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Abstract

The paper analyses on an experimental basis the phenomenon of non-optimal diversification in portfolio choice decisions. The main obstacles to achieving optimal diversification are investigated – the correlation neglect hypothesis and information processing, both of which lead to suboptimal diversification decisions. This is possible by constructing the investment alternatives in the experimental design in such a way that the Markowitz efficient frontier is reduced to a single point in the return-risk diagram, enabling unambiguous interpretation of the results. The subjects 1) neglect the correlation between the assets, 2) use naïve diversification strategies and 3) take irrelevant information as the basis for their investment decisions, whereby the first effect is the strongest.

Keywords: *portfolio choice; investment decisions; correlation neglect; information processing*

JEL-Classification: C91, D81, G11

Correlation neglect, naïve diversification, and irrelevant information as stumbling blocks for optimal diversification

1 Introduction

The question of optimal portfolio choices is vital – for investment bankers dealing with billions of dollars as well for individual investors securing their retirement income. In many instances the investment decisions of both experienced and novice investors are far from optimal and frequently made on the basis of simple rules and heuristics (see, for example, Benartzi and Thaler (2007)). This is especially true of inexperienced individual investors. One of the most critical stumbling blocks is lack of diversification, which leads to suboptimal portfolio choices, higher welfare costs and even to overall instability of financial markets (see Brennan and Torous (1999)). A host of studies addresses the lack of diversification among individual investors,[1] with special attention paid to the investment strategies of individuals in their pension savings plans.[2] De Bondt (1998) characterizes the individual investor as a person who discovers naïve patterns in past price movements, trades suboptimally and does not diversify sufficiently. Lack of diversification could mean, for example, investments in employer stocks (possibly correlated with labour income) or in national or regional companies. The finding of non-optimal diversification is confirmed in both field and experimental studies (Benartzi and Thaler (2001), Fox et al. (2005a), Goetzmann and Kumar (2001 and 2007), Guiso and Jappelli (2006)). On the other hand, consumer choice research and psychological studies show that individuals tend to seek variety, particularly under conditions of uncertainty (Fox et al. (2005a and 2005b)), and allocate their resources according to a naïve diversification strategy (*1/n* heuristic). How can this contradiction – lack of

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[1] See, for example, Lease et al. (1974), Blume and Friend (1975), Bode et al. (1994), Kelly (1995), Schiereck and Weber (2000).

[2] See, for example, Benartzi (2001), Benartzi and Thaler (2001), Agnew et al. (2003), Meulbroek (2005), Huberman and Sengmueller (2004), Goetzmann and Kumar (2008).

diversification, on the one hand, and the search for variety, on the other – be explained? One possibility is that naïve diversification strategies are used only in cases of complete uncertainty. However, individuals tend to be uncertainty averse, preferring some information to no information at all. Due among other things to cognitive limits, information capacities and overconfidence, subjects experience difficulty with the evaluation and processing of information (in terms of its importance or relevance). This can lead to both under- and over-diversification, neither of which constitutes a favourable basis for optimal investment decisions.

How can suboptimal diversification be explained? Apart from institutional factors (see, for example, French and Poterba (1991)), market sentiments or overconfidence (see, for example, Frijns et al. (2008)) behavioural factors in information processing can also lead to suboptimal diversification. These are the subject of this paper.

Since diversification gains are based solely on incomplete correlation between assets (see Markowitz (1952)), it is crucial that an investor be in a position to estimate and incorporate this information correctly into the decision-making process. A less risky and more profitable portfolio can be created with two separate, not fully correlated assets, where both investment alternatives are combined. The following graph in Figure 1 shows the Markowitz efficient frontier, indicating the best possible combination of two separate assets with different risk and return levels.

The two assets are x_1 (low risk, low return) and x_2 (high risk, high return). The x_2 axis shows the share of this asset in the portfolio, ranging from zero (portfolio thus consisting of x_1 asset only) to one (portfolio consisting of x_2 asset only). The x_2 asset not only promises a higher return (cf. x_2/return quadrant) but also represents a greater risk (cf. x_2/risk quadrant).

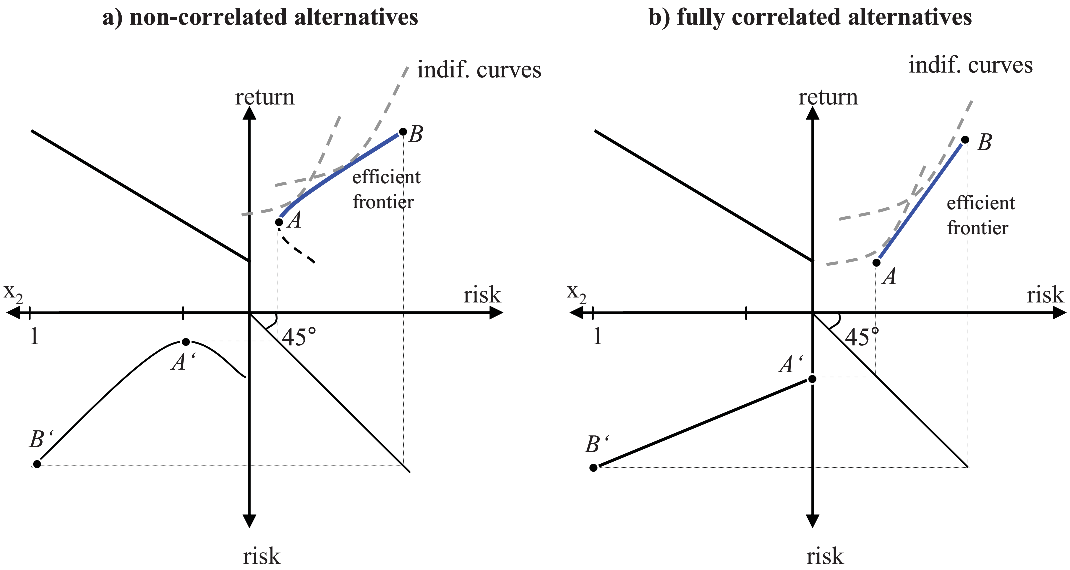

Fig. 1. Risk-return diagrams for non-correlated and fully correlated assets

If the assets are not fully correlated (Figure 1a) it is possible to find a combination that reduces the risk of the portfolio without lessening its profitability. The curve in the x_2/risk quadrant indicates a risk reduction of the portfolio as the x_2 asset share increases. Different portfolio structures lead to different risk/return pairs in the risk/return quadrant. The AB part of the curve depicts the efficient frontier, i.e., different portfolios with the highest return for the given risk level. The final investment decision lies at the efficient frontier and depends on the risk preference of the individual (shown as dashed indifferent curves). Hence if the correlation between the assets is taken into account, it is possible to reduce risk and increase the return – unlike a portfolio consisting of only one low-risk asset.

In the case of fully correlated alternatives (Figure 1b) the efficient frontier is a line AB. All portfolios on the line are "optimal" if they correspond to the individual's risk preference (shown as dashed indifferent curves). If the correlation is recognized and assessed correctly, risk cannot be minimized below that of the low-risk asset.

The question of whether individuals are able to recognize correlation in general has been widely addressed by psychologists (see Shanks (2004) for a review) and economists (see for example Lipe (1990) or Clemen and Reilly (1999)). In their view, subjects are not always in a position to compute and make a judgement about covariance. A survey on the influence of correlation on diversification decisions was conducted in a psychological study by Hedesstrom et al. (2006), who propose covariance neglect as a possible source of non-optimal diversification. According to this study, subjects not only tend to under-diversify their portfolios, but also to engage in too much diversification, using naïve diversification heuristics where it is less opportune, e.g., when assets are fully correlated. Several behavioural types are identified in the conclusion – rational investors who diversify in non-correlated rather than correlated treatments – and various types of irrational investment behaviour. However, their psychological experimental study employs hypothetical investment decision tasks ("imagine investing a sum of money for a period of ten years"), does not include economic incentives to choose a "better" portfolio and, without any risk elicitation procedure, assumes subjects to be risk averse. In addition, tasks are not formulated clearly enough. Our experiment is designed to link improved portfolio performance with the payoff. Risk preferences are taken into account and investment tasks are simple, explicit and informative.

Economic experiments testing the ability of individuals to incorporate correlation in the decision-making include e.g. Kroll et al. (1988), Kroll and Levy (1992), Lipe (1998) and Neugebauer (2008) and find mixed evidence on correlation considerations. A joint feature of the studies in this field is that the efficient frontier is represented in form of a curve or a line. This means that the optimal decision is dependent on risk attitudes of the individuals and is not unambiguous (cf. Fig 1). Our experimental design with a single efficient point allows for a clear interpretation of the results.

As correlation is the most relevant information for diversification decisions, it is also essential to address information that is utterly irrelevant to the choice of portfolio and study individual behavioural responses to it.

The use of (irrelevant) information by individual investors was addressed, for example, by De Bondt (1998), who suggests that individuals misinterpret additional information, ascertaining data patterns that do not exist in reality. Furthermore, the more information they acquire, the worse the portfolio choices they make (cf. Guiso and Jappelli (2006)). This study offers interesting findings based on field data. Inherent in this data is its generation in an uncontrolled environment and consequently its shortcomings. The issue of unobserved factors (such as ability) that affect both portfolio performance and the acquisition of information is addressed with an instrumental variable option but not solved satisfactorily. The second criticism of this study is the comparison of different portfolios on the basis of the Sharpe ratio. This performance indicator (return-to-risk ratio) cannot make an unambiguous distinction between an optimal and a non-optimal portfolio. A portfolio with a lower Sharpe ratio can be still rational if the risk preference of the investor is taken into account (cf. the efficient frontier lines in Figure 1a and 1b).

The principal focus of our experimental study lies on these two factors of information evaluation (relevant and irrelevant), possibly explaining the phenomenon of suboptimal diversification. The above-mentioned studies motivate two hypotheses for our experimental study:

1. Subjects recognize the correlation between assets and invest according to their risk preferences.
2. Subjects are not affected in their decision-making by explicitly irrelevant information.

The rest of the paper is organized as follows: in Section 2 we suggest an experimental setting to investigate individual behaviour. Experimental results are presented and discussed in Section 3. Section 4 concludes.

2 Experimental design

The experiment is designed as a simple portfolio choice task: subjects may invest in two different assets (equities). Equity dividends for the year 2009 are the sole incentive. Thus equity price development is of no consequence for determination of the payoff, as long as the subjects do not hold the equities and obtain merely a one-time dividend payment, making long-term considerations irrelevant.

The experiment design must address three key questions:

a) How should the correlation between assets be modelled?

b) How should portfolio performance be compared, taking individual risk preference into account?

c) What additional irrelevant information should be introduced?

The following sections discuss these features of the experimental design (correlation, comparability and additional information), and describe the general experimental procedure.

2.1 Correlation

The *fully correlated* investment alternatives are represented as two dependent equities (A and B) of the same industry. Each equity has two possible dividend payments, i.e., high and low, both with a 50% probability. As dependent equities, their dividends are either both high or both low. The dividend payment of the first equity (A) is 4 euros in the high season and 0 euros in the low season. The dividend payment of the second equity (B) is 3 euros in the high season and 1 euro in the low season. There is a 50% high or low season probability. The A equity is therefore a higher-risk asset, while the B equity is low risk, with risk measured in terms of variance.

Subjects choose four equities from the two available types. They thus have five options to build the portfolio, ranging from all four equities of the same equity or any mix of the two investment alternatives (AAAA, AAAB, AABB, ABBB, BBBB). The investment alternatives are constructed in such a way that any one combination of the two stocks yields the same expected return, i.e., 8 euros. As the variance in the dividend payments of equity A is higher, the portfolio variance increases with its number in the portfolio (see Table I). The lowest risk (measured in terms of variance) is achieved only when the lower risk equity B is chosen (the optimal portfolio is shaded in the table).

Table I. Portfolio performance under the full correlation condition

Portfolio structure (optimal is shaded)	BBBB	ABBB	AABB	AAAB	AAAA
Expected dividend payment	8	8	8	8	8
Variance	16	25	36	49	64

The *non-correlated* investment alternatives are represented as two independent equities (X and Q) of different industries. Each equity has two dividend payments, high or low, each with 50% probability. Since the equities are independent and dividend payments not synchronized, each equity can lead to a dividend payment of either 0 or 2 euros. Thus the two equities have the same return and risk (measured in terms of variance). Again, the subjects have the possibility to obtain four equities and decide how many of each kind they take. Any combination of the two stocks yields the same expected return, i.e., 4 euros. As the equities are not fully correlated, it is possible to reduce the portfolio risk by combining the two equities. The lowest risk is achieved when resources are distributed evenly between the two equities (see Table II, optimal portfolio is shaded).

Table II. Portfolio performance under the no correlation condition

Portfolio structure (optimal is shaded)	XXXX	XXXQ	XXQQ	XQQQ	QQQQ
Expected dividend payment	4	4	4	4	4
Variance	16	8.8	6.4	8.8	16

Information on possible outcomes and their probabilities, as well as on the dependence/ independence of investment alternatives is given to the subjects to enable them to calculate the portfolio performance indicators.

2.2 Comparability

A distinct feature of our experimental design is the construction of the investment alternatives, which reduces the Markowitz efficient frontier to a single point in the risk/return diagram, cf. Figure 2.

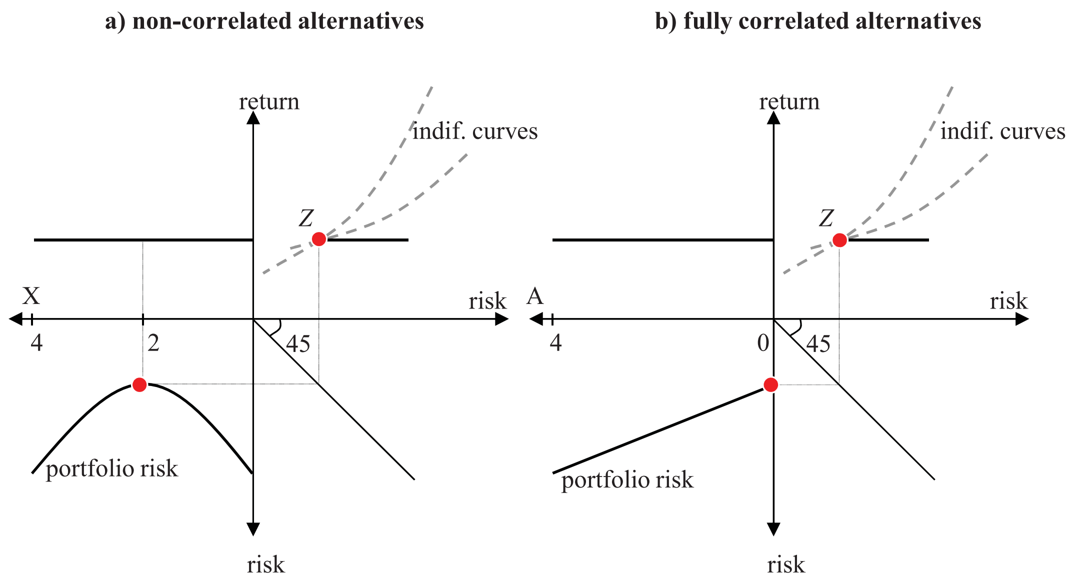

Fig. 2. Risk-return diagrams for investment alternatives in the experiment with the same expected return.

The expected return (dividend payment) is the same regardless of the investment decision (return/X quadrant in the Figure 2a and return/A quadrant in the Figure 2b). The portfolio variance is the only performance indicator that varies depending on the portfolio structure. The return remains constant. Given the same return, the only optimal portfolio is the point Z in the risk/return quadrants. The given combination of investment alternatives has a (second-order) stochastic dominance over other alternatives. In the case of non-correlated investment alternatives, it is the even split between the equities X and Q (Figure 2a); in the case of fully correlated investment alternatives, it is investment in the less risky equity, B (Figure 2b). This decision is rational for all levels of risk aversion; any other choices would be either risk-seeking or irrational. Such a construction allows for an unambiguous interpretation of experiment results.

2.3 Irrelevant information

Along with correlation, additional information is the second treatment variable and is represented in the form of the dividend payment history of the last ten years. As the dividend payment is a strictly random process (with 50% probability for high or low dividends), the dividend history does not contain any additional relevant information.

The histories presented are sections of random sequences with a target mean of 2 euros (for fully correlated equities) or 1 euro (for non-correlated equities). Sequences of past dividend payments for fully correlated equities are presented in Table III, and the dividend history of uncorrelated equities in Table IV. The question marks indicate that the dividend payment for the year 2009 has not yet been defined and represents the monetary incentive in the experiment.

Table III. Dividend payment history in the full correlation treatment

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
First equity	4 €	0 €	4 €	0 €	0 €	0 €	4 €	4 €	0 €	4 €	?
Second equity	3 €	1 €	3 €	1 €	1 €	1 €	3 €	3 €	1 €	3 €	?

Table IV. Dividend payment history in the non-correlation treatment

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
First equity	0 €	0 €	2 €	0 €	0 €	0 €	2 €	2 €	2 €	2 €	?
Second equity	0 €	2 €	2 €	2 €	0 €	2 €	0 €	0 €	2 €	0 €	?

In each of two treatments, the subjects are either informed or not informed about past dividend payments. They are also informed in both treatments about the random nature of the dividend payment process, its probabilities and the (in)dependency between the equity dividend payments. Since the sequence of past dividend payments contains no relevant additional information and subjects are informed, the sequence presentation should not affect subjects’ choices.

2.4 Experimental procedure

In order to test the hypotheses formulated, the experiment has two treatment variables: "correlation" and "irrelevant information", where "correlation" is the dependency between the two investment alternatives and "irrelevant information" the history of past dividend payments. There are four treatments in this 2x2 factorial design, as indicated in Table V.

Table V. Treatment order

	full correlation	no correlation
With irrelevant information	1	2
Without irrelevant information	4	3

In order to account for possible order or learning effects, the four treatments are conducted in the reverse order in two groups – one group with a 1-2-3-4 order and the other with a 4-3-2-1 order.

The unambiguous interpretation of the results is only possible for risk averse subjects, so that a risk elicitation procedure is required. Risk elicitation is conducted according to the study by Holt and Laury (2002) following experimental treatments.

Dividends for the year 2009 are determined following treatments and risk elicitation. As they are random, a coin is tossed in front of the subjects in order to determine the dividends. A short questionnaire is completed after the experiment, after which payoffs are calculated and paid.

In summary, the experiment consists of the following steps: introduction; four treatments in sequence; risk elicitation; lottery for risk elicitation; dividend determination; a questionnaire on demographic and personal characteristics; payment. Full instructions for the experiments are presented in the appendix.

3 Experimental results

After some general remarks, the sections present descriptive statistics for frequency of choice and mean portfolio variance (section 3.2), the results of group comparisons (section 3.3) and the hypotheses test (section 3.4).

3.1 General remarks

The experiment was conducted at the University with 47 participants randomly assigned to each of the two groups, 23 in the first and 24 in the second. Thirty-two participants are economics students, 15 are students of the social sciences. All of them have some economic background or are expected to be familiar with the theory of optimal diversification.

A risk elicitation procedure was conducted after the experiment and 40 of the 47 participants (20 in each group) were identified as risk-averse individuals who chose more than four As in the Holt/Laury (2002) lottery choice. According to the structure of the portfolios, only the risk-averse choose the least risk alternative and will therefore be analysed in this section.

The mean payoff in the experiment was 24.60 euros for approximately 90 minutes of participation.

3.2 Frequency of choice and mean portfolio variance

The frequency of portfolio choice decisions made by the risk-averse is illustrated in Table VI. The upper part of the Table shows the results of the full correlation treatment, the lower part indicates the outcome of the no correlation treatment. The optimal choice portfolios are shaded: the BBBB structure would be optimal in the case of fully correlated alternatives and the XXQQ structure in the case of non-correlated alternatives.

Table VI. Frequency of participant choices, persons.

Group	Treatment	Portfolio structure (optimal is shaded)					Total
Fully correlated alternatives		BBBB	ABBB	AABB	AAAB	AAAA	
1	1 (with history)	5	9	5	0	1	20
	4 (without history)	6	8	5	0	1	20
2	1 (with history)	6	8	4	2	0	20
	4 (without history)	7	9	2	1	1	20
Non-correlated alternatives		XXXX	XXXQ	XXQQ	XQQQ	QQQQ	Total
1	2 (with history)	0	2	16	2	0	20
	3 (without history)	0	0	19	1	0	20
2	2 (with history)	0	1	12	6	1	20
	3 (without history)	0	0	19	0	1	20

This frequency Table clearly indicates non-optimal diversification: over-diversification in the full correlation treatment and some under-diversification in the no correlation treatment. In both cases individuals seek variety, reluctant as they are to invest in one equity type. While it appears to be a feasible strategy in the case of non-correlated alternatives, it fails in the case of those that are fully correlated.

A more detailed statistical analysis of the portfolio performance could be based on different criteria. The investment alternatives are designed to allow comparison of the portfolios according to variance alone, as long as the expected return of any portfolio choice is the same. The optimal portfolio should exhibit the lowest variance, anything higher would mean under- or over-diversification.

Table VII shows the mean portfolio variance. The first column indicates the decision number with a short description in parenthesis. The decision order in the first group was 1-2-3-4 and 4-3-2-1 in the second group.

The second column (a) represents the (hypothetical) mean portfolio variance when participant choices are *random*. In other words, if all five available portfolios had a 20% probability of being chosen, the portfolio variance yielded would correspond to column (a). The data in this column is used to test whether the actual decisions of participants are random.

The third column (b) indicates the mean portfolio variance when subject choices are *rational*, i.e., the lowest possible portfolio variance. The lowest portfolio variance is 16 under the full correlation condition and 6.4 under the no correlation condition. The data in this column is used to test whether decisions were rational.

Table VII. Mean portfolio variance: hypothetical and actual decision-making

	Hypothetical mean portfolio variance		Actual mean portfolio variance		
Decision number	random decision (a)	rational decision (b)	Group 1 decision order 1-2-3-4	Group 2 decision order 4-3-2-1	both groups
1 (corr/hist)	38.0	16.0	27.45 a)*** b)***	26.9 a)*** b)***	27.175 a)*** b)***
2 (no corr/hist)	11.2	6.4	6.88 a)*** b)**	7.72 a)*** b)***	7.30 a)*** b)***
3 (no corr/no hist)	11.2	6.4	6.52 a)*** b)	6.88 a)*** b)	6.70 a)*** b)
4 (corr/no hist)	38.0	16.0	27.00 a)*** b)***	26.1 a)*** b)***	26.55 a)*** b)***

Significance levels: 1% ***, 5% **, 10% *; asterisks after the label (a) indicate the significance of the difference to the a) column (hypothetical random choice); asterisks after the label (b) indicate the significance of the difference to the b) column (hypothetical rational choice).

The mean portfolio variance of *actual decisions* is shown in the last three columns: for the first group (decision order 1-2-3-4), for the second group (decision order 4-3-2-1), and finally for both groups. Each figure is followed by the test results in superscript. Asterisks after the label (a) indicate the significance levels of the difference between the actual and the hypothetical mean portfolio variance of a random decision (compared with column (a)). Asterisks after the label (b) indicate the significance levels of the difference between the actual and the hypothetical mean portfolio variance of a rational decision (compared with column (b)). The significance test used is the Wilcoxon signed rank test; significance levels are represented in the form of asterisks: *** for a 1% level, ** for a 5% level and * for a 10% level. In the second decision (no correlation, history), for example, the participant choices of the first group are at a 5% level significantly different from rational choice. In the third decision (no correlation, no history) participant choices in the second group do not differ significantly from rational choices.

The following conclusions can be drawn from the analysis of the mean portfolio variance:

1) Participant decision-making in all treatments is significantly different from random decision-making. The test statistics (represented in the form of asterisks after the label (a) in the last three columns) indicate that the actual mean portfolio variance in each individual decision is significantly different (at the 1% level) from the variance of a randomly chosen portfolio.

2) A rational investor in the case of fully correlated alternatives (first and fourth decision) would have invested all resources in the less risky equity, leading to a mean portfolio variance of 16. Instead, individuals tend to seek variety and diversify their portfolios. As a result, the mean variance of the chosen portfolio is significantly higher compared to rational decision-making (1% level, cf. three asterisks after the (b) labels in the Table, first and fourth decision); in this case individuals over-diversify.

3) In the case of non-correlated alternatives (second and third decision), a rational investor would have split the resources evenly between the assets. Rational investment behaviour would lead to a mean portfolio variance of 6.4. The actual choices under the "no information" condition (third decision) do not differ significantly from the rational decisions. As long as (irrelevant) information is present (second decision), subjects fail to make rational choices and under-diversify. From this evidence it can be interpreted that rationality under the "no information" condition is not a deliberate decision but merely an adoption of "variety seek" heuristics used in the case of uncertainty.

4) The naïve diversification strategy (variety seeking) is irrational in the case of fully correlated alternatives and would be helpful in the case of those that are non-correlated. Actual choices show that subjects do not adopt the variety seeking heuristics as the only decision-making instrument. In the second decision they diversify too little compared to the naïve strategy, which is also

rational. In the first and fourth decisions they over-diversify compared to the rational strategy but still too little compared with the naïve diversification strategy.

3.3 Between and within group comparison

The experimental design consists of two groups participating in four treatments in a different order. This allows for control of order effects. Table VIII below shows the analysis of the mean portfolio variance at different levels of aggregation for both groups. Decisions are presented in the rows individually (1, 2, 3, 4) and aggregated at the level of the treatment variables (history, no history, full correlation, no correlation). The two groups are compared; the p-value of the test statistics (Wilcoxon signed rank test) is shown in the last column. The hypothesis of the equality of medians in the groups cannot be rejected. Hence there is no significant order effect *between* the groups in all treatments and both groups can be considered together.

Table VIII. Between-group comparison: mean portfolio variance and order effects

	Mean portfolio variance		Wilcoxon signed rank test, p-value
Decision	Group 1	Group 2	
1 (history, full correlation)	27.45	26.90	0.8794
2 (history, no correlation)	6.88	7.72	0.1594
3 (no history, no correlation	6.52	6.88	1.0000
4 (no history, full correlation)	27.00	26.10	0.6248
1+2 (“history”)	17.165	17.31	0.6987
3+4 (“no history”)	16.76	16.49	0.8897
1+4 (“full correlation”)	27.23	26.50	0.6423
2+3 (“no correlation”)	6.70	7.30	0.2177
Total	16.96	16.90	0.8598

Significance levels: 1% ***, 5% **, 10%*.

As the same individuals run four different treatments one after another, there is room for learning effects. If this were the case, the first group should do better in decision

4 compared to decision 1, and in decision 3 compared to decision 2. The reverse order effects should be applicable to the second group. The statistical analysis of this problem is represented in Table IX. Whereas some positive effects (albeit negligible) can be observed in the first group, the portfolio variance even increases after repetition in the second group (also insignificant). According to this *within-group* comparison, we can state that there is no learning effect to the experiment.

Table IX. Within-group comparison: mean portfolio variance and learning effects

Comparable decisions	Mean portfolio variance	
	Group 1	Group 2
1	27.45	26.9
4	27.0	26.1
p-value of the difference (1 vs. 4), matched pairs	*0.617*	*0.474*
2	6.88	7.72
3	6.52	6.88
p-value of the difference (2 vs. 3), matched pairs	*0.149*	*0.091***

Significance levels: 1% ***, 5% **, 10%*.

The statistical comparative analysis of the two groups shows that regardless of whether subjects receive irrelevant additional information at the beginning of the experiment or later on, it does not affect their investment behaviour. The order change of the correlation treatment in the decision tasks does not produce significant differences. Since there are no differences between the groups and no learning effect within the groups, the hypothesis test can be made on the basis of the entire set of (risk averse) subjects.

3.4 Hypotheses test

Correlation neglect

The decisions with and without correlation are not comparable in terms of portfolio variance: the portfolio variance under the “no correlation” condition ranges from 6.4 to 16, whereas under the “full correlation” condition it ranges from 16 to 64. Comparability can be achieved if we recode the variance values at the different variance levels. The “no correlation” condition has three possible values for the mean portfolio variance; the “full correlation” condition has five possible values for the mean portfolio variance (cf. Tables I and II). It is therefore possible to recode the variances as presented in Table X.

Table X. Recoding of portfolio variance

	Portfolio variance				
“full correlation” condition	16	25	36	49	64
recoded	1	2	3	4	5
“no correlation” condition	16	8.8	6.4	8.8	16
recoded	5	3	1	3	5

The transformation enables a portfolio performance comparison between “full correlation” and “no correlation” conditions and therefore attestation of possible correlation neglect in investment decisions.

Table XI shows this comparison. The “full correlation”/“no correlation” conditions are represented in columns, the “history”/“no history” condition in rows. The figures in the Table indicate the recoded mean portfolio variance in the respective decisions. The highest variance is achieved under the history/full correlation condition, the lowest variance is achieved under the no history/no correlation condition. The difference between “full correlation”/“no correlation” conditions is tested with the one-sided Wilcoxon-Mann-Whitney and Wilcoxon signed rank tests and the respective p-values are noted in the last two columns. The hypothesis of median equality between the “full correlation” and “no correlation” condition can be rejected outright (p-value<1%), see Table XI.

Table XI. Recoded mean portfolio variance and correlation neglect

		full correlation		p-value[a)]	p-value[b)]
		yes	no		
history	yes	2.125	1.650	0.048**	0.0049***
	no	2.050	1.150	0.0001***	0.0000***
total		2.088	1.400	0.0000***	0.0000***

[a)] matched pairs, Wilcoxon signed rank test, tie-adj., one sided

[b)] Wilcoxon-Mann-Whitney test, tie-adj., one-sided

Significance levels: 1% ***, 5% **, 10%*.

This finding means that the participants diversify their portfolios regardless of the correlation between the investment alternatives: the low recoded portfolio variance in the case of the "no correlation" condition is the result of diversification; the high recoded portfolio variance in the case of the "full correlation" condition has the same origin. The difference is significant, i.e., subjects diversify without taking the correlation between the assets into account – diversification is hence "naïve" rather than rational.

Additional information effect

The second hypothesis to be tested is whether representation of dividend history has an effect on subjects' investment decisions. The comparison should be made between the "history" and "no history" conditions for both "full correlation" and "no correlation" treatments. The results are represented in Table XII. Again, the mean portfolio variance is recoded into the variance levels instead of the variance values scheme (see Table X). The last two rows in Table XII indicate the p-values for the Wilcoxon signed rank and Wilcoxon-Mann-Whitney tie-adjusted, one-sided test on the difference between the variances in "history" and "no history" treatments.

Table XII. Recoded mean portfolio variance and the "history" effect

		Both groups		
		full correlation		total
		yes	no	
history	yes	2.125	1.650	1.888
	no	2.050	1.150	1.600
	p-value[a)]	0.2371	0.0117**	0.0358**
	p-value[b)]	0.2978	0.0023***	0.0174**

[a)] matched pairs, wilcoxon signed rank test, tie-adj., one-sided

[b)] wilcoxon-mann-whitney test, tie-adj., one-sided

Significance levels: 1% ***, 5% **, 10%*.

The results show that there is some "history" effect – participants decide differently depending on irrelevant information on dividend history over the last ten years. The effect is most pronounced under the "no correlation" condition and insignificant under the "full correlation" condition. This means that the correlation neglect effect is stronger than the "history" effect: if investment alternatives are correlated, subjects are less rational, an effect that dominates the outcome. Still, the composite examination of the history/no history treatment cannot reject the hypothesis of a no "history" effect. The subjects interpret the additional information incorrectly. Only six of the total number of subjects succeeded in making a correct decision in all treatments.

4 Concluding remarks

The experiment shows that the subjects are not in a position to use the information that is most relevant to investment alternatives and ignore correlation in making their portfolio choice. Moreover, they are unable to prescind from clearly irrelevant information. The first effect dominates the second – in the absence of irrelevant information, the subjects neglect the correlation between the assets. The effect is even more pronounced with additional irrelevant information. These findings shed more light on individual investment behaviour and pose questions about regulating pension funds to ensure optimal diversification of pension savings.

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7 Appendix: Experiment Instructions

Full Correlation Condition

You can choose between two shares (share A and share B) of a specific sector of industry. The Table indicates how high dividend payments for both stocks were during the past ten years. If the economic situation in the sector is good, the dividend for share A is €4 and for share B, €3. If the economic situation in the sector is poor, the dividend for share A is €0 and for share B, €1. The economic trend in this sector can vary from year to year and must be seen as a random process: there is a respective 50% probability of a good or poor economic situation in the year 2009.

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Share A	€4	€0	€4	€0	€0	€0	€4	€4	€0	€4	?
Share B	€3	€1	€3	€1	€1	€1	€3	€3	€1	€3	?

You receive four free shares. You may choose four A shares, four B shares, three A shares + one B share, three B shares + one A share or two A shares + two B shares. The dividends yielded in 2009 for your four shares are paid out to you. How the share price develops is of no significance to you.

Make your selection now!

I select O 4 A shares

O 4 B shares

O 3 A shares + 1 B share.

O 3 B shares + 1 A share.

O 2 A shares + 2 B shares.

Please give brief reasons for your selection (e.g., on the back of the paper). These reasons have **no** effect on the payout! You can therefore write down your thoughts openly.

(Note: The sentence referring to past dividend payments and the Table itself have been omitted under the "no history" condition)

No Correlation Condition

You can choose between two shares (share X and share Q), which are independent of each other. The Table indicates how high the dividend payments for both stocks were during the past ten years. In the case of both companies, the dividend payments are a random process with the two possible values of €2 and €0, and an expectancy value of €1.

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
first equity	€0	€0	€2	€0	€0	€0	€2	€2	€2	€2	?
second equity	€0	€2	€2	€2	€0	€2	€0	€0	€2	€0	?

You receive four free shares. You can decide whether you want to have four X shares, four Q shares, three X shares + one Q share, three Q shares + one X share or two X shares + two Q shares. The dividends for your four shares yielded in 2009 are paid out to you. The share price development is of no significance to you.

Make your selection now!

I select

O 4 X shares

O 4 Q shares

O 3 X shares + 1 Q share.

O 3 Q shares + 1 X share.

O 2 X shares + 2 Q shares.

Please give brief reasons for your selection (e.g., on the back of the paper). These reasons have **no** effect on the payout! You can therefore write down your thoughts openly.

(Note: The sentence referring to past dividend payments and the Table itself have been omitted under the “no history” condition)

Risk elicitation

You make your decision in the Table below. Each decision is a choice between variant A and variant B. Each variant is a type of lottery with different payout sums and probabilities of occurrence. You make ten decisions and note them in the right-hand column of the Table. One of these decisions will be used to determine your payout in the lottery. This is done as follows: after you have made all ten decisions, a ten-sided dice is thrown to determine which of the ten decisions will be used. Thus each of the decisions has a 10% probability of being used. The chosen lottery (A or B) is then played. The probability of occurrence is simulated with the help of playing cards: the number of red cards in a pile of ten cards indicates the probability with which the higher payout sum will occur.

Example of decision no. 8: in a pile of ten cards there are eight red and two black cards. The probability that a randomly drawn card is red is thus 80%. If the card drawn is red, you receive €2 in variant A and €3.85 in variant B. If the card drawn is black, however, you receive €1.60 in variant A and €0.10 in variant B.

You thus make ten decisions (either A or B). One of these is randomly chosen (with a dice) and played (with playing cards) – the result determines your payout.

Before you fill in the Table, please answer the following questions as a check that we have explained everything correctly. Please let us know when you have completed the answers so that we can check them. Do not fill in the Table until your answers have been checked.

Questions:

How high is the maximum payout in the lottery? _______ How high is the minimum payout? ______

If the dice selects the 7th decision, you have chosen variant A in the 7th decision, and you have chosen a black card from the pile, how high is your payout? __________

How many black cards are in the pile if the dice selects the 10th decision? ______

How many red cards are in the pile if the dice selects the 4th decision? ________

Now please make the ten decisions: which variant would you choose – A or B?

	Lottery A:				Lottery B:				Your choice: A or B?
No.	p(€2)		p(€1.60)		p(€3.85)		p(€0.10)		
1	10%	€2	90%	€1.60	10%	€3.85	90%	€0.10	
2	20%	€2	80%	€1.60	20%	€3.85	80%	€0.10	
3	30%	€2	70%	€1.60	30%	€3.85	70%	€0.10	
4	40%	€2	60%	€1.60	40%	€3.85	60%	€0.10	
5	50%	€2	50%	€1.60	50%	€3.85	50%	€0.10	
6	60%	€2	40%	€1.60	60%	€3.85	40%	€0.10	
7	70%	€2	30%	€1.60	70%	€3.85	30%	€0.10	
8	80%	€2	20%	€1.60	80%	€3.85	20%	€0.10	
9	90%	€2	10%	€1.60	90%	€3.85	10%	€0.10	
10	100%	€2	0%	€1.60	100%	€3.85	0%	€0.10	