# THE EFFECTS OF ROBO-ADVISERS ON STOCK MARKET PARTICIPATION AND HOUSEHOLD INVESTMENT BEHAVIOR

## Technical Report

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THINK
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# THE EFFECTS OF ROBO-ADVISERS ON STOCK MARKET PARTICIPATION AND HOUSEHOLD INVESTMENT BEHAVIOR[*]

## TECHNICAL REPORT

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### Abstract

Digitalization and artificial intelligence significantly increased the availability of many financial services beyond the few high-net-worth individuals and made them available to many investors. One such product is a Robo-Adviser, and we show that a Robo-Adviser facilitates participation in financial markets. Our empirical study finds that more than one in three investors in a Robo-Adviser are new participants in financial markets that otherwise would not have participated in financial markets. For investors previously participating in financial markets, the Robo-Adviser provides much fewer benefits. Most of these investors already owning diversified products, such as ETFs or mutual funds. Compared to these investors, the Robo-Adviser only invests in diversified products and trades four times more frequently each year. An investor who previously participated in financial markets does not adopt either of those behaviors.

**Keywords:** FinTech, Robo-Adviser, Investment Behavior, Retail Investor, Household Finance.

# 1. Introduction

In developed countries, stock market participation is surprisingly low. In Germany, for example, less than one-sixth of the population invests in stocks (Deutsches Aktieninstitut, 2019). In the US, the average, "middle-aged" US family (a family led by an individual aged 41–60) holds more wealth in cars than in stocks (Ravikumar & Karson, 2018). Even high-income families invest far less in the stock market than might be expected. For example, only 40% of US households making an income between $100,000 and $200,000 even invest in stocks (Chien & Morris, 2017).

A lack of financial literacy is a key reason why households feel uncomfortable investing in the financial market (Deutsches Aktieninstitut, 2019). Until recently, reliance on the assistance of a professional financial adviser was the primary means of overcoming this obstacle. Nevertheless, this solution was out of reach for most households, as financial advisers commonly require high minimum investments (often 500,000 Euro) to compensate for the cost of human labor. However, this situation is beginning to change as a result of recent developments in FinTech, which have replaced human labor with machines in many financial services, thereby reducing costs. Such technologies have the potential to bring many personalized services, previously only available to high-net-worth households, to the average retail investor. One such service, at the focus of this study, is the Robo-Adviser—an automated system that invests clients' money according to academically vetted principles like Value-at-Risk or Strategic Asset Allocations, while personalizing investment portfolios to each retail investor.

Hopes are that Robo-Advisers not only increase the diversification of retail investors, reduce the variance of their portfolio and attenuate biases that retail investors have when trading stocks, but also that more individuals start actively investing in the stock market. The Robo-Adviser's (frequent) trading is easily observable, as daily emails inform the retail investor of all the trades done by the Robo-Adviser. This straightforward observation of the Robo-Adviser's trading means that retail investors can easily get real-time feedback on what the Robo-Adviser is doing and how the investments are paying off, compared to traditional financial advice. This real-time feedback can influence the retail investors when investing money outside the Robo-Adviser, in the retail investor's active portfolio. For example, observing the lower volatility from diversification may have led the retail investor to diversify the portfolio she/he actively manages.

At the same time, the complete automation of Robo-Advisers can also lead to unwanted consequences. The retail investor's preferences are captured via a survey that might not adequately capture the retail investor's preferences and result in an undesirable portfolio allocation[2]. This problem is not unique to Robo-Advisers but instead arises whenever investing is delegated. Still, a multiple-choice survey may have more difficulty determining the preferences than a face-to-face conversation. Furthermore, the real-time information about the Robo-Adviser's trading may also have negative influences. For example, if retail investors replicate the Robo-Adviser's frequent trading, the retail investor's active portfolio's returns may reduce as fees rack up.

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[2]The question of whether the Robo-Adviser chooses a suitable investment strategy for each retail investor is beyond the scope of this paper. While we do know the asset classes that are invested in, we do not know the weights of the invidual securities and importantly do not observe the survey responses to determine whether the allocation is suitable.

This paper studies the benefits of FinTech to consumers contributing to our understanding of the problems laid out in (Goldstein, Jiang, & Karolyi, 2019). The closest paper to ours is (D'Acunto, Prabhala, & Rossi, 2019), which studies the effects of using software that provides additional advice when deciding how to trade. (D'Acunto, Prabhala, & Rossi, 2019) study a very human-driven investment process, where the retail investor has to decide when to trade. For each trade, she has to decide whether to use the software for suggestions and then decide to follow the software's suggestions. Our study instead studies a fully automated investment process. The Robo-Adviser decides when and what to trade without any human intervention. (Abraham, Schmukler, & Tessada, 2019) propose this definition of a Robo-Adviser and, to our knowledge, our study is the first to study Robo-Advisers as covered under their definition. (D'Hondt, Winne, Ghysels, & Raymond, 2019) attempt to study a fully automated Robo-Adviser but rely on simulating a Robo-Adviser's behavior, rather than using a Robo-Adviser's actual trading, as we do. Furthermore, our study considers that using a Robo-Advisers is not binary, meaning that the Robo-Advisers manages either no or all investor investments. Instead, the investor can ask the Robo-Advisor to manage only a part of her portfolio. Thus, the investor continues to invest the other part of her portfolio actively. As we observe this management of the other part, we can examine how the retail investor's behavior changes after adopting the Robo-Adviser.

This paper aims to determine whether Robo-Advisers encourage new households to invest in financial markets and whether existing retail investors benefit from Robo-Advisers. To accomplish this aim, we examine how many investors in Robo-Advisers are new to the financial market and how many are not. For the latter, we determine whether the Robo-Adviser helps retail investors increase their returns across their whole portfolio, not just the portfolio invested with the Robo-Adviser.

We use a proprietary data set from a bank cooperating with one of the largest Robo-Adviser in Germany. This data set's unique feature is that we observe retail investors' behavior using a Robo-Adviser and retail investors not using the Robo-Adviser. Furthermore, we follow the behavior of the users before and after using the Robo-Adviser.

Given the low participation of households in financial markets, especially in Germany, and the difficulty in increasing participation in financial markets, any increase in the participation in financial markets is beneficial. Examining a balanced panel of bank customers, including bank customers that invest with the Robo-Adviser (Robo-Adviser users) and bank customers that do not invest with the Robo-Adviser (control group), we find that a large portion of Robo-Adviser users had previously not participated in financial markets. When Robo-Adviser was first introduced in 2017, we observed that 35% of Robo-Adviser users have previously not participated in financial markets. For the control group, this fraction was only 5%. While we cannot rule out that these households own investment portfolios at other banks, we have reason to believe that these bank customers did not own a bank account at another bank. Furthermore, our analysis shows that these new retail investors would not have participated in financial markets if the Robo-Adviser would not have been there. While participation in financial markets can lead to significant losses if invested carelessly, Robo-Advisers provide retail investors with high diversification, reducing the risks when investing. Our central result is that the Robo-Adviser lives up to his promise and increases participation in financial markets by appealing to people that otherwise would not participate in financial markets.

While Robo-Advisers attract many households to become retail investors, investing with a Robo-Adviser is not a binary choice. Instead, the majority of Robo-Adviser users invest actively on their own and with the Robo-Adviser. These Robo-Adviser users mainly use the Robo-Adviser as a gimmick, investing close to the minimum required

amount with the Robo-Adviser. Thus, the most pronounced effect the Robo-Adviser can have on these investors is changing how the Robo-Adviser users manage their active portfolio[3]. We compare Robo-Adviser users' active portfolio with control group retail investors' active portfolio by utilizing a difference-in-difference regression and controlling for observable characteristics before the Robo-Adviser introduction[4].

The Robo-Adviser investment differs from retail investor's investing by being more diversified and trading much more frequently.Looking at the margins of trading frequency and diversification of the actively managed portfolio, we find no evidence of any change in existing retail investors' investment behavior. We conclude that retail investors already participating in financial markets do not benefit from the Robo-Adviser.

We conclude that the Robo-Adviser increases participation in financial markets by attracting retail investors who would have otherwise not participated in financial markets, possibly due to their perceived lack of financial literacy. Furthermore, the initial investment amounts appear as a barrier to adoption. Many retail investors invest at or near the minimum investment amount, indicating they would ideally invest a lower amount. Furthermore, for retail investors already participating in financial markets or ready to invest on their own in financial markets, the Robo-Adviser does not seem beneficial. However, given the limited usage of Robo-Adviser by existing retail investors, the gains of attracting new investors to financial markets outweigh the potential losses, in the form of higher fees, to the existing retail investors.

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[3] If the Robo-Adviser holds only a small part of the retail investor's wealth in financial market any benefit or cost on that part is small with respect to the whole portfolio. However, if the Robo-Adviser influences the behavior of the retail investor the consequences affect the large actively managed portfolio.

[4] Furthermore, in non-reported results we conduct a propensity score matching based on characteristics before the Robo-Adviser introduction and find very similar results.

# 2. Background

## 2.1 Description of Robo-Adviser

A Robo-Adviser is a product offered by a financial services company. The product is fully automated, requiring no human intervention to function (Abraham, Schmukler, & Tessada, 2019). Investing with a Robo-Adviser starts with the onboarding process. After filling out a survey, the retail investor's response gets translated into an investment strategy in an automated way. It continues with the investment, where the Robo-Adviser, an algorithm, automatically decides what and when to trade. This description of a Robo-Adviser, put forward by the World Bank in (Abraham, Schmukler, & Tessada, 2019), differs markedly from the product studied in (D'Acunto, Prabhala, & Rossi, 2019), where the retail investor has to choose to use the software for every trade, and then the retail investor decides to follow or deviate from the recommendation of the software.

### 2.1.1 Personalized Advice by a Robo-Adviser

Through the cooperation of the bank and firm offering the Robo-Adviser, the retail investor can open an account to manage his money by the Robo-Adviser through this bank directly[5]. The retail investor begins the process by filling out a survey that aims to understand the retail investor's investment preferences. Questions in the survey include the length of the investment horizon, literacy of financial products, income, wealth, liquid wealth, and investment aim.

After the retail investor has completed the survey, the retail investors' answers are translated into a Value-at-Risk which the Robo-Adviser targets. The Robo-Adviser then invests the money entrusted to it by the retail investor according to the Value-at-Risk corresponding to the survey and based on the Robo-Adviser's calculation of the different asset classes' moments. The Robo-Adviser invests in various asset classes exclusively through ETFs. ETFs cover the investment classes stocks, sovereign bonds, corporate bonds, covered bonds, real estate, and commodities and covering the regions, Europe, USA, Japan, Asia excluding Japan and Emerging Markets. All ETFs have a Total Expense Ratio between 0.07% and 0.40% per year. The Robo-Adviser uses the same ETF for an asset class across all Robo-Adviser users, so the same ETF always represents European stocks for all Robo-Adviser users.

After the Robo-Adviser allocates the money, the Robo-Adviser decides when to rebalance the portfolio and how to differ the asset allocation to maintain the Value-at-Risk target. The fees paid by the retail investor to the bank and the Robo-Adviser firm cover the costs of these trades.

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[5] All Robo-Adviser's cooperate with a bank, but generally with a lesser known smaller bank. The retail investor's money is kept at the bank and the firm offering the Robo-Adviser has authority to execute orders on the retail investor's account.

Given that the portfolio is at the bank, the retail investor sees the Robo-Adviser portfolio separated from his portfolio but equally saliently. The retail investor receives emails for all trades done by the Robo-Adviser shortly after the trade execution[6].

### 2.1.2 *Investment behavior of a Robo-Adviser*

To guide the analysis from now on, we compare the Robo-Adviser's behavior to the retail investor's behavior. As laid out below, we study portfolio characteristics, so only aspects where the Robo-Adviser differs from retail investors should lead to differently good portfolios.

The first difference comes directly from the investment style of the Robo-Adviser. By only investing in ETFs, the Robo-Adviser will manage a highly diversified portfolio and remove any idiosyncratic risk. Individual retail investors are much more exposed to idiosyncratic risk. They often hold single stocks and no ETFs or Mutual Funds, with 20% of the Robo-Adviser Customers and almost 40% of the Control Group holding no ETFs or Mutual Funds[7]. Furthermore, holding only 10 securities on average, retail investors do not achieve diversification through holding individual stocks.

A second difference is the trading frequency by the Robo-Adviser. The Robo-Adviser trades much more frequently than retail investors do, as Figure 1 shows, and comparing these 82.99 trades by the Robo-Adviser to the 21.85 trades by the Robo-Adviser Users in 2016 from Table 1. Implementing this large number of trades would be very costly for the retail investor, as they pay at least 4.95 Euro in fees to the bank per trade. Thus, trading this frequently would lead to at least an additional 302.64 Euro (=$4.95 \times (82.99 - 21.85)$) in trading cost per year, three times the current (estimated) trading cost. The large number of Robo-Adviser trades come from rebalancing the portfolio, where every time the Robo-Adviser decides to sell a little from a few ETFs, while simultaneously a few other ETFs are bought a little, thereby slightly changing each constituent's weight in the portfolio. The Robo-Adviser achieves much lower costs through two steps. Firstly, the Robo-Adviser nets trading positions across Robo-Adviser users, leading to a small net trade compared to the many gross trades across users. Secondly, the Robo-Adviser has lower fees for trading by not paying a commission per trade. From the perspective of the Robo-Adviser user, the Robo-Adviser user only pays a fixed management fee, which includes the trading cost.

We will use these two differences in behavior between the Robo-Adviser and retail investors to study whether the Robo-Adviser benefits retail investors.

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[6] Most often the Robo-Adviser trades many securities when trading, but trades relatively infrequently. So an investor is not swamped weekly by emails about the Robo-Advisor's trading.

[7] One might imagine Robo-Advisers being less prone to behavioral biases. However, while Robo-Advisers through their non-human nature cannot be prone to behavioral biases, data mining and other quantitative strategies may lead to similar adverse effects in trading.

**Figure 1**: Number of Trades by the Robo-Adviser
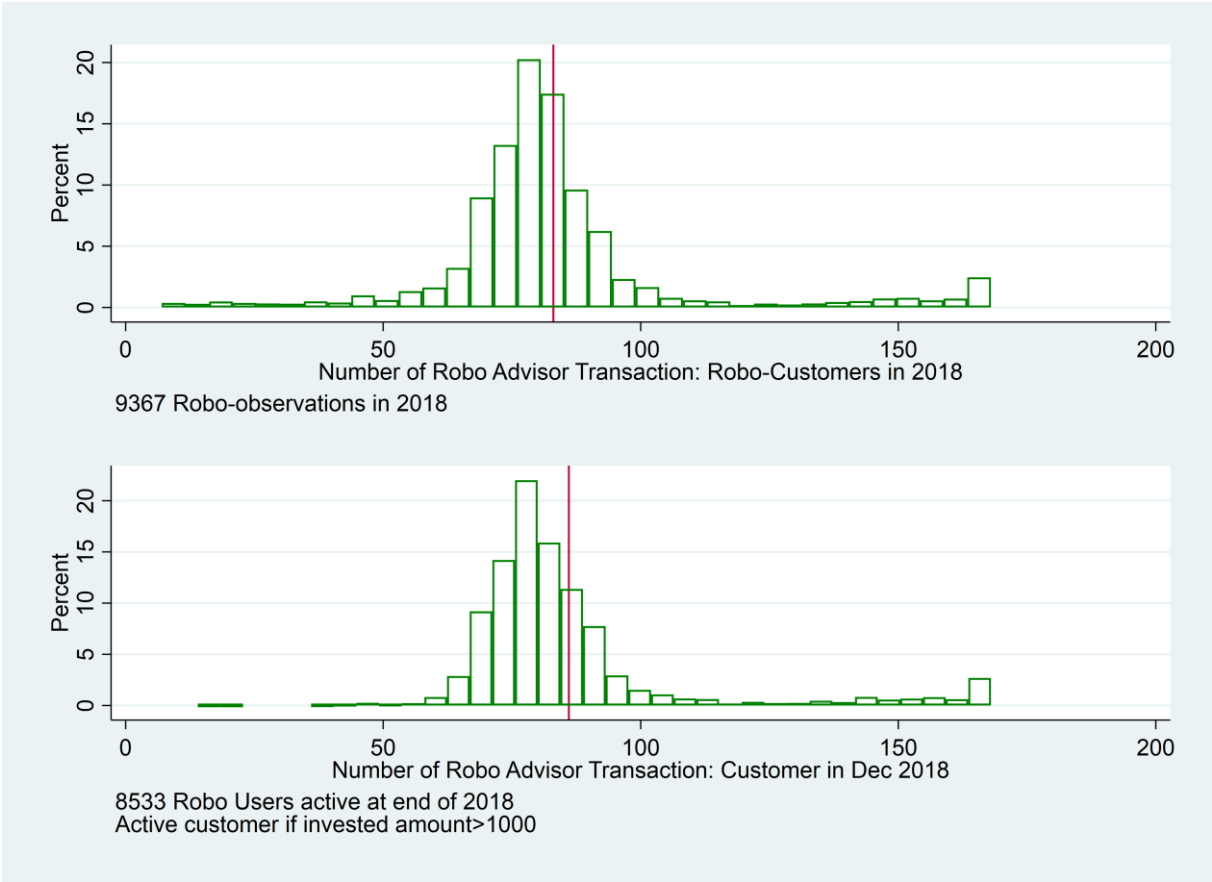


*Note*: This histogram shows the number of trades by the Robo-Adviser in 2018. The top graph shows the number of trades by the Robo-Adviser in 2018 across all Robo-Adviser users in 2017. The bottom graph restricts the sample to Robo-Adviser users who invest money with the Robo-Adviser in 2017 and 2018.

## 2.2 Theoretical Framework

### 2.2.1 Effects of the Choice to Invest with the Robo-Adviser

Our data observes three portfolios, two for Robo-Adviser users and one for control group retail investors. For Robo-Adviser users, we observe the portfolio managed by the Robo-Adviser and the retail investor's active portfolio, which the Robo-Adviser user manages. While for control group retail investors, we observe their active portfolio. As we lay out below, our empirical results argue that the Robo-Adviser should mainly affect Robo-Adviser's portfolio through its effects on the retail investor's active portfolio. Therefore, we compare the active portfolio of Robo-Adviser users with the active portfolio of the control group retail investors in a difference-in-difference regression.

Since both types of retail investors are bank customers, they have the choice to invest with the Robo-Adviser, but only Robo-Adviser users decide to do so. Not all retail investors are equally likely to invest with the Robo-Adviser. Therefore, Robo-Adviser users and control group retail investors are likely different. Therefore, we include retail investor's observable characteristics before the Robo-Adviser introduction in the regression. Thereby, we only compare similar Robo-Adviser users and the control group retail investors. We also performed propensity score matching on the pre-Robo-Adviser introduction retail investor's characteristics. Those results are not reported but are qualitatively similar.

Next, we describe how we evaluate the three portfolios and describe under which conditions we compare which of the two portfolios with each other.

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### 2.2.2 Evaluating Good and Bad Portfolios

Robo-Advisers are a very recent phenomenon. Thus, the time series of Robo-Adviser's behavior is very limited, spanning two years in our data. Therefore any observed returns will be driven by the time series specific return of an asset class, e.g., Bonds vs. Stocks or German stocks vs. US stocks. To remove this luck component, we will focus on the characteristics of a portfolio, such as diversification or biases. Retail investors display biases in their trading, for example, (Barber & Odean, 2000) show that trading very frequently does not increase returns but instead produces costs that can reduce the post-cost returns by 40%. In addition, many retail investors lack diversification in their portfolios. We will study whether the Robo-Adviser reduces the biases and increases diversification in the total portfolio, combining the Robo-Adviser's portfolio and the Robo-Adviser user's portfolio. If diversification increases or biases reduce, these changes would allow the Robo-Adviser to achieve higher returns in the long run.

Focusing on the characteristics of a portfolio, like diversification or the number of trades in a period, replaces the realized return as the very noisy and business cycle biased estimate for expected return[8], by characteristics of portfolios as the estimate for the expected return[9]. This approach relies on determining the characteristics of a good portfolio—we lay out the characteristics describing a good portfolio shortly.

### 2.2.3 Determinants of a Good Portfolio

A good portfolio's characteristics might be debatable to some degree, but it clearly contains two following two characteristics. The first characteristic is diversification. In the absence of precise insider information, retail investors should not invest in only a few stocks but instead diversify by holding many stocks of a benchmark or an index product on the benchmark. The second characteristic is the cost of the portfolio, as good portfolios should have low fees. Fees include both fees to mutual fund managers but also trading fees. We focus on the latter to avoid discussing whether fees to mutual fund managers are justified or not (see, for example (Barras, Scaillet, & Wermers, 2010; Fama & French, 2010)). Nevertheless, (Barber & Odean, 2000) support this view as they find that trading frequently does not increase the return but incurs substantial costs.

These two characteristics are arguably essential characteristics of a portfolio, as diversification allows investors to reduce their portfolio volatility by 50%. The average stock has the same return as the market but twice the volatility of the market. Transaction cost can quickly reduce the post-cost return of a portfolio by 40%, as (Barber & Odean, 2000) have shown. So, both of these characteristics have the potential to change the return of a portfolio in a meaningful way.

### 2.2.4 Robo-Adviser's (potential) Influence on Portfolio Characteristics

When focusing on the characteristics of a good portfolio, it is essential to determine which characteristics to study and which characteristics can plausibly change. The first restriction will on be restricting what characteristics we will examine. We only focus on characteristics where the Robo-Adviser's portfolio differs from the retail investor's portfolio. Characteristics that the Robo-Adviser and the retail investor implement the same should lead to similar

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[8] Not even for many retail investors does the realized average return represent the true average return due to the effect of the market. Basically, the time series is too short to construct an unconditional average.

[9] We have the following framework in mind. An investor decides an investment strategy $\theta_i$. Implementing the investment strategy $\theta_i$ produces a portfolio $P(\theta_i)$. We are interested in determining the return and volatility of the portfolio $P(\theta_i)$. Given the short time period, measuring the unconditional expected returns via the realized returns is impossible. However, $\theta_i$ gives us a portfolio $P(\theta_i)$. The properties of this portfolio can be much better mapped to expected returns or volatility. For example diversification should lower volatility or more frequent trading at some point should reduce returns, if a fixed cost is paid per trade. Thus analyzing the portfolio $P(\theta_i)$ instead of the return allows for a clearer inference on the expected return.

expected returns. Therefore, only among characteristics where the Robo-Adviser behaves differently from the retail investor should expected returns differ. Furthermore, when studying the actively managed part of the retail investor's portfolio, the characteristics that differ from the Robo-Adviser could change from observing the behavior of the Robo-Adviser. Thus, the Robo-Adviser may influence how the retail investor invests in their active portfolio.

As seen above, the most significant differences in the portfolio characteristics between the retail investor's active portfolio and the Robo-Adviser's portfolio are the trading frequency and the diversification of the Robo-Adviser. These two characteristics incidentally are also the characteristics that are unequivocally part of a good portfolio. In the analysis going forward, we, therefore, focus on these two characteristics.

### 2.2.5 *Positive and Negative Changes of Retail Investor's Portfolio Characteristics*

The Robo-Adviser's portfolio is by construction diversified. The Robo-Adviser chooses only from a universe of 13 ETFs, which all have a sufficient number of holdings and are, therefore, by construction, highly diversified. On the other hand, retail investors choose not only from ETFs or Mutual Funds but also from individual stocks. Observing an increase in the ETF and Mutual Fund Share in the portfolio is likely associated with an increase in diversification, which we deem favorable. Furthermore, suppose the Robo-Adviser replaces individual stocks that the retail investor would have owned with ETFs, which the Robo-Adviser selected. In that case, we consider this replacement also as positive for the portfolio.

Robo-Adviser pays no commission[10] on an individual trade, we observe the Robo-Adviser trading much more frequently. On the other hand, the retail investor pays a commission for every trade she does, making trading much more costly. In Mifid II (introduced in January 2019), the EU requires banks and brokers to inform retail investors of trading costs pre-trade. However, this information was not readily available during our sample period. The fact that information on trading cost is later mandated suggests that retail investors did not understand or know the magnitude of trading cost. Observing the Robo-Adviser trading frequently and the academically vetted nature of the investment approach may lead the Robo-Adviser user to reasonably infer that frequent trading is beneficial. Instead, frequent trading creates higher trading costs for the retail investor. Therefore, observing an increasing trading frequency for the active portfolio of retail investors is considered negatively. In contrast, the Robo-Adviser's frequent trading is not viewed as unfavorable since there are no costs per trade to the investor[11].

### 2.2.6 *Importance of Retail Investor's and Robo-Adviser's Portfolio to the Retail Investor*

Finally, we explain how to compare the Robo-Adviser's portfolio with the retail investor's portfolio. Robo-Adviser users may have an active portfolio managed by themselves besides the portfolio with the Robo-Adviser, both of which constitute the retail investor's total portfolio. Changes in either portfolio's characteristics affect the characteristics of the combined portfolio.

Firstly, once investing with the Robo-Adviser, the fraction of money managed actively by the retail investor decreases. As the Robo-Adviser and the retail investor may differ in their investment behavior, i.e., their respective portfolios have different characteristics, the characteristic of the combined portfolio may change. We call changes

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[10] The retail investor faces no cost when the Robo-Advisor trades, except potentially the bid-ask spread, but the Robo-Adviser pays the bank additional costs, when completing more than 100 trades a year.
[11] One could argue that many trades by the Robo-Adviser create costs that have to be paid for. These cost could be passed on to the customer via the flat fee, however the pass-through cannot be determined. In addition, the trading fees paid the Robo-Adviser are much smaller than for the retail investor, which means that the Robo-Adviser should be trading more frequently.

due to the differences in characteristics of the Robo-Adviser's and the retail investor's active portfolio the composition channel. These changes arise since the difference in the composition of characteristics between the Robo-Adviser's and the retail investor's portfolio is the cause of these changes.

Secondly, investing with the Robo-Adviser may lead to changes in how the retail investor invests her money, changing the characteristics of her active portfolio. These changes arise from observing the investment behavior of the Robo-Adviser. These changes again affect the characteristics of the retail investor's combined portfolio. As these changes spillover from the Robo-Adviser to the retail investor, we call these changes the spillover channel.

Suppose the retail investor invests most of his wealth with the Robo-Adviser. In that case, the composition channel will determine the combined portfolio's characteristics. The spillover channel only affects the active portfolio, which only has a minor influence on the combined portfolio. However, suppose the retail investor invests only a little wealth with the Robo-Adviser. In that case, the spillover channel will likely dominate, as the composition channel from investing with the Robo-Adviser only exerts a minor influence on the combined portfolio.

For the composition channel, the comparison between the Robo-Adviser portfolio and the counterfactual active portfolio, i.e., the active portfolio of a comparable control group retail investor, is necessary to analyze. To test the spillover channel, we compare the active retail investor's actual active portfolio to the counterfactual active portfolio, i.e., the control group retail investor's active portfolio. Thus, the analysis and comparison group rest upon how the retail investors invest with the Robo-Adviser, especially concerning the investment amount.

# 3. Data Description

3.1 **Data Source**

In this study, we worked with a large German retail bank. The bank specializes in low overhead costs, providing no bank branches and instead opting for a pure online banking platform. Thus, our sample consists of retail investors that are internet-affine. In October 2017, the bank started cooperating with a market leader in Robo-Advising services in Germany (based on amount managed), allowing the bank's customers to manage money with the Robo-Adviser. The bank's customers did not have to open another bank account, thus observing the Robo-Adviser's transactions within their bank account, although markedly separated. The service costs a yearly rate in the area of 0.5-0.8%, similar to other Robo-Advisers. These fees cover the service costs for both the bank and the Robo-Advising company. Only the expenses of the underlying ETFs that the Robo-Adviser buys. Signing up directly with the Robo-Adviser is arguably more difficult for the bank's customers since it requires opening up a new bank account at another bank, which is much smaller, on top of the investment mandate to the Robo-Adviser.

Furthermore, the fees paid when signing up directly with the Robo-Adviser are unchanged. Thus, bank customers who open an account with the Robo-Adviser are likely to do so via the bank. Furthermore, the bank takes pride in itself with a lean and straightforward product lineup that does not include an in-house active management service. Therefore, the bank does not suffer from an incentive problem to advise the product to its customers[12]. The minimum money to have managed by the Robo-Advising firm is 10,000 Euro.

We observe all customers that invest with the Robo-Adviser in 2017, the year of the Robo-Adviser introduction. At the end of years 2016, 2017, and 2018, we see the funds managed by the Robo-Adviser for them and the trades completed by the Robo-Adviser, and the money invested in financial markets under these retail investors' control. From now on, we call the funds not managed by the Robo-Adviser the retail investor's active portfolio, as the retail investor has active control about how to invest the money not under the Robo-Adviser's control. The portfolio allows us to see the asset classes invested in, the amount in each asset class, the number of securities held, the number of buys and sells each year, and the corresponding trading volumes.

We observed a random sample of 10,000 retail investors that held at least 10,000 Euro in their account at the end of 2017, and traded at least once in 2017. These restrictions apply to have a comparable sample to the retail investors using the Robo-Adviser without removing the selection. 10,000 Euros invested was chosen as this is the minimum investment with the Robo-Adviser. We used one trade to ensure that the retail investors undertook at least one investment decision in 2017, as the retail investors using the Robo-Adviser did. We observe their active portfolio for these non-Robo-Adviser retail investors in the same detail as we do for the Robo-Adviser retail investors and observe each of these retail investors in 2016, 2017, 2018.

We assume that all bank customers observed in this sample have an investment portfolio with this bank. If they have an investment portfolio, i.e., if a retail investor is a bank customer and has an investment account, they have an investment account at the bank. This assumption allows us to conclude that retail investors with no portfolio at the bank in 2016 were not participating in financial markets.

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[12] As seen below, some banks closed their Robo-Advisers in 2018. However, they did have an in-house active management service that demanded larger fees than the Robo-Adviser.

We believe this assumption is reasonable as the bank provides comparatively cheaper brokerage services than other full-online banks with brokerage services. The bank charges both lower fixed commission and variable commission than comparable large banks in Germany, leading us to estimate that the trading cost is at least 10% lower at this bank. Therefore, opening a brokerage account with this bank is cheaper. Thus, even if the bank customers have additional bank accounts, they would have their portfolio with the given bank.

This assumption is especially important for the later Robo-Adviser users. At the time of the Robo-Adviser introduction, other major German banks introduced their own Robo-Adviser earlier in the same year. The other banks' Robo-Advisers invest similarly and fee-wise are similar to the Robo-Adviser studied in this paper. Therefore, bank customers that were not trading with this bank but already had a portfolio at another bank would likely use the other banks Robo-Adviser. There they would have all their portfolios in one place and could easier monitor the effects of market movements on their portfolio. Thus, we believe that later Robo-Adviser users either had a portfolio at the bank or no portfolio at all.

## 3.2 Description of all Retail Investors investing in 2016

The sample consists of 9,551 Robo-Adviser users and 9,767 retail investors in the control group. Many of these investors in both groups only start investing in 2017. To compare the groups before introducing the Robo-Adviser, Table 1 shows the summary statistics for the treatment group (Robo-Adviser users) and control group (retail investors in the control group) in 2016. It also outlines the differences between the groups. We restrict these groups to active retail investors in 2016. A retail investor is active if the retail investor has at least 2000 Euro in his portfolio at the end of the year, bought Securities valued at 2000 Euro, or sold Securities valued at 2000 Euro[13].

Table 1 depicts differences in the portfolios of the Robo-Adviser users and the retail investors in the control group. While the portfolio value is almost identical across the groups, the allocation is very different. Retail investors in the control group mainly invest in stocks, with 80.38% owning stocks and investing on average more than half their wealth in stocks, leading to a mean stock holding of an extra 12,217.92 Euro Robo-Adviser users. Later Robo-Adviser users[14] instead are much more open to diversified products such as ETFs and Mutual Funds. They are 18.36 and 12.83 percentage points more likely to hold ETFs or Mutual Funds. The 12,217.92 Euro invested more into stocks by the retail investors in the control group is invested into ETFs and Mutual Funds by the later Robo-Adviser users. This difference in ETF and Mutual Fund ownership is the main difference. It shows that Robo-Adviser users are already more diversified[15] before the Robo-Adviser introduction. While academics have long taught the benefits of diversification, diversification only entered with the recent rise of passive investing through, for example, ETFs. Given only the recent rise of passive investing, many investors may not know or understand the benefits of diversification, thereby being put off by Robo-Advisers[16].

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[13] These restrictions remove mainly retail investor's with portfolio in 2016.

[14] We are looking at 2016, so these retail investors only later adopt the Robo-Adviser.

[15] The fact that the number of securities is the same across groups and only 10, highlights that the retail investors in the control group do not replicate the diversification by simply buying many stocks in the index.

[16] However, still at least 50% of control group retail investors own ETFs or Mutual Funds. Alternatively, ETFs and Mutual Funds are not just diversified but also delegate the investment decision. The higher likelihood of ETFs and Mutual Funds among Robo-Adviser users may therefore represent the higher propensity to delegate investing in general.

The Robo-Adviser users are also more likely to invest money into derivatives, which go by the name of "Zertifikate" in Germany. In contrast, the total value invested in them is generally tiny. Furthermore, Robo-Adviser users seem to less likely to be female, more often male, and attract more Joint Accounts[17]. Finally, the Robo-Adviser users trade more often by having three more trades in 2016, which they realize by trading a smaller quantity per trade, as the total trade volume is the same.

**Table 1**: Summary Statistics of Active Retail Investors:

|  | Control Group | | Robo-Adviser Users | | Difference | |
|---|---|---|---|---|---|---|
|  | mean | sd | mean | sd | b | t |
| Female | 0.2003 | 0.4002 | 0.1061 | 0.3080 | 0.0942*** | (15.53) |
| Male | 0.5720 | 0.4948 | 0.6285 | 0.4832 | -0.0565*** | (-6.96) |
| Age | 53.35 | 16.18 | 53.42 | 12.84 | -0.07 | (-0.28) |
| Years being Customer | 12.23 | 4.91 | 12.89 | 4.84 | -0.66*** | (-8.18) |
| Portfolio Value | 78882.16 | 113638.31 | 80413.80 | 119503.40 | -1531.64 | (-0.80) |
| Portfolio Age | 8.37 | 4.93 | 8.37 | 4.99 | 0.00 | (0.01) |
| Stock Ind. | 0.8038 | 0.3971 | 0.7377 | 0.4399 | 0.0661*** | (9.61) |
| Bond Ind. | 0.1323 | 0.3388 | 0.1657 | 0.3718 | -0.0334*** | (-5.71) |
| ETF Ind. | 0.3130 | 0.4637 | 0.4966 | 0.5000 | -0.1836*** | (-23.14) |
| Mutual Fund Ind. | 0.5081 | 0.5000 | 0.6364 | 0.4811 | -0.1283*** | (-15.71) |
| Levered Prod. Ind. | 0.0371 | 0.1890 | 0.0353 | 0.1846 | 0.0018 | (0.57) |
| Derivative Ind. | 0.1009 | 0.3012 | 0.1591 | 0.3658 | -0.0583*** | (-10.69) |
| Other Security Ind | 0.0311 | 0.1736 | 0.0296 | 0.1694 | 0.0016 | (0.54) |
| Stock Value | 48750.30 | 93638.14 | 36532.38 | 78845.21 | 12217.92*** | (8.37) |
| Bond Value | 3380.27 | 15144.07 | 3613.88 | 14946.22 | -233.61 | (-0.94) |
| ETF Value | 8163.75 | 25300.40 | 13442.25 | 30472.64 | -5278.50*** | (-11.58) |
| Mutual Fund Value | 17376.35 | 38537.33 | 24799.20 | 46645.86 | -7422.84*** | (-10.66) |
| Levered Prod. Value | 111.10 | 739.60 | 110.89 | 742.59 | 0.22 | (0.02) |
| Derivative Value | 1029.60 | 4810.74 | 1838.30 | 6436.96 | -808.70*** | (-8.83) |
| Other Security Value | 70.79 | 562.24 | 76.92 | 586.29 | -6.12 | (-0.65) |
| # Buys | 13.48 | 23.76 | 16.82 | 27.58 | -3.34*** | (-7.95) |
| # Trades | 18.63 | 33.58 | 21.85 | 36.28 | -3.23*** | (-5.61) |
| # Sells | 5.24 | 12.64 | 4.99 | 12.10 | 0.24 | (1.17) |
| Buy Volume | 39745.33 | 101224.91 | 39629.90 | 93597.63 | 115.43 | (0.07) |
| Sell Volume | -30792.39 | 92197.54 | -29193.10 | 85782.91 | -1599.29 | (-1.08) |
| # Asset Classes | 1.92 | 1.00 | 2.25 | 1.14 | -0.33*** | (-18.69) |
| # Securities | 10.21 | 10.13 | 10.52 | 10.85 | -0.31 | (-1.77) |
| N | 9032 | | 6089 | | 15121 | |

*Note*: This table shows the Summary Statistics for active retail investors in 2016. A retail investor is active if the retail investor had at least 2000 Euro in his portfolio at the end of 2016 or bought/sold 2000 Euro in stocks.

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[17] Joint Accounts are the difference between the Percentage of Female and the Percentage of Males and make up 22.77% of the control group accounts and 26.64% of the Robo-Adviser users.

# 4. Results

Households' participation in Financial Markets is low, and the hope is that Robo-Advisers will increase their participation in Financial Markets.

Understanding why a retail investor in 2017 might not have a portfolio in 2016 can be due to two reasons. First, the bank customer was a bank customer in 2016 but did not have a portfolio with the bank. Secondly, the bank customer was not yet a customer with the bank in 2016 and joined only in 2017. Our analysis excludes the second group of new bank customers, as they might have held a portfolio at another bank. The bank provides trading services at lower costs than the closest competitors, and the closest competitors have also introduced Robo-Advisers. Therefore, we have no reason to believe that the first group was not active in financial markets in 2016 and are genuinely new traders (see Section 3.1).

**Figure 2**: Share of Retail Investors Newly Participating in the Financial Market:
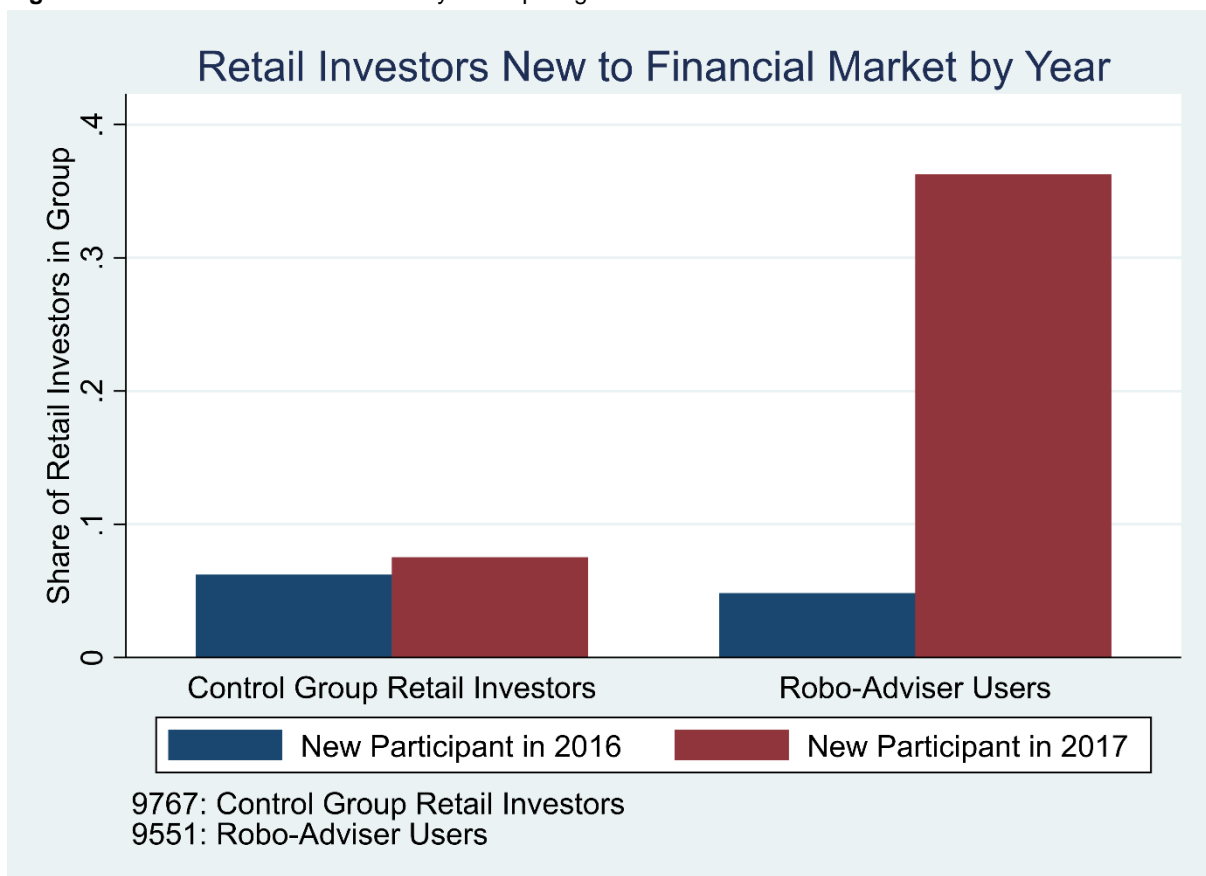


*Note*: This bar graph shows the share of new participants in financial markets for 2016 and 2017 in both the control group of retail investors and Robo-Adviser users. We classify a retail investor as a new participant in financial markets if the retail investor starts investing with either the Robo-Adviser or in an active portfolio for the first time that year.

Figure 2 shows that in 2016, roughly 5% of retail investors in both the control group and the group of Robo-Adviser users were new to financial markets. However, in 2017, Figure 2 shows that a substantial fraction of Robo-Adviser users (who are bank customers in 2016), namely 36.25%, are new participants in financial markets. Compared to

the control group of retail investors, this group of retail investors newly participating in financial markets makes up only 7%. Thus, a much larger share of Robo-Adviser users is new to financial markets. They have previously not had an active portfolio with the bank than retail investors in the control group. Thus, showing that the Robo-Adviser attracts 3,462 new households to participate in financial markets newly.

While these investors are new investors to financial markets, the comparison does not reveal whether these investors would have invested in financial markets if the Robo-Adviser were not introduced. To address these concerns, we calculate whether the monthly number of new retail investors per month in 2017 changes after introducing the Robo-Adviser in October 2017[18]. Panel A of Table 2 compares the monthly number of new traders in the control group pre- and post-Robo-Adviser introduction. When looking at the accounts' opening throughout the year, we observe seasonal patterns with many accounts being opened at the beginning of the year. Thus, creating a bias predicting the number of new traders per month decreases at the end of the year. Therefore, finding no significant change in the number of new traders per month after introducing the Robo-Adviser underlines that these investors would have otherwise not participated in financial markets.

Panel B of Table 2 provides further support for these results. As there may be seasonal differences in the monthly number of new participants in financial markets across the year, Panel B includes the variable *Prob. to Trade$_i$* which is the probability that a new participant in financial markets starts trading in month *i*. *Prob. to Trade*'s coefficient thus reports the number of new participants that year. Specification (1) in Table 2 shows the results from Panel A again. In Specification (2), we utilize only *Prob. to Trade* without a constant, which shows that the number of monthly new participants in financial markets dropped by an insignificant 0.467 traders, which represents a drop of less than $1\% (= \frac{0.467}{\frac{529}{11}})$ in the number of monthly new participants in financial markets. Specification (3) introduces a constant and continues to find very similar insignificant effects.

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[18] The post-Robo-Adviser introduction period are months October and November. The sample construction introduced no new investors in December 2017.

**Table 2**: Monthly New Control Group Retail Investors Pre- and Post-Robo Adviser Introduction:

| | Pre-Robo | | Post-Robo | | Difference | |
|---|---|---|---|---|---|---|
| | mean | sd | mean | sd | b | t |
| New Traders per Month | 48.78 | 20.77 | 45.00 | 19.80 | 3.78 | (0.23) |
| $N$ | 9 | | 2 | | 11 | |

**(a) Panel A: Comparison in means**

| | (1) | (2) | (3) |
|---|---|---|---|
| | New Traders per Month | | |
| Post Robo-Introduction | -3.778 | -0.467 | -1.435 |
| | (-0.29) | (-0.04) | (-0.12) |
| Prob. to trade | | 465.8*** | 408.9* |
| | | (9.24) | (2.57) |
| Constant | 48.78*** | | 6.523 |
| | (6.76) | | (0.40) |
| N | 11 | 11 | 11 |
| $R^2$ | 0.00604 | 0.927 | 0.459 |

*Note*: This Table reports the difference in the number of traders pre- and post-Robo-Adviser introduction. Panel A reports the difference in means pre- and post-Robo-Adviser introduction. In contrast, Panel B controls once for the seasonal effects of starting to trade. Since new investors in December were excluded in the sample construction, we exclude the month of December is excluded in Panel A and Panel B. Panel A: Comparison in means. Panel B: This table is based on regressions to control for additional factors. Specification (1) tests whether the means differ pre- and post-Robo-Adviser introduction. Specification (2) and Specification (3) control for the difference in the probability of starting to trade each month (*Prob. to Trade*). *Prob. to Trade* is constructed as the average yearly distribution of new traders across a year. It is calculated as $Prob.to\ trade_i = \frac{1}{T}\sum_{s=1}^{T}\frac{\#\ New\ Traders\ in\ month\ i\ in\ Year\ s}{\#\ New\ Traders\ in\ Year\ s}$.

We, therefore, conclude that the Robo-Adviser does not motivate new active retail investors to invest with the Robo-Adviser instead of investing actively on their own, but rather motivates new households to participate in financial markets. So, the Robo-Adviser does not crowd out active investors. The Robo-Adviser, therefore, seems to attract many new retail investors to financial markets. It, therefore, seems to fulfill the hope of attracting especially new participants to financial markets, which is particularly crucial in a country like Germany, where only 16.2% of the population owns stocks through any participation. It, therefore, seems to contribute much to the overall welfare by encouraging new people to participate in financial markets.

### 4.2 Investment in the Robo-Adviser by Active retail investors in 2016

To evaluate the Robo-Adviser's benefits to active retail investors, it is crucial to determine the amount invested with the Robo-Adviser. As the Robo-Adviser requires a minimum investment of 10,000 Euro by the retail investor, the minimal mean fraction is already 28% (mean of $\frac{10,000}{10,000+\ Portfolio\ Value\ 2017}$)[19]. Panel A of Figure 3 shows that the average fraction of money invested with the Robo-Adviser is 34.55%, indicating that retail investor invests only a small part of their portfolio with the Robo-Adviser. Panel B of Figure 3 further confirms these findings. It shows

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[19] In unreported results we find that the investment in the Robo-Adviser is mainly extra money invested in Financial markets. While many results support that all money is additional investment, with no crowding out, the most conservative estimates find that the Net Investment (Buy Volume- Sell Volume) is only 10% of the total investment with the Robo-Adviser. Because even our largest estimates show that money invested with the Robo-Adviser is mainly additional investment into financial markets, we use $10,000 + Portfolio\ Value$ 2017 as the total wealth in financial markets.

that in 2017 40% of investors invest the minimum amount with the Robo-Adviser and 80% invest less than 20,000 Euro with the Robo-Adviser. In the analysis going forward, we focus on the actively managed portfolio and look for behavioral changes in the actively managed portfolio.

**Figure 3**: Distribution of Money Invested with the Robo-Adviser:
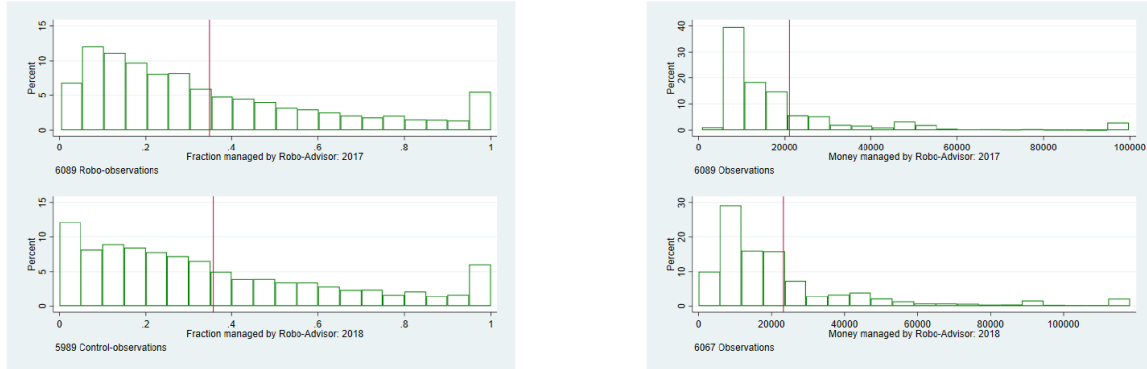


*Note*: The figure shows the distribution of the money invested with the Robo-Adviser in 2017. On the left-hand side (Panel A), it shows the fraction of the money managed by Robo-Adviser in comparison to the total investment in Financial Markets. In contrast, on the right-hand side (Panel B), the corresponding dollar amount distribution is shown for investment amounts smaller than 100,000 Euro.

### 4.3    Behavioral Changes in Active Portfolios by Active retail investors

Since Robo-Adviser users invest close to the Robo-Adviser's minimal possible amount, the overall portfolio's characteristics mainly change through the behavior channel. Therefore, we compare the Robo-Adviser users' active portfolio with the control group retail investors' portfolio. The characteristics of which time series are studied are *Diversified*, whether the investor holds ETFs or Mutual Funds in their active portfolio, *Number of Asset Classes*, the number of assets classes an investor invests in, with the most common asset classes being Stocks, Bonds, ETFs and Mutual Funds, *ETF Share*, the percentage of the active portfolio invested in ETFs, *Mutual Fund Share*, the percentage of investments invested in Mutual Funds, and *Number of Trades*, the number of times a retail investor trades during a year. We employ a difference in difference regression to control for the observable characteristics and compare a Robo-Adviser user to a comparable control group retail investor. Controlling for the observable characteristics of both the retail investor and the retail investor's portfolio in 2016, we treat the control group retail investor's active portfolio as the counterfactual active portfolio to the treated active portfolio of a Robo-Adviser user. We thus study the portfolio's difference after the adoption of the Robo-Adviser, as shown in the equation below.

$$y_{i,t} = \beta_1 \text{Robo-Adviser User}_i + \beta_2 \, D(\text{Robo-Adviser User} \times \geq 2017)_{i,t} + \beta_3 \, D(\text{Robo-Adviser User} \times 2018)_{i,t} + \gamma_t$$
$$+ \, \delta \, X_{i,2016} + \epsilon_{i,t}$$

In this setup, in the equation above, we control for initial differences in behavior by adding the portfolio characteristics in 2016 ($X_{i,2016}$). We are interested in the coefficient $\beta_3$ which we define as the impact of the Robo-Adviser. The coefficient $\beta_3$ is the incremental change of the 2018 difference between the Robo-Adviser Users and the Control Group. We look only at this incremental impact as the adoption of the Robo-Adviser happens only late in 2017. Thus, any "learning" from the Robo-Adviser likely occurs only in 2018. Furthermore, any unobserved factors that lead both to adoption in the Robo-Adviser and an increase in the dependent variable $y_{i,t}$ can contaminate the 2017 estimate. For example, a retail investor might want to diversify more and thus decide to buy both ETFs and adopt the Robo-Adviser, independent of his portfolio characteristics in 2016. Suppose a common

unobserved factor leads to a change in the dependent variable and the Robo-Adviser's adoption. In that case, we should observe the changes simultaneously and thus see an impact on the 2017 coefficients but no further change on the 2018 coefficients. Furthermore, learning from the Robo-Adviser takes time, and accordingly, changes in behavior induced by the Robo-Adviser should be observed only in 2018[20]. We cluster the standard errors at the individual level to account for time persistent individual effects.

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[20] Unreported results study the effects on early and late adopters in 2017. Any positive comovement between the decision to adopt and the trading behavior should affect both groups the same in 2017. Only aspects of learning should be stronger for the early adopters compared to the late adopters. If there is a positive effect from learning from the Robo-Adviser, the late adopters should have lower responses in 2017, but larger responses in 2018. We find that all incremental effects estimated on the late adopters are statistically indistinguishable from zero and tend to go in the opposite directions between 2017 and 2018.

**Table 3**: Retail Investors changing of Portfolio Characteristics after investing with a Robo-Adviser:

| | (1) Diversified Ind. | (2) Asset Classes | (3) ETF Share | (4) Mutual Fund Share | (5) Trades | (6) Buys | (7) Sells |
|---|---|---|---|---|---|---|---|
| $D(Robo)$ | 0.000980 | 0.0315*** | 0.00350 | 0.0199*** | 0.138 | 0.129 | -0.0331 |
| | (0.22) | (9.63) | (0.98) | (4.89) | (1.05) | (1.49) | (-0.64) |
| $D(Robo \times \geq 2017)$ | -0.00756 | -0.0229* | 0.00446 | 0.00675* | 1.580*** | 0.907*** | 0.661*** |
| | (-1.57) | (-2.00) | (1.60) | (2.46) | (4.15) | (3.34) | (4.23) |
| $D(Robo \times 2018)$ | -0.00601 | 0.00643 | 0.00210 | -0.0129*** | -1.554*** | -1.204*** | -0.306 |
| | (-1.52) | (0.69) | (0.91) | (-5.54) | (-4.06) | (-4.44) | (-1.95) |
| Control | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Weighting Correction | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 43162 | 43162 | 42810 | 42810 | 43162 | 43162 | 43162 |
| $R^2$ | 0.646 | 0.774 | 0.521 | 0.591 | 0.706 | 0.716 | 0.662 |

*Note*: This table shows how the portfolio characteristics of retail investors change after investing with a Robo-Adviser via a Difference-in-Difference regression. It compares the actively managed portfolio of the Robo-Adviser Users with the (actively managed) portfolio of Non-Robo-Adviser Users from 2016 (before the Robo-Advisor introduction) to 2018. It includes only retail investors with an active portfolio in 2016. The dependent variables are: *Diversified Ind.* is an indicator equal to one if the retail investor holds ETFs or Mutual Funds in his (active) portfolio. *Asset Classes* count the number of asset classes in the retail investor's portfolio. *ETF Share*, *Mutual Fund Share* report the fraction of the active portfolio held in Mutual Funds or ETFs. *Trades*, *Buys*, *Sells* reports the number of trades/buys/sells during that year by the retail investor. The Weighting Correction refers to the Correction used to adjust for the Robo-Advisor Users' Oversampling relative to the Non-Robo-Advisor Users. The panel is unbalanced with investors leaving in 2018. The control variables include personal characteristics: Sex, Joint Account, Age and portfolio characteristics: Years as Customer, Years since opening the portfolio and the 2016 investment characteristics portfolio value, stock dummy, bond dummy, ETF dummy, Mutual Funds Dummy, Levered Product Dummy, Derivative Dummy, Buy Volume, Sell Volume, Number of Asset Classes, Number of Securities and Turnover. The standard errors cluster at the individual level.

Table 3 shows how retail investors change their active portfolio characteristics after investing with the Robo-Adviser. The studied characteristics are diversification and trading cost. Looking at diversification, Specification (1) and (2) in Table 3 precisely estimate that there is no change in the probability of owning diversified securities, like ETFs and mutual funds, or the number of asset classes a retail investor holds after investing money with the Robo-Adviser. Specifications (3) and (4) further confirm these results. Specification (3) shows that retail investors that invest money with the Robo-Adviser increase their investment share of ETFs by no more than retail investors increase their investment share of ETFs that do not invest in the Robo-Adviser. While Specification (4) finds a slight but significant decrease in the investment share of mutual funds in 2018, the coefficient is no longer significant when combined with the relative increase of the investment share in 2017 and beyond. Thus, this change is likely purely temporary, as many of these investment products have withdrawals only infrequently.

Looking at the trading frequency in Specifications (5) through (7), the results do not support the hypothesis that adopting the Robo-Adviser leads to increased trading by the retail investor, despite the Robo-Adviser trading on average 60 times more often than the average retail investor. Instead of increasing the trading frequency, the results indicate that adopting the Robo-Adviser leads to decreased trading frequency (-1.554 trades in 2018). As the money invested with the Robo-Adviser is almost exclusively additional money invested in financial markets[21], we would not expect a drop in the trading frequency. Closer inspection reveals that this drop in trading frequency results from an increase in the trading frequency in 2017 and beyond (1.580). Estimating an effect for only 2018 would result in a coefficient of only $0.026 (= 1.580 - 1.554)$. Thus, to the degree that Robo-Adviser users learn from the Robo-Adviser, these effects are purely temporary as they revert entirely in 2018 and only exist in 2017.

The results show that investing with the Robo-Adviser does not lead to any changes in the retail investor's active portfolio. Even among the subsamples where behavioral changes are most likely due to poor previous investing or little prior knowledge, we find no changes to the investment characteristics. Table 1 shows that Robo-Adviser users invest significantly more in ETFs and Mutual Funds than control group retail investors, who instead invest that money into only a few individual stocks[22]. Given that the Robo-Adviser Users are already more likely to own ETFs and mutual funds, they probably understand that they should invest in diversified securities and are already doing so, so learning diversification from the Robo-Adviser is not necessary for them. They implemented investing in ETFs already beforehand. This result is in line with prior findings (Koestner, Loos, Meyer, & Hackethal, 2017) that retail investors have a hard time avoiding past mistakes.

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[21] Unreported results show that of the average 25,000 Euro managed by the Robo-Adviser in 2017, at most 10% can be explained by reduced net investment into Financial Markets.

[22] Table 1 also shows that Robo-Adviser users and control group retail investors hold the same number of securities, 10 on average, so that control group retail investors likely do not achieve diversification by buying many individual stocks.

# 5. Conclusion and discussion

Digitalization has expanded to Financial Services, making many products formerly exclusive to wealthy clients available to all retail investors. However, the suitability of these services is yet unknown. In this paper, we study one such service, namely financial advice, in the form of Robo-Advisers.

Using a novel data set that observes not only the trading by the Robo-Adviser but also the active trading of retail investors investing with the Robo-Adviser (Robo-Adviser users) and not investing with the Robo-Adviser (retail investors in the control group), we find that the Robo-Adviser serves a meaningful role by introducing 30% of its users to financial markets, who would have otherwise not participated in financial markets. These are households entirely new to financial markets, and without the Robo-Adviser, these households would not have invested actively on their own. Given the low stock market participation, especially in Germany, where only 16.2% of the population own stocks through any means of participation, increasing participation in the stock market is an essential service.

However, for retail investors already participating in financial markets, Robo-Advisers seem not to benefit them. Retail investors adopting the Robo-Adviser already own a significant amount of ETFs and Mutual Funds and, therefore, likely do not need the additional diversification from Robo-Advisers. These retail investors currently invest only close to the minimum amount possible with the Robo-Adviser. The Robo-Adviser does not change their combined portfolio, i.e., the portfolio held by the Robo-Adviser and the active portfolio by the retail investor, in a meaningful way. These findings are supported by the Robo-Adviser not influencing the behavior of the retail investor. Given the much more frequent trading with the Robo-Adviser, one might expect the retail investors to trade more often after observing the Robo-Adviser. Still, we find no evidence of an increase in trading frequency. Given that these retail investors' diversification is already high, with more than 60% holding mutual funds and 50% holding ETFs, we find no increase in diversification among these groups. These findings hold even among subgroups most arguably most susceptible to these changes.

However, we find that the money invested with the Robo-Adviser constitutes at least 90% additional investment in financial markets, with at most 10% being money that would have been invested otherwise in the stock market.

Summing up, we conclude that the Robo-Adviser does not seem beneficial for retail investors who manage active portfolios independently. However, the Robo-Adviser increases participation in financial markets by attracting retail investors who would otherwise not have participated, possibly because of their perceived lack of financial literacy. These retail investors are not just investing in financial markets but immediately own very diversified portfolios. Attracting new investors to financial markets is particularly important given the low stock market participation in many countries, especially Germany, where only 16.2% of the population owns stocks. Nevertheless, the minimum investment amount required for such services may still be a barrier to adoption.

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