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Complexity, asymmetry of information and mispricing of financial derivatives

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Delft, 3 October 2023
Joris Daniel Francine Laureys

Executive Summary

Starting from the 1980s, financialization has been at the center of our economy and financial innovation has made great strides in the modern world (Algieri, 2018). The financial sector has grown much faster than the rest of the economy and shifted from being a means to an end to an end by itself. Financial markets, which once had the main goal of creating new possibilities to finance other sectors to let the whole economy bloom and prosper, started to redirect the fundings internally, leading the world's economy to an era of wealth exploitation instead of wealth creation (Stiglitz, 2019).

This process started with financial deregulation that paved the way for brand new types of financial products to arise. The attractiveness of this newly re-discovered class of financial instruments called "derivatives" led them to become the main vehicle of money management in recent years, not without causing any problems though. The big stock market crash of 2008 has shown the world the dangers of not fully understanding these products that became over time always more complex, adding new features in the mix to keep its attractiveness. More importantly, the financial crisis of the late 2000s highlighted the dark side of these products, that is their negative implications, with mismanaging by one or the other financial actor involved. In light of the financial market crash of 2008, the governments took safety measures by re-instating old regulations and introducing new ones, with as main intent slowing down and controlling the trend of financial innovation for derivative products. However, this has proven to be counterproductive as the innovation did not stop, leading to a financial landscape where financial derivatives are being made increasingly more complex in order to circumvent (new) regulations and to exploit the ignorance of the investors to profit from (Célérier & Vallée, 2013).

Therefore, a dilemma arises: how can a government control the increasing complexity of financial derivatives if both financial deregulation and tightening of the rules lead to the same outcome?
The only way to being able to figure out how to tackle this challenge is to understand what an increase in complexity of financial derivatives brings to the table for both investors and issuing institutions, and which factors come into play. Academic literature points out that high complexity of financial instruments may be associated with incorrect pricing and withholding information.

This thesis investigates the relationship between these three factors (product complexity; mispricing; and asymmetric information) that are peculiar of financial derivatives. However, it does so in an indirect way, availing itself of other concepts, such as perceived risk and asymmetry of knowledge, which are easier to manage, but still closely related to the other two notions. Perceived risk influences the expected returns to investors -due to risk-return relationship- and therefore is related to the difference in price attached to a financial derivative; asymmetry of knowledge, defined in this thesis as the difference in financial knowledge between two parties, can be considered one aspect of the broader notion of asymmetry of information.

This thesis evolves around a replication study: experiments have been conducted to bring up to light the link between complexity and perceived risk in financial derivatives, as was previously done by Koonce et all. (2005). A total of 54 people representing potential investors took part in 3 consecutive experiments. They were asked to make both absolute and relative risk judgments of different (but financially equivalent) investment positions. The respondents were not informed that the various investment positions were financially equivalent in terms of risk and returns. The concept of financially equivalent investments can be widely interpreted, leading to possible

ambiguity. This thesis breaks down and theoretically studies what the key elements are for two investment positions to be equivalent financially. Two have been identified: economic exposure and risk exposure. The thesis investigates the first and finds von Neumann & Morgenstern's Expected Utility Theory (2009) as a starting point to indicate that the probability of outcome and the related payoffs need to be identical as necessary, but not sufficient conditions for two financial positions to be financially equivalent. Building from the basis of risk management, bearing identical risk, both in type and magnitude, has been identified as second necessary, but not sufficient condition. The work continues by showing two possible ways to create financially equivalent positions: (a) keeping the same financial instrument but with different clauses or (b) using a combination of financial instruments to replicate the mechanism of another one. This last procedure has been used in this thesis to correctly manipulate the complexity in the financial positions used within the 3 experiments, holding everything else constant.

The replication of Koonce et al.'s experiments was done with some tailored changes that were made to aim to generalise the relationship found between complexity and perceived risk by an investor. In particular, this thesis explored to what extent asymmetry of information and asymmetry of knowledge affect the misjudgment of a potential investor. The experiments conducted in this thesis show clearly that asymmetry of information, under the form of different amount of disclosed information, amplifies the misjudgement of a potential investor. When investors are presented with more information, in particular when both the potential gains and the potential losses of a financial position are disclosed by a firm using financial derivatives, they tend to make better risk assessment than when only potential losses are disclosed to them. Regarding asymmetry of knowledge, the quantity of observations resulted insufficient to draw statistical conclusions. However, at first glance descriptive analysis seems to indicate that there is not any difference between knowledgeable investors and not. While acknowledging that part of the analysis was hindered by a relatively small number of respondents (which leads to a limited data sample), the results obtained fail to add generalisability to the previous findings of Koonce et al.'s experiments. On the contrary, the analysis of the conducted experiments seems to indicate that the results vary and are dependent on the financial derivative that is being studied. For instance, this study finds that the manipulation of complexity in a financial position using interest rate swaps as the main derivative product did not result in a change of perceived risk by participants. On the contrary, the positions characterized by futures and options as derivative products showed a higher possibility of perceived risk manipulation. In conclusion, information asymmetry has an increased impact when complexity of a financial derivative is high.

Moreover, where Koonce et al. (2005) failed to prove the validity of additional information exposure of the financial derivatives as a policy to potentially protect investors, from the results of the experiments conducted in this thesis, visual aid in form of a payoff graph of the financial position is found to be more effective. Moreover, across the 3 experiments there is no evidence of the presence of the Dunning-Krueger effect in financial matters. This means people are self-aware of their financial literacy and do not over- or underestimate what their actual knowledge in this field is. Therefore, overconfidence of investors as a main potential problem in financial derivative usage can be disregarded (Garcia, 2013).

To conclude, this thesis investigates the concept of complexity in financial derivatives. It studies how complexity can be defined in these financial instruments and if it can be quantified. The academic literature shows ambiguity in the definition of complexity in financial instruments and there is also a lack of methods to measure *complexity* in a quantitative manner. This thesis tries to fill these two knowledge gaps by providing an

exploratory framework to measure complexity in financial instruments in a quantitative manner. The framework focuses on the "building blocks" (Brunnermeier, Oehmke, & Jel, 2009), on the roots that make a financial derivative complex, identifying them as the various features such instruments present, including the underlying mathematical model that describes them or the number of underlying instruments that define them. A model is therefore constructed that sees complexity of a financial instrument as a linear function of the values their features can assume. The framework presented in this work relies on the assumption that different investors tend to associate complexity in a similar way, indicating that the concepts are more objective than subjective. This assumption is proven to be valid with an additional experiment conducted, that shows how the answers to from various investors to the question "Overall, how complex do you think products X is?" are normally distributed for a various range of financial products. The experiment itself proves also the general validity of the model presented and it indicates the mathematical model and the number & dependency of the underlying assets that define the instruments as key influence on financial derivative complexity, while it shows that the trading modality (Public financial markets or OTC) does not have any influence.

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1 Introduction

"Derivatives are financial weapons of mass destruction, carrying dangers that, while now latent, are potentially lethal."

These are the words with which the Chairman and CEO of the Berkshire Hathaway, Warren Edward Buffett, showed his concern and adversity for these special type of financial products in a letter to its shareholders in 2002 (Buffett, 2003). Despite the monition of the *Oracle of Omaha*, the world of financial derivatives has grown substantially and keeps growing with new generations of financial innovation (Battiston, Caldarelli, Georg, May, & Stiglitz, 2013). To understand what drives this growth and how it changed during the course of time, a quick-peak at some history is needed.

1.1 Financialisation

Starting from the 1980s, financialization has been at the center of our economy and financial innovation has made great strides in the modern world (Algieri, 2018). The financial sector has grown much faster than the rest of the economy. And especially, financial sector profits have increased considerably faster than profits in the rest of the economy. Taking the US as an example, Mazzucato and Randall Wray (2015) report how the share of the financial sector in total value added increased from 10% to 20% of GDP, while the share the financial sector in total corporate profits spiked from 10% to 40%. However, this divergence of the two growth rates is noticeable only starting in the 80's, while before that the growth rates were approximately at the same rate (Mazzucato & Wray, 2015). This is mainly due to the financial deregulation started in the late 1970s, where over time all the regulations introduced with the Glass-Steagall Act 1933, just after the stock market crash of 1929, were being either revised or chipped away. Deregulation was at the basis of the growth of the financial sector, where finance started to finance itself and not other sectors, therefore depriving the real economy of part of the investment needed to bloom and prosper. This problem, stated as the problem of "wealth exploitation instead of wealth creation", is critically assessed by Stiglitz in his book "People, Power and Profits: Progressive Capitalism for an Age of Discontent" (2019), where the author explores in part the impact of financialization on the ever slowing growth of US real economy and the rise of inequality.

Deregulation opened the door widely to the creation of new types of financial products, especially financial derivatives. Their existence is not limited to modern times but goes back even to B.C. times in very simple forms (Chance, 1995). Throughout history they developed with major key players involved, such as the Royal Exchange in London and the Chicago Board of Trade that was opened in 1848 (Chance, 1995). However, the boom of these financial instruments and its further development is particular to modern times, as clearly indicated by the statistics collected by the Bank for International Settlements: the market of OTC derivatives (over-the-counter derivatives, i.e. the trading between two parties that occurs without the supervision of an organized market, such as an exchange) grew by 1210% from 1995 to 2011, reaching approximately the 700 trillion USD mark, while during the same period world's GDP increased by a mere 240%, to approximately 72,4 trillion US dollars (*Bank for International Settlements*, 2023). Nowadays the market size amounts to 632 trillion USD OTC derivatives and 90 trillion USD of exchange traded futures and options (*Bank for International Settlements*,

2023). To compare, global GDP in 2023 amounts to 112.6 trillion USD (*Bank for International Settlements*, 2023).

The growth of the financial derivative market slowed down (and even partially decreased) after the big stock market crash of 2008 and after the Dodd-Franklin Act of 2010 that introduced new regulations. However, this did not stop the development of these financial instruments, rather it enhanced it. Reintroducing part of the regulations, players in this financial landscape began to construct even more complex financial instruments in order to be able to "hide" some profits in the complex payoff structure, exploiting the ignorance of the buyer and the asymmetry of information between the two parties involved (Célérier & Vallée, 2013).

In this way, in addition to the problem of the use of derivatives as means of exploitation of wealth and not as wealth creation or to let the economy grow as a whole (Stiglitz, 2019), a new problem arose from these financial instruments: over time, the number of people (usually sellers of the products) who truly know the correct functioning of such instruments due to their increased complexity decreased and therefore these sellers have the advantage of more information compared to a larger group of buyers who lack the knowledge necessary to fully grasp what they are undertaking. A starting point to tackle down this problem is to understand the relationships between complexity, asymmetry of information and mispricing of these financial instruments. However, as the existing literature demonstrates, this is not an easy task.

1.2 Financial derivatives and their purpose

Before diving in the rest of this Master Thesis, let us clarify what will be used as definition of a financial derivative. As defined by the International Monetary Fund (*IMF Committee on Balance of Payments Statistics - financial derivatives*, 2023), financial derivatives are financial instruments which value derives from the value of a specific underlying asset. This means that its value depends both on the way the financial derivative is structured and on the value of the specific asset (or index, or another financial instrument) it is associated to.
These particular financial instruments can be traded in public financial markets or over-the-counter markets (OTC, i.e. in a non-regulated market where transactions find place directly between two parties without the supervision of a centralized third one, like an exchange) and are used for different purposes, as defined by Hull (2003):

- Hedging & Risk Management: the use of financial derivatives to minimize risk caused by fluctuations in the market and therefore minimize possible losses.
- Speculation: the use of financial derivatives to make profit speculating on the change of market conditions.
- Arbitrage: trading with financial instruments exploiting the difference between prices in two different markets, guaranteeing a positive return.

Even though some types of financial derivatives, such as credit-default swaps (CDS) and interest-rate swaps (IRS), are constructed as a type of insurance and therefore are mainly used for hedging purposes, it would be wrong to categorize these specific types of financial product as *'pure'* hedging products. In fact, history showed us how many times these instruments have also been used for speculative purposes: this happens when the buyer of the financial derivatives does not possess the underlying asset that the financial product wants to insure. The structure of the financial product ceases to act like an insurance and starts behaving like a gambling product: therefore, we talk about speculation. This became especially clear just before the financial crisis of 2008, where the use of purely (*'naked'*) speculative CDS led to the collapse of the financial markets (Friedman & Friedman, 2011), but CDS remain an important factor as shown by Norden & Roedeva (2012).

The use of financial derivatives for speculation has particular interest for government and policy makers. As stated by Lynch (2012), there are special financial derivatives that can be called "Purely Speculative Derivatives" or "PSDs" that are more and more similar to the action of gambling, or can even be considered a real *"Gambling by another name"*. These types of derivatives, despite having to some limited extent positive benefits for society, like helping with asset-price discovery and to encourage financial innovation, also have negative effects, such as a general decrease in social wealth (due to the fact that they are a less-than-zero-sum transaction) and they strongly increase moral hazard [1].

[1] When speculating, some investors take upon themselves some extra risk that they usually would not bear, due to the fact that they are confident that they would be bailed out, meaning their debts would be repaid, by a third party. This was especially true just before the financial crisis of 2008, where multiple investors and financial institutions kept undertaking more and more risk because they thought that some financial entities were "to big to fail" (TBTF), meaning that if something would have gone wrong, government would have intervened and would make sure this entities would not default. Moral hazard in speculative finance is dangerous because of the increasing systemic risk that is bears. Another type of moral hazard in finance can be seen in purposefully lacking in risk-management by company managers: if a company manager acquires CDS of the company for

1.3 Problem Identification & Societal Relevance

The growing financialisation of the world's economy has without doubt stimulated brilliant minds to study more in depth the topic of financial derivatives, both from an analytical perspective and a societal perspective. From the analytical point of view, major improvements have been made since the start of the journey in the exploration of various possibilities that the world of financial products and especially financial derivatives offers. More than 200.000 papers have been published on the topic of *"pricing models of financial derivatives"* (DigitalScienceResearchSolutions, 2023) and continuous improvements to existing models and/or assumptions are made, as demonstrated by a recent study made by Yunyu Zhang (2020), where the author studies how a Monte Carlo model to analyse price fluctuations for a particular family of financial instruments, *options*, can improve the generally well-accepted Black-Scholes model (Black & Scholes, 1973).

Also, the topic of *"behavioural finance"* saw a growing trend in the last decade (DigitalScienceResearchSolutions, 2023). This because the finance world and markets directly affect our society and an individual's life. Growing concerns on the actual benefits, but more importantly on the possible downsides of the use of financial derivatives by retail investors, led more social researchers to study what drives the evolution of these instruments, how this evolution affects the perception of its users and led them to evaluate how impactfull new policy regulations are to contain the possible problems that arise with this evolution. Studies around this topic concentrate also on the two financial market crashes that happened in 1987 and 2008: Grima & Thalassinos argue how nowadays people have a general bad perception of financial derivatives due to these major "financial catastrophic" events (2020). To reassure society about these events and to offer more protection to the buyers of these financial products, governments started to strengthen the regulatory environment around them (Algieri, 2018).

The major regulatory framework currently used in Europe for the use of financial derivatives is the *MiFID II*, that stands for "Markets in Financial Instruments Directive" and came into force starting 2014. It focuses on an increase in the transparency in financial markets that operate within the European Union and on a standardization for the regulatory disclosure for financial firms (Kenton, 2020). MiFID II was introduced as an improvement of the previously used framework MiFID I and will be soon be replaced by MiFID III, expected to come into force partly on August 2023 and partly in Q3 of 2024 (*Simmons & Simmons*, 2022).

However, with these new regulatory frameworks, governments seem not to have tackled, at least not fully, the problem of "exploitation instead of creation of wealth" introduced by Stiglitz (2019), created by the rise of the financial markets and even more by the extraordinary growth of the OTC derivatives market.

Moreover, the general upgrade of the regulatory framework is argued to have also negative unwanted effects. Some researchers state that this upgrade drives financial firms to develop even more complex financial instruments (Célérier & Vallée, 2013).

The asymmetry of information between sellers and buyers seems to be increasing with

which he/she is working, he would be less incentivized to do good for the company or he/she would be even incentivized to "work against" the company, because he/she would gain from the default of the company

complexity of the financial derivatives (J. Coval, Jurek, & Stafford, 2009). Moreover, this increase is also leading to an always bigger knowledge asymmetry between the two parties (Grima & Thalassinos, 2020). Keeping these two factors in mind, as the goal of the governments is to try to reduce the asymmetry of information between the parties and therefore protect the buyers, they strengthen the regulatory system even more.

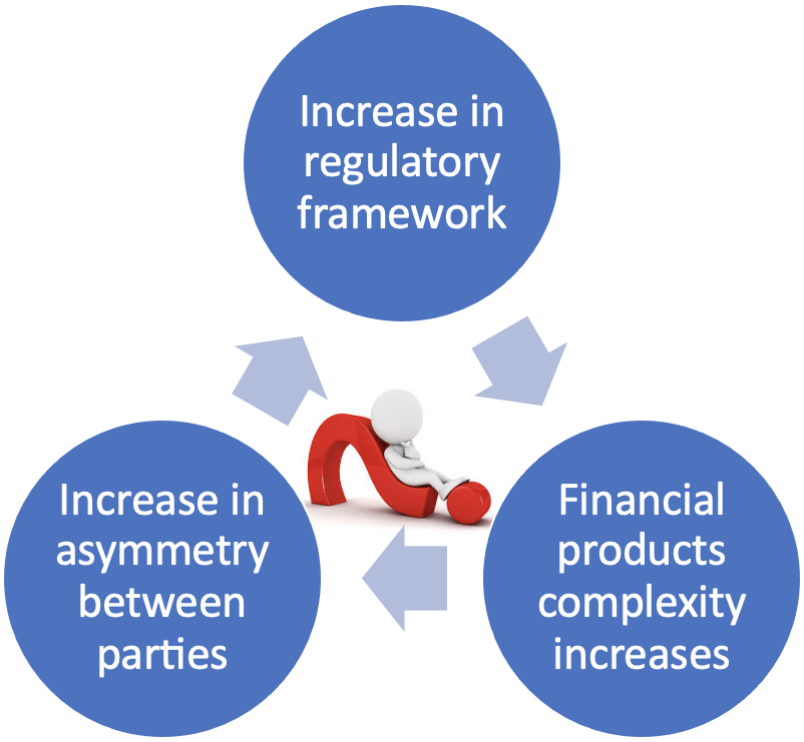

Figure 1: Problem Identification

This leads to a major problem of vicious cycle, where there seems no way out. And the one that will suffer from it will be whoever buys financial derivatives, which means retail investors who usually exploit the potential higher returns of these instruments through speculation, and non-financial firms that also use the products in order to hedge their risks.

A possible solution to avoid ending up in this downward spiral is to start studying more closely the correlation there is between complexity, asymmetry of information and mispricing of the financial derivatives. A better understanding of the correlation between these factors is useful, because it will lead to a better awareness regarding the topic by the governmental entities and the investors, whether they are retail investors or non-financial firms. This potentially translates in:

- Less asymmetry of information or at least less asymmetry of knowledge between the two parties (Grima & Thalassinos, 2020).
- More efficient measures undertaken by the governmental entities to prevent problems regarding the use and trading of derivative financial instruments.

These two effects combined would stop the vicious cycle above described, or at least keep it under control.

1.4 Research Questions

The relation between complexity, asymmetry of information and mispricing of the financial derivatives seems to be the key to generally better understand how these instruments can have a more positive, or in some cases lesser negative, impact on society. As emerges from the review literature review, the 3 subtopics and their relation has been explored to some extent but needs further attention. Studies in this field are limited mostly by qualitative studies and with few experiments to gather empirical data. Moreover, no study ever attempted to analyse the relation between the 3 subtopics altogether, but only between a pair of them. The experiments conducted by Durney, Libby and Silva (2021), are at present the closest when it comes to finding an empirical answer to the main research question of this thesis:

RQ: To what extent are complexity, asymmetry of information and mispricing of financial derivatives correlated?

The research question stated is very broad and difficult to answer without a more in-depth analysis. Multiple building blocks, gathered through other sub-research questions, will be needed to attempt to formulate a satisfying answer.

The first one can be derived by studying Durney, Libby and Silva's work (2021) together with some parts of the paper written by Koonce et al. (2005). They technically investigate the correlation between complexity of financial instruments and perceived risk by potential investors. By doing so they introduce a new variable to the table, that is the *"perceived risk by investors"*. In financial markets pricing is usually related also to a risk-premium. Risk and return are usually strictly positively correlated. Bearing higher risk translates in a higher possible payoff. However,

SRQ1: Is this sufficient to establish a correlation between mispricing and complexity of a financial derivative?

If not, an alternative way to study this relation has to be found. This process starts by identifying what mispricing indicates:

SRQ2: When speaking of financial derivatives, how is mispricing defined?

Moreover, it comes natural to then ask what is meant with the word "complexity". In different areas of studies, it can assume different meanings. Even within the same academic field, or even at the specific topic level, some differences may arise in the definition between researchers. This is also the case for complexity of financial products, where multiple definitions have been assumed in different studies. Therefore, the following sub-research questions will need to be answered:

SRQ3a: How can complexity be defined in a financial product?
and
SRQ3b: Can complexity in a financial product be quantitatively defined?

The third major subtopic that will be explored in this thesis is the asymmetry of information. To understand the impact it has on the main research question, a closer look needs to be given to the following:

SRQ4a: To what extent does asymmetry of information affect the misjudgment of a potential investor?

A first type of asymmetry of information can be seen as the difference in knowledge between two parties about the practical functioning of a particular financial products itself and not the information that is withheld by one of the two parties. Therefore, it is important to see:

SRQ4b: To what extent does lack of knowledge affect the misjudgment of a potential investor?

Finally, to be able to answer in a complete manner to the main research question, behavioural finance has to be taken into account. Specifically, the decision theory underlying the decision process of an investor has to be studied and to what extent the psychology of this actor plays a role in his decisions. As stated by Castellano & Cerqueti (2013) and explained more in depth by Ritter (2003), different effects can incur while taking a decision of a potential investment and lead investors to irrational decision making. A follow up sub-research questions therefore is:

SRQ5a: To what extent does the framing effect impact the decision of a potential investor?

Framing effect indicates how decisions can change based on how the various alternatives are represented, framed. In its simplest way it presents itself as a different choice of wording.

1.5 Thesis Outline

The rest of this Master thesis will be structured as follows. Next chapter 2, will briefly introduce the research methodology that has been used to answer the research questions. In Chapter 3 an extensive literature review on the three main subtopics regarding financial derivatives (complexity, asymmetry of information, mispricing) is presented, with the goal to have a general overview of the topic assessed and to formulate a tentative answer to a part of the research sub-questions. Chapter 4 will present a more technical overview of a specific set of financial derivatives that will then be used in the experiment. The experiment itself will be explained in Chapter 5. Chapter 5 will also present limitations and the results obtained by this experiment. Chapter 6 will discuss a new possible framework to define complexity in a quantitative way, reporting the findings of a survey with the intention of validating this model. To conclude, Chapter 7 will summarize the different findings of this Master Thesis and will discuss briefly directions for future research.

Presenting various topics and different approaches to carry on the study, Table 1 summarizes which part of the thesis will deal with which research question.

N°	Research Question	Research Method	Chapters
RQ	To what extent are complexity, asymmetry of information and mispricing of financial derivatives correlated?	Literature Review Survey experiment	3 to 7
SRQ1	Is this sufficient to establish a correlation between mispricing and complexity of a financial derivative?	Literature Review	3
SRQ2	When speaking of financial derivatives, how is mispricing defined?	Literature Review	3
SRQ3a	How can complexity be defined in a financial product?	Literature Review Model Framework	3-6
SRQ3b	Can complexity in a financial product be quantitatively defined?	Literature Review Model Framework	3-6
SRQ4a	To what extent does asymmetry of information affect the misjudgment of a potential investor?	Literature Review Survey experiment	3-4-5
SRQ4b	To what extent does lack of knowledge affect the misjudgment of a potential investor?	Literature Review Survey experiment	3-4-5
SRQ5a	To what extent does the framing effect impact the decision of a potential investor?	Survey experiment	5

Table 1: Thesis Outline

2 Methodology

This chapter will outline the methodology used to undergo the entirety of the thesis research and will briefly introduce some characteristics of the various methods that were necessary to effectively analyse the results of the study. As introduced in Section 1.5, the project has been performed with a mixed-method strategy, where both qualitative and quantitative data collection has been carried out. Qualitative research has been performed throughout an extensive literature review and conducting interviews with experts in the field of financial instruments. Quantitative research has been performed through surveys, then compared to quantitative data found in the current academic literature. The following subsections will elaborate on the various methods and techniques adopted, with also some insights on the development of these during the overall course of the project.

2.1 Research Design

2.1.1 Literature review

The literature review is a crucial backbone for the theoretical background necessary to undertake this project. The main aim of this qualitative approach is to:

- Understand the basic theory behind the majority of the most used financial products currently available for investors.
- Understanding the current state of the art regarding the regulation framework of these financial products, especially in Europe.
- Construct a general overview of the topic, in order to understand the challenges that have to be tackled from both an academic and regulatory point of view.

Multiple academic databases have been used to collect the information needed: Google Scholar, Science Direct, JSTOR, SSRN: Social Science Research Network, ScienceOpen, Web of Science, Scopus. The first four have been explored more extensively due to the presence of more papers about quantitative finance, but especially about behavioural finance.

Table 2 includes the main keywords used during the initial research, followed by a subset of synonyms for these terms. The table is non exhaustive. Moreover, most of the academic papers that were useful and have been used by the author to compose the literature review, have been found by following the *"citation chain"* of papers that were close to the topic under study.

Keyword	Synonyms
Financial Products	Derivatives, Financial Derivatives
Complexity	Difficulty, Sophistication
Risk	Uncertainty, Perceived risk, Actual risk
Investor behavior	Investor perception, Investor reasoning
Price	Misprice, Price setting, Evaluation, Value
Regulation	Regulation framework, Set of rules, Rules

Table 2: Keywords

While most studies tend to discard academic papers deemed too old or with few citations, in this particular case the relevance of the paper has been judged based only on its content and its familiarity with the topic of financial products and behavioural finance. This alternative approach has been done mainly due to two reasons:

- Discarding papers based on their publication date would have resulted in not considering some important works done throughout the years that have set the fundamentals in the field of the financial products and behavioural finance. Exemplar papers of this type are Akerlof's paper about uncertainty in a market and its mechanisms (1978) and Black & Scholes' fundamental paper on a mathematical model used for pricing of options (1973), a model that still is used today.
- Because the research topic is rather niche, discarding papers based on number of citations would have reduced too much the number of available academic papers. Moreover, different aspects of the topic would not have been studied properly.

2.2 Interviews

As part of the research, interviews have been conducted over the course of the entire master thesis project. The interviewees in question are people working in the financial sector with expertise in both general financial products exchanged on the financial markets and also in financial derivatives traded on the OTC markets. The interviews were only partly structured, with many arguments and insights going around the topic in question. The main goal of these meetings is to:

- Educate the author of this thesis on more complex financial products and consolidating the knowledge gained through the academic literature, comparing it to real life scenarios.
- Guide the author in the construction of *virtual* financial products that are used for the quantitative part of the research. This can be found in Chapter 4.
- Guide the author in understanding the practical process of derivative trading in the OTC market, in order to fully grasp what the potential problems and bottlenecks could be in these transactions.
- Assist in the creation of a well-rounded survey, then used to gather empirical data regarding *perceived risk by investors*, and validate the basics of the framework created to calculate complexity in financial products in Chapter 6.

These interviews were held online and were not single-time, but were held on multiple occasions to allow the back and forth of feedback and adjustments during the creation of the surveys and the framework.

2.3 Surveys

The thesis project consists also of an empirical part, that utilises surveys to collect data. In total, two surveys have been created by the author, in order to:

- Conduct a novel experiment to study the relationship between complexity of a financial product and the perceived risk by a potential investor. This experiment builds upon a previous research done by Koonce et al. (2005) and another study by Durney, Libby & Silva (2021). While the latter is used more as a more simple inspiration, the former is used as a general guideline in this thesis project.
- Gather data to assess the validity of the framework created by the author in Chapter 6 to calculate an objective value of complexity.

The surveys have been created through the *Qualtrics* platform, provided by TU Delft. Therefore, all rules and constrictions imposed by the university have been followed.
The remaining part of this chapter will highlight the main features of the two surveys and how the data sample is defined. However, a more in-depth explanation on the content and the intent of both surveys can be found respectively in Chapter 5 and Chapter 6.

2.3.1 Defining Questions

Both surveys are characterized by two types of questions:

- General Questions: questions about previous work experience, previous education and similar will be used to generally characterize each participant (still maintaining their anonymity). These questions will be necessary to answer to the Sub-Research Question 4b in particular.
- Specific Questions: a set of questions that will be constructed with the aim to answer all the other Sub-Research Questions, especially the SRQ4a and SRQ5a in one survey, and SRQ3b in the other.

Moreover, the survey-based experiment will be with both a *between-subjects* and *within-subjects* design. The choice to use both methods is to be able to see whether or not the preferred selection of one type of experiment towards the other would lead to different results, as can happen in some cases (Charness, Gneezy, & Kuhn, 2012), (Tversky & Kahneman, 1986).

Finally, within the single survey, some questions will present themselves twice or with slightly different changes but with similar expected results. This is true for both surveys. This feature is peculiar to check whether or not the taker of the survey is constant with his reasoning and decision and is not affected by *Preference Reversal*[2]. Castellano & Cerqueti

[2]As defined by Johnson et al. (1988), *Preference Reversal* is a phenomenon where a decision maker, when presented with different options to choose from, changes his preference between this option when asked multiple

(2013) list different studies that clearly show how approximately 25% of people change their answer for similar question within the same survey. If it happens that one participant will incur in *Preference Reversal*, the results of her/his answers will be considered void.

The efficiency and validity of both surveys have first been tested with the First Supervisor, Prof. Servaas Storm, a financial expert with more than 10 years' experience in the world of financial products, and a group of trial participants, that consisted in a small group of (3) fellow students that attended the *TPM021A - Economics and Finance* course at TU Delft. Their feedback has been used to tailor the questions in a more comprehensive way for the target audience, that will be described in the next paragraph. The answers obtained by this trial survey are not be considered in the final results.

2.3.2 Defining Sample

Defining correctly the sample from whom the data is gathered is a delicate and crucial process. Two consideration have to be made:

- **Validity of the answers:** we do not want to include in our results random answers given by participants that have completely or close to zero knowledge about financial products. Therefore, the target sample will be freshly or almost graduated students who at least have taken a couple of courses regarding economics or finance. Even better will be including people working in the financial sector or people who actively make use of financial derivatives. Moreover, to ensure the validity of the competence in financial knowledge of the survey takers, screening questions are present in the surveys.
- **Size of the sample:** A minimum number of answers are expected to have statistically significant results (Piovesana & Senior, 2018). Multiple sources indicate 50 as a sufficient sample to obtain stable results (Piovesana & Senior, 2018). However, the more the sample size grows, the more reliable the results will be.

Taking these two features into account, the following target groups have been contacted to participate in the surveys.

- Students:
  - **Intra-faculty TU Delft:** Students who are enrolled in the Master's Degree of Technology, Policy and Management, with a special attention to those who chose *TPM021A - Economic and Finance* as their specialisation and therefore participated in courses where the basics of the financial markets and financial products are taught. As previously stated, some of these students have participated in the trial survey and were therefore excluded from the analysis.
  - **Inter-faculty TU Delft:** Students attending the Financial Engineering track at Applied Mathematics. Also, former TU Delft students who either attended *TPM021A - Economic and Finance* or graduated in financial engineering.
  - **Inter-universities:** Students from other universities, such as Erasmus University Rotterdam (Netherlands), Politecnico di Milano (Italy), Bocconi (Italy), ESSEC

times. In other words, the decision maker has a preferred option the first time he/she is asked to choose, but has a different preference when asked a second time. Johnson et al. (1988) argue also how this reversal of preference is more frequent when the options to choose from are harder to process

Business School (France). Students eligible to participate have the same constraints as TU Delft students (studies focused on economics or finance).

- People with work experience in financial markets:
  - **Companies:** People working in companies such as banks, investment funds or in the financial department of non-financial firms. Generally, people with working experience in the financial sector.

These target groups have been contacted mainly directly through personal networks. Only the TPM students have been contacted through a mailing-list, with the help of Professor Servaas Storm. To circulate the survey, other professors have been contacted, but without any result. Contacting participants privately could potentially lead to less impartiality of the answers and, more importantly, to problems to generalise the findings. This is because considering only the personal network of a specific person, in this case the author, can already lead to take into consideration subjects with specific traits and could lead to less randomisation, therefore potentially not representing the total population. For this reason, recruiting the sample through a third party would have been better and would have led to more accurate results. Potentially, a higher number of participants with a more diversified background would have been recruited. However, due to lack of resources, this possibility was discarded.

2.4 Analysis

The data gathered through the surveys have been analysed with the help of the software RStudio. Different analyses have been made, such as Analysis of Variances (ANOVA), the Shapiro-Wilk normality test and linear regressions. All code snippets used are provided in the appendix.

3 Literature Overview

The literature on financial derivatives is extremely variegated, but it concentrates on subtopics such as mathematical models to price different derivatives and the general complexity around these financial instruments. However, a narrower topic around derivatives is how to correctly assess the complexity of the financial product, with regard to the asymmetric information underlying it and the action of mispricing such instruments. Therefore, this chapter will be divided in 3 subsections, describing the major findings about complexity, asymmetry of information and mispricing separately. However, because the subtopics are closely intertwined with each other, some papers are reported in more than one subsection. Others papers attempt to combine two aspects (such as complexity and asymmetry of information) and these papers are reviewed directly together, in order to not interrupt the flow of the argument.

3.1 Complexity

Most of the times complexity in financial products is not considered as an important factor in finance and economical models due to the fact that all the people are considered rational: as investors they are able to process an unlimited amount of information (when presented with it), cost-less and immediately, therefore reducing the complexity of the products to non-existent (Brunnermeier et al., 2009). However, this is not the case when bounded rationality is considered, a more realistic feature of our world. For example, every investor has to some extent computational limitations, therefore hindering his ability to completely and correctly assess the product he is evaluating. This is the reason complexity is of major importance to be studied thoroughly in financial products (Brunnermeier et al., 2009).

There is no denying the fact that financial derivatives are considered to be complex to the vast majority of people. For the way they are structured, even the financial instruments considered "simpler" such as options that are defined by a model, the Black-Scholes-Merton model, that incorporates advanced mathematics that are beyond understanding for anyone who doesn't have college-level education (MacKenzie, 2006). Even when reading through Yue-Kwen Kwok's book "Mathematical Models for Financial Derivatives" (2008), one can easily see how even college-level education might not be sufficient to fully grasp the reasoning and derivation of certain payoff formulas.

The wide variety of these financial instruments leaves open the possibility for a wide variety of complexity when defining derivatives. Academics try to categorize them both by qualitative and quantitative complexity, with the latter having more problems.

Stulz (2004) defines two broad categories of derivatives based on their qualitative complexity: plain vanilla versus exotic derivatives. The former denotation includes the following type of derivatives: forwards, futures, options and a combination of those. These instruments have generally less inputs and more straightforward payoff formulas compared to others, but more importantly, have an easy to understand concept of the way they work. It is a contract between two parties, where one of them has the right (for the options) or obligation (forwards and futures) to buy or sell a specific asset at a specific price called strike-price at a specific point in time called maturity date. The difference between forwards and futures lies in the fact that forwards are traded on the OTC market and have privately

negotiated terms, while futures are traded on public financial markets and usually have standardized terms (Phung, 2023).
All other types of derivatives, the one that cannot be obtained by a combination of the mentioned plain vanilla derivatives, are characterized by a payoff formula with complicated functions of one or more underlying assets (Stulz, 2004). As can be noticed, this type of distinction is relatively basic and has a major problem of defying the more complex exotic derivatives as the ones characterized by more complex functions. But even for the plain vanilla derivatives, the actual complexity within the category is not distinguished and this could lead an investor to think that all types of options are basic, while in reality most of these types of contracts present really complex features.

Different researchers came up with more specific methods on how to assess the complexity of a financial derivative, introducing some quantitative parts. Célérier and Vallée (2013) came up with an original and easy to understand method, where they split the whole possible structure of financial instruments and see where a potential investor could incur in difficulties: the more difficulties the investor has to face to understand the complete structure of the financial instrument, the more complex it will considered. They divide the problem step by step and include 8 concrete nodes, where the investor faces possible difficulties, with different features. The main nodes identified by them are:

- **Underlying Product:** it evaluates the type of underlying products such as Stock Equity, Index Equity, Commodities, Foreign Exchanges, Interest Rates, Credit Default or others.
- **Primary Structure:** it evaluates how the capital return, coupon rate and participation rate are structured.
- **Underlying Selection:** it evaluates how the possible selection of the different underlying occurs. This can be for example the best or the worst performing assets among the one underlying.
- **Exposure Modulation on both upside and downside:** the presence of a limitation on upsides or an increase in possibles downsides can be present in different ways, with some features more difficult to understand.
- **Path Dependence:** whether or not the financial product is path dependent and how time influences this dependence (if present).
- **Exotic Condition:** it evaluates the presence of exotic features that may put extra complexity on the financial product. Examples can be moving conditional levels that have to be met or the fact that the conditions have to be met for the totality of the time holding the financial products or the totality of the underlying instruments.
- **Early Redemption:** sometimes financial products are presented with certain triggers that can terminate the contract on an earlier date than the one agreed upon at the beginning.

This division in 8 nodes made by Célérier and Valléè (2013) is what seems to be the most advanced quantitative model to define complexity in financial products. Another study attempts to identify formulas with which complexity of financial products can be quantitatively defined (Koziol, Roßmann, & Weitz, 2018). Moreover, in their discussion of how difficult it is to generalise a notion such as complexity, they conduct an experiment where they show how people change their opinion on the complexity of something based also on the perspective with which complexity is being looked at.

Brunnermeier and Oehmke (2009) critically argue how associating the amount of effort needed to do a bottom-up valuation (meaning understanding all the basic underlying assumptions and valuating based on that) with complexity is not entirely correct: the complexity of a derivative should be associated with the *building blocks* underlying it. An example of this are options, that are considered more simple financial derivatives, despite the fact that it is difficult to understand the mathematics behind its model. They are considered less complex because only few notions, so-called *building blocks* are necessary to understand how they work, without digging into the math. Moreover, they argue that a higher liquidity of a market gives more informative signals, and therefore makes financial instruments less complex (Brunnermeier et al., 2009).

Taking into account the quantitative model (Célérier & Vallée, 2013) and the simplification of the *building blocks* (Brunnermeier et al., 2009), Chapter 6 will attempt to create a new framework with which complexity in financial products could be assessed in a quasi-objective quantitative way. A similar attempt has been done by the economics and financial consulting firm *Rutter Associates LLC* (2016). However, they lack in objectiveness and in a strong mathematical model that explains their complexity calculator.

Moreover, both papers (Célérier & Vallée, 2013; Brunnermeier et al., 2009) address the issue of increasing complexity with the rapid growth of the usage of financial instruments. Célérier and Vallée (2013) view the increase of complexity as a consequence of the financial crisis and the strengthening of regulations. Because of regulations requiring more disclosure requirements in order to protect retail investors, financial firms increased complexity of their products to create *consumer obfuscation*, with less people being able to correctly see through the product design or product pricing. This is especially dangerous for unsophisticated retail investors, who do not see the increase in complexity because of a "war" between financial firms and regulations, but feel the consequences (more losses or lower gains). Moreover, it is important to point out that an increase in complexity could create also problems to understand the financial products for the distributors, therefore sellers, not only end buyers of the products. The attention the paper gives to unsophisticated retail investors is very interesting and is novel, because most literature considers non-financial firms using derivative for hedging or experts in the field. However, as many other papers, it studies causes and consequences, relations between complexity, asymmetry of information and mispricing of derivatives but only in a qualitative way.

Brunnermeier and Oehmke (2009) have a different vision on the topic: they support the idea that in order to reduce complexity of financial derivatives an increase in regulation is needed, especially with the introduction of a standardization of contractual terms. The two authors also argue that systemic risk of such instruments could be reduced with a process of mandatory approval of new securities and possible investors. Their paper *"Complexity in financial markets"* (2009), presents sound arguments in favor of their vision, although it lacks counterarguments on why the opposite way of reasoning is wrong.

Durney, Libby and Silva (2021) explore the field of human-behavior and how they perceive risk based on complexity of the financial derivatives. They argue, that investors base their determination of risk of a financial instrument on how complex this instrument is. They use the theory of attribute substitution to make this hypothesis. The paper provides a well described experiment that assesses the correlation between complexity and perceived risk. The experiment is divided in 4 phases and with manipulation of the information provided to the participants, they correctly assess the influence of other factors that could influence the perceived risk, such as bad news on the derivative market from the media. The experiment

the authors undertook is well designed, although it presents some limitations on the selection criteria of participants. First of all, people participating in the experiment are confined in one cluster (the authors report the totality of participants as native English speakers based in the US) (Durney et al., 2021). This limits the result because it doesn't take into account the variegated cultural framework that there is in Europe for example, that could lead to more scattered findings. Moreover, their first screening is based on level of sophistication of the participant, where they took only people who understand the basics of derivatives: despite being challenging, it could be useful to investigate also how the knowledge-level regarding derivatives could influence the outcomes. Finally, a bigger number of participants would lead to more accurate results. However, a useful tool used in the experiment to better assess the findings, has been double-check questions and trick questions in order to see whether or not some answers were given randomly. Moreover, being part of the pricing of a financial instrument (but more generally of any asset) defined by the riskiness it has, this experiment can help to understand better a possible correlation between complexity and mispricing of derivatives, being perceived risk different than actual risk. Further research is needed in this direction.
A similar experiment has been made but taking into account also different input factors for selection criteria such as age, gender, occupation and average annual income (Prasad, 2016). However, this paper presents some major flaws, one of them being a poor explanation of the methods utilized. Nevertheless, it indicates a possible view on how to continue investigating in retail investors awareness of financial instruments.

Koonce, Lipe and McAnally (2005) also explore risk judgment in financial instruments, adding to the literature of behavioural finance. Differently from Durney et all. (2021), the study focuses on the labelling effects and disclosure effects in financial products. They hypothesise that similar, if not identical, financial products presented under different names, therefore labelled differently, will be assessed by retail investor as not having the same risk. This clearly shows the presence of biases when investors make their risk judgments. This is a problem for the more unsophisticated investors and potentially it could be something that the creators and distributors of financial derivatives will exploit to increase their profits. With a series of experiments, both with between-participants and within-participants methods, they are able to demonstrate this effect. Moreover, with another series of experiment they also find out that the inclusion of two-sided disclosures, meaning that both potential gains and potential losses are disclosed to the investor ex ante, increases the correct assessment by investors compared to one-sided disclosures.

3.2 Asymmetric Information

In economics, asymmetric information is defined as the situation in which one of the two parties involved in a transaction possesses more information than the other (Bloomenthal, 2021).

The fundamentals about asymmetric information between sellers and buyers in a market are explained by George Akerlof (1978) in his famous paper *The market for "lemons": Quality uncertainty and the market mechanism* (1978). It argues that the imbalance of information between the buyers and the sellers shapes the market of that specific product. The more imbalance there is, with sellers withholding information from their buyers, the more the deal will be favorable for who is selling.

Coval, Jurek and Stafford (2009), elaborate on this and explain how asymmetric information applies to markets of financial derivatives. Through easy examples, the authors point out how with pooling and tranching of a large number of credit-sensitive assets, sellers of financial derivatives can create products that at first sight appear risk-free, as confirmed by the credit rating agencies, but that hide enormous systemic risk. And because buyers base their judgement on the security rating given by the agencies (J. Coval et al., 2009), they do not fully understand the product they are buying. Moreover, they do not understand the magnitude that even small mistakes in defining the underlying parameters of the financial instrument have on the payoff of the product (J. Coval et al., 2009). They demonstrate moreover how the sensitivity to these mistakes grows with the complexity, here defined as the number of times a pool of assets has been pooled and tranched, of the financial products. In their follow-up paper they even succeed in evidencing how investors generally have a lower return than what they are supposed to (J. D. Coval, Jurek, & Stafford, 2009). With these couple of papers, Coval, Jurek and Stafford (2009) do explain one of the causes of the big crash of the financial market in 2008. However, despite the good basis to a further argumentation on how asymmetric information is related to complexity and risk of financial instruments, the authors do not develop in more depth this topic.

Two other papers argue about an asymmetric position of seller and buyer: however, these papers argue that the problem underlying financial derivatives is not the financial product itself, but the people involved with these products (Grima & Thalassinos, 2020). Garcìa (2013) argues how a big part of the problem in using financial derivatives is due to overconfidence of the investors in their knowledge and generally a bias in trusting private information much more than public information. Grima and Thalassinos (2020) point out how there is a difference in perception of complex financial instruments between economists and non-economists. While the former see these financial innovations generally as positive, the latter have a tendency to evaluate the new financial instruments as something bad. The paper offers value building a conceptual framework with all the possible issues related to the use of financial derivatives (Grima & Thalassinos, 2020). The authors, through a qualitative study state that the biggest of these problems is the lack of knowledge around these instruments: buyers (but sometimes also sellers) do not understand how derivatives work (Grima & Thalassinos, 2020). It could be argued that besides *Asymmetry of Information* there is an *Asymmetry in Knowledge* between different parties. Grima and Thalassinos (2020) correctly indicate that the complexity of a financial derivative could be subdivided in two: an intrinsic complexity that results in the fact that most people do not understand the underlying mechanism of the product; an extrinsic complexity due to the asymmetry of information. However, no effort of trying to find to what extent both contribute to the total complexity has been made.

While most of the literature focuses on the asymmetry of information, or considers the

asymmetry of knowledge as an integral part of the definition of the first, a clear distinction should be made. When there is an imbalance between the information that two parties have, one could blame and accuse the party holding more information of not sharing further details with the party holding the least information, creating therefore an arguably unfair advantage in the transaction process. This unfairness ceases to exist when the information is publicly available and the suffering party does not actively pursue the gathering of this present information. However, when the difference of the status between the two parties is given by a difference in knowledge, the capabilities they possess in order to correctly understand the main object of the transaction, the more knowledgeable party should never be held accountable for any discrepancy in the matter. It should be up to the every involved party to have the capabilities to enter transactions that they can handle. This is especially a problem for retail investors. Being non-professional investors, most of the times they lack the knowledge to fully understand how a specific financial instruments work.

A recent study by Klapper & Lusardi (2020) shows how financial illiteracy is worldwide spread. As by their definition, someone who is financially literate is someone who has basic understanding of at least 3 out of 4 fundamental concepts in financial decision making: interest rates, interest compounding, risk diversification and inflation. They found that only one third of adults worldwide do posses this type of knowledge. Naturally this perspective changes if major developed countries and major emerging countries are divided. While the latter average only 28%, if one would consider only the major developed countries, the percentage of financially literate people would increase to an average of 55%, with some countries like Canada, Germany and the United Kingdom going above 65%, while other like Italy lagging behind with 37%.
This result shows how financial literacy is variegated around the world, but how it is in general very poor, especially considering the simplicity of the questions asked during this experiment (Klapper & Lusardi, 2020).

Another study by Lusardi et al. (2010), shows how for younger adults it gets even worse. They find that only 27% of the youth is financially literate and that this is strongly influenced by socio-demographic characteristics and family financial sophistication, with the most predominant being the level of education of the parents: more educated parents seem to lead to more financial sophisticated youngsters. Similar results are obtained by Garg & Singh (2018).

Dewi et all. (2020) pointed out how different variables influence financial literacy. Among them they indicate *Subjective Financial Knowledge* and *Financial Awareness*. *Subjective Financial Knowledge* is recurrent in the literature studying investors behaviour and what affects them the most (Allgood & Walstad, 2013; Babiarz & Robb, 2013; Khan, Rothwell, Cherney, & Sussman, 2017; Mishra & Sharma, 2011). While *Objective Financial Knowledge* indicates which financial notions (such as numeracy, assets, debts, concept of inflation and compound investing and much more) and to what extend a person can comprehend, all researchers agree on defining *Subjective Financial Knowledge* as the financial knowledge and capabilities of assessment in the matter that people perceive they have. This distinction is straightforward, but of uttermost importance due to the Dunning-Kruger effect that will be introduced in the next paragraph. Moreover, recent studies focus more and more on the subjective rather than the objective financial knowledge of an individual when looking at explanations on peculiar financial behaviour and decision-making processes on financial

matters. This is due to the fact that several studies have identified the subjective part as the dominant factor, with a more significant impact on individuals behaviour (Robb & Woodyard, 2011). *Financial Awareness* indicates the capability of an individual to effectively manage tasks of financial nature, being acquainted with the knowledge necessary to perform these tasks. *Financial Awareness* influences perceived knowledge by an investor (Priyadharshini, 2017). As argued by Priyadharshini (2017), the increase in both of these variables has a positive impact on financial decision making. In the same way, Guiso & Jappelli (2005) argued that a lack of financial awareness leads to a more difficult understanding of financial knowledge matters.

However, special attention has to be given to the Dunning-Kruger (DK) effect, that states that people with limited expertise and experience in a specific area, tend to overestimate their knowledge or expertise in that specific area, leading to a cognitive bias (Kruger & Dunning, 1999). This phenomenon has been studied in several areas of expertise and seems to have had numerous empirical evidences. However, when the same study has been applied to financial literacy by Gignac (2022), the results did not support the hypothesis of the Dunning-Krueger effect, therefore showing that the overestimation of one's own financial knowledge does not vary across the spectrum of people with different actual financial abilities, from below average to above average. To prove his thesis of the non-existence of the Dunning-Krueger effect in this particular field of study, the author used the methods previously developed by him with the help of Zajenkowski (2020), where they critically discuss how this particular effect is mostly observed due to a, so-called by them, statistical artifact. Building on Krajc & Ortmann's (2008) and Krueger & Mueller's (2002) previous works, they argue that in order to check the presence of the DK effect, not only a simple correlation has to be found between the two observed variables (actual and perceived expertise or experience in a specific area), but also that the observed residual variance of the particular data-set should be heteroskedastic. Checking this last condition is what leads the author to discard the possibility of the presence of the DK effect in financial knowledge, even though it can be clearly observed in their data that people with actual low financial knowledge tend to overestimate themselves in the matter much more than more knowledgeable people, and that people with high financial literacy tend to underestimate their capabilities in the topic. However, Hiller (2023) critically looks at the new approach used by Gignac & Zajenkowski (2020) pointing out how their results are possibly incorrect due to poor selection on how to recode the response people. He correctly shows how the scale used in their studies critically changes the outcome of the study and therefore shows that also in Financial awareness the DK effect is present.

The topic of financial literacy has been studied thoroughly by Lusardi, considered the top author in this particular area of expertise (Goyal & Kumar, 2020). One of her latest works clearly states an undesired effect of the worldwide spread financial illiteracy (Lusardi, Michaud, & Mitchell, 2017). Not only does this problem increase the possible asymmetry of knowledge between two parties in a financial transaction, but it leads to further wealth inequality and therefore, based on her other findings (Lusardi & Mitchell, 2011, 2014), it can become a vicious cycle were the gap between financially literate and illiterate people gets wider and the latter group increases in size (Lusardi et al., 2017).

3.3 Pricing & Mispricing

A good portion of existing literature about the topic of pricing financial derivatives is composed of technical papers where various models are developed to correctly assess the value of these complex instruments. These models all revolve around the so-called "Theory of Options". As reported by MacKenzie (2006), the key paper that laid the foundations of this theory appeared in 1973 and was published by Fischer Black and Myron Scholes (Black & Scholes, 1973). However, in the same year, also Robert C. Merton published a different paper containing a similar approach to option pricing (Merton, 1973). These papers started the era of mathematical equations and models to assess the valuation of options starting from different inputs.

In his paper MacKenzie (2006) elaborates an argument on whether or not the Black-Scholes-Merton formula and therefore model can correctly be used to price derivatives. His argument does not focus on the underlying assumptions or the logical reasoning of the model. Instead the author reasons based on the so-called notion of *"Bayesian Performativity"*. By this definition, he means a model, which proposes some practices based on its theory, that would alter the real-life economic processes, leading towards outcomes that conform with the model itself (MacKenzie, 2006). The author carefully explains the difference between this type of performativity and what is known as *Self-fulfilling prophecies*. The latter differs because it doesn't exclude the possibility of arbitrariness. MacKenzie (2006) argues that any other arbitrary option-pricing formula, if leading to possible arbitrage opportunities by the users, would not lead to altering of the economic processes that would confirm the correctness of such formula. Therefore, the Black-Scholes-Merton model is not a self-fulfilling prophecy, but is characterised by *"Bayesian Performativity"*.

This reasoning goes deeper to the roots than any analytical reviews on the models, because instead of focusing on simple building blocks of the model, it critically evaluates the impact of the "Theory of Options" on the world's economy and how, in turn, the world's economy reinforces empirical validity of the model described by Black, Scholes and Merton. However, despite the novelty of the approach selected to assess the foundations of the model by many considered the benchmark in financial instrument pricing (MacKenzie, 2006), the author fails to support his reasoning with empirical data throughout the years: in the paper only a small portion of empirical data is reported and only for the early years of application of the Black-Scholes-Merton formula.

In a section of the paper "Should we fear Derivatives?", Stulz (2004) opens up about the major difficulties that lead to mispricing of derivatives. He identifies one main problem in the illiquidity of the market of derivatives. This is a general belief (Grima & Thalassinos, 2020) and is especially true for the OTC market, that handles the biggest portion of outstanding derivatives traded (*Bank for International Settlements*, 2023). Stulz (2004) points out how liquid assets and financial instruments do not necessarily need a pricing model, because they will follow the market opinion, while it is a whole different story for illiquid instruments. Without a model they cannot be correctly priced. But every model is based on assumptions, that the author argues to be most of the time significantly distant from what happens in the real world. Brunnermeier and Oehme (2009) also make light on the fact that because of assumptions and approximations, models are intrinsically limited and are likely to be incurred in the so-called *modelling pitfalls*. The paper of Stulz (2004) provides some empirical facts on the incorrect pricing of derivatives. Moreover, the author explains also a correlation between complexity and liquidity, that could lead to a correlation between complexity and the mispricing of financial derivatives. As good as this argument sounds, the author doesn't provide nor empirical evidence

of this correlation himself, nor from someone else. Similarly, but with more detail, Ruf (2011) also elaborates on the overpricing of structured products. He mainly focuses on the dynamics of this recurrent event and also indicates the lack of liquidity as one of the main factors.

Blommestein (2009) investigates the causes that lead to action of incorrectly pricing financial derivatives. He does this after providing data that support the statement that financial markets do underprice risk. His focus lies on how a financial derivative works and not which model has been used to value it. By definition a financial derivative has one or more underlying assets. Blommestein argues there is a global shortage of collateralizable assets, because of less investing in the real economy and a shift of the savings towards financial assets: that created an imbalance between demand and supply of debt instruments. This imbalance made that the risk-premium would be lower than what it is supposed to be. Blommestein (2009) also acknowledges that there is an intrinsic structure of the financial products itself that incentivizes people, in this case the sellers, to incorrectly price their instrument sold. The author also argues about social-behavioural factors that amplify mispricing: the intrinsic human nature of underestimating anomalies in the market, that together with the structure of the market itself leads to bubbles and crashes, therefore to overpricing and under-pricing (Blommestein, 2009). However, even if Blommestein (2009) tackles the problem of incorrectly pricing derivatives by looking also at the impact of human behaviour and not only on the validity of a model, the author does not explore in depth to what extent every one of these factors impact mispricing. It would be of interest knowing which of these factors contributes more to this problem regarding financial derivatives.

Chang, Donohoe and Sougiannis (2016) try to bridge the sphere of complexity and mispricing of financial derivatives. However, they do so by looking at a correlation between the complexity of the derivatives that are used by non-financial firm and the capacity of analysts to correctly forecast future earnings (and therefore the value of the company). Through empirical data collection they remark this correlation as a positive one: the more complex the financial derivatives in use, the bigger mistake made by analysts in forecasting earnings. They also analyse the data more closely and notice other factors that contribute to this wrong assessment, such as the "novelty" of non-financial firms in using derivatives. This shows how the knowledge of such instruments is vital for a better usage.

Moreover, the authors also try to divide the problem of complexity into intrinsic complexity and reporting complexity. They argue that the difficult and less-transparent task of reporting the use of derivatives in their financial statements increases the misjudgment by analysts (Chang et al., 2016). This is confirmed by research by Chernenko and Faulkender (2011), who studied how non-financial firms used financial derivatives, for hedging or speculation purposes. Their result shows that what some firm report to be hedging activities, in reality is much closer to speculating, indicating that the firm is not really using derivatives to hedge risks or reports it poorly in its financial statements (Chernenko & Faulkender, 2011). However, the paper of Chang, Donohoe and Sougiannis (2016), does explore only the world of non-financial firms using financial derivatives, while retail investors are not considered. Moreover, the paper does not show a malpractice in the calculation of the value of derivatives, but of firms using this particular financial instrument.

Sometimes the word mispricing leads to ambiguity because as previously stated, it is already difficult enough to understand which is the correct model to price a financial derivative. Moreover, often and willingly the modern models used are limited by assumptions that do not reflect the reality of our world (MacKenzie, 2006). How can someone spot an error from the correct value of a good sold, when the correct value itself is not universally true

and known?

Here is where the concept of *fair value* comes into play. The fair value of a financial product can be defined as the *"the amount for which it can be exchanged between knowledgeable, willing parties in an arm's length transaction"* (Scott & Scott, 2003; Breton, 2004). This holds true for more liquid financial products. When illiquidity becomes more prominent, a more general concept of fair value can be seen as the value calculated with valuation techniques (therefore formulas and models) that are commonly accepted and used in today's market for similar assets or liabilities (FASB, 2004).

Keeping this definition in mind, Joergensen et al. (2012) build a framework to spot mispricing for a financial product called Principal Protected Note (PPN). They argue how after calculating the fair value of a product, there will be a difference between what was the actual price paid for that instrument issued and their fair value. This difference is called Total Cost and is indicated by TC, calculated with the following formula:

$$TC = \frac{(P^I - P^F)}{P^I} * 100\% \tag{1}$$

Where P^I indicates the price with which the product has been issued, while P^F indicates the fair value of the product.

This difference should be present and is something to be expected, because it indicates the cost of the contracts itself that the buyer will incur, therefore representing the profit the seller makes on this particular transaction. This is true due to the fact that when calculating the fair value of a financial product, the models underlying the various formulas nowadays used are built on the concept of zero present value, meaning that a transaction occurs at a fair value when the sum of all future cash flows, after being discounted, should be equal to the amount paid today. However, the actual total cost should be equal to the costs that are being disclosed in the contract of the financial product. In case this value is not the same, that means the difference should be given by what they call *hidden cost* (Joergensen et al., 2012). They argue that, if studying a large number of similar financial products, the HC would oscillate around the value of 0, indicating that the instruments was fairly priced, with the oscillation given by random estimation errors. However, if it oscillates around a value greater than 0, then the financial product has been systemically over-priced.

In their empirical study, Joergensen et al. (2012) are able to shed light on this systemic overpricing in Principal Protected Notes in the Danish market by 6 %. Similarly, Henderson & Pearson (2011) find that the prices on multiple popular retail products were on average 8% greater than the estimated fair value. They did not use the same methodology as Joergensen et al. (2012) and they did not take into account the disclosed cost in the contract. However, this cost usually does not exceed the 2-3%, quite far away from the total of 8% extra charging. Both papers critically overview this problem and highlight some of its negative consequences, such as the exploitation of the more poorly educated in financial matters retail investors and that possibly leads to creation of wealth inequality.

4 Financial Instruments

The following chapter will briefly discuss what are the characteristic of financial instruments and how they are different from each other. It will discuss the major risks that occur when acquiring financial products and how these work. Finally, it will discuss the concept of *equivalency* for these categories of investments and based on this concept, examples of equivalent investment positions will be build. Some of these positions will then be used in the experiment outlined in 5.

4.1 Characteristics and types of financial instruments

The world of financial instruments is very broad: from the more known bonds, stocks, options, futures, forwards, exchange-traded funds (ETFs), certifications, to the less known interest rate swaps (IRS), credit default swaps (CDS), collateralized debt obligations (CDOs), synthetic CDOs or swaptions. Some of these instruments result a bit easier to understand to investors, some others are more complicated. A general definition of a financial instrument is a contract, a legal agreement involving any kind of monetary value, as by Kenton (2023). As a general guideline, financial instruments can be divided in two big groups: cash instruments and derivative instruments. Cash instruments' value depends directly on the market development, while financial derivatives' value is depending on the value of its underlying. Bonds and stocks belong to the first category, while the other before-mentioned instruments belong to the latter. Usually cash instruments are directly traded on regulated financial markets, while most of financial derivatives are traded on the OTC market.

All these instruments have their peculiarities that are usually described in the contract itself and that differ from each other. First of all, they are usually described by a mathematical model that defines how they function and what their payoff would be. Again, these models can be more or less complicated. Moreover, they can be more or less accurate, depending on the assumptions on which the mathematical models are built. A specific type of instrument can also be described by similar, but different types of mathematical models, that usually lead to the same payoff structure, but with slight changes in their value. An example are options, a financial product that gives to the holder of this instruments (the buyer), the right, but not the obligation to buy or sell (depending if it is a call or a put option) a set quantity of a specific asset at a specific given future date, called maturity date, for a agreed upon price, called strike price. The monetary value of options is usually calculated with Black & Scholes' mathematical model (Black & Scholes, 1973), but different variations of this model exist with different underlying assumptions.

Besides the model with which their price is calculated and their functioning is described, financial instruments are characterized by possible clauses they have written in their contract, that could change the way the product works entirely. When traded on regulated financial markets, a certain class of financial instrument has a standardized set of clauses, as well as standardized mathematical models underlying it.

Lastly, different types of financial instruments bear different type of investment risk. In the following section, a closer look at the main risks that an investor could incur when purchasing a financial product are described.

4.2 Risk & Uncertainty

Before diving into the different types of risk that exists in financial investments, a general definition of risk has to be agreed upon. This is not an easy task and is still under discussion by some researchers, due to the subtle difference between risk and uncertainty (Machina & Viscusi, 2013). Let us start with the definition reported in one of Knight's early works, *"Risk, uncertainty and Profit* (1921). Frank Knight states that the concept of risk and the concept of uncertainty are radically different, even though in common economic terms the term *"risk"* is used to explain both. The author argues that the main difference between them is that risk is a quantity that can be measured, while uncertainty cannot. Both terms indicate a state of possible future outcomes, but when we talk about risk the probability that these future outcomes take place is known and therefore a general (risk-weighted) outcome can be measured. To quote the author himself, risk can be defined as *"measurable uncertainty"* (Knight, 1921).
As argued by LeRoy & Singell (1987), Knight's definition can be misinterpret and slight variations of the definition can occur. For example, Calow (1998) reports that in environmental literature risk can present itself in three different definitions:

- Risk is the likelihood of future outcomes. Therefore, risk is purely measured by the probability of these outcomes happening.
- Risk is seen as the magnitude of the negative consequence of a particular outcome. Here the focus doesn't lie on the probability of the outcome, but on the *maximum damage* someone would incur if a specific event would take place.
- A combination of the first two definitions. Risk as a combination of uncertainty and magnitude of the loss, therefore calculated as the product of the probability of the event happening and the quantity of the loss in case the event would occur.

As can be seen, different interpretations look at the problem from different points of view. But a common thread that all these definitions share can be summed up in the following definition, that will be used in the remaining part of this master thesis.

Risk is the possibility of unfavourable outcomes to happen. These outcomes can be foreseeable and therefore measured with probability, or unforeseeable. Therefore, risk can be seen as having exposure to uncertainty.

4.2.1 Types of financial risk

Now that we have defined what we consider as risk, let us consider financial risk and its different types in greater detail. Generally, when talking about financial investments, two distinct categories of risk can be defined:

- **Systematic Risk:** risk that is inherent to the entire market or market segment (Chen, 2023). This risk is also known as undiversifiable risk, due to the fact that it cannot be controlled (reduced) through the act of diversifying an investment portfolio. However, systematic risk can be kept under control through hedging and a better asset allocation. This means that to manage systematic risk, creating a well-balanced asset allocation (having different class of assets in a portfolio, such as stocks, bonds, cash, real estate)

reduces the sensitivity of the overall portfolio to the market fluctuations. For example, if the stock market should have worse returns in a span of time, it does not mean that also the bond market and the real estate market have worse returns. Therefore, having different classes of assets in your portfolio helps to mitigate systematic risk. Examples of these types of risk are interest rate risk, inflation risk and global political risk.

- **Non-systematic Risk:** risk that is related to a specific company or a specific industry (Chen, 2023). Therefore, it is also known as specific risk or idiosyncratic risk. Non-systematic risk cannot be measured but it can be sufficiently diversified and therefore mitigated. Examples of these types of risk are business risk and operational risk. As can be seen, these risks are peculiar to a particular company and do not affect the entirety of the market.

Systemic risk is also important to take into consideration when doing a financial investment, especially when acquiring structured products. Systemic risk indicates the risk of creating a *"chain reaction of falling interconnected dominos"* as defined by Kaufman (2003), meaning that a single unfavourable event in a specific scope potentially can lead to multiple simultaneous unfavorable outcomes even though these are not directly related. Coval et al. (2009) and Koehler (2011) stress the importance of these type of risk when dealing with structured finance. While Coval et al. (J. D. Coval et al., 2009) point out the difficulty of correctly assessing the total risk that structured products bear due to inter-dependency and correlation of the products underlying, Koehler (2011) argues how there is a relationship between this type of risk and the complexity of a financial product. While it is generally true that structured products that have multiple levels of derivation bear exponentially more systemic risk than other products, due to their *layered* nature, that does not mean that there is a relationship between the two concepts. This is because, as will be discussed in Chapter 6, complexity is not only defined by the number of derivation levels a product has, but many more features come into play.

Let us now define more accurately the most common typology of risks that financial products can bear:

- **Business Risk/Operational Risk:** it summarizes the risk of conducting business by any firm. This type of risk is unsystematic and can be minimized through diversification. Financial products bear this risk if their underlying asset is related to a firm that carries this risk.

- **Interest Rate Risk:** the value of a financial instrument can vary with a change in interest rates. Therefore, we talk about interest rate risk when a possible unfavourable change in the interest rate leads to a decrease in value of a financial product. The magnitude of this type of risk is product dependent.

- **Liquidity Risk:** this type of risk occurs when it becomes challenging to convert a financial position into cash. This means that there are fewer buyers than sellers of a specific financial product, leading to a possibility to not being able to sell your financial product in a short amount of time. For example, stocks with low trading volumes generally carry higher liquidity risk than the ones with higher daily trading volume. Generally, trading on the OTC market, being it mostly a *thin market*, defined as a market with a low number of buyers and sellers, increases this risk (Kenton, 2022). Another example of investment that carries high liquidity risk is Private Equity, where the money invested is

usually locked into a bigger pool for a certain amount of time that can vary from a few years to a decade.

- **Credit Risk/ Default Risk /Counterparty Risk:** it generally defines the risk that the opposite party with whom you establish a contract will default and not be able to meet entirely its financial commitments. To better evaluate this type of risk, credit rating agencies like Standard & Poor, Moody's Investor Services and Finch Ratings assess the history and the likeliness of specific firms to fully meet their contractual agreement. Moreover, this type of risk can be minimized by asking for collateral when the credit rating of the counterparty is not of the highest.

- **Volatility Risk:** it indicates the possibility of fluctuations in the price of a certain financial product. These fluctuations can be very wide leading to higher volatility risk and are usually always present. Even though in a longer period of time the value of a financial product can increase (or decrease), within that period of time its price can momentarily go down (or go up). Volatility risk is influenced also by the expectations and speculations of investors. It is especially present in short-term investments.

- **Model Risk:** every financial product has a mathematical model that defines it. Model risk identifies as the possibility that either the model used is deficient (for example it builds upon wrong assumptions) or that is incorrectly used (Koehler, 2011). This risk is mostly present for financial products traded on the OTC market, where there is no standardization of the models and methods used to evaluate an instrument.

- **Underlying valuation risk:** refers to the risk that the underlying asset of a financial product is valued differently during the transaction from its actual value. In other words, it indicates the possibility of assessing the value of its underlying wrongly.

Depending on the type of financial instrument and on the clauses that are reported in the contract as financial agreement, a product can bear one or multiple of these risks and with different levels of magnitude.

4.3 Equivalency of financial products

This section defines what is meant by having two financial positions that are deemed *equivalent*. Let us start with the obvious: two financial positions are considered equivalent if their economic exposure is the same (Koonce et al., 2005). That means, the value of these two financial positions is equal at any given moment for any given outcome. A rational investor would be indifferent in investing in either financial position. The characteristics of such positions can be described through von Neumann & Morgenstern's *Expected Utility Theory* (Ackert & Deaves, 2009). To be considered equivalent, two investments need to have the same expected utility prospect (U), that can be calculated as a multiplication between the outcome of every possible scenario in terms of the utility function $f(u)$ and its probability to happen (P).

$$U = \sum_i (P_i * f(u_i)) \tag{2}$$

The utility function is used instead of the actual value of the possible outcome. This is because it is important to consider the preference of each investor. However, the condition to have the same expected utility is necessary, but not sufficient to have two financial positions

regarded as equivalent. As previously stated, any given outcome should lead to equal value in both positions. If we look at the expected utility theory, it could be that the total expected utility of two positions is the same, but looking at singular possible outcomes, the expected utility is different. For example, let us suppose that we can choose from two possible investments, both with same invested capital of €100 and that depend on the stock price of the same company (let's call it DelftGaming) at the end of the day: investment A pays its investor back €150 and €300 if DelftGaming stock price has risen by at least 1% and 5% respectively. Investment B guarantees the amount of initial capital invested and repays its investors €300 if there is at least a 5% rise in stock prices. After studying the stock price of DelftGaming, you expect the following probability for the different outcomes: 25% chance that the stock price rises above the 5% mark, 50% chance it rises above the 1% mark but does not reach the 5% threshold and 25% chance that the price drops or doesn't rise enough. Table 3 and Table 4 summarise the situation:

Scenario	x <1%	1% <x <5%	x >5%
Probability	25%	50%	25%
Payoff Scenario	€0	€150	€300
Expected Utility	€0	€75	€75
TOTAL EXPECTED UTILITY			€150

Table 3: Investment A

Scenario	x <1%	1% <x <5%	x >5%
Probability	25%	50%	25%
Payoff Scenario	€100	€100	€300
Expected Utility	€25	€50	€75
TOTAL EXPECTED UTILITY			€150

Table 4: Investment B

Both investments have the same total expected utility of €150. However, in reality, only one out of the 3 scenarios will happen and the payoff of the investment is different in each scenario. In order to be considered equivalent positions, meaning having the same economic exposure, all possible scenario should have the same payoff. This reasoning holds true also for continuous probability distributions. Therefore, it can be concluded that to be considered equivalent, two financial positions need to have the same payoff at any given possible outcome. This can be easily seen by confronting their payoff graphs: they need to be the same.

However, payoff graphs show only a certain type of risk an investment incurs that is the change in market price and volatility risk. In order to be properly considered equivalent, two positions should also bear the same amount of other risks. For example, I could have two option contracts in two separate markets, the American financial market and the European financial market. Both options have as underlying the value of the SP500 index. Their payoff is identical for any given possible outcome. However, they bear different liquidity risk. If I would like to sell the contract before the maturity date, it could be that on the American financial market I

find a buyer whom I can sell my position, while in the European financial market I may struggle to find one.

The next section will also contain two financial positions with the same payoff graphs, but with different counter-party risk. These positions will be studied more in-depth.

4.4 Examples of equivalent positions

This section will describe two possible ways to construct different financial positions deemed equivalent. To do so inspiration will be taken from the works of Durney, Libby and Silva (2021) and Koonce et al. (2005). The first of the two methods is straightforward and does not add any interesting point of view to be further explored, while the second method will be used in this thesis to conduct an experiment that is described in Chapter 5.

4.4.1 Same product, different features

In experiment number 2 conducted by Durney, Libby & Silva (2021), we encounter what the authors indicate as two financial products that have economic equivalence despite having different features. In reality, the two instruments described by them are exactly the same, but their clauses are described differently, highlighting a different dimension of complexity. For their example they use Bermudan call options. This type of option has a less common exercise style than the classic European or American option. How these different styles work is described briefly in the textbox.

Overview of Options types

An Call (or Put) Option is a financial instrument that gives the right, without imposing an obligation, to buy (or sell) an agreed upon quantity of a specific asset at a specific price at a given future date. This price is called *Strike price* and the date is called *Maturity Date*. However, different exercise styles have been developed over time. The three main styles are:

- **European Style:** the option contract can only be exercised at maturity date.
- **American Style:** the option contract can be exercised at any given moment prior to the maturity date.
- **Bermudan Style:** the option contract can be exercised a discrete number of times before the maturity date, on specific dates that are previously agreed upon.

Moreover, besides their exercise style, option can differ in other features, such as how the underlying is defined or when the premium (cost of entering the contract) has to be paid. For example:

- **Asian Option:** in this type of option, the payoff is not calculated considering the price of the underlying at maturity date. Instead, an average price over an agreed upon period of time before maturity is taken into consideration. This helps to reduce the volatility risk.
- **Boston Option:** option contract with the same characteristics as an American option, but with the difference that the premium has to be paid only at maturity date, not when entering the contract.

Durney, Libby & Silva (2021) argue that the early exercise in Bermudan Options does not affect their economic characteristic, as long as the number of exercise dates is equal. For example, let us assume two different contracts. Both contracts have the same underlying model, the same underlying asset, the same option type, the same strike price, the same maturity date and the same premium. They are identical except for the clauses of when the contract can be exercised. The clauses of the first contract state that exercise is possible on the 1st and 16th day of every month. In the second one, it is stated that exercise is possible on the days where the number of the day coincides with the number of the month and on the last Friday of every month. Both contracts have therefore 24 exercise dates in a year and can be considered economically equivalent, despite being different.

However, this difference is not really substantial and is reduced to having a harder time to interpret the clauses, therefore bearing more complexity according to the authors. Otherwise, the two positions are identical. As will be seen in the next paragraph, it is possible to create equivalent financial positions using different type of financial instruments combined. This second approach highlights more the difference between such positions.

4.4.2 Fixed Rate - Variable Rate - Interest Rate Swap

Koonce et al. (2005) use a different approach to create two economically equivalent financial positions. They do so by combining different financial products, more precisely derivatives. This method turns out to be more adequate because it stressed out that the two positions are obtained in alternative ways and do not differ simply in the wording of the clauses. For their purposes the authors utilize the example of a fixed-rate debt position and a variable-rate debt position in combination with an interest rate swap from variable to fixed. Let us look at these two positions more closely, by analysing first the cash flows that they produce.

A fixed-rate debt position leads an investor to the following cash flow. Let us call the notional amount X and the fixed rate *f*. If the interest rate payments have to be done yearly, the cost of entering this position is f*X every year.

A variable-rate debt position with the same notional amount has a cost of $LIBOR$*X every year, if we assume that the variable rate is exactly equal to the LIBOR. However, if an investor would enter at the same time a variable-to-fixed interest rate swap position for the same notional amount X and the same fixed rate *f*, this is what is yearly cash flow would look like. Besides the $LIBOR$*X cash outflow due to the variable-rate debt position, the investor has an additional cash outflow of f*X due to his swap position. However, he also has a cash inflow of $LIBOR$*X due to his swap position. The total outstanding cash flow of the combination of these two financial instruments is *de facto* the cash flow outstanding for a fixed-rate debt position with the same notional amount.

A change, both an increase or a decrease, in interest rate would not change the amount that has to be paid for both positions. Both positions are locked into paying a fixed amount equal to f*X. An increase in the interest rate would cause an economic gain due to the fact that the investor would not have to pay the higher interest rates. This holds true for both positions. Moreover, if the fixed-rate f is equal between the two positions, the economic gain is identical in value for both positions. A decrease in the interest rate would cause an economic loss due to the fact that the investor would have to pay the fixed rate that will be higher than the current interest rate. This holds true for both positions. Moreover, if the fixed-rate f is equal between the two positions, the economic loss is identical in value for both positions.

This characteristic is the first necessary condition to have two economically equivalent financial positions as described before: they have the same payoff (in this case it would be more accurate to say payout due to the outflow of money) at any given moment for any given interest rate value. The second condition of bearing the same amount of risk is also already partially discussed. The risk of a decrease in interest rate causing an economic loss is equal for both positions. This is because the variable-to-fixed rate interest rate swap is able to offset (to hedge) the greater risk that a variable-rate debt position bears.

However, another risk comes into play: counterparty risk. This risk is slightly different for the positions. In the variable-rate debt in combination with a variable-to-fixed interest rate swap, an additional party comes into play, therefore raising the counterparty risk. This risk can be assumed to be negligible for interest rate swaps according to different theoretical studies and historical data, as reported by Koonce et al. (2005).

Interest Rate Swap

Definition: An interest rate swap (IRS) is an agreement between two different parties to exchange interest rates over a notional amount agreed upon. Usually, that means that party A will pay party B an amount based on an interest rate that is fixed, while party B will pay party A an amount that varies depending on the current interest rates. Entering an IRS position from variable-to-fixed interest rate is usually seen as a hedging position, because you protect yourself in the possibility of an increase of interest rates. The other way around is usually seen as speculation, as you hope to make profit when the interest rate go down.
The variable interest rate, called also floating interest rate, is calculated with the LIBOR or EURIBOR. LIBOR stands for London Inter-Bank Offered Rate, while EURIBOR stands for European Inter-Bank Offered Rate. These rates indicate the borrowing cost between banks and are an average of interest rate calculated from estimates submitted by the leading banks in London and Europe respectively.

4.4.3 Future - Call Option - Put Option

There are also other combinations of financial derivatives that can lead to two economically equivalent outstanding positions. An example concerns the following two positions: a European long call option versus a future in combination with a European long put option. Again, in order to create equivalent positions, the three instruments need to have the same *Strike Price* and *Maturity Date*. Moreover, the two options need to have the same premium to enter the contract. It is assumed that no premium is paid to enter the future position. Therefore, to enter the positions, the same investment needs to be done due to equality of the premiums amount of the two options. It is safe to assume that these premium costs are equal, otherwise an arbitrage opportunity would arise. For this type of instrument (options and future), the payoff of the position will not be determined by the interest rates, but by the price of the underlying at maturity date. Therefore, we do not talk about interest rate risk anymore, but of volatility risk. Let us again analyse the payoffs of the two positions.

The first position, the European long call option, would be exercised at maturity date if the price of the underlying would result higher than the strike price. If the price would be equal or lower, the investor (assuming his rationality) would not exercise his right. For any outcome, whether or not the underlying's price is higher or lower than the strike price, the investor has to pay the premium (P) to enter this position in the first place. If x is the price of the underlying and S is the strike price, we can summarise the first position's total payoff as:

$$f_c(x) = \begin{cases} x - S - P, & \text{if } x > S \\ -P, & \text{if } x \leq S \end{cases} \tag{3}$$

The second position is composed by two financial products with each having an individual payoff. The payoff of the first instrument, a Future, is determined by the price of the underlying asset and its strike price. Because we assume the same underlying asset and the same strike price as in the case of the European long call option, its payoff can be written as follows:

$$f_f(x) = \begin{cases} x - S, & \text{if } x > S \\ x - S, & \text{if } x \leq S \end{cases} \tag{4}$$

Notice how the function of the payoff is continuous and is not influenced by the relative position of the price of the underlying asset regarding the strike price threshold. This peculiarity has to do with the obligation of exercising the contract at maturity date, that is typical of a Future product. If we look at the second instrument, the European long put option, its payoff is similar to the payoff of the European long call option but reversed. Assuming the same underlying asset, strike price, premium and maturity date as before, the payoff present itself as:

$$f_p(x) = \begin{cases} -P, & \text{if } x > S \\ S - x - P, & \text{if } x \leq S \end{cases} \tag{5}$$

The payoff of the second position is the result of a combination of the two individual financial products that characterises the total outstanding position, leading to:

$$f_{tot}(x) = f_f(x) + f_p(x) = \begin{cases} x - S - P, & \text{if } x > S \\ -P, & \text{if } x \leq S \end{cases} \tag{6}$$

Equation 3 and equation 6 lead to the same function, indicating that the payoff of the two outstanding positions is identical for any given value of the price of the underlying asset at maturity date. This can be explained as follows: If the price of the underlying asset is greater than the strike price, the investor of the first position exercises his right to buy at a discounted price (S), leading to an economic gain. The investor number two instead is obliged to exercise his future agreement and buy the underlying at a discounted price (S), leading to an economic gain. In case the strike price results to be greater than the price of the underlying asset, the investor of the first position, if rational, decides to not exercise his right to buy the underlying at the price of S, but will buy it on the market for the lower price. The position results in an economic loss due to its initial investment of the premium (P). In contrary, regarding the second position, the investor would again be bound to buy the underlying asset at the higher price S, therefore causing a temporary economic loss. However, he will then exercise his put option right to sell the underlying asset at the stipulated price (S), and proceed to buy the asset at the lower market price, causing an economic gain. This economic gain and economic loss cancel out and leave the investor with the same situation as in position number 1, with a limited economic loss of the initial investment to buy the long put option (P).

The first necessary condition of having the same payoff whichever outcome occurs (whichever value the underlying's price assumes) holds true. Again, part of the risk that these instruments bear, the volatility risk of the underlying's price, is already discussed with the reasoning about the payoff. The European long put option offsets (hedges) the extra volatility risk that a future bears (unlimited possible downside, compared to the limited possible downside of the European long call option). But as seen in the previous paragraph about the variable-rate debt position combined with an IRS, also here counterparty risk is not entirely equal. In fact, the investor in position number two handles with two parties at the same time, therefore increasing the risk that either one does not meet the financial agreements. However, again it can be assumed that this risk is negligible compared to the other shared risks that these positions bear. This is because both Options and Futures are traded on the public exchange markets, that are standardized and regulated. (Options can also be traded on the OTC market).

Future versus Forwards

Definition: A Future contract of a Forward contract is a financial derivative contract that gives the holders of this instrument the obligation to buy (or to sell) an agreed upon quantity of a particular asset (the underlying) at a set price (strike price) at a given future date (maturity date).
Differences: Future contracts are traded on public stock exchanges and therefore are characterised by standardized features and bear very little risk, as payment at maturity date is guaranteed. On the contrary, Forward contracts are not standardized and have a high degree of personalisation, based on the needs of the two parties. Moreover, they are privately negotiated on the OTC market and therefore they carry more risk, especially counterparty risk.

5 Complexity versus Perceived Risk

This chapter is dedicated to the experiments conducted and an analysis of their results. In total three experiments will be described that have as main objective to replicate the first three experiments performed by Koonce et al. (2005). Their fourth and last experiment is not being taken into consideration because it is out of the scope of this master thesis. Despite being a replication, novel features will be added to the experiments both to overcome limitations of the previous research and potentially to explore new paths for further studies. Other minor design features that are present in the three original experiment are also not incorporated in the experiment used in this master thesis to avoid an "over-request" of time and resources input by participants. This should lead to more satisfactory answers and should minimize the chance of dropouts. Moreover, the experiments are highly influenced also by the more recent study done by Durney, Libby & Silva (2021) and will use the findings of Chapter 4.

Before explaining the design and analysing the results for each experiment, hypotheses will be formulated and discussed based on Koonce et all. previous work (2005). At the end of the Chapter, a brief conclusion and limitations of all the experiments will be presented, with a highlight on how further research could proceed.

5.1 Hypotheses formulation

As shown in the literature review in Chapter 3, in the domain of behavioural finance the focus is shifting on how complexity affects investment decision-making because of perceived risk by investors. Durney, Libby & Silva (2021) firstly hypothesise and then demonstrate with a tailored experiment that complexity in financial instruments is interpreted by investors as a key determinant to evaluate risk, due to availability heuristics[3], being complexity a more cognitively accessible construct than risk. However, this could lead to pitfalls, because not necessarily higher complexity in a financial product translates in higher risk (even though they tend to be correlated (Koehler, 2011), it does not imply a cause-and-effect relationship. Durney, Libby & Silva (2021) establish the connection between complexity and perceived risk by investor by increasing the intrinsic complexity of contract clauses related to a financial instrument, while always using the same product. In my opinion, this comes down to only differences the wording of the financial product and therefore it does not address the difference between financial positions that have a more or less complex mechanism but are economically equivalent. This feature is instead studied by Koonce et all. (2005). The authors talk about these different positions as being the same financial instruments but labelled differently. However, the positions are characterised by real differences in mechanisms, not just an alternative labelling. Therefore, I partially disagree on indicating the difference between the positions as just *"labelling"*, but I consider it like Durney, Libby & Silva as a difference in complexity. However, this does not change the hypotheses made by them, but shifts slightly the interpretation given afterwards. Moreover, despite the fact that previous research seems to indicate that availability heuristic generates a main cognitive bias with which investors judge risk (Folkes, 1988), the HALO[4]

[3] *Availability heuristics* indicates the tendency of using mental-shortcuts in decision making. When confronted with a decision, people will rely on information that comes to their mind more easily and quickly. In this case, because the concept of complexity is easier to understand than the concept of risk, Durney et al. (2021) argue that investors use the construct of complexity to assess the risk of a financial derivatives. This means they do not assess the intrinsic risk of the financial position, rather they will base their judgment on how complex they think the financial contract is.

[4] The HALO effect indicates the tendency of being locked into an impression of a specific topic and judging everything related to that topic consequently.

effect could have also a significant effect in the assessment process. Investors may be consider a financial product more risky just because it is a financial derivative instead of another type of instrument, because they associate financial derivatives with risk. This hypothesis will not be tested in these experiments, but could be an inspiration for further research.
The main hypotheses that will be tested are:

- **Complexity & Perceived Risk:** A financial position will be judged as riskier if it presents a more complex working mechanism, even though it presents the same actual risk as and is economically equivalent to a financial position with a simpler working mechanism.
  This will be tested through two other hypotheses in experiment 1 & 2:
  - **H1a:** Variable rate debt combined with a variable-to-fixed interest rate swap will be judged as riskier compared to a fixed rate debt.
  - **H1aa:** A future combined with a European long put option will be judged as riskier compared to a European long call option.
- **Labelling & Perceived Risk:** A financial position will be judged as less risky (compared to an equivalent financial position) if it is labelled as being designed for hedging purposes. This will be tested through other two hypothesis in experiment 1 & 2:
  - **H1b:** Variable rate debt combined with a variable-to-fixed interest rate swap will be judged less risky if labelled as variable rate debt combined with a variable-to-fixed interest rate swap used as hedge.
  - **H1bb:** A future combined with a European long put option will be judged as less risky if labelled "future combined with a European long put option used as hedge".

While hypotheses H1a and H1b are the same as the ones used by Koonce et al. (2005), H1aa and H1bb are novel, even though similar. A limitation of the previous research was that the labelling effect was studied only for one type of financial position and therefore the results could hold true only for this particular type of instrument and not be generalise-able. Therefore, in the experiments conducted in this master thesis alongside the financial positions tested by Koonce et al., another financial position characterised by a different type of financial derivative will be added into the experiment (Hypotheses H1aa and H1bb). These financial positions are described at the end of Chapter 4, where equivalent positions were created.

Moreover, building upon the results of Koonce et al. (2005), I evaluate if there is any other improvement in the disclosure of information that could help investor with the task of assessing risk. They argued that providing investors with more information about financial products such as cash flows and fair value effects[5] would reduce the effect of assessing risk differently due to different labelling. Adding to the information provided as text an image representing the payoff graph of the outstanding positions, should help even more, due to the visual aid provided to the investor. In many fields, visual aid has been proven to be effective to help people understand something quicker and better. Therefore, we test also the following hypothesis with experiment 1 & 2:

[5]Koonce et al. (2005) indicate fair value effects as the changes in fair value of a financial position. This means, whether a position has gained/lost in value (an increase/decrease in price) consequent to a change in the circumstances that affect the outcome of the financial positions.

- **Information exposure and Visual Aid:**
  - **H1c:** With the help of the extra information and visual aid provided, investors will judge fixed rate debt, variable rate debt with a variable-to-fixed interest rate swap, and variable rate debt with a variable-to-fixed interest rate swap used as hedge as equally risky.
  - **H1cc:** With the help of the extra information and visual aid provided, investors will judge a European long call option, a future combined with a European long put option, and a future combined with a European long put option used as hedge as equally risky.

Lastly, experiment number three aims to evaluate if different type of disclosures of a certain position (e.g., differences in information provided, concept that can be resorted to asymmetry of information between two parties) lead to different risk judges of the same financial instrument. As argued by the original authors, when investors face information that is only partially disclosed (usually it is the downside of the investment, i.e., the possible negative outcomes) investors will tend to assess wrongly the risk associated with that particular financial product because he has to infer the missing information (usually the upside, the positive outcomes). This action of inferring leads them to draw biased conclusions, that could be avoided if full disclosure would take place. When only the loss side of the outcome a financial product is disclosed

While the first two experiments differ in some parts from the original work of Koonce et all. (2005), this last experiment replicates step by step the previous research. However, the hypothesis that will be tested differs:

- **H2:** Disclosing both potential gain and potential loss leads investors to judge the position's risk differently than when only potential losses are disclosed.

Lastly, an additional hypothesis is made regarding asymmetry of knowledge. It is true that some products mentioned in the experiment, despite being common financial derivatives, are less familiar for people without a strong financial background. Having briefly studied or working in an environment that uses daily this type of financial instruments, gives a hedge to understand better what the total outstanding positions are and what risks they bear. Therefore:

- **H3a:** People with study experience in finance, or finance related courses, tend to evaluate all outstanding positions as equally risky.
- **H3b:** People with working experience in the financial sector, or any job related to finance, tend to evaluate all outstanding positions as equally risky.

5.2 General Structure of the Experiments

While in the study of Koonce et al. (2005), the experiments were paired so that participants would take part either in the first and third experiment, or in the second and forth, for this master thesis project all three replicated experiments were presented to the totality of the sample. In order to do so, a unique questionnaire has been created that is composed by five parts: *"Demographic and Exploratory Questions"*, *"Screening Questions*, *Experiment 1*, *Experiment 2*, *Experiment 3*. The first two parts and a part of the third experiment are

commonly shared between participants, meaning every survey taker was presented with the same question, even though in different order. Afterwards, participants were divided with a rotation algorithm into two general groups, which were presented with different questions, but similar in type. An overview of the flow of the survey and therefore of the experiments can be found in Figure 2. A detailed explanation of the all the question used and the different goals of each section can be found in the Appendix A. In the remaining of this chapter only questions related to the experiments or other analysis that are conducted are discussed.

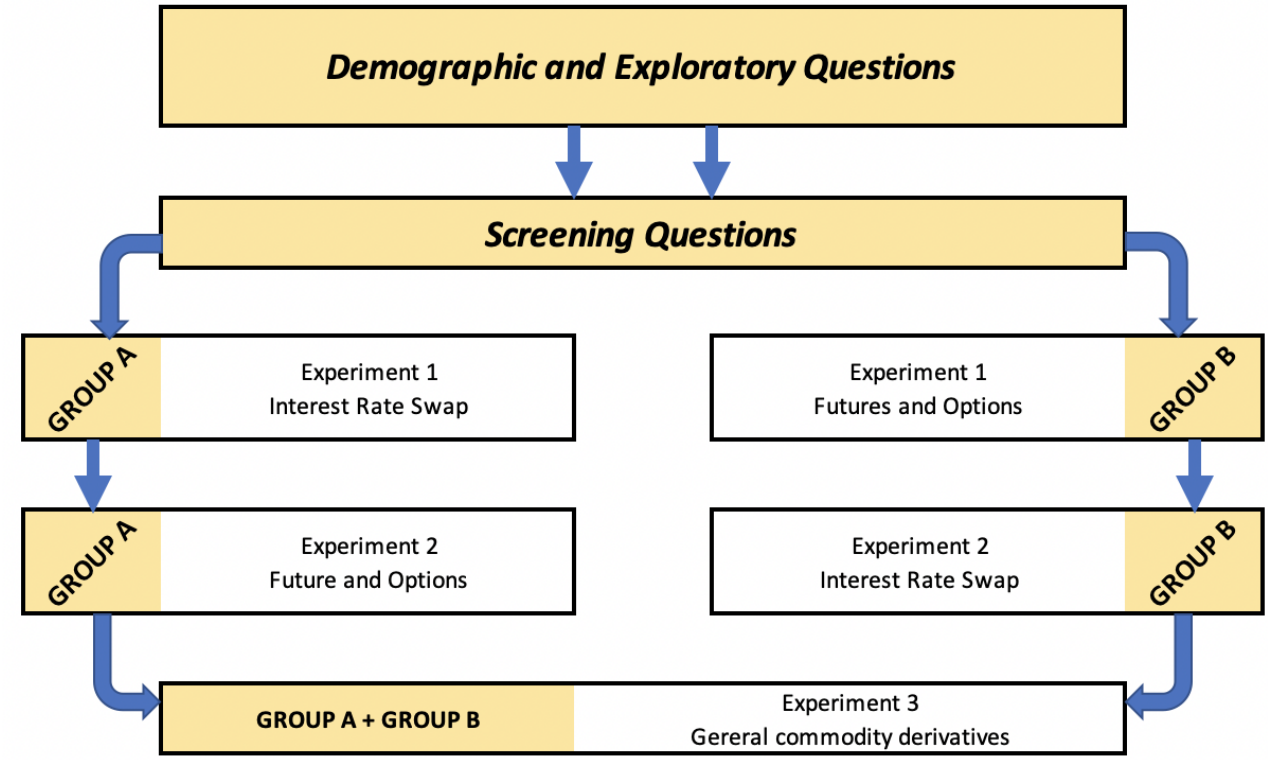

Figure 2: Survey flow for both groups

5.3 Participants

In their work, Koonce et al. (2005), recruit M.B.A. students to participate in their experiments. They do so, arguing that they could easily simulate a reasonably informed individual investor. Despite not disagreeing with this statement, a different approach is used for the experiments conducted for this master thesis. Participants were recruited with regard to their level of education. They were selected to participate if at least one of these statements applied for them:

- **Studies:** Having a knowledge background in financial matters due to studies in finance or similar areas (business, financial engineering...).
- **Work experience:** Having work experience in the financial sector, or any job related to finance.
- **Investing:** Having a significant history or being currently investing in financial instruments.

This different type of selection is mainly done because of two reasons: the first one, more practical, is because of the challenges both in time and resources it would have taken to recruit only M.B.A. students or people with much more experience in the finance world. The second reason, is that by having a more diverse sample, results could represent real world investors more appropriately. Investors do not have all the same knowledge and there is a part of them that uses financial products even though not having a strong financial background. However, to avoid contaminating the data with answers from people who do not belong to any of the three aforementioned categories, multiple screening questions were present throughout the survey. Moreover, after the initial exploratory questions, participants faced a small section with questions about their general knowledge of finance. This has been done to ensure that also the people who belong to one of the three categories had the competences necessary to complete the survey in a satisfactory way. The screening questions were structured in a way to test the financial literacy of the participant in accordance with the definition of fundamental concepts in financial decision making reported by Klapper & Lussardi (2020): knowledge about interest compounding, risk diversification, interest rates were tested, alongside more specific questions about risk assessment and basic financial derivatives that usually do not appear in financial knowledge assessment. Because of these extra questions, the threshold was set at 4 out of 6 necessary correct answers to continue with the experiment, instead of the classic 3 out of 4 (Klapper & Lusardi, 2020). Further analysis with the screening questions answers has been done and can be found in the textbox *"Dunning-Krueger Effect in Financial Matters"*.

In total 134 people participated in the survey, but only 62 of them were able to complete all three experiments. The rest of them did not complete the survey and dropped out and/or did not pass the initial screening test. Out of these 62 only 54 succeeded in passing the second more technical screening test. Despite not being as knowledgeable as participants in the original experiments, 93% has received higher education, with 55% of them having taken 3 or more major courses in finance and 65% having taken 3 or more major courses in advanced mathematics or statistics. Moreover 57% do invest or have a significant history in investing, but only 35% has work experience in the finance sector. However, when asked about their familiarity with financial products and financial markets, participants rate themselves as more knowledgeable (mean of 57.78 on a 101-point scale) as compared to participants in Koonce et al.'s study (mean of 45.85). Interestingly, the distribution of risk appetite is quite normal, with 22% of participants identifying as risk-seekers, 24% as risk-adverse and 52% as risk-neutral. This is important because it shows how the outcome of the analysis is not dependent on the risk appetite of an investor. More demographic statistics and insights about the participants can be found in Appendix D.

Dunning-Krueger Effect in Financial Matters

Definition: The Dunning-Krueger effect is seen as the phenomena where people with limited expertise and experience in a specific area, tend to overestimate their knowledge or expertise in that specific area, leading to a cognitive bias (Kruger & Dunning, 1999). **Dunning-Kruger effect in financial matters:** throughout the survey, participants were asked to assess their knowledge about financial products and financial markets. These answers have been compared with their performance in the various screening questions, to understand if there was evidence of the Dunning-Krueger effect in the data sample. A positive correlation of 0,5 has been identified between self-assessed and actual knowledge of the participants, indicating that the Dunning-Kruger effect is absent in this case. A negative or close to zero correlation is a necessary condition to support the hypothesis of the presence of this effect, but is not sufficient. The observed residual variance of the data sample should to be result heteroskedatic as argued by Krueger & Mueller (2002). This can be done with a Gelsjer test of heteroscedasticity. For our data sample, after conducting this test, a positive statistically non-significant (p=0,25) Pearson correlation was found, assuring the non-presence of the Dunning-Krueger effect. The data sample was composed of 91 respondents.

5.4 Experiment 1

After the technical screening test questions, participants were divided in two groups to participate at two slightly different versions of the same experiment. This is done for two reasons: the first one, as briefly stated previously, is to test whether the results obtained by Koonce et al. in experiment 1 & 2 are instrument-type dependent. Dividing the survey takers in two groups allows us to evaluate two different financial positions characterised by different financial derivatives, as shown in Figure 2. The second reason is to avoid that conducting experiment number 2 right after experiment number 1 with the same financial positions, would make that participants would be somewhat prepared (having knowledge from the previous part of the survey) and therefore answer differently.
Experiment 1 is characterised by a double 3x2 mixed design. The first variable, type of instrument, was varied at three levels on a between-participants of a specific group basis. Group A's participants (26 in total) were shown a description of a company that had one of the following outstanding positions:

- Fixed rate debt
- Variable rate debt combined with a variable to fixed interest rate swap
- Variable rate debt combined with a variable to fixed interest rate swap used as hedge

Similarly, Group B's participants (28 in total) were shown a description of a company that had one of the following outstanding positions:

- European long call option
- Future combined with a European long put option
- Future combined with a European long put option used as hedge

In the Appendix A, the precise descriptions of these companies can be found. Recall that these positions (the three of Group A and the three of Group B) hold the same economic exposure and bear the same amount of risk, if not a slightly different counterparty risk that can be considered negligible.

Exposure to additional information and visual aid, the second variable was varied at two levels (before the exposure and after the exposure) and was manipulated within-participant basis. This means, that a participant from either Group A or Group B was shown one of the three possible descriptions of a company of his group and asked to assess how risky they consider the company's outstanding position. Afterwards, he was asked to reassess his previous answer after being shown with additional information and the payoff graph of the position as visual aid (the exact information provided can be found in the Appendix A under question Q3.A.2 for group A and Q3.B.2 for group B). The risk assessment was based on a 101-point scale, with 0 indicating "No risk at all" and 100 indicating "Extremely Risky".

5.4.1 Analysis of the results

Figure 3 reports the analysis based on the observations of Group A. Instead, Figure 4 reports the analysis based on the observations of Group B. Both tables are characterised by two panels: a first panel that lists the descriptive statistics (mean, standard deviation and n=number of observations) and a second one that reports the results of the tests for the various hypotheses.

Panel A: Descriptive Statistic			
Type of Instruments		*Before Information Exposure*	*After Information Exposure*
Fixed-rate Debt (n=10)	Mean	39,90	37,80
	St. Dev.	17,32	16,63
Variable-Debt combined with Variable-to-Fixed Interest rate swap (n=7)	Mean	41,57	38,14
	St. Dev.	33,92	29,95
Variable-Debt combined with Variable-to-Fixed Interest rate swap used as hedge (n=6)	Mean	25,50	27,00
	St. Dev.	12,06	11,97
Panel B: Hypotesis Testing			
Hypothesis	Comparison	Statistics	p_value
H1a	Fixed versus Swap (Before exposure)	t = -0,12	0,91
H1b	Swap versus Hedge (Before exposure)	t = 1,17	0,28
H1c	Interaction of type of financial instrument and exposure	F = 0,062	0,80
	Extra Analysis:		
	Fixed versus Swap (After exposure)	t = -0,03	0,98
	Swap versus Hedge (After exposure)	t = 0,90	0,39

Figure 3: Observations Experiment 1 Group A

GROUP A: Conducting a first analysis of variance, we find that the type of financial instrument does not affect the risk assessment of the participants ($F_{2,42} = 0.44$, p=0.647). This can also be seen with the rejection of hypothesis H1a and H1b. According to the respondents in Group A, the mean risk for the company with a fixed-rate debt position is not different from the mean risk of a variable-rate debt combined with a variable-to-fixed IRS position (t=-0.12, p=0.91). Moreover, according to the respondents of Group A, the mean risk of the position labelled as hedge does not statistically differ from the same position not labelled as hedge (t=1.17, p=0.28). Additionally, the responses fail to support also the hypothesis H1c ($F_{2,42} = 0.062$, p=0.80), showing that there is no statistically significant interaction between instrument type and exposure to information (if there is no interaction, it can be concluded that being exposed to additional information does not change participants' risk assessment).

GROUP B: Conducting the same analysis for GROUP B, we again fail to find support for all 3 hypotheses (p=0.49; p=0.99; p=0.22). However, the effect of additional information exposure and visual aid seems to be more marked and significant, but still not enough to be statistically relevant.

The outcome of experiment 1 is bitter-sweet. Despite seeming to have some peculiarities that could potentially lead to novel conclusions, (for example the higher impact the label *"used as hedge"* has on the interest rate swap, t=1.17 and p=0.28, compared to the impact it has on

the future combined with European long put option position, t=0,01 and p=0,99), all analyses indicate that these differences are not statistically significant. These findings are different from the original research by Koonce et al. (2005). Possibly, this difference due to two reasons: the first one is the difference in the characteristic of the participants, mainly in knowledge. The second one is that the number of observations in this master thesis is relatively small and this limits the robustness and reliability of the present findings.

Panel A: Descriptive Statistic			
Type of Instruments		*Before Information Exposure*	*After Information Exposure*
European Long Call Option (n=6)	Mean	39,83	36,33
	St. Dev.	15,90	16,38
Future combined with Europan Long Put Option (n=9)	Mean	47,22	43,33
	St. Dev.	24,34	24,70
Future combined with Europan Long Put Option used as hedge (n=10)	Mean	47,10	32,60
	St. Dev.	28,25	20,51
Panel B: Hypotesis Testing			
Hypothesis	Comparison	Statistics	p_value
H1a	Call versus Future+Put (Before exposure)	t = -0,71	0,49
H1b	Future+Put versus Hedge (Before exposure)	t = 0,01	0,99
H1c	Interaction of type of financial instrument and exposure	F = 1,579	0,22
	Extra Analysis:		
	Call versus Future+Put (After exposure)	t = -0,66	0,52
	Future+Put versus Hedge (After exposure)	t = 1,02	0,32

Figure 4: Observations Experiment 1 Group B

5.5 Experiment 2

Experiment 2 builds upon experiment 1 and assigns participants a similar task as before, meaning they have to do a risk assessment, but with a difference: instead of being presented with a description of financial positions of one company, they are presented with 3 different outstanding financial positions held by 3 *"otherwise identical"* companies[6]. That means that the companies differ only in their financial exposure given by the financial instrument described. This feature is necessary in order to correctly isolate the effect of the financial instruments used as difference in risk assessment by the participant. In fact, when asked about what type of risk they evaluate when making their risk assessment, 2 participants (3.7%) name unsystematic business risk. By specifying that the companies are otherwise identical, we are providing the participants with the information that all 3 companies bear the same unsystematic business risk. After being shown the 3 descriptions, they are asked to rank the companies from the one with the most risky financial position to the least risky financial position (3-point scale, with 1 indicating most risky and 3 indicating least risky). Moreover, they were specifically told that ties were allowed, giving the possibility to evaluating all 3 as equally risky. In experiment 2 the focus shifts from absolute risk to relative risk judgement, that should result in an easier task (Koonce et al., 2005). Moreover, in this experiment only the variable of additional information exposure is manipulated at two levels. As in the previous experiment, survey-takers were asked to make their risk judgements both before and after they were provided with payoff graph (the visual aid) and the additional information. Besides ranking the 3 companies based on their financial positions' riskiness, participants were asked also to rank them based on the likelihood of being chosen as an investment (ties were allowed and a 3-point scale was used, with 1 indicating the most likely and 3 the least likely). While Koonce et al. (2005) used this additional question to confirm the results obtained with the first question, in this master thesis it has been used for a different purpose: checking whether or not the phenomenon of Preference Reversal would start to take place at this point of the survey. Recall that as defined by Johnson et al. (1988), Preference Reversal indicates a decision maker's act to change his opinion (therefore, his answer) on a particular topic within the same study. Even though some participants had contradictory answers, indicating a possible Preference Reversal (or also a simple distraction) it happened in less than 20% of the total data sample. This is lower than what has been found to be the average in surveys (Castellano & Cerqueti, 2013).

As argued in Chapter 4, the different positions are not completely financially equivalent because they have a slightly different amount of counterparty risk. Therefore, between experiment 1 and 2, participants are asked to share what risks they take into consideration when making their risk-assessment about those companies. Of 54 participants, only 4 (7.5%) indicate counterparty risk, credit risk or default risk. Not considering the answers of these participants in the analysis does not change qualitatively the outcome. Therefore, they are included.

[6] As previously explained, participants of group A, that had the interest rate swap as main financial derivative in experiment 1, will now be shown the 3 positions with futures and options. Viceversa, group B will now asses the risk for the companies using interest rate swaps as financial derivative

5.5.1 Analysis of the results

Figure 5 summarises the analysis based on the observations of Group A, while Figure 6 summarises the analysis based on the observations of Group B. As first thing that can be noticed is the higher number of observations per scenario than for experiment 1. This number is still smaller than the number of observations in the original study (26/28 against 100). However, it gets closer to the target of 50 observations, a data-set big enough to reproduces stable results (Piovesana & Senior, 2018).

Panel A: Descriptive Statistic			
Type of Instruments		*Before Information Exposure*	*After Information Exposure*
European Long Call Option (n=28)	Mean	2,32	2,21
	St. Dev.	0,82	0,83
Future combined with Europan Long Put Option (n=28)	Mean	1,61	1,64
	St. Dev.	0,74	0,62
Future combined with Europan Long Put Option used as hedge (n=28)	Mean	1,96	1,86
	St. Dev.	0,64	0,80

Panel B: Hypotesis Testing			
Hypothesis	Comparison	Statistics	p_value
H1a	Call versus Future+Put (Before exposure)	t = 3,11	0,003
H1b	Future+Put versus Hedge (Before exposure)	t = -1	0,26
H1c	Interaction of type of financial instrument and exposure	F = 0,27	0,60
	Extra Analysis:		
	Call versus Future+Put (After exposure)	t = 2,90	0,005
	Future+Put versus Hedge (After exposure)	t = 0	1,00

Figure 5: Observations Experiment 2 Group A

Evaluating Group A and Group B, two different effects can be noticed:
Group A: Allowing participants to make relative instead of absolute risk judgements, brings a completely different outcome. With an ANOVA analysis it is shown how the instrument type significantly affects the risk assessment of the participants ($F_{2,164} = 10.53$, $p<0.0001$). In fact, a specific contrast paired t-test shows that the mean ranking of the European long call option position is significantly lower than the mean ranking of the future combined with European Long Put Option (t=3.11, p=0.003). This supports hypothesis H1aa, that a financial position composed by a future combined with a European long put option is judged riskier than a financial position dictated by a European long call option. However, hypothesis H1bb and H1c are rejected (p=0.26 and p=0.60). This means that additional information and visual aid do not change participants perspective on the judgement ranking. This can also be seen due to the fact that again the mean ranking assessment of the European Long call option (2.21) result is higher than both the one of the future combined with a European long put option (1.64) and the one of the future combined with a European long put option used as hedge (1.86), (p=0.005 and p=0.007 respectively). The label "used as hedge" does not lead to a statistically significant difference in assessment from the same financial position without the label (p=0.26 before exposure and p=1 after exposure). This could be due to the fact that a combination of two financial derivatives is considered riskier than what a simple label can, in fact, "hedge".

GroupB: When assessing the interest rate swap as main financial derivative we have

Panel A: Descriptive Statistic			
Type of Instruments		*Before Information Exposure*	*After Information Exposure*
Fixed-rate Debt (n=26)	Mean	2,00	1,85
	St. Dev.	0,89	0,83
Variable-Debt combined with Variable-to-Fixed Interest rate swap (n=26)	Mean	1,96	1,89
	St. Dev.	0,60	0,59
Variable-Debt combined with Variable-to-Fixed Interest rate swap used as hedge (n=26)	Mean	2,42	2,27
	St. Dev.	0,70	0,78
Panel B: Hypotesis Testing			
Hypothesis	Comparison	Statistics	p_value
H1a	Fixed versus Swap (Before exposure)	t = 0,19	0,85
H1b	Swap versus Hedge (Before exposure)	t = -2,47	0,02
H1c	Interaction of type of financial instrument and exposure	F = 5,49	0,02
	Extra Analysis:		
	Fixed versus Swap (After exposure)	t = 0	1,00
	Swap versus Hedge (After exposure)	t = -1,92	0,06

Figure 6: Observations Experiment 2 Group B

instead the opposite results. The instrument type seems again not to affect significantly participants' risk assessment ($F_{2,152} = 0.83$, p=0.44). However, with a paired t-test analysis it is found that the mean assessment risk ranking of the variable rate debt combined with the variable to fixed IRS is lower than the same positions labelled with the words "used as hedge" (t=-2,47, p=0,02). This means that the label is effective in reducing the perceived risk by participants. However, this difference is less strongly statistically significant after additional information exposure (p=0.06, just above threshold). Analysis shows further strong support for the H1c hypothesis ($F_{2,152} = 5.49$, p=0.02), indicating a positive effect of the payoff graph as visual aid (both Koonce et al.'s experiments failed to validate the hypothesis of using additional information exposure as aid for investors to correctly assess risk).

5.6 Conclusions and Limitations

General conclusions can be drawn from these first two experiments when compared with the results obtained from the original work. Despite experiment 1 resulting generally as inconclusive, experiment 2 give two main insights:

- **Dependency of the financial position:** It is clear that the type of financial derivative we are using when conducting the experiment strongly influences whether or not the hypothesis can be deemed as correct. Therefore, doing this experiment based on only one type of financial derivative as done by Koonce et all. (2005) is reductive and can potentially lead to wrong implications. Using already another set of financial derivative has proven to lead to different results. However, more research with more financial derivative must be made to draw more accurate conclusions.

- **Payoff Graph as visual aid:** In the original experiment, an exposure to additional information did not result in a change of risk assessment and therefore could not be deemed as a potential aid for investors when they evaluate risk. However, in the second

experiment conducted in this master thesis, holding everything else constant and adding even more information via the payoff graph, it results in a statistically significant change in risk assessment, indicating that visual aid may be the solution to explain more effectively the risks associated with a financial derivative.

5.7 Experiment 3

Experiment 3 shifts the focus from type of financial derivative used by firms to how they disclose information about usage of these financial products to its investors. The experiment's goal is to test if disclosing more information to an investor helps him to make better risk assessments. To do this, participants were asked to assess the riskiness of a firm's financial exposure after being shown information contained in the annual report of the company. They were told that the firm used financial derivatives to manage price exposures on some of their existing inventories and anticipated future purchases. Therefore, it could be deducted that the company's intent was to hedge against possible unfavourable changes in the market prices. Participants were asked to assess risk twice: a first time, when a one-sided loss-only disclosure was shown to them; a second time, when also two-sided gain and loss disclosure was presented. As shown by Figure 2, experiment 3 has been conducted with both previous groups combined. It is characterised by a 2x3 mixed design. The first variable, *"type of disclosure"*, was varied at two levels on a within-participants basis:

- One-sided loss-only disclosures
- Two-sided loss and gain disclosures

The second variable, the *"Gain & Loss pattern"* was manipulated on three levels on a between-participants basis. This variable indicated the relative size of the potential gains in comparison of the potential losses. The three facets this independent variable could assume are the following:

- **G>L:** The disclosed potential gains are greater than the disclosed potential losses.
- **G=L:** The disclosed potential gains and disclosed potential losses have are equal in absolute value.
- **G<L:** The disclosed potential gains are smaller than the disclosed potential losses (in absolute value).

In Appendix A, how exactly information was disclosed to participants can be found. Also the various Gain & Loss patterns are summarised, including the numbers shown to participants. While experiment 1 & 2 present different features and different wording than the original work of Koonce et all. (2005), in this last experiment nothing has been changed. The reasons behind this choice are the following: firstly, the original work is complete and robust enough to test hypothesis H2. Adding or changing some parts would potentially have brought more unwanted effects than novelty to the experiment. Secondly, the reason to also leave the wording of the disclosures and explanation of the questions the same, is to show that a possible difference in results is only given by having chosen a different population sample. Minimizing the differences in a replicatory study leads to more robust comparisons between the two separate works.

5.7.1 Analysis of the results

Figure 7 summarises the various analyses conducted. Panel A includes descriptive statistics for both one- and two-sided disclosure, while panel B reports the result of ANOVA analyses and t-test analyses to test hypotheses H2. The one-sided loss-only disclosure was the same for all participants. Therefore, due to random allocation of the data sample in one of the three groups, it is expected that there is no difference in mean of risk assessment between the three conditions (gain/loss pattern). Statistics confirm this, indicating that there is no statistically significant difference in mean between the three groups whit one-sided disclosures ($F_{2,40}$= 1,824; p= 0,175). When comparing means in risk assessment of the two-sided disclosure, we see a difference in mean of statistical significance ($F_{2,40}$= 14,24; p= $2{,}14*10^{-5}$). This indicates that participants change their risk assessment when more information is disclosed to them. However, ANOVA analyses show that this difference in assessment is mainly given due to the interaction between the type of disclosure and the gain & loss pattern, our two independent variables ($F_{2,80}$= 6,27; p= 0,003). The difference cannot only be explained through one-sided versus two-sided disclosures ($F_{1,80}$= 2,935; p= 0,09). This can also be seen when comparing *one-sided versus two-sided disclosures* within the single groups, characterized by the three different conditions. When gains are either greater or smaller than the relative losses, the mean risk judgment of the two-sided disclosure is statistically different than the mean risk judgment of one-sided loss-only disclosure (for L>G, t=-2.66, Δ_{mean}=-9.19, p=0.02; for L<G, t=3.21, Δ_{mean}=22, p=0.01). When losses are equal to gains in size, then participants do not significantly change their risk assessment between types of disclosure (t=1.96, Δ_{mean}=8.54, p=0.07).

Panel A: Descriptive Statistic			
Type of Instruments		*One-sided disclosure (loss only)*	*Two-sided disclosure (loss and gain)*
Loss > Gain (n=16)	Mean	67,81	77,00
	St. Dev.	14,77	13,55
Loss = Gain (n=13)	Mean	77,38	68,85
	St. Dev.	12,83	19,82
Loss < Gain (n=14)	Mean	65,86	43,86
	St. Dev.	21,48	19,09
Panel B: Hypotesis Testing			
Hypothesis	Comparison	Statistics	p_value
	ANOVA - "Type of Disclosure"	F = 2,94	0,09
	ANOVA - "Gain & Loss Pattern"	F = 10,30	<<0,01
	ANOVA - Interaction	F = 6,27	<0,01
	Analysis "One-sided vs Two-sided":		
H2	Losses > Gains	t = -2,66	0,02
H2	Losses = Gains	t = 1,96	0,07
H2	Losses < Gains	t = 3,21	0,01
	Analysis "Two-sided comparison":		
	L>G vs L=G	t = 0,54	0,60
	L>G vs L<G	t = 3,82	0,01
	L=G vs L<G	t = 6,81	<<0,01

Figure 7: Observations Experiment 3

5.8 Conclusions and Limitations

The results of experiment 3 clearly show how a two-sided disclosure leads to a more accurate risk assessment by an investor: the mean of risk judgment of the $L<G$ pattern, is statistically smaller than the mean of risk judgment when losses are equal or greater than the gains in size (t=6,81 and p«0,01; t=3,82 and p=0,01). However, the means of risk assessment for the $L>G$ and $L=G$ pattern cannot be statistically distinguished (t=0,54 and p=0,60). These results, seem to indicate that

Differently than the findings of Koonce et al. (2005), the study in this thesis suggest that participants, when presented with a one-sided loss-only disclosure, make their risk judgments as if the undisclosed gains are equal in size to the losses. Considering gains and losses equal in size is consistent with the firm using futures as financial derivatives to hedge against a change in market prices, the most common hedging strategy within manufacturing companies. Moreover, this study shows that participants infer gains are equal (46%) or greater (40%) in size than the relative losses.

Despite all the conclusions that can be drawn from this study and its comparison with the original study by Koonce et al. (2005), the robustness of the findings in this study is limited due to the relative small size of the sample. The limited sample size is especially important when studying the data to test hypothesis 3a and hypothesis 3b. If we were to divide the subgroups of study experience or the subgroups of work experience, for each experiment the already relatively low number of participants per group in each experiment would drop even more. Because of this lack of observations, the total data was deemed insufficient to test in an accurate manner the last two hypotheses. Future research could pick up the same experiments described in this thesis focusing on gathering more observations, to be able to test the additional hypotheses and then be able to answer to sub-research question SRQ4b: *To what extent does lack of knowledge affect the misjudgment of a potential investor?*

6 Complexity Framework

Attributing an exact definition at complexity poses already a challenge outside the financial world. Already just looking at the definition provided by English dictionaries an you will notice how difficult it is to explain the word complexity without the words difficult or hard (defining complexity using one of these two words seems like an *escamotage*, it doesn't really solve the problem to understand what complexity is). Therefore, it is understandable how much of an hard time financial researchers have when they try to come up with a common standard to define complexity in a financial product. Throughout the years many qualitative ways have been developed to define this concept and some research even have tried to attribute a quantitative value to it. This is a necessary action. As argued by Becker et all. (2012) it is mandatory to have a definition of complexity that is uniform and objectively comprehensible in order for all the regulations regarding the financial instruments to work properly. In fact, there is a fundamental problem that leads me to attempt to create a novel framework to determine in a quantitative way complexity: in the regulatory framework of the financial world in Europe, laws and regulations about financial derivatives have been drawn up in the MiFiD II, a document within it is stated that certain products are deemed to complex for certain investors and therefore need to be more regulated and limited to professional investors. As good as it sounds, when it starts to define what complex financial products are, it simply proceed to list classes of financial derivatives almost without contextualizing (meaning disregarding on their features and considering a financial product as complex or not based on their "label" or general class they belong). Not having a precise way to quantify the complexity of financial derivatives leads to several problems:

- Small and less experienced investor are less protected because they cannot fully understand what they are dealing with (therefore I recall the definition given by Becker et all. (2012), complexity needs to be *objectively comprehensible*).
- Increased difficulty in implementing law and regulations, due to the vagueness and subtle edges of certain definitions.
- There will always be a risk to over- or under-regulate a specific financial product, therefore possibly hindering the growth of the financial market.

In the remaining part of this Chapter, a tentative framework to define complexity quantitatively will be proposed. This framework does not claim to be perfect and will present several limitations. It's main goal is to provide a possible inspiration for further studies in the research towards a unified quantitative definition.

6.1 Description of Framework

Just like other frameworks build qualitatively, the MiFiD II's categorisation of complex financial derivatives does not take into consideration the spectrum of different features that define complexity itself. Starting from the idea of *"building blocks"* introduced by Brunnermeier and Oehmke (2009), I regard the different features in a financial derivatives as the smaller building blocks an investor has to understand to assess correctly these financial products. The academic literature reports the following as main features in a financial derivative (non-exhaustive list): mathematical model, payoff formulation, payoff disclosure, trading mode, number of underlying instruments, dependency between underlying

instruments, number of clauses in the contract, featuring indirect costs, featuring leverage. Naturally, every features will have its own challenges to be properly understood and therefore it can be more or less time and resources (mental power) consuming for the investor to first understand. If we could define the spectrum, the different facets that every feature can assume as a function, it would be possible to hypothesis a total complexity function that is related to all these other functions. In the most simple way this relationship could be linear, leading to the following:

$$F_c = \alpha_1 f_1(x_1) + \alpha_2 f_2(x_2) + \alpha_3 f_3(x_3) + ... = \sum \alpha_i f_i(x_i) \tag{7}$$

Equation 7 could roughly be a general formula to calculate the total complexity of a financial derivative, without being bound by their class or type. F_c, the complexity of the financial derivative is the dependent variable, while $f_i(x_i)$ are the i independent variables and represent as previously stated, the spectrum of a specific feature. Ideally, this spectrum would be continuous and continuous variables would be used. However, sometimes it is difficult to evaluate a particular feature in a continuous way. For example, the number of clauses in a contract is discrete and not continuum. The mathematical model describing the financial products has a more qualitative spectrum: broad categories can be assigned to levels of education needed to fully understand the model, but cannot be quantified making it impossible to create a continuous spectrum. What is missing to create the link between the dependent variable and the independent variables is their coefficient. However, these coefficients α_i could be reversed engineered if with sufficient data a linear regression would be run (or a different type of regression should the hypothesised equation 7. While the independent variable can be more easily observed and therefore quantified, the dependent variable cannot be observed in the real world. It is a value attached by people. Then it is spontaneous to ask on whom perception of risk should the linear regression be run and the coefficients be calibrated? In my opinion, it is an investor that faces this complexity and therefore it can be argued that is has to be him that evaluates how complex a financial products really is. Moreover, I believe that the set of subjective values leads to a more unified "objective" value, meaning that a normal distribution could be observed when people assess the complexity of the same financial derivative. If this feature of the subjective answers does not hold true, than the framework should be readapted and another way of data collection should be explored [7]. This feature of normality will be tested simultaneously with the calculation of the coefficients with the data collected throughout a survey. Next paragraph will discuss the construction on such survey.

6.2 Survey construction

The survey with which data has been collected is divided in 3 parts. The first part ensure that participants are not entirely random but have a least either work experience in the financial sector or have a knowledge background in finance. The second part tries to establish a first connection between features and complexity in financial derivatives with a direct assessment. This is done firstly with an open question:

As an investor, what are the main factors/features that define complexity in financial products?

[7]For example, only a set number of highly financially knowledgeable individuals could be taken into consideration. However, I strongly argue that, because investors are the ultimate individuals that perceive financial derivatives' complexity, the input should start in a way or another from their perspective

Afterwards, the participant to the survey is presented with the the main features listed in the academic literature[8] and is asked to the following:

To what extent are the following factors/features relevant for complexity in financial products?

Answer could be given on a 11-point scale, ranging from 0 as "not relevant at all" to 10 as "extremely relevant". The open question has been put before to avoid bias in the answer if this was taken afterwards, not being influenced by features already outlined. Moreover, in this way it has been possible to assess if novel features not listed were considered by participants[9].

The third and last section of the survey consisted in an indirect assessment of the relation between features and complexity. Participants were shown a set of financial products, each defined by some feature characteristics. They were then asked to give their evaluation of complexity of the different financial products. For example:

A total of 10 financial products with different features will be presented to you. Please indicate, from 0 to 10, how complex you think each of the following financial products are. (0 = non complex at all, 5 = moderate complexity, 10 = extremely complex)

Financial product 19:

- The mathematical model is easily understandable, a high-school level of preparation suffices to understand it
- The contract presents some clauses, but that can be summarized in one page or less
- The financial product depends only on a few underlying instruments
- The underlying instruments have somewhat dependency between each other
- The financial product is traded on Public Financial Markets

As can be noticed, the financial products presented are characterised by only 5 features. Moreover, neither continuous nor discrete values have been used, but **categorical variables** have been adopted. This is done for computational distress and is a mere simplification. Every variable has been divided in 3 categories as displayed with their possible values in the Appendix B (besides Trading Mode that has only 2 categories: Public Financial Markets or OTC market). Adding an extra category per feature or adding an ulterior feature would lead in an exponential increase of the combinations possible and therefore in the data that would need to be collected.

[8]The features presented were Mathematical model, Payoff formulation & disclosure, trading mode, number of underlying instruments, dependency between underlying instruments, number of clauses in the contract, featuring indirect costs, featuring leverage. Payoff's formulation & disclosure has been put under one feature to simplify the reasoning for the investor (considering all as a bundle and not as separate, requires less effort. Moreover, a ninth "feature" was included in the mix: risk. Despite not being a feature and not influencing a financial product's complexity, this question was to check the results of the experiments conducted in Chapter 5, that indeed risk and complexity are perceived as influencing each other.

[9]Listing the questions in this order has unfortunately had an unwanted effect of multiple dropouts before even starting the crucial part of the survey, leading to a decreased sample size. Only 41 out the 76 participants completed the survey, despite it shortness (5 to 10 min) compared to the survey for the experiments in Chapter 5 (20-25 min)

Using categorical variables poses a limitation because it reduces the possible inputs of the dependant variables. Therefore, the outcome of the model could fail to capture slight changes in the independent variable, resulting in an approximation. However, it has to be said that having categorical variables also overcomes some problems that numerical variables could have in such a study. Involving human subjects with a fairly generic questions such as "level of complexity of a financial product", often leads to unreliable answers when they are provided with too much choices or too much information as an input. General information usually is processed more easily and therefore the answer given will most likely be more accurate. This is also the reason that the scale of possible answer is being reduced from "0 to 100", to "0 to 10".

Out of the 10 financial products shown to every participant, 2 of them were randomly drawn with a rotation algorithm from a subset of 4, while the other 8 were drawn from the remaining subset of 122. This has been done simultaneously to:

- Observing at least a couple of values for each combination of features
- Having a small number (4) of financial products where the number of observations would be sufficient to test the normality of the distributions.

6.3 Analysis direct assessment

The analysis through direct assessment has been performed with the first two question of the surveys, leading to an "open questions analysis" and a "relevance analysis". This two analysis have generally been used to try and predict the outcome of the indirect assessment analysis that is used to validate the conceptualized model of total complexity as a linear function of different functions.

6.3.1 Open Question Analysis

The direct assessment started with the open question reported in paragraph 6.2. Table 8 reports the amount of time each feature was indicated by a participant [10]. Total participants were 41, but only 31 of them reported one or multiple answers.

	Mathematical Model	Payoff Formulation	Trading Mode	N° Underlying	Dependency	N° of Clauses	Risk	Indirect costs	Leverage	Timeframe
Frequency	11	2	5	12	6	9	6	0	2	8
% (out of 41)	27%	5%	12%	29%	15%	22%	15%	0%	5%	20%
% (out of 31)	35%	6%	16%	39%	19%	29%	19%	0%	6%	26%

Figure 8: Results from open question

As can be noticed some features seem to be taken more into consideration than others. More specifically, *Number of Underlying Instruments Mathematical Model* and *Number of clauses in the contract* has been indicate by at least in 9 (approximately 30%) of the 31 answers. Therefore, it should be expected that in the next direct assessment question, this features will present an higher extent of relevancy for complexity. The other features hypothesized by the author and usually reported in the financial literature, present

[10]Sometimes the name of the feature presented itself in a different way, but having the same concept, they have been grouped together.

themselves will less frequency; one of them, the presence of *Indirect costs* does not even get mentioned once. Interestingly, a new feature not considered in the further studies proposed in this master thesis presented itself with a quite high frequency: 8 out of the 31 answers by participants included the *Time-frame* of the instrument as a major feature that defines complexity of a financial product. This is probably the case because with a bigger time-frame, it is more difficult to correctly assess the price of the underlyings due to higher uncertainty.

6.3.2 Direct assessment relevance analysis

The results of this first analysis are partially reflected in the results of the second question of the survey, where the direct assessment with pre-thought features has been made. However, some results seem not to match the previous analysis. This slight difference are most likely due to difficulty that usually people encounter when addressing an open question, both because of the reduced capability to express themselves (hindered even more by the survey methodology; an interview based question could reduce this problem) and because of the "absolute" answer, versus the relative type of answer they can give when presented with all the features.

Table 9 reports a brief overview of the descriptive statistics of the analysis results. As for observation, it can be seen how *Risk* is considered pretty relevant when assessing the complexity of a financial instruments. This is even more true for participants that have work experience in the financial factor: they attribute ar *Risk* the highest score of 8,07 out of 10. This particular result helps to consolidate the findings of Chapter 5 and Koonce et all. (2005): people think that the concept of risk is related to the concept of complexity, even though as argued in Chapter 4, this is not the case. If we take out *Risk* from the analysis, the next highest scores are attributed to *Number of Underlying Instruments*, *Dependency between underlying instruments* and *Mathematical Model*. Participants with work experience tend to evaluate the dependency between underlying instruments slightly more relevant to define complexity than the total number of underlyings, while participants without work experience the other way around. Interestingly, the feature *Dependency* presents a high score compared to other features with this type of assessment, while in the first analysis with the open question it didn't show up with to much frequency (only 19%). Moreover, while the feature *Number of clauses* presents an higher frequency in the first analysis, it can be noticed how this second analysis seems to indicate a slightly lower relevance of this particular feature. The remaining features (*Payoff formulation, Trading Mode, Indirect cost and Leverage*) appear to be less relevant than the others in both analysis. A last observation can be made when looking more closely at the difference between participants with work experience in the financial sector and participants without. The latter group judges in general all features less relevant to define complexity, but in there answers there is more variety (average standard deviation is equal to 2.67, while for work-experienced participants it shrinks to 2.23). Therefore, we expect that the dummy variable *Work Experience* used in the next analysis will provide a significant result and therefore can be added to the general model.

		Model	ormulation & Di	Trading Mode	N Underlying	Dependency	N clauses	Risk	Indirect costs	Leverage
Mean	Total Sample	6,68	6,21	5,87	7,04	6,96	6,36	6,81	5,26	5,94
	NO Work Experience	6,41	5,81	5,47	6,75	6,53	6,06	6,22	5,16	5,63
	YES Work Experience	7,27	7,07	6,73	7,67	7,87	7,00	8,07	5,47	6,60
Standard Deviation	Total Sample	2,53	2,60	2,48	2,56	2,57	2,55	2,97	2,59	2,41
	NO Work Experience	2,71	2,66	2,37	2,75	2,72	2,55	3,30	2,48	2,49
	YeS Work Experience	2,05	2,31	2,58	2,06	2,00	2,51	1,53	2,90	2,16

Figure 9: Results from direct data collection

6.3.3 Conclusions direct assessment analysis

Looking at the first two analysis, despite some slight differences, some key insights can be formulated and expected to be translated into the next *Indirect Assessment Analysis*. It is expected that the features *Mathematical Model*, *Number of Underlying Instruments* and *Dependency between underlying instruments* will actively influence how participants address complexity and therefore they will be significant in the proposed model. Same should hold true for *Number of Clauses*, but for this particular feature some doubts remain after the results of the second analysis. It is probably expected to have a slight impact on the model, but still significant. On the contrary, the feature *Trading Mode* is expected not to be included in the model: both previous analysis show how participants tend to consider it less relevant than the other features. Lastly, as said in previous paragraph, we expect that *Work Experience* as dummy variable will have an impact on the model and will be significant.

6.4 Analysis indirect assessment

As last part of the survey, participants had to assess complexity of 10 different financial products with different features shown to them. This lead to 410 observations that are used to conduct the factorized linear regression to validated the model proposed at the start of this Chapter 6. The following paragraphs will highlight the result of the normality tests, discuss the possibility of normalising the observed data to reduce the noise given by subjectivity, show the results of an initial box-plot analysis that precedes the factorized linear regression and its validation through the AIC method.

6.4.1 Normality

For 4 of the 126 financial products, more data has been collected to try and have enough to check for normality. Unfortunately, only 22 data samples for each of those different financial instruments has been collected, reducing the accuracy and therefore confidence with which we can state that the data is normally distributed. However, for small data samples, normality can still be checked with special normality tests such as the Shapiro-Wilk test. Tabel 10 shows the results of such test. Appendix E reports the histograms that show the distribution of observations for each of the 4 financial instruments.

Total data-set					Adjusted data-set				
Descriptive Statistics									
	FP19	FP47	FP86	FP110		FP19	FP47	FP86	FP110
Mean	3,5	6,14	6,62	7,95	Mean	3,63	6,14	6,62	7,95
Median	3	6	7	8	Median	3	6	7	8
Mode	3	6	6	8	Mode	3	6	6	8
Shapiro_Wilk test for normality									
p_value	0,047	0,14	0,14	0,15	p_value	0,06	0,14	0,14	0,15

Figure 10: Shapiro-Wilk test for normality

As can be seen, only 1 out of 4 financial products do not seem to have the observed data distributed normally according to the Shapiro-Wilk test for normality. However, when looking more closely at the dataset, it was found that 2 participants answered the same to all questions, leading to think that the survey was not taken seriously. This has been confirmed by looking at the time these two participants took to complete all the questions: 15% of the total average time taken by the other participants. Therefore, this 2 participants were excluded and the data-set was adjusted. As can be seen, with the adjusted data-set all 4 of the financial products show a normal distribution of its observations, therefore seeming to indicate that while the complexity score given by participants is subjective, it tends to a more "objective" score. It has to be said that in theory, for a distribution to be considered normal, mean, median and mode have to be exactly the same. This is only true for 2 out of the 4 financial instruments tested. However, for the other two, the differences are limited and most likely will disappear with more observation.

However, demonstrating that the subjective answers from each participant would be normally distributed for every financial product, is not enough to cancel the noise that the subjectivity of the answers brings to the data. Following paragraph will look into methods to reduce this noise with different normalising data techniques.

6.4.2 Normalisation of the data

When using a scale from 1 to 10 in our observations of assessed complexity and these observations come from different participants, we face the problem that different people interpret the given scale in different ways. For example, even though two participants would agree that financial product 1 is rather simple, therefore characterised by a low complexity score, they could answer in two different ways, because they interpret the scale differently. Participant A finds financial product 1 extremely easy and assign a complexity score of 1 to it, while participant B, despite also finding the financial instrument 1 extremely easy, assigns a value of 3. On the other side, participant A finds financial product 126 extremely difficult and assigns a complexity score of 10, while participant B, despite the same thoughts, assigns a score of 8. Participant A uses the full range of the scale, while participant B does not, because he generally thinks that the extremes of a scale should never be used. This leads to subjectivity noise in the data observed that could be reduced with a *min-max normalisation*. In this way, all the answers of every participant are transformed in new complexity scores as if they were using the full range of the scale provided. This could be done applying the following formula for each observation:

$$x_{i,scaled} = \frac{(x_i - min(x))}{(max(x) - min(x))} * (max(x_{scaled}) - min(x_{scaled})) + min(x_{scaled}) \tag{8}$$

were $\max(x_{scaled})$ would be 10 and $\min(x_{scaled})$ would be 1 (as in the original scale presented to all participants; max(x) and min(x) instead are the maximum complexity scores given by the single participant; x_i is the actual complexity scored given by the participant to that particular financial product.

As straightforward as this type of normalisation can be, it would lead to further inaccurate analysis in this particular case. Min-max normalisation is usually done if there are different participants that answer the same question. However, in this dataset, participants do not answer the same questions. If min-max were still to be utilized to adjust the data-set, major information loss would occur. There is a possibility that participant A has been shown only easier financial instruments and therefore his range of complexity score goes from 1 to 5, while participant B has been shown only more complex financial products leading to a range of 5 to 10. Let's supposed that they both answered 5 to a particular financial products. If we re-scale their answers, we would have that for participant A the complexity score would be 10 and for participant B the complexity would be 1, even though they both assessed the financial product as with moderate complexity (5). Normalisation of the data, due to the different questions asked to each participant, has therefore not been done. The analysis further described in next paragraphs will make used of the *"untouched"* dataset. This is a limitation of the study because the noise of subjectivity has not been minimized, but still avoids to draw incorrect conclusions due to major information loss in the normalisation. The last part of this paragraph will propose another possible type of normalisation that takes into account the possibility of having different questions between participants.

Instead of taking the totally (10) of a participants answers, let's take only a subset that is made of the 2 questions that at least half the total population has observed. In this way we are looking at only financial products (questions) that have been asked to assess to the totality of the participants (actually only half of them, because half the people had financial product 19 and 86 has fixed question and the other half had financial product 47 and 110; the reasoning

still holds, but should be applied twice). These two financial products, because observed by everybody, could be used to determine whether a participant uses a wider or a narrower scale, without losing information about the other financial products. This could be calculated with the following equation:

$$Newcomplexityscore = \frac{\Delta_i}{\Delta_{average}} * (Oldcomplexityscore - mean_i) + mean_i \tag{9}$$

were mean_i indicates the average of complexity scores given by participant i to the two fixed questions; Δ_i indicates the difference between the complexity scores given by participant i to the two fixed questions; $\Delta_{average}$ indicates the average difference between the complexity scores given by all participants to the two fixed questions and is therefore calculated as:

$$\Delta_{average} = \frac{\sum \Delta_i}{n} \tag{10}$$

were n indicates the total number of participants and the sum is run for all i participants.

However, also this method present some challenges. While it preserves more accurately information and at the same time it reduces subjectivity noise, a problem arises when a particular participant gives the same complexity score to both fixed financial products, leading its Δ_i to be equal to 0. With a Δ_i equal to 0, all participants complexity scores assessments given at the variable financial products will be equal to the complexity scores given at the two fixed financial products, hence again, losing part of the information.

Unfortunately, being the questions asked to each participant mostly different, normalisation is not possible without a trade-off in loss of information. Therefore, it is suggested for future analysis to conduct the same experiment but with more questions equal for all participants. These questions would then initially be used to calibrate the model, before running the total linear regression. Another solution would be to present a more in depth explanation of the scale before the start of the experiment: participant could be provided with a financial product that has an intrinsic score of 1 (all features are set to have the minimum value they can assume) and another that has an intrinsic score of 10 (all features are set to have the maximum value they can assume). This could also help to achieve more accurate results when conducting further analysis such as the regressions.

6.4.3 Box-plot Analysis

Before analysing the 410 observation with a factorized linear regression, a box-plot analysis has been conducted to visually represent how each independent categorical variable has an impact on the dependent variable *"complexity score"*. Moreover, this visualisation has also been divided for both values that the dummy variable *"Work Experience"* can assume, with the intent to show the different reasoning of the participants with work experience when compared to those without. All these visual analysis are reported in Appendix C. Also descriptive statistics consisting of mean, median, mode and standard deviation has been conducted and are reported in various tables in Appendix C.

With the initial visual interpretation of the box-plot analysis is can be anticipated how the independent variable *Mathematical Model* seems to have a significant impact on the dependent

variable *Complexity Score*. However, the impact seems diminishing with higher values of the independent variable. This is true for observations of both groups, work-experienced in the financial sector and not. On the contrary, there seem to be no visual difference between the boxes of value 1 and value 2 of *Trading Mode*, alluding to the fact that this feature does not have an impact on the dependent variable. When looking at the relationship between *Dependency of the underlyings* and the dependent variable, the biggest takeaway is the difference between how participant with work experience and those without see it. The latter group seem to have a more steep increase in *Complexity Score* with an increase of the independent variable than the former group. Regarding the independent variable labeled as *Number of Underlying*, it seem to have a significant impact on dependent variable observed, with an increased effect the higher the value it assumes. Finally, the *Number of Clauses* box-plots seem to indicate that there is no relationship at all with the complexity score for people without work experience, while for those with experience there is a significant relationship. This difference can be mainly due to the fact that people with experience in the field have seen many more financial products and therefore have seen a wide variety of financial products with different number of clauses, leading them to a more sophisticated assessment.

6.5 Linear Regression

Following the box-plot analysis, a factorized linear regression has been performed with the software R_Studio. The analysis indicated the overall significance of the model (p_value$<$0.0001), but also states that a better fit could be found (adjusted R-squared = 0.3314). This could be done in future researches with a different type of regression. The complete results are summarized in the following table and do not deviate from the outcomes predicted with previous analysis:

	Estimate	Std Error	t value	p value	Signif.
(Intercept)	3,4967	0,3554	9,84	2,00E-16	***
Model 2	1,6229	0,2364	6,866	2,54E-11	***
Model 3	2,5288	0,234	10,807	2,00E-16	***
Clauses 2	-0,1273	0,2263	-0,562	5,74E-01	
Clauses 3	0,3517	0,2376	1,481	1,39E-01	
Underlying 2	1,2432	0,3268	3,804	1,65E-04	***
Underlying 3	2,1939	0,3219	6,815	3,49E-11	***
Dependency 1	-1,4283	0,2751	-5,192	3,32E-07	***
Dependency 2	-0,6327	0,2496	-2,535	1,16E-01	*
Dependency 3	NA	NA	NA	NA	
Trading Mode 2	0,1743	0,196	0,889	3,74E-01	
Work Exp 1	0,7747	0,2118	3,657	2,89E-04	***
Study Exp 1	-0,2165	0,2233	-0,969	3,33E-01	

Figure 11: Linear Regression with factors

As can be noticed, for one value of the independent variable *Dependency between underlyings* an error results when performing the analysis. This is to be expected due to a partial collinearity with another independent variable labeled as *Number of Underlyings*. This is shown in the correlation table reported in Figure 12.

The linear regression result could be summarized in the following equation:

$$F_c = 3.50 + \begin{cases} 0, & \text{if } x_1 = 1 \\ +1.62, & \text{if } x_1 = 2 \\ +2.53, & \text{if } x_1 = 3 \end{cases} + \begin{cases} 0, & \text{if } x_2 = 1 \\ +1.24, & \text{if } x_2 = 2 \\ +2.19, & \text{if } x_2 = 3 \end{cases} + \begin{cases} 0, & \text{if } x_3 = 0 \\ -1.43, & \text{if } x_3 = 1 \\ -0.63, & \text{if } x_3 = 2 \end{cases} + 0.77 * x_d \quad (11)$$

were the variable x_1, x_2, x_3, x_d are respectively the dependent variables labeled as *Mathematical Model, Number of Underlyings, Dependecy between underlyings,* and the dummy variable *Work Experience*.

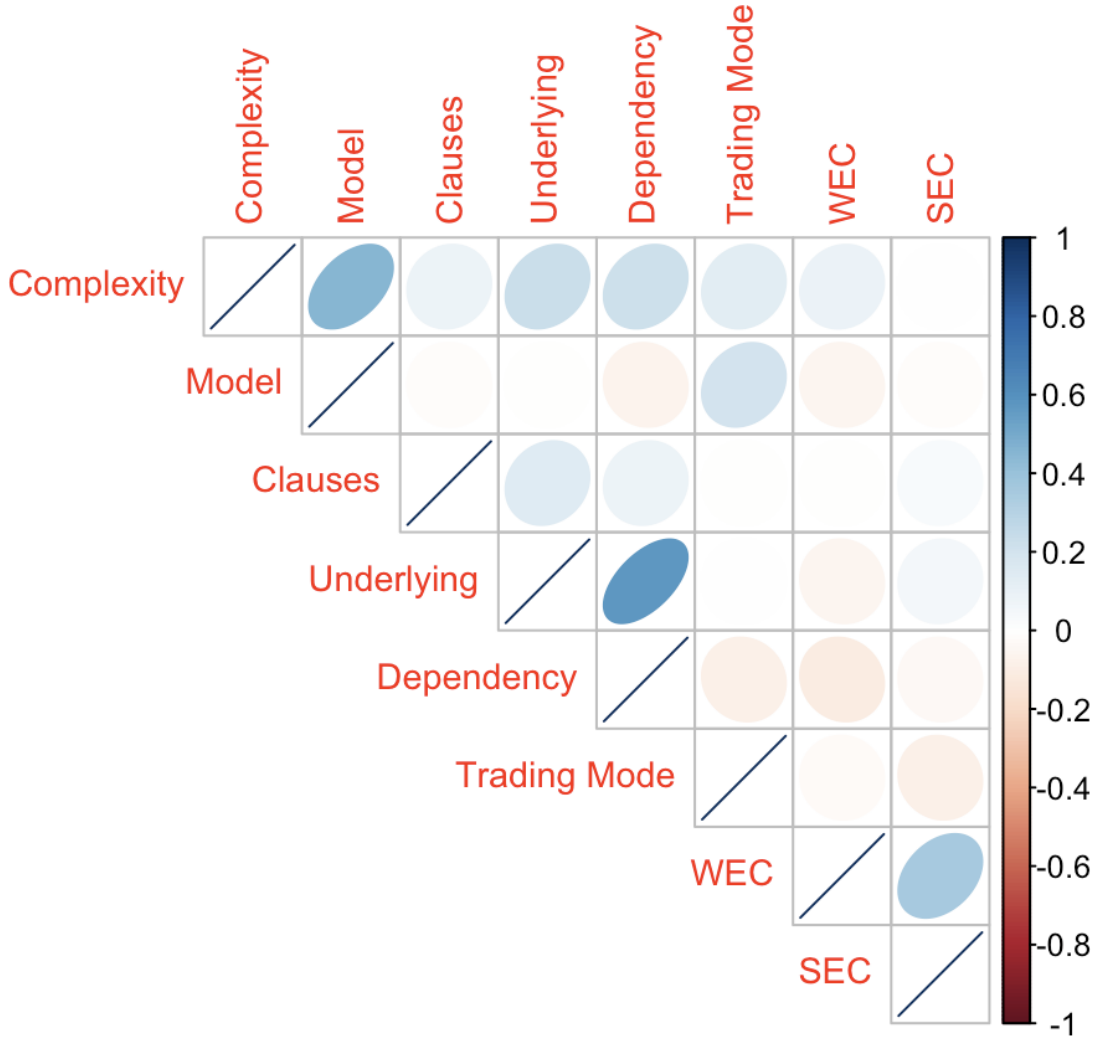

Figure 12: Correlation Table

In order to assess the goodness of fit of the regression previously presented, the AIC method has been used. This method is particularly interesting because it assess the model studied with a double point of view: while it rewards the goodness of fit, on the other side it penalises when an the number of functions that describes the model (our dependent variables) increase. This is what we are looking for since we want to create an accurate model, but at the mean time a simple one, defined by a small amount of features so that it is easier comprehensible objectively, as by initial goal defined by Becker et all. (2012).

The AIC goodness of fit proposes a slightly different model result as the one obtained with a simple factorized regression. With this method, also the dependent variable *Number of Clauses* should be included (here as x_4) leading to the following equation:

$$F_c = 3.46 + \begin{cases} 0, & \text{if } x_1 = 1 \\ +1.65, & \text{if } x_1 = 2 \\ +2.57, & \text{if } x_1 = 3 \end{cases} + \begin{cases} 0, & \text{if } x_2 = 1 \\ +1.22, & \text{if } x_2 = 2 \\ +2.17, & \text{if } x_2 = 3 \end{cases} + \begin{cases} 0, & \text{if } x_3 = 0 \\ -1.43, & \text{if } x_3 = 1 \\ -0.64, & \text{if } x_3 = 2 \end{cases} + \begin{cases} 0, & \text{if } x_4 = 1 \\ -0.13, & \text{if } x_4 = 2 \\ +0.34, & \text{if } x_4 = 3 \end{cases} + 0.77 * x_d \tag{12}$$

Equation 11 and 12 are similar with some slight changes in coefficients and an extra dependent variable in the latter. However, if the AIC method steps are studied closely it can be

seen how the exclusion of the dependent variable *Number of Clauses* does qualitatively change the outcome. This can be deducted when the AIC values are observed (the lower the value, the better the model fits the data). When considering the exclusion of *Number of Clauses* as dependent variable, the AIC values is 532.82; the inclusion has an AIC value of 532.69. As can be seen this difference is negligible if compared to, example, the exclusion of the *Mathematical Model* (AIC of 641.54). Therefore, both equation could be considered equally valid. Equation 11 is preferred by the author as it reduces the computational input necessary to comprehend the model and gets a step closer to the goal of objectively comprehensible definition of complexity in financial instruments (Becker et al., 2012).

6.6 Conclusions and Limitations Model Framework

Overall, the framework built at the beginning of the chapter presents a novel solution to assess quantitatively the complexity of financial instruments, without being bounded by their class type (option, swap, future, CDOs..) but considering all the *building blocks*, the features that characterise the particular product. This avoids the unpleasant possibility to identify a usually less complex financial derivative like futures as easy while its actual complexity is high due to the presence of peculiar features. This model is elegantly simple and can be summarised with the equation 11, that could be adapted as a part for other future researches.
However, multiple limitations accompany the model framework: first of all, more observations are needed to improve the accuracy of the regression and to test ulterior normality in the distribution. Moreover, using only a factorised linear regression also consists in a limitation: a different type of regression could find a better fit (with an higher value of R-squared). The non-normalised dataset also poses a limitation: future research could adapt a better approach to avoid having to normalise the data and/or use known methods that would not lead to excessive loss of information. Lastly, multiple intrinsic limitations are caused by the choice of using categorical variables instead of continuous variables. Despite using the latter would require both an higher level of sophistication of modelling and of people taking part in the survey, it would undoubtedly lead to more accurate results. The limitations based on the framing choice of the different categories for each variable is discussed more in depth in the Appendix B.

7 Conclusions and reflections

7.1 Main findings of this study

This master thesis project explores the world of financial derivatives with the intention to establish a connection between three main concepts that delve around these products: complexity, asymmetry of information and mispricing. The process resulted challenging and had to be taken step by step, studying more targeted topics to try and create an unique overview. As far as the academic literature goes, a relationship between mispricing of a financial derivative and its complexity is indirectly stated: investors perceived risk differently based on the complexity of the financial products and therefore they expect a different return on their investment, leading to a mismatch of the price they attach to the instruments and the fair value of those. Therefore, a first sub-research question has been formulated to assess whether:

SRQ1: Is this relationship between perceived risk and complexity of a financial product sufficient to establish a correlation between mispricing and complexity of a financial derivative?

The literature answers this question negatively: this relationship is not sufficient. Chapter 3 reports an extensive literature review on the topics and does not find a strong enough demonstration that could simplify a difference in actual and perceived risk to mispricing in financial derivatives. Chapter 3 also deals with the definition of the concepts of mispricing and complexity in financial derivatives and addresses in particular the second sub-research question:

SRQ2: When speaking of financial derivatives, how is mispricing defined?

This thesis accepts and revolves around the definitions of *fair value* and *hidden costs* used by Joergensen et al. (2012) in their work. Mispricing is defined as the discrepancy between the actual price of purchase of a financial product and its fair value of purchase, defined as *"the amount for which a financial product can be exchanged between knowledgeable, willing parties"* (Scott & Scott, 2003; Breton, 2004). This difference between the two values is easily quantifiable, hence minimizing the possibility to have misunderstandings like with qualitative definitions. Moreover, this thesis aimed at answering the following:

SRQ3a: How can complexity be defined in a financial product?

Chapter 3 studies in-depth also how scholars define the concept of complexity in financial derivatives, the *second pillar* of this master thesis. In the academic literature, mostly qualitative definitions are used. Some of these definitions are reduced to differentiate only simple from difficult (plain vanilla or exotic derivatives). Other, start having a more generalisable definition, taking into consideration the amount of effort that an investors would incur when trying to fully understand the financial product itself. However, these qualitative methods of assessment, such as the one stated in the MiFiD II regulations, are basic and reductive, leading more often than not in potential problems. This led to a further sub-research question that was investigated:

SRQ3b: Can complexity in a financial product be quantitatively defined?

Complexity can be quantitatively defined and it should. As defined by Becker et al. (2012), a quantitative definition helps bringing us closer to the end goal of having an *objectively comprehensible definition*. This thesis reports a novel framework that elaborates on the vision of *building blocks* by Brunnermeier et all. (2009) and identifies the total overall complexity of a financial instruments as a linear function of complexity of the singular features that characterise it. However, not all features have the same impact: the *Mathematical Model* that describes the mechanisms of the financial product, the *number of underlyings* and the *dependency between underlyings* all significantly contribute to the overall complexity, while *trading mode* and *number of clauses* present in the contract result not to contribute in a significant way to the model described in Chapter 6.

As *third and last pillar* of this thesis, the concept of asymmetry of information is explored with empirical experiments described in Chapter 5. The aim of this Chapter is to shed light on the following sub-research questions:

SRQ4a: To what extent does asymmetry of information affect the misjudgement of a potential investor?
and
SRQ4b: To what extent does lack of knowledge affect the misjudgement of a potential investor?

The experiments conducted in this thesis show clearly that asymmetry of information, under the form of different amount of disclosed information, amplifies the misjudgement of a potential investor. When investors are presented with more information, in particular when both the potential gains and the potential losses of a financial position are disclosed by a firm using financial derivatives, they tend to make better risk assessment than when only potential losses are disclosed to them. Moreover, the results of the study find that when presented with a one-sided loss-only disclosure, potential investors tend to infer that the gains are equal or greater in size than the losses, correctly referring to the use of entering future contracts or buying call options, the most common practices of manufacturing firms.

Across all 3 experiments the object of the study was an heterogeneous sample regarding financial knowledge, with different backgrounds, study experience and work experience. When looking closely at the data, descriptive analysis seems to indicate that there isn't any difference between knowledgeable investors and not: both sub-groups seem to incur in the same judgemental errors when assessing risk of financial derivatives. Moreover, the complete study of all 3 experiments shows that in financial matters the Dunning-Krueger effect seems not to be present, indicating that people are self-aware of their actual financial literacy, without over- or underestimating their capabilities in financial matters.

This master thesis, partly as replicatory study of the work by Koonce et al. (2005), focuses also on the importance on how financial positions are framed, explained in different manners, asking itself:

SRQ5: To what extent does the framing effect impact the decision of a potential investor?

Results of the first two experiments indicate the framing effect has a different impact on the judgement of potential investors based on the type of financial derivatives that describe

the financial position they are faced with: the more the position is complex, the more this effect has an impact and leads to misjudgment. That means, the magnitude of this impact is dependant on the overall complexity of the financial position. The findings are novel, as they diverge from the results of the original work by Koonce et al. (2005). Divergence in findings is also to be found in the possible remedies that could help a potential investor make a more informed risk assessment, possibly reducing the misjudgement. In contrast with Koonce et al. (2005), the second experiment highlights how misjudgement from a potential investor could be reduced if, when faced with a financial decision, more information is provided under the form of a payoff graph, that functions as visual aid, helping them picture more clearly the possible outcomes of the financial position.

While this thesis has successfully analyzed the complexity, the information asymmetry, and the mispricing of financial derivatives, it must be acknowledged that it fails to fully address the main research question:

RQ: To what extent are complexity, asymmetry of information and mispricing of financial derivatives correlated?

The thesis sheds light on the important relationship between all these 3 concepts. It shows how asymmetry of information seems to be more present where the financial product's complexity is high; it shows how mispricing is a widely present phenomenon for more or less complex financial derivatives and how this is related to the difference in amount of information between the two financial actors involved. Despite not quantifying the correlation, this thesis lays the groundwork for future studies, providing the basic knowledge, instruments and essential insights into these crucial financial concepts.

7.2 Implications of the findings for financial markets and regulation

The findings of this thesis shed light on various concepts regarding financial derivatives. These findings carry some interesting, yet complicated, insights for policy regulators and have a possible impact on financial markets' efficiency. Throughout the totality of the study, a recurrent topic, confirmed by the findings of the experiments in Chapter 5, is that an increased transparency and a decrease of complexity of financial derivatives should lead potential investors to make better risk judgements, alluding to a better assessment of the fair value of different financial products. This phenomena of having on average a more informed investors, due to less asymmetry of information, should increase the efficiency of the financial markets: market prices should reflect more properly the economic fundamentals and not be influenced by biases of the investor. Decreasing asymmetry of information, by increasing transparency, allows potential investors to make decisions based on a complete set of information. However, simply increasing transparency is not enough. If complexity remains high, an increase in transparency is useful only for more knowledgeable investors, that have the means to understand all the information that is provided to them. The less knowledgeable investors, even though provided with more information, would still not be able to make a rational investment decision, because they still fail to understand the mechanisms of the more complex financial derivative. Asymmetry of knowledge remains a possible barrier, even if market transparency is at his highest. A decrease in overall market's and financial derivative's complexity would lead to create a bigger pool of knowledgeable potential investors. This is not because investors actually become more knowledgeable, but due to a decrease of the

knowledge necessary to understand the market and the financial derivatives. However, if transparency remains low, knowledgeable investors, even though they are more, would still not be able to make a informed decision that would lead to an increase in market efficiency. Both factors need to change at the same time. Regulatory frameworks are trying to keep transparency high by imposing constantly new rules that financial institutions have to follow when creating and selling financial products such as derivatives. However, by only doing so they are involuntary increasing complexity of these financial instruments, because sellers, wanting to regain an hedge on the buyers, want to increase the asymmetry of knowledge between the parties. On the other hand, when decreasing complexity, transparency of information does not decrease. Therefore, policy makers should target directly complexity of financial derivatives, instead of transparency of these instruments.

7.3 Limitations of the study

The different experiments and the framework presented in this master thesis present several limitations. These limitations reduce the general robustness of the findings previously reported. The limitation that is the most impacting is the low number of observations across all the experiments. The limited sample size is given by both external and internal factors to this thesis. A major external factor is the low response rate by people contacted to participate in the survey: approximately more than a 1000 people have been contacted through various channels, such as university networks, work networks, personal networks. Only 134 have initiated the surveys: a rather low response rate between the 10% and 15%. Moreover, only 62 (corresponding to 46%) did manage to conclude the whole survey and submit a complete answer to all the questions. The finishing rate being so low is probably due to an internal factor: how the survey was structured. The survey resulted to be too long and too demanding for being a non paid survey. Moreover, the design of the experiment was to ambitious: people were divided into too many groups in order to study different characteristics of the topic. Choosing only one characteristic and focusing on that would have increased the number of observations and therefore, the validity of the findings. Moreover, the target group chosen is most likely not the ideal population sample. The population sample that took part in these experiments does not reflect the actual population of investors. Despite not agreeing with the idea of using only M.B.A. students as proxy for investors, as done by Koonce et al. (2005), using a more heterogeneous population sample has limitations on its own: in fact, only 28% of the participants in the survey has previously invested in financial derivatives, reducing the number of participants that could fully grasp the notions behind the various questions. However, the low number of observations does not discredit the validity of the findings, especially when these were originated from a comparison with the previous original study by Koonce et al. (2005). In fact, the findings in this master thesis can be used to show the non generalizability of the conclusions of the original work.

The findings reported in this master thesis cannot be generalized. As mentioned previously, the population sample that took part in the survey does not reflect the actual population of investors. Moreover, within the population sample, geographical clusters can be found, with more than 60% or survey takers coming from 2 countries (Italy and Belgium). This is mainly due to the sampling method chosen in this master thesis. In order to obtain more observations with the few resources available, non-probability convenience sampling has been used. This method sacrifices external validity, hence generalizability, to try and get more observations to increase internal validity. Moreover, the findings will always bear qualitative significance and can be

used to study human behaviour in decision making when faced with financial investments.

7.4 Reflections and suggestions for further research

The thesis delves into the intricate topic of the complexity of financial derivatives. Understanding the relationship between these concepts is important to identify what the main problem is that leads potential investors to not effectively make use of these instruments and financial firms to take advantage of this situation. Therefore, it is important to address because of the possible consequences the use of financial derivatives has on the real economy and the wealth distribution. Studying these topics could help not only the regulatory agencies to better implement new rules that keep the situation under control (such as having a model to determine complexity in a objective quantitative manner), but also for the potential investors to understand the type of instruments they are using and the intrinsic risk they carry.

Academic literature about financial derivatives focuses mostly on technical papers that evaluate models used to assess the prices of these financial instruments. Only a relatively small section regards the behavioural finance behind them. In this direction the literature seems to identify broadly the problem. However, it consists mostly of exploratory researches and lacks more in-depth studies, especially quantitative studies that aim to bring generalizability to the findings.

However, after having performed various quantitative experiments in the matter, I recognise the challenge of going in such direction. More studies in this direction would lead to cumulative knowledge and would ease the burden for future researchers, that could ultimately be able to fully answer the questions that are being posed nowadays, such as the ones explored in this master thesis. For this reason, I think research should continue in this direction, taking inspiration from this work and the original by Koonce et al. (2005). Some features can be adapt to test peculiar scenarios. However, future research should mainly focus on increasing the number of observations in the data-set, to increase statistical significance and to better understand the link between the aforementioned concepts of complexity, asymmetry of information and mispricing in financial derivatives.

Especially the concept of complexity in financial derivatives and the model framework that quantitatively defines it presented in Chapter 6 is worthy of further research. Further analysis should include new features and see if these have an impact on the complexity of financial instruments, alongside testing if the initial parameters for the model found in this thesis still hold. Furthur studies should also check for a more accurate regression or a more accurate function that could increase the fit of the curve.

Moreover, follow-up research on this topic does not necessarily need to be performed in the same way as done in this project. Performing these experiments through surveys has its limitations: generally there is a barrier where participants could easily misinterpret the task they are given or question they are asked. Therefore, I recommend for further research to approach the problem utilizing a dynamic interview method: this should help to understand more in-depth the reasoning of potential investors on specific topics, alongside giving the flexibility to quickly adapt the focus of the research based on necessity and on new leads.

Using a survey-based approach is still a valid method to undergo this research. However, few adjustments have to be made relatively to the ones performed in this thesis. Collecting data on a wide scale of question in order to study the totality of the broad spectrum of complexity

in financial products, needs to be done only after the model has been calibrated correctly. This can be done by starting to gather more observations of the same questions. Moreover, as initial starting point to construct the model research could focus on a sub-group of knowledgeable investors and only after that checking whether the reasoning could expand and adapt to the totality of the investors population. This means, the model would not be a direct reflection of the quantitative data gathered throughout the population of investors, but would be an Expert Based Model. The judgments of experts should lead to more accurate modelling.

Further research is also needed to find policy suggestions to help the regulatory framework. As previously argued, policy regulators' aim should be to lower overall complexity of the market of financial derivatives. This could be done applying the concepts of game theory like previously done by Carlin (2009), studying if introducing a new player in the market with a fixed complexity of its financial products that is lower than the complexity of all other players would lead to an overall decrease of financial derivatives complexity on the market. Theoretically, it can be studied if this new strategy introduced (lowering the complexity of its financial derivatives) is an evolutionary stable dominant strategy.

Finally, starting form Joergensen et al.'s (2012) quantitative definition of mispricing and on the quantitative definition of complexity reported in this thesis, further research could start looking into a correlation of these two concepts. This can be done selecting a number of financial derivatives and closely study them to evaluate if and to what extent they are mispriced, alongside evaluating how complex they are based on the model built in Chapter 6. In fact, this master thesis provides the basic knowledge and instruments necessary for follow-up research to dive more in-depth and potentially be able to answer precisely the main research question:

RQ: To what extent are complexity, asymmetry of information and mispricing of financial derivatives correlated?

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A Survey - Complexity & Perceived Risk

Section 0: Opening Statement

You are being invited to participate in a research study titled "Complexity & Risk in Financial Products". This study is being done by Joris Laureys from the TU Delft.

The purpose of this research study is evaluating complexity in financial products and will take you 20 minutes to complete. The data will be used for the writing of a master's thesis. We will be asking you to provide some opinions on financial products.

The survey is designed to be anonymous and demographic questions will be limited to a minimum. This is done in order to minimize any possible risk of breach of privacy; however, with online activity the risk of a breach is always possible. Moreover, data collected will be safely stored with TUDelft approved instruments following Dutch Privacy Rules and will be accessible only by me (Joris Laureys) and my supervisory team.

Demographic and quantitative data will be made publicly available at the end of the study as supporting material to the Master Thesis. However, you cannot be re-identified based on this data. Qualitative data (answers to open questions) may be paraphrased in the Masters Thesis but will not be made publicly available. This data will be deleted at the end of the Master Thesis.

Your participation in this study is entirely voluntary and you can withdraw at any time. To avoid possible uncomfortable situations, some question permits the survey taker to answer with "I prefer not to say". To have more accurate results, survey takers are requested not to use external tools to complete questions.

For any enquiry, please contact me at the following address: J.D.F.laureys@student.tudelft.nl By continuing, the participants are agreeing with this Opening Statement and the survey will begin:

Section 1: Demographic Questions

Total number of questions: 14
Objective of the section:

- Briefly collect information about the survey takers. This information will then be used to see if different work or studies background (and maybe to a lesser extent age groups and different countries of origin) have an impact on the answers given.
- Identify those who would be considered *professional investors* by MiFid II regulations.
- Initial screening of participants (either sufficient level of education, or work experience or prior investing experience).

Questions:

Q1.1: What is your gender?

- Male

- Female
- Other
- Prefer not to say

Q1.2: How old are you?
Q1.3: What is your nationality?
Q1.4: What is your highest level of education? If you are still studying, please indicate both obtained and current level of education.

- High School or less
- Bachelor's degree
- Master's degree
- PhD
- Other (specify please)

N.B.: Questions Q1.5 and Q1.6 are displayed only if the answer given in question Q1.4 is different than *"High School or less"*.
Q1.5: Please indicate the type of degree you currently have and/or are studying for:

- Finance
- Financial Engineering
- Economics or Business Administration
- Business Engineering
- Engineering (other)
- Other

Q1.6: How many major courses did you take of the following type?

- Finance:
  - 2 or less
  - 3 to 5
  - More than 5
- Statistics or advanced mathematics:
  - 2 or less
  - 3 to 5
  - More than 5

Q1.7: How many years did you work in the finance sector, or any job related to finance?

- None
- Less than 5 years
- 5 to 10 years
- 10 to 20 years
- More than 20 years

Q1.8: Do you currently invest (or have a significant history in investing)?

- Yes
- No

N.B.: Question Q1.9 is displayed only if the answer given in question Q1.8 is *"Yes"*. **Q1.9:** How do you mainly invest?

- Completely by myself
- Mainly by myself, with some help of financial advisors
- Mainly with the help of financial advisors
- Only through delegating financial advisors

N.B.: Question Q1.10 is displayed only if the answer given in question Q1.8 is *"Yes"* AND if the answer given in question Q1.9 is different than *"Only through delegating financial advisors.* **Q1.10:** How likely would you use the following instruments in your investment strategy?

- Instrument type:
  - Public stocks and bonds
  - Indexes, funds and instruments alike
  - Financial derivatives
  - Other
- Possible answers:
  - Highly unlikely
  - Not likely, rarely used
  - Likely, commonly used
  - Highly likely, frequently used instrument

Q1.11: How do you consider yourself?

- Risk-averse
- Risk-neutral

- Risk-seeking
- I prefer not to say

Q1.12: How familiar are you with financial products and financial markets?
Answer is given on a 11-point scale, with 0 indicating "Not familiar at all", 5 indicating "Moderately familiar" and 10 indicating "Extremely familiar".

Q1.13: What is your net worth?

- Over 500.000€
- Under 500.000€
- I prefer not to say

Q1.14: Considering last year, on average how many financial transaction did you undertake in one trimester?

- 10 or more
- Less than 10
- I prefer not to say

Section 2: Screening Questions & Financial Literacy

Total number of questions: 4
Objective of the section:

- Evaluate if the survey taker understands basic financial knowledge and therefore can be considered having at least basic financial literacy. Even though the survey aims to evaluate how different education impacts retail investors perspective, we exclude from the attainable data sample those survey takers that fail to correctly answer basic finance questions. This is done in order to prevent random people answering the survey and to minimize noise in the data.
- Evaluate if there is a possible "Dunning-Kruger Effect", where people with less knowledge tend to evaluate themselves better than they are. Results are confronted with Q1.12. All questions present the option "I do not know" to try and minimize casual guessing.

Questions:

Q2.1: Suppose you have 100€ in your savings account and the interest is 2% a year. The interest you receive is added to your savings account each and every year. After 5 years, with constant interest rates, how much do you think you would have in the account if you left the money to grow?

- 100€

- More than 100€, less than 110€
- 110€
- More than 110€
- I do not know

Q2.2: If interest rates go down, what happens to bond prices?

- Bond prices increase
- Bond prices do not change
- Bond prices decrease
- I do not know

Q2.3: "DuckyDucky" is a non-financial firm that uses rubber as main input to manufacture its product. To protect itself against a possible increase in rubber's price, the firm enters a long call option position with its supplier. "DuckyDucky" enters this position with a purpose of:

- Hedging
- Speculation
- Other
- I do not know

Q2.4: Consider the following statements and indicate if they are True or False.

- **Statement 1:** All bonds are risk-free investments.
- **Statement 2:** Buying a single company's stock usually provides a safer return than a stock mutual fund.
- **Statement 3:** A "Future" is a type of financial derivative that gives you the right, but not the obligation, to buy/sell a specific product at a specific price at a specific time.

Section 3: Complexity & Perceived Risk

Total number of questions: 10
Objective of the section:

- Replicate experiments 1, 2 and 3 conducted by Koonce et al. (2005).
- Evaluate whether retail investors correlate product complexity and risk. This is done presenting 2 economically equivalent positions (therefore equal risk) undertaken by a company, with a difference in complexity. Survey takers will be asked to assess the risk of both positions.

- Assess if "visual aid" (both positions are disclosed with payoff graphs) could help to reduce the misperceived risk found by Koonce et. al (2005).

As first step, participants are randomly, but with equal probability, selected to participate in either Group A or Group B. Within their groups, they are again randomly selected to be part of Group A1, Group A2 or Group A3 (or Group B1, Group B2, Group B3).

Questions Experiment 1 & 2 - Group A:

Q3.A.1.1: "TastyMeals" is a food and beverage company and is looking to expand its business in a new market segment. In order to do so, their managers evaluate an initial investment of € 1 million. To finance this investment, they undertake a 10-year loan from "Delftse Bank" with fixed interest rate at 4% with yearly payments. Therefore, they have a fixed interest rate-debt position.
Overall, how risky do you consider TastyMeals' position?
Answer type: Answer is given on a 101-point scale, with 0 indicating "Not risky at all", 50 indicating "Moderate risk" and 100 indicating "High Risk". The option "I do not know" is also provided.

Q3.A.1.2: "DeliciousFood" is a food and beverage company and is looking to expand its business in a new market segment. In order to do so, their managers evaluate an initial investment of € 1 million. To finance this investment, they undertake a 10-year loan from "Delftse Bank" with variable interest rate with yearly payments. Moreover, "DeliciousFood" enters a variable to fixed interest rate swap position with yearly payments and fixed rate at 4%. Therefore, their outstanding position is a variable interest rate-debt combined with variable to fixed interest rate swap.

Overall, how risky do you consider "DeliciousFood" position?
Answer type: Answer is given on a 101-point scale, with 0 indicating "Not risky at all", 50 indicating "Moderate risk" and 100 indicating "High Risk". The option "I do not know" is also provided.

Q3.A.1.3: "SuperbDishes" is a food and beverage company and is looking to expand its business in a new market segment. In order to do so, their managers evaluate an initial investment of € 1 million. To finance this investment, they undertake a 10-year loan from "Delftse Bank" with variable interest rate with yearly payments. Moreover, "SuperbDishes" enters a variable to fixed interest rate swap position with yearly payments and fixed rate at 4%. Therefore, their outstanding position is a variable interest rate-debt combined with variable to fixed interest rate swap used as hedge.

Overall, how risky do you consider SuperbDishes' position?
Answer type: Answer is given on a 101-point scale, with 0 indicating "Not risky at all", 50 indicating "Moderate risk" and 100 indicating "High Risk". The option "I do not know" is also provided.

Q3.A.2: Consider the following information:

An increase in interest rates would not change the net interest payment cash flows of the

fixed interest rate-debt. That is, the company would be "locked into" paying the same net cash amount of interest. A decrease in interest rates would not change the net interest payment cash flows of the fixed interest rate-debt. That is, the company would be "locked into" paying the same net cash amount of interest. The following graph shows the yearly interest payments as a function of the interest rate:

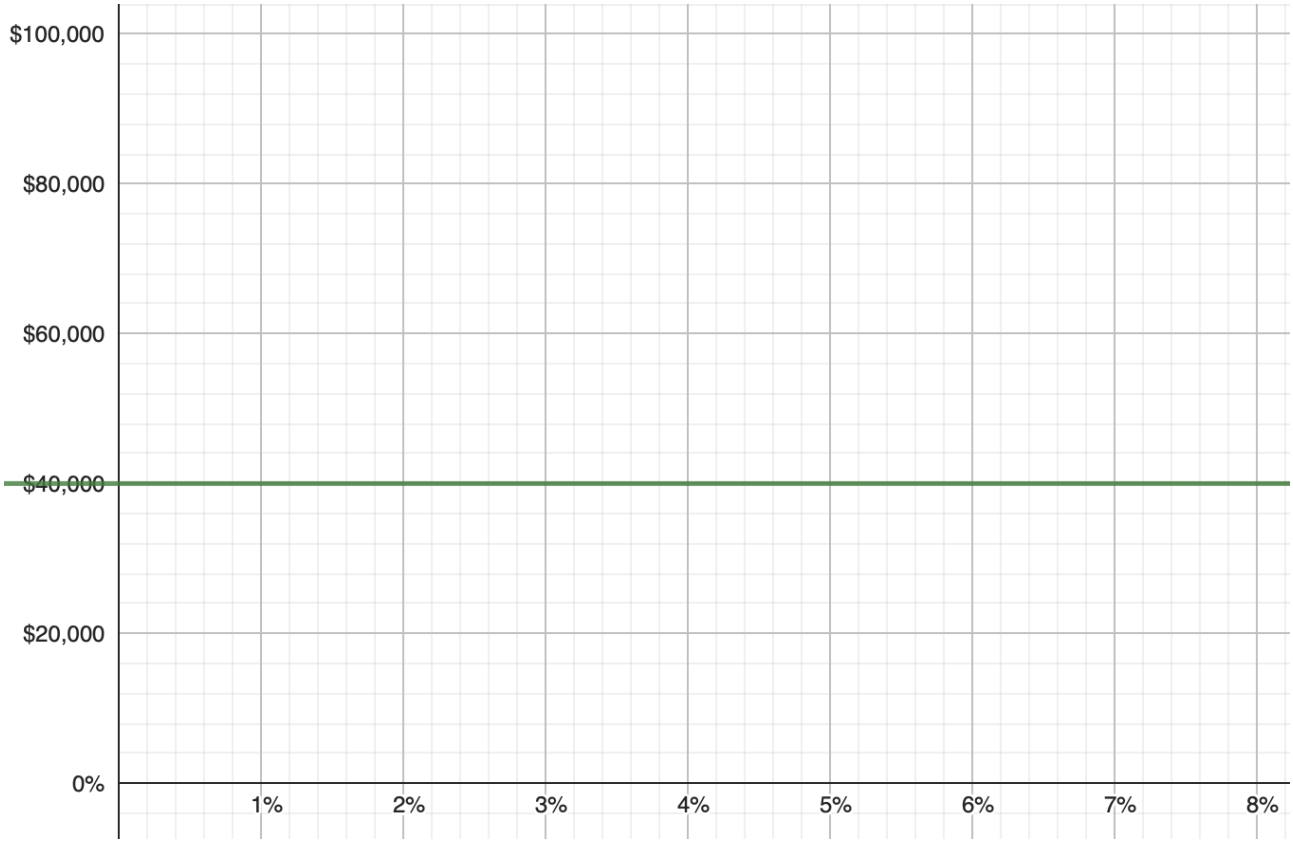

Figure 13: Visual aid shown to participant - Swap

An increase in interest rates would create an economic gain because the company would not have to pay the higher, current market rate of interest. In other words, if interest rates increase, then the fair value of this fixed interest rate-debt would decrease. This would cause an economic gain. A decrease in interest rates would create an economic loss because the company would still have to pay the higher fixed rate of interest. In other words, if interest rates decrease, then the fair value of this fixed interest rate-debt would increase. This would cause an economic loss.

With the following information, please re-evaluate the riskiness of *CompanyXXX*'s position:
Answer type: Answer is given on a 101-point scale, with 0 indicating "Not risky at all", 50 indicating "Moderate risk" and 100 indicating "High Risk". The option "I do not know" is also provided.

Q3.A.3: "Plastics&co", "GreenPlastics", "TechSolutions" are all producers of high-performance plastic dispensers and use raw plastic as their main input.

"Plastics&co" uses a strategy of long call options with strike price at 75€/ton for 20 ton of raw plastic. The premium paid by the company for this contract is 100€.

"GreenPlastics" uses a strategy of future contracts with strike price at 75€/ton for 20 ton of raw plastic. Moreover, the company buys a long European put option with strike price at 75€/ton for 20 ton of raw plastic. For this contract, it pays a premium of 100€. Therefore, GreenPlastics' position is a future combined with bought long put options.

"TechSolutions" uses a strategy of future contracts with strike price at 75€/ton for 20 ton of raw plastic. Moreover, the company buys a long European put option with strike price at 75€/ton for 20 ton of raw plastic. For this contract, it pays a premium of 100€. Therefore, TechSolutions' position is a future combined with bought long put options used as hedge.

The 3 companies have different outstanding positions, but are otherwise identical.

Please rank the three companies in terms of how risky an investor would think they are with 1 representing the most risky company, 2 the next most risky company and 3 indicating the least risky. Ties are allowed.

Q3.A.4: Please rank the three companies in terms of how likely an investor would choose the company as an investment. 1 represent the most likely, 2 the next most likely and 3 indicating the least likely. Ties are allowed.

Q3.A.5: Consider the following information:

An increase in the price of raw plastic would lead to an economic gain for all 3 companies because they will be able to buy the raw material at the fixed price (75€/ton) that is lower than the market price . A decrease in the price of raw plastic would lead to an economic loss for all 3 companies. They will buy the raw material at the lower current market price, but will still have paid the premium (100€) to enter their position. The following graph shows the potential profit or loss of the company as a function of the price of raw plastic per ton. It represents the scenario for all 3 companies:

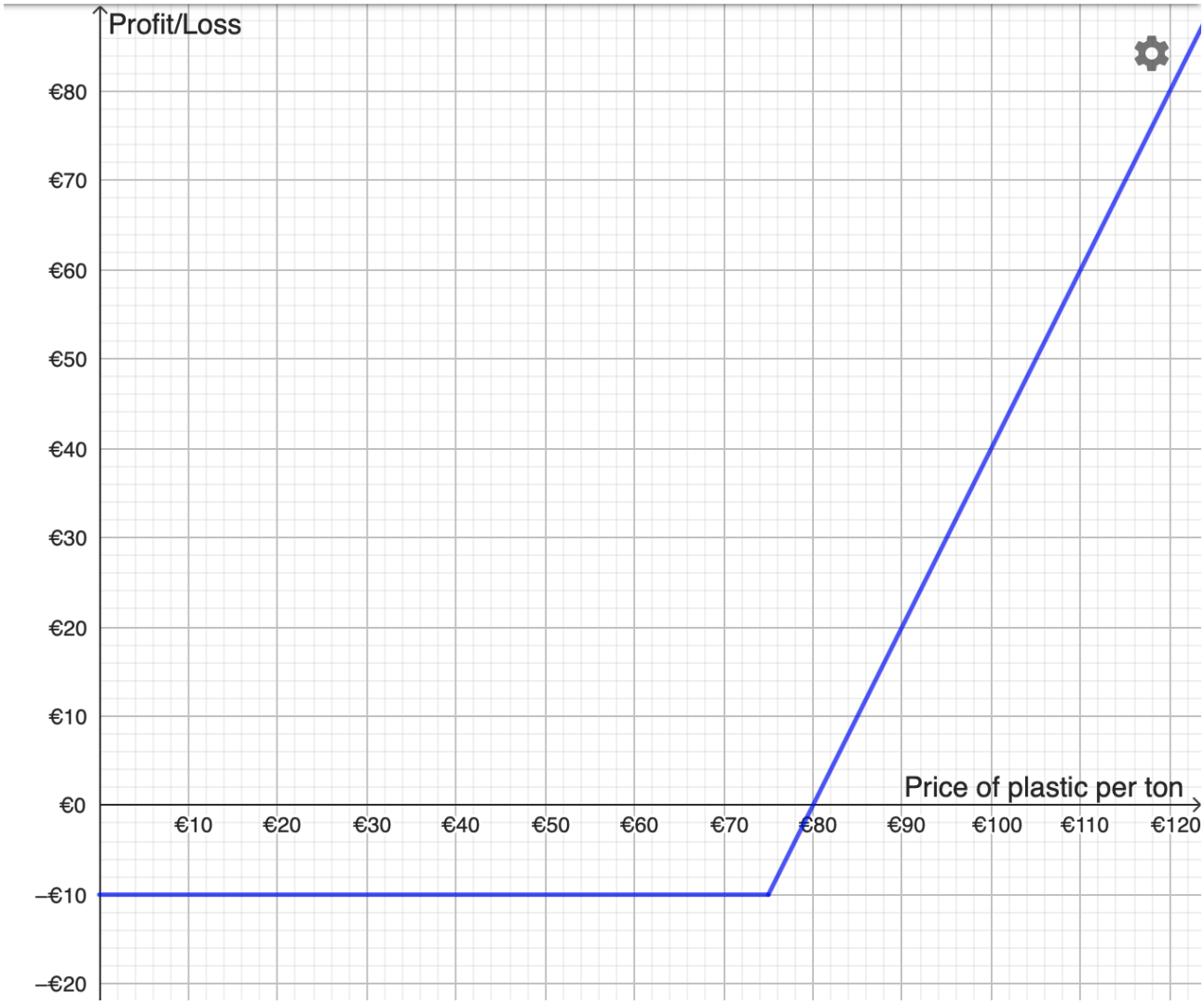

Figure 14: Visual aid shown to participant - Option

A reminder that the 3 company are identical manufacturing companies, if not for their outstanding position of financial products used.

Plastics&co uses a strategy of long European call options.

GreenPlastics uses a strategy of future contracts combined with bought long European put options.

TechSolutions uses a strategy of future contracts combined with bought long European put options used as hedge.

Please rank the three companies in terms of how risky an investor would think they are with 1 representing the most risky company, 2 the next most risky company and 3 indicating the least risky. Ties are allowed.

Q3.A.6: Please rank the three companies in terms of how likely an investor would choose the company as an investment. 1 represent the most likely, 2 the next most likely and 3 indicating the least likely. Ties are allowed.

Q3.A.7: What types of risk did you consider in making your risk rankings? A brief list suffices.

Questions Experiment 1 & 2 - Group B:

Q3.B.1.1: “Plastics&co" is a producer of high-performance plastic dispensers and uses raw plastic as its main input. The company uses a strategy of long European call options with strike price at 75€/ton for 20 ton of raw plastic. The premium paid by the company for this contract is 100€.

Overall, how risky do you consider Plastics&co’s position?
Answer type: Answer is given on a 101-point scale, with 0 indicating "Not risky at all", 50 indicating "Moderate risk" and 100 indicating "High Risk". The option "I do not know" is also provided.

Q3.B.1.2: "GreenPlastics" is a producer of high-performance plastic dispensers and uses raw plastic as its main input. The company uses a strategy of future contracts with strike price at 75€/ton for 20 ton of raw plastic. Moreover, the company buys long European put options with strike price at 75€/ton for 20 ton of raw plastic. For this contract, it pays a premium of 100€. Therefore, the GreenPlastics’ position is a future combined with long European put options.

Overall, how risky do you consider GreenPlastics’ position?
Answer type: Answer is given on a 101-point scale, with 0 indicating "Not risky at all", 50 indicating "Moderate risk" and 100 indicating "High Risk". The option "I do not know" is also provided.

Q3.B.1.3: “TechSolutions” is a producer of high-performance plastic dispensers and uses raw plastic as its main input. The company uses a strategy of future contracts with strike price at 75€/ton for 20 ton of raw plastic. Moreover, the company buys long European put options with strike price at 75€/ton for 20 ton of raw plastic. For this contract, it pays a premium of 100€. Therefore, the TechSolutions’ position is a future combined with long European put options used as a hedge.

Overall, how risky do you consider TechSolutions’ position?
Answer type: Answer is given on a 101-point scale, with 0 indicating "Not risky at all", 50 indicating "Moderate risk" and 100 indicating "High Risk". The option "I do not know" is also provided.

Q3.B.2: Consider the following information:

An increase in the price of raw plastic would lead to an economic gain for *CompanyXXX* because they will be able to buy the raw material at the fixed price (75€/ton) that is lower than the market price. A decrease in the price of raw plastic would lead to an economic loss for *CompanyXXX*. They will buy the raw material at the lower current market price, but will still have paid the premium (100€) to enter their position. The following graph shows the potential profit or loss of the company as a function of the price of raw plastic per ton:

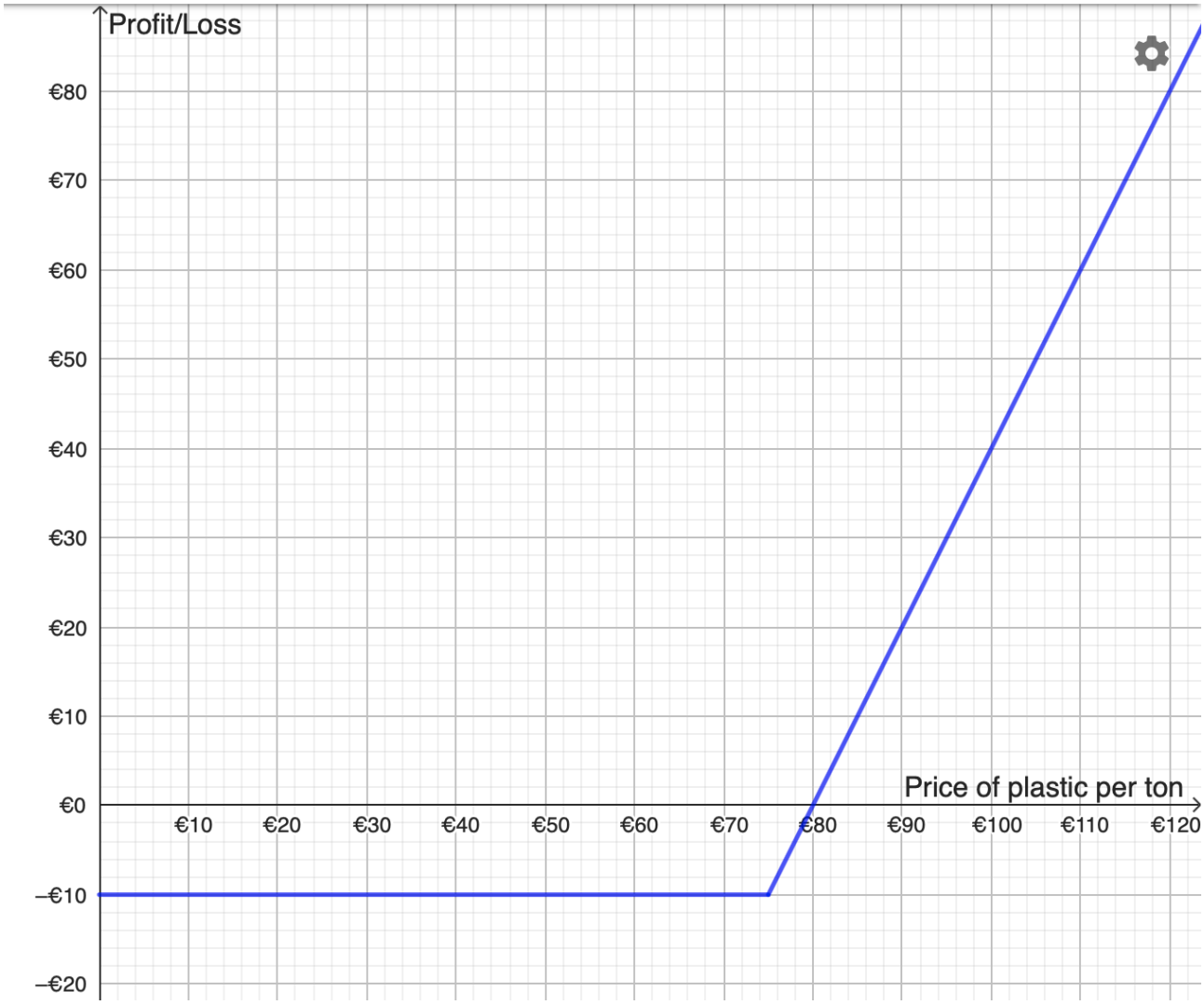

Figure 15: Visual aid shown to participant - Option

An increase in interest rates would create an economic gain because the company would not have to pay the higher, current market rate of interest. In other words, if interest rates increase, then the fair value of this fixed interest rate-debt would decrease. This would cause an economic gain. A decrease in interest rates would create an economic loss because the company would still have to pay the higher fixed rate of interest. In other words, if interest rates decrease, then the fair value of this fixed interest rate-debt would increase. This would cause an economic loss.

With the following information, please re-evaluate the riskiness of *CompanyXXX*'s position:
Answer type: Answer is given on a 101-point scale, with 0 indicating "Not risky at all", 50 indicating "Moderate risk" and 100 indicating "High Risk". The option "I do not know" is also provided.

Q3.B.3: "TastyMeals", "DeliciousFood" and "SuperbDishes" are all food and beverage companies. They all decide to expand their business in a new market segment. In order to do so, their managers evaluate an initial investment needed of 1 million €.

"TastyMeals" decides to finance this investment in the following way: they undertake a 10-

year loan from “Delftse Bank” with fixed interest rate at 4% with yearly payments. Therefore, they have a fixed interest rate-debt position.

"DeliciousFood" decides to finance this investment in the following way: they undertake a 10-year loan from “Delftse Bank” with variable interest rate with yearly payments. Moreover, the company enters a variable to fixed interest rate swap position with yearly payments and fixed rate at 4%. Therefore, their outstanding position is a variable interest rate-debt combined with variable to fixed interest rate swap.

"SuperDishes" decides to finance this investment in the following way: they undertake a 10-year loan from “Delftse Bank” with variable interest rate with yearly payments. Moreover, the company enters a variable to fixed interest rate swap position with yearly payments and fixed rate at 4%. Therefore, their outstanding position is a variable interest rate-debt combined with variable to fixed interest rate swap used as hedge.

The 3 companies have different outstanding positions, but are otherwise identical.

Please rank the three companies in terms of how risky an investor would think they are with 1 representing the most risky company, 2 the next most risky company and 3 indicating the least risky. Ties are allowed.

Q3.B.4: Please rank the three companies in terms of how likely an investor would choose the company as an investment. 1 represent the most likely, 2 the next most likely and 3 indicating the least likely. Ties are allowed.

Q3.B.5: The following additional information is provided to you. The information applies for all 3 companies:

Both an increase and a decrease in interest rates would not change the net interest payment cash flows of the company. That is, the company would be "locked into" paying the same net cash amount of interest. The following graph shows the yearly payments as a function of the interest rate:

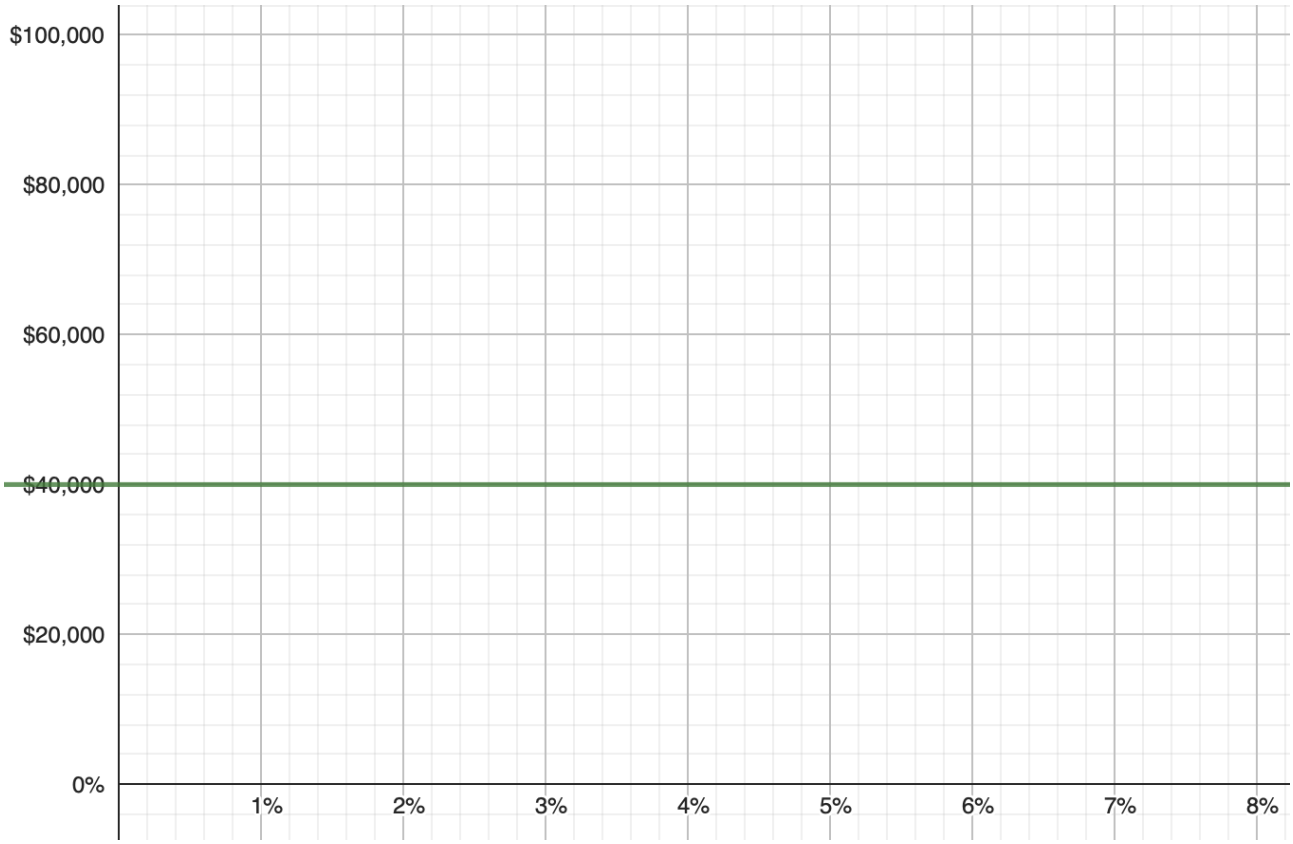

Figure 16: Visual aid shown to participant - Swap

An increase in interest rates would create an economic gain because the company would not have to pay the higher, current market rate of interest. In other words, if interest rates increase, then the fair value of the company's position would decrease. This would cause an economic gain. A decrease in interest rates would create an economic loss because the company would still have to pay the higher fixed rate of interest. In other words, if interest rates decrease, then the fair value of the company's position would decrease. This would cause an economic loss.

A reminder that the 3 companies are all in the food and beverage sector. They are identical, if not for their outstanding position of financial products.

"TastyMeals" has a fixed interest rate-debt position. "DeliciousFood" has an outstanding position of a variable interest rate-debt combined with variable to fixed interest rate swap. "SuperDishes" has an outstanding position is a variable interest rate-debt combined with variable to fixed interest rate swap used as hedge.

Please rank the three companies in terms of how risky an investor would think they are with 1 representing the most risky company, 2 the next most risky company and 3 indicating the least risky. Ties are allowed.

Q3.B.6: Please rank the three companies in terms of how likely an investor would choose the company as an investment. 1 represent the most likely, 2 the next most likely and 3 indicating the least likely. Ties are allowed.

Q3.B.7: What types of risk did you consider in making your risk rankings? A brief list

suffices.

Questions Experiment 3 - Both Groups:

Introduction: In their normal course of business, the SaltySnack Company purchases commodities such as oats, corn, corn sweetener, and wheat. The Company uses derivatives such as commodity futures and options to manage price exposures on some of their existing inventories and on some portion of their anticipated future purchases. Consequently, the SaltySnack Company has a net commodity exposure to changes in prices on existing inventory, on the commodity derivatives the company uses, and on anticipated purchases of inventory over the coming year. You read SaltySnack's annual report and find the following information:

The following table illustrates how an hypothetical 10% unfavorable change in market prices would affect SaltySnack's net income over the coming year due to SaltySnack's net commodity exposure.

Hypothetical change in market prices	**(Decrease) in next year's income in €**	**(Decrease) in next year's income as % of total**
10% unfavourable change:	€(68,061,000)	(14.64)%

Table 5: Annual report only-loss disclosure

Q3.8: How risky is SaltySnack's exposure strategy?
Answer type: Answer is given on a 101-point scale, with 0 indicating "Not risky at all", 50 indicating "Moderate risk" and 100 indicating "High Risk". The option "I do not know" is also provided.

Q3.9: How large do you think potential gains would be for SaltySnack's company with an hypothetical 10% favorable change in market prices?

- Greater than the losses
- Equal amount as losses
- Smaller than the losses

Q3.10: You read further in SaltySnack's annual report and find additional information on their exposure strategy.

The following table illustrates how an hypothetical 10% unfavorable change and 10% favorable change in market prices would affect SaltySnack's net income over the coming year due to SaltySnack's net commodity exposure.

Hypothetical change in market prices	**Increase (decrease) in next year's income in €**	**Increase (decrease) in next year's income as % of total**
10% unfavourable change:	€(68,061,000)	(14.64)%
10% favourable change:	€68,061,000	14.64%

Table 6: Annual report two-sided disclosure: L=G

Hypothetical change in market prices	**Increase (decrease) in next year's income in €**	**Increase (decrease) in next year's income as % of total**
10% unfavourable change:	€(68,061,000)	(14.64)%
10% favourable change:	€39,295,000	8.45%

Table 7: Annual report two-sided disclosure: L>G

Hypothetical change in market prices	**Increase (decrease) in next year's income in €**	**Increase (decrease) in next year's income as % of total**
10% unfavourable change:	€(68,061,000)	(14.64)%
10% favourable change:	€117,885,000	25.36%

Table 8: Annual report two-sided disclosure: L<G

Based on the new information given, how risky is SaltySnack's exposure strategy?
Answer type: Answer is given on a 101-point scale, with 0 indicating "Not risky at all", 50 indicating "Moderate risk" and 100 indicating "High Risk". The option "I do not know" is also provided.

B Features Complexity Model

The categorical variables used in the complexity model in Chapter 6 to define the features are 5 in total, each with 2 or 3 values it can assume. This led to the creation of 126 possible combinations. An extensive insight of these variables follows:

1 - Mathematical Model

Description: This feature indicates all the formal construct that defines how the financial instrument works and generally can be reduced to formulas that should be able to price the financial products with his fair value.
Number of categories: 3
Description of categories and respective values:

- **Value (1) - Description:** The mathematical model is easily understandable, a high-school level of preparation suffices to understand it.
- **Value (2) - Description:** The mathematical model is challenging to understand, university level of preparation in mathematics is necessary to understand it.
- **Value (3) - Description:** The mathematical model is extremely difficult to understand, both advance mathematical and advanced financial knowledge is needed to understand it.

Distribution: The following table shows the distribution of values assumed by the categorical variables when showed to the participants. The rotation algorithm used to randomize questions should help to minimise the difference between categories. However, differences exist due to some participants not carrying out the totality of the survey.

Value	Frequency
1	132
2	131
3	147

Table 9: Mathematical Model Recurrence

Reasoning (ante) and reflections (post): The choice of dividing the variable in three qualitative categories comes from the challenges that a quantitative subdivision would face. Moreover, this qualitative subdivision seems to relate the best with how people think in practical manners: the categories have been forged and confirmed with the trial survey. However, it has to be said that this subdivision is arbitrary and that other division may (or not) have been more suitable. For example, there is some subjectivity in the level of preparation given by universities: one may think it is only slightly more higher or that there is a huge gap in the level of education when compared to high school studies. This could be due to internal factors, such as the attitude and capabilities of the single individual, or external factors, such as the difference in universities attended. To try and mark the difference between categories, words such as "easily", "challenging" and "extremely difficult" have been used to emphasize the level of knowledge needed. After the analysis it can be noticed that the difference between

the first two categories is more pronounced than the difference between the subsequent two categories. Further analysis is needed to see whether the difference is due to the arbitrary choice of categories or it is an actual difference indicating that the marginal increase in overall complexity decreases with the increase of complexity in the mathematical model. This can be studied changing the description of the last category and see if any difference in results occurs. Moreover, further research could try to use a more quantitative subdivision using a similar concept of *"computational complexity"* described by Arora et all. (2011).

2 - Number of Clauses

Description: This feature indicates all the clauses that are written in the contract of the financial product and therefore can change its way of functioning or its validity. Usually they put some constraints on the payoff of the financial product, but even more often they list some legal constraints that the buyer of the product will be bounded to.
Number of categories: 3
Description of categories and respective values:

- **Value (1) - Description:** The contract presents only a few clauses.
- **Value (2) - Description:** The contract presents some clauses, but that can be summarized in one page or less.
- **Value (3) - Description:** The contract presents itself with several clauses, that cannot be summarized in one page or less.

Distribution: The following table shows the distribution of values assumed by the categorical variables when showed to the participants. The rotation algorithm used to randomize questions should help to minimise the difference between categories. However, differences exist due to some participants not carrying out the totality of the survey.

Value	Frequency
1	156
2	143
3	111

Table 10: Number of clauses frequency

Reasoning (ante) and reflections (post): The clauses in a contract can be easily quantified. However, creating quantitative categories resulted in a challenge. How many clauses is few for a financial product? How many should there be to consider the contract overfull of clauses? During the interview with the financial expert this topic has been tackled, but the conclusions were not a specific number: the number of clauses in a contract are usually really high in number and most of those or some clauses that do not add anything specific to the contract itself, but are present as standards or for other reasons (for example, privacy issues when acquiring a financial products through a bank). Moreover, the expert highlighted that usually the key clauses of the contract are summarized in one page for the client. Therefore, the expert proposed to divide the categories considering the possibility to summarise the clauses in one page page or not. This *escamotage* led to a more qualitative subdivision, but arguably

more effective due to the easier understanding of the survey participants. Suppose that a quantitative division was made and the description would state "more than 100 clauses", some people may ask themselves whether that is an high number for financial products, leading to a less clear subdivision. In general, simplifying the divisions leads the participants to better interpret the division, as was shown in the trial surveys. For future research, a quantitative subdivision method could still be used indicating the discrete quantity of clauses present in the contract, while in the mean time providing participants with the average number of clauses in financial products.

3 - Number of Underlying Instruments

Description: This feature indicates the number of assets or other financial products that act as underlying for the financial instrument.
Number of categories: 3
Description of categories and respective values:

- **Value (1) - Description:** The financial product depends only on one underlying instrument.
- **Value (2) - Description:** The financial product depends only on a few underlying instruments.
- **Value (3) - Description:** The financial product depends on multiple underlying instruments.

Distribution: The following table shows the distribution of values assumed by the categorical variables when showed to the participants. The category with value 1 has been presented with less frequency to participants. This is expected due to the fact that when this particular categorical variable assumes the value of 1, the categorical value named "Dependency of the Underlyings" can only assume one value (that is 0), while otherwise it can assume three different values (1, 2 or 3). This creates exactly one third of the combinations possible for the value 1 when compared with the value of 2 and 3. We can see how the frequencies reported in Table 11, have a ratio that tends to this value. Moreover, the rotation algorithm used to randomize questions should help to minimise the difference between categories 2 and 3. However, still some differences exist due to some participants not carrying out the totality of the survey.

Value	Frequency
1	68
2	179
3	163

Table 11: Number of underlying instruments frequency

Reasoning (ante) and reflections (post): As for the *"Number of clauses"*, also the number of underlying instruments can be easily quantified. But again, using a quantitative subdivision would result in worse description and lesser understanding by participants. The number of underlying has a really wide range: from simple options that only have one underlying

to some ETF's that include a couple of hundreds. To avoid over-information and be more direct with the division, the descriptions featured "only one", "only a few" and "multiple". It has to be said that the etimology of the word multiple could result ambiguous, leading some participants to think multiple as "two or more", the actual meaning of the word. Therefore, it could be that for some people the number of underlyings when described as few or as multiple overlapped to some extent. To minimize this effect the word "only" has been used in addition to "few", to emphasize the scarce number of underlying in comparison with multiple. This seems to have worked as the marginal increase in overall complexity seems to stay the between categories of this feature.

4 - Dependency between Underlying Instruments

Description: This feature indicates if the assets or other financial instruments that act as underlying to the main financial instruments depend on one another and to what extent.
Number of categories: 4
Description of categories and respective values:

- **Value (0) - Description:** No description is shown to the participant. This always and only happens when the value of the categorical value *"Number of Underlying Instruments"* is set equal to 1.
- **Value (1) - Description:** The underlying instruments have negligible dependency between each other.
- **Value (2) - Description:** The underlying instruments have somewhat dependency between each other.
- **Value (3) - Description:** The underlying instruments have high dependency between each other.

Distribution: The following table shows the distribution of values assumed by the categorical variables when showed to the participants. The category with value 0 has been presented with less frequency to participants, due to not being shown if the feature *"Number of Underlying Instruments"* assumes a value of 2 or more. Moreover, the category with value 2 present an higher frequency because 3 out of 4 of the financial products asked to at least half the participants presents this feature with value 2. For the rest, the rotation algorithm used to randomize questions should help to minimise the difference between categories 1 and 3.

Value	Frequency
0	68
1	95
2	151
3	96

Table 12: Dependency between underlying instruments frequency

Reasoning (ante) and reflections (post): When dividing this categorical variables in subgroups, as first approach a quantitative division was proposed: the division followed the

concept of correlation that could be measured (even though it is often a difficult task for financial matters). As first group there was the negligible correlation (|x|<0,1), followed by a moderate presence of correlation (0,1<|x|<0,5) and as last group high correlation (|x|>0,5). However, correlation does not imply dependency. Moreover, dependency does not imply correlation. Therefore, this approach has been discarded and qualitative division has been chosen. Future research could see if a more detailed description of the dependency and correlation between underlyings changes the outcome of the analysis, maybe with some quantitative methods.

5 - Trading Mode

Description: This feature simply discloses whether the financial product is traded on Public Financial Markets (therefore bounded to more regulation and usually carrying less or none asymmetry of information between buyer and seller) or on the Over the Counter Market.
Number of categories: 2
Description of categories and respective values:

- **Value (1) - Description:** The financial product is traded on Public Financial Markets.
- **Value (2) - Description:** The financial product is traded on the Over-the-Counter Market.

Distribution: The following table shows the distribution of values assumed by the categorical variables when showed to the participants. The rotation algorithm used to randomize questions should help to minimise the difference between categories. However, differences exist due to some participants not carrying out the totality of the survey.

Value	Frequency
1	210
2	200

Table 13: Trading Mode frequency

Reasoning (ante) and reflections (post): The simple subdivision in which market the financial instruments is traded is pretty forward. However, it has to be taken into account that there is a possibility that not all the participants have ever traded on the OTC market and therefore they possibly do not know the features of this particular market (less regulations and usually more discrepancy in information with the counter-party). Future research could try to rerun this analysis with a more detailed explanation of how the specific market in which the financial instrument is traded works. In this analysis, this has not been done to avoid having to much text in the questions, possibly leading to lack of concentration during the survey and/or people taking the research less seriously. Maybe a different approach, like small interviews, could be used to better tackle this challenge.

Dummy variable 1 - Work Experience

Description: This dummy variable indicates the level of work experience that the participants has in the financial sector, or any job related to finance.
Number of possible answers: 5
Description of answers and respective values:

- **1 - Value (0) - Description:** The participant does not have any work experience in the financial sector, or any job related to finance.
- **2 - Value (1) - Description:** The participant has some work experience in the financial sector, or any job related to finance, but does not exceed 5 years.
- **3 - Value (1) - Description:** The participant has more than 5 years of work experience in the financial sector, or any job related to finance, but does not exceed 10 years.
- **4 - Value (1) - Description:** The participant has more than 10 years of work experience in the financial sector, or any job related to finance, but does not exceed 20 years.
- **5 - Value (1) - Description:** The participant has more than 20 years of work experience in the financial sector, or any job related to finance.

Distribution: The following table shows the distribution of values assumed by this dummy variable.

Value	Frequency
0	270
1	140

Table 14: Work Experience frequency

Reasoning (ante) and reflections (post): Work experience could be easily quantified and therefore using it as a continuous variable would be the optimal choice. However, predicting a low number of participants, a categorical subdivision has been chosen to simplify the model. The number of respondents was even lower than expected and more importantly, some of the groups chosen were underrepresented. Therefore, the successive analysis has been run with work experience as a dummy variable, grouping all different subsets of some work experience together. In the future, if an bigger and more heterogeneous population could participate in the research, the analysis could be run with work experience as a continuous variable, that would lead possibly to more accurate results.

Dummy variable 2 - Study Experience

Description: This dummy variable indicates whether or not the participant has undertaken financial courses during his university experience.
Number of possible answers: 3
Description of answers and respective values:

- **1 - Value (0) - Description:** The participant did not study finance and did not undertake any financial courses at university level.
- **2 - Value (1) - Description:** The participant did not study finance. However, he did undertake some financial courses at university level.
- **3 - Value (1) - Description:** The participant did obtain an university degree in finance.

Distribution: The following table shows the distribution of values assumed by this dummy variable.

Value	Frequency
0	290
1	120

Table 15: Study Experience frequency

Reasoning (ante) and reflections (post): A first division has been made dividing people who did obtain at least a Bachelor's degree in Finance and people who didn't. However, to give credit to all those participants that did not undertake an academic career in finance, but did still study to some extent the financial world during their university studies, a middle category was created. At the end, this category of participants has been group with those who had at least a Bachelor's degree in finance due to lack of representatives in this last group. This effectively create to only having two groups, therefore led to considering study experience also as a dummy variable.

C Box-Plot Analysis visualisation

All graphs present on the Y-axis the *Complexity Score* and on the X-axis the specified independent variable.

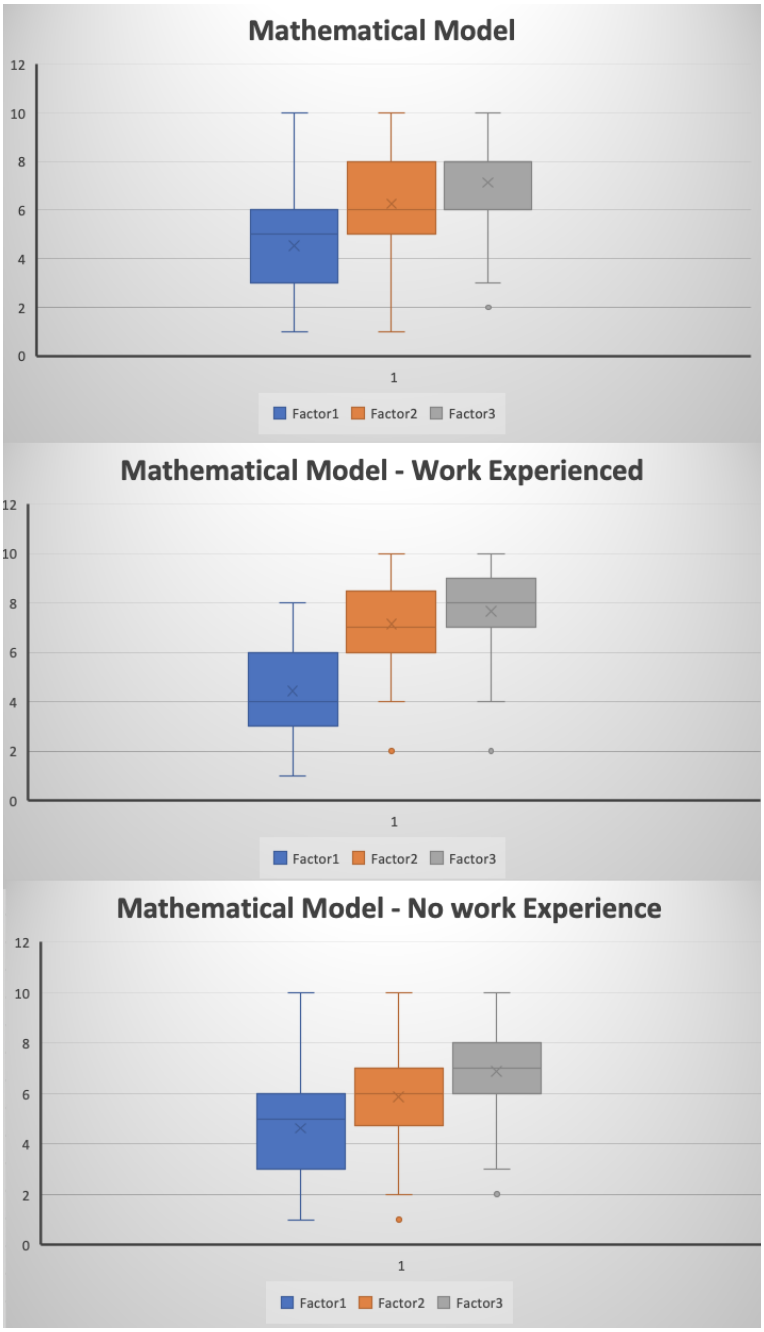

Figure 17: Complexity vs Mathematical Model

	Total			Work Experienced			No Work Experience		
	Factor1	Factor2	Factor3	Factor1	Factor2	Factor3	Factor1	Factor2	Factor3
Mean	4,55	6,27	7,14	4,43	7,15	7,67	4,62	5,87	6,88
Median	5	6	8	4	7	8	5	6	7
Mode	5	6	8	6	8	8	5	6	8
Dev-Std	2,18	2,10	1,88	1,94	1,94	1,69	2,32	2,06	1,92

Figure 18: Descriptive analysis Mathematical Model

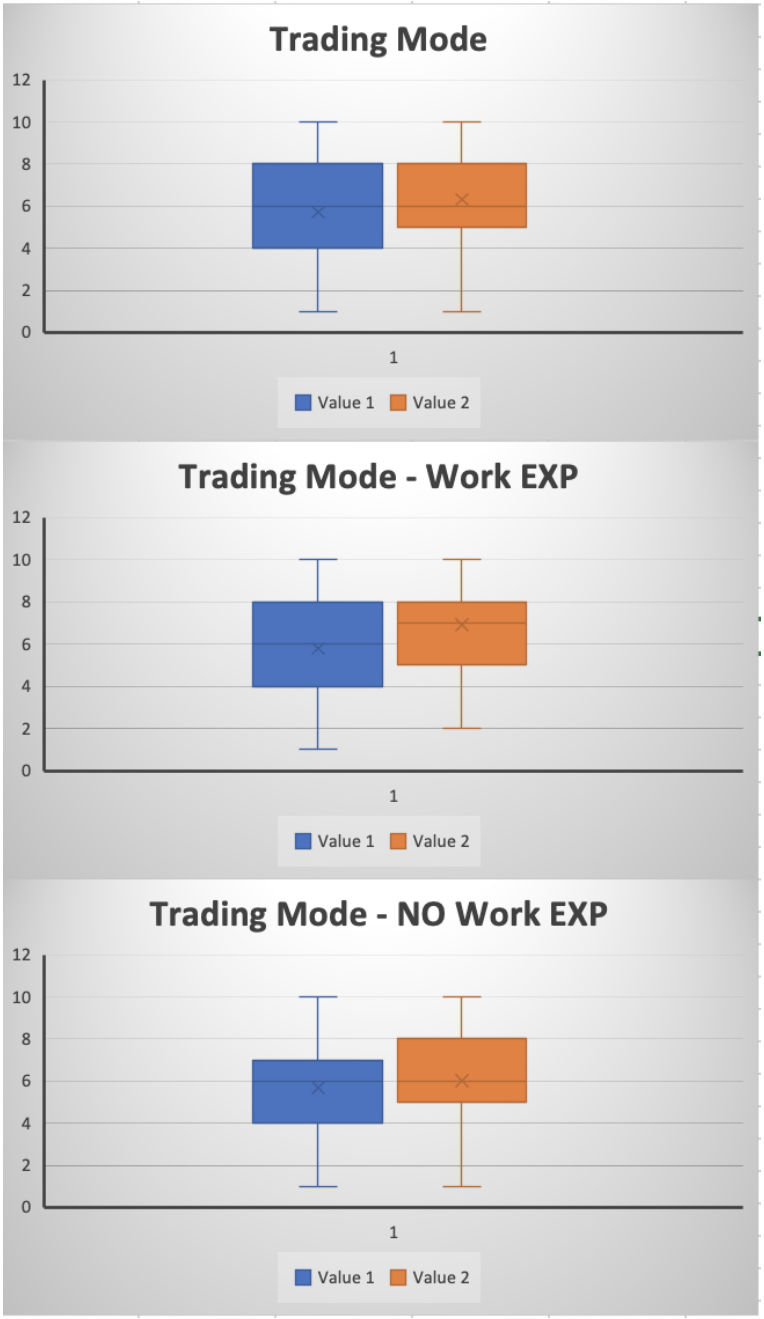

Figure 19: Complexity vs Trading Mode

	Total		Work Experienced		No Work Experience	
	Factor1	Factor2	Factor1	Factor2	Factor1	Factor2
Mean	5,72	6,32	5,79	6,90	5,67	6,04
Median	6	6	6	7	6	6
Mode	5	8	6	8	5	8
Dev-Std	2,34	2,26	2,47	2,10	2,27	2,28

Figure 20: Descriptive analysis Trading Mode

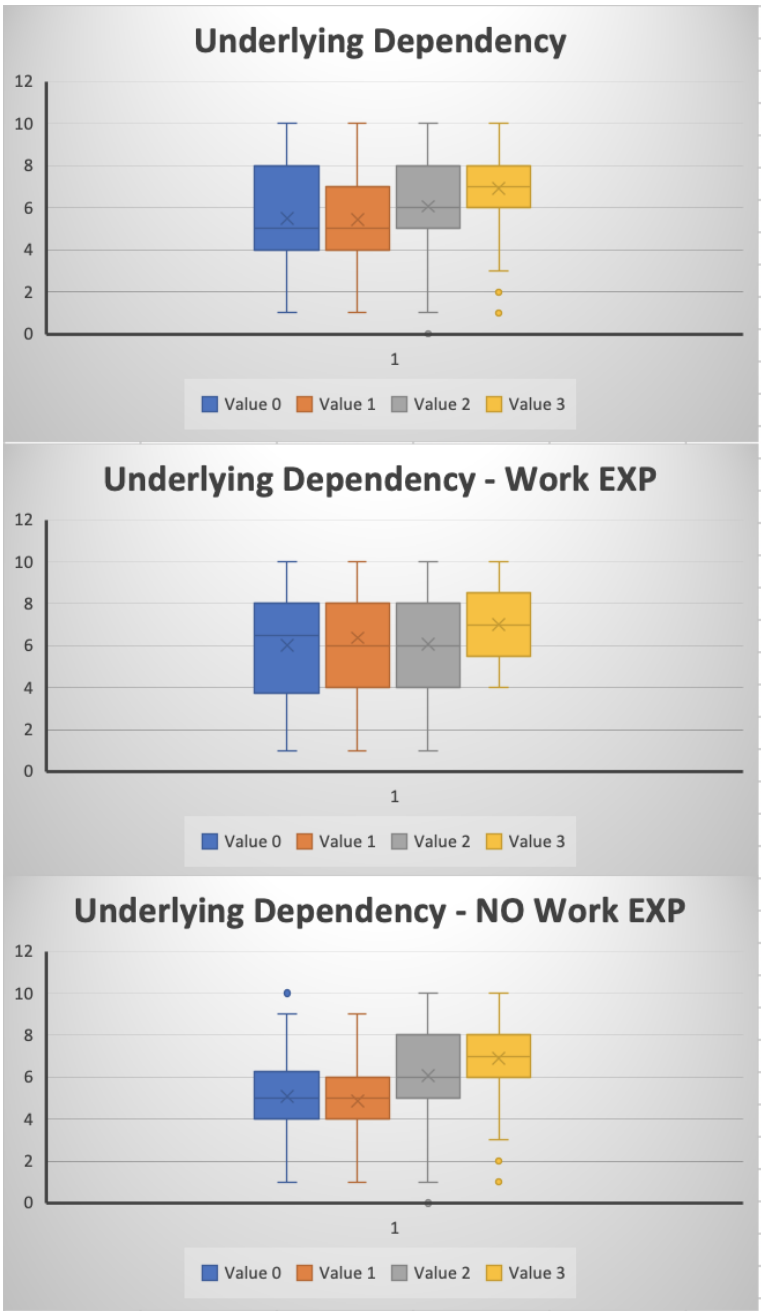

Figure 21: Complexity vs Dependency

	Total				Work Experienced				No Work Experience			
	Factor1	Factor2	Factor3	Factor4	Factor1	Factor2	Factor3	Factor4	Factor1	Factor2	Factor3	Factor4
Mean	5,50	5,42	6,07	6,92	6,03	6,37	6,09	7,00	5,08	4,87	6,06	6,880597
Median	5	5	6	7	7	6	6	7	5	5	6	7
Mode	5	5	8	8	5	8	6	7	5	5	8	8
Dev-Std	2,46	2,29	2,30	1,99	2,66	2,47	2,34	1,83	2,23	2,00	2,30	2,0708832

Figure 22: Descriptive analysis Dependency

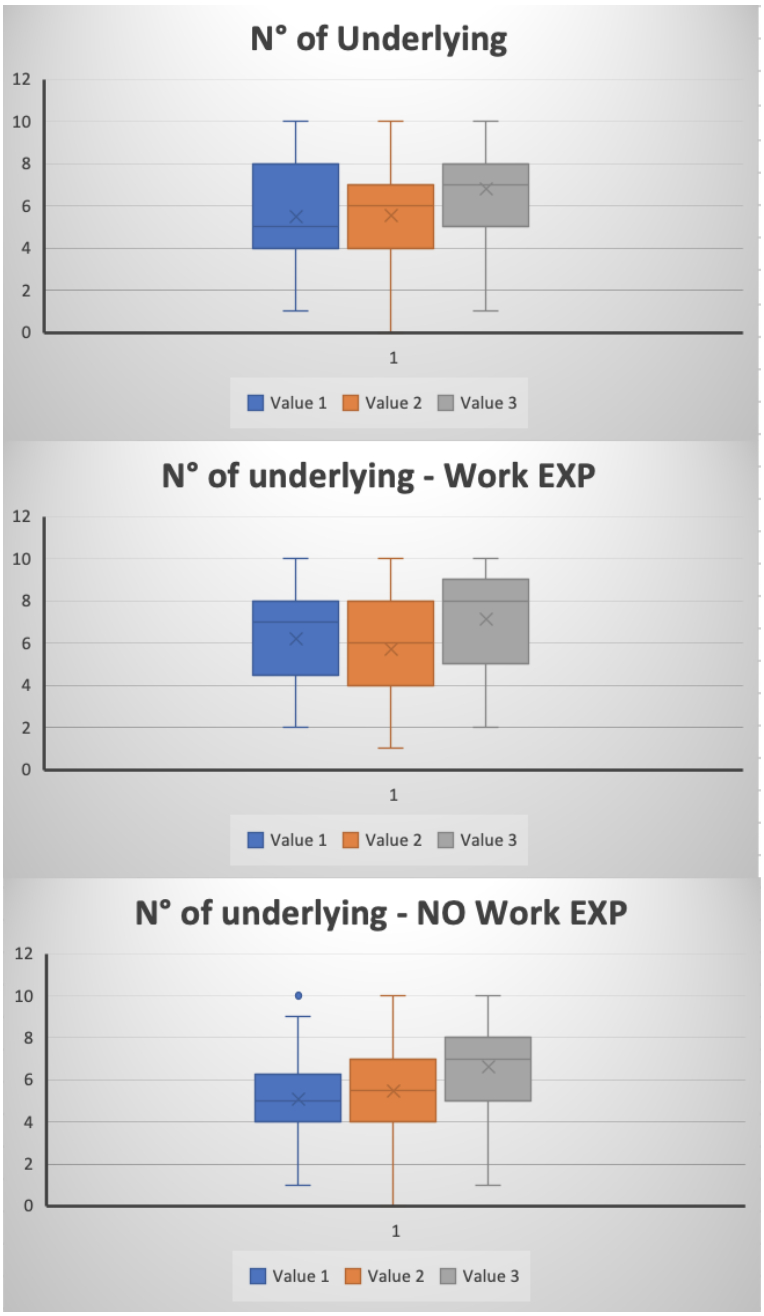

Figure 23: Complexity vs Number of Underlying

	Total			Work Experienced			No Work Experience		
	Factor1	Factor2	Factor3	Factor1	Factor2	Factor3	Factor1	Factor2	Factor3
Mean	5,50	5,53	6,79	6,21	5,71	7,13	5,08	5,44	6,61
Median	5	6	7	7	6	8	5	6	7
Mode	5	6	7	5	6	8	5	5	8
Dev-Std	2,46	2,24	2,14	2,53	2,24	2,09	2,23	2,25	2,15

Figure 24: Descriptive analysis Number of underlying

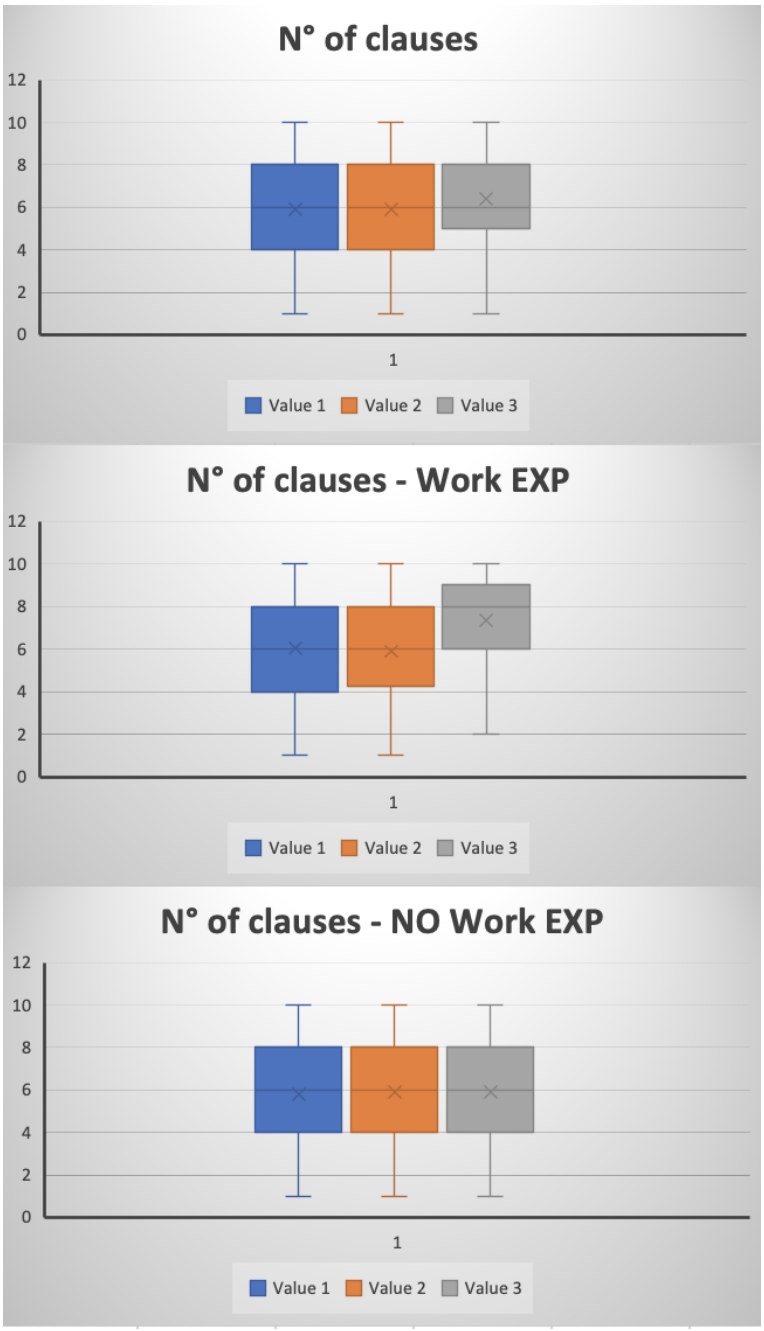

Figure 25: Complexity vs Number of clauses

	Total			Work Experienced			No Work Experience		
	Factor1	Factor2	Factor3	Factor1	Factor2	Factor3	Factor1	Factor2	Factor3
Mean	5,88	5,90	6,39	6,02	5,90	7,34	5,81	5,89	5,89
Median	6	6	6	6	6	8	6	6	6
Mode	8	8	8	7	8	8	8	8	5
Dev-Std	2,31	2,25	2,38	2,37	2,33	2,12	2,29	2,22	2,37

Figure 26: Descriptive analysis Number of clauses

D Demographics Data Sample

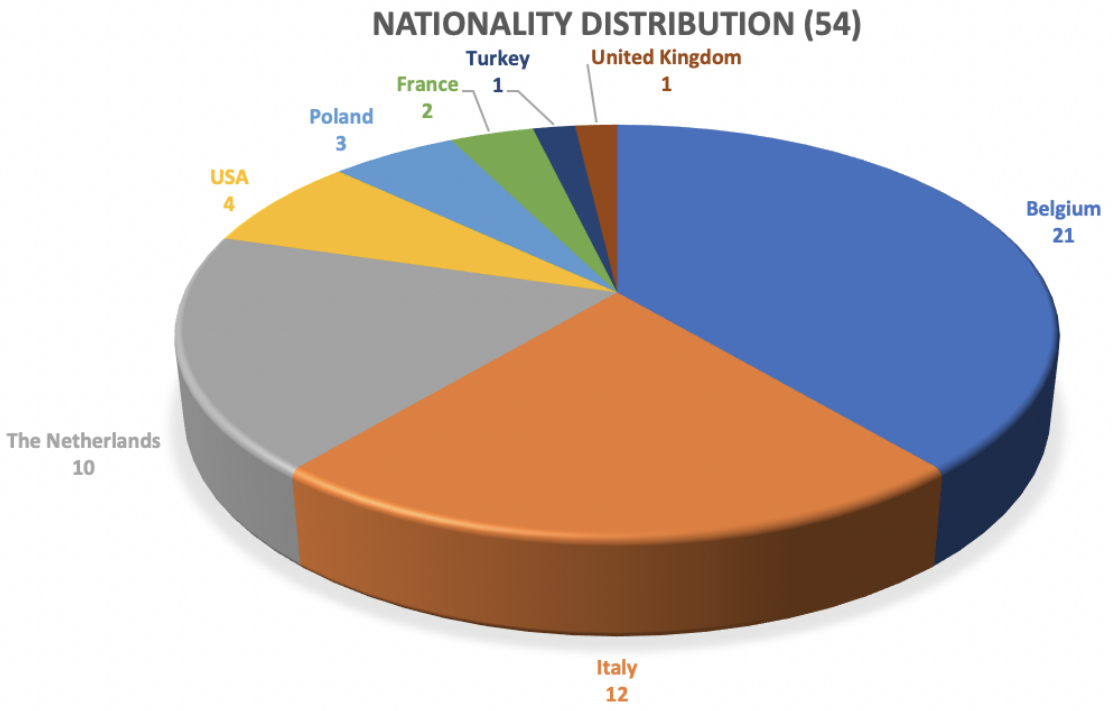

Figure 27: Nationality Distribution

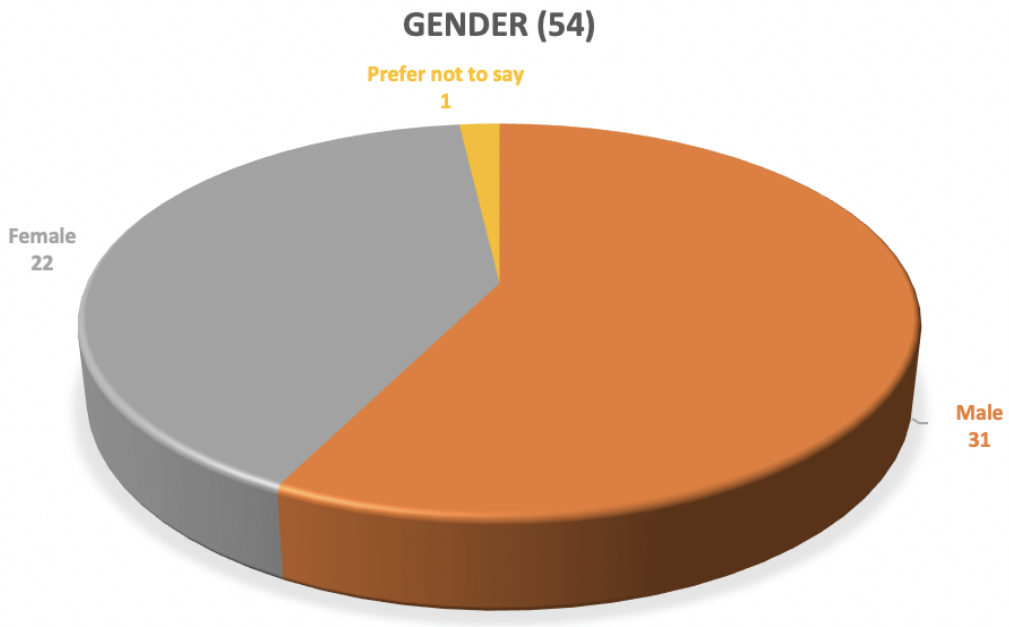

Figure 28: Gender

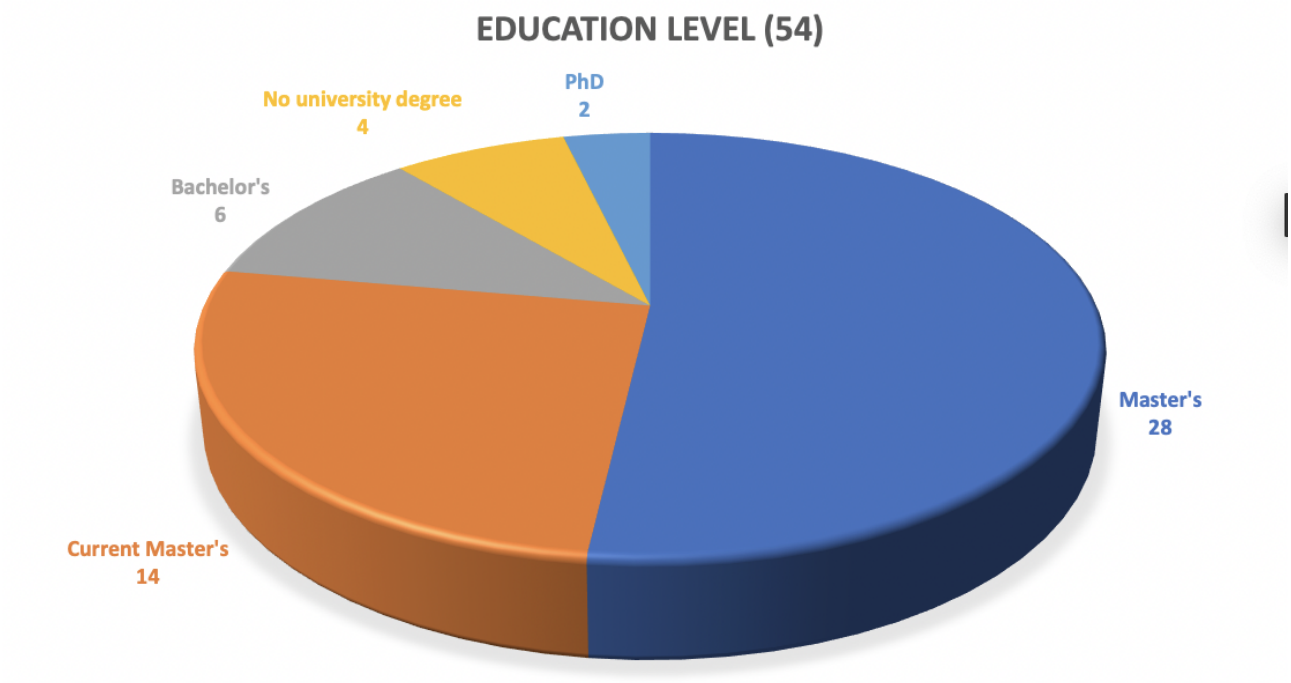

Figure 29: Education level

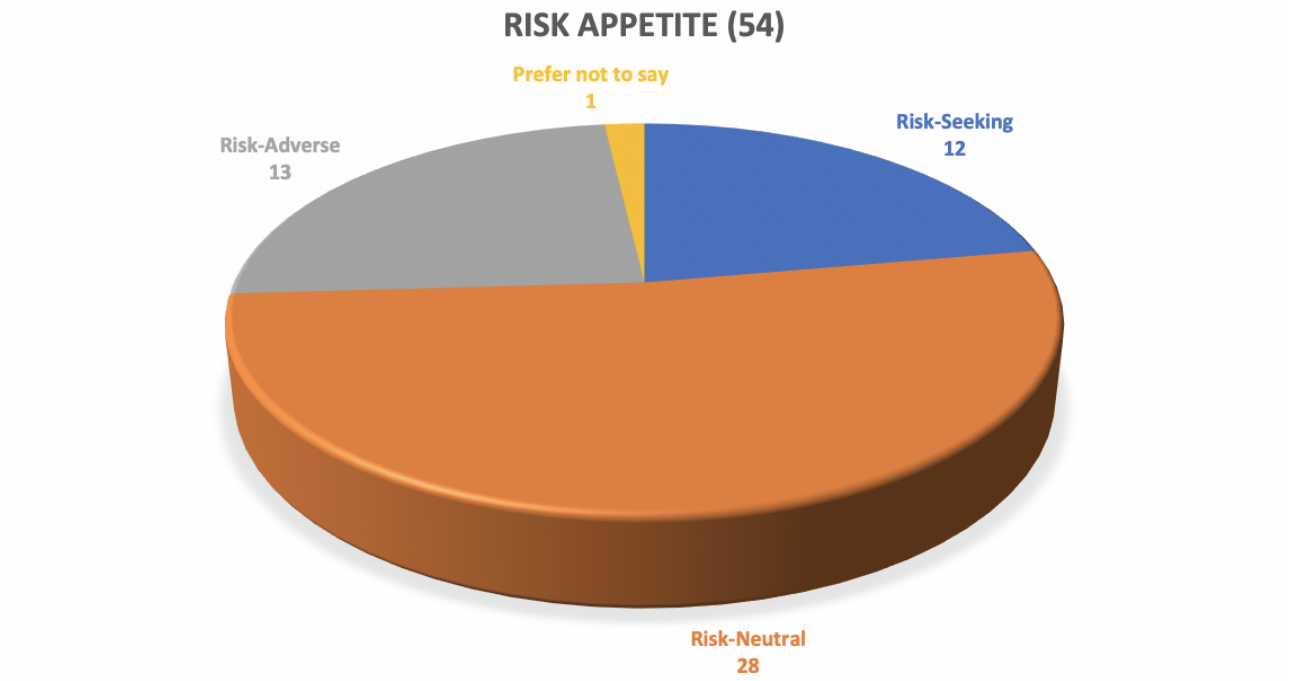

Figure 30: Risk Appetite

E Recurrent observations framework

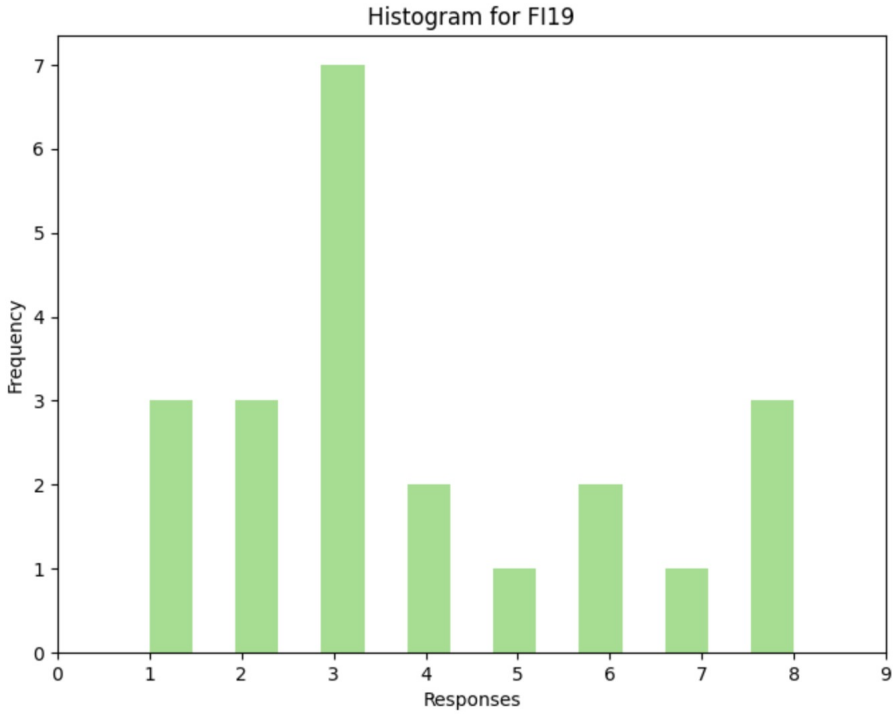

Figure 31: Histogram observations financial product 19

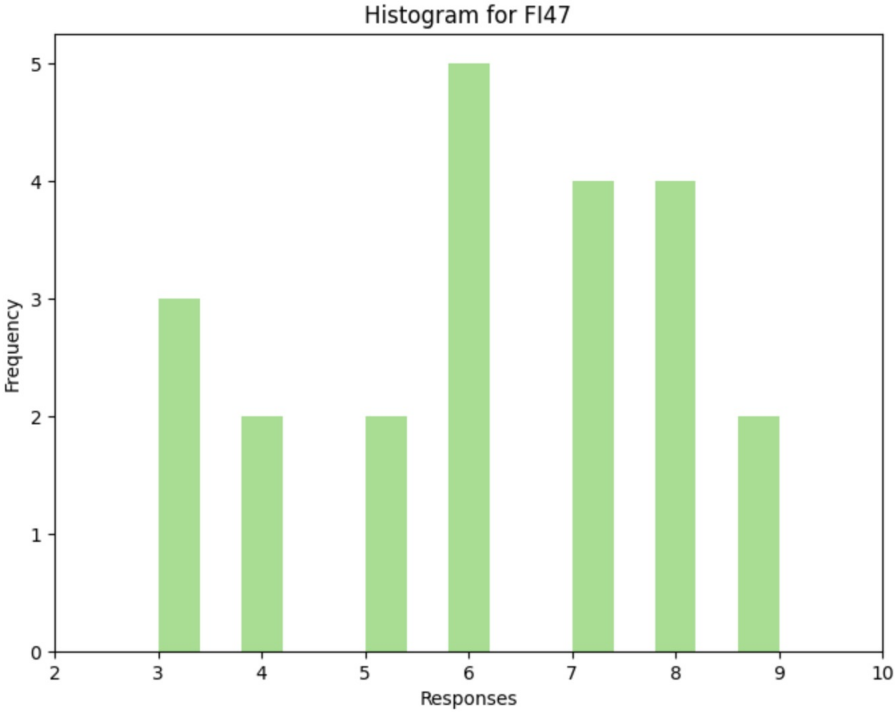

Figure 32: Histogram observations financial product 47

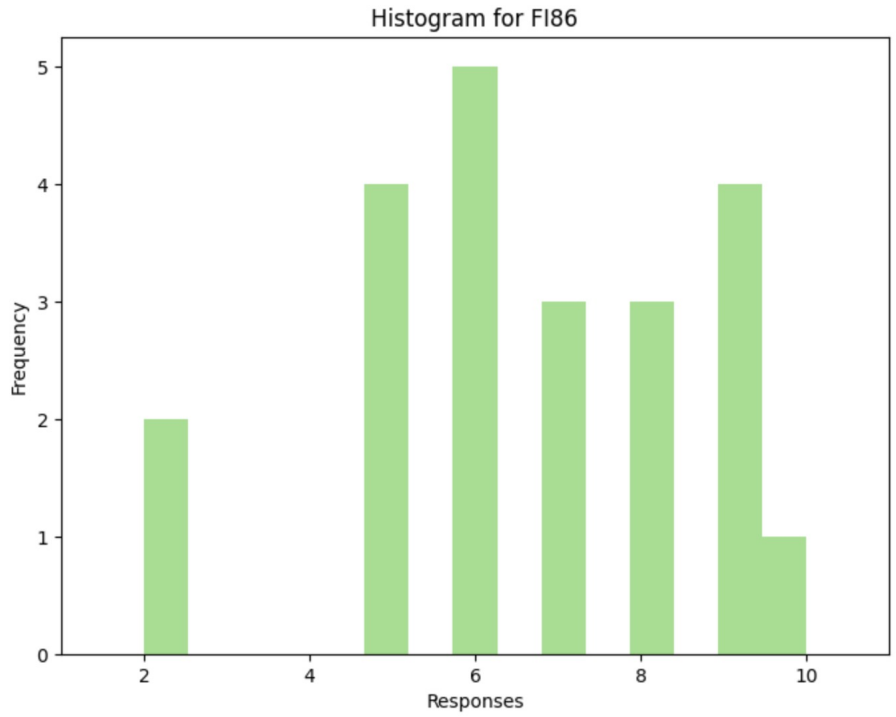

Figure 33: Histogram observations financial product 86

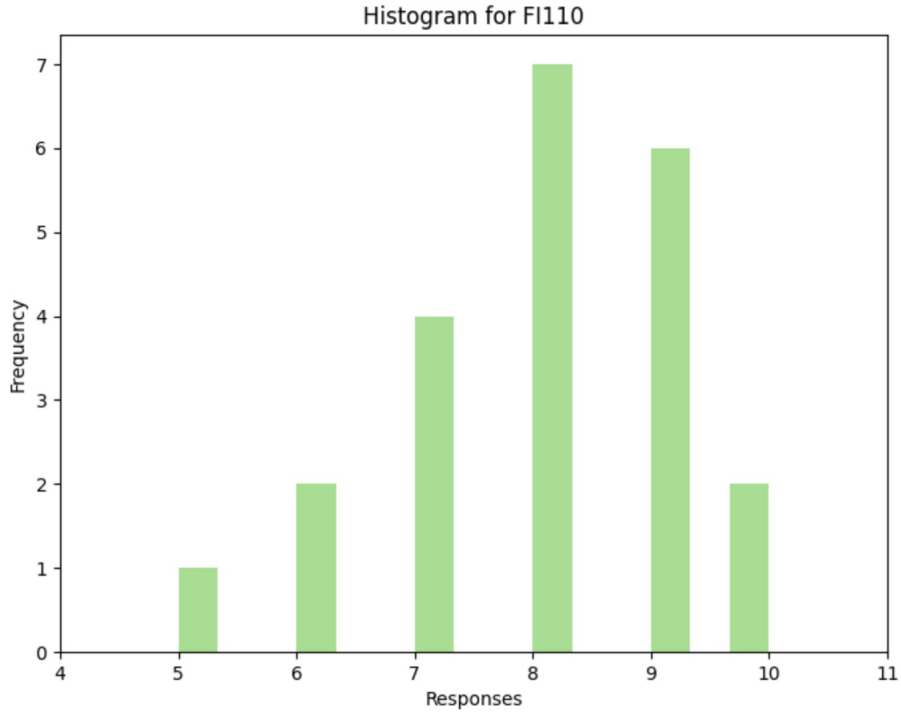

Figure 34: Histogram observations financial product 110