on in this thesis. The fact that the list can only be found in ESMA's guidelines and that the requirements are not discussed in more detail, shows that the topic is not as prevalent as some people want it to be. On the other hand, robo advisers are specifically addressed in these guidelines which also shows that the regulator has new innovations like robo advisers on their mind. ESMA specifically clarifies in those guidelines, that they do not intend to introduce additional requirements for robo advisers.[269] An employee of *BaFin* also stated during the interview that he believes the regulation of robo advisers to already be stable with the additions that were already made.[270]

As all of the discussed guidelines only take into account the suitability assessment algorithms, there is need to establish something similar for the portfolio management algorithms.

5.2.2 Technical Regulation

Independent of the type and the class of algorithm, it needs to be established, how the proper functioning of an algorithm can be regulated from a technical perspective. This is relevant for both, the suitability assessment and the portfolio management algorithms. The technical regulation of an algorithm means to make sure, that the algorithm does, what it is supposed to do. There are different steps that need to be followed. These steps have been established after gaining information from the interviews.

(1) Verbal/written description

The functioning of the algorithm can be described to the regulator verbally or in written form. This is the first necessary step in the process of the technical regulation as it gives the regulator a first overview of what the algorithm does or is

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[269] ESMA, 2018, p. 15.
[270] See Interview 9.

supposed to do. This description should go beyond a general description of a suitability assessment or portfolio management algorithm and include firm specific information. Concrete questions and their impact on the portfolio suggestion for example should already be included in the verbal description.

(2) Black-Box Testing

The verbal description should then be supported by a black-box testing of the algorithm. Such a black-box testing is usually conducted by testing the algorithm with several different scenarios and checking whether the output corresponds with the input data. Less complex algorithms like the suitability assessment algorithm are well suited to be tested with such a method. Usually, example customers are created, their information is inserted into the algorithm and the resulting portfolio suggestion is reviewed to see if it corresponds to the input data in the way it is intended to. More complex algorithms, like class C, D, and E portfolio management algorithms can only be tested to a certain extend with this method as they either depend on different market situations which are harder to model or are using AI making the algorithm change frequently. These changes would require a constant testing of the algorithm if total control was the goal.

(3) Diagrams

Additionally to a verbal description and the black-box testing of the algorithm, diagrams of the functioning of the algorithm can be useful for the regulator, who is usually not an IT expert, to better understand it. There are many different types of diagrams in the programming world, often programmers themselves use them in the planning phase of their programs. Mostly these diagrams use unified modeling language (UML) which is a language easy to understand even for people with no IT background. One robo adviser said, they already provide the auditors with flowchart diagrams describing the functioning of the algorithm.[271]

(4) Source Code

The last step when regulating algorithms would be for the regulator to look at the source code. Working through the code of an algorithm would be the only

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[271] See Appendix 4, Interview 6.

way to be completely sure if the algorithm does what it is supposed to. Though, doing so is far from reality. Regulators usually do not have an IT background to understand the source code of an algorithm. Even if the regulator had the necessary people, which is not the case as of now[272], checking a whole program with thousands of lines of code would take too much time and go beyond the purpose of regulation.

(5) Further Data Requests

Additionally to understanding the functioning of the algorithm and making sure, it does what it is supposed to do, regulators can request additional data. This data could include change logs, customer questionnaires and the corresponding portfolio suggestion, description of the trades that happened throughout the year and explanations, why these trades were done. Ideas about what additional data to request can come out of the standard guidelines for algorithms that were introduced in the last part.

5.2.3 Regulatory Frameworks

After establishing the possibilities of an ongoing and technical regulation of algorithms, possible regulatory frameworks will be presented. There are two possibilities to regulate something that is not regulated yet: either by classifying it as something that is already regulated or by creating a regulation for it. These are also the two options for robo adviser algorithm regulation that will be presented here.

Option 1:   Use existing regulation for algorithmic trading (Art. 17 of MiFID II) and classify some algorithms under the definition of algorithmic trading.

As already established, portfolio management algorithms of robo advisers could fall under the definition of algorithmic trading. Class C, D, and E algorithms can initiate orders, time and determine the quantity of the trades without human input and based on market data. Even class A and B algorithms, which only do re-

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[272] See Appendix 4, Interviews 7, 8, 9.

balancing and reinvestment, are programmed to do these two things without human input at a specific time and to a predefined ratio. But since the output of rebalancing and reinvestment is not dependent on market movements and is always done the same way with no real decision of the algorithm itself, these two classes are not defined as algorithmic trading according to this thesis. The other three classes on the other hand could be defined as algorithmic trading and could therefore be regulated under Art. 17 of MiFID II. This option would be simple to put into place as the necessary regulation already exists. The regulator would have to state that robo adviser algorithms need to be classified by the investment firms and, depending on their class, fall under the regulation of Art. 17 of MiFID II. For robo advisers with class C, D, and E algorithms this would require a lot more regulatory work as Art. 17 is primarily meant for complex and market influencing algorithms which is not (yet) the case for robo adviser algorithms. Still, especially the organizational requirements outlined in Art. 17 could easily be transferred to robo adviser algorithms. Meanwhile, class A and B algorithms would still need to comply with the standard guidelines for algorithms and be technically regulated.

Option 2:   Create separate regulation for robo adviser algorithms by using the algorithmic trading regulation as a template.

The second option would be to create a separate regulation for robo adviser algorithms. For this regulation, Art. 17 of MiFID II could be used as a template as many requirements can be transferred from algorithmic trading to robo adviser algorithms, especially the organizational requirements and general guidelines for algorithms and IT systems. The advantage of this option is that a regulation specifically for robo adviser algorithms can be drawn that fits both parts as well as all classes of portfolio management algorithms. Further, new learnings and specifics of robo adviser algorithms can be included in the new law. The disadvantage is, that creating and entering into force a new regulation is a lot of work and takes time. Also, before creating a new law, it needs to be assured that the new regulation is necessary and all contingencies and possible future developments are taken into account.

Further possibilities

Additionally to the presented regulatory frameworks, there are some more extreme possibilities about how robo adviser algorithms can be regulated.

(1) Pre-market approval: licensing the algorithm

Another possible suggestion to regulate robo adviser algorithms would be to introduce a pre-market approval mechanism in form of a license for the algorithm. So far investment firms themselves, which include robo advisory firms, require authorization by the home member state's competent authority before being allowed to conduct business, according to Art. 5 MiFID II. In order to receive such authorization, e.g. certain organizational requirements (Art. 16 MiFID II) as well as requirements about the management body and its obligations (Art. 9 of MiFID II) need to be fulfilled. These requirements relate to the investment firm which is the operator of the algorithm. The algorithm itself does not underlie any requirements for the receipt of authorization. By introducing a license for robo adviser algorithms, the regulator could ensure that the algorithms comply with certain standards. The difficulty about such a license would be to find standards, a robo adviser algorithm has to comply with and to properly execute such a licensing mechanism. The standards for algorithmic trading algorithms outlined in Art. 17 of MiFID II could again be used as a template for standards for such a licensing. The execution of the licensing would probably be more difficult as it would require an extensive check of the algorithm by the regulator before the algorithm is put into use. This would mean a lot more effort for the firms and therefore higher entry barriers for start-ups, possibly hindering innovation. As suggested by two interviewees, such a license could be provided by auditors in form of a certificate[273] instead of it being a license provided by *BaFin*.

(2) Voluntary certification of the algorithm

The suggestion of certifying the algorithm leads to another option of how to regulate robo adviser algorithms. Instead of making it obligatory to receive a license

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[273] See Appendix 4, Interview 1, 4.

before using robo adviser algorithms, a provider could choose to apply for a voluntary certificate for his algorithm. This certificate could lead to a competitive advantage, demonstrating investors that the algorithms comply with specific requirements. Such optional certifications exist in different forms already, for example the ISAE 3402 certification, which certifies that a firm has adequate internal controls[274], or different ISO certifications[275]. Such voluntary certification would require an independent organization to address this subject and offer such an option.

(3) <u>Strategic regulation</u>

Vzbv in Germany brought the topic of regulating robo adviser algorithms to the eye of the public in 2018. Following their position paper, many online newspapers covered the topic. The vzbv demanded not only to regulate the algorithms technically but to also regulate the investment strategy behind the algorithms. Niels Nauhauser from the customer protection agency in Baden-Württemberg explained, that only strategies that have empirical evidence should be allowed to be offered. This would exclude strategies like stock picking and market timing as they are proven not to work and offering such strategies is not in the best interest of the customer, according to Nauhauser.[276] The demand is therefore that firms offering robo advisory services have to prove that their strategy has empirical evidence. Nauhauser compares it to the medical field: only medication that is proven to work is allowed on the market. It seems easier though to prove a medication works or not, either the symptoms of the disease disappear, or they do not (very simplified). When it comes to investing, several questions must be answered before being able to say if a strategy works or not. Against what benchmark should we compare the strategy? What is the time horizon? How do we test it? These are only some of the questions that have to be answered in advance and they show that this demand seems hard to satisfy. I also believe that one can find an empirical study that shows a strategy works for almost every strategy and if not, create one himself. A debate about what is 'good' empirical evidence and

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[274] For more information see International Auditing and Assurance Standards Board, 2011; ISEA3402.com, 2019.

[275] For more information see International Organization for Standardization, 2019.

[276] See Appendix 4, Interview 5.

which studies count, which do not and what happens if empirical evidence contradicts one another will most likely occur. Regulating the strategy is also hard because even if there is empirical evidence for or against a strategy, the regulator does not know which strategy will work in the future as markets change constantly. Another argument against the regulation of the investment strategy of robo advisers is, that if the strategies were to be regulated, all other firms, including fund- and asset managers, would have to be regulated as well. There is no argument why only robo advisers' strategies should be regulated when the customer can invest in a fund with a non-regulated strategy. In the end, the customer should be able to decide himself if he finds a strategy suitable and believes in it or not. Countering that believe, many investors do not have any background in the financial industry, do not know anything about investment strategies and should therefore be guided. In my opinion this guiding should not be done through regulation but rather by independent institutes (e.g. the vzbv) or newspapers. One interviewee also stated that the regulation of strategies could lead to a false sense of security for the investors.[277] If the regulator states, that a strategy is approved, investors might think that they cannot lose money (which can always happen when investing in the financial markets) when choosing that strategy. More importantly, the strategy must be communicated correctly. If I want to offer a strategy that invests in *Volkswagen* stocks every time the full moon in Budapest is visible, I am allowed to do so as long as I communicate my strategy correctly. The investor is seen as capable to decide whether a strategy makes sense to them or not.

(4) Own regulatory body for algorithms

The possibility of creating a new regulatory body only responsible for algorithms, or especially for AI, is discussed in two separate papers by Matthew Scherer and Andrew Tutt. Scherer proposes the introduction of an 'agency […] responsible for certifying AI programs'.[278] According to Tutt, the advantages of establishing a central federal agency for algorithms outweigh all other options.

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[277] See Appendix 4, Interview 1.
[278] Scherer, 2016, p. 394.

He argues that algorithms are very complex and therefore need extensive expertise and are different to other products because responsibilities are difficult to assign and trace. Further, he states that algorithms can inflict 'unusually grave harm', naming algorithms assisting in surgeries and driving cars as examples.[279] Ulf Linke disclosed that *BaFin* currently has a working group that is dealing with the question of algorithmic regulation concerning all algorithms used in the financial industry. The group is trying to answer the question of whether and how algorithms should be regulated.[280] This working group is proof that the demands for regulating algorithms are being taken serious by the regulator.

The option of creating a regulatory body only for algorithms is very interesting. As only robo adviser algorithms have been dealt with in this thesis, the answer of whether a regulatory body for algorithms in Germany makes sense, cannot be answered as it goes beyond the scope of this thesis. A regulatory body only for robo adviser algorithms can be rejected though as the costs and effort to establish such an agency would outweigh the risks of robo adviser algorithms immensely. As algorithms and AI further develop, the option of an agency, or at least a separate department, for algorithms gets more interesting and should be cause for further research. The working group at *BaFin* about the regulation of algorithms could be a start for such a separate department of algorithmic regulation.

After having gained an overview of the different possibilities there are to regulate robo adviser algorithms, the following and last chapter will make a specific proposal for regulating robo adviser algorithms by picking the best possibilities presented in this chapter.

5.3 Proposition of Algorithmic Regulation in Germany

Certain things are important to implement for both parts of the robo adviser algorithms which include verbally describing the algorithm and its functioning,

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[279] Tutt, 2016, pp. 116–117.
[280] See Interview 9

running different scenarios as a black-box testing and supporting these descriptions with different diagrams. This should be state of the art during the yearly audit for both parts of the algorithm. The best way to check the algorithm is most probably during the yearly audit while auditors are at the company. That way they are able to get a verbal description and a test run through the algorithm. After that, auditors are more likely to understand the additional data that is provided to them, including diagrams and other information. Following, the two parts of the algorithm are highlighted separately.

Suitability Assessment Algorithm

As previously established, the suitability assessment is already strictly regulated. Included in this regulation is also a recommendation about how algorithms behind the suitability assessment should or could be regulated. In practice, some auditors already do some checks of the algorithm. Therefore, guidelines, the suitability assessment algorithm must comply with, already exist[281] and some parts of the technical regulation mentioned under 5.2.2 are already done in practice. The suggestion presented in this thesis is, that no further regulation is needed but the regulator must make sure, that the technical regulation of the algorithms is done consistently and that the guidelines are being complied with. The technical regulation should include a verbal and/or written explanation, the presentation of suitable diagrams and black-box testing. Robo adviser firms must be able to provide auditors with all this information for the yearly audit and before receiving authorization. Further, auditors must make sure that the algorithm complies with the mentioned standard guidelines for algorithms. They should actively ask for data regarding things such as changes of the algorithm, the implementation of monitoring procedures, and internal procedures to ensure the compliance with the requirements. The goal is to have standardized processes and documents that need to be reviewed. Additional regulations regarding the suitability assessment algorithm seem over engineered at this point and in my opinion, the existing regulation is enough and simply the practical implementation needs to be adjusted.

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[281] See paragraph 82 of ESMA's guidelines regarding the suitability assessment.

Portfolio Management Algorithm

When discussing the regulatory needs for the portfolio management algorithms, the suggestions get more complex as the needs differ for the different classes of algorithms. The trade-off between regulating the risks and hindering innovation plays a big role when deciding which classes of algorithms should be regulated how.

The features of class A and B algorithms do not pose great risks. A strict regulation would therefore only possibly hinder innovations. Still these algorithms should comply with the standard guidelines for algorithms and be technically regulated at the yearly audit.

Class C algorithms pose higher risks than class A and B algorithms because they are programmed to trade without human input. If the goal is to keep the risk level the same and markets go down, the algorithm would automatically sell stocks and buy bonds for example. The fact that the algorithm trades without human input and only according to market movements poses risks such as wrong execution in unknown market environments. These algorithms can potentially influence the market if the robo adviser market and their AuM increases. Therefore, they need a stricter regulation than class A and B algorithms.

The same applies to class D and E algorithms. They do the same as class C algorithms but add additional uncertainty by using machine learning techniques (class D) or other AI (class E). No form of AI is regulated so far and an employee of *BaFin* stated the use of AI will pose new challenges for regulators[282]. As current robo adviser algorithms are not intelligently learning (except simple machine learning techniques) yet and AI is not the topic of this thesis, no regulatory proposal for AI will be made. However, these algorithms still need to be regulated more strictly than classes A and B. Two suggestions of how this could be done were made under 5.2.3. Even though introducing a new regulation specifically for robo adviser algorithms would be the cleaner solution as the regulation could be tailored specifically to the different classes of robo adviser algorithms, this option seems unlikely to happen. Therefore, this thesis suggests

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[282] See Interview 9.

the categorization of class C, D, and E algorithms under the definition of algorithmic trading in the future. If they are categorized under this definition, robo adviser algorithms fall under the regulation of algorithmic trading and would therefore be regulated.

In order to be able to treat the different algorithm classes differently, the regulator needs to ensure that investment firms firstly notify the regulator that they are using algorithms and secondly categorize their algorithm in one of the classes. It is up to the firm to argue, why their portfolio management algorithm falls under a specific category. As a default category, every algorithm should be classified as an E algorithm to incentivize the firms to do the categorization thoroughly and show prove why their algorithm possibly belongs to a lower category with less regulatory responsibilities.

If the robo adviser algorithm fell under the definition of algorithmic trading, it would mean higher duties of care for the providers regarding the portfolio management algorithm. The robo adviser providers would not only have to notify the regulator about the usage of an algorithmic trading algorithm but they would also need to comply with all the standards for algorithms mentioned in Art. 17 of MiFID II, see also chapter 4.4.

The rationale behind the decision to suggest the categorization of some algorithms as algorithmic trading is that this solution imposes the least amount of change and effort and is therefore the most realistic suggestion for the medium term. An employee of *BaFin* stated that with the changes that have already been implemented, the regulation of robo advisers is already stable.[283] Still, the existing working group about algorithms within *BaFin* suggests that algorithms in general might be the topic of future regulations. Waiting and seeing what happens with a new innovation such as the usage of algorithms in financial services might also be a good choice for the regulator in order to see whether the market adopts the technology and get a sense about the potential risks of the new technology.[284] The suggested solution without any change of the laws is therefore a

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[283] See Interview 9.
[284] Arner et al., 2015, pp. 33–34.

good trade-off between waiting a little longer and seeing where robo advisory might evolve to and still regulating the risks that already occur.

This thesis makes a suggestion for regulating robo adviser algorithms specifically. Finding a solution for the regulation of algorithms in general might also be an option. If such an overarching solution were to come, it would still take time until it is implemented. At least until then, the suggested approach could serve as a suitable solution.

6. Conclusion and Outlook

This thesis started with the assumption that there is a trade-off between regulating risks and stalling innovation. This assumption was confirmed regarding robo adviser algorithms. Further, it was established that finding the right path of regulating robo adviser algorithms is not easy and the degree of optimal regulation depends on who you ask. The goal of this thesis was to examine all the different opinions about the right regulation, get an in-depth view of the current regulatory practices, the functioning and complexity of robo adviser algorithms and objectively answer the research questions based on the gained knowledge. While answering the questions, it was also important to give answers and suggestions that are realistic. Sometimes realistic suggestions were made while sacrificing optimal suggestions as they were simply not viable.

Concluding this thesis, the answer of whether a regulation for robo adviser algorithms is necessary and sensible was generally answered with 'yes'. The demonstration of several possibilities to introduce or amend such a regulation showed, that it is possible to implement realistic and practicable solutions. If the suggested solution of this thesis were to be implemented, no new laws would be required. The regulator would have to do two things. First, introduce standard guidelines for algorithms and a classification for portfolio management algorithms of robo advisers. Second, they would have to make sure that investment firms comply with the introduced guidelines regarding both parts of the algorithm and introduce the classification of portfolio management algorithms to the standard procedures of a robo adviser. These suggestions seem realistically implementable without having to introduce new laws, increasing the regulator's

resources drastically and limiting innovation noticeably. Even though for algorithms that pose greater risks and are therefore defined as algorithmic trading algorithms it would mean more regulatory duties. I believe that the regulation does not hinder innovation in a drastic way as Art. 17 does not include the regulation of investment strategies and basically states standard guidelines that algorithms should comply with. Most companies have internal procedures and standards[285] they already apply to their algorithm which would only need to be adjusted and made accessible to the regulator.

The scope of the thesis was well defined, still assumptions and simplifications needed to be made in order to focus on important parts. Especially when it came to the regulation of algorithms and algorithms in general, a lot more information than displayed in this thesis exists. The topic of algorithms and AI is relatively new to regulators and is a future challenge for regulators and researchers. The existing working group about algorithms at *BaFin* shows that the regulator has already identified that need. The existence of papers about regulatory bodies for algorithms or the regulation of AI further illustrates that researchers have also acknowledged that need. The topic of regulating algorithms and AI will still occupy many people in the future. Personally, I find the thought of a regulatory solution for all algorithms used in the financial industry very appealing and promising.

There is not one simple and correct solution for the regulation of robo adviser algorithms. This thesis provides one possible answer but also marks a starting point for further discussions on this topic, allowing different, well informed opinions to emerge.

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[285] See Appendix 4, Interviews 2, 3, 4.

Appendix

Inter-view #	Interview Part-ner	Type	Subtype	Interview held on	Interview length
1	Franz Linner, fintego	Robo adviser	Bank	17.01.2019	48 min.
2	Anonymous	Robo adviser	Start-up	17.01.2019	33 min.
3	Anonymous	Robo adviser	Bank	18.01.2019	30 min.
4	Anonymous	Robo adviser	Bank	22.01.2019	34 min.
5	Niels Nauhauser, Verbraucherzent-rale BW	External	Inde-pendent	22.01.2019	45 min.
6	Anonymous	Robo adviser	Bank	31.01.2019	62 min.
7	Sascha Demge-nsky, PwC	External	Inde-pendent	01.02.2019	66 min.
8	Anonymous	Robo adviser	Bank	05.02.2019	34 min.
9	Ulf Linke, and three other re-spresentatives of BaFin	External	Regula-tor	14.02.2019	36 min.
10	Dirk Rathjen, Institut für Ver-mögensaufbau	External	Inde-pendent	14.02.2019	60 min.
11	Anonymous	Robo adviser (Broker)	Start-up	28.03.2019	34 min.

Appendix 1: Overview of expert interviews conducted

Guiding questions for the interview with *xy, firm xyz*

Algorithms:

1. How complex is the algorithm of *xyz*? (e.g. development time, how many people work on it, lines of code)
2. Which part is more complex: the suitability assessment and the allocation of the portfolios (first part) or the portfolio management? Are there further parts of the algorithms?
3. How many changes are made to the algorithm? How are these changes documented?
4. What is the main difference between the algortihms of different robo advisers in your opinion? Does the investment strategy have a big influence on the difference?
5. What are the biggest risks of the algorithms in your opinion?

Current Regulation:

6. How does the supervision of *BaFin* work? Do you have to provide details about the algorithm?
7. Do you have to fulfill the same conditions for the people behind the robo adviser as for regular investment advisers? (see §87 WpHG/ MiFID II Art. 9(3)) If yes, who is vetted? Do they also check IT personnel?
8. What are topics that are important to know about the current regulation? Are there any flaws in the execution?
9. How is the transmission of the suitability declaration done?

Opinion about algorithmic regulation:

10. In your opinion, should robo adviser algorithms be regulated? Why or why not?
11. In your opinion, how would a regulation be possible?
    a. Examples: view code, diagrams, notes about the functioning of the algorithm?
    b. Once at the beginning (licensing) or constantly?
12. In your opinion, would an additional regulation/ licensing of the algorithms increase entry barriers for start-ups or affect current business significantly?
13. Algorithmic high frequency trading: there is a regulation in MiFID II (Art. 17) about algorithmic trading. Do you think it could be transferred to robo adviser algorithms?

Additional Questions:

14. Is artificial intelligence used in your algorithm? Do you plan to do so in the future?

15. According to forecasts, the robo adviser market will grow fast in the following years. How do you think the market will develop?

Appendix 2: Example of guiding questions for expert interviews (translated from German to English)

	Legal Form	Costs €20,000	Costs €50,000	Costs €100,000	Average
quirion	Portfolio Manager	0.50%	0.38%	0.43%	0.44%
Whitebox	Portfolio Manager	1.13%	0.75%	0.60%	0.83%
ROBIN	Portfolio Manager	1.25%	0.80%	0.80%	0.95%
Vaamo	Portfolio Manager	1.09%	0.79%	0.49%	0.79%
fintego	Portfolio Manager	0.75%	0.40%	0.40%	0.52%
ginmon	Portfolio Manager	0.80%	0.75%	0.75%	0.77%
Scalable Capital	Portfolio Manager	1.00%	0.75%	0.75%	0.83%
Visualvest	Portfolio Manager	0.93%	0.60%	0.60%	0.71%
Investify	Portfolio Manager	1.00%	1.00%	0.80%	0.93%
Baloise Monviso	Portfolio Manager	1.28%	1.24%	1.24%	1.25%
Prospery	Portfolio Manager	1.19%	0.69%	0.69%	0.86%
Cominvest	Portfolio Manager	0.95%	0.95%	0.95%	0.95%
Warburg	Portfolio Manager	1.60%	1.00%	0.90%	1.17%
easyfolio	Broker	0.95%	0.75%	0.75%	0.82%
Growney	Broker	0.69%	0.39%	0.39%	0.49%
LIQID	Portfolio Manager	0.50%	0.50%	0.50%	0.50%
Solidvest	Portfolio Manager	1.40%	1.40%	1.10%	1.30%
Sutor Bank	Portfolio Manager	0.90%	0.70%	0.70%	0.77%

truevest	Broker	1.49%	1.49%	1.49%	1.49%
WeltInvest	Broker	0.82%	0.33%	0.33%	0.49%
Wuestenrot ETF Depot	Portfolio Manager	0.75%	0.45%	0.45%	0.55%
Minveo	Portfolio Manager	1.00%	1.00%	1.00%	1.00%
Sum: 22		**Average: 1.00%**	**Average: 0.78%**	**Average: 0.73%**	**Average: 0.84%**

Appendix 3: Overview of robo adviser pool viewed in this thesis including legal form and costs[286]

Interview #

Robo Advisers	
Details	
Our robo adviser has 50.000 customers in three countries.	2
Six people are working on the robo adviser from a portfolio management perspective of whom a few have knowledge in relevant programming languages.	3
The portfolio is changed 50-100% per year meaning about once a year the portfolio is exchanged. Four to eight times a year the portfolio is swapped.	3
Current Market Situation	
There is no robo adviser that does investment advisory. They all have the portfolio management license or are doing investment brokerage. With the broker license a firm is allowed to sell a predefined portfolio but is not allowed to change it afterwards.	2
A management fee of 1% is pretty high if only rebalancing is done, you might as well choose an actively managed fund instead.	10
Differences	

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[286] extraETF.com, 2019.

Robo advisers entering the market need to differentiate themselves from others by offering something new. Therefore, different strategies and different focuses are offered.	1

Target Group	
The target group consists of people who respond positively to the word robo advice. The typical investor of *Scalable* for example has a university degree and invests around €40.000. He must have some knowledge that actively managed funds often underperform but should not have too much knowledge to be aware that quantitative managed funds often underperform as well. This strategy of only addressing about 3% of the population is very smart for start-ups but not necessarily for bigger banks.	10

Market Growth Expectations	
The market is going to keep growing but not as fast as predicted by some studies.	1
The market will continue to grow as predicted.	2
The growth expectations of the past two years have not been met. When predicting technical innovations, short term predictions are often too high and long term prediction too low.	3
I believe the robo adviser market will one day take over up to 10% of the investment market.	4
I believe the robo advisory market will grow because online distribution will become even more important in the future.	6
We expect the market to grow just like it did in the US. The portfolios are good, and the costs are low. I think the trend will move away from actively managed funds and away from human advisers to ETFs.	8
The market will grow due to growing digitalization.	7
I do not think the market will grow as expected. Many people will still go to human advisers at banks.	10
I believe the market will continue to grow. Once robo advisers gain a critical market share, they will be known by the public and continue to grow even further.	11

Market Development Expectations	

Robo advisers will find big partners to cooperate with, like *Scalable* did with *INGdiba* and we do with another bank. You need somebody in the market that distributes your product.	1
A consolidation will happen in the market, which has already began. Not everybody will make it through the next years. *Investify* has already been sold for example.	1
A consolidation will happen in the market which supports the development as that is a sign for maturity in a market. Five to ten robo advisers will probably remain, now there are about 30 on the market.	2
Different expansions like savings products or themed investments will emerge and the product range will widen.	4
It will be important for every player on the market to have a robo adviser as it decreases the production costs of financial services drastically.	4
We expect that the regulator will understand that further regulation is necessary. They need to review the quality of the advice because customers do not have the chance to do so themselves.	5
Someday machines will be smarter than humans and robo advisers will take over. The scary thing about it is that humans will not be able to comprehend the decisions made by machines anymore.	7
The industry will move away from standardized portfolios that simply do rebalancing and will offer more individualized portfolios. The rebalancing will then be done with the individual portfolio and not the overall strategy. It will become more complex as can already be seen in the US.	8
The industry is waiting on whether *Google* or *Amazon* will soon enter the portfolio management industry.	8
The industry will move further towards automatization and individualization.	8
Big data approaches might be a possible trend. Socio-economic criteria could be used to give better advice. With growing amounts of data, artificial intelligence could use that to come up with suggestions.	8

I believe the robo adviser market will be consolidated. There are about 30 robo advisers on the German market as of now and more are coming. The first consolidation has already started though and I believe in the end there will be three or four providers left. Something similar happened in the US already.	11

Investment Strategy

You can differentiate between three parts. The strategic allocation, which is the long-term basic alignment of the portfolio, meaning the share of stocks and bonds, the global scatter and the diversification overall. Then there is the tactical allocation, which is basically market timing and third there is stock picking. Studies show that over 90% of the success of an investment comes from the strategic allocation. This also means, active management does not work. Studies show that after 10 years, only 1% of active managers outperform the benchmark.	1
The strategy states where I invest in and the algorithm then implements this strategy.	1
Fintego is on the simple side of the strategy but there are others who offer very complex strategies using mathematical risk-based approaches.	1
There is a further differentiation between passive (*fintego*) and active management.	1
There are two main differences in the investment strategies, the ones that are more passive and simply do rebalancing once a year and the ones that follow a more quantitative and mathematical approach and reallocate the portfolios more often.	2
Active robo advisers can further be divided into those who only adjust their portfolios through algorithms and those who additionally use quantitative assessments of the markets by experts. Robo advisers who adjust the portfolios rule-based only use historical data.	3
The two different approaches are the ones that follow a strategic allocation with a fixed asset ratio and the other ones that do not have a fixed asset distribution but use mathematical operations and adjust the portfolios based on risk KPIs.	4
The first part of the algorithm works the same at every robo adviser. The investment strategy is different at every robo adviser.	6

One trend is to do rebalancing, others use dynamic risk management to control their portfolios which is a lot more complex. It does not mean that more effort leads to higher returns though.	8
Strategic allocation is the most important part of the strategy and many institutes do not know how they do it. I do not believe there is much foundation behind how start-ups and even banks do their strategic allocation.	10
Strategies following quantitative risk approaches often loose the beginning of a market gain and participate the start of a market downturn.	10
We chose a passive investment strategy instead of an active one not only because of our broker license but also because we wanted to follow a passive strategy based on empirical research. We simply do a yearly rebalancing. The asset allocation within the different portfolios is always the same.	11
Our strategy is basically the same as most of the robo advisers which have a portfolio management license. The only difference is, that we have to explicitly include rebalancing in the contract with customers whereas portfolio management companies are simply allowed to do rebalancing and other changes to the portfolios.	11

Algorithm

Complexity	
On a scale from 1-10, where 10 is very complex, *fintego's* algorithm would be a 2 at maximum. The strategic allocation happens within 5 asset classes and the selected portfolios stay the same. Rebalancing is done when the deviation from the chosen allocation is larger than 15%.	1
The second part of the algorithm was modelled in excel before, so it is not very complex. The suitability assessment was a lot more complex to program.	1
We have 9-10 people working on the algorithm, the first development took about 24 months and the algorithm has more than 100.000 lines of code.	2
There is a higher complexity due to different tax systems in three different countries.	2
The second part of the algorithm is more complex.	2

The code was developed over a longer period and it cannot be specified how complex the algorithm is.	3
The first part is not very complex and can probably be programmed over the weekend or rebuilt in excel. The second part is a lot more complex as the portfolios must be managed and specific risk figures have to be adhered.	3
The second part of the algorithm is more complex because of the mathematical model behind it, therefore more lines of code are needed. The first part is complicated because the regulation needs to be reflected.	4
2-3 people from the portfolio management and 6 people from IT (programming) have been working on the algorithm for about 6 months.	4
The development of the robo adviser took nine months.	6
The algorithm consists of 7-12 files with about 20.000 lines of code each.	6
We have 10 people working on the robo adviser on the portfolio management and 6 external programmers.	6
The first part is more complex because all the regulation must be taken into account. The second part is still done by humans, so it is not complexly programmed.	6
The algorithm is not very complex. The first part are questions that determine the customer's risk preferences and risk bearing capacity which follow a simple mapping mechanism.	8
The second part, including the calculation of curves, minimum investment limits and taxes, is more complex than the first. Though, the final decisions about investments is not done by the algorithm but by humans.	8
Changes in Algorithms	
The logic itself is not changed. Sometimes we change things on the website and once a year we check if the used ETFs are still the right ones.	1
We constantly have 10 people working on and changing the algorithm.	2
We use standard procedures to document and test code before it is executed.	2
The algorithm is adjusted on a regular basis, IT security is adhered and changes are documented.	3

Not many changes are being done to the algorithm but if a change is being made, it must go through control functions such as compliance, legal and risk before the change is implemented.	4
We are constantly changing the algorithm. Every other week we have sprint meeting where we discuss the changes that need to be made.	6

Risks of Robo Advisers and Robo Adviser Algorithms

Robo advisers that function as an automated trading tool could strengthen market effects and start a spiral.	1
Robo advisers that are based on the Value-at-Risk principle simulate safety where there is no safety. Risks are being managed but 5% of all risks are not taken into consideration. This could mislead customers and if robo advisers, which are following that strategy cannot live up to their promises, the whole robo adviser market could suffer through bad reputation.	1
The conception of the algorithm especially when it comes to diversification is a risk.	2
Data protection: if data were to be lost, it could lead to a reputational damage.	2
Robo advisers are not daily traders, therefore I do not see a risk of unpredictable behavior that has influence on the markets. We adjust the portfolio every 2-3 weeks.	2
The same risks apply as for other areas of IT.	3
One of the greatest risks is that the algorithm does not function as it is supposed to. The more complex it gets, the more testing and validation needs to be done because the algorithm must function in every situation.	4
Another risk is that the algorithms do not deliver the quality which is expected of them.	4
Robo advisers suggest that their algorithm is scientifically substantiated and free of interests which is not the case.	5
The risk exists that needs are explored incompletely and the portfolio suggestion is not in the interest of the customer. This risk also exists for regular investment advisory at banks.	5
The risks are the same as for any other algorithm.	6

The more complex an algorithm gets, the harder it is to keep oversight and controllability. The longer an algorithm is used and enhanced, the higher the probability that its complexity might get out of hand and cannot be controlled anymore.	6
Risks occur once artificial intelligence is used, namely neural networks. In the end it can happen that the programmer does not know what the program does anymore.	7
The risk is that if an error occurs it would automatically affect all customers. If a human adviser made a mistake, it would only affect one or a few customers.	8
The questionnaires are not constructed user friendly because of regulatory requirements. The questionnaires are not constructed valid and reliably and the questions are chosen by legal experts who do not know how to construct questionnaires effectively and user friendly.	10
The second part of the algorithm holds the risk that whatever the robo adviser does, does not align with the goals of the customer. If the goal is to grow assets in the long term, rebalancing might be a valid thing to do. If you want to generate alpha though, rebalancing does not help and more complex methods need to be implemented which only 10% of robo advisers do.	10
One of the biggest risks in my opinion is intransparency. The customers do not know how the algorithm is built and what it does. Especially at robo advisers with an active strategy.	11
Another risk is that the algorithms have not been tested in different market environments yet. We have had a low interest environment for a long time, leading to lower returns. Algorithms that allocate between stocks and bonds might not react correctly in different environments as they rely on historic data.	11
Further Information about Algorithms	
The first part of the algorithm differs depending on how the provider interprets the regulation. There is some leeway and differences between fintechs (start-ups) and bigger banks can be seen because banks have to take into consideration every information they have about a customer, even if it is from other forms of contact like a bank account or a loan. Fintechs only have and only can consider the information the customer provides them with.	4

The cash flow management is part of the portfolio management.	2
When selecting which titles to invest in we use algorithms to analyze the data.	6
I do not see a big advantage for customers in the first part of the algorithm as many already offer that.	10
Granting loans is done through algorithms for over 20 years already. Also parts of security checks when credit cards are used abroad for the first time is done through algorithms.	5

Usage of Artificial Intelligence in the Algorithm	
No we do not use AI but I heard some robo advisers are already working on that. We do not plan on using it in the near future.	1
We use machine learning techniques but that has nothing to do with self-writing algorithms. We plan on further establishing these techniques in the future.	2
We are thinking about using machine learning techniques to gather additional market data and use it for the construction of the portfolios.	3
We use a genetic optimizer which basically reproduces until it finds an optimum. A genetic optimizer falls under the definition of artificial intelligence. However, we do not plan to use artificial intelligence as an added value for customers as we do not see the benefits of it.	4
We do not use AI and we do not plan on doing so in the near future.	6

Regulation

Current Regulation of Robo Advisers	
The audit is mostly about the suitability test and not about the investment strategy. The auditors look at the result and check if the input data results in the expected output portfolio.	1
Several numbers like the equity must be reported to *BaFin* on a regular basis.	2
Yearly auditors check all processes and documents and send their report to *BaFin* as well as the *Bundesbank*.	2
We have 4 people working on regulation at our company.	2
Sometimes *BaFin* itself visits a company.	2

The strategy is discussed with *BaFin* but they do not give their opinion about it as that is not their job, the market itself does that.	2
It is checked whether the offer of the robo adviser coincides with what the robo adviser advertised to the customer. As long as I tell the customer the right thing, I can offer any strategy I find suitable. The transparency is the most important part and is checked by *BaFin*.	2
The suitability test is checked very precisely by the BaFin. They check the questions, every wording and whether the portfolio suggestion at the end fits the risk profile of the customer.	2
When a new product is being developed it must go through the so called 'new product process'. The different departments look at the new product from their individual viewpoints. The process is being reviewed at the yearly audit.	3
Auditors might want to see the algorithm or how the program is filed but the source code does not need to be turned in.	3
The regulation is already very strict.	3
The regulator does black-box testing meaning they review if the portfolio that is suggested in the end fits the input from the suitability test.	3
The logic of the algorithm does not need to be shared with *BaFin* but we went through the algorithm with them and showed them how it worked. The focus was on the suitability test though and not the portfolio management in the second step.	4
The regulation is done yearly by auditors. Regarding the algorithm we provide them with flowcharts illustrating the functioning of the algorithm. Also, different scenarios are being tested. If the code was requested, we would have to hand it over, but this request will not come as auditors cannot use 120.000 lines of code for anything.	6
A tool is built and the functioning needs to be communicated to the customer correctly. The remaining risk of whether the offered product actually works is carried by the customer as long as he has been informed about the product correctly.	7

The requirements of what information is needed and how it must be communicated to the customer is regulated very detailed already. The risk of investing still remains of course. Getting rid of that risk is not the regulators job.	7
Auditors take example customers and check if the output portfolio is consistent with the answers they gave.	8
We also do a suitability assessment where we try to find out about the knowledge an investor already has about financial products. But we do not do a risk classification, we simply use the result of the assessment to tell the investor if he is choosing a portfolio that might be too risky for his profile. Though the investor can still choose that portfolio if he wants. We believe that private investors can decide themselves, which portfolio fits the best to their current situation. This is the biggest difference to portfolio management robo advisers: our suitability assessment only leads to warnings but not to restrictions.	11
Robo Adviser License	
You must prove that you have the knowledge and the processes to do portfolio management. Me and my colleagues are registered at *BaFin* as a certificate of competence.	1
As far as I know, no details about the algorithm must be disclosed when receiving the license.	1
The portfolio management license is the current standard on the market as the investment advisory license does not cover all necessary actions. There used to be providers that offered the same services as we did (portfolio management) but only had an investment advisory license. But that changed recently as most robo advisers now have the portfolio management license.	1
To receive the § 34f GewO broker license, you must show a certificate of competence.	11
After receiving the license, a yearly audit is done, resulting in a report which proves that you comply with the duties of the license. This report is done by an external auditor.	11
Certificate of Competence	
The education and the professional experience must be disclosed. Also, once a year a themed training has to be done.	1

We are three people who are being reviewed in the portfolio management department.	1
IT employees are not being reviewed.	1
Managing directors are being reviewed and need permits by *BaFin*. Among other things it is being checked if they have experience with handling clients' money.	2
Also authorized signatories (Prokuristen) and the head of compliance are vetted.	2
Trainings are being done in investment advisory as well as portfolio management.	4
Every employee must have the certificate of competence.	6
Suitability Declaration	
At the end of the suitability test a PDF document is sent to the customer as the suitability declaration.	1, 2, 4, 6
The suitability declaration must be sent out to the customers on a quarterly basis stating that the products are still suitable for the customer and its preferences.	1, 4, 6
Opinion about the Regulation of Robo Adviser Algorithms	
No, for regular robo advisers. It is difficult because first I am not sure if the regulator understands algorithms, especially the more complex ones. Secondly, nobody knows beforehand which algorithm will lead to the best performance in the future. A regulation would give the customer a sense of false security, leading to a believe that the algorithm and therefore the investment strategy is good, which is not automatically true as the regulator cannot say if the strategy will work or not.	1
Robo advisers that function as an automated trading tool should at least have to announce that as they are able to influence markets.	1
The regulation of how robo advisers advertise their products and whether that is in line with what they actually offer is more important as that is not always the case.	2
I do not think regulating the algorithm is sensible or possible. In the end, the market must decide which algorithm leads to the best outcome. But it has to be regulated if the IT is functioning properly and that the processes are constructed the right way.	3

If the investment logic were to be regulated, fund- and asset managers would need to be regulated as well. I find it more important that the quality is regulated.	4
The first part is already very well regulated. The second part should not be regulated because then all investment products would need to be regulated.	4
The current regulation is not enough. It is allowed to offer investment strategies that have no empirical evidence, like stock picking and market timing which is proven not to work. Therefore, only strategies with empirical evidence should be allowed to be offered on the robo adviser market (example: only medication that is proven to work is allowed to be offered on the market of medicine as well). The advisory is therefore not done in the interest of the customer so far.	5
Further, the first part of the algorithm, the demand exploration needs to be regulated better. So far it is not done properly. Each single question needs to be checked. They need to make sense and what they are trying to find out needs to have empirical evidence as well.	5
There is a discrepancy between the usability and the regulation of robo advisers. The huge amount of questions in the suitability assessment is not user friendly but is required by regulation.	6
The way robo advisers are allowed to do marketing should be better regulated.	6
The algorithm does not need to be completely free of errors but there need to be control systems installed in case of an error. Also, the company must be able to explain how the algorithm works, which might be a problem when neuronal networks are used.	7
The question is not whether the algorithms should be regulated, they already are. I think it is more about what performance standards they must be able to hold up to. The regulator does not care how you get to a suggestion but they do care about the quality of the output.	7
I do not think the regulator will introduce a license.	7
The demand of the vzbv to regulate the strategies behind the algorithm is far-fetched.	7
Whether more detailed regulation is needed is only a political question in my opinion. If a more detailed regulation is being introduced by the regulator, it is	7

an advantage for the institutes because they have less insecurities about how to conform with the regulation.	
There is a discrepancy between programmers and the regulator. Programmers think in 'yes' and 'no' and 'black' and 'white' whereas the regulator thinks in 'grey'.	7
There is no optimal regulation. It is always a trade-off between more detailed regulation and less regulation.	7
I would be surprised if robo advisers were regulated further in the near future because I think if that happened, it would have to include banks and advisers as well. I do not see why robo advisers should play a separate role. The first part, the questionnaire is already regulated very detailed.	8
The first part is already regulated but not very well regarding the questionnaire design and should be regulated better.	10
For those robo advisers who only do rebalancing, a regulation is not needed.	10
Robo advisers that do more than just rebalancing should have to give out information about their services which is already done through the product information paper. Other funds do not have to reveal their strategy either. Nor do medical companies open up about the exact formula of their medication for example. Therefore, I do not see a necessity to regulate robo advisers further.	10
I believe that the regulation is already very detailed and we have to be aware not to over regulate. Regulation has brought banks backwards as they were too busy complying with them and were not able to invest in new products anymore. Therefore, they are far behind when it comes to digitalization.	11
I believe that transparency should be a goal for robo advisers. Many customers do not understand the functioning of the algorithms.	11
The product of robo advisers is not that complex and we should therefore be careful not to over-regulate it.	11
As there is no systemic risk posed by robo advisers, I do not see a need to regulate them further. If there was systemic risk involved, it should be regulated.	11

Reasons against the Regulation of Robo Adviser Algorithms

Nobody knows beforehand which algorithm will lead to the best performance in the future.	1
Regulators might not understand the algorithms, especially more complex ones.	1
A regulation would give the customer a sense of false security leading to the believe that the algorithm and therefore the investment strategy is good, which is not automatically true as the regulator cannot say if the strategy will work or not.	1
If *BaFin* starts to regulate strategies it would lead to an enforced synchronization on capital markets where you force people to invest in a state-approved portfolio which has nothing to do with a free capital market anymore but is more like a planned economy.	2
Forcing people to make homogenous investment decisions would lead to large herd behavior and could have tremendous effects on capital markets.	2
If the investment logic was to be regulated, fund- and asset managers would need to be regulated as well.	4
Everybody should be able to decide for themselves which strategy they want to follow.	6
Empirical evidence for stock picking can be found, contradicting the claims of the vzbv.	6
The general statements in the regulation make sure that the regulator has room to interpret the laws and catch border-crossing institutes. If the line was defined concretely, the black sheep of the industry would know exactly how to walk right on that line and the regulator could not do anything about it.	7
Institutes offering new technological solutions will continue to have to proactively convince the regulator of their solution. I do not think we have the abilities to cushion every risk beforehand especially when it comes to digitalization.	7
Good design of the algorithm is a competitive advantage. If everything was regulated there would be no more choice options and it would look like a very socialist system.	8

Instead of regulation there should be more transparency about the costs, possible conflicts of incentives and how revenue is made.	8
Regulation has brought banks backwards as they were too busy complying with them and were not able to invest in new products anymore. Therefore they are far behind when it comes to digitalization and other companies like *Google* or *Apple* with their highly developed IT systems were able to enter the financial market.	11
Over-regulation could also lead to robo advisers not being able to conduct their business anymore as they do not have as much money and resources as bigger banks.	11
Reasons for the Regulation of Robo Adviser Algorithms	
Robo advisers that function as an automated trading tool should at least have to announce that, as they are able to influence markets.	1
The regulation of an algorithm is easier and more efficient than the regulation of several different investment advisers because once the algorithm is checked, it reacts the same way for every customer.	5
The advisory needs to be in the interest of the customer, which is not the case so far and which could be fulfilled by regulating investment strategies.	5
If the result of capital market research is, that everybody should invest in a long-term, well diversified, world portfolio, then everybody should do that. (example: there are specific diseases that are always treated the same as well because that treatment is the best possible)	5
There is information asymmetry between the providers and the investors as well as opportunistic behavior from the provider side.	5
It must be regulated correctly because some providers could gain an advantage by designing their questionnaire more user friendly than others.	6
The financial industry has proven in the past thousand of years that investor protection is not automatically given and it therefore has to be regulated.	6
Implementation of Robo Adviser Algorithm Regulation	
An auditor could check the algorithm from a logical viewpoint and issue a certificate.	1, 4

Different scenarios can be reviewed to see if the outcome coincides with the input (black-box testing). We have a department which does that inhouse, called model validation.	4
The regulator could see how the code works by looking at different scenarios but the problem with scenarios is, that they only cover a sample and never see the whole picture, therefore the regulator must view the whole code.	5
Regulation should be done in the beginning as well as throughout the lifetime as algorithms change. Or at least changes need to be indicated and then the algorithm needs to be checked again.	5
Flow charts can help to understand the functioning of the algorithm. Looking at the whole code does not seem to be appropriate or even possible.	6
I think the personnel of *BaFin* would not be enough and properly qualified to actively regulate algorithms. It would not be affordable nor would we have the people to create a regulator that checks everything before entering the market.	7
Looking at the whole code preventively does not seem appropriate. If we get to a point where the whole code will be viewed, it will be done by machines and not by humans.	7
I do not think *BaFin* has the personnel to look through lines of code.	8
The functioning could be explained and a testing of whether the necessary diligence is used should be implemented. I do not think that the regulator will look at the whole code.	10
Influence of Additional Regulation on Entry Barriers for Start-Ups and Ongoing Business	
Yes, additional regulation would have a big influence as further resources are needed. As a start-up you already have a limited number of people and must deal with attaining the license and finding a custodian office. An additional regulation where a strategy is regulated that other people already gained a nobel prize for seems unnecessary.	1
Yes, more people would be needed which costs money and takes constant effort.	2
Entry barriers would be raised because you would need to show that your algorithm has the necessary quality.	4

The ongoing business would only be influenced negatively if quality checks are not yet being done internally.	4
Yes, receiving the §32 license is already an entry barrier itself and further tightening of the regulation would make it even harder.	6
Further, the tightening of the regulation would lead to more consolidation and therefore less competition which is bad for the market.	6
Some institutes stopped offering investment advice because they were not willing to take the risks anymore due to very comprehensive and at the same time very general regulations. That is something that can happen when over regulating.	7
If the regulator wanted documentation on all changes of the algorithm it would be a lot of work to provide them with the relevant documents as changes constantly occur.	8
I do not think that a regulation would be that much more work. Either there are concrete guidelines that need to be followed or the regulator would tell you exactly what needs to be changed.	8
Role of *BaFin*	
BaFin is mostly responsible to protect the regular investor and not institutional investors.	2
Functioning of Supervisory Law and the Role of the Regulator	
There is no concrete specification of how algorithms should look like. Supervisory law states general clauses that provide information about what must be done in order to minimize the risk when doing financial activities. There is no detailed instruction about what that looks like. It is up to the financial institute to provide the regulator with a competent suggestion of how these general clauses can be put into practice. The role of the regulator is then to decide if that suggestion is in line with the rules.	7
The law cannot provide one strategy for all products. It can only provide a guideline of what kind of result must come out of the strategy.	7

The requirements of what information and how it must be communicated to the customer is regulated very detailed already. The risk of investing still remains of course. Getting rid of that risk is not the regulators job.	7
Regulation starts with a general principle and gets more detailed afterwards. There is no lack in regulation because the general statements include everything. There is only insecurity about how to apply the general statements which is why the regulator publishes papers about details on specific topics.	7
The actual role of regulation was to keep the customers' trust in the financial system. Customer protection used to be only a side effect. Since 3 or 4 years ago, customer protection is now also a part of the regulation mission.	7
Algorithmic Trading	
If a robo adviser worked completely autonomous without human interaction it would fall under the regulation of algorithmic trading. If the algorithm behind a robo adviser is complex a model validation like it is being done in algorithmic trading could make sense.	4
The fact that an algorithm is already regulated shows, that it is possible to do so. Robo adviser algorithms are even less complex than algorithmic trading.	5
Further Information about Regulation	
In England a very strict regulation called RDR (Retail Distribution Review) was established a few years ago, leading to banks not offering any investment advice anymore.	2
Banks must show that they have relevant IT knowledge on board level for 1,5 years.	3
The IT-systems have to comply with the BAIT ("Bankenaufsichtsrechliche Anforderungen an die IT") which is a document given out by *BaFin* stating what IT-systems have to be like.	6
The additional regulation of MiFiD II costs us €6-8 million per year.	6
BaFin checks institutes and their investment advisers on a regular basis but the institute knows about the check and can send a competent adviser.	5

Appendix 4: Qualitative analysis of expert interviews

Appendix 5: Screenshot *Google* search results for 'robo-advisor' on 06.11.2018

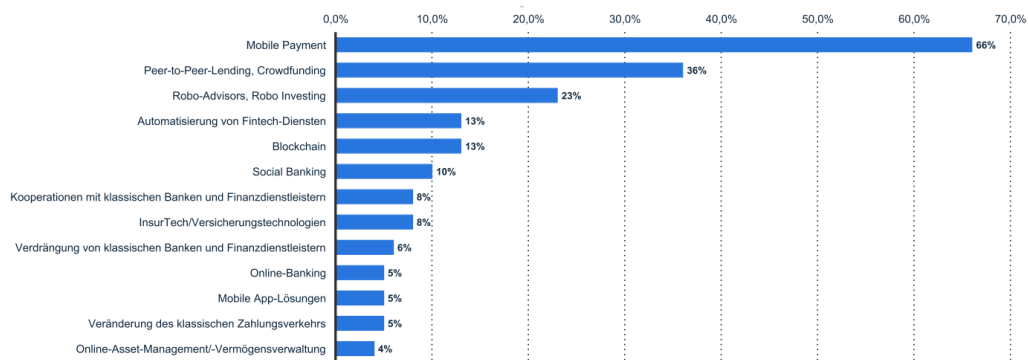Appendix 6: Screenshot *Google* search result for 'robo-advisor' on 26.04.2019
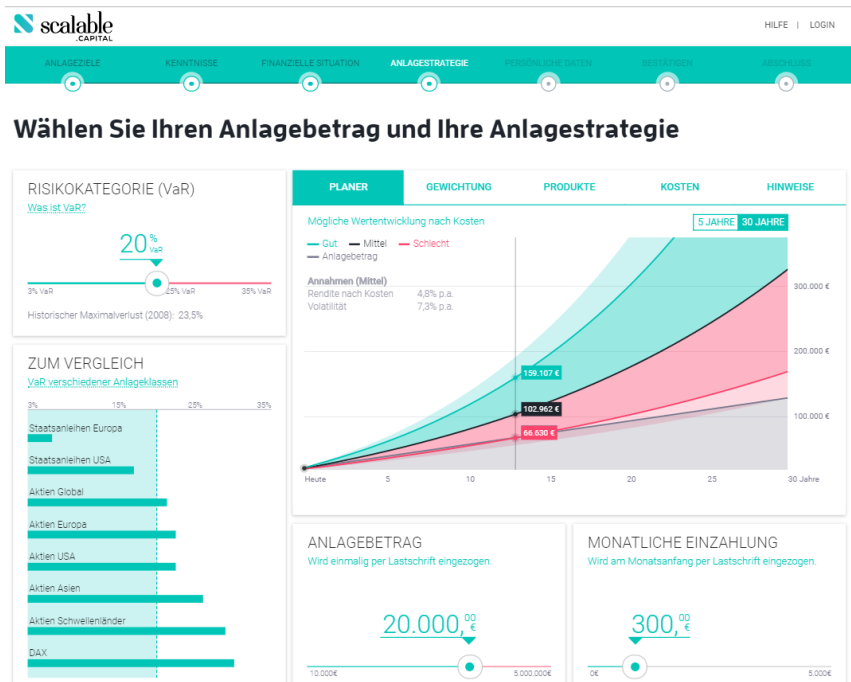
Appendix 7: Example of investment advice of a robo adviser, namely *Scalable Capital*
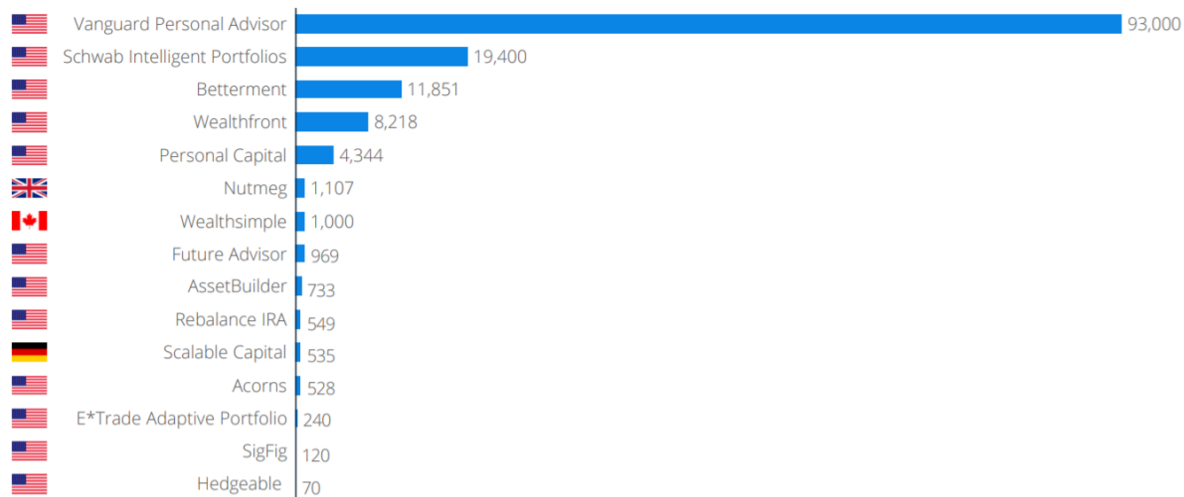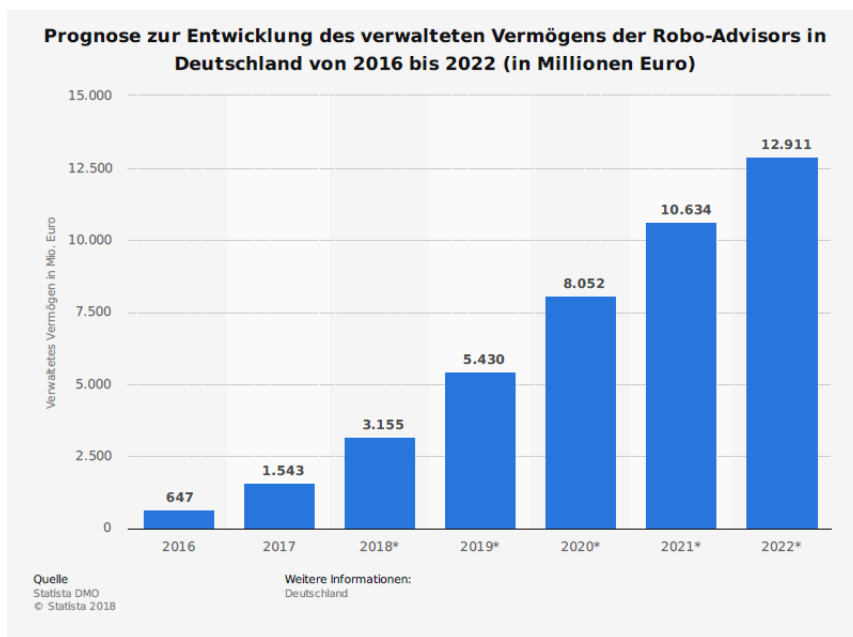

Appendix 8: Top robo advisers by AuM (in USD million)[287]
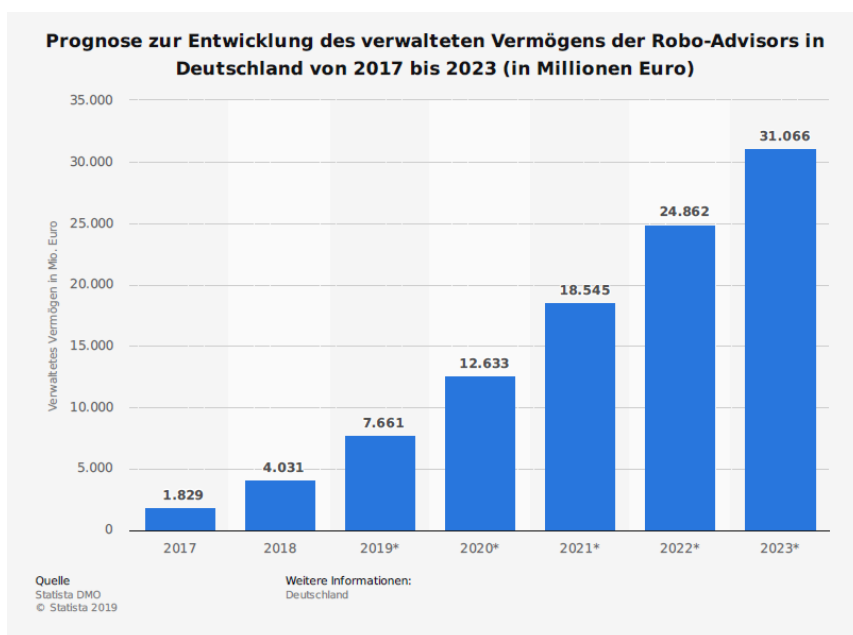
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[287] Striapunina, 2018, p. 14.

Appendix 9: Survey about the biggest trends of the fintech industry in 2016[288]

Appendix 10: Past AuM and forecast of AuM of robo advisers in Germany from 2016 to 2022 as of December 2018[289]

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[288] Statista, 2017, p. 9.
[289] Statista, 2018.

Prognose zur Entwicklung des verwalteten Vermögens der Robo-Advisors in Deutschland von 2017 bis 2023 (in Millionen Euro)

Appendix 11: Past AuM and forecast of AuM of robo advisers in Germany from 2017 to 2023 as of March 2019[290]

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[290] Statista, 2019a.

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