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Choices at Various Levels of Uncertainty
AN EXPERIMENTAL TEST OF
THE RESTATED DIVERSIFICATION THEOREM ^a

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Abstract

Bayesian decision theory assumes that agents making choices assign subjective probabilities to outcomes, also at choices where information on probabilities is obviously absent. Yet, Skogh and Wu (2005) show that risk adverse agents may gain by risk sharing also in unknown (and unassigned) probabilities of losses, as long as the agents presume that the risks are equal. This “restated diversification theorem” is tested below by an experiment where the players may lose half their endowments in each of five risky rounds. The probability of loss, and the information about this probability, varies with the rounds. The result supports the hypothesis of beneficial risk sharing at genuine uncertainty. Moreover, the result tentatively supports an evolutionary theory of the development of the insurance industry – starting with mutual pooling at uncertainty, turning into insurance priced *ex ante* when actuarial information is available.

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1 Introduction

The paper presents an exploratory experiment of individual choice at various levels of uncertainty, and risk. *Risk* prevails, if the probability distribution of losses is known or predictable by the players, while *uncertainty* prevails if the probability of a loss is unknown.

The choices concern insurance versus sharing of losses. *Insurance* is defined as a contract by which one agent, the insured, trades a risk to an insurer at a premium fixed *ex ante*. Loss *sharing* prevails, on the other hand, when two or more agents agree to cover losses in a common pool. A difference between insurance and loss sharing is that insurance requires a price for the risk, which sharing does not. A shortcoming of sharing is that the diversification is limited. A hypothesis here, confirmed by the experiment, is that loss sharing is preferred to insurance at a high degree of uncertainty, while insurance is chosen when the premium is based on calculated risk.

The idea and structure of the experiment is described in *Section 2*. *Section 3* presents the experiment. Results are in *Section 4*. *Section 5* concludes.

2 The Restated Diversification Theorem

The “diversification theorem” says that if a risk adverse individual can choose two assets with identical but random returns, the individual prefers to invest half of the endowment in each asset (Rothschild & Stiglitz, 1971, p. 83). This theorem is basic in portfolio theory. Nonetheless, its institutional and decision-theoretical implications have not been fully elaborated upon.

The theorem may be restated in the following way: Two identical risk-averse individuals with assets of the same value and probability distribution gain by equal sharing of losses. Important here is that the restated theorem holds for any distribution of outcomes, as long as the distribution is the same for both parties in the pool. The probability of a loss may be 0.1 or 0.0001, in both cases the parties gain by sharing the loss.

The restated theorem implies that loss sharing is also mutually beneficial if the probability is unknown, unpredictable or genuinely uncertain. In fact, it is not necessary that the probability of a loss is the same for both; it suffices that the parties accept a presumption of equality. That is, the parties may join the pool if there is no reason to assume that their losses differ. In other words, possible differences may be neglected as long as there is no knowledge of them. Moreover, some expected, but relatively small differences, might be accepted to gain by pooling.¹

Note the difference and similarity of the concepts “presumption of equality” and “insufficient reason”. If there are k different possible outcomes and there is uncertainty about the probabilities it may be reasonable to expect the same probability $1/k$ for each of the outcomes. In other words, there is “insufficient reason” to differentiate the assigned probabilities (Sinn, 1980). The “presumption of equality” refers, on the other hand, to a situation where the agents treat each other as equal risks due to lack of information that discriminates the pool members.

¹In “Risk-sharing Institutions for Unpredictable Losses” Skogh (1999) shows that mutually beneficial sharing is possible without the assignment of a probability. It is enough that the sharing parties presume that they are faced with the same risk. Skogh and Wu (2005) identify limits to loss sharing when the pool members differ in risk aversion and potential losses.

An insurance premium is normally based on technical or actuarial information on the probability of losses.² Without such information the pricing will become arbitrary, and the negotiation costs may be large. Indeed, insurance may not be feasible at all. On the other hand, if insurance is available at an actuarially fair competitive premium the risk may be traded without considerable negotiation costs.

Contrary to insurance, sharing can be undertaken without pricing the potential loss. As noted, a shortcoming of sharing is that the losses must be presumed to be fairly equal to certify an expected mutual gain by pooling. Moreover, the pool must be large to diversify effectively, but large collective pools may cause important transaction costs and moral hazard. Hence, sharing may be inferior, especially if sufficient information makes insurance feasible.

3 The Experiment Design

3.1 Hypotheses

The experiment investigates whether risk adverse individuals facing uncertainty or risk share losses – or insure. The players know their potential losses. They may lose 500 “points” each round. Risk prevails, as defined above, when the probability of the loss is known or predictable. Uncertainty prevails when the probability is unpredictable. The experiment starts with a choice under uncertainty. That is, the player knows nothing about the probability of a loss. Information is added and finally the player’s choice is based on a known probability of a loss. The main hypotheses are the following:

²Insurer may, of course, bet on completely uncertain contingencies as they sometimes did in Lloyd’s, but industry normally requires information of risks, see Berliner (1982).

H1. Sharing is chosen at uncertainty. The reason is that sharing does not require negotiations of an arbitrary premium. A presumption of equality may simplify sharing when information is absent. Balls are picked randomly for the players from the same urn and their potential losses are the same. Hence there is no reason for the players to believe that the risk differs among pool members. Insurance at uncertainty is inferior because of arbitrary pricing and high negotiation costs.

H2. Insurance is chosen at risk. Full insurance is chosen if a contract is offered at an actuarially fair premium. The reason is that risk is eliminated, and the cost of negotiation is zero at a “take it or leave it” offer. This hypothesis fits to the standard theory of insurance.

H3. In between the extremes of hypotheses 1 and 2, the individuals change in favour of insurance as relevant information on probabilities becomes available.

3.2 Rules of the Game

Participants in the experiment receive at the start 50 SEK for participation. This amount cannot be lost in the game.³ In addition each player receives 1000 “points” which is an endowment that may well be lost during the game. The final outcome of the trade depends on five risky events (rounds). Five hundred points may be lost each round. At a total loss of 700 points or more there is no gain left in SEK (real money). To reduce the risk of large losses the participants may share losses with other players, or insure. The

³ Nine SEK was at that time roughly \$1. In Hamburg the students received an equivalent amount in German Marks.

information on the risk varies; at the first round there is no information on the probability of a loss. At the final round there is full information of the probability.⁴

At the end of the game the remaining points are transferred into an amount of SEK. The payment in SEK is shown in *Table 1* and *Figure 1*. The players are informed about the payoff.

The non-linear payoff is chosen to induce risk aversion. It is supposed to make everyone, extreme risk-lovers included, behave as if they are risk-averse. If no points are lost 100 SEK is received. If 100 points are lost, still 99 SEK are gained. That is, losing small amounts in points does not matter much. However, a loss of 500 points causes a loss of 50 SEK, and a loss of 700 points or more causes zero points in the game.

Table 1: The payoff

Points earned	1000	900	800	700	600	500	400	300
Payoff in SEK	100	99	96	90	75	50	15	0

Note: Points earned are the points a participant has left after all rounds at the end of the game. An equivalent amount of money was paid to the German participants.

⁴The order of the rounds was the opposite in the replication study.

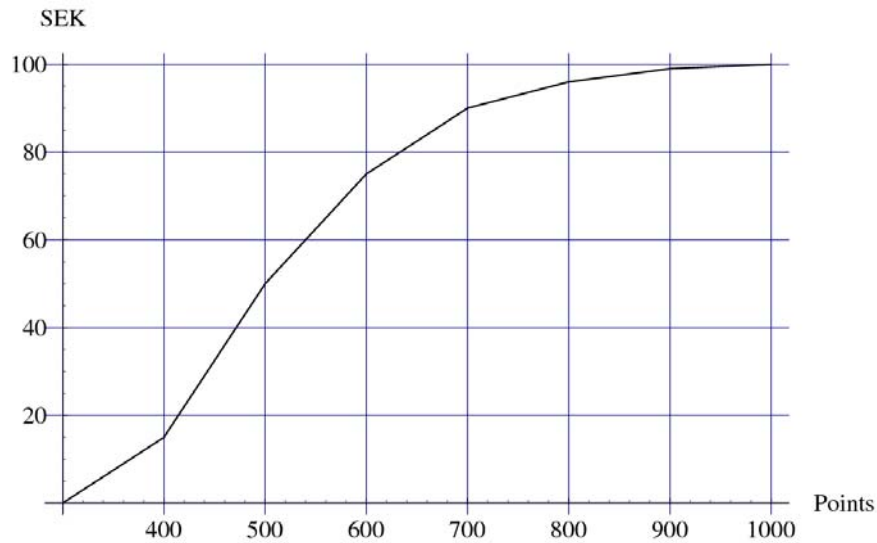


Figure 1: The payoff structure

In each of the five rounds, the players are informed that an urn contains 100 balls of various colours. For each player, and for each round, a ball is randomly picked. If a ball of a specific colour is received from the urn the player loses 500 points. Further information varies across the five rounds that will be described later on.

The player may carry the potential loss individually, insure or share with other players. The players are joined in groups of four. They can only co-operate within their own group. The players have the following alternatives:

No action. The round is played alone, with the potential loss of 500 points.

Loss-sharing. Sharing includes several options:

1. Equal sharing within the group. That is, four partners cover 1/4 each of the losses of the group. If, for instance, one of the partners in the first round receives a black ball each partner pays 125 points to cover the loss. If all receive a black ball each pays 500 points, and so on.

2. Partial sharing. Less than four share their losses, or all (or less) cover less than the whole loss. For instance, player A may cover 30 per cent of B's while B covers 30 per cent of A's losses.

Insurance. Insurance includes three options:

1. A player insures other player(s) by charging a premium in advance. For instance, the premium for coverage of 200 points could be 10, 20, 50, *etc.* depending on the beliefs on the risk, choice of deductible, and bargaining power of the players. Each player is allowed to insure losses of up to 250 points each round. This is to avoid insolvent insurers.
2. The player buys insurance and pays someone or several in the group to cover a potential loss. The player may act both as insurer and insured. Note that mutual insurance where partners insure each other at the same (arbitrary) premium is equivalent to sharing.
3. An external insurer (the supervisor of the game) offers insurance coverage at a fixed premium. This option is not available in the first and third round.

Round 1. In this round the players receive the information that the urn contains 100 balls of various colours, and if a black ball is picked for the player, a loss of 500 points will be experienced. There is no information on the numbers of black balls. In fact, there is no information on whether there are any black balls at all. Hence, a high degree of uncertainty prevails in the first round. The players may take "no action", share losses or insure each other, but there is no external insurance available.

Round 2. This round is identical to round 1, with the addition of the option of an external insurer. The external insurance offers a contract where the price is 1 point

for the coverage of a loss of 2 points. Full coverage of the loss of 500 points thus costs 250 points.

Round 3. In this round information about the balls is added. The players are informed that the 100 balls in the urn are of at least five colours. Each player receives a colour, and if a ball with this colour is picked for the player, 500 points are lost. There is no external insurance available in this round.

Round 4. This round is identical to Round 3, but with the option of external insurance. The external insurance offers coverage at a premium of 1 point for coverage of a loss of 5 points. Full coverage thus requires a premium of 100 points.

Round 5. Players are now informed that 10 out of the 100 balls are blue, and if a black ball is received the player will lose 500 points. External insurance is a possible choice of action with an insurance coverage at a premium of 1 point for coverage of a loss of 10 points. Hence, full coverage costs 50 points.

The decisions of each individual player were written down on a decision form, one for each round.⁵ The random picking of balls took place after the players had decided on all five rounds. Otherwise, the choices in rounds 2-5 would be influenced by the remaining endowment, and the individual experience at earlier rounds.

The picking of balls was made by the supervisor of the game, and not by the players themselves. The reason was to avoid cheating and the “illusion of control”, that is “strategic behaviour” by players believing they can influence the outcome by choice of “their” colour, by shaking the urn in a specific manner, *etc.*

⁵The decision form is available from the authors upon request.

Finally, losses were calculated and payments were made according to *Table 1*. The player filled two additional forms: an individual evaluation of the game, and a receipt of the payment received.

4 Results

Two experiments were conducted. The first experiment started with choice under uncertainty and ended with risk, while the replication experiment started with choice at risk and ended with uncertainty. The reason was to identify potential ordering effects and to investigate if the hypotheses even hold up if information is taken away (replication study) instead of added (the first experiment).

4.1 The First Experiment

The first experiment took place at different occasions in 2000–2002 at Linköping University, Hamburg University and Lund Institute of Technology. In total 108 players participated in the game. Sixty-six were male and 40 female (2 unknown). The participants were students of Law, Economics, and Engineering and studied on an intermediate level. The players were divided in 27 groups of four each. Two participants responded incompletely during the rounds, therefore the analysis below is based on the remaining 106 subjects.

The participants completed the “introductory form”. Most answered that they liked competition and playing games, and whereas 28 disliked gambling, 55 liked it, and 18 liked it a lot (5 answers missing). Hence, there was presumably a mix of risk-averse and risk-lovers among the players. However, the non-linear payment illustrated in *Figure 1*

ought to have made most of them behave as risk averse. The players also answered an evaluation form. Most found the game interesting and easy to understand.

The participants had only little or no knowledge of insurance or loss sharing. The risk that the students received information in advance of the experiment was minimal, because it was spread geographically and involved students from different fields.

Fifteen minutes were spent to explain the rules of the game. The game took around 45 minutes. There was no time limit set.

The results of the experiment are presented in *Table 2*. The rows identify the number of players taking a particular action and columns the round. Rows with labels in italics give the total number of subject taking one overall type of action. For example, “Sharing” is the sum of “Equal” and “Partial”.

We first give a descriptive analysis for each round. Thereafter, we compare the rounds with each other.

Table 2: Number of players adopting a certain action

Round	1	2	3	4	5
<i>Sharing</i>	104 (98 %)	82 (77 %)	67 (63 %)	23 (22 %)	10 (9 %)
Equal	96 (90 %)	73 (69 %)	59 (56 %)	21 (20 %)	10 (9 %)
Partial	8 (8 %)	9 (8 %)	8 (8 %)	2 (2 %)	0 (0 %)
<i>Insurance</i>	0 (0 %)	11 (10 %)	7 (7 %)	50 (47 %)	66 (62 %)
Internal	0 (0 %)	9 (8 %)	7 (7 %)	6 (6 %)	2 (2 %)
External	–	2 (2 %)	–	42 (40 %)	64 (60 %)
Int/Ext	–	0 (0 %)	–	2 (2 %)	0 (0 %)
<i>Other</i>	2 (2 %)	13 (12 %)	32 (30 %)	33 (31 %)	30 (28 %)
No action	2 (2 %)	13 (12 %)	32 (30 %)	33 (31 %)	26 (25 %)
Mixed	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	4 (4 %)
<i>Total</i>	106 (100 %)	106 (100 %)	106 (100 %)	106 (100 %)	106 (100 %)
Insurers	0 (0 %)	10 (9 %)	7 (7 %)	8 (8 %)	2 (2 %)

Note: The rows with italic labels give the total numbers for the overall category of action. "Equal" presents the number of individuals who have chosen to share the whole potential loss equally with 3 or less persons willing to share equally in the group. "Partial" presents the number of individuals who have chosen to share less than the whole loss with 3 or less persons in the group. "Int/Ext" means that players have covered some potential loss of points with internal and some with external insurance. "Mixed" means that players have partially insured some amount of points and partially shared the potential loss.

4.1.1 Round 1

The first round investigated the choice at almost genuine uncertainty. The players were informed that the urn contained 100 balls of various colours. If a black ball was picked the player lost 500 points. There was no further information.

A first option to the player was “no action”, that is to take the risk without sharing or insurance. Only two made this choice as can be seen in *Table 2*.

A second option was to purchase internal insurance from some player in the group. That required that someone was willing to insure at a price both could agree on. The risk aversion induced by the payoff (*Figure 1*) makes internal insurance unexpected. None chose internal insurance.

A third option was to share the potential loss within the group. Equal sharing by all in the group diversify the risk. Loss sharing does not, as noted in *Section 2*, require a price to make sharing feasible. Ninety-six players (24 groups) chose equal sharing with all four in the group, while 8 participants chose partial sharing. This fits *Hypothesis 1*. Yet, it was not expected that practically all should share losses. Obviously, the players could rather efficiently join a pool of equal sharing. “No action” was rarely chosen and arbitrary insurance internally among the players was not practised at all.

4.1.2 Round 2

In Round 2 the choice of an external insurer was added. The insurer offered a contract where the price was 1 point for the coverage of a loss of 2 points.

The premium was actuarially fair if 50 percent of the balls were black. As there was no information the players could apply the rule of “insufficient reason”, that is, to assign the same probabilities to the two alternatives “black” and “other” colour. The transaction costs were reduced by the offered “take it or leave it” contract that eliminates negotiations on the price.

The numbers of players sharing losses within the group, fully or partially, decreased from 104 in Round 1 to 82 in Round 2, see *Table 2, Rows 1–4*. That is partly explained

by the presence of insurance, but also by the fact that “no action” increased from two to thirteen. Only two players purchased external insurance. Thus, the option of external insurance made little difference. Thus, there is no support for the idea of “insufficient reason”. More carefully designed experimentation is needed on this point. Maybe the players believed that the number of black balls was less than 50 percent and thus that the premium was unfair. “Various colours” may have been (correctly) interpreted that black was one of many colours and thus less than 50. Another explanation is that 250 points as premium was regarded unaffordable; paying such a high premium also for further rounds would cause bankruptcy. Given that bankruptcy is expected it may be rational to gamble and hope that the outcome will be better than expected.

4.1.3 Round 3

In this round the players were informed that the urn contained 100 balls of at least five colours. Each player in the groups of four received a colour out of five (black, blue, red, green, violet,...). There was no external insurer present in this round.

The result was that 67 shared losses, fully or partly. “No action” increased to 32. Indeed, in rounds 3 to 5 the “no action” choice increased to 30 percent of the players, which may indicate that some became frustrated or bored during the game. Another explanation is that they believed that cooperation did not pay. Indeed, a “no action” gambling strategy could be a reasonable choice throughout the game. At each round half of the endowment could be lost. If the believed probabilities of losses are relatively large, bankruptcy may be the expected outcome of the five rounds. Gambling may in that case be a way to survive by luck.

4.1.4 Round 4

Round 4 added an external insurer to Round 3. The external insurer offered insurance coverage at a premium of 1 point for coverage of a loss of 5 points. The premium was, again, fair if “insufficient reason” was applied and there were no more than five colours in the urn. However, uncertainty remained on this point.

The choice of “no action” was 33. The choice of sharing decreased to 23. External insurance was the choice of 42 participants. The number of players choosing internal insurance remained about the same as in Round 3. Two players chose both an external and an internal insurance, see Row 7 “Int/Ext” in *Table 2*. It is obvious that the presence of seemingly fair insurance was important.

4.1.5 Round 5

In this round players were informed that the urn contained 10 blue balls. The external insurer offered insurance at a premium of 1 point for coverage of a loss of 10 points. Thus full coverage of 500 points cost 50 points. Twenty-six players took “no action” and 4 players shared some part of the potential losses and insured other parts. Ten players preferred to continue sharing losses, equally or partially, while 64 purchased external insurance. Sixty players insured fully. Two players preferred to insure internally.

4.1.6 Comparing the Rounds

In order to investigate changes in players’ choices, we tested for the homogeneity between different rounds using the Stuart-Maxwell test (see Stuart, 1955; Maxwell,

1970) for overall marginal homogeneity and the McNemar test (see e.g. Siegel & Castellan, Jr., 1988) for individual categories. In all cases we used two-sided tests.

The only thing that differentiated Round 2 from Round 1 was the choice of an external insurer, and hence the information about insurance premium. However, none chose external insurance. A closer look at the change in each category reveals that there was a significant change in “Equal sharing”, from 96 to 73, (McNemar test, $\chi^2 = 21.16$, $p < 0.001$, $df = 1$), in “No action”, from 2 players to 13, (McNemar test, $\chi^2 = 9.30$, $p < 0.01$, $df = 1$), and in “Internal insurance”, from 0 to 9, (McNemar exact test, $p < 0.01$, $df = 1$).

In both Round 1 and Round 3 players did not have the choice of “external insurance”. However, in Round 3 some information about the risk was added. It is, therefore, interesting to compare these two rounds. A test for overall homogeneity shows that there is a significant change from Round 1 to Round 3 (Stuart-Maxwell test, $\chi^2 = 37.08$, $p < 0.001$, $df = 6$). Particularly, there is a significant decrease in players choosing the action “Equal sharing” (McNemar test, $\chi^2 = 33.39$, $p < 0.001$, $df = 1$) and a significant increase in “No action” (McNemar test, $\chi^2 = 28.12$, $p < 0.001$, $df = 1$).

Round 4 added the choice of an external insurance. Comparing Round 1 with Round 4 gives one important result. There is a significant decrease in numbers of players adopting the action “Equal sharing”, from 96 to 21, (McNemar test, $\chi^2 = 66.77$, $p < 0.001$, $df = 1$).

Adding more information about the risk in Round 5 decreases the number of players choosing “Equal sharing” and increases the number of players choosing “External insurance” even further. Contrasting Round 4 with Round 5, for instance, shows a significant fall in the number of subjects adopting “Equal sharing” (McNemar test, $\chi^2 =$

11.00, $p < 0.001$, $df = 1$) and a significant raise in the number of subjects adopting the alternative “External insurance” (McNemar test, $\chi^2 = 11.00$, $p < 0.001$, $df = 1$).

These results fit the *Hypotheses 1 and 2*; sharing is chosen when uncertainty prevails while insurance is chosen at risk. The tendency is clear – as the uncertainty decreases the number of participants sharing the potential losses fall from 104 in Round 1 to 82, 67, 23 and 10 in the following rounds. Similarly, “external insurance” increases from two at uncertainty to 64 players in the final round.⁶

4.2 The Replication Study

In the first experiment, rounds were presented to the players in the order they have been presented above. The information on potential outcomes thus increased as the game proceeded. Especially the potential bankruptcy issue may become evident when several rounds have been presented. That may cause more “no action” at later rounds. “No action” could also be due to poorly motivated, or bored, players. To test for this and other ordering effects we replicated the experiment with the difference that Round 5 was now the first round, Round 4 the second round, *etc.*

The reversed experiment was designed for 60 players in 15 groups. Among these, 41 were men and 19 were women. As in the first experiment, participants completed an “introductory form”. Most answered that they like competition and playing games, and whereas 19 disliked gambling, 30 liked it, and 6 liked it a lot (5 missing answers).

The results from the replication experiment are summarized in *Table 3*. Note that Round 1 here was Round 5 in the original experiment, Round 2 was earlier Round 4, and so on.

⁶For the record, there is also significant change between round 2 and round 3 (Stuart-Maxwell test, $\chi^2 = 11.62$, $p < 0.071$, $df = 6$) and round 3 and 4 (Stuart-Maxwell test, $\chi^2 = 28.60$, $p < 0.001$, $df = 6$).

Table 3: Replication study: number of players adopting a certain action

Round	1	2	3	4	5
<i>Sharing</i>	6 (10 %)	30 (50 %)	35 (58 %)	39 (65 %)	34 (57 %)
Equal	3 (5 %)	20 (33 %)	19 (32 %)	34 (57 %)	25 (42 %)
Partial	3 (5 %)	10 (17 %)	16 (27 %)	5 (8 %)	9 (15 %)
<i>Insurance</i>	35 (58 %)	17 (28 %)	2 (3 %)	0 (0 %)	3 (5 %)
Internal	0 (0 %)	0 (0 %)	2 (3 %)	0 (0 %)	3 (5 %)
External	35 (58 %)	17 (28 %)	–	0 (0 %)	–
Int/Ext	0 (0 %)	0 (0 %)	–	0 (0 %)	–
<i>Other</i>	19 (32 %)	13 (22 %)	23 (38 %)	21 (35 %)	23 (38 %)
No action	19 (32 %)	13 (22 %)	23 (38 %)	21 (35 %)	23 (38 %)
Mixed	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)
<i>Total</i>	60 (100 %)	60 (100 %)	60 (100 %)	60 (100 %)	60 (100 %)
Insurers	0 (0 %)	0 (0 %)	1 (2 %)	0 (0 %)	2 (3 %)

Note: The rows with italic labels give the total numbers for the overall category of action. See further the note, *Table 2*.

4.2.1 Round 1

The first round was the case with most information about risk (Round 5 in the first experiment), that is, the players were informed that the urn contained 10 blue balls. Insurance was offered at a fair premium. As can be seen from the *Table 3*, 35 players chose external insurance. Nineteen players chose “no action”. Six players only chose some kind of sharing.

4.2.2 Round 2

In the second round (Round 4 in the first experiment) information about the balls was reduced. The players were faced with a new urn that contained 100 balls of at least five colours. External insurance was possible at a price of 1 point for coverage of 5 points.

Fifty per cent of the participants chose some loss-sharing option, 20 players chose “Equal sharing” and 10 chose “Partial sharing”. Thirteen players took “No action” and 17 “External insurance”.

4.2.3 Round 3

In Round 3 the option of an external insurer was excluded. Beside the external insurer, the round was identical to the previous one.

Almost 60 per cent of the participants chose some alternative of loss sharing, while almost all the remaining participants chose “No action”.

4.2.4 Round 4

Round 4 created even more uncertainty (Round 2 in the first experiment). In this case players were faced with a third urn containing 100 balls of various colours. If the player received a black ball he/she would lose 500 points. External insurance was an option to the price of 1 point for the coverage of 2 points.

As in Round 3, players either took the loss-sharing option, 65 per cent, or the no action option (35 per cent).

4.2.5 Round 5

Excluding the option of an external insurance from round 4 defined the final and fifth round. Again, the players either took one of the loss-sharing options or no action at all, except for 3 players buying an internal insurance.

4.2.6 Comparing the Rounds

The overall change from Round 1 to Round 2 is significant (Stuart-Maxwell test, $\chi^2 = 25.15$, $p < 0.001$, $df = 6$). A closer look at the data shows that it is the result of the significant increase in the number of players choosing a loss-sharing option – “Equal sharing” from 3 to 20 (McNemar test, $\chi^2 = 17.00$, $p < 0.001$, $df = 1$) and “Partial sharing” from 3 to 10 (McNemar exact test, $p = 0.015$, $df = 1$), and the significant decrease in the number of players choosing “External insurance”, from 35 to 17, (McNemar test, $\chi^2 = 13.50$, $p < 0.001$, $df = 1$). So, as information about the potential loss is reduced, players tend to move from insurance to loss sharing.

Comparing rounds 2 and 4 in the second experiment also reveals this pattern. In Round 2 there is more information available than in Round 4 where the player has almost no information. The choice of “Equal sharing” significantly increased from 20 to 34 players (McNemar test, $\chi^2 = 14.00$, $p < 0.001$, $df = 1$), while the number of subjects choosing “External insurance” significantly decreased from 17 to zero players (McNemar test, $\chi^2 = 17.00$, $p < 0.001$, $df = 1$).

We could, however, not reject the homogeneity between Rounds 3 and 5 (Stuart-Maxwell test, $\chi^2 = 3.62$, $p = 0.72$, $df = 6$).

4.3 Comparing the Experiments

Both experiments, the first and the replication, show that when there is little or no information about the probabilities of losses players share losses and when there is sufficient information, people choose to insure. A remaining question is if there are ordering effects.

Table 4 shows a comparison of the first and the second experiment. We performed a χ^2 -test for independence for each round. That is, we compared Round 1 in the first experiment with Round 5 in the second experiment, Round 2 in the first experiment with Round 4 in the second, and so on. Only the test of Round 3 in both experiments and test of Round 5 in the first experiment, and Round 1 in the replication experiment could not be rejected as being equal.

The conclusion that may be drawn is that there seems to be an ordering effect. However, both experiments support the hypothesis that sharing is chosen under uncertainty and insurance when information is available.

Table 4: Comparison of the first and the replication experiment

Exp. 1	Exp. 2	χ^2	Df	p – value
1	5	47.01	2	$p < 0.001$
2	4	10.42	2	$p < 0.01$
3	3	1.67	2	$p = 0.43$
4	2	14.22	2	$p < 0.001$
5	1	0.26	2	$p = 0.88$

Note: Exp. 1 gives the rounds in the first experiment and Exp. 2 gives the rounds in the replication experiment. We have only compared the overall values, i.e. “Sharing”, “Insurance”, and “Other” between rounds in the two experiments.

5 Conclusions

This experiment is the first empirical test of the “Restated diversification theorem” saying that parties facing the same potential loss may profit by equal sharing (pooling)

without the assignment of loss probabilities⁷. Students without specific experience of insurance or mutual sharing, share losses at uncertainty in a way that supports the theorem. That is, sharing is chosen because it eliminates the problem of pricing at uncertainty.

The choice of sharing becomes less frequent as more information and external insurance becomes available. The reason may be that full insurance eliminates risks completely. Negotiation costs are also reduced with more information on probabilities, and by the presence of a “take it or leave it” contract.

An alternative explanation in favour of sharing is that there is a moral code or idea of fairness promoting equal sharing. It is true that a moral standard may simplify sharing agreements, but the frequent abandonment of sharing in favour of insurance at risk indicates that individual rationality is important.

The copious literature on decisions under risk and uncertainty, following Savage (1954), typically assumes actors acting at risk. At uncertainty it is assumed that the actors assign subjective probabilities to potential outcomes. This assumption may simplify the analysis, but it becomes unsatisfactory in cases where the player evidently knows nothing about the probability of outcomes. A defence of the subjective probability approach is that individuals cannot make decisions without assignment of probabilities. The sharing examples above show that this is not fully true – risk sharing among equals may take place without assignment of probability.

⁷ Our experiment is, to our knowledge, one of the first where behaviour at varying levels of uncertainty is examined. There are no experiments where the players gradually receive more information that reduces uncertainty, and results in changed behaviour by the players. The famous “Ellsbergs paradox” experiment (Ellsberg, 1961) has similarities with this experiment in that balls are picked under uncertainty and at known probabilities. The option of sharing versus insurance is not investigated by Ellsberg.

Note also that insurance paid *ex ante* and sharing *ex post* are quite different contracts. Sharing has, as shown above, an advantage among equals facing uncertainty. This may explain why ship owners, guilds, and joint ventures tend to share risks - especially at the early stage of development when the probability distribution is most uncertain. In other areas – with available actuarial information and competitive premiums – insurance may be superior. The difference of sharing and insurance is thus of relevance for the understanding of the evolution of the insurance industry - from mutual pools to insurance based on premiums that require predictability. The theory is also of relevance in the analysis of the coverage of “development risks”, that is new hazards that cannot be predicted statistically.⁸

⁸See Skogh (1998, 1999) and Faure and Skogh (1992)

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