INVESTMENT GAME

EC 438.01 Experimental Economics

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1. Introduction

Investors are faced with making difficult investment decisions every day. Their aim is to maximize their earnings while minimizing their risk. They try investing their assets in the most optimal way under the influence of different factors. Those factors include but are not limited to their age, gender, risk aversion level, wealth, investments return factor and return probability, etc.

One way of calculating investment decisions is by a mathematical formula developed by John L Kelly named the Kelly criterion. This formula is used to determine how much of his/her asset an investor should invest according to the probability of a given payoff. While conducting our analysis on return factor and return probability we take the Kelly criterion into consideration.

Thaler (1980) states that people are less willing to give up what they already have than to pay the price to acquire it. This is also supported by Kahneman and Tversky's (1984) prospect theory that people value gains and losses differently. They will rather have a certain amount of gain than a higher return with a probability of loss of all. When investing, investors are faced with this probability of loss every day. Therefore, their investment decisions may vary according to how much they want to risk their capital.

In "Investment Game" individuals are expected to invest their capital between two options. There are four rounds, each round has 10 decisions and each decision is between two options- a risky asset and a non-risky asset. While one of these options has a sure return, the other one has either a probability of a higher return or a probability of a loss of the initial endowment.

Return factor and return probability differentiate across decisions while endowments are the changing factors between rounds. We hypothesize that as the return factor increases investment amount will increase; as the return probability increases risky investment amount will increase; as the endowment increases risky investment amount will decrease. It is important to note that the experiment is based on individual decisions therefore one investor's decision does not affect another investor's return. We are going to examine how an individual investor's decisions were affected when he/she was faced with different scenarios of allocating their money. These scenarios are better explained in the procedure part of the paper.

The paper is organized as follows. Part 2 of the paper outlines the experimental design procedures. Part 3 examines theory. Part 4 states our hypothesis. Part 5 presents the results and part 6 discusses the findings and draws some tentative conclusions and suggestions for further work.

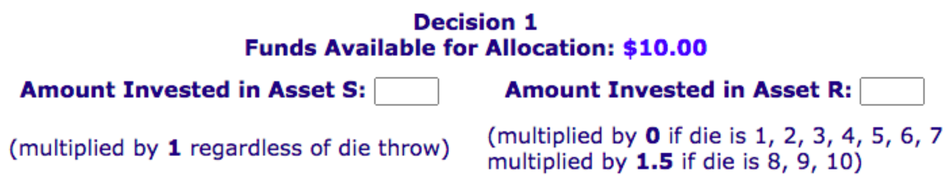
2. Experimental Design Procedures

The experiment was conducted in Bogazici University Finance Lab and online via Zoom during the Experimental Economics courses lecture time on April 25th, 2022. All of the participants were either junior or senior Economics students at Bogazici University, and the native language of all participants except one Erasmus student was Turkish. The experiment was conducted in English via the University of Virginia's Veconlab software. There were 40 participants, 19 of them were females and 21 of them were males. The experiment lasted for approximately 30 minutes. Participants used their personal laptops or lab computers to play the game. Prior to starting the game, participants read a detailed description of the game.

The game consisted of four treatments and each treatment included one round. In each round, they were asked to decide portfolio choices between safe and risky assets.

In this experiment, participants were allowed to make several investment decisions. For each decision, an initial amount of money was given that must be invested. Each round had 10 decisions, and for each decision, there were two available assets. One of the assets was safer (denoted as "Asset S"), but the other asset offered the possibility of a higher return (denoted as "Asset R").

To better understand, we can look at the first decision of the first round. Each dollar invested in Asset S returns $1 for sure, and each dollar invested in Asset R returns $0 with the 0.7 probability or $1.5 with the 0.3 probability according to the throw of a ten-sided die. (**Dollars invested are multiplied by 0 (7 chances out of 10) or by 1.5 (3 chances out of 10).)** Participants were given the opportunity to invest their initial cash between the assets in any manner. Investing all in one asset, all in the other, or investing some in each were possible choices. The only necessary condition for this allocation was that the amounts invested in Asset S and Asset R sum to the amount of initial endowment available for that decision ($10 in this example).



At the end of each round, participants' earnings from each investment decision were calculated, and one of the decisions was selected at random to determine participants' earnings for that round.

In all four treatments, 10, 20, 50, and 100 dollars were given as initial endowments, respectively, and it was stated that all of them should be invested in safe or risky assets for every 10 decisions. While the probability of winning the risky asset for the first five decisions in each experiment was 0.3, it increased to 0.7 for the last five decisions. The return factor of the risky asset changed to 1.5, 2, 2.5, 3, and 4, respectively, both in the first five decisions and in the last five decisions.

The endowments were respectively 10$, 20$, 50$ and 100$	**Decision 1**	**Decision 2**	**Decision 3**	**Decision 4**	**Decision 5**	**Decision 6**	**Decision 7**	**Decision 8**	**Decision 9**	**Decision 10**
Probability to win	0.3	0.3	0.3	0.3	0.3	0.7	0.7	0.7	0.7	0.7
Return factor	1.5	2	2.5	3	4	1.5	2	2.5	3	4

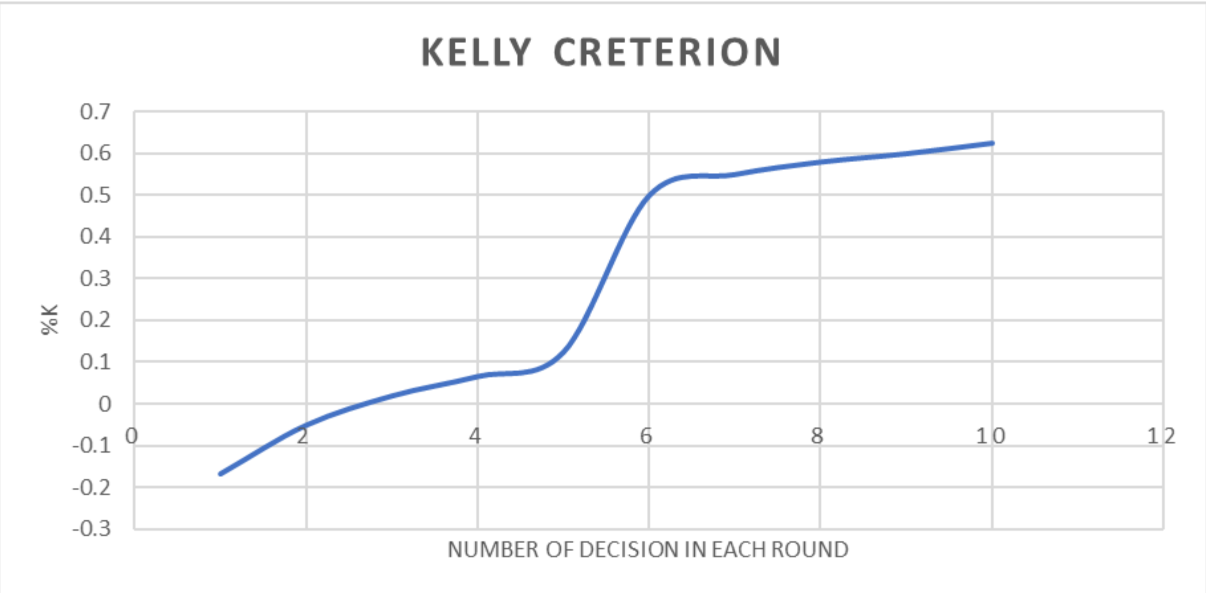
3. Theory

This experiment adapted from the Kelly Criterion published by John Kelly Jr. in 1956. Kelly Criterion offers a formula which optimizes the allocation of money or budget on given assets. It is used in gambling in order to determine the optimal portion of initial money or assets to be bet and investment game while deciding how much of a portion of the budget or the optimal fraction of retained assets should be put into trade or investment. In our experiment, we show the decision behavior of people on allocating their initial money given the few circumstances.

Kelly Criterion calculates what percentage of bankroll, %K, should be invested by regarding the probability of winning, p, and fractional odds from reward to risk or ratio between gaining and losing, b, as follows:

$$\%K = p - \left[\frac{1-p}{b}\right]$$

This formula implies that the percentage of an investor's initial amount of money to put into a trade have risen if the probability of winning and the ratio between gaining and losing increases. On the other hand, we can consider the ratio between gaining and losing as the return factor. For example, to understand how to determine the ratio between gaining and losing, b; if the return multiplier for a single trade is 2 while the initial amount of putting money was 10$, the gaining amount should be 20$. Considering the thought that nothing is gained from the investment as a loss return multiplier which is 1 in our example, the ratio between gaining and losing, b, should be 2. In addition, in experiment, calculated fraction of bankroll to be invested for each of decisions based on the setup of the experiment in terms of Kelly formula is as follows:



In addition, this experiment is also adapted in terms of revealing the endowment effect from “Anomalies: The Endowment Effect, Loss Aversion, and Status Quo Bias” by Daniel Kahneman, Jack L. Knetsch, Richard H. Thaler (1991). It implies that people often focus on not losing instead of gaining because of the concept of loss aversion. Based on this point, the main effect of endowment is related to the pain of giving the items or assets which people owned up. We customized this approach to our experiment by systematically increasing the amount of initial endowment of people in each round who attend the experiment, and observed how to differentiate effects of increasing the amount of endowment and how people react against the changes in the amount of initial endowment.

4. Research Hypotheses

4.1. Increased initial endowment leads participants to more secure assets.

Many standard behavioral economics experiments start the game by providing participants with an initial endowment. In this game, where we already talked about the experimental design in detail, the participants were given a hypothetical initial endowment in the form of money for each treatment. Our initial endowment in each treatment had an increasing trend and changed to 10, 20, 50, and 100 dollars in each treatment respectively.

According to the concept of the "endowment effect" discussed by Thaler (1980), people may hesitate to take risks because they are afraid of losing the asset they already hold. If we apply this concept discussed in the literature to our experience, we believe that participants' increased initial endowment will increase their avoidance of risky behaviors. Thus, according to our hypothesis, for example, when the initial endowment is 100, we predict that the participants will invest more in safe assets and avoid risky assets more than when the initial endowment is 20. We think that as their initial endowment increases, they will want to avoid losing this money in line with Thaler's concept and the tendency toward safe assets will increase.

4.2. As the high return factor increases, the participants invest more in risky assets.

According to Frijns, Koellen, and Lehnert (2006), an increase in the risk-return trade-off (more return for a given amount of risk) increases demand for the risky assets. Like this finding in the literature, in this investment game we created, we hypothesize that, if all other components remain stable, the increase in the high return factor encourages the participants to increase their investments in risky assets. According to this hypothesis, we expect a positive relationship between the high return factor showing the return of the risky asset in our experiment and the risk-taking of the participants.

4.3. As the high return probability increases, the participants invest more in risky assets.

We suggest that an increase in high return probability will have the same effect as an increase in the high return factor has on the behavior of the participants. Increasing the high return probability means that for our game the probability of winning on these risky assets has increased from 0.3 to 0.7. We can interpret the increase in the probability of winning and the decrease in the probability of loss in risky assets as the fact that risky assets become a little more secure. We suggest that the investments of the participants in risky assets will increase in the face of this increased probability of earning.

5. Results

5.1. Summary statistics

The summary statistics of our data, which consists of 40 observations in each decision in each round is as follows (variable Invested reports the amount invested in risky asset in that decision):

Summary statistics – Round 1

Variable	Obs	Mean	Std. Dev.	Min	Max
Endowment	40	10	0	10	10
Invested1	40	2.075	2.463971	0	10
Invested2	40	2.725	2.407121	0	10
Invested3	40	3.3	2.448966	0	10
Invested4	40	4.3125	2.578728	0	10
Invested5	40	5.4	2.41576	1	10
Invested6	40	6.35	2.806129	0	10
Invested7	40	7.2	2.244081	0	10
Invested8	40	7.8	2.077967	0	10
Invested9	40	8.2	2.05314	0	10
Invested10	40	8.625	1.67466	4	10
Earnings	40	13.2875	9.861793	0	40
Cumulative~s	40	23.2875	9.861793	10	50

Summary statistics – Round 2

Variable	Obs	Mean	Std. Dev.	Min	Max
Endowment	40	20	0	20	20
Invested1	40	3.95	5.053306	0	20
Invested2	40	5.8	5.238908	0	20
Invested3	40	6.525	5.043338	0	20
Invested4	40	8.725	4.96649	0	20
Invested5	40	9.825	5.052988	0	20
Invested6	40	11.225	5.404118	0	20
Invested7	40	13	5.237929	0	20
Invested8	40	14.5	5.301185	0	20
Invested9	40	15.075	5.370324	0	20
Invested10	40	16.525	4.551627	0	20
Earnings	40	23.3875	19.28647	0	80
Cumulative~s	40	46.675	19.74567	16	98

Summary statistics – Round 3

Variable	Obs	Mean	Std. Dev.	Min	Max
Endowment	40	50	0	50	50
Invested1	40	11.8	15.87968	0	50
Invested2	40	13.025	15.12595	0	50
Invested3	40	15.575	15.01433	0	50
Invested4	40	19.625	14.57727	0	50
Invested5	40	22.925	13.73446	0	50
Invested6	40	30.35	14.48704	0	50
Invested7	40	34.65	12.52802	0	50
Invested8	40	36.075	12.81503	0	50
Invested9	40	39.875	11.0713	0	50
Invested10	40	41.325	11.27827	0	50
Earnings	40	62.55	43.00444	0	170
Cumulative~s	40	109.225	46.70062	20	200

Summary statistics – Round 4

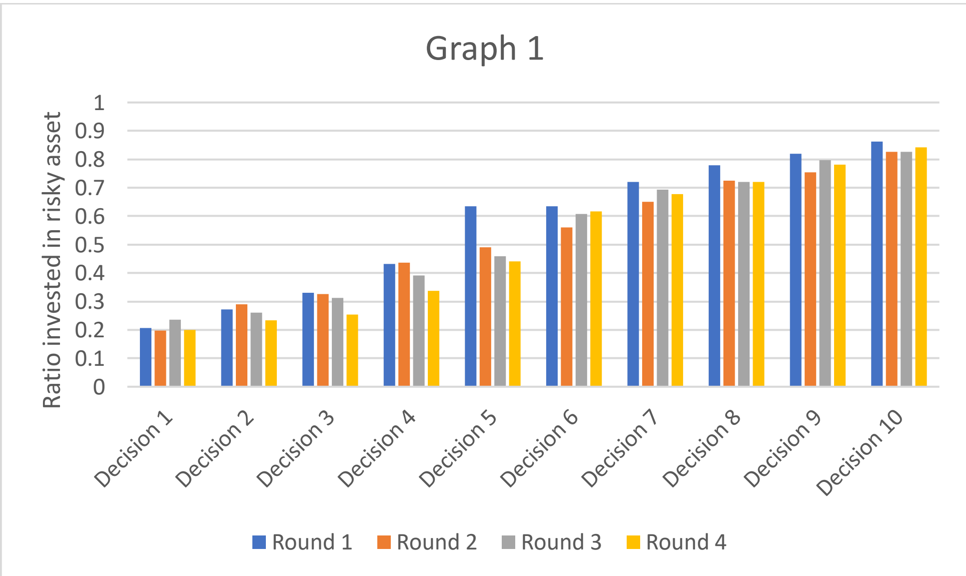
Variable	Obs	Mean	Std. Dev.	Min	Max
Endowment	40	100	0	100	100
Invested1	40	20	31.5619	0	100
Invested2	40	23.425	29.51305	0	100
Invested3	40	25.325	28.47166	0	100
Invested4	40	33.7	29.32855	0	100
Invested5	40	44.125	30.69468	0	100
Invested6	40	61.625	27.92819	0	100
Invested7	40	67.85	25.85021	0	100
Invested8	40	71.975	25.52775	0	100
Invested9	40	78.15	23.77733	0	100
Invested10	40	84.325	23.17203	0	100
Earnings	40	131.1625	97.50519	0	400
Cumulative~s	40	240.3875	112.3893	20	503

5.2. The General Case

5.2.1. Graphical Analysis

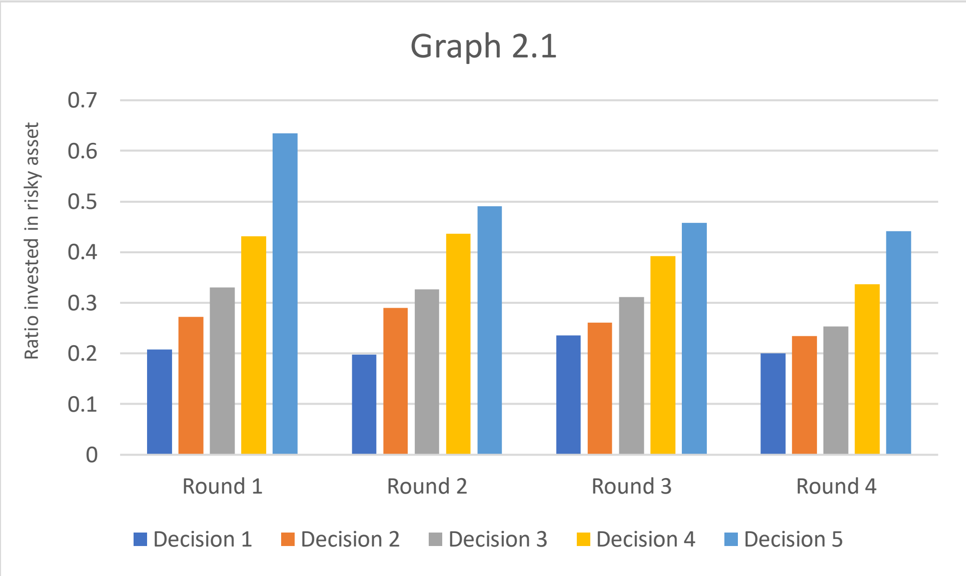
First of all, we created Graph 1 using all the data we have. We calculated the ratio of the endowment that is invested in the risky asset option for each participant and then took the average. This graph allows us to make a comparison between rounds and decisions.

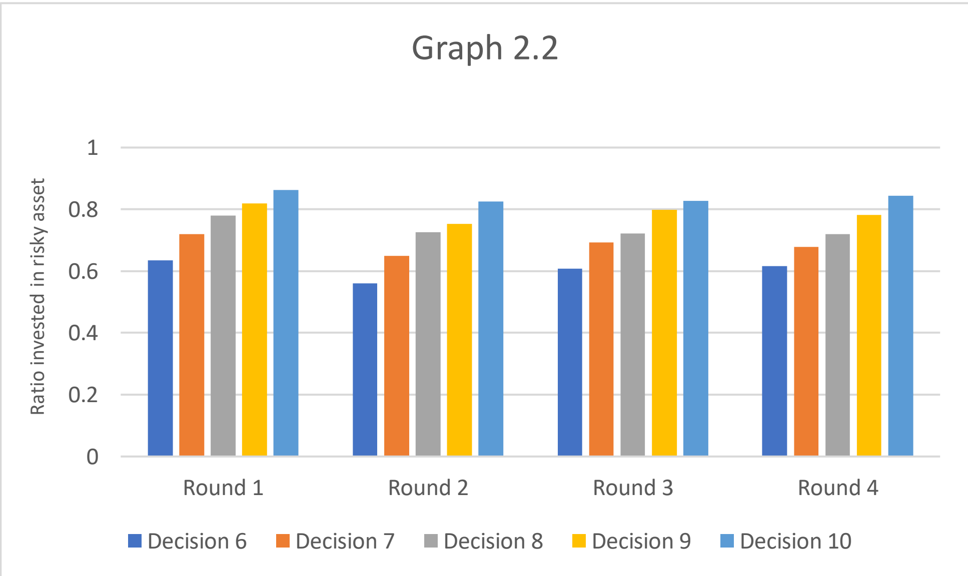
Graph 1 shows that for most of the decisions, in average, people chose to invest a higher portion of their endowment when their endowment is lower. For example, in Round1 Decision3 - where the high return factor is 2.5, the high return probability is 0.3 and the endowment is 10$ - people invested approximately 33% of their endowments in risky asset, while in the following rounds the percentage of their endowments invested in risky assets decrease (32.6% in Round 2 where initial endowment increased two 20$, 31% in Round 3 where endowment is 50$ and 25%in Round 4 where endowment is 100$). Although these ratios seem to support our hypothesis on the effect of the endowment, there are different results for some decisions, for example in Decision 1 people invested more of their endowment in risky asset in the 3rd round where their endowment is 50$. We will run some statistical tests to see the significance of the effect of the endowment later in this section.



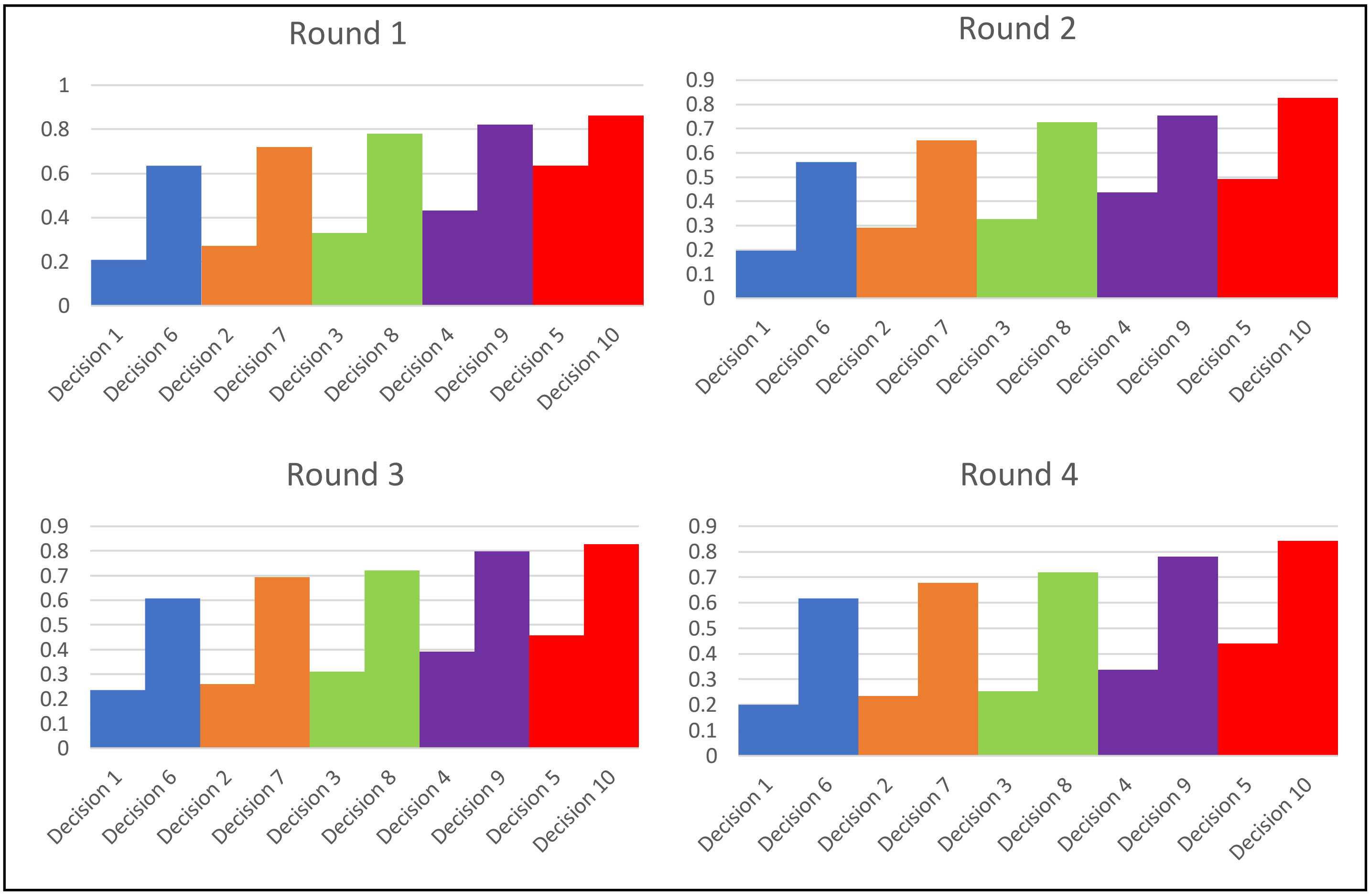
Graphs 2.1 and 2.2 shows the effect of high return factor of the risky asset on the ratio of the endowment invested in risky asset. Graph 2.1 depicts the change of the ratio through the decision 1 to 5 where the probability of win is fixed at 0.3, Graph 2.2 depicts the change through decisions 6 – 10, where probability of win is 0.7. The high return factor is 1.5 for decision 1 (and 6), 2 for decision 2 (and 7),2.5 for decision 3 (and 8), 3 for decision 4 (and 9), 4 for decision

5 (and 10). We can see that in each round the percentage of money invested in risky asset increases as the high return factor increases although the probability of winning and endowment remain constant.





Finally, last four graphs show the change in ratio invested when the probability of winning increases. The decisions which have the same high return factor and in which participant have the same endowment but different probabilities of high return (decisions 1&6, decision 2&7 etc.) are paired and compared next to each other and showed in same colors.



5.2.2. Regression

In this subsection, we used OLS regression to see the effects of endowment, high return factor and high return probability of investment decision using all observations that we have. The dependent variable is the ratio invested in risky asset in all decisions and independent variables are the endowments, high return factors and a binary variable (*highlow*) which is 0 if the return probability is 0,3 and 1 if the high return probability is 0,7 for every decision in the experiment. Results show that each of our independent variables have statistically significant effects on the share of the endowment that is invested in the risky asset: Having high return probability in the risky asset and a high return factor have a positive effect on the ratio invested and higher endowment has a negative effect as we suggested in our hypothesis, although the magnitude of the coefficient on Endowment is smaller.

In the following subsections, we will test each hypothesis separately using OLS and t - tests.

General Case – Regression Results

Number of obs	1,600
F(3, 1596)	389.83
Prob > F	0.0000
R-squared	0.4101
Root MSE	.26159

ratio_invested	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
Endowment	-.000478	.000189	-2.53	0.012	-.0008487	-.0001072
highlow	.3938125	.0130796	30.11	0.000	.3681575	.4194675
highreturnfactor	.1066106	.0076533	13.93	0.000	.0915991	.1216222
_cons	.0814341	.0232471	3.50	0.000	.0358362	.1270321

5.3. Endowment

To see the effect of endowment separately, we run regressions for each decision taking the endowment as the independent variable and ratio invested as the independent variable. Table 1 shows the results. For example, for Decision 3, the coefficient on Endowment states the effect of Endowment on the share that is invested to risky asset, while high return probability and high return factors are constant. We can see that the Endowment's effect is statistically insignificant in our sample except for decision 4 & 5 where the magnitudes of the coefficients are small.

Table 1

	(Decision 6)	(Decision 7)	(Decision 8)	(Decision 9)	(Decision 10)
VARIABLES	ratio_invested	ratio_invested	ratio_invested	ratio_invested	ratio_invested
Endowment	0.000137	-0.000136	-0.000455	-0.000117	-6.79e-05
	(0.000631)	(0.000562)	(0.000556)	(0.000529)	(0.000483)
Constant	0.599***	0.692***	0.757***	0.793***	0.843***
	(0.0360)	(0.0321)	(0.0317)	(0.0302)	(0.0275)
Observations	160	160	160	160	160
R-squared	0.000	0.000	0.004	0.000	0.000

	(Decision 1)	(Decision 2)	(Decision 3)	(Decision 4)	(Decision 5)
VARIABLES	ratio_invested	ratio_invested	ratio_invested	ratio_invested	ratio_invested
Endowment	-4.08e-06	-0.000531	-0.000861	-0.00112*	-0.00162**
	(0.000641)	(0.000620)	(0.000609)	(0.000614)	(0.000638)
Constant	0.210***	0.288***	0.344***	0.450***	0.579***
	(0.0365)	(0.0354)	(0.0347)	(0.0350)	(0.0364)
Observations	160	160	160	160	160
R-squared	0.000	0.005	0.012	0.021	0.039

5.4. High Return Factor

Table 2.1 show the effect of high return factor of the risky asset on investment decisions at the first 5 decisions in our design and Table 2.2 shows the same with the last five decisions in our design. In first five decision in each round, the endowment and probability of winning is constant, holding them constant, the high return factor has a positive and statistically significant effect on the ratio invested in the risky asset. The effect is the highest in magnitude at first five decisions of the first round, where the endowment is the lowest and the there is a low probability of winning.

Table 2.1. Decisions 1 - 5 (Probability of High Return = 0.3)

VARIABLES	(Round 1) ratio_invested	(Round 2) ratio_invested	(Round 3) ratio_invested	(Round 4) ratio_invested
highreturnfactor	0.172***	0.118***	0.0951***	0.0991***
	(0.0208)	(0.0208)	(0.0243)	(0.0245)
Constant	-0.0722	0.0402	0.0846	0.0355
	(0.0570)	(0.0569)	(0.0666)	(0.0670)
Observations	200	200	200	200
Endowment ($)	10	20	50	100
R-squared	0.257	0.141	0.072	0.077

Table 2.2. Decision 6 – 10 (Probability of High Return = 0.7)

VARIABLES	(Round 1) ratio_invested	(Round 2) ratio_invested	(Round 3) ratio_invested	(Round 4) ratio_invested
highreturnfactor	0.0884***	0.102***	0.0866***	0.0909***
	(0.0181)	(0.0212)	(0.0205)	(0.0207)
Constant	0.534***	0.437***	0.504***	0.492***
	(0.0495)	(0.0581)	(0.0561)	(0.0566)
Observations	200	200	200	200
Endowment ($)	10	20	50	100
R-squared	0.108	0.105	0.083	0.089

5.5. High Return Probability

To see effect of probability of high return in investment decisions, first we will run a t-test to see whether there is a difference in the means of shares of the endowment invested in risky asset between high probability of high return and low probability of high return. Decisions in which we have same high return factor and same endowment but different probabilities of high return are paired for each round (Decisions 1&6,2&7,3&8,4&9,5&10) and t-test were applied to see the difference.

Our null hypothesis which is there is no effect of probability of high return on the investment can be rejected if the difference of means is statistically significant.

For all pairs in each round we ran t-test to see the difference in means and we saw the p values for all test are small enough to reject the null hypothesis: averages of ratio invested in risky asset for both low and high probability are significantly different. Below there is an example of these tests (Round 1 Decision 3 and 8). In the Replication Codes in Appendix all t-test results can be found.

T-test (Round 1 - Decision 3 and 8)

```
Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
Invest~3 |      40         3.3    .3872156    2.448966    2.516783    4.083217
Invest~8 |      40         7.8    .3285555    2.077967    7.135434    8.464566
---------+--------------------------------------------------------------------
    diff |      40        -4.5    .5595901    3.539158   -5.631878   -3.368122
------------------------------------------------------------------------------
     mean(diff) = mean(Invested3 - Invested8)                     t =  -8.0416
 Ho: mean(diff) = 0                              degrees of freedom =       39

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000
```

To see the effect of high return probability we also ran regressions for all rounds and decision pairs and Table 3.1 - 3.4 show the results of these regressions. We saw statistically significant and positive effects of high return probability on investment decisions in all rounds and every decision, as expected.

Table 3.1 (Round 1)

VARIABLES	(1) ratio_invested	(2) ratio_invested	(3) ratio_invested	(4) ratio_invested	(5) ratio_invested
highlow	0.428***	0.448***	0.450***	0.389***	0.228***
	(0.0590)	(0.0520)	(0.0508)	(0.0521)	(0.0517)
Constant	0.207***	0.272***	0.330***	0.431***	0.635***
	(0.0418)	(0.0368)	(0.0359)	(0.0369)	(0.0365)
Observations	80	80	80	80	80
R-squared	0.402	0.487	0.502	0.416	0.199

Table 3.2 (Round 2)

VARIABLES	(1) ratio_invested	(2) ratio_invested	(3) ratio_invested	(4) ratio_invested	(5) ratio_invested
highlow	0.364***	0.360***	0.399***	0.318***	0.335***
	(0.0585)	(0.0586)	(0.0578)	(0.0578)	(0.0538)
Constant	0.197***	0.290***	0.326***	0.436***	0.491***
	(0.0414)	(0.0414)	(0.0409)	(0.0409)	(0.0380)
Observations	80	80	80	80	80
R-squared	0.331	0.326	0.379	0.279	0.332

Table 3.3 (Round 3)

VARIABLES	(1) ratio_invested	(2) ratio_invested	(3) ratio_invested	(4) ratio_invested	(5) ratio_invested
highlow	0.371***	0.433***	0.410***	0.405***	0.368***
	(0.0680)	(0.0621)	(0.0624)	(0.0579)	(0.0562)
Constant	0.236***	0.261***	0.311***	0.392***	0.458***
	(0.0481)	(0.0439)	(0.0441)	(0.0409)	(0.0397)
Observations	80	80	80	80	80
R-squared	0.276	0.383	0.356	0.386	0.355

Table 3.4 (Round 4)

VARIABLES	(1) ratio_invested	(2) ratio_invested	(3) ratio_invested	(4) ratio_invested	(5) ratio_invested
highlow	0.416***	0.444***	0.467***	0.445***	0.402***
	(0.0666)	(0.0620)	(0.0605)	(0.0597)	(0.0608)
Constant	0.200***	0.234***	0.253***	0.337***	0.441***
	(0.0471)	(0.0439)	(0.0428)	(0.0422)	(0.0430)
Observations	80	80	80	80	80
R-squared	0.333	0.397	0.433	0.415	0.359

6. Conclusion

Our paper was set to examine individuals' decisions while allocating their capital in different probability, return and endowment factors. We have used regression analysis and conducted t-test to test our hypothesis and reach our results. Our findings show that while two of our hypotheses were confirmed, we could not find sufficient evidence to reject our third hypothesis completely.

According to our regression analysis, the probability factor was found to be significant for investors while allocating their money between assets. As the probability of a higher return increased, investors seem to invest more in the risky asset.

Likewise, our regression analysis showed that a high return factor was of significance to participants' investment decisions. As the possible return on investment rose, so did the amount invested in that option. We have also observed that high return factor was of more significance when initial endowment given was lower (ex: when endowment is 10)

Our last hypothesis, which was about how endowment affected investment decisions, was found to be of insignificance in general level as we see that the ratio of amount invested has not changed notably. When looking at the decisions separately, in some decisions we came across some significance but it is important to note that the significance was very small. Our sample of data can be the reason for this as it was relatively small and consisted of participants whom can be said to have similar backgrounds such as age and educational level. We also thought there might be a possibility that people may invest more because of a possibility of higher return when the endowment amount increases. But we believed the possibility of loss would be a holding back factor as our participants were students and small amounts of money were of an importance to them. Therefore, we thought of them to be risk averse. An explanation for this contradictory result may be that the capital they were allocating were not real money. For that reason, a loss probability occurring did not affect them as significantly as we have thought.

This experiment can be further improved with a wider range of data and higher incentives for successful investments. Also new tests can be conducted to measure how the dice roll that determines which decision is taken into account at the end of each round has an effect on investors decisions.

7. References

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