EXPERIMENTS ON RISK PERCEPTION AND INVESTMENT DECISIONS OF ECONOMIC ACTORS

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ABSTRACT

In a simple simulated experiment we compare the risk perception and risk taking of participants to the concept of coherent risk measures. Using a sample of 50 participants the aim of our preliminary research is to test the defined experimental environment and define the further directions of its development. Using simulated financial positive homogeneity, subadditivity and monotonicity are perceived by the participants. Translation invariance is applied only by half of the sample. Capital allocation between risky and risk free asset highly correlates with price changes in the most risk averse group of participants. The most risk taking part of the sample followed a strategy to reallocate their gains from risky asset to the risk free one and reorganized their portfolio less frequently but by larger amounts. The behavior of medium risk taker/risk averse participants has to be tested in a more detailed research.

INTRODUCTION

Risk aversion of economic actors is a basic concept both in economics and finance when describing decision making under uncertain circumstances. Risk differs from uncertainty in a way that in risky situation all the possible future outcomes and also the related probability distribution is known. Risk is commonly seen as the deviation from the expected value of the outcome. Though the risk treats the case when the realization differs from the expected value.

There exist a widespread literature of risk measures. The well-known modern portfolio theory (MPT) of Markowitz (1952) applies a mean-variance analyses where the variance of returns stands as a risk measure. The beta in the Capital Asset Pricing Model (CAPM) (Sharpe 1964) is also a well-known risk measure. It measures only the non-diversifiable part of the total risk, the systematic risk thus it does not includes the whole variance of expected returns. Beta shows how the expected excess return of assets are related to the market risk premium trough the non-diversifiable risk of the asset compared to the market risk. Several decades later the Value-at-Risk concept is used among practitioners and regulators to measure and manage market risk of portfolios. (Jorion 2007) But in case of normally distributed returns also VaR is closely related to variance. Artzner et al (1999) define the properties of measures which are appropriate from a theoretical point of view to measure risk. Coherent risk measures are ρ functions which satisfy the following four characteristics:

Translation invariance: adding an amount to our initial X position and investing it into risk free investment reduces the risk measure by *a*:

$$\rho(X+a)= \rho(X)-a \qquad (1)$$

Subadditivity: there are X and Y investment opportunities, and ρ function measures their risk the following way:

$$\rho(X+Y)\leq\rho(X)+\rho(Y) \qquad (2)$$

Positive homogeneity: for all $\lambda\geq 0$ and X initial investment:

$$\rho(\lambda X)= \lambda \rho(X) \qquad (3)$$

Monotonicity: for all $X\leq Y$ initial investments:

$$\rho(x)\leq\rho(Y) \qquad (4)$$

(Artzner et al. 1999)

Risk aversion of investors is not only a basic element in the above cited models, but also in many of standard theories. (i. e. Bernoulli 1738; Pratt1964; Arrow 1965 as also Holt and Laury (2002) cite.) This can be derived from the expected utility theory of von Neumann and Morgenstern (1953) where assuming a concave utility function over wealth leads to risk aversion of consumers. Although risk aversion is a corner stone of many models, there is no evident experimental method available in the literature how it should be tested or modeled.

The results of Kahnemnann and Tversky (1973, 1984) provide an unevadable challenge to the rationality assumption of economics. According to them the

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decision making of humans in risky situations is based on shortcuts instead of the classical rationality defined by von Neumann and Morgenstern. Thus the maximization of expected utility does not hold. From their work evolved the behavioral finance. This field provides already plenty of empirical studies on experiments and methods to test the risk aversion of actors or more generally to explorer the perception of risk and the attitude towards risk. Charness, Gneezy and Imas (2013) provide a summary on experimental methods on risk preferences. They describe several measurement tools like elicitation methods and multiple price list method. But most of their analytical tools are static. Eckel and Grossman (2008) tested the risk aversion differences of men and women. They defined three categories of methods: abstract gambling, contextual environment experiments and field studies. Simulated environments belong to their second category. Cohn et al (2015) published one of the most recent study in the topic, they focused on professionals' countercyclical risk aversion. They used a questionnaire with simulated asset prices.

Developing a measurement tool which belongs to the group of contextual environment experiments, we will focus on a new question in this field. The aim of our paper is to compare the professional risk concept to the perceived risk by non-professional participants.

In our paper we compare the risk perception of economic actors to the theoretical construction of coherent risk measures. We test whether the four assumptions of coherency is perceived the same way by the participants of an experiment when evaluating simulated financial data and comparing riskiness of different datasets. Simulating a single risky price process we also collect some evidence on capital allocation decisions of participants. The results can be the first step toward our further research where risk perception and decisions on risky investment are tested in a more complex experiment.

The paper continues as follows. First we describe the applied methodology for the simulation, then we provide details on the experiments and dataset. After the results on coherency axioms we summarize the capital allocation strategy of participants over 10 periods. Finally we conclude.

THE APPLIED METHODOLOGY

In our paper we test the perception of financial risk using a simulated financial data. We designed a questionnaire which was an Excel file where the Structured Monte Carlo simulation (SMC) was run by Visual Basic (VB) codes. We chose the Geometric Browninan Motion (GBM) to describe the process of the financial instruments representing different level of financial risk. The commonly used GBM is a stochastic process which is continuous over time. It assumes that the changes of a S_t stochastic process (i.e. the value of a stock) are characterized by the following equation:

$$dS_t=\mu S_t dt + \sigma S_t dW_t \quad (5)$$

The W_t represents a stochastic process, the Wiener process and incorporates risk to the model. The parameters of the μ drift and the σ standard deviation are constant. The index t is standing for a given point of time t, while dt is time horizon of the price changes. (Hull 2009)

To analyse the results we use descriptive statistics.

THE EXPERIMENTS AND THE DATASET

Our research project is a pilot study to test the developed SMC and experimental environment. Thus the size of the sample refers to this goal: 50 participants were part of the experiment. Based on the collected initial results the setting and the framework of the experiments will be improved in a later research project.

Instead of real investment situations the experiments provided the participants simulated financial data where they had to make financial decisions. There were no monetary incentives, participants did not receive any monetary payoff depending on their profit/loss attained in the simulation.

The sample is a group of students of a Hungarian College in their first and second year of studies. The participation was voluntary and anonym. Who decided to participate at the experiment they run the SMC-file on their own computer. A short description of rules and the research was attached.

Using the randomly simulated data all the participants met one realization of the simulated distributions. In the first six answers, participants had to decide which one of the simulated price process is riskier. In all the cases the prices were illustrated on a chart, so participants had the possibility visually differentiate between the time series.

The participants had to compare the riskiness of the following assets where the time horizon was one year and price changes occurred on a weekly bases (dt=1/52):

Question (1): $A_0=100$, $\mu_A=10\%$, $\sigma_A=15\%$, $B_t=4A_t$

Question (2): $A_0=100$, $\mu_A=10\%$, $\sigma_A=20\%$, $B_0=100$, $B_t=10+A_t$

Question (3): $A_0=100$, $\mu_A=10\%$, $\sigma_A=20\%$, $B_0=100$, $\mu_B=5\%$, $\sigma_B=20\%$, $C_0=100$, $C_t= 0.5A_t +0.5B_t$

Question (4): $A_0=80$, $\mu_A=10\%$, $\sigma_A=15\%$, $B_0=100$, $\mu_B=12\%$, $\sigma_B=25\%$,

Question (5): $A_0=80$, $\mu_A=10\%$, $\sigma_A=15\%$, $B_0=60$, $\mu_B=12\%$, $\sigma_B=25\%$

Question (6): $A_0=100$, $\mu_A=10\%$, $\sigma_A=15\%$, $B_0=100$, $\mu_B=12\%$, $\sigma_B=25\%$

In the last question all the participants faced an investment decision in a SMC. They had to divide their initial capital to risk free and to risky investment assets. Then the VB code simulated the prices of the chosen asset for the first year of the investment where price changes occurred on a monthly basis. After the first period the investor had the opportunity to restructure the portfolio. In these question we simulated investment decisions over a horizon of 10 years where the investor could reallocate the portfolio at the beginning of each

year. There were only one risky asset available thus the question represents the capital allocation problem between risky and risk free sub portfolio instead of security selection. (Thus we followed the logic of Capital Asset Pricing Model (CAPM) (Sharpe 1964) where security selection starts only after the capital allocation was made.)
Question (7): A_0=100, μ_A=10%, σ_A=20%,
The dataset contained all the individually simulated price changes and the investment decisions made by the participants. We also collected the self-defined risk aversion (on a range of 1 to 4) of the participants.
In this preliminary research we focused on the applicability of the simulated experiments. We apply only descriptive statistics to analyse the results because the sample size does not allow more sophisticated methods.

HOW PARTICIPANTS PERCIEVE COHERENCY AXIOMS

In the first part of the experiment we confront the risk perception of participants and the axioms of coherent risk measures. We tested whether the heuristical risk notion of non-professionals is similar to that of the well-designed risk measures if professionals. Table 1 contains the summary of answers in the first six questions (Q1-Q6) representing the axioms of coherency. (The first row of Table 1 represents that 12% of the 50 participants perceived simulated A series of financial data riskier than the B one. But 88% of the 50 participants find that simulated B series of financial data incorporates higher risk than A one.)

Table 1: Answers on Q1-Q6. Testing of coherency.
Source: Own calculation

	A	B	C	sum
Q1	10%	90%		100%
Q2	52%	48%		100%
Q3	88%	8%	4%	100%
Q4	12%	88%		100%
Q5	30%	70%		100%
Q6	28%	72%		100%

Question (1) gave the most homogene result. Positive homogeneity was tested here according to $\rho(\lambda X)= \lambda \rho(X)$ axiom the following way: A_0=100, μ_A=10%, σ_A=15%, $B_t=4A_t$. 90% of participants knew that the higher the exposure the higher the risk in a certain investment.
Translation invariance was represented by Question (2). For the assumption of $\rho(X+a)= (\rho(X)-a)$, we defined A_0=100, μ_A=10%, σ_A=20%, B_0=100, $B_t=10+A_t$. As the results show, approximately half of the sample realized that process contains a risk free components thus B always dominates A. However the stochastic component in both processes is the same Wiener-process, so the perfect linear correlation may explain why participants of the experiment was unsure how to compare riskiness of A and B.
Subadditivity is tested by Question (3), where according to the subadditivity axiom C should be less risky, then A plus B. Only 4% of participants perceived the diversified C portfolio riskier than the other ones. Most of the answers (88%) was correct evaluating A as the most risky process. So subadditivity was perceived by most of the participants.
Monotonicity has been tested a certain way already in Question (1). An appropriate way for testing could be in a later research also a process setting as follows: e.g. A_0=80, μ_A=10%, σ_A=15%, B_0=100, μ_B=10%, σ_B=15%, where the generated random processes of A and B would not be perfectly correlated as in Question (4). We assume that this question would have been resulted in a slightly lower percent of right answers. (Compared to 90%.)
On the above presented preliminary results the risk perception of participants in our experiments shows similarities to the risk idea of researchers. Three from the four axioms of coherency, namely positive homogeneity, monotonicity and subadditivity are perceived also in the experiments. Translation invariance shows a less evident result. In further research it could be interesting to add a larger risk free part to the risky element of process B_t.

PERCIEVED RISK AND THE LEVEL OF RISKY PROCESS

The remaining questions (Question 4-6) analyze how the same dynamic with different starting value is perceived. A and B processes are defined by their different A_0 and B_0 initial value while their parameters are the same. (Q4-5: μ_A=10%, σ_A=15%, μ_B=12%, σ_B=25%)
The results somehow interfere with monotonicity or positive homogeneity. The fact, that in most of the scenarios process B in Question (4) dominates process A contributed to the perceived risk level. (Remember, Question (1) for positive homogeneity or monotonicity gave the most homogene answers.) We can also value our assumption on the cross tables of Questions (4)-5 or Questions (1) and (4). (See Table 2). 31 participants evaluated B riskier independent of B_0 or A_0. Only 17 participants ranked riskiness according the B_0 or A_0, and 13 of them perceived positive homogeneity or monotonicity in Question (1). Thus these 13 participants applied their initial idea on positive homogeneity as well in other questions. In Question (5) ($A_0>B_0$) and Question (6) ($A_0=B_0$) where ranking of A_0 and A_0 contradict the dynamic of the processes, answers are less homogene. (See Table 1.) Thus we assume that the higher the absolute values of the process the higher the perceived risk. This assumption could be tested in our further research using a sample of a larger size. (Having only 50 participants, the cells' values in a cross table are too low to calculate measures of independence. So Table 2 is only an illustration of a cross table.)

Table 2: Cross table of Q4-Q5.
Source: Own calculation

		Q5		
		A	B	Sum
	A	2	4	6
	B	13	31	44
Q4	Sum	15	35	50

Table 3: Cross table of Q1-Q4.
Source: Own calculation

		Q4		
		A	B	Sum
	A	0	6	6
	B	5	39	44
Q1	Sum	5	45	50

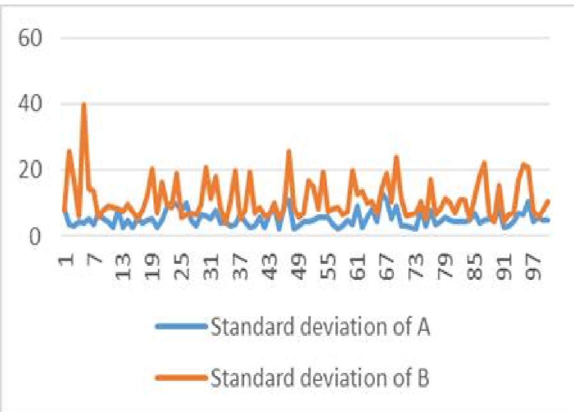
Standard deviation or variance which do not belong to coherent risk measures but are used to capture risk in several models, we can say that it has been an industry standard for decides. (I.e. MPT, CAPM – Capital Asset Pricing Modell) It is interesting that these two show the same pitfalls than the above describes answers. We run 1000 scenarios for processes A_t and B_t, and calculated the standard deviation of the simulated series, on all the processes of Q1-Q6. Table 4 and Figure 1-3. show that the simulation corresponds to the perceived risk of participants.

Table 4: Comparison of standard deviation of A_t and B_t for Q4-Q6.
Source: own simulation

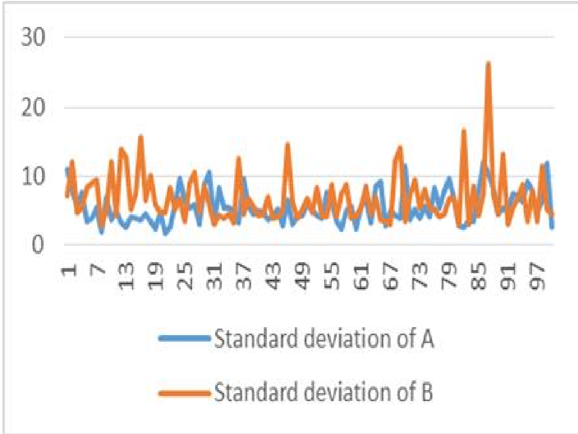
	σ_A	σ_B	% of B answers
Q4	126*	874	88%
Q5	408	592	70%
Q6	227	773	72%

*Number of cases from 1000 simulations where $\sigma_A > \sigma_B$ for Q4. Other cells' values are explained similarly.

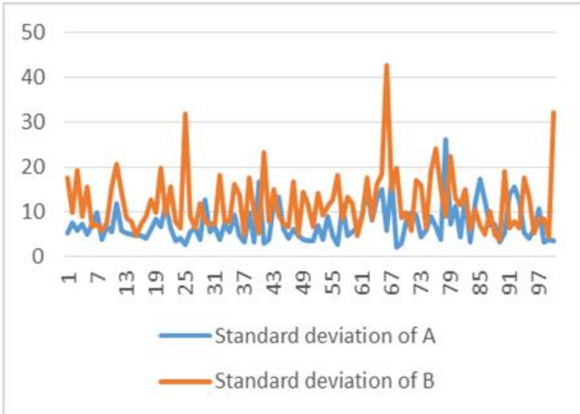
Figures 1: Standard deviations of A and B over 100 realizations in Q4
Source: own simulation



Figures 2: Standard deviations of A and B over 100 realizations in Q5
Source: own simulation



Figures 3: Standard deviations of A and B over 100 realizations in Q6
Source: own simulation

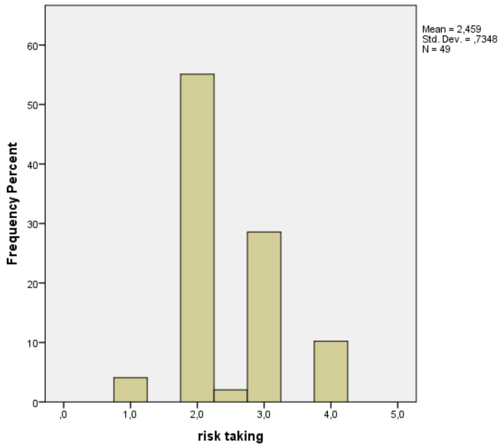


INVESTMENT DECISIONS IN THE CASE OF ONE SIMULATED RISKY ASSET

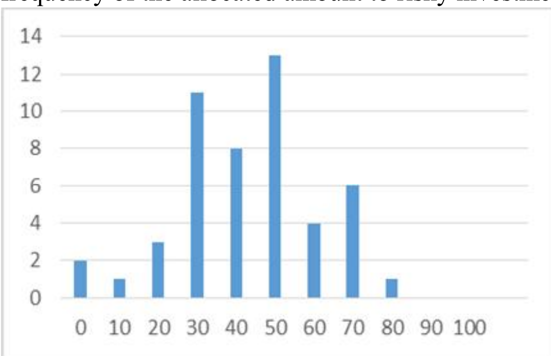
In Question 7 participants faced a 10 years long investment opportunity where they could allocate their initial amount of 100 capital to risky and risk free investment. In Figures 4 there is the histogram of the risk taking ability they defined at the beginning of the experiment (from 1 – totally risk averse to 4 – totally risk taking)

Figures 5 illustrate the first decision on risky sub-portfolio of participants. These two figures suggest that participants are sligthly risk averse at the beginning of the simulation.

Figures 4: Histogram of risk taking level of participants.
Source: SPSS



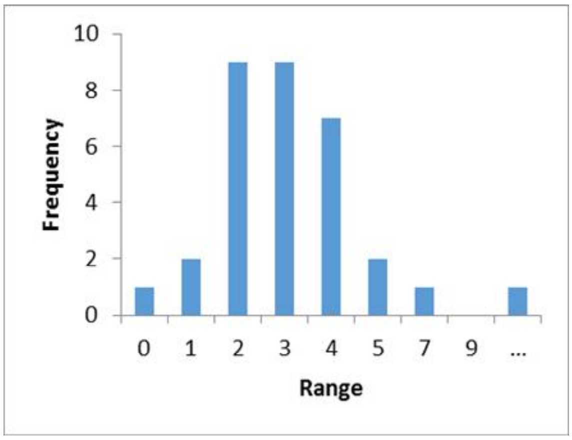
Figures 5: Histogram of allocation decision: The frequency of the allocated amount to risky investment**



** i.e.: 3 of the participants allocated 20 from the initial capital of 100 to the risky asset.

To evaluate the later decisions which are already based on the simulated price process of the chosen risky subportfolio Figures 6 show the distribution of total cumulated price changes (Approxomatly $\Pi_i(1+r_i)$ where i=0; 1…10) of the 49 participants. (One of the 50 participants failed to run the simulation.) The number of cases where a participant dicreased the risky part of the portfolio over the 10 years horizon correlates with the cumulated price changes of the risky investment. (Depending on the definition of cumulated change – absolute values or percentages – the linear correlation coefficient ranges from -0.613 to -0.632.) The correlation atteins 0.85 the highest value in the most risk averse group (risk taking level 1), but it has a weak negative value (-0.28) at risk taking level 4. Less frequent but high volume changes in risky asset allocation explain this correlation. The absolute value of linear correlation decreases over time at riks taking level of 4. These participants allocated the gains from the risky asset to the risk free one at the beginning of the simulation. The middle groups (risk taking level 2-3) show a positive correlation near to 0.5. But there is a periodicity in correlation over time at both of these risk taking levels however the price changes are unique and randomly generated for all participants in all the 10 periods. This autoregressive phenomenon needs further research and larger sample size to be explained.

Figures 6: Frequency of cumulated price changes in risky assets***
Source: Excel

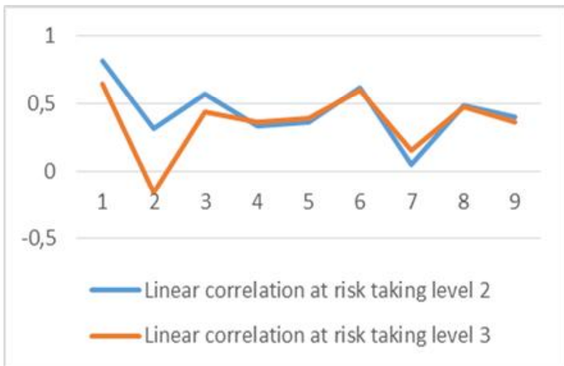


***i.e.: a cumulated change of 2 means that the value of the risky asset doubled over the 10 years.

Table 5: Linear correlation between price changes of risky asset and investment decision among different risk taking levels.
Source: own calculation

Risk taking level	Linear correlation of absolute changes	Linear correlation of % changes
1	0,85	0,60
2	0,49	0,30
3	0,40	0,26
4	-0,28	0,28

Figures 7: Linear correation of absolute value changes over 10 periodes
Source: Excel



CONCLUSIONS

Risk aversion of economic actors derived from the expected utility theory of von Neumann and Morgenstern (1953) is a basic concept both in economics and finance when describing decision making under uncertain circumstances. On the risk measurement for professional tools (i.e. capital allocation, regulatory capital) there exist a widespread literature. The most accepted concept which is the coherency of risk measures was first published by Artzner et al. (1999). But for the risk perception or risk aversion of non-professionals there is no evident experimental method available in the literature how it should be tested or modelled.

In this paper we developed a simulated investment environment and tested this questionnaire on a sample of 50 participants. First we explored the points where more detailed questions should be applied. Second we also present some preliminary results which have to be tested on a larger sample.

In our paper we compared the risk perception of economic actors to the theoretical construction of coherent risk measures. The experimental environment was appropriate to this goal. We need to define new questions only for the axiom of monotonicity. Our results show that the intuition on risk of the participants does not contradict the coherency axioms set by researchers. Positive homogeneity, monotonicity and subadditivity are perceived also in the experiments by non-professional participants. Translation invariance shows a less evident results.

There are further analysis on the relationship between the perceived risk and the level of risky process. This topic is related to coherency axioms like monotonicity or positive homogeneity. We analyzed in three questions how the same dynamic with different starting value is perceived. Thus we assume that the higher the absolute values of the process the higher the perceived risk. The perceived riskiness in these questions is similar to the risk measured by standard deviation or variance which are the most widely used to describe risk. All these three questions helped to deeper understand the results concerning coherency axioms thus we can include them in a further research.

In a simple investment decision game participants are sligthly risk risk averse at the beginning of the simulation. They risk only a smaller part of their capital. Later, the more risk averse the participant the higher the correlation between price changes and capital allocation. The most risk taking part of the sample changed less frequently capital allocation but their changes were larger than those of participants with other risk taking levels. Risk taker participants allocated the gains from the risky asset to the risk free one at the beginning of the simulation which effect in later periods disappeared. The middle groups (risk taking level 2-3) show a positive correlation near to 0.5 between price changes and capital allocation. The autoregressive charahcteristic of the reallocating decisions will be part of our further resaerch.

Thus the experiment had only 50 participants, the results on Questions (1-6) are to be tested in the future at a larger sample. The capital allocation decisions of 49 participants over 10 periods provide sufficent data on reallocations but the autoregression should be tested before treating investment decisions independent of the point of time they were made.

There are several limits to our pilot study not only the size of the sample. The most important one is that the participants are not professionals yet and there were not any financial concecvences of their investment decisions. Thus their behavior could be more close to gampling than to decisions in real investment situations. More robust results can be achieved with more experienced participants.

REFERENCES

Arrow, K. J. 1956: „Aspects of the Theory of Risk Bearing" Helsinki *Academic Bookstores* cited in Holt and Laury 2002.

Artzner, P., Delbaen, F. and Eber, J.M. 1999: „Coherent Measures of Risk". *Mathematical Finance*, Vol. 9, No. 3. .203-228.

Bernoulli, D. 1738: "Specimen Theoriae Novae de Mensura Sortis." *Comentarii Academiae Scientiarum Imperialis Petropolitanae*, 5, pp. 175-92, translated by L. Sommer 1954 in *Econometrica*, Vol. 22 .23-36. cited in Holt and Laury 2002

Charness, G., Gneezy, U. and Imas, A 2013: „Experimental methods: Eliciting risk preferences" *Journal of Economic Behavior & Organization* Vol. 87. .43-51.

Cohn, A., Engelmann, J., Fehr, E. and Marechal, M. A. 2015: „Evidence for Countercyclical Risk Aversion: An Experiment with Financial Professionals" *American Economic Review* Vol. 105. No, 2. .860-85.

Eckel, C. C. and Grossman, P. J. 2008: „Men, Women and Risk Aversion: Experimental Evidence" (Chapter 113) in *Handbook of Experimental Economics Results*, Vol. 1, .1061–1073.

Holt, C. A. and Laury, S. K. 2002: "Risk Aversion and Incentive Effects" *American Economic Review,*Vol. 92. No. 5. .1644-1655.

Hull, J. C. 2009: „Options, Futures, and other Derivatives" Pearson (9 ed.).

Jorion, P. 2007: „Value-at-Risk". *McGraw-Hill* ISBN 0-07-146495-6

Khaneman, D. and Tversky, A. 1973: On the psychology of prediction. *Psychological Review* Vol. 80. No.4. .237–25l.

Khaneman, D. and Tversky, A. 1984: Choices, Values, and Frames. *American Psychologist* Vol. 39. No. 4. .341–350.

Markowitz, H.M. 1952: "Portfolio Selection". *The Journal of Finance.* Vol. 7 No. 1. . 77–91.

Neumann, J.von and Morgenstern, O. 1953: „Theory of Games and Economic Behavior". *Princeton*, NJ. Princeton University Press, 1953

Pratt, J. W. 1964: "Risk Aversion in the Small and in the Large." *Econometrica* Vol. 32. No. 1-2. . 122-36. cited in Holt and Laury 2002

Sharpe, W. F. 1964: "Capital asset prices: A theory of market equilibrium under conditions of risk." *Journal of Finance*, Vol. 19 No. 3. .425–442.

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