To Decrease or Not to Decrease: The Impact of Zero and Negative Interest Rates on Investment Decisions

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Abstract

The suggestion to implement a negative monetary policy has divided economists and politicians. The effects of this experiment on the willingness of individuals and financial intermediaries to borrow and spend money and increase their risk are controversial. To provide insight into the debate, we provide experimental evidence revealing two important results. First, zero interest rates are more efficient than negative interest rates in terms of the impact on the willingness of individuals to borrow money and take risks. We suggest two behavioral explanations for this result. Second, we find no statistical difference between the effect that positive and negative interest rates have on the change in the allocation of risky assets in investment portfolios.

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1. Introduction

In July 2012, Denmark's National Bank was one of the first financial institutions to introduce negative interest rates by cutting its main policy rate below zero to -0.2%. Given that to date, this policy remains in place Denmark holds the record for having this unconventional policy rate longer than any other country. Since then, other central banks have followed this path. In January 2014 the European Central Bank (ECB) cut its deposit rate below zero to -0.1%. Exactly one year later the Swiss National Bank (SNB) cut its deposit rate to -0.75%, the lowest negative interest rate ever. In February 2015, the Swedish Central Bank (Riksbank) reduced its repo rate, meaning the rate at which banks borrow or deposit money, to -0.1% and in January 2016, the Bank of Japan (BOJ) joined this group with a rate of -0.1%.

It is common knowledge that the policy rate is a reference point for the financial markets and various financial securities. Therefore, this unconventional policy has an impact on the interest rates of deposits and loans, money market rates and capital market rates. For example, Figure 1 presents data on the policy rates, deposit rates, money market rates and capital market rates of several leading central banks. The right-hand chart in Figure 1 illustrates the time series of the policy rates, while the left-hand chart depicts the April 2020 deposit rates, interbank rates for one year and government bond yields for two years. As the figure indicates, a negative policy rate has a significant spillover effect on both money market rates, evident in the interbank rate up to one year, and capital market rates, evident in short and intermediate term government bonds.

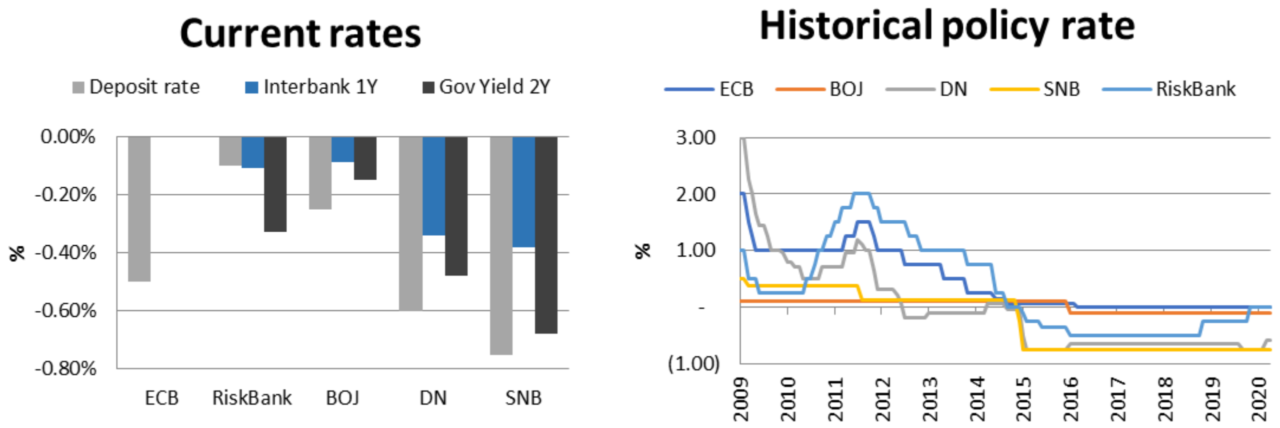

Figure 1. Policy rates, money market rates and capital market rates. The left-hand graph presents the deposit rates, interbank rates for one year and government bond yields for two years for the European Central Bank (ECB), Swedish Central Bank (Riksbank), Denmark's National Bank (DN), the Swiss National Bank (SNB) and the Bank of Japan (BOJ) as of April 2020. The right-hand graph presents the time series of the policy rates. Source: Bloomberg.

A key role of the monetary policies of many central banks is to achieve price stability while managing economic fluctuations to support growth. Deep economic recessions accompanied by low and even negative inflation along with low interest rates have pushed some central banks to take the unusual step of imposing negative policy rates. The goal was to stimulate the economy by: 1) encouraging banks to lend money instead of holding it in central banks and 2) reducing borrowing costs and increasing the investment spending of companies and individuals' private consumption. For many policymakers and economists it might still be too early to judge whether negative interest rates have had a positive impact on inflation and economic growth or caused lasting damage to the economy. Nevertheless, in the case of Japan the answer might be the latter. Christensen and Spiegel (2019) found that Japan's negative rate policies may have reduced rather than increased expected inflation, as hoped. This finding raises questions about the efficacy of a negative rate policy.

There are a number of academic papers that have investigated the implications of zero interest rates for monetary policy. Heider, Saidi and Schepens (2017) argued that, unlike a positive interest rate policy, the transmission in a negative interest rate policy depends on the banks' funding structure.

Drechsler et al. (2018) demonstrated how monetary policy affects the risk premium component of the cost of capital using a dynamic asset pricing model. Bech and Malkhozov (2016) showed empirically that negative policy rates affect money market rates in much the same way as positive rates. However, they suggested that there is great uncertainty regarding the behavior of individuals and institutions if rates were to decline further into negative domains or remain negative for a prolonged period.

Other papers provided empirical evidence about the consequences of low interest rates for the investment decisions of financial institutions such as banks or mutual funds. Rajan (2006), Gambacorta (2009), Maddaloni and Peydro (2011), Jimenez et al. (2014), Di Maggio and Kacperczyk (2017) and Acharya and Naqvi (2019) documented that financial institutions have a greater appetite for risk taking when interest rates are low, a phenomenon known as reaching for yield.

Another important aspect of a negative interest rate policy that is still unclear is related to its behavioral impact on financial investment decisions. Policy rates affect the willingness of individuals and institutions to borrow money and to take risks. Negative interest rates turn the concept of the value of money over time upside down. Banks are forced to pay interest for depositing money in central banks rather than earning interest on it. Borrowers get paid for taking out loans and savers are penalized. These outcomes, which are contrary to what is normally expected, not only have a negative effect on the banking system, and pension funds and insurance companies trying to generate sufficient returns, but also may distort individuals' behavior, in particular their borrowing practices and risk taking.

Leading economists and practitioners have talked about the unknown consequences of negative interest rates for the investment decisions of individuals and institutions in non-academic journals. Stefan Ingves (2020), governor of the Riksbank, said during interview with the *Financial Times*: "If the choice were to be at zero or slightly negative, to be at zero is a good place to be[3]." The interview took place only two months after the Riksbank decided in December 2019 to return the repo rate to zero after five years in negative territory. Similarly, the Federal Open Market Committee (FOMC), headed by Chairman Jerome Powell, stated in the minutes from October 2019: "All participants judged that negative interest rates currently did not appear to be an attractive monetary policy tool in the United States. Participants commented that there was limited scope to bring the policy rate into negative territory, that the evidence on the beneficial effects of negative interest rates abroad was mixed, and that it was unclear what effects negative rates might have on the willingness of financial intermediaries to lend and on the spending plans of households and businesses.[4]"

Several papers have studied the behavioral aspects of low interest rates on the investment decisions of individuals and argued that this phenomenon is not confined to financial institutions only. Lian et al. (2018) reported that individuals' allocations to risky assets are significantly greater when interest rates are low, holding fixed the excess returns of the risky assets. Ganzach and Wohl (2018) showed that the level of risk-free rates impacts the attractiveness of risky assets. Specifically, they argued that the lower the risk-free rate the greater the attractiveness of risky assets.

However, while most papers deal with low but positive interest rates, studies about the impact of zero and negative interest rates on individuals' investment decisions are still scarce. The goal of this paper is to fill this gap. Using three lab experiments, we first demonstrate that a zero interest rate policy has the strongest impact on individuals' investment decisions in terms of their decisions to borrow money and the percentage of risky assets in their portfolios. We suggest two behavioral explanations

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[3] Why Sweden ditched its negative rate experiment (*Financial Times*). https://www.ft.com/content/478fe908-5168-11ea-8841-482eed0038b1

[4] Minutes of the Federal Open Market Committee, October 29-30, 2019. https://www.federalreserve.gov/newsevents/pressreleases/monetary20191120a.htm

for this result. The first is related to the reference point in the Prospect Theory (Kahneman and Tversky 1979). The second is linked to the psychological effect of the number zero on people's decisions, as documented in several papers such as Shampanier, Mazar and Ariely (2007) and Zhang and Slovic (2019). Additional possible explanations of the strong impact of zero interest rates may be related to the alternative explanation of Ganzach and Wohl (2018) called the zero=loss explanation. Second, we find no statistical difference between the effect that positive and negative interest rates have on the change in the allocation of risky assets in investment portfolios. Nevertheless, it is important to emphasize that while the change in the allocation of investment money to risky assets does not necessarily differ, the level of the allocation to risky assets increases when interest rates move downwards. We verify this result using the Becker-DeGroot-Marschak (BDM) procedure.

The remainder of this paper is organized as follows. Section 2 presents a Literature review and discusses the relevant theories. Section 3 describes the experimental procedure. Sections 4 through 6 present the results of the three experiments, respectively. Section 7 provides potential explanations for the results and Section 8 concludes.

2. Literature Review of Relevant Theories

Standard economic views about the effect of risk-free rates on the investment decisions of financial institutions and households are not always consistent with behavioral explanations. While the former argue that the attractiveness of risky assets is driven by their risk premium (the difference between their expected return and that of a risk-free asset), many academic papers have documented an increase in the appetite of financial institutions for risky assets when interest rates are low, a phenomenon known as reaching for yield. What drives this phenomenon? A common theory focuses on institutional frictions. For example, papers such as Feroli et al. (2014), Morris and Shin (2014) and Acharya and Naqvi (2019) examined agency problems. Others such as Drechsler et al. (2018) focused on the cost of capital for institutions. A number of studies provided empirical evidence that financial institutions invest in riskier assets when interest rates are low.

This phenomenon is not confined to financial institutions only. It also affects the evaluations that individuals make about possible returns and the trade-off for risk in two ways. First, it influences the investment decisions of individuals, who, as end investors, allocate their savings between risk-free and risky assets (bonds and stocks). Second, individuals' preferences may shift the investment decisions of financial institutions. For example, Choi and Kronlund (2018) showed that the inflow of money to an institution's funds from end investors searching for yield affects the investment decisions of money market funds and capital market mutual funds. Lian et al. (2018) reported that individuals demonstrate a stronger preference for risky assets when the risk-free rate is low. They suggested two behavioral explanations for this result. The first is related to the framework of the Prospect Theory (Kahneman and Tversky 1979). When interest rates fall below people's reference point, they are more willing to invest in risky assets.

How do people determine this reference point? According to Prospect Theory, it is people's current level of wealth. Later studies proposed other reference points. Barberis, Huang and Santos (2001) suggested a reference point that is equal to the risk-free rate. Kőszegi and Rabin (2006) proposed a reference point that is equal to investors' rational expectations about asset returns in a choice task. Other studies such as Kahneman and Miller (1986) and Malmendier and Nagel (2011) maintained that people's experience has a significant impact on their reference point. The second explanation is related to the salience theory of Bordalo, Gennaioli, and Shleifer (2013) in which investment decisions could be affected by the salience of the higher average returns of the risky asset. For example, an average return of 6% on a risky asset appears more salient compared to a 1% risk-free asset than an average return of 10% on a risky asset compared to a 5% risk-free asset.

Ganzach and Wohl (2018) showed that the level of risk-free rates impacts the attractiveness of risky assets. Specifically, they argued that the lower the risk-free rate the greater the attractiveness of risky assets. The explanation for this result is related to the behavioral principle of diminishing marginal sensitivity – an identical risk premium (the difference between the returns of a risky asset and a risk-free asset) is more significant to individuals when the risk-free rate is low than when the risk-free rate is high. Thus, the effect of risk-free rates on the attractiveness of risky assets would occur for a wide range of risk-free rates. An alternative explanation, which they mentioned needs further investigation, is connected to the anchoring effect whereby people anchor the risk premium based on historical returns rather than adjusting it to the risk-free rate. However, even Ganzach and Wohl (2018) pointed out that a zero risk-free rate might be very different from other risk-free rates because it might be regarded as a loss (labeled as zero=loss explanation). Moreover, they argued that in future works the experimental methodology to study the effect of zero risk-free rates should include situations in which the rates are above and below zero, not just zero alone. In many respects this is what our experimental design does.

Other studies deal with the psychological effect of zero on people's decisions. As documented in several papers, the number zero itself has an additional psychological impact on people's behavior. For example, Shampanier, Mazar and Ariely (2007) argued that when the price of a good drops to zero, it not only reduces its cost but also adds to its benefits and therefore has a significant impact on consumers' selections. Similarly, in their study of life-saving decisions, Zhang and Slovic (2019) found that people strongly preferred options in which there were zero deaths, even when the expected loss was relatively high. While those studies did not focus on zero risk-free rates specifically, they provide behavioral principles that may shed light on people's actions in the case of zero risk-free rates.

Experimental findings in which the lower the risk-free rate, the greater the attractiveness of risky assets for a wide range of risk-free rates both in the positive and negative interest rate domains would support Ganzach and Wohl's (2018) and Lian et al.'s (2018) explanation of diminishing marginal sensitivity. Experimental findings that zero and negative risk-free rates have a significant impact on the attractiveness of risky assets would support Ganzach and Wohl's (2018) alternative zero=loss explanation.[5] Finally, experimental findings that zero risk-free rates have a significant impact on the attractiveness of risky assets would support the Prospect Theory (Kahneman and Tversky 1979) and Shampanier, Mazar and Ariely's (2007) and Zhang and Slovic's (2019) argument about the psychological effect of the number zero on people's decisions.

3. Experimental design

We asked undergraduate management students at Ben-Gurion University in Israel to participate in a lab experiment that would take about 30 minutes. The rewards for participation were both half a credit point toward their grade and a payment of up to 25 NIS (new Israeli shekels, approximately $7) at the end of the experiment according to their investment decisions. The average payment of all three experiments was NIS 9.90 (approximately $3), which in terms of money is a return of about 6.6% per experimental unit. There were three different experiments, but each participant could participate in only one experiment. The first experiment consisted of 205 participants randomly divided into four treatment groups. The second experiment contained 80 participants randomly divided into two treatment groups. The third experiment consisted 80 participants who were also randomly divided into two treatment groups. Before each part of the experiment, the participants received an explanation including detailed examples. Each experiment had three sections. The first section measured the time preferences of the participants based on Israel, Rosenboim and Shavit (2014). The second section presented allocation assignments and the third section measured the risk aversion of the participants based on Holt and Laury (2002). The payoff to participants was based on the investment decision they made in a randomly chosen question (the mechanism of the payment is described in Appendix A).

[5] Although Ganzach and Wohl (2018) suggested this theory for zero risk-free rates because they are regarded as a loss for investors, the same rationale should be even more significant for negative risk-free rates.

3.1. Measurement of time preferences

To avoid the anchoring effect documented in Strack and Mussweiler (1997) and Brewer and Chapman (2002), we used a between-subjects design. Therefore, it was important to ensure that the participants' time preferences did not affect their allocation assignment. As section 3.4 describes, we balanced the participants' time preferences in all of the treatment groups.

The time preference question was based on Israel, Rosenboim and Shavit (2014). The participants were told that they would receive NIS 10,000 today from the experimenter and were instructed to write down the amount they would ask to receive one year from today rather than receiving the NIS 10,000 today:

Q: You are going to receive NIS 10,000 immediately. Instead, we are offering you the option of receiving a different amount one year from today. What is the minimum amount you are willing to accept one year from now in order to postpone receipt of the NIS 10,000 today?

A: Instead of NIS 10,000 today, I am willing to accept NIS______ one year from now.

Note that the amount the participants received in the time preference question, NIS 10,000, was the same as in the investment decision questions. We made this choice to avoid any potential effect on the investment allocation due to different initial amounts of money in the different parts in the experiment.[6]

3.2. Allocation assignment

Each treatment group had the same allocation problem with the same assets but with different interest rates. First, the assets were presented to the participants. Then they were informed that they had NIS 10,000 and they had the option to borrow up to an additional NIS 10,000. They had to decide how much money, if any, they would like to borrow. In the next step, we asked them to allocate the

[6] See also Shavit, Benzion, Shapir and Galil (2013).

amount of money they had (up to NIS 20,000) among three assets in two types of settings (a mean variance allocation and a lottery allocation) to test whether the participants' allocations were sensitive to the framing of the assets.

In the first setting (the mean variance allocation), they had to allocate their money (between NIS 10,000 and NIS 20,000) among three assets with continuous payoffs: 1) Deposit, a risk-free asset, 2) Asset B[7], a bond with a mean of 5% and a standard deviation of 5%, and 3) Asset S[8], a stock with a mean of 7% and a standard deviation of 19%. We did not tell the participants about the types of assets (bonds, stocks), just their means and standard deviations.

In the second setting, we repeated the same procedure as in the mean variance allocation but with different assets. Now the participants allocated their money among three assets: 1) Deposit, a risk-free asset, 2) Lottery B, paying 0% or 10% with the same probability, reflecting the 5% average yield of Asset B, and 3) Lottery S, paying negative 12% or 26% with the same probability, reflecting the 7% average yield of Asset S. The results, presented in Appendix A, were not significantly different from those of the first setting.

In each setting, we calculated the weight of the loans, the allocation weight to the risk-free asset and allocation weight to the risky assets. To do so, we used the following equations. First, we calculated the weight of the loan for each participant using Equation 1:

$$(1) \qquad w_{1_i} = -\frac{Loan}{10{,}000} * 100$$

Where w_{1_i} is the weight of the loan. $Loan$ is the amount of the loan each participant took (ranging from zero to NIS 10,000) and 10,000 is the initial amount given to each participant.

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7 Reflecting the average yield and risk for the last 10 years of AA corporate bonds in the US market.
8 Reflecting the average yield and risk for the last 10 years of the S&P 500 stock index.

Second, we calculated the weight allocated to each asset (Deposit, Asset B and Asset S) using the following equations. Note that the participants' potential allocation is up to NIS 10,000 if they did not borrow any money and NIS 20,000 if they borrowed the maximum amount:

(2) $$w_{2_i} = \frac{Deposit}{10{,}000} * 100, \quad w_{3_i} = \frac{Asset\ B}{10{,}000} * 100, \quad w_{4_i} = \frac{Asset\ S}{10{,}000} * 100$$

where w_{2_i} is the weight allocated to Deposit, w_{3_i} is the weight allocated to Asset B, and w_{4_i} is the weight allocated to Asset S. $Deposit$ is the amount each participant allocated to Deposit, $Asset\ B$ is the amount each participant allocated to Asset B and $Asset\ S$ is the amount each participant allocated to Asset S. The sum of all of the weights is 100%.

Third, we defined leverage as:

(3) $$Leverage = -w_{1_i}.$$

Then, we defined the allocation weight to the risk-free asset as:

(4) $$w_{rf_i} = w_{1_i} + w_{2_i},$$

Where w_{rf_i} is the allocation weight to the risk-free asset, w_{1_i} is the loan weight and w_{2_i} is the Deposit weight.

Finally, we defined the allocation weight to the risky assets as:

(5) $$w_{rs_i} = w_{3_i} + w_{4_i}$$

Where w_{rs_i} is the allocation weight to risky assets, w_{3_i} is the allocation weight to Asset B and w_{4_i} is the allocation weight to Asset S.

Therefore, the allocation weight to risk-free asset (w_{rs_i}) and the allocation weight to risky assets (w_{rf_i}) defined as:

(6) $$w_{rf_i} + w_{rs_i} = 1$$

3.3. Risk aversion

Our risk aversion measurement was based on Holt and Laury (2002). We asked the participants to choose among 10 choices of paired lotteries. The payoff in option A was between NIS 200 and NIS 160. The payoff in option B was between NIS 385 and NIS 10. In the first decision, the participants were asked to choose between option A, which was a lottery between 1/10 NIS 200 and 9/10 NIS 160, and option B, which was a lottery of 1/10 NIS 385 or 9/10 NIS 10. In this situation, only extreme risk takers would choose option B. In the next decision, we increased the probability of the higher payoff (i.e., 2/10 NIS 200 or 8/10 NIS 160 in option A and 2/10 NIS 385 or 8/10 NIS 10 in option B) and so on until the last decision was 10/10 NIS 200 or 0/10 NIS 160 in option A and 10/10 NIS 385 or 0/10 NIS 10 in option B. When the probability of a high payoff increases enough, the participant should cross over to option B.

3.4. Between-subjects design

An analysis of a between-subjects design requires that the participants' time preferences, risk aversion, gender and investment experience are balanced in all treatment groups. Using variance analysis (ANOVA), we did not find any significant differences between the panels in their time preferences (F-statistic=0.36, sig=0.9858), risk aversion (F-statistic=1.23, sig=0.2861), gender (F-statistic=0.15, sig=0.9938), and investment experience (F-statistic=0.39, sig=0.9056).

4. First experiment

In the first experiment we had 205 participants randomly divided into four treatment groups. Each treatment group had the same allocation problem with the same assets but with different interest rates (for loans and deposits) in two types of settings (a mean variance allocation and a lottery allocation). In the initial scenario the interest rates were 2% for treatment group 1, 1% for treatment group 2, zero (0%) for treatment group 3 and negative 1% for treatment group 4. Based on Ganzach and Wohl's (2018) recommendation to examine this issue in situations other than zero interest rates, we used different risk-free rates to compare the demand for risky assets when rates are high and low, not just when the risk-free rate is zero. We maintain that utilizing this approach increases the validity of our results.

Each participant received NIS 10,000 and had the option to borrow up to an additional NIS 10,000 (at the same interest rate as the deposit). Their first task was to decide how much money, if any, to borrow. Then, in the first setting (the mean variance allocation), they had to allocate their money (between NIS 10,000 and NIS 20,000) among three assets with continuous payoffs: 1) Deposit, a risk-free asset, 2) Asset B, a bond with a mean of 5% and a standard deviation of 5%, and 3) Asset S, a stock with a mean of 7% and a standard deviation of 19%. Then, we reduced the interest rate by 1% for each treatment group[9] and asked the participants to allocate their money again. Simultaneously, we reduced the yields of Assets B and S by 1% (i.e., Asset B with a mean of 4% and a standard deviation of 5%, and Asset S with a mean of 6% and a standard deviation of 19%). In other words, across the panels, we kept the risk premium (the difference between the yields of Assets B and S and Deposit) and the risks of the risky assets (the standard deviation) fixed.

Figure 2 presents the results of the mean leverage of each treatment group in the initial scenario (starting level) and the new scenario (final level). As shown, the starting level is higher as the interest rate is lower.[10] The starting level for positive 2%, positive 1%, 0% and negative 1% interest rates are roughly 32%, 41%, 62% and 42%, respectively. In addition, the mean leverage increases in each treatment group when the interest rate shifts downward. One exception is treatment group 3, who reduced their leverage slightly when the interest rate declined from zero to negative 1%.

[9] In the new scenario, the interest rates were 1% for treatment group 1, zero (0%) for treatment group 2, negative 1% for treatment group 3 and negative 2% for treatment group 4.

[10] One exception is in case of zero-interest rate. In that case, the initial starting level is the highest and above the initial level of negative 1%.

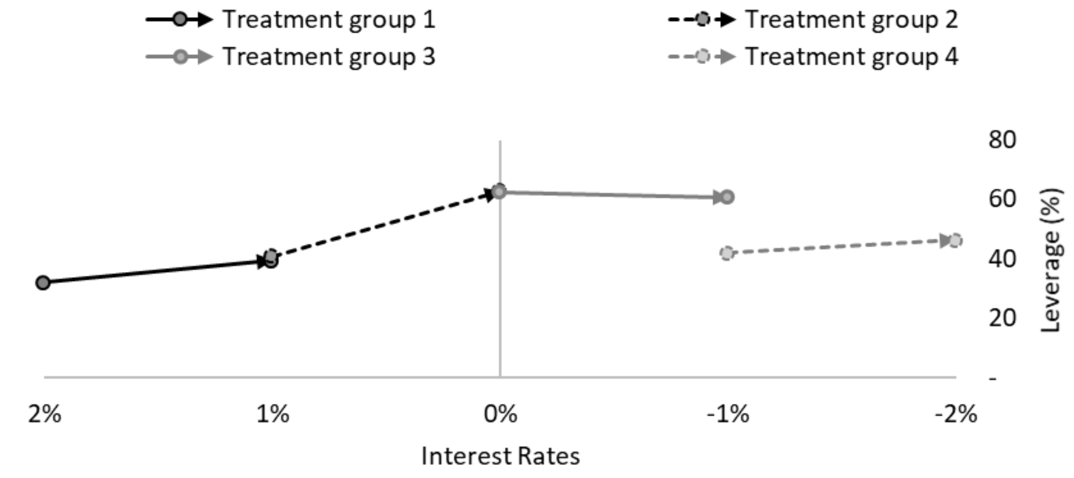

Figure 2. Mean leverage. This figure presents the results of the mean leverage of each treatment group in the initial scenario (starting level) and the new scenario (final level).

Table 1 shows the results of the mean change in leverage, which we calculated for each participant as the difference between the leverage in the initial scenario and the new scenario. Column 3 shows the mean of the change in leverage, while column 4 shows the standard deviation of the change in leverage. As the table illustrates, the mean increase in leverage is the highest when the interest rate declines from positive levels to zero (treatment group 2). In addition, the difference in treatment group 2 is statistically significant (p-value =0.004).

Treatment group	**Interest Rates**	**Variance Allocation**	
		Δ Mean	Δ STD
1	2% to 1%	7.22	29.87
2	1% to 0%	21.86***	42.57
3	0% to -1%	-1.75	33.58
4	-1% to -2%	4.30	25.67

Table 1. Change in leverage. This table presents the results of the mean change in leverage, which we calculated for each participant as the difference between the leverage in the initial scenario and the new scenario. *** $p < 0.01$, ** $p < 0.05$.

Table 2 provides the results of a post hoc ANOVA using the Tukey method (1953). As the table illustrates, the difference in the average change in leverage between positive interest rates (treatment group 1) and negative interest rates (treatment group 4) is statistically insignificant. However, the change in leverage in treatment group 2 compared to treatment groups 3 and 4 is statistically significant both for the mean variance allocation (p-value =0.004) and the lottery allocation (p-value =0.005).

Treatment group	**Mean Variance Allocation**	
	Difference	P-Value Tukey
2 vs. 1	14.63	0.123
3 vs. 1	-8.98	0.522
4 vs. 1	-2.92	0.971
3 vs. 2	-23.61	0.002***
4 vs. 2	-17.56	0.045**
4 vs. 3	6.05	0.799

Table 2. Post hoc ANOVA. This table provides the results of a post hoc ANOVA of the average change in leverage using the Tukey method (1953). *** $p < 0.01$, ** $p < 0.05$.

Analysis of the number of participants who increased their leverage in the different treatment group supports the finding that there is no statistical difference in the change in leverage in the positive and negative interest rate environments (treatment group 1 compared to group 4). The number (percentage) of participants who increased their leverage was 16 (30.77%) in treatment group 1, 21 (41.18%) in treatment group 2, 9 (17.30%) in treatment group 3 and 13 (26%) in treatment group 4. The difference between treatment group 1 and 4 is statistically insignificant both in the first setting (Z= 0.5352, p-value 0.5925) and the second setting (Z= 1.0740, p-value 0.2827).

Next, we considered the allocation to the risk-free asset (and, by definition, according to Equation (6) the allocation to the risky assets). Figure 3 presents the results of the average allocation to the risk-free asset of each treatment group in the initial scenario (starting level) and the new scenario (final level). As shown, the starting level of the allocation to the risk-free asset drops when the interest rate declines. Once again, the exception is the starting level for negative 1%, which is higher than the starting point at 0% but lower than the starting level of positive 1% and 2%. In addition, the allocation to the risk-free asset is relatively small even in the case of a positive interest rate of 2%. Indeed, this allocation even becomes negative as interest rates decline, indicating increasing risk appetite. This result reinforces the hypothesis that low positive interest rates, particularly zero or negative rates, increase the willingness of investors to take risks. Interestingly, we find that the decrease in allocations to the risk-free asset in the case of zero interest rates is by far more significant than in other interest rate domains.

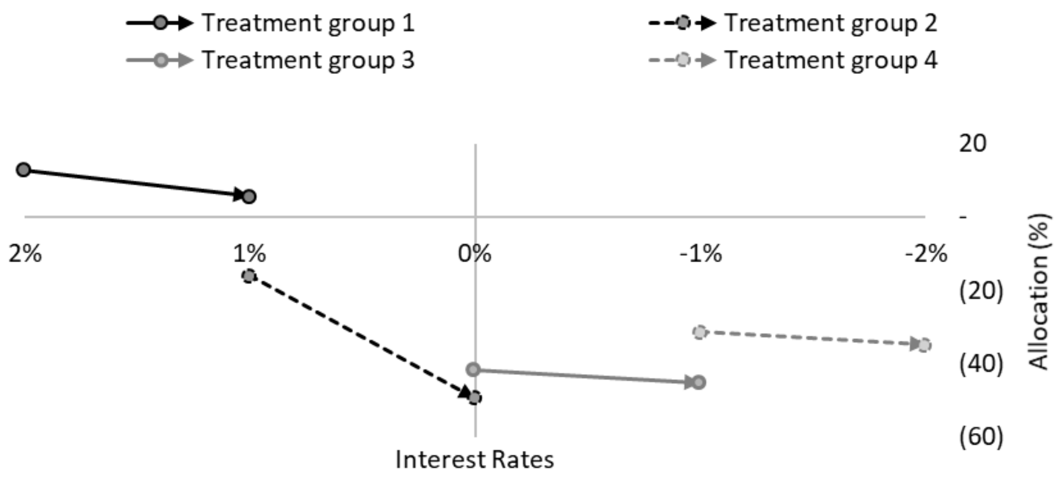

Figure 3. Average allocation to the risk-free asset This figure presents the results of the average allocation to the risk-free asset of each treatment group in the initial scenario (starting level) and the new scenario (final level).

Table 3 shows the average change in allocation to the risk-free asset, which we calculated as the difference between the allocation to the risk-free asset in the initial scenario and in the new scenario. Column 3 shows the mean of the change in allocation to the risk-free asset, while column 4 shows the standard deviation of the change in allocation to the risk-free asset. The drop in the allocations to the risk-free asset in treatment group 2 is statistically significant both in the mean variance allocation (p-value =0.0003) and lottery allocation (p-value =0.0007).

Treatment group	Interest Rates	Mean Variance Allocation	
		Δ Mean	Δ STD
1	2% to 1%	-7.21	38.44
2	1% to 0%	-33.38***	47.31
3	0% to -1%	-3.24	40.97
4	-1% to -2%	-3.52	32.84

Table 3. Change in allocations to the risk-free asset. This table shows the average change in allocation to the risk-free asset, which we calculated as the difference between the allocation to the risk-free asset in the initial scenario and in the new scenario. *** $p < 0.01$, ** $p < 0.05$.

Table 4 reports the results of the post hoc ANOVA indicating that the difference in the change in allocations to the risk-free asset in the positive and negative interest rate environments is statistically insignificant. However, the difference in the allocations to the risk-free asset in treatment group 2 compared to all the other treatment groups is statistically significant.

Treatment group	Mean Variance Allocation	
	Difference	P-Value Tukey
2 vs. 1	-26.16	0.006***
3 vs. 1	3.96	0.958
4 vs. 1	3.69	0.967
3 vs. 2	30.13	0.001***
4 vs. 2	29.86	0.001***
4 vs. 3	-0.27	1.000

Table 4. Post hoc ANOVA. This table provides the results of a post hoc ANOVA of the allocations to the risk-free asset using the Tukey method (1953). *** $p < 0.01$, ** $p < 0.05$

Consistently, analysis of the number of participants who reduced their allocation to the risk-free asset supports the finding in which there is no statistical difference in the change between treatment groups 1 and 4. For example, in the first setting the number (percentage) of participants who reduced their allocation to the risk-free asset was 19 (36.53%) in treatment group 1, 33 (64.70%) in treatment group 2, 14 (26.92%) in treatment group 3 and 17 (34.00%) in treatment group 4. The difference between treatment groups 1 and 4 is statistically insignificant both in the first setting (Z= 0.6567, p-value 0.5114) and the second setting (Z= 0.2927, p-value 0.7698).

A decrease in the allocation to the risk-free asset means an increase in the allocation to the risky assets because ($w_{rs_i} = 1 - w_{rf_i}$). An increase in the portion of risky assets means either an increase in the allocation to bonds, which are generally less risky, or to stocks, which are riskier. Figure 4 presents the results of the average allocation between the risky assets of each treatment group in the initial scenario (starting level) and the new scenario (final level). There are two interesting findings. First, the average allocation to bonds is higher than the average allocation to stocks in each starting level of each treatment group. This result suggests that although low positive and negative interest rates provide an incentive for individuals to increase their risk, they prefer the less risky option. Second, consistent with previous findings, we find that the starting level increases when interest rates decline. Once again, the exception is the starting level for negative 1%, which is lower than the starting point at 0% but higher than the starting level of positive 1% and 2%.

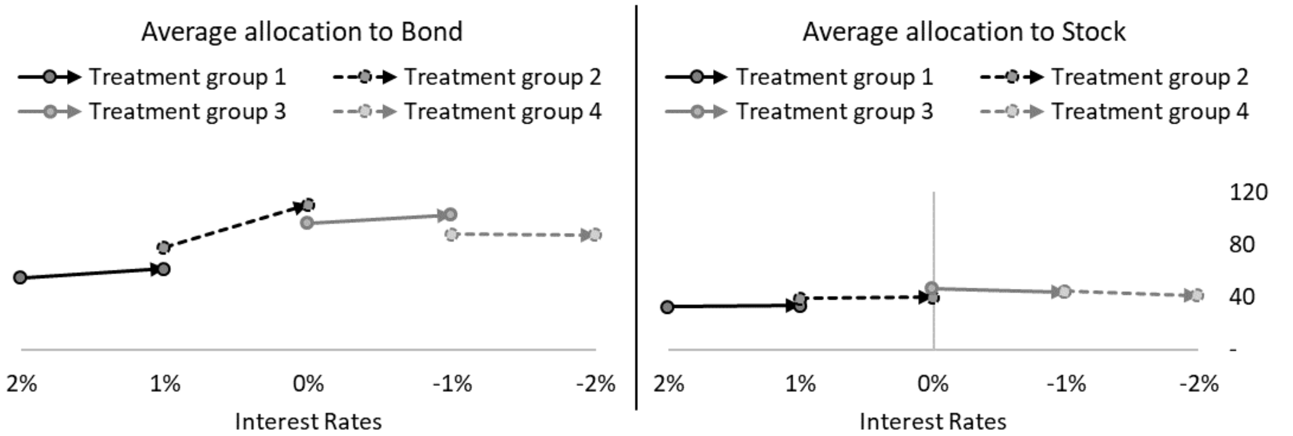

Figure 4. Average allocation between risky assets. This figure shows the results of the average allocation between the risky assets of each treatment group in the initial scenario (starting level) and the new scenario (final level).

Table 5 presents the average change in allocation between the risky assets, calculated as the difference between the allocation to risky assets in the initial scenario and in the new scenario. Column 2 shows the mean of the change in allocation to risky assets, while column 3 shows the standard deviation of the change in allocation to risky assets.

Treatment group	**Bond**		**Stock**	
	Δ Mean	Δ STD	Δ Mean	Δ STD
1	6.50	32.19	0.70	27.47
2	32.41***	54.97	0.96	49.25
3	6.31	36.32	-3.06	26.12
4	-0.28	46.28	3.80	46.95

Table 5. Change in allocations to risky assets. This table shows average change in allocation between the risky assets, calculated as the difference between the allocation to risky assets in the initial scenario and in the new scenario. *** $p < 0.01$, ** $p < 0.05$.

Table 6 reports the post hoc ANOVA test for changes in allocations to risky assets. It shows that among the treatment groups, the difference in the allocations to bonds is statistically significant only for treatment group 2.

Treatment group	**Mean Variance Allocation**	
	Difference	P-Value Tukey
2 vs. 1	25.91	0.014**
3 vs. 1	-0.18	1.000
4 vs. 1	-6.78	0.858
3 vs. 2	-26.09	0.013**
4 vs. 2	-32.69	0.001***
4 vs. 3	-6.59	0.868

Table 6. Post hoc ANOVA. This table provides the results of a post hoc ANOVA of the allocations to risky assets using the Tukey method (1953). *** $p < 0.01$, ** $p < 0.05$.

5. Second experiment

To verify the results of the first experiment we repeated the same procedure as in the first experiment with one difference. This time when we reduced the interest rate of the risk-free asset, we did not reduce the interest rate of the risky assets. Therefore, we increased the risk premium. The purpose of this manipulation was to study the behavior of individuals and institutions during times of economic stress when risk premiums increase.[11] Specifically, due to the interesting finding of no statistical difference between positive and negative interest rate environments in the change in leverage and allocation to risky assets, we repeated the same procedure only for positive and negative interest rate environments.

Eighty students participated in this experiment. In the initial scenario, the interest rate was 2% for treatment group 5 and negative 1% for treatment group 6. Participants had to decide how much money, if any, they wanted to borrow and allocated their money among the three assets (the risk-free asset, the bond and the stock). Then, we reduced the interest rate by 1% (i.e. from 2% to 1% for treatment group 5 and from negative 1% to negative 2% for treatment group) 6, without reducing the yields of Assets B and S by 1% (i.e. they remained at 5% for Asset B and 7% for Asset S] and asked participants to allocate their money again.

Figure 5 presents the results of the mean leverage of each treatment group in the initial scenario (starting level) and the new scenario (final level). As shown, the starting level is roughly the same in the positive (mean leverage of 52%) and negative (mean leverage of 54%) interest rate domain. However, while in the positive interest rate domain when the interest rate declines, the mean leverage increases, in the negative interest rate domain there is a small drop of roughly 4%.

[11] For example, the annual market premium in the US market, calculated as the difference between the return of the S&P 500 over generic US Treasury bonds for 10 years, increased from roughly 6% to a maximum of 10% during the European sovereign debt crisis.

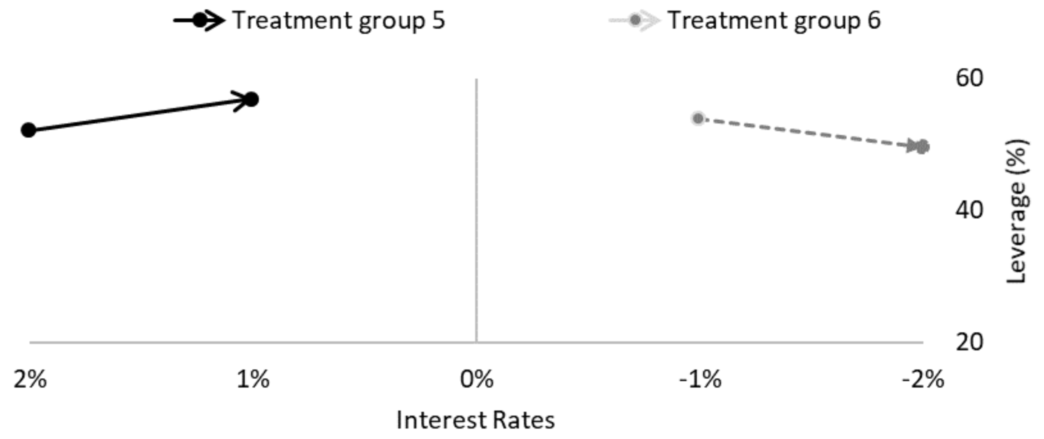

Figure 5. Mean leverage This figure presents the results of the mean leverage of each treatment group in the initial scenario (starting level) and the new scenario (final level).

Table 7 shows the results of the average change in leverage, which we calculated for each participant as the difference between the leverage in the initial scenario and the new scenario. Column 3 shows the mean of the change in leverage, while column 4 shows the standard deviation of the leverage. As shown, the leverage increased in the positive interest rate environment (treatment group 5) by roughly 5% but decreased in the negative interest rate environment (treatment group 6) by about 4%. The difference is statistically insignificant (t-test= 1.8075 p-value =0.0745). In the lottery allocation, the increase in leverage in treatment group 5 was roughly 3.5% and about 5.5% in treatment group 6. The difference is statistically insignificant (t-test= -0.36 p-value =0.7179).

Treatment group	**Interest Rates**	**Mean Variance Allocation**		**Lottery allocation**	
		Δ Mean	Δ STD	Δ Mean	Δ STD
5	2% to 1%	4.77	21.35	3.47	17.62
6	-1% to -2%	-4.35	23.73	5.55	31.61
Differences		9.12	5.04	-2.07	5.72

Table 7. Change in leverage. This table presents the results of the mean change in leverage, which we calculated for each participant as the difference between the leverage in the initial scenario and the new scenario. *** $p < 0.01$, ** $p < 0.05$

Next, we examined the allocations that the participants made to the risk-free asset. The number (percentage) of participants who reduced their allocations to the risk-free asset in treatment group 5 was 18 out of 40 (45.0%) compared to 10 out of 40 (25.0%) in treatment group 6. The difference is statistically insignificant at the 5% level (Z= 1.8752, p-value 0.0608). In the lottery allocation, the number (percentage) of participants who reduced their allocations to the risk-free asset in treatment group 5 was 17 out of 40 (42.50%) compared to 14 out of 40 (35.0%) in treatment group 6. The difference is statistically insignificant at the 5% level (Z= 0.6885, p-value 0.4912).

Figure 6 presents the results of the average allocation to the risk-free asset of each treatment group in the initial scenario (starting level) and the new scenario (final level). As shown, the starting level of the allocation to the risk-free asset is lower (roughly negative 32%) in the negative interest rate domain compared to the positive interest rate domain (roughly negative 10%). In addition, the decrease in the allocation to the risk-free asset is higher when the interest rate declines in the positive interest rate domain than in the negative interest rate domain.

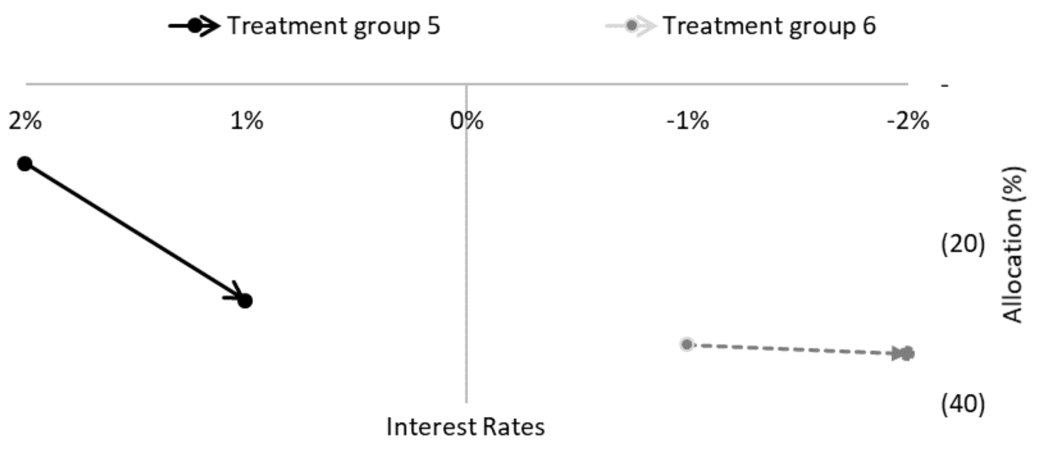

Figure 6. Average allocation to the risk-free asset. This figure presents the results of the average allocation to the risk-free asset of each treatment group in the initial scenario (starting level) and the new scenario (final level).

Table 8 shows the average change in allocation to the risk-free asset, calculated as the difference between the allocation to the risk-free asset in the initial scenario and the new scenario. Column 3 shows the mean of the change in allocation to the risk-free asset, while column 4 shows the standard deviation of the change in allocation to the risk-free asset. As shown, the change in the allocations to the risk-free asset in treatment group 5 was roughly negative 17% compared to only about negative 1% in treatment group 6. The difference is statistically significant at the 5% level (t-test= -2.4694 p-value =0.0157). However, in the lottery allocation, the difference between treatment groups 5 and 6 (roughly negative 9%) is statistically insignificant (t-test=-0.0466 p-value =0.9629).

Treatment group	**Mean Variance Allocation**		**Lottery Allocation**	
	Δ Mean	Δ STD	Δ Mean	Δ STD
5	-17.20***	27.48	-8.90***	24.49
6	-1.27	30.13	-8.55	40.66
Differences	-15.92	6.44	-0.35	7.50

Table 8. Change in allocations to the risk-free asset. This table shows the average change in allocation to the risk-free asset, which we calculated as the difference between the allocation to the risk-free asset in the initial scenario and in the new scenario. *** $p < 0.01$, ** $p < 0.05$.

Thus, in this experiment both in positive and negative interest rate environments, the participants increased their leverage and reduced their allocations to the risk-free asset, by definition, increasing their allocations to the risky assets. However, their responses were sensitive to the type of allocation. In the lottery allocation, the participants in both interest rate environments increased their leverage and reduced their allocations to the risk-free asset at the same magnitude. In the mean variance allocation, the participants in the negative interest rate environment reduced, rather than increased, their leverage and reduced their allocations to the risk-free asset. The participants in the positive interest rate environment behaved in a similar manner but with a lower magnitude.[12] Moreover, if we compare the results of the second experiment to the first experiment, we find that the participants in the lottery allocation increased their leverage and reduced their allocations to the risk-free asset more sharply in the second experiment than the first experiment. The intuition for this result is our manipulation in which we increased the risk premium in the second experiment, thereby increasing the attractiveness of the risky assets.[13]

It is important to highlight that while the change in allocation to risky assets does not necessarily differ in the positive and negative interest rate environments, the level increases when interest rates shift downward. The average allocation to the risk-free asset in the mean variance allocation is negative 9.8% when the interest rate is 2%, negative 27% when it is 1%, negative 32.5% when it is negative 1% and negative 33.8% when the interest rate is negative 2%. We find the same pattern in the lottery allocation.

6. Third experiment

Due to the findings in both experiment 1 and 2 of no statistical difference between positive and negative interest rate environments in the change in leverage and allocation to risky assets, we wanted to examine risk-taking behavior in the positive interest rate environment compared to the negative one. Specifically, we investigated whether there is a difference in risk pricing in positive and negative interest rate environments using the Becker-DeGroot-Marschak (BDM) procedure. Again, we randomly divided 80 participants into two treatment groups. In the initial scenario, the interest rates

[12] This result might be related to the fact that the participants in the negative interest rate environment reduced, rather than increased, their leverage when the interest rate declined. Hence, their initial allocation was smaller than in the positive environment, which affected the magnitude of their allocation.
[13] We did not observe this pattern in the experiments in the first setting because the participants in the second experiment reduced, rather than increased, their leverage, making it difficult to compare the experiments.

were a positive interest rate of 2% for treatment group 7 and a negative interest rate of 1% for treatment group 8. The participants in each treatment group bid a price for two lottery tickets. Participants had to take out a loan to buy the lottery tickets (we did not give them an initial amount of NIS 10,000). Then, the computer randomly chose a value between the lower payoff and the higher payoff of each lottery ticket based on a uniform distribution. If the value chosen by the computer was lower than the participant's bid, s/he could participate in the lottery. If the value chosen by the computer was higher than the participant's bid, s/he could not participate in the lottery. If it was lower, the participant paid his/her bid and received the lottery's results (BDM auction, Becker, DeGroot, & Marschak, 1964).

Then, we reduced the interest rate for taking out a loan by 1% for each treatment group. In the new scenario the interest rates were a positive interest rate of 1% for treatment group 7 and a negative interest rate of 2% for treatment group 8. We asked the participants to bid for the two lottery tickets. Note that we kept the payoff of each lottery unchanged (i.e., the lottery payments remained 0% or 10% with the same probability in Lottery B and negative 12% or 26% with the same probability in Lottery S).

The number (percentage) of participants who increased their bid for the less risky lottery in the positive interest rate environment (treatment group 7) was 17 out of 36 (47.22%) compared to 15 out of 36 (41.66%) in the negative interest rate environment (treatment group 8). The difference is statistically insignificant (Z= 0.474, p-value 0.635). The number (percentage) of participants who increased their bid for the riskier lottery in treatment group 7 was 10 out of 36 (27.77%) compared to 16 out of 36 (44.44%) in treatment group 8. The difference is again statistically insignificant (Z= -1.472, p-value 0.1409). Table 9 reports the average change in the bids of the participants (in NIS) for less risky and riskier lotteries. The results for treatment group 7 show the average change in the bids when the interest rate declined from 2% to 1%, while those for treatment group 8 indicate the average change in the bids when the interest rate declined from negative 1% to negative 2%. Column Δ_{Mean}

lists the change in the average bids, column Δ_{STD} presents the change in the standard deviation of the bids and column $\Delta_{RiskPremium}$ shows the change in the risk premium calculated based on Equation 7:

$$(7) \qquad \mathrm{R}_{premium} = 1 - \frac{M_{pricing}}{E_{payoff}}$$

where $\mathrm{R}_{premium}$ is the average risk premium, $M_{pricing}$ is the average bid and E_{payoff} is the expected payoff of the lottery.

As the table illustrates, there is no difference in the participants' pricing in the positive and negative interest rate environments for the less risky and riskier lotteries. In the less risky lottery, the risk premium increased by 7.8% in the positive interest rate environment compared to 5.6% in the negative interest rate environment. The difference is statistically insignificant (Z= 0.3733, p-value 0.7089). This result also holds for the riskier lottery (Z= -0.6736, p-value 0.5005).

Treatment group	**Interest rates**	Δ_{Mean}	Δ_{STD}	$\Delta_{RiskPremium}$	Δ_{Mean}	Δ_{STD}	$\Delta_{RiskPremium}$
7	2% to 1%	392	2,428	7.8%	294	2,999	4.2%
8	-1% to -2%	284	3,010	5.6%	565	2,235	8.0%

Table 9. Average bids of the participants. This table shows average bids of the participants (in NIS).

7. Discussion

7.1. Zero interest rate

We document that a zero-interest rate policy has the strongest impact on individuals' investment decisions. Specifically, a decline in the interest rate from a positive one to zero (treatment group 2) has the strongest effect on leverage (the highest increase) and on the allocation between risk-free (a decrease) and risky assets (an increase). The findings hold across various experimental settings including the mean variance allocation and lottery allocation. Analysis of the behavior of the participants with regard to risky assets (bonds and stocks) reveals that the increase in allocations to risky bonds is statistically significant. Furthermore, dropping the interest rate below zero (a negative interest rate policy) is less effective in terms of leverage and shifting individuals' allocations to risky assets. Indeed, moving from a zero-interest rate policy to a negative interest rate policy might even have the opposite effect. Specifically, when interest rates decline from zero to a negative interest rate, the average leverage decreases instead of increases. Both results clearly indicate that individuals react strongly to zero interest rates.

There are several potential explanations for these findings. The first is related to Prospect Theory (Kahneman and Tversky 1979), which posits that in a loss environment individuals are willing to take risks when there is a strong probability of loss (the certainty effect), whereas they are risk averse when there is little chance of a loss (the possibility effect). In a positive environment, the opposite is true. They are less willing to take risks when there is a strong probability of gain and more willing to do so when there is little chance of a gain. The results of the first experiment exemplify this theory. When the interest rate decreased in the positive interest rate environment (from 2% to 1% and from 1% to zero), the participants increased their allocation to risky assets significantly more than when the interest rate decreased in the negative interest rate environment (from zero to negative 1% and from negative 1% to negative 2%). Thus, when people pay money for their leverage (a loss environment), they increase their allocation to risky assets. In contrast, when they receive money from their leverage (a positive environment), they are less willing to put this money at risk by increasing the allocation to risky assets. If we compare the allocation around the zero-interest rate (from positive 1% to a zero-interest rate and from a zero interest rate to negative 1%), we find the opposite behavior. When interest rates drop to zero, people invest in accordance with our expectation that they will increase their leverage. However, the decline to zero has the strongest impact on this decision. When interest rates drop below zero, people invest in a manner that is contrary to our expectations, meaning, they reduce their leverage.

These results underscore the important role that the change to and from zero interest rates plays. Therefore, it is crucial to identify the factors that affect people's reference point. According to Prospect Theory (Kahneman and Tversky 1979) that reference point is people's current level of wealth. Later studies proposed other reference points. Barberis, Huang and Santos (2001) suggested a reference point that is equal to the risk-free rate. Kőszegi and Rabin (2006) proposed a reference point that is equal to investors' rational expectations about asset returns in a choice task. Other studies such as Kahneman and Miller (1986) and Malmendier and Nagel (2011) maintained that people's experience has a significant impact on their reference point. All of these theories support the intuition that a zero-interest rate is traditionally seen as the lower bound for nominal interest rates (as opposed to real interest rates, which might be negative if the inflation rate is higher than the nominal interest rate). Hence, we can argue that people regard a zero-interest rate as a reference point. Therefore, the change from positive interest rates to zero interest rates and from zero interest rates to negative interest rates has different effects on people's investment decisions.

The second possible explanation is related to the psychological effect of zero on people's decisions. In theory, reducing the interest rate by 1% from 2% to 1% and from 1% to zero should have the same economic impact. Nevertheless, as several papers have documented, the figure zero itself triggers an additional impact. For example, Shampanier, Mazar and Ariely (2007) argued that when the price of a good drops to zero, it not only reduces its cost but also adds to its benefits and therefore has a significant impact on consumers' selections. Similarly, in their study of life saving decisions, Zhang and Slovic (2019) found that people strongly preferred options in which there were zero deaths, even when the expected loss was relatively high. Finally, Ganzach and Wohl's (2018) contention that zero=loss may explain our finding about the significant impact that a zero risk-free rate has on the risk premium.

7.2. Negative interest rates

In the first experiment, we did not find any robust evidence of different changes in leverage (an increase) and allocations between risk-free (a decrease) and risky assets (an increase) in the positive and negative interest rate environments when holding the excess returns on the risky assets constant. One potential explanation for this result may come from the reference dependence component of Prospect Theory (Kahneman and Tversky 1979). The theory posits that to define gains and losses, people tend to think of possible outcomes relative to a certain reference point (individuals try to achieve a certain level of returns). When the risk-free rate is lower than the reference point, a simple model of the Prospect Theory with a reference point and a piecewise linear utility predicts that changes in allocation would be proportional to shifts in the risk-free rate, holding the excess returns on the risky assets constant. In our first experiment, treatment group 1 starts with a risk-free rate of 2%, which is the highest interest rate, and treatment group 4 starts with a risk-free rate of negative 1%, which is the lowest interest rate. In both cases the risk-free rate is likely to be below people's target returns. Therefore, the theory predicts that the allocations to risky assets would increase as the interest rate decreases. However, it does not necessarily predict that the change in allocations would increase more when the interest rate drops by 1% from negative 1% to negative 2% compared to decreases of 1% from 2% to 1%. Indeed, this was also the case in the second experiment for the lottery allocation (in the mean variance allocation we did find that the difference was statistically significant at the 5% level), where we reduced the risk-free rate but increased the excess returns on the risky assets.

In addition, the results in the first and second experiments of no difference between the positive and negative interest rate environments in the change in allocations may be related to the money illusion. According to this theory, individuals tend to think in terms of nominal values rather than in real terms. As documented in Shafir, Diamond and Tversky (1997), the existence of the money illusion influences people's decisions in many real-world situations. While the money illusion alone cannot explain this result, it may interact with reference dependence. Nominal returns may determine people's reference points. Therefore, a negative nominal interest rate may affect their behavior differently than a negative real interest rate. The fact that a negative real yield is much more intuitive than a negative nominal yield may reinforce this point, particularly among those who are less sophisticated investors. Leading economists and practitioners have both expressed this idea. For example, former Fed chair, Ben S. Bernanke (2016), wrote, "The idea of negative interest rate strikes many people as odd. Economists are less put off by it, perhaps they are used to dealing with 'real' interest rates, which are often negative[14]".

8. Conclusion

Ongoing low levels of growth and inflation accompanied by ultra-low nominal interest rates have pushed central banks to try to stimulate the economy by setting interest rates below zero. This monetary policy experiment has divided economists and politicians. For many, this policy is controversial and raises several concerns about the ability of this policy to increase inflation and spur growth, and the potential of a negative impact on financial stability. For others, the cost of negative interest rates is manageable.

Other major concerns are related to the potential impact on financial institutions and individuals' behavior, particularly their willingness to borrow money and take risks. While central bankers and politicians are still struggling to answer these questions, we provide experimental evidence to offer some guidance. We find two fascinating results. First, a zero interest rate is more efficient than a negative interest rate in terms of the impact on people's willingness to borrow money and take risks. Second, we find no statistical difference between the effect that positive and negative interest rates have on the change in the allocation of risky assets in investment portfolios.

[14] What tools does the Fed have left? Part 1: Negative interest rates. https://www.brookings.edu/blog/ben-bernanke/2016/03/18/what-tools-does-the-fed-have-left-part-1-negative-interest-rates/.

Shedding light on how people and institutions behave when interest rates are negative is important and relevant not just because some countries have adopted this policy but also because some are still considering it. As President Donald Trump tweeted in September 2019, “The Federal Reserve should get our interest rates down to ZERO, or less.”

Finally, the counterintuitive effect of negative interest rates on saving accounts implies that savers should pay interest rather than receive it. Hence, one can argue that there is no reason for savers to accept negative rates and would prefer to hold cash. However, in practice the answer to this question is less clear because there are risks associated with holding cash such as losing it or being robbed. This argument is reinforced because worldwide negative interest rates are low, below 1%. (Currently, the most negative rate is 0.75% in Switzerland). Hence, further work is needed to understand how far below zero interest rates can go before they will prompt people to hoard cash.

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