UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

The Adoption of Artificial Intelligence in Swedish Funds

Bachelor's Thesis in Financial and Industrial Management
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Preface

The thesis has been conducted by two students at the School of Business, Economics and Law at the University of Gothenburg, as part of a bachelor's thesis project in Industrial and Financial Management.

We would like to thank our supervisor Shahryar Sooroshian, who has guided us through the entire process from start to end, the portfolio managers who have taken their time to answer our questions, as well as the feedback that we have gotten from our partner groups who have been working hard on their own theses. These contributions have enabled us to finish this thesis as well as get a closer insight into the financial sector.

Gothenburg, January 2021

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Abstract

Fund managers have historically made use of traditional portfolio strategies such as Markowitz portfolio selection, as part of their decision making. But as the world has started to shift towards a more automated lifestyle, the question arises if fund management will follow. The aim of the thesis was to investigate if Swedish funds adopt artificial intelligence as part of their decision making. Five interviews with fund managers were conducted through mail and phone interviews. In order to evaluate whether artificial intelligence is efficient in asset management, a comparison between funds that utilizes artificial intelligence and their benchmark index, together with the Sharpe ratio, have been made which looked specifically into the latest recession. The final findings from the thesis were that funds do in fact try to incorporate artificial intelligence into asset management. Some of the funds are in the early developing stages but many funds lack the competence and investment to develop or buy necessary tools. It was also shown that most funds that are managed partly or fully by artificial intelligence yielded a higher return during the 2020 corona pandemic, compared to their benchmark index. But when taking the risk into account with the Sharpe ratio, only half of them had a small but positive Sharpe ratio.

Keywords: *Artificial intelligence; performance; funds; finance; asset management; portfolio theory; efficient market; behavioral finance.*

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1. Introduction

Conventionally, financial trading has been led by humans, but due to the technical evolution, computers are beginning to take a bigger role in trading analysis. Artificial intelligence has started to gain popularity as society starts to head more and more towards an automated lifestyle. The rapid growth is forecasted to continue, and the financial industry is no exception as machines are preferred for tasks where they outperform humans (Furman et. al, 2016). An interesting topic to look at would therefore be how artificial intelligence will impact the financial sector, especially when it comes to funds managed by artificial intelligence.

According to Castleman (2020), artificial intelligence (AI) and machine learning (ML) is transforming finance in several ways. In terms of risk management, case history can be analyzed with algorithms and potential risks can be identified. The Financial Stability Board (2017) sees several potentials utilizing AI and machine learning, such as identifying signals on price movements and efficiently making use of available data and market research. Deloitte Consulting (2017) claims AI can reduce costs by enhancing operational efficiency and strengthen risk management with adaptive forecasting models and pattern recognition. In an article by Thomas (2017), the CEO of Alliance Capital Management believes human emotions such as fear, greed and regret could have more to do with investment behavior rather than fundamentals. The CEO believes understanding behavioral finance could be the ultimate goal of investing, and AI is considered to have the best chance of doing so. Deloitte Consulting (2017) suggests some of the challenges regarding the implementation of AI can be found in the lack of awareness and expertise of the technology.

1.1 Problem discussion

Traditional values within the financial industry are being challenged and disrupted by applications and tools based on AI technologies (Castleman, 2020). However, the use

of artificial intelligence and machine learning when managing portfolios is still low. According to a survey from CFA (2019) only 10% of the portfolio managers asked had used artificial intelligence or machine learning in the last 12 months. Instead, portfolio managers continue to rely on excel and other market data tools, which can be considered sufficient for analysis. The growing size of datasets, associated with big data collecting, demands other technologies in order to provide insights (CFA, 2019). Furthermore, Sweden's first fund that fully relies on artificial neural networks was only introduced in 2019 and was managed by the fintech company Century Analytics called CenturyOne and focused mainly on the trade of currencies (Leijonhufvud, 2019). CenturyOne was shortly closed in April 2020 due to inabilities of securing long-term funding during the Corona pandemic (Guzu, 2020). No other mutual fund in Sweden has followed Century One so not much information can be found when it comes to AI in asset management leaving much of the field left to explore.

Artificial intelligence is not only able to improve but also replace a wide variety of tasks which are usually carried out by people (Deloitte, 2017). According to CFA (2019), routines of finding and entering information will most likely be taken over by AI. As new technologies develop, traditional financial institutions and fintech start-ups are looking for new skills from job candidates (Liu, 2019). As a potential growth factor in the financial industry and market that is likely to lead to a big change (Furman et. al, 2016), it is of interest to do a thorough market analysis of where the financial sector is heading by studying the extent of use of artificial intelligence.

Regarding AI from a macroeconomic perspective, Seiler (2018) believes that with the capacity for large data volumes, the amount and types of indicators monitored could be significantly increased by intelligent algorithms. He further believes that the precision and quality of macroeconomic analysis regarding the current state of the economy could be improved by AI. Seiler implies that AI might be able to find information which could lead to a change in stock prices that has not been disclosed publicly yet. Nyman and Ormerod (2017) showed one year earlier in their paper that AI has the potential to predict an up-coming recession in the market. In regard to the findings, it would be of significance to look into how well funds managed by AI perform during recessions.

By also studying the disadvantages and advantages of AI, a better understanding of the future in fund management can be reached. The information obtained from the thesis will not only be useful as a tool for investors to evaluate what funds they want to invest in, but also an insight into if AI is worth it in terms of performance and ethical and social aspects.

1.2 Purpose

The purpose of this thesis is to explore the use of artificial intelligence in today's funds and determine where the market is heading. It is of interest in the study to find the reason behind the low usage of AI to see what benefits and barriers exist. In order to answer the research questions, a qualitative study through interviews with Swedish fund managers as well as a quantitative study which looks at performances of funds powered by AI, has been conducted, which is further described in section 2, method.

1.3 Research questions

With regards to the objective of this thesis in mind, the following questions are central for the research and thesis:

- To what extent do traditional Swedish fund managers use artificial intelligence?
- What are the benefits and barriers of artificial intelligence?
- How will artificial intelligence affect the future of fund management?
- How do artificial intelligence funds perform in times of recession compared to their benchmark?

1.4 Scope of the thesis

There are some limitations regarding the scope of this research which will be brought up in this section. The biggest limitation is the allocated amount of time which is a little over 2 months during the autumn semester. The main subject that is treated in

this thesis is AI but there was no attempt to try to implement AI as it is not included in the purpose of this thesis. Another variable that is taken into consideration is the current situation with the coronavirus which restricts most physical contact. In regards to this, most of the tasks will therefore be conducted remotely.

Only a few chosen companies will be taken into account during the thesis since the time limitation does not allow looking into a higher number of funds in Sweden. The focus of this project lies mainly on Swedish funds, but since AI in funds is a relatively new phenomenon, information gathering might be difficult. Therefore, information gathering about funds managed by AI will also come from international funds.

2. Method

The report will include both quantitative data in the form of secondary and primary data from research papers, articles and stock market data, and qualitative data in the form of interviews. The quantitative methods aim to find data to compare how the funds which are managed by AI have performed in comparison to their benchmark index. An important aspect to look specifically into is during historical declines in the market. The literature review is mainly for understanding the mechanism of AI and finding out the negative and positive aspects as well as researching about the funds that are managed by AI. The general structure of the method can be found in figure 1.

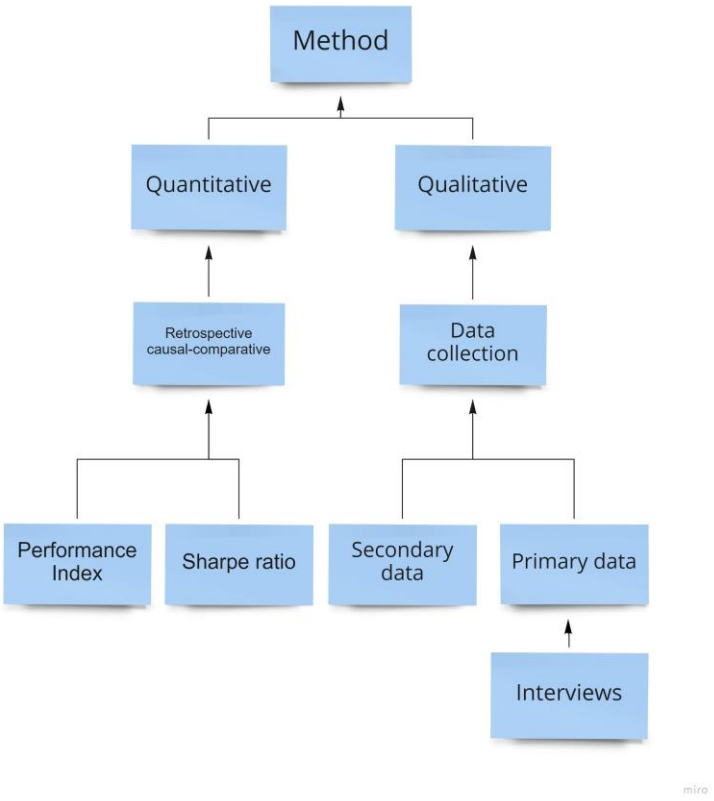

Figure 1. Diagram of the different parts in the method

2.1 Quantitative method

The quantitative method seeks to test different hypotheses, make predictions and also look into causes and effects (Apuke, 2017). By processing numerical data with mathematical tools, the quantitative method is dedicated to explaining phenomena or

answering questions. Quantitative measurements can be of different characteristics such as causal-comparative, experimental or correlational and usually involve numbers and statistics. Retrospective causal-comparative is yet another subcategory and comprehends differences between groups after the effect has happened. An important factor in this method is that it should be as objective as possible.

A retrospective causal-comparative quantitative method has been chosen in order to find out how well the funds managed by AI performs during recessions compared to the market. This is done by gathering data from the stock market and comparing the market trend with the funds trend during certain periods. The period was chosen such that an unexpected event, which has been documented, leads to a downward trend. The downward trends can be either temporary or pro-longed. In this study, the periods chosen are during the first half of 2020, from beginning of January to end of June, when the corona hit the worst. The second period was chosen as the full year of 2020 when the market had recovered.

The variables that will be used for measurement of performance will be (Sharpe, 1994)

$$Performance\ Index\ =\ Return\ on\ fund\ -\ Benchmark\ Index \qquad (1)$$

which will either be positive or negative depending on if the fund handles the times of recession better. A benchmark index is usually chosen by a portfolio manager or other people who performs the measuring (Gupta, 2005). The benchmark index serves as variables that can be used as a reference, usually consisting of an index, for how well the fund performs and is normally stated by the fund itself. As the performance index measurement cannot stand by itself since it does not account for the risk taken, another measurement for measuring the funds' performance will be the ex-post Sharpe ratio that takes risks into account and is derived as followed (Sharpe, 1994):

First step is to calculate the differential return between the fund and benchmark index at time *t*, which is essentially the same as eq. 1 but with other notations.

$$D_T = R_{Ft} - R_{Bt} \qquad (2)$$

Thereafter the average of D_T from $t = 1$ through T is calculated as

$$\bar{D} = \frac{1}{T} \sum_{t=1}^{T} D_t \qquad (3)$$

The standard deviation which represents the risk is calculated as

$$\sigma_D = \sqrt{\frac{\sum_{t=1}^{T} (D_t - \bar{D})^2}{T-1}} \qquad (4)$$

The Sharpe ratio is lastly defined as

$$\text{Sharpe Ratio} = \frac{\bar{D}}{\sigma_D} \qquad (5)$$

William Sharpe (1994) himself explains that the Sharpe ratio can be compared to t-statistic, which is a measurement used for evaluating the statistical significance of a mean differential return, since the Sharpe ratio multiplied with the square root of the time period T is equal to the t-statistic.

The mathematical tool used will be the spreadsheet program Microsoft Excel and the results will be presented as a table. To measure the performance of funds that are utilizing AI, funds that will be included must base their decisions on AI.

2.2.1 Limitations

The strength in quantitative methods is that it produces objective results from mathematical variables but as the variables are already predetermined, it gives little to no room for imagination and creativity (Eyisi, 2016). The quantitative method usually follows a certain pattern which the researcher decides and directs, leading to almost no input from the subject that is being studied. The researcher becomes detached from the object that is being studied and difficulties with in-depth understanding arises.

Eyisi (2016) continues with explaining that the approach is mostly suitable for explaining what is already known rather than trying to invent new ideas or recondition old ideas. A quantitative approach usually consists of a large amount of data but as there are an insufficient amount of funds in Sweden that are using AI for fund management as of today, data from foreign funds will therefore also be included. This data will not be as relevant for the purpose of this thesis as it aims to treat Swedish funds but the data will give good indications of how the funds perform overall when using or not using AI. This will be useful as AI is a tool that is used in an almost homogeneous way around the world.

The Sharpe Ratio that is used cannot forecast future performance but only evaluated historical data about the fund (Sharpe, 1994). The ratio also only considers two variables, the average differential return and the risk meaning it does not consider other variables such as strategy, correlations, etc. One of the critics to the theory, David Harding (2002), stated that the ratio is irrelevant since it depends too much on the standard deviation which has no meaning since it is not normally distributed throughout the time series.

2.2. Qualitative method

Qualitative methods are especially useful when an object cannot be quantified into mathematical variables, such as social relationships and phenomenon's that require deep analysis in order to improve understanding (Almeida, Faria & Queirós, 2017). In this thesis, a qualitative part in the form of a structured interview, has been carried out.

The qualitative study aims to find out why fund managers have or have not started to use AI and with respect to that, interviews with fund managers have been scheduled. It is also interesting to see if they are planning to use AI and what their thoughts on the subject are. Due to the current situation of COVID-19, the interviews were conducted through a phone interview as well as through mail. The interviews were transcribed and saved as text documents as this makes it easier to analyze and gives less room for misunderstandings (Patel & Davidsson, 2011). It will also make it easily accessible if one of the parts for some reason would not be able to attend the meeting. Depending

on the respondent, the identity of the respondent will either be presented or remain anonymous.

There will be an effort to collect as much data through the interviews as possible but this will fully depend on if there is enough interest from the respondents. The current situation with the coronavirus and the time restrictions has also been regarded. The minimum number of interviews has been decided to be at least 5 which has been based on an article from Springer (Dworkin, S.L, 2012), that suggests that any number of interviews ranging from 5 to 50 interviews is appropriate. The questions that have been handed out to the respondents can be seen in appendix 1. The questions are both in English and in Swedish since many of the respondents may be more comfortable with Swedish. Most of the respondents chose to answer in Swedish regardless of the language the questions were asked in. One of the respondents chose to answer in Norwegian. The answers were analyzed comparatively by going through each question and comparing the respondent's answers. The answers were then put into context by applying the information that was gathered from the qualitative study.

2.2.1 Interview composition

To extract as much information as possible from the interviews, there are six types of questions the researcher can ask the respondent (Patton 2002). Patton categorizes interview questions as: opinions, experiences, knowledge, background, feelings and sensory. With these categories in mind, the motivation behind the questions were formed. As the purpose of the thesis is to understand where the industry of fund management is heading regarding the adoption of AI, many questions were based on opinions and feelings. The questions were also based on the fund managers knowledge and experience regarding AI.

There are different ways to structure an interview. According to Bryman (2012), three commonly used techniques are the standardized interviews, semi-structured interviews and unstructured interviews. In a standardized interview, the interviewees receive the same predetermined questions to ensure that the answers can be aggregated (Bryman 2012). A semi-structured interview refers to a context where the interviewer is able to vary the sequence of questions and ask further questions in response to compelling

replies (Bryman 2012). The interview was conducted in a structured form meaning that all the interviewees were given the same questions which makes it easier to compare the answers (Almeida, Faria & Queirós, 2017)

As the interviews will be conducted remotely, the interview structure was prepared and designed according to the respondents preferred choice of meeting. An interview through a virtual meeting will give room for more of a semi-structured interview as opposed to an emailed interview. The questions were asked with high standardization as they were asked in a certain order (Patel och Davidsson, 2011).

2.2.2 Limitations

Due to the nature of qualitative methods, the answers from the respondent and the interpretation and conclusions of the answers made by the authors will be subjective (USC Library, 2020). Critics means that the qualitative method cannot give reliable information since the method is mainly based on opinions and personal experience and that there is no way the data can be verified in a way that the qualitative method can be (Eyisi, 2016). Even though this will lead to the thesis moving away from being ultimately objective, the qualitative method is the most suitable for this research as it aims to understand the current situation, the market and where it is heading. The qualitative method is suitable for exploring new phenomena and gives room for interpretation. As AI is relatively new, the qualitative method invites thoughts and ideas that can be freely comprehended.

The structured way of preparing an interview gives little to no room for more detailed answers as well as low flexibility in what the respondents can choose as an answer (Almeida, Faria & Queirós, 2017). The information obtained will therefore mostly be shaped after what the interviewer wants from the respondents which at the same time makes it easier to compare and filter out unnecessary information.

A qualitative approach believes that the world, in perspective of experience and phenomenons, have many different sides and is therefore dependent on how the researcher interprets the information during that certain time period. Such an approach makes it difficult to simplify information and the research can thus not be repeated by

anyone else in the future and expect the exact same results. But as this thesis is not expected to be repeated once again in the future but rather expected to be used as a base for future research, the method remains valid for the purpose.

Another limitation stems from the fact that only a sample size of the total number of funds will be evaluated (Patel & Davidsson, 2011). The problem that arises is that the findings get limited to the specific subgroup the study was directed to, leading to a low grade of generalized conclusion being drawn (Eyisi, 2016).

2.3. Primary and Secondary Data

The data collected is categorized as either primary or secondary data. Data which comes from firsthand sources and is collected by the researcher, is considered primary data. The gathering of primary data can be made using methods such as interviews and surveys (Hox and Boeije, 2005). Primary data is commonly preferred as it represents information that comes directly from the source of interest which has not been interpreted before (USC Library, 2020). This thesis will collect primary data by conducting interviews as the main source of data which will be interpreted.

Secondary data contrasts with primary data, referring to data which is already available and collected by previous researchers. Secondary data includes data from sources such as scientific articles, books, official statistical data and other data archives (Hox and Boeije, 2005). A useful attribute of secondary data is the property to be used in the big picture in order to improve overall research, but as the purpose of secondary data differs from the purpose of this thesis, secondary data can instead constitute to collect what is already known and give a hint to what needs to be improved (USC Library, 2020). This thesis will collect secondary data from course literature and various scientific articles in order to create a theoretical framework.

Data has been collected with the intention in mind that they should be as up-to-date as possible since the information in secondary data might have been changed over time and thus affect the reliability (Olabode, Olateju & Bakare, 2019). Another variable that might affect the quality of the data that Olabode et. al (2019) brought up in a study

about the reliability of secondary data is source bias, which can appear as a more optimistic or pessimistic view of a subject that could affect the results. They further suggest that researchers should, if possible, always check multiple sources in order to verify the validity. An explanation should be given if the information is contradicting each other and if there is none, the source should not be used.

3. Theoretical Reference Frame

A literature study has been conducted on research that has addressed similar topics together with an overview of artificial intelligence and classical financial theories. The results of the literature study will be presented in this chapter and will lay the foundation for the thesis.

In the first part of this chapter, classical financial theories will be presented in order to reach an understanding about how AI will be able to reduce some of their disadvantages. Artificial intelligence and some of its subcategories will be described in the latter part about AI. The last subject will comprehend related research that has been previously conducted.

3.1 Efficient market hypothesis

With the potential benefits of using AI in fund management being increased capabilities regarding information processing and pattern prediction, the theory of efficient markets needs to be regarded. Eugene Fama's efficient market hypothesis (1970), which earned him the Nobel prize in economic science 2013, defines efficient markets as markets where a number of profit maximizing rational investors compete. The competition of trying to predict future values of securities, leads to the situation where all the information available is already reflected in the share price (Fama 1970). Fama claims new information to affect the prices immediately, making the market efficient and the prediction of stock price movements impossible in the short term. Fama (1970) presents three variations of efficient markets: weak, semi-strong and strong form.

The weak efficient market suggests future prices to be independent of past information regarding price and volume, implying technical analysis to be ineffective. Future price changes of a security is hence a subject of the random walk hypothesis which proposes that stock prices move randomly. In a semi-strong efficient market, all public

information is reflected in the share price meaning that the market will quickly reach a new equilibrium as supply and demand changes due to new information. Both technical and fundamental analysis is considered ineffective, regarding producing a consistently higher risk adjusted return, than the market. The strongest form of efficient markets says all information is reflected in its share price, even information not available for the public is included. Private information of securities will be exploited by those holding the information until the price reaches its new equilibrium.

3.1.1 Criticism of the efficient market hypothesis

The debate on whether the financial markets are efficient or not, divides economics apart. "The Efficient Market and Its Critics" by Burton G. Malkiel (2003) examines the criticism and contradictory theories based on three schools of thought. Arguments for market inefficiency often refers to historical events such as the dot com bubble, where the pricing of internet stocks is believed to have been caused by irrational behavior of investors (Malkiel 2003). Malkiel explains that pricing irregularities and predictable patterns may appear over time, as the cumulative judgement of investors sometimes makes mistakes. The author concludes that markets cannot be perfectly efficient, as the incentive for professionals to quickly process new information would in such scenarios be non-existent.

One of the theories challenging the efficient market hypothesis is momentum investing, where investors combine fundamental and technical analysis, which claims price patterns do exist. According to Malkiel (2003), several studies have shown short-term significance regarding price patterns. These predictable patterns, however, seem to disappear once they are made public, as investors incorporate the new information into their strategy. The author further exemplifies this occurrence, with a pattern known as the "January effect", where stock prices surged in the beginning of January, but seemed to disappear shortly after its discovery.

Another contradictory theory of the efficient market hypothesis is behavioral finance, which will be further presented in chapter 3.3. Advocates of behavioral finance suggest

investors to be influenced by psychology rather than rationality, causing overreaction and underreaction to new information (Malkiel, 2003). However, Fama (1998) points out in the article “Market efficiency, long-term returns, and behavioral finance”, that an overreaction of stock prices to new information is equally common as an underreaction. Fama (1998) also states that post-event reversals are about as common as post-event continuations of pre-event irregular returns. Thus, Fama (1998) concludes the pricing irregularities to be a result of chance, with the probability of security prices going up or down equally likely, in line with market efficiency.

3.2 Portfolio theory

To understand how AI can be useful when managing assets, earlier theories of portfolio management need to be studied. Economist Harry Markowitz (Markowitz, 1952) wrote an article about portfolio selection as early as 1952, introducing the modern portfolio theory. The theory is based on the idea that investors want to optimize return for any amount of risk, and that by diversifying through unrelated assets, risks can be minimized. The overall risk of a portfolio is a function of each asset's variance and the correlation between pairs of assets. By utilizing the modern portfolio theory, investors can hold high-risk assets, given that other assets held make up for it in terms of risk reduction. Markowitz (1952) further splits risk into two categories, systematic and non-systematic. The systematic risk being the risk of entire markets failing, such as entering recession, which the modern portfolio does not claim to be able to reduce. The non-systematic risk is the specific risk of individual assets and can be reduced by applying the diversification of modern portfolio theory. The hard part with this theory is to find the expected return which can be calculated in different ways, often leading to a big gap between the true and approximated expected return.

By recognizing the flaws and relevancy of the modern portfolio theory, the usefulness of AI can be further specified. Markowitz (1952) used several assumptions to reach his conclusion. While the modern portfolio theory suggests investors to be rational, solely motivated by risk and return, with the same view of expected returns, theories of behavioral finance suggest otherwise.

3.3 Behavioral finance

In addition to previous traditional theories presented, the area of how psychology influences the behavior of investors is of interest to study. Traditional theories exclude the effects of psychology and assume humans to be rational, up to date with available information and make decisions based on their best expected outcome. Behavioral finance explores how the behavior of investors and financial analysts is influenced by psychology. Ricciardi and Simon (2000) argue that the field of behavioural finance aims to clarify and raise understanding of investors' reasoning habits, including the emotional processes involved and the extent to which they impact the decision-making process.

To further explore how AI can be applied to fund management and the potential benefits it may have regarding human behavior and decision making, relevant sub-theories of behavioral finance which can affect investors will be presented in this chapter.

3.3.1 Overconfidence

Research has found overconfidence to be a source of psychological influence. Humans tend to overestimate the accuracy of their knowledge and skills resulting in false predictions (Barber and Odean 1998, Ricciardi and Simon 2000). Barber and Odean (1998) conclude stock picking to be the type of task where people are most overconfident. They point out that selecting stocks that will outperform the market to be a difficult task, as predictability is low, and the feedback is noisy. Their research also shows how gender bias influences investing. Male investors were found more likely to overestimate their investing skills, trading more frequently, resulting in worse timing and higher trading costs. Financial cognitive dissonance, where investors fail to learn from their past mistakes, further adds to the overconfidence dilemma (Ricciardi and Simon, 2000).

3.3.2 Financial cognitive dissonance

The theory of cognitive dissonance by Festinger (Morton, cited in Ricciardi and Simon, 2000) suggests that when exposed to conflicting beliefs, behaviors or attitudes, people experience internal stress and anxiety. Individuals either attempt to change their beliefs and opinions or attempt to rationalize their choice in order to reduce the dissonance. Ricciardi and Simon (2000) argue that the theory may be applied to investors of the stock market. By rationalizing conflicting behaviors, investors attempt to envision that they comply with their own beliefs and values. An example would be that investors tend to rationalize buying stocks based on a sudden price momentum which is justified as society transforms into a new economic era. Decisions such as buying on momentum may lead to financial crises like the dot com bubble that reached the edge in the early 2000's.

3.3.3 Common behavioral biases

In addition to the previous psychological behaviors mentioned, there are several different biases faced by investors. Baker and Ricciardi (2014) explains how these fundamental issues can affect investment decisions. For example, regret aversion can emotionally affect the investors willingness to take risks. It can also explain investor tendencies of selling trailing investments where the decline tells them they made a bad decision. Another bias according to Baker and Ricciardi (2014) is the familiarity bias, closely linked to home bias, which occurs when an investor foresees obvious gains from diversification due to preferences such as local and domestic securities.

3.5 Artificial intelligence

Artificial intelligence is a widely used computer tool commonly used to calculate and predict patterns or classify different objects (Söhnke M. Bartram, Branke, J and Motahari. M, 2020). When talking about AI, included is neural networks, machine learning and deep learning. Although these terms are the most popular on search

engines when searching for AI, AI is more than just these categories and include natural language processing, genetic algorithms and clustering which will also briefly be presented in this chapter.

3.5.1 Neural Networks

The basic structure of a neural network takes data that needs to be processed as input which gets propagated through the network. Neural networks utilize the most basics of AI, which is constructing neurons in terms of giving weights to the different inputs (Söhnke M. Bartram, Branke, J & Motahari. M, 2020). The neurons are constructed as different layers and the more layers it contains, the deeper the network gets which gives rise to the term deep neural network.

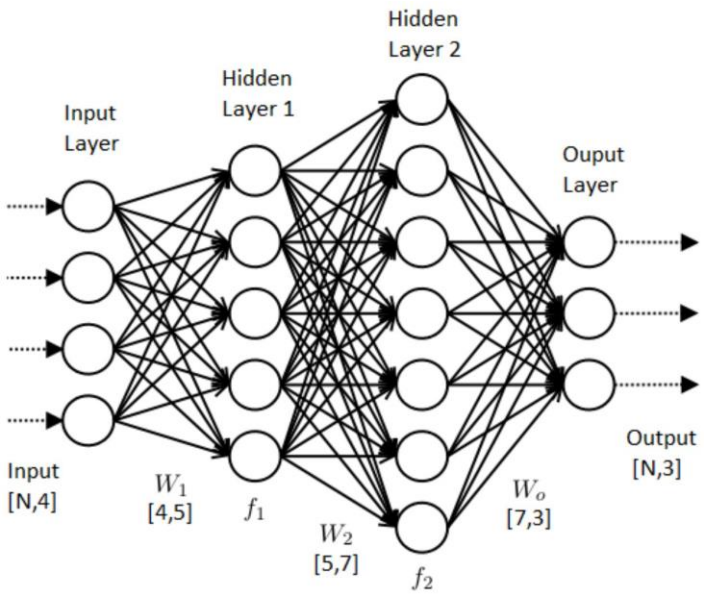

Figure 2. The components of artificial neural network (Bapu Ahire, 2018)

As can be seen in figure 2, the input gets sent into the neural network and propagates through weights in the hidden layers, like the human brain (Söhnke M. Bartram, Branke, J & Motahari. M, 2020). The output of one hidden layer goes through an activation function, which could be the multiplication operator or a sigmoid function and becomes an input to the next hidden layer. A practical use of artificial neural networks is a linear classifier used in for example linear regression. The weights are

updated such that the distance between the line and different points are minimized (Krogh, 2008).

3.5.2 Machine Learning

Machine learning utilizes neural networks to learn from the input data without the programmer telling specifically how. Instead of just sending the input through the neural network once, machine learning can receive feedback and update the weights in order to get a better result with less errors (Jajodia & Garg, 2019). For example, one could train a machine to classify pictures of dogs and cats by using the pictures as input and evaluate what the machine thinks is in the picture from the output. This is done by making use of convolution which is a class of linear operation. If the machine is wrong, feedback is given for the machine to perform better with regards to the error, referred to as backpropagation. The machine learns by analyzing the features of the image, if the architecture is good enough, subtle features that differentiate breeds of cat and dogs could also be recognized (Parkhi et al. 2012). Since the pictures that the machine learns from may contain features that have nothing to do with if the picture contains a cat or dog, there is a risk that it incorrectly associates these features with a cat or dog. An example of this could be that the machine associates water with dogs, simply because many of the pictures used to train the machine were of dogs playing in water. This is known as overfitting. In order to overcome this, three non-overlapping datasets are created. The training set is used to train the machine, the validation set is used to evaluate the machine as it is being trained and the last one, the test set, is only used once after training to evaluate how well the machine can perform its task.

3.5.3 Deep learning

Deep learning is the most complex subcategory out of the three and uses a lot of different linear and non-linear methods to evaluate and learn (Söhnke M. Bartram, Branke, J & Motahari. M, 2020). Furthermore, the network can learn in different ways either by being supervised as in it is given what the right answer is, or it could be unsupervised meaning that it does not know the right answer in each step but tries to learn by itself.

This type of network uses the same architecture as machine learning but with hundreds of millions different weights that are adjusted. The downside is that the networks are usually very extensive, and millions of calculations are made in order to get a good output, sometimes referred to as a "black box". This makes it hard to see what is happening inside the neural network and it is very unclear what feature the network uses to get the desired output. The extensive nature of the deep learning networks has carved the way for more abstract functions such as speech recognition, face recognition and language translation (Lecun, Bengio & Hinton, 2015).

3.5.4 Artificial intelligence in asset management

As explained earlier, portfolio optimization today utilizes Markowitz's mean-variance theory to find the optimal portfolio. The problem with this is that the expected return is hard to determine and a large amount of data is needed to determine the variance-covariance matrix together with an assumption that the correlation between the two assets is stable (Söhnke M. Bartram, Branke, J & Motahari. M, 2020). Artificial neural networks can eliminate these problems by predicting an expected return that is far more accurate than with traditional methods, while also constructing a portfolio that can handle more constraints that would otherwise have been hard to incorporate into Markowitz's model.

Different methods for utilizing AI in asset management have been described by Söhnke M. Bartram, Branke, J & Motahari. M (2020). One example that is brought up is natural language processing (NLP) which is used for analyzing text, speech or videos in news in the finance sector, social media, etc. This is useful as it can be used to filter out unnecessary news and use the more advantageous news to predict how the market will react accordingly. A tool like this is especially advantageous for predicting recession and financial crisis as AI is especially good at finding underlying patterns.

Another popular method that is brought up is genetic algorithms (GA). GA is inspired by evolution theory and utilizes natural phenomenon's that can be observed in nature (Söhnke M. Bartram, Branke, J & Motahari. M 2020). The basic idea is to generate a

population of stochastic solutions which is evaluated and mutated as new solutions arise. The bad performing solutions get scrapped and make way for new better solutions which are then iterated until an optimal solution is found. GA has been used as a tool to generate a portfolio where the number of assets are restricted, which is done by solving the mean-variance problem.

Camerer (2017, p. 587-608) compares the human behaviour of overconfidence to the machine's property of overfitting. He explains that the larger the training set is, e.g., literature that the human reads, the more confident the human will be that the accuracy of the test set will be high, although in reality it is not. Artificial intelligence can correct the weights based on the output and hence eliminate the error but due to cognitive dissonance and overconfidence, humans tend to ignore past experience. Camerer further explains that AI can be used as a personalization tool which recommends suitable stocks or derivatives based on the person's preferences. Moreover, Christoph March (2019) showed through experimenting with computer players, which were based on AI, that their human counterparts' behavior changed when they were facing a computer. He observed that humans tend to behave more selfishly and more rationally while also trying to exploit computers as much as possible. March (2019) ends his paper with the conclusion that his findings might, in a future shaped by AI, give a hint as to how humans might choose to make use of a computer's advice in their decision-making process.

3.5.5 Ethical views

Professor Andrew Ng from Stanford (Lynch 2017), who is thought to belong to the most knowledgeable people in the AI field, once said that he cannot think of any field that will not be affected by AI in the future. Naturally, a question that arises from this statement is if it means that humans will lose their job, and in worst case, if it will lead to AI taking over the human race. Since the questions are about the company's product, the companies must give a reasonable answer as to why AI need not to be feared.

The British Institute of Business Ethics (IBE, 2018) presented important variables that companies should consider when dealing with AI in business. The first variable they

brought up was accuracy. With this they imply that AI needs to be free from systematic bias, and most importantly, human bias. But as this can be rather difficult, companies should instead establish a clear statement of where the lines are drawn, for example, how much is human bias allowed to impact AI decision making? Transparency is therefore important, not only regarding bias but also transparency in software making and data collection as the GDPR law needs to be considered. Another aspect that was brought up was the problem with the "black box", which was explained in the previous chapter. The IBE reports that companies try to tackle this problem by inventing new software that is able to output what the neural network is doing and also what the drawbacks and benefits are.

What can companies do to combat these ethical issues with artificial intelligence? IBE (2018) proposed that companies should have well-established policies for people working with AI and also make sure that these policies are also withheld by their business partners. They should also establish an ethics department that makes sure these policies are followed, introduce tests that the AIs need to pass and educate the people about the effects of AI.

3.6 Similar research

A similar research was conducted by Jamal Cardinal and Seher Karakoc (2020) at Södertörns Högskola, where they compared artificial intelligence and portfolio management during a period of 3 years. The authors did not limit themselves by only looking at Swedish funds but also international funds. They made the comparison by making use of for instance the Sharpe ratio, and different alphas. In terms of return, the funds managed by AI generated on average a higher return than the traditionally managed funds. Though when looking at the Sharpe ratio, the artificially managed funds generated a low return when also looking at the risk taken. Furthermore, only 1 out of the eleven artificially managed funds were able to exceed the indexes that they used for comparison. The conclusions of their study were that there is not enough information yet to determine if the funds managed by AI give better returns than traditionally managed funds. In regard to their conclusion, the research question of this

thesis will be of value to determine if there will be more funds and thereof information, which enables AI in their decision-making process.

Another relevant work was done by Neha Soni et. al (2020) which treated the subject of artificial intelligence in business and the reason why it has exploded in recent years despite having been around for decades. The authors start with explaining that the improvement in computational power through GPU (graphics processing units) and TPU (tensor processing units), increasing availability of open-source software and open platforms such as GitHub, which enables programmers to share their codes, has made the AI industry boom. The research also showed that out of all the hundred start-ups in AI during 2017 and 2018, all of them were in 13 countries out of 195. The researchers refer to it as "AI divide" which creates even more inequality in society since AI is only concentrated in a few countries. The conclusion is that there are some challenges within AI including AI divide, trust, ethical issues etc. They also concluded that AI is not just a "hype" but has the power to change global economics. The findings from this research paper can contribute to a better understanding of the AI market.

4. Empirical Results

This chapter will begin with a short presentation of the funds included in the thesis and will move on with further presenting the outcome of the interviews together with the results of the quantitative empirical material.

4.1 The funds and responses

Lannebo Funds AB was founded in 2000 by Anders Lannebo and a group of fund managers. The founders saw a shortage in the Swedish Fund market, which in the late 1990s was dominated by the large banks, to offer genuine active management. Today, Lannebo manages approximately 80 billion SEK for private savers, institutions and companies. The portfolio of Lannebo Small Cap averages 50 holdings (Lannebo, 2020). Lannebo AB is as of today not using either AI or machine learning in their managing process. A more traditional approach based on fundamental analysis is used. However, their opinions on the subject and reasons for not using it will provide useful information. An interview with the fund manager of Lannebo Small Cap, has been conducted.

Lynx Asset Management AB was founded in Stockholm 1999 by Martin Sandquist, Jonas Bengtsson and Svante Bergström (Lynx, 2020). The founders were previously part of the proprietary trading unit at Nordbanken where the idea of "The Lynx Program" was formed. The program is based on a systematic approach with quantitative models used to continuously capture market opportunities. Today, the hedge fund manages over $5 billion and is one of the ten biggest commodity trading advisors. Lynx offers three funds with different strategic approaches. Lynx began utilizing machine learning techniques in 2011. Their investment process is fully systematic, from generating signals to executing trades as well as managing risk. Lynx constellation mainly uses various models of AI in order to forecast market return. The model finds patterns that cause disruption in the market such as investor behavior or periodic phenomenon's which is done by actively training the models with data (Lynx,

2020). Lynx Asset Management AB is a hedge fund which, unlike mutual funds, are allowed to utilize leverage, short selling and derivatives. Despite being a hedge fund, Lynx is still of interest for this thesis as their knowledge about AI and machine learning within fund management is extensive. An interview with a fund manager at Lynx, has been conducted.

Storebrand ASA is a norwegian finance and insurance group with a history dating back to 1767. Storebrand has since branched out to serve the nordic markets. Storebrand Asset Management Sweden is a subsidiary of Storebrand ASA and currently manages approximately 800 billion SEK. (Storebrand, 2020). Storebrand will in this thesis be represented by a portfolio manager from the index- and quant team.

The Second Swedish National Pension Fund is one of northern Europe's biggest funds, managing around 358 billion SEK and was founded as one out of six funds to administer the national pension (AP2, 2020). In an interview conducted by their business partner SAS institute, the head manager of the quantitative department of the Second Swedish National Pension Fund, Tomas Morsing, said that they have mostly been working with Microsoft Excel until they recently switched over to SAS Enterprise Business Intelligence Server (SAS, 2020).

4.2 The use of artificial intelligence in fund management

Table 1. Funds that are utilizing artificial intelligence or are in their research stage.

Funds interviewed	Implemented AI	Research Stage
The Second Swedish National Pension Fund	Yes	Yes
Lannebo	No	No
Lynx Asset Management	Yes	No
Storebrand Asset Management	No	Yes
Catella	No	No

Based on the interviews conducted, the response can be seen in table 1 which shows whether the funds are using AI as well as if they are in the early developing stage. Of the equity funds, only the Second Swedish National Pension Fund stands out to be utilizing AI in forms of natural language processing, which they see the most potential in. Artificial intelligence is used in their process of analyzing and extracting data and serves as a supporting tool in the decision-making process. The other respondents however, all believe that AI has the potential to be an advantageous tool when making decisions. The respondent at Storebrand expresses that the technology of AI is still at an early phase. Lannebo AB says they have not yet incorporated any sort of AI technology in their managing process but reckon it would be a useful supporting tool. The respondent, however, thinks the technology is not ready to make decisions on its own.

The hedge fund Lynx asset management states they have more than ten models where investment decisions are based on machine learning. Machine learning is further used in their executing algorithms, where orders are executed automatically on stock exchanges all over the world. One of their funds, Lynx constellation, solely invests based on machine learning. When asked to what extent they are willing to let AI overtake the decision making, the respondent of Lynx said they are highly willing to. At some point in the process though, human decisions always take place.

Catella operates actively managed funds which focuses mainly on Nordic funds (Catella n.d). A short answer from one of Catellas fund managers stated that they currently do not make use of AI because they have not advanced the technology far enough, but they do believe that there will be, if not already, more tools available in the future.

Most of the respondents agree that human intuition plays an important role in the investment process but also denote that society is heading more and more toward human intuition as a secondary tool to algorithms and models. At Storebrand, the human intuition is already secondary. The respondent says that they are using models and optimization algorithms when deciding to invest. However, the respondent points out that sanity checks are of importance for avoiding errors in input data or algorithms that might lead to poor investment decisions.

4.3 Benefits and barriers of artificial intelligence

According to the respondents, most of them believe that AI can be beneficial when handling big data quantities in a structured way. The Second Swedish National Pension Fund indicates that AI is an unexplored technique which means that there is a lot to discover in the field that could prove to be useful. Lynx management highlights that if patterns exist in some way in the market, so that the market is rather deterministic than stochastic, then AI could potentially be able to find that pattern. Lannebo AB thinks that AI could optimize information retrieval and might also be useful in currency trading rather than the stock market. Furthermore, they also see potential in AI in the area of trading currency parities which, unlike stocks, trade against each other.

Lynx believes that a catastrophic situation could take place if data is insufficient. Consequences of insufficient data are overfitting and poor out-of-sample results caused by substandard validation and test results. Lynx further points out that the algorithm might deviate from the original purpose, which can result in heavy losses if validation and testing have not been conducted in a satisfying way. All of the funds allude that the algorithms need to be tested before going into use. The Second Swedish National Pension Fund pointed out that there is a need for building up knowledge in the field resulting in heavy costs for the investors. Storebrand also expressed their concerns regarding potential danger that might be caused by data mining.

Regarding the legal aspects, most of the funds were not aware of any legal restrictions that have been established regarding AI. Lynx sees a potential risk that the algorithms could learn to manipulate the market which could be restricted in the future. The Second Swedish National Pension fund believes that the legal restrictions depend on what application and data is used. They have observed that there are stricter regulations regarding autonomous self-driving cars and personal data according to the GDPR law, but fewer restrictions regarding predictions of stock market prices.

When asked about why their funds have incorporated AI into their decision-making, an answer from The Second Swedish National Pension fund explained that it is seen

as a competitive advantage. Lannebo on the other hand, which is a small fund in terms of capital, sees AI as a challenging task to take on both regarding the technical task but also because they are a smaller firm that would need large investments in order to establish new technology, Lannebo further remarks that the stock market includes too many parameters to take into consideration, such as the corona pandemic and the U.S 2020 election, which they believe AI is not able to foresee and would result in many errors. Although, an advantage they can see in the use of AI is to analyze correlations and for gathering data. Storebrand has a more cautious and skeptical view toward AI since they think that it is at a too early stage to be used. Their concerns stem from the fact they do not know in which way AI might be effective in the investment process as well as the risk of data mining.

The summarized table of benefits and barriers gathered from the fund managers can be seen in table 2 below.

Table 2. Funds responses regarding benefits and barriers

Funds interviewed	Benefits	Barriers
The Second Swedish National Pension Fund	- Able to find incorrect pricing - Competitive advantage - Helpful tool - Have not yet seen full potential	- Time consuming to build knowledge - Needs large investments
Lannebo	- Supporting tool - Cumbersome tasks - Information gathering - Correlations	- Difficult subject - Too many parameters which AI cannot find - Needs large investment - Technology is too young
Lynx Asset Management	- Find complex connections - Find patterns - Execution algorithms - Analyse large data amounts	- Substandard data will lead to catastropic events - Needs good validation results
Storebrand Asset Management	- Useful tool - Incorporate large data amounts - Structure large data	- Data mining - Need more empirical studies - Overfitting - Needs good out of sample results

4.4 Artificial intelligence's impact on the future of fund management

All the respondents are positive that the use of AI within fund management will increase. The Second Swedish National Pension Fund has in recent years seen an upwards trend in big data, machine learning and AI. As most trends however, the respondent suspects that the interest might fluctuate, as the expectations of the technology may have been set too high. As of now, the respondent sees great optimism about natural language processing (NLP) and believes machine interpretation of texts will gain popularity.

According to Lynx, AI within systematic fund management will increase, but it is still difficult to predict whether systematic fund management will increase its relative market share on the fund market. The respondent explains that a crucial factor is the access to quality data. Without it, AI-based fund management is faced with poor conditions to succeed.

When asked about the effect artificial intelligence might have on professions such as fund managers and financial analysts, the respondents reckon that the competence requirements will change. Lannebo points out that similar to how a financial analyst today differs from 25 years ago, the competence requirements will change in terms of financial tools being used. The Second AP Fund and Lynx both agree, as AI will enable additional sources of data and new methods for analyzing, the fund manager will need to have an understanding of the technology. Storebrand argues for an increasing demand in knowledge regarding structuring databases, programming, machine learning and building models. The respondent concludes that the ability to adapt investment decisions and adopt new technology into fund management, will be more important than it has previously been. All the fund managers thoughts on where the market will be heading as well as AI's impact on profession can be found in table 3.

Table 3. Fund managers thoughts about the future impact of artificial intelligence on the market and on professions.

Funds interviewed	Future market	Impact on professions
The Second Swedish National Pension Fund	- Up and down trends - Positive view for NLP - Scepticism from customers	- Higher demand for fund managers to understand the technology
Lannebo	- AI will become a support tool - Demand for AI will increase	- Competencies will change
Lynx Asset Management	- Increase use of AI in systematic asset management	- Increased demand for fund managers to understand the technology
Storebrand Asset Management	- Niche funds will arise that specializes in AI	- Need for competence will change - Need for ML/programming/big data will become bigger
Catella	- New tools and services in AI will arise	-

4.5 Performance of funds powered by artificial intelligence during the 2020 recession

The funds that have been chosen for quantitative research are managed by artificial intelligence and/or machine learning. The benchmark index has been chosen as a measurement of performance which is selected by each fund and represents the relevant index that the funds seek to outperform. In order to take the risk into account, the ex-post Sharpe ratio has also been constructed for each fund. A short description about the funds that will be evaluated is found below and the results will be presented after.

4.5.1 Relevant funds

Lynx has been excluded from evaluation since it is a hedge fund and takes both long and short positions, while the included funds only take long positions. However, their

historical data is still of interest for further analysis since they base much of their decision-making on AI. Since the start in 1999, The Lynx Program has generated a total return of approximately 500% and an average annual return of 9,13%. Compared to indexes such as the S&P500 and MSCI World NDTR, The Lynx Program has outperformed both in the long term of 20 years, where the S&P500 gained approximately 173% and the MSCI World NDTR index gained around 155%. (Lynx, 2020; Yahoo Finance, 2020).

Century One is another fund that was shortly presented in the introduction but has also been excluded since the fund was closed down in April (Guzu, 2020). The fund focused mainly on currency trading and had a negative year-to-date loss of -5.2% when the fund was liquidated. The return was, according to the company Century Analytics, not that dramatical since the first half of 2020 was very turbulent. What ultimately led to the liquidation was that they failed to secure long-term investments, fueled by bad initial performance and the pandemic. The fund is still interesting to look at since it is Sweden's first currency fund that mainly used AI in their asset management, but due to the unfortunate events, not much data and information could be found about the funds' performance or benchmark index.

QRAFT AI U.S Large Cap ETF launched in 2019 and is an actively managed exchange-traded fund targeting U.S large-capitalization stocks by utilizing a proprietary AI system. The portfolio consists of 350 holdings and aims to provide long-term capital gains for investors. The fund is benchmarked against the S&P500 (QRAFT, 2020).

FIM Artificial Intelligence was the first artificially managed fund in the Nordics (Pohjanpalo, 2017). The fund had its launch in Finland in November 2017 and merged with S-Sparfond Modig in October 2020 (FIM, 2020). The portfolio consisted of 50 companies from developed markets, each company with a market cap above 1 billion euros. The technology used 700 variables together with reallocating each 6 months (Pohjanpalo, 2017). The fund is benchmarked against the MSCI World Index.

AI Powered Equity ETF (AIEQ) and AI Powered International Equity ETF (AIIQ) launched in 2017 and 2018, respectively. Both ETF's were created by the company

Equbot with AIEQ having a US stock portfolio and AIIQ a global excluding US stock portfolio. The output of the AI claims to equal 1000 analysts working around the clock, combining fundamental and technical analysis, with an automated investment process removing human bias and errors. AIEQ is benchmarked against the S&P 500 index and AIIQ against the FTSE Global All Cap ex US index. (ETFMG, 2020)

ODDO BHF Artificial Intelligence is a systematic equity fund launched in Luxembourg 2018. The fund uses AI algorithms based on big data to locate promising equities globally and quantitative models to identify a desirable selection of around 60 stocks. The fund is benchmarked against the MSCI World (NR) USD index. (ODDO BHF, 2018).

4.5.2 Results of performance analysis

The time period chosen to examine is between 1st of January to 1st of July 2020 denoted as half year of 2020, as well as 1st of January to 31st of December, denoted as full year of 2020. Tables 1 and 2 present the result of the quantitative study, which uses the approach explained in chapter 2. Table 1 shows the return, index, performance and Sharpe ratio of the fund during the first half of 2020, while table 2 shows the same variables but for the full year of 2020. The global spread of COVID-19 had a big economic impact in 2020, causing stock markets to decline over 30% during the first half of 2020 and economies to enter recession (OECD, 2020).

Table 4. Performance of funds that use artificial intelligence during the first half of 2020.[1]

Funds using AI (H1 2020)	Return	Index	Performance	Sharpe Ratio
QRAFT AI U.S Large Cap ETF	7,63%	-4,45% (S&P500)	12,08%	−0,01794
FIM Artificiell Intelligens	−14,65%	-6,64% (MSCI)	−8,01%	−0,0792
AI Powered Equity ETF	−1,32%	-4,45% (S&P500)	3,13%	0,00404
AI Powered International Equity	−4,98%	-12,89%	7,91%	0,03807

[1] Data obtained from Yahoo Finance

ETF		(FTSE)		
ODDO BHF Artificial Intelligence	−1,40%	-6,64% (MSCI)	5,24%	0,03259

Table 5. Performance of funds that use artificial intelligence during the full year of 2020. [2]

Funds using AI (2020)	Return	Index	Performance	Sharpe Ratio
QRAFT AI U.S Large Cap ETF	38,68%	16,26% (S&P500)	22,42%	−0,0181
FIM Artificiell Intelligens	N/A	-	-	-
AI Powered Equity ETF	24,42%	16,26% (S&P500)	8,16%	−0,00469
AI Powered International Equity ETF	14,67%	8,3% (FTSE)	6,37%	0,00229
ODDO BHF Artificial Intelligence	11,11%	15,9% (MSCI NR)	−4,79%	0,00669

[2] Data obtained from Yahoo Finance

5. Discussion

A discussion of the empirical material will be presented in this chapter. The discussion will be based on the literature review and will start with discussing the traditional financial theories. Behavioral finance and ethical views will thereafter be comprehended, followed by an analysis of the quantitative study which treated the performance of funds that use artificial intelligence during 2020.

5.1 Traditional financial theories

The respondent of the Second Swedish National Pension Fund believes that by using AI for analysing and extracting information, incorrect pricing can be found in markets. Finding incorrect priced securities would be against the efficient market theory. According to the efficient market hypothesis (1970), even in a weak-form efficiency, stock prices reflect all available public information. The management of Lynx (2020) disapproves theories suggesting that market prices fully and correctly reflect the knowledge and information available. In any form of market efficiency, Fama (1970) implies technical analysis to be ineffective. Lynx however, believes that market variations are not fully random and instead follow recurring patterns. Capturing market opportunities which arise from market inefficiencies is the core basis of Lynx's strategy. By performing at a 500% return during the same time period where indexes such as the MSCI World NDTR index gained 155% and the S&P500 gained 173%, Lynx's strategy of capitalizing on market inefficiencies can be deemed as effective. Malkiel (2003) concludes that several studies have shown significance regarding short term price patterns, supporting Lynx's strategy. However, Malkiel claims the patterns disappear once it is publicly discovered, which would suggest Lynx's ability to profit stems from non-public patterns and information.

5.2 Behavioral Finance and Ethical Views

The traditional financial theories of efficient markets and modern portfolio theory assume investors to be rational and unbiased. According to Lynx (2020), market variations are affected by various factors such as psychological biases, different financial motivations and misconceptions. The various factors mentioned by Lynx are in line with theories of behavioral finance, where psychology is assumed to have a substantial influence on an investor's decisions. By having a systematic approach and applying machine learning, Lynx imply that they can collect and analyze more data than the human brain is capable of. This could propose that a broader collection of data would be beneficial in regard to psychological shortcomings such as familiarity and home bias. Reducing investor tendencies of having geographical preferences could enable further diversification, spreading the risks amongst different financial markets. Furthermore, Lynx's systematic models are designed to act on large amounts of data, which they suggest remove any risk associated with human irrational and emotional decision making. By successfully removing the risks associated with human behavior, the previous mentioned theories of psychological influences and biases affecting an investor's decision, would be reduced. The ability of AI to remove human tendencies to be overconfident and overestimate their skills and knowledge is supported by Camerer (2017). Camerers study also supports the change in human behavior when working with or against computers which is a factor that might affect fund managers and their process of decision making in the future. The respondents did not consider the ethical perspective of AI when asked about the barriers which indicates that they either do not consider it as a barrier or that they do not consider AI to yet be in the stage where the ethical view needs to be considered.

5.3 Artificial intelligence funds' performance during 2020

When looking into the performance index, four out of five funds powered by AI managed to beat their respective index during the first half of 2020 when the pandemic hit the hardest on the market. FIM artificial intelligence, which was optimally merged with another fund, had a negative performance index of -8.01% during the same time period. When looking at the overall performance during the full year of 2020, three

out of four funds performed better than their benchmark index. The one whose performance was lower was ODDO BHF artificial intelligence. FIM artificial intelligence was not included since no information was available after the merging.

When also taking the risk into account, QRAFT AI U.S Large Cap ETF, which has a positive return of +12.08% during the first half and a return of +22.42% during the full year, has now a negative Sharpe ratio indicating that the return does not amount to the risk taken. AI Powered Equity ETF also had a negative Sharpe ratio during the full year while the other two evaluated funds had a small, but positive Sharpe ratio.

A previous study by Cardinal and Karakoc (2020) described earlier, which looked into similar funds, found that their performances during 2017-2020 were generally worse than their benchmark index. As only two time periods were investigated in this thesis and slightly contradicting information has been found in another study, no conclusion whether or not AI funds perform better in times of recession can be drawn. What can be said is that some of them indeed achieved better results compared to the benchmarking index. Some funds performed worse and some were merged while others were forced to shut down during the recession caused by the COVID-19 outbreak. The end of funds managed by AI might imply that they were not good enough to withstand a hard decline in the market.

It is hard to say for sure how much the performance depends on AI or the portfolio managers as no closer look into the process has been made. It could be beneficial to look into more time periods, but it would not eliminate the possibility that either luck or the competency of the portfolio manager played a role.

5.4 Limitations of the study

Artificial intelligence in funds is a relatively new phenomenon and not enough research and empiric material is available, which in turn has limited the information gathering for this thesis. Not much detailed information about the technical aspects of what techniques the funds are using were obtained. As the aim of this thesis is not to

be seen from a technical perspective, a potential future research would therefore be to investigate the technical aspects.

The benchmark index might or might not be the "correct" index for studying a fund's performance as it is hard to know which index is the most appropriate to benchmark against (Gupta, 2005). The Sharpe ratio only includes the differential return and the risk taken and excludes other important variables such as correlation (Sharpe, 1994). More information and measurements, as well as different relevant ratios, would have been needed in order to discover a correlation between performance of the fund and the use of AI.

Another factor that affected the quantitative study is that the funds that were analyzed, were mainly foreign funds due to lack of data from national funds that use AI. It is therefore hard to say if the studied funds have any correlation to the Swedish funds' performance, but it is still relevant to study since most of the techniques used are the same globally but might perform differently depending on the data.

This thesis has only taken a few funds into account and the amount of funds is far from the total amount of funds in Sweden that utilizes AI. Conclusions can in this case only be drawn from the information that comes from a small sample size and cannot be generalized or applied to other funds. Each respondent is seen as a representative of their fund during the time of which the interview was held. Some of the questions were sent out in a language which may not have corresponded to the respondent's native language and may have given room for miscommunication. Such scenario is possible but unlikely since the answers they gave were appropriate for the questions. The answers have not been verified and are not guaranteed to be free from misinformation, though they are assumed to be correct and trustworthy.

6. Conclusion

The ambition of this thesis was to explore artificial intelligence within fund management. The areas explored include the extent of use amongst funds, the benefits and barriers, the future impact and the performance during times of recession.

Regarding to what extent Swedish fund managers are using AI, the results conclude that there are traditional funds, as well as hedge funds, that are currently utilizing AI in Sweden. The use of AI was found in both fundamental and technical strategic approaches. Machine learning (ML) is used to find patterns in large databases and execute orders automatically. Natural language processing (NLP) is used to gather and interpret text from news and social media. The results, however, show that AI amongst the sampled funds are not widely utilized, as three out of five have not used AI.

As for the benefits and barriers, most of the interviewed funds see several benefits in AI as an investment tool. The joint conviction and belief is that financial markets are not fully efficient and that AI has the potential to find mispriced assets and identify recurring patterns. Market inefficiencies are believed to be caused by factors of human psychology where the use of AI is considered to create a competitive advantage. Further benefits are found in AI's ability to collect, structure and analyze large quantities of data. The barriers of adapting AI, include a limited knowledge and expertise amongst the funds, as well as an uncertainty regarding the investment size necessary to incorporate it. Most of the funds interviewed are skeptical if AI is mature enough to be incorporated, since evidence to support its impact on performance is uncertain.

As only a few funds have been surveyed, no general conclusion can be drawn as to where the adoption of AI in funds are heading. The shared view of fund managers, as well as researchers, is that the demand on fund manager's AI competence will increase. The fund managers believe that AI will continue to advance in the coming years as more research and tests are conducted. More research is necessary in the area regarding

the performance of different algorithms that can be used for fund management, but also regarding limitations and social- and ethical issues.

Most of the studied funds which were used for the comparative quantitative approach managed to perform better than their benchmark index during the 2020 recession but only half of them performed better when taking the risk into account. Doubts about the connection between performance and AI persist since previous studies showed otherwise. Artificial intelligence remains relevant for asset management, but more time is needed in order to evaluate and draw conclusions.

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Appendix A

Questions for fund managers - English

1. Do you believe that artificial intelligence can make advantageous investment decisions?
2. How important do you consider human intuition to be when deciding on investments?
3. Is your company working with artificial intelligence for managing funds as of today?
4. Why or why not have your company started with this?
5. If there is a development process for this, to what extent are you willing to let artificial intelligence manage the fund?
6. What do you think the market will look like in the future regarding this subject?
7. What are the positive and negative aspects in your opinion regarding this subject?
8. What are the legal restrictions regarding this?
9. How do you think artificial intelligence will affect professions such as fund managers and financial analysts?
10. How do you think your clients/customers would react to an AI driven fund?
11. Would you invest your own money in an AI managed fund?

Questions for fund managers - Swedish

The questions have also been translated to Swedish as they are directed for Swedish funds.

1. Tror du att artificiell intelligens kan skapa fördelaktiga investeringsbeslut?
2. Hur viktigt anser du att mänsklig intuition är vid investeringsbeslut?
3. Använder ditt företag artificiell intelligens i någon form inom förvaltandet? Om ja, hur då?
4. Varför eller varför har ditt företag inte inkorporerat AI?
5. Om ni har en utvecklingsprocess för att inkorporera detta, till vilken grad är du villig att låta artificiell intelligens ta över förvaltningen vad gäller beslutsfattande?

6. Hur tror du att fondmarknaden kommer att se ut i framtiden vad gäller AI-förvaltade fonder?
7. Vad anser du finns för positiva och negativa aspekter gällande AI inom fondförvaltning?
8. Finns det några juridiska begränsningar gällande AI inom fondförvaltning?
9. Hur tror du att artificiell intelligens kommer att påverka yrken så som fondförvaltare och finansanalytiker i framtiden?
10. Hur tror du att dina klienter/kunder skulle reagera på en AI-förvaltad fond?
11. Skulle du investera dina egna pengar i en AI-förvaltad fond?

Appendix B

Interview 1

Jan Lennartson, Phd in Mathematical Statistics, Quantitative Portfolio Manager at the Second Swedish National Pension Fund. E-mail and personal online interview through teams.

Do you believe that artificial intelligence can make advantageous investment decisions?

- Ja, genom att analysera data och extrahera information tror jag man kan finna felprissättningar i marknaden.

How important do you consider human intuition to be when deciding on investments?

- Intuition är viktigt i forskning då planlös sökande sällan ger de stora insikterna men jag tror framtidens portföljförvaltare i än större grad kommer basera sina beslut på dataunderlag.

Is your company working with artificial intelligence for managing funds as of today?

- Ja.

Why or why not have your company started with this?

- Det ses som en konkurrensfördel

If there is a development process for this, are you planning to let artificial intelligence take over managing the funds or use it as a supporting tool in the decision process?

- AI eller Machine Learning fungerar som hjälpmedel för oss.

What do you think the market will look like in the future regarding this subject?

- Som alla trender kommer det gå både upp och ned med intresset för AI&ML, de senaste par åren har Big Data, ML och AI varit väldig hett. Vissa förväntningar har varit för höga därav kommer säkerligen delar av intresset att svalna medan annat byggs upp. Just nu finns det en stor optimism kring NLP så vi kommer nog se många applikationer av maskintolkning av texter.

What are the positive and negative aspects in your opinion regarding this subject?

- Det positiva är att det är nya tekniker som vi ännu inte har sett deras fulla kapacitet, det negativa är väl att det kommer ta tid att bygga kunskap i ämnet och flera av fältets barnsjukdomar kommer kosta investerare pengar.

What are the legal restrictions regarding this?

- Det är väldigt beroende på datan och applikationen. Givet persondata tänker jag mig att det finns mycket skarpare krav via t.ex. GDPR. Jag tänker mig också att beroende på vilken applikation det avser kan det finnas olika legala krav, jämför t.ex. autonom körning eller modellering av borgensumma i rättsfall med att använda ML till att prediktera avkastningen för SP500. Det sistnämnda fallet tror jag innefattar få legala aspekter medan de första två kräver stor juridisk genomlysning.

How do you think artificial intelligence will affect professions such as fund managers and financial analysts?

- Det kommer, liksom det redan blivit, vara ytterligare en datakälla och samling modeller som målar upp bilden av hur marknaden ser ut. Gissningsvis kommer det ställas höga krav på portföljförvaltare att förstå tekniken.

How do you think your clients/customers would react to an AI driven fund?

- Liksom övriga fonder, först med initial optimism/hype sedan med sund skepsism tills dess att någon fond kan påvisa goda out-of-sample resultat.

Would you invest your own money in an AI managed fund?

- Utan goda out-of-sample resultat: nej. Med goda resultat samt en förståelig attribuering; möjligen ja.

Interview 2

Johan Ståhl, fund manager of Small Cap fund - Lannebo Småbolag, Small Cap fund - Lannebo Småbolag EUR and Small Cap fund - Lannebo småbolag SEK C. Phone interview.

Tror du att AI kan skapa fördelaktiga investeringsbeslut?

- Det går inte att utesluta.

Hur viktigt anser du att mänsklig intuition är vid investeringsbeslut?

- Absolut viktigt.

Använder ditt företag AI i någon form inom förvaltandet? Om ja, hur då?

- Nej, inte på det sättet. Har själv inte jobbat med AI, inte heller våra yngre medarbetare använder AI.

Varför eller varför har ditt företag inte inkorporerat AI?

- Dels för att det är svårt att göra det. Aktiemarknaden består av så otroligt många parametrar. Om det hade gått att trappa ner till färre parametrar möjligen. Svarta svanar, som corona, kan inte förutses (det pratades brexit, oro i mellanöstern, oro i usa-valet, spänningar i kina etc). Hur ska då ai-baserade investeringsbeslut fånga upp alla dessa parametrar utan att det blir fel. Tror på användningsområden inom datainsamling och göra korrelationer etc. Vi är en mindre firma och det skulle troligtvis kräva enorma investeringar och kostnader.

Till vilken grad är du villig att låta AI ta över förvaltningen vad gäller beslutsfattande?

- Tror på AI som ett stöd men att tekniken inte riktigt är där för att enkom ta beslut genom AI.

Hur tror du att fondmarknaden kommer att se ut i framtiden vad gäller AI-förvaltade fonder?

- Tror på att användning av AI i form av stöd kommer öka i framtiden

Vad finns det för positiva och negativa aspekter gällande AI inom fondförvaltning?

- Ser positiva aspekter inom effektivisering av tungrodda uppgifter utöver själva beslutsprocessen så som backoffice-arbetet. Även informationsinhämtningen kan effektiviseras.

  Negativa aspekter finns då det historiska exempel visat att automatisering och placeringsinriktning i form av olika pariteter har gått illa för vissa. Ser ändå AI's potential i pariteter inom valutahandel då alla valutor inte kan gå upp och handlas mot varandra till skillnad från aktier. Det är bolag som ligger bakom aktier och bolagen ser olika ut.

Finns det några juridiska begränsningar gällande AI inom fondförvaltning?

(obesvarad)

Hur tror du att AI kommer att påverka yrken så som fondförvaltare och finansanalytiker i framtiden?

- Tror att kompetens kommer förändras, främst i form av verktyg som används. Det är inte så stor skillnad på kompetensen hos finansanalytiker idag och för 25 år sedan, men nya verktyg/hjälpmedel skapar bättre förutsättningar. Liknande hur en formel 1-bil idag skiljer sig från 40 år sedan, där förarens kompetens och instinkt är densamma men bilens utveckling skapar bättre förutsättningar.

Hur tror du att dina klienter/kunder skulle reagera på en AI-förvaltad fond?

- Med tanke på alla olika fondinriktningar som finns bör även efterfrågan på ai-förvaltade fonder finnas. Det handlar om paketering.

Skulle du investera dina egna pengar i en AI-förvaltad fond?

- Omöjligt att säga utan att veta specifikt hur den är AI-förvaltad.

När var första gången du kom i kontakt med AI i finanssammanhang?

- Tror inte att det är särskilt utvecklat. Kommer mer i kontakt med AI genom att bolagen som fonden äger använder AI, till exempel i deras produktion.

Interview 3

David Jansson, fund manager at Lynx asset management. E-mail response.

Tror du att artificiell intelligens kan skapa fördelaktiga investeringsbeslut?

- Ja, det tror jag. Vi är en systematisk förvaltare och har använt maskininlärning (ML) i investeringsbesluten i tio år. ML-algoritmer har möjligheten att finna komplexa samband i stora datamängder på ett sätt som är omöjligt att göra annars. Om man tror att det går att hitta konsistenta mönster i finansiell data är ML ett väldigt bra sätt att kunna identifiera dessa mönster.

Hur viktigt anser du att mänsklig intuition är vid investeringsbeslut?

- Vår uppfattning är att ett systematiskt angreppssätt till investeringsbeslut har förmågan att över lång tid prestera väl. Dock innebär även systematisk förvaltning att många mänskliga beslut ska fattas. Skickliga förvaltare har förmågan att fatta kloka beslut kring hur den systematiska förvaltningen ska bedrivas. Huruvida det ska kallas intuition eller kompetens kan diskuteras.

Använder ditt företag artificiell intelligens i någon form inom förvaltandet? Om ja, hur då?

- Vi har mer än tio modeller som fattar investeringsbeslut helt baserade på maskininlärning i vårt huvudprogram Lynx. Dessutom har vi en fond (Lynx Constellation) som uteslutande investerar med hjälp av ML. Vidare används ML i våra exekveringsalgoritmer, som automatiskt exekverar fondens ordrar på börser över hela världen.

Till vilken grad är du villig att låta artificiell intelligens ta över förvaltningen vad gäller beslutsfattande?

- Till väldigt stor del. Dock är det som jag skrev ovan alltid så att någonstans i processen kommer mänskliga beslut in.

Hur tror du att fondmarknaden kommer att se ut i framtiden vad gäller AI-förvaltade fonder?

- Användningen av AI kommer öka inom systematisk förvaltning. Huruvida systematisk förvaltning kommer öka sin relativa marknadsandel av den totala fondmarknaden är dock svårt att sia om. Vår förhoppning är att så är fallet. En avgörande faktor är tillgången till data. Utan bra data har inte AI-baserad förvaltning några förutsättningar att lyckas.

Vad anser du finns för positiva och negativa aspekter gällande AI inom fondförvaltning?

- Fördelen är att systematisk, AI-baserad förvaltning har förmågan att analysera datamängder som inte är möjligt för människor att hinna med att analysera och AI kan se mönster i denna data som inte en människa kan göra.
- Negativa aspekter är exempelvis att undermålig data kan leda till förödande konsekvenser. När beslutsfattandet överlåts till algoritmer är det helt avgörande att testning och validering har gjorts på ett tillfredsställande sätt. Risken är annars att algoritmen löper amok om ny data kommer in och orsakar enorma förluster i förvaltningen.

Finns det några juridiska begränsningar gällande AI inom fondförvaltning?

- Inte direkt. Det skulle möjligtvis kunna gälla risken för att algoritmerna skulle lära sig att manipulera marknaden på ett otillåtet sätt.

Hur tror du att artificiell intelligens kommer att påverka yrken så som fondförvaltare och finansanalytiker i framtiden?

- Det kommer säkerligen ställas högre krav på förståelse för hur AI fungerar. Både för att kunna analysera bolag inom det området och för att kunna tillämpa AI-baserade metoder i sitt arbete.

Hur tror du att dina klienter/kunder skulle reagera på en AI-förvaltad fond?

- Vi har fått god respons på vår AI-baserade fondprodukt från institutionella investerare. En utmaning kan vara att förklara hur positionstagningen sker eftersom algoritmerna är tämligen avancerade.

Skulle du investera dina egna pengar i en AI-förvaltad fond?

- Ja

När var första gången du kom i kontakt med AI i finanssammanhang?

- Runt 2007

Interview 4

Geir Magne Bøe, Portfolio Manager at Storebrand Asset Management, Index- and Quant team. E-mail response.

Tror du att artificiell intelligens kan skapa fördelaktiga investeringsbeslut? Utveckla gärna

- Vi tror at AI kan være et nyttig verktøy/rammeverk som supplement til investeringsbeslutninger i fremtiden. Fortsatt litt umoden teknologi, men vi tror det kan være mulig å inkludere større datamengder i investeringsprosessen ved å ta i bruk AI.

Hur viktigt anser du att mänsklig intuition är vid investeringsbeslut?

- Menneskelig intuisjon er sekundert for oss i dag. Vi benytter modeller og optimeringsalgoritmer til å ta investeringsbeslutninger. Det er likevel viktig med "sanity check", for å unngå at feil i inputdata eller algoritmer gir dårlige investeringsbeslutninger.

Använder ditt företag artificiell intelligens i någon form inom förvaltandet? Om ja, hur då?

- Nei, foreløpig har ikke vårt team benyttet det. Tror heller ikke andre deler av organisasjonen har benyttet det til investeringsbeslutninger hittil. Vi følger med på teknologiutviklingen og har gjort litt testing i forenklede test cases for å bygge kompetanse på området. Enkelte investeringsbanker har også bidratt med presentasjoner og innsikt.

Varför eller varför har ditt företag inte inkorporerat AI?

- Fortsatt noe uklart hvilke deler av investeringsprosessen AI kunne vært effektfullt. Vi benytter statistiske faktorer som har sterk empirisk støtte, både over tid og i ulike land/regioner. Vi er forsiktige med å inkludere nye faktorer, for å ikke bli utsatt for "data mining". Vi tror AI fortsatt er en for umoden teknologi til å inkorporeres i våre investeringsstrategier.

Om ni har en utvecklingsprocess för att inkorporera detta, till vilken grad är du villig att låta artificiell intelligens ta över förvaltningen vad gäller beslutsfattande?

- Ingen konkret prosess pågående. Vi tror at det er mulig AI en gang i fremtiden vil kunne supplere og effektivisere forvaltningen. Det er vanskelig å si om AI vil kunne ta over forvaltningen, og i så fall vil det trolig være ganske langt frem i tid.

Hur tror du att fondmarknaden kommer att se ut i framtiden vad gäller AI-förvaltade fonder?

- Vi tror at det vil komme nisjefond som i stor grad/fullt ut baserer seg på AI teknologi. Storebrand kommer ikke til å være first mover i dette markedet, men vi følger med på teknologien.

Vad anser du finns för positiva och negativa aspekter gällande AI inom fondförvaltning?

- Positive: Mulighet for å inkorporere større datamenger på en strukurert måte i investeringsbeslutningen / porteføljekonstruksjon. Negative: Fare for datamining / overfitting / spuriøse resultater "out of sample".

Finns det några juridiska begränsningar gällande AI inom fondförvaltning?

- Ikke så vidt vi kjenner til

Hur tror du att artificiell intelligens kommer att påverka yrken så som fondförvaltare och finansanalytiker i framtiden?

- Generelt tror vi at kompetansebehovet for fondsforvaltere ser noe annerledes ut i fremtiden enn i dag. Behovet for å kunne strukturere store datamengder / programmering/modellbygging/ Machine learning vil trolig få en større posisjon enn det tidligere har vært. Evne til å kunne tilpasse investeringsbeslutninger og adoptere ny teknologi inn i fondsforvaltningen vil bli viktigere enn den har vært.

Hur tror du att dina klienter/kunder skulle reagera på en AI-förvaltad fond?

- Vi tror at noen kunder ville vært interessert. De fleste v kundene ville nok hatt en avventende holdning og ønsket å se at teknologien ville gi god track record over en lenger tidsperiode før de investerte.

Skulle du investera dina egna pengar i en AI-förvaltad fond?

- Kunne vært aktuelt, men ville brukt tid på å forstå teknologien, implementeringen og vill krevd at det var en viss track record.

Mail correspondence

Fund manager at Catella

- Dessvärre använder vi oss inte av AI i förvaltningen. Det kommer säkert komma verktyg och tjänster för detta, finns säkert redan, men på Catella vi är inte så långt framme i utvecklingen.