

Analogical transfer of experience and the misuse of diversification

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Abstract

When the payoff function is convex, diversification can be the wrong strategy for dealing with risky choices. We constructed two experimental settings in which it is stochastically dominant not to diversify. Nevertheless, subjects inappropriately preferred the diversification strategy. A de-biasing treatment suggests that this diversification fallacy may be interpreted as the outcome of the analogical transfer of decision heuristics learned in more usual domains.

1. Introduction

Diversification is an effective investment strategy for dealing with risky alternatives; still, putting the eggs in different baskets can be sometimes a misleading heuristic. Diversification seeks to minimize risk (typically, return variance) by splitting investment in different types of imperfectly correlated assets. While the portfolio mean return is just the weighted average of assets returns, it is a statistical fact that when asset returns are imperfectly correlated, the portfolio variance is less than the weighted mean of assets variances. Thus, variance averse individuals can exploit this feature to compose diversified portfolios that reduce variance whilst preserving mean return. The concept of diversification is very intuitive: in Markovitz words, it is “both observed and sensible; a rule of behavior which does not imply the superiority of diversification must be rejected both as a hypothesis and as a maxim” (Markovitz, 1952).

However, there are also cases in which faith in “the superiority of diversification” turns out to be a source of error. Generally speaking, the relationship between variability and investment is ambivalent, depending on the payoff function of investment. If the payoff function is convex in some random variables, then a mean preserving larger variability will increase the return to investment due to Jensen’s inequality, while when the payoff function is concave the variance of the random variables discourages investment. Concave payoffs prevail when irreversible investments make returns to investment asymmetric (Bernanke, 1983; Pindyck, 1988). On the other hand, convex returns prevail when the investment process is characterized by some kind of flexibility, such as the flexibility of labor relative to capital (Abel 1983), the option to abandon a project (Roberts and Weissman, 1981), the limited liability rule truncating the downside risk for shareholders (Stiglitz and Weiss, 1981). In all these cases, risk neutral or risk averse individuals are better off choosing the alternative with the highest variability.

Remarkably, almost all empirical studies found a negative relationship between investment and uncertainty, as the comprehensive review by Carruth *et al.* shows (Carruth *et al.*, 2000). This might be explained by the simple fact that irreversibility factors prevail in all the empirical settings analyzed, which are primarily, but not exclusively (see for instance Guiso and Parigi, 1996), US manufacturing firms. Yet, the almost universal absence of positive relationships might reflect a behavioral bias. Decision makers might transfer the decision rules appropriate to the most common conditions of irreversibility also to decisions where the opposite conditions prevail. According to such behavioral interpretation, decision makers might invariably react negatively to uncertainty because they are prey to the faith in “the superiority of diversification”.

Our explanation is consonant with the theory of “fast and frugal heuristics” (Gigerenzer and Todd, 1999), which suggests the existence of a “toolbox” of (cognitively efficient) decision rules that individuals apply to specific domains. Those rules are well adapted to the prevailing structure of the domain, but may turn out to be suboptimal when structure is different. In our

case, a diversification rule is effective in the domain of risky choice in most common environments, but fails when the payoff structure is convex. This is also in accordance with theories of human decision making that emphasize that when dealing with new or complex problems individuals tend to resort to past experience and analogy processes in their search for solutions. For example, case based decision theory (Gilboa and Schmeidler, 1995) postulates that we tend to weigh the success of past choices by their similarity with current decision problems to select the most promising alternatives.

In what follows, we construct two experimental settings in which the structure of the decision problem is such that it is stochastically dominant not to diversify. The two experimental settings are different in surface, but share the same structure. The first experimental setting presents a very simple decision setting in which individuals have a choice between rolling two six-faced dice or rolling a single die with 12 faces. The problem is designed in order to make the two dice strategy stochastically dominated. The second experimental setting presents a more realistic economic choice, but in a more complex setting. Subjects have to choose between two real options with underlying activities which are more or less correlated. Once more, the option with less underlying variance is dominated by the other one. We show that in both cases individuals fall prey to a diversification fallacy and choose the dominated action.

We interpret this diversification fallacy as the result of the transfer of an “eggs in the basket” decision heuristic that is applied to an inappropriate domain. If this is true, there must be ways to present to subjects alternative sources of decision heuristics that induce more appropriate behavior. In order to do this, we have devised for each experimental setting a de-biasing treatment in which, while keeping constant the decision problem, contexts are evoked in which the rule of choosing the more variable option is more salient. The de-biasing treatments reflect the different nature of the two experiments. In the simpler dice decision setting we resort to a purely behavioral de-biasing treatment in which the same problem is framed in terms of a winner-take-all tournament – a context in which aggressive risk taking is a prevailing strategy (Fischbacher and Thöni, 2008). In the more complex real option experimental setting, we resort to a richer narrative structure, in which different stories similar in structure but different in domain are provided to subjects before they choose (a strategy often used in the psychological literature on analogical transfer). Both de-biasing strategies are complementary, in that whereas the purely behavioral one avoids any intrusive manipulation of subjects representation of the problem, the narrative treatment allows for a more direct control of the content of the transfer. We find that both strategies induce equivalent results, effectively de-biasing subjects’ choices.

The structure of the paper is as follows: In section 2.1 we introduce our experimental design. Section 2.2 and 2.3 present the results of the two baseline treatments, while section 2.4. presents the results of our de-biasing treatments. Section 3 discusses our results and their relations with theories of choice emphasizing the analogical transfer of choice rules.

2. The experiments

2.1 The experiments design

We designed two experimental settings in which subjects have to make binary choices under risk. Our experiments are designed to reflect two main structural features. First, payoffs are convex. Second, the “diversification” option is stochastically dominated by its more “concentrated” alternative, so that optimal behavior is independent from risk attitudes. Keeping constant these features, the two settings are superficially very different. The first one presents a highly simplified choice among lotteries (under the very familiar cover of rolling

dice). It doesn't require any economic competence and thus is suited to test general cognitive processes. The second one is more complex and requires some economic competences to be understood, but represents a more realistic investment decision with a "real option" structure.

Each experimental setting has two versions, the baseline and a de-biasing treatment. The de-biasing treatment is introduced to show that bias in the baseline version is due to the inappropriate transfer of familiar decision rules. By making available different decision contexts in which more appropriate rules are available, we expect subjects to reverse their choice patterns. The de-biasing procedure differs in the two experimental settings, in consonance with the different semantic richness of the experimental settings. In the first one, we follow a purely behavioral de-biasing procedure, by reproducing the rolling dice problem in a strategically equivalent tournament setting. In the second one, we follow the tradition in the experimental psychology of analogical transfer by providing subjects with set of stories (in apparently unrelated domains) which illustrate different decision heuristics.

2.2 The first experimental task: rolling dice

In our first two experiments subjects face the following task (see Appendix 1 for the instructions).

Task 1a. Each subject has a choice between rolling two six-faced dice or a single die with twelve faces. If the outcome is larger or equal to eight, the subject earns a Euro for each point scored (e.g. with two dice: $4+5=9$, the subjects earns 9 euros). Otherwise she gets nothing.

Despite its simplicity, the task deserves a few comments. If there was not a threshold at eight and the payoffs were proportional to all possible outcomes, rolling two dice would yield a more concentrated and less risky probability distribution of possible outcomes than rolling one die. Furthermore, in such a case rolling two dice would second order stochastically dominate rolling a single die (see Figure 1). Therefore every risk averse subject should prefer rolling two dice rather than a single one. The introduction of the threshold sharply modifies the attractiveness of the two options since in such a case the cumulative probability function of the outcomes of rolling one die lies always below the two dice's one, therefore first order stochastically dominating it. All subjects, regardless their attitude toward risk, should prefer rolling a die.

Figure 1. Rolling dice: the probability distribution of outcomes.

Outcomes	One die	Two dice	$\sum_i F(x_i) - G(x_i)$
	Cumulative Probabilities (F)	Cumulative Probabilities (G)	
1	0.083	0.000	0.083
2	0.167	0.028	0.222
3	0.250	0.083	0.389
4	0.333	0.167	0.556
5	0.417	0.278	0.694
6	0.500	0.417	0.778
7	0.583	0.583	0.778
8	0.667	0.722	0.722
9	0.750	0.833	0.639
10	0.833	0.917	0.556
11	0.917	0.972	0.500
12	1.000	1.000	0.500

These features make this example a meaningful device to test the diversification fallacy of the “eggs in the basket” decision heuristic which, even if working well in the general case, would lead to the wrong decision when the threshold is not properly taken into consideration.

We thus ran experiments 1 and 2, in which two different populations were facing task 1a. The first population (experiment 1) was composed of senior undergraduate students of economics or business. All subjects had already taken courses of basic economic decision making and at least one course in statistics. The second population (experiment 2) was composed of senior undergraduate students in architecture and in linguistics – no one of them with prior exposure to courses in economics and statistics. The experiments were run in a quiet room with small groups of subjects participating at each session. Subjects could take all the time it needed to make a choice between rolling one 12-faces die or two 6-faces dice in the task 1a. Subjects were left free to make calculations on paper if they wanted. After making their choice, subjects would actually roll a fair 12-face die or two fair 6-faces dice and get a reward according to the rules above.

Table 1. Experiments 1 and 2: Preferences between options.

	<i>N</i>	<i>Option A (rolling 2 dice)</i>	<i>Option B (rolling 1 die)</i>	<i>p-value (bin. test, one-tail)</i>
<i>Experiment 1 (skilled subjects)</i>	84	60 (71.4%)	24 (28.6%)	0.015
<i>Experiment 2 (unskilled subjects)</i>	22	19 (86.3%)	3 (13.7%)	0.000

* The p-value refers to the null hypothesis that subjects decide randomly.

Table 1 reports the results of the experiments conducted using Task 1a, for both the skilled and unskilled populations. Most subjects clearly chose the “eggs in the basket” strategy, with no significant difference between the two experimental populations (despite the former training in statistics for the economics and business students).

Such result can be compared with two behavioral benchmarks. The first one is the economically “correct” response: rational subjects should roll one die. The second one is a kind of “level-0” rationality behavior (Stahl and Wilson, 1995; Camerer *et al.*, 2001): individuals unable to understand the structure of the problem might decide randomly. Our data show that the distribution of choices is significantly different from both optimal and random behavior. Thus, subjects’ mistaken decisions reflect some systematic source of error.

Despite their very limited value as a source of data, post-experiment informal interviews tend to support the hypothesis of a kind of “diversification fallacy”. Interviews suggested that most subjects chose the two dice according to a variety of motivations predominantly driven by considerations such as “it is less risky to roll two dice” or even “if one die takes a low value it will be compensated by the other one” (which implies the illusion of some kind of negative correlation between the two dice, probably induced by “faith in the law of small numbers”, Tversky and Kahneman, 1971).

2.3 The second experimental task: a real option investment

While Task 1a, due to its simplicity, allows to address the general impact of the “eggs in the basket heuristic” on decisions made by subjects (skilled or not), it lacks of economic realism. We proposed therefore another task featuring a real option investment case.

Investing in options is an important example of convex revenue structure. A call/put option is a right to buy/sell a given quantity of an underlying asset at a given price (strike price) on or before a given date. The option grants a right to the holder, but does not impose an obligation: this asymmetry means that one must pay to acquire the right to buy/sell the asset.

A call option holder will benefit from a possible rise above the strike price of the underlying asset without being affected by a possible fall below it, since in this case she can abandon the option avoiding its exercise. Thus, the holder of a call option will face a distribution of payoff truncated by the strike price: she gets only the right tail of the distribution since she will abandon the option when the underlying asset is below the strike price. Therefore, a rational subject, no matter if risk adverse, should be willing to pay *ceteris paribus* a higher premium for an option whose underlying asset has larger variance.

TASK 2a. Subjects have to choose between two investment prospects: in each prospect, a broker sells a right (but not an obligation) to buy at the end of the year two real estates. The estates are owned by the same proprietor. Currently, there are temporary legal constraints that forbid constructing on such estates. However, the constraint will legally decay within one year. The right to buy is sold by the broker at the price of 50 experimental points. If the investor buys the option to acquire the estates, at the end of the year she will decide whether to jointly buy or not the estates at a fixed price, corresponding to the current price at the moment of the broker’s proposal (300 experimental points). If she decides not to buy, she will lose the 50 points paid for the option right. If she decides to buy at the end of the year, she will be able to jointly resell the estates at their end of the year market value. In this case, her final profit will be given by the end of the year price of the estates minus 300 pts and minus the 50 points paid for the option right (see figure 2 and Appendix 2 for more details).

In both prospects, the price of each estate at the end of the year has the same expected value and the same variance. The two alternative prospects offered by the broker differ only for one important detail. In one case (prospect A), the future prices of the estates are uncorrelated. In the other one (prospect B), they are strongly correlated ($\rho=0.8$). Subjects are shown scatterplots displaying the joint distribution of the prices at the end of the year for each option. Subjects are informed that the price will be actually drawn from such distributions on a computerized random generating device. At the end of the experiment, one experimental point will be converted in 0.1 euros.

Clearly, both prospects represent conventional call options. However, uncertainty is represented by the joint distributions of future prices, thus emphasizing their correlation, instead of using a single synthetic indicator of volatility, as usual. As outlined in Appendix 3, the returns of both prospects are normally distributed with the same mean but different variance. It follows that it is always better to invest in the not-diversified prospect, independently of the individual risk attitudes (Black and Scholes, 1973).

Figure 2. about here

Table 2 reports the results of the experiments conducted using Task 2a, for both the economics and non-economics populations. In experiment 3 subjects were 33 third-year undergraduate students with a major in economics or business at the University of Venezia. All of them had taken at least one course in statistics, and had been exposed in many courses to fundamentals of economic decision making. Most subjects chose the “diversified” option, with no correlation between the prices of the two estates. Remarkably, a chi square test demonstrates that the distribution of choices is not statistically distinguishable from that one of the analogue population in the rolling dice task in experiment 1.

In experiment 4 subjects were 64 University students of Venice with a major in science or in architecture, without any particular background in economics. The choices were almost evenly split between the two alternatives. Post-experiment informal interviews suggest that this behavior is not due to a better understanding of the problem by subjects not trained in economics, but rather by the difficulty for subjects to understand the task. This is understandable since real options have a complex structure which is often opaque also to well trained managers and investors (Howell and Jagle, 1997; Lander and Pinches, 1998).

A plausible interpretation of this result is that decision makers with an economic background recognize the task as similar to already known decision problems and, ignoring the effect of payoff convexity, import a diversification heuristic well established in their education, therefore confirming that sometimes no knowledge can be better than little or superficial knowledge.

Table 2. Experiments 3 and 4: Preferences between options.

	N	Option A (no correlation)	Option B (strong correlation)	p-value (binomial test, one-tail)*
Experiment 3 (skilled subjects)	33	22 (66.7%)	11 (33.3%)	0.041
Experiment 4 (unskilled subjects)	64	31 (48.4%)	33 (51.6%)	0.45

* p-value based on the null hypothesis that subjects decide randomly.

2.4 The de-biasing treatment

2.4.1 The de-biasing design

The previous results raise questions about the mechanisms causing the diversification fallacy and generating systematic error. Our conjecture is that subjects may inappropriately transfer decision making strategies that turned out to be successful in similar domains, as suggested by case-based decision making theory (Gilboa and Schmeidler, 1995) and by psychological theories of analogical inference (Holyoak and Thagard, 1995; see also Knez and Camerer, 2000 and Devetag, 2005 for some experimental evidence related to game playing).

Psychological experiments on analogy making resort predominantly to story-reading to explore how analogy works. Subjects are provided with stories which, although belonging to

different domains, could indirectly suggest some particular course of action. We followed this approach in the real option investment experiments, while in the rolling dice ones we preferred to introduce a less invasive form of de-biasing than the case-reading procedure. The description of the latter task is so simple that a story reading could be interpreted by subjects as a direct hint for the right answer. Therefore we introduced an experimental treatment in which alternatives to the diversification heuristic are made available by the task itself, rather than implied by a narrative.

2.4.2 Rolling dice

We transformed task 1a in a simple winner-take-all tournament.

TASK 1b. Each subject is part of a group of 4 randomly paired subjects. Each subject submits a choice between rolling two six-faced dice or a single die with twelve faces. Her choice is unknown to other players until all choices are made. Subsequently, each player rolls one or two dice according to her previous choice. Among those players who will have obtained an outcome equal or larger than 8, the one with the largest outcome will earn 15 euros. Other players will earn nothing. If there is a tie, a random tie-breaking rule will be applied. If no one gets a score equal or larger than 8, no one earns any reward.

As for task 1a, also in this case it is stochastically dominant to roll a single 12-faces die. From this point of view, task 1b is equivalent to task 1a. However, the experimental literature on winner-take-all games shows that subjects tend to behave more aggressively and to take more risk in such conditions (Fischbacher and Thoni, 2008). We thus expected that the tournament frame would make available to many subjects an alternative heuristic, suggesting to take more risk and possibly put all eggs in a same basket.

We performed experiment 5 using task 1b with a population of senior undergraduate students of economics or business, to make it comparable with experiment 1. In order to test whether the de-biasing treatment modified the preferences found in the previous corresponding experiments we report a chi-square test showing a significant effect of the tournament treatment, that reduces the relative frequency of the “diversification” choice.

Table 3. Experiment 5: preferences between options.

<i>N</i>	<i>Option A</i> (rolling 2 dice)	<i>Option B</i> (rolling 1 die)	<i>Chi-square test</i> (<i>p</i> -value)
40 (<i>skilled subjects</i>)	16 (40 %)	24 (60%)	0.001

The chi-square tests whether differences with the distribution in experiment 1 are significant.

2.4.3 The real option investment

In this case we followed a consolidated tradition in the psychological experimental literature on analogy making (Holyoak and Thagard, 1995) and provided subjects with additional cases supporting the “eggs in the basket” heuristic or instead supporting concentration of risks. We expected subjects to react to the exposure to such cases by modifying their choice behavior according to the cases provided to them.

Following the same experimental psychology tradition, we designed cases from domains relatively remote from the target domain of economic investment. This makes the transfer much less obvious and thus limits the risk that reading cases is perceived by subjects as reading instructions on how to behave in the experiment.

Task 2b presents the same investment problem of task 2a. However, before choosing, subjects had to read two cases of decision making in a different domain (military decision making) presenting structural similarities with the investment problem they were facing. There were two experimental groups, and each group had a set of two stories, one concerning risk taking and the second one concerning diversification strategies (see Box 1, below references). While the “risk taking” story (henceforth: **case 2**) was the same for both experimental groups, the “diversification” story was different for the two groups (henceforth: **cases 1a** and **1b**). In one case (**1a**), the story reported a successful use of a risk concentrating strategy; in the other one (**1b**), the story reported a successful use of the “eggs in the basket” heuristic. The “risk taking” and the “diversification” cases reported similar (positive) outcomes of the decisions made. However, they differed in the degree of similarity with the target investment decision. In particular, we conjectured that the “diversification” stories were more similar to the target problem, and thus should affect predominantly subjects’ final decisions.

We validated our conjecture concerning the relative similarity of each case to the target decision by using two independent groups of subjects (students of Economics or Business of the University of Venezia, paid according to a fix show-up fee of 4 euros). Each subject in group A read **cases 1a** and **2** and the target decision, and had to choose the case more similar to the target decision. Similarly, each subject in group B read **cases 1b** and **2** and the target decision, and had to choose the case more similar to the target decision.

Table 4 reports the results of such preliminary experiment, clearly demonstrating that most subjects found cases 1a and 1b relatively more similar than case 2 to the target decision.

Table 4. Similarities between cases and target problem.

	<i>N</i>	<i>Case 1 is chosen as more similar to the target problem than Case 2</i>	<i>p-value (binomial test, one-tail)</i>
Cases 1a, 2	16	12	0.038
Cases 1b, 2	16	14	0.002

Legend: **case 1a** supports the “eggs in the basket” heuristic, **case 1b** supports concentration (see box 1).

Once this was established, we performed experiment 6 and 7 using task 2b (with a new pool of experimental subjects, once more students of Economics at the University of Venezia, paid as in Experiments 3 and 4). Our conjecture was that subjects reading **cases 1a and 2** (experiment 6) would be more prey to the diversification fallacy than subjects reading **cases 1b and 2** (experiment 7).

Table 5. Experiment 6 and 7: preferences between options.

	<i>N</i>	<i>Option A (no correlation)</i>	<i>Option B (strong correlation)</i>	<i>Chi-square test p-value</i>
Experiment 6 Cases 1a, 2	32	19 (59.4%)	13 (40.6%)	0.540
Experiment 7 Cases 1b, 2	36	11 (30.6%)	25 (69.4%)	0.003

Legend: **case 1a** supports diversification, **case 1b** supports concentration of risks (see box 1). The chi-square tests whether differences with the distribution in experiment 3 are significant. Table 5 shows the results of experiments 6 and 7. As predicted, there was a neat reversal in the modal outcome according to the pair of stories provided to subjects. The results clearly

support our conjecture: a one-tailed Chi-Square test yields a significant difference between the two experimental treatments. Furthermore, the outcomes of the **case 1a and 2** treatment are not statistically distinguishable from those of experiment 3.

Remarkably, the distribution of choices in experiment 7 is not distinguishable (the chi-square lends a p -value = 0.737) from that one in the tournament treatment (experiment 5) confirming the equivalence of both the de-biasing treatments here proposed.

3. Discussion

Our experiments demonstrate that subjects tend to diversify when it should not be the case, a behavior opposite to the “underdiversification” observed in many empirical works on portfolio and asset allocation choices (Blume and Friend, 1975; Dorn and Huberman, 2005; Polkovnichenko, 2005).

The diversification fallacy we point to should not be confused with other biases related to diversification phenomena recently highlighted in the literature. The concept of a “diversification heuristic” has been introduced (Simonson, 1990; Read and Lowenstein, 1995) to describe variety-seeking behavior when decisions are made in one shot rather than in different moments of time. This is clearly different from the fallacy described in this paper, which is unrelated to the timing of decisions. A second diversification bias has been observed in terms of an evenly dividing investments among available alternatives, labeled the “1/n heuristic” by Benartzi and Thaler (Benartzi and Thaler, 2001). This is once more different from what we observe, since our experiments focus on the choice between two alternatives (one more “diversified” than the other), not on the proportional allocation within a given menu of choice. More generally, it has been observed that diversification behavior often neglects the portfolio’s covariation structure (Kroll *et al.*, 1988, Siebenmorgen and Weber, 2003, Dorn and Huberman, 2007). Instead, we observe that individuals may use information on covariation in biased ways.

We found the diversification fallacy occurs when the payoff structure is convex, reproducing the asymmetry around a threshold point typical of the option-like prospects. Options have a cognitively complex structure and it has already been shown that especially real options may be opaque to investors and managers (Howell and Jagle, 1997, Lander and Pinches, 1998). Subjects not recognizing that the option structure cuts the negative effects of downward outcomes could be the typical prey of the diversification fallacy.

Our results suggest also why the diversification fallacy does occur. They clearly point to the fact that subjects transfer (inappropriate) decision rules from domains in which they have learned to apply such rules. The possibility to recognize such source domains is crucial: the experiments on the real option choice show that an expert subject, who can understand the task and reconduce it to a familiar decision problem, is more likely to be biased than an inexperienced one, who in the absence of familiarities cues behaves in a substantially random way. In particular, our debiasing procedures show the important role played by the context (a tournament vs. an individual bet) and the availability of similar cases (the military stories) in triggering a specific decision. This lends support to theories of choice that emphasize the transfer of rules and the analogical nature of human decision making (Gigerenzer and Todd, 1999). The example of the military stories further establishes that when multiple sources are available and may suggest different decision strategies, similarity with the target problem at hand determines which one will be used, a point clearly consonant with the case-based theory of decision making (Gilboa and Schmeidler, 1995).

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Box 1: the set of stories.

<p style="text-align: center;">Case 1a</p> <p>Major Smith had to attack a fortified town: the defendants were less than Smith's troops but the fortification balanced the forces. The fortification had two weak points and Smith thought to resort to a surprise attack to these points. Many troops were necessary to break these points.</p> <p>Major Smith thought there were two ways to conduce the mission:</p> <ol style="list-style-type: none"> 1. to try an heavy attack in one point. If the surprise-effect would have been effective Smith's troops could take the town easily. Otherwise the attack would had been very difficult; 2. to split the forces in both points. In such a case, the most probable outcome was a mixed one: in one point the surprise was effective, while in the other one it wasn't. Smith could anyway take the town without too many losses, concentrated mainly in the point where the surprise was not effective. <p>Smith chose the second option because concentrating the troops was a high risk choice with an outcome alternatively very good or very bad. By splitting the forces Smith had a higher probability to take the town with acceptable losses: so Smith chose the "not all the eggs in a basket" strategy. Smith succeeded in his mission and casualties in his troops were 15.</p>	<p style="text-align: center;">Case 1b</p> <p>Major Smith, the commander of a storm troops battalion, had to plan a sabotage to an important enemy base. A successful sabotage would made possible the attack by the army. Smith decided that some saboteurs would creep into the base to find out its weak points and sabotage them. Straight after having damaged the operations of the base, the army would have attacked it heavily.</p> <p>Major Smith thought there were two ways to conduce the mission:</p> <ol style="list-style-type: none"> 1. to split the forces, sending a storm troop in each entry point of the base. The probability that one the troops could creep into the base and find out some weak points was quite high. However the small number of soldiers in each troop lowered the possibility to damage seriously the base. As a consequence, the attack by the army would have been more difficult; 2. to concentrate the troops in only one entry point. In such a case, if the troops could find out a weak point the joint action of the troops would have damaged seriously the base, making easier the attack by the army. <p>Major Smith chose the second option because the mission put at risk only the troops directly involved in it while the potential benefit was very high only if the base would have been seriously damaged. In other words, Smith came to the conclusion that, contrary to common sense, in such situations "putting all the eggs in a basket" was the best choice. Smith succeeded in his mission and casualties in his troops were 15.</p>
<p style="text-align: center;">Case 2</p> <p>Major Smith had to bring reinforcements to a battalion defending a strategic position in an impervious place. He could reach the place through two ways: the first way (the "risky way") was short but it exposed Smith's troops to a high ambush danger. The second way (the "riskless way") was longer but it did not expose Smith's troops to a high danger.</p> <p>Smith had to decide what way to go through. It was important to reach early the defending battalion to avoid the risk the enemy forces captured the strategic position. He estimated that going through the riskless way he could almost surely reach the battle place in about a day. On the other hand, going through the risky way he could reach it in half a day, but in case of an ambush the time would be quite longer than a day.</p> <p>Smith chose the riskless way. Smith succeeded in his mission and casualties in his troops were 15.</p>	

APPENDIX 1

TASK 1a

You are going to participate to an experiment in which you will be rolling dice. If the outcome is larger or equal to eight, you will earn a Euro for each point scored. Otherwise you will get nothing.

You have to choose one the two following options:

A) You roll two six-faced fair dice. Your score will be the sum of the score of each die.

B) You roll a single fair die with twelve faces.

Which option do you choose?

APPENDIX 2

TASK 2a

A real estate broker proposes the following deal.

There are two estates owned by the same proprietor: currently, there are temporary legal constraints that forbid constructing on such estates. However, the constraint will legally decay within one year. The current price of each of these estates, if it were immediately suitable for building, would be 150 points, summing up to 300 for both.

The owner wants to sell both at the end of the year.

If you pay now 50 points you have the right, but not the obligation, to buy together the two estates (i.e. you can buy both or none) at the end of the year, paying a price of 300 points. Of course, you will buy the estates only if their aggregate price will be more than 300: in such a case you will sell them to a real estate investment trust, obtaining:

$$\text{Market price} - 300 - 50$$

It is worth buying even if the market price, while being more than 300, is less than 350: you will suffer a net loss, but you will recover at least part of the initial cost of 50.

If the market price will be less than 300 you will not buy the estates: in such a case you will lose 50.

The broker proposes two prospects you have to choose between. In both cases you must pay now 50 and the current price of the estates is the same (150 + 150).

PROSPECT A

The two estates are very different and in far away regions. Therefore, their prices are independent (the correlation is about 0), since they are affected by very different factors. For instance, if the first estate's price goes up you can't say it is more probable the other estate's price goes up nor it goes down.

PROSPECT B

The two estates are similar and in the same region. Therefore, their prices are strongly correlated (the correlation is about 0.8), since they are affected by several common factors. For instance, if the first estate's price goes up is very likely that the other estate's price goes up as well (the contrary if the price goes down).

PAYOFF

The end of the year prices of the estates will be simulated using the probability distribution underlying the scatterplots in figure 3. It is worth noting that the price volatility is the same for all the estates. When the prices are correlated (prospect B) the prices are fixed accordingly.

Your payoff will be settled by the simulated prices.

Fig. 3 about here

APPENDIX 3

The simulation procedure

The prices and the figures used in the Task 1 have been computed using the following model of expected percentage returns of estates in each prospect:

$$\text{Return (Estate}_i) = \beta F + \varepsilon_i$$

where β is a parameter, while F and ε_i are variables normally and independently distributed. While F represents a common factor for both estates in each prospect, with mean 0.05 and variance 0.2, ε_i represents an idiosyncratic factor.

In Prospect A the value of the parameter β is 0, while the mean and variance of each idiosyncratic factor are 0.05 and 0.25 respectively. In Prospect B the value of the parameter β is 1, while the mean and variance of each idiosyncratic factor are 0 and 0.05 respectively.

It follows that:

- the mean and variance of the returns are the same for all estates (0.05 and 0.25);
- in Prospect A the theoretical correlation between estates is 0 and the distribution of portfolio return is $N(0.05, 0.125)$;
- in Prospect B the theoretical correlation between estates is 0.8 and the distribution of portfolio return is $N(0.05, 0.225)$.