Three Essays on Behavioural Economics

submitted in fulfillment of the requirements for the degree of Doctor of Philosophy in Economics

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Contents

Introduction

The current PhD dissertation is the collection of three research articles in experimental economics. The focus of two of them is the problem of bank runs. The first paper is an experiment based on the extension of a well - known theoretical model of Diamond and Dybvig. The second paper is based on an alternative approach to the problem of bank runs, such that experimental subjects are less restricted by the theoretical assumptions and are given more freedom to behave as they do in real life. The third article is a preliminary version of the working paper that is devoted to the question of insufficient pension savings and the how pension system design may stimulate people to save more.

The first paper presents an extended version of the Diamond and Dybvig model in which depositors of one bank besides keeping and withdrawing are given an option to redeposit the money from one bank to the other. Most of the theoretical, empirical and experimental literature on bank runs considers the decision of a depositor to keep or to withdraw the money within the framework of one bank. Whereas in real life people are surrounded by many banking institutions, so always have a choice among them. In case of doubts regarding the financial stability of their bank, depositors may relocate the deposit from their bank to another one. The availability of such a choice may have a twofold effect. On one hand, it gives depositors freedom to choose a bank that they consider financially stable, thus it should lead to less banking panics. On the other hand, depositors may get less loyal and in case of any doubts change their initial deposit allocation.

The first paper is aimed to analyse whether depositors who are provided with a choice among banks actually use such an option. Specifically, whether they tend to relocate deposits instead of simply withdrawing the money. It may seem unimportant from the perspective of a specific bank what does a depositor do with the withdrawn amount - keeps it in cash or relocates it to another bank. However, it is crucial from the macroeconomic point of view. In case the money is kept "under the pillow", it stays outside of the banking system, whereas being redeposited it continues to be lent to other individuals or enterprises; thus, stimulates economic activity. For all these reasons, I consider the research focus of the first paper important for understanding the phenomenon of bank runs.

Overall, I find theoretically and later support it experimentally, that when a redepositing option is available, the number of simultaneous bank runs decreases compared with the case when depositors cannot relocate their deposits. At the same time, the frequency of bank runs becomes highly disproportional across banks and the number of individual bankruptcies increases. Apart from that, I find that individual characteristics of depositors play an important role. Risk averse subject tend to withdraw more compared to risk neutral and risk seeking depositors. Also, if a depositor has experienced a bank run in the past, it will increase the chances that he will not keep his money in the bank in the future.

The second paper is aimed to analyze the withdrawal behavior of banks' depositors in times of economic crisis. The set-up of the model differs from the classical framework of Diamond and Dybvig (1983): subjects are not restricted by the number of times they can withdraw or keep the money back. Additionally, there is no specific order in which subjects decide. Also, the amount which can be withdrawn or kept back to the bank is defined by the subject and not by experimenters. In addition, it is assumed that a certain part of a deposit is covered by the deposit insurance, which allows to define the panic as a situation in which a depositor withdraws even the amount covered by the deposit insurance.

As it is difficult to find the theoretically optimal behavior in such a complicated game, its solution is reached using the mathematical simulation. Later, the results of the experiment are compared with the results of the simulation. There are two versions of the experiment conducted. In the first version, there is no possibility of interaction between the subjects, whereas in the second version subjects can communicate via the chat box which is always available on the computer screen. Experimental subjects are not limited by the number of messages they can send. Besides that, they can communicate with any of the players.

Overall, the experiment seeks to analyze the influence of several factors, such as the possibility to communicate, the culture of subjects, deposit insurance and the liquidity of the bank on the withdrawal behavior. It is found that communication helps to stop bank runs, whereas information about the worsening of economic conditions together with irrational behavior increase the incidence of withdrawals. Also, not only the fact of communication, but also its mood plays an essential role. Sometimes subjects wrote positive messages reassuring others the bank is financially stable, other times the message could contain an expectation that the bank run is about to happen. Overall, by sorting out all the messages as negative, neutral and positive, it has been found that the mood of communication is sensitive to changes in economic conditions and was a possible signal of upcoming withdrawals. Once the ratio of positive to negative messages approaches one, withdrawals increase sharply. Besides that, the results show that personal features of subjects influence their withdrawal behaviour. There is some evidence that women withdraw more quickly as well as irrationally but in smaller amounts, while men tend to wait to make a decision but then withdraw more at one time. Besides that, it was found that Russians withdraw more money but less often than Germans.

The third paper is the preliminary draft of a working paper. It is devoted to the analysis of people's saving decisions across different pension systems and income profiles. The problem of insufficient savings for retirement is acute for the majority of countries. However, it is still not completely clear, which factors influence saving choices and what makes people to save more for the retirement. To answer these questions, we conducted an experiment in which subjects were presented with different saving alternatives, that theoretically should not influence the saved amount.

There are six experimental treatments that vary in two dimensions. First, in half of the sessions the income that the subjects can spend and save for the future, is constant and known, whereas in other half of the sessions it is stochastic, thus unknown. The second dimension of comparison is the type of pension system. The first pension system has no particular mechanism that would oblige people to save. Everything that is not spent on consumption becomes "pocket" savings, which can be used by the subjects at any moment in time. In a pension system of the second type, people are obliged to save a certain fraction of their income in every working period. The total obligatory saved amount cannot be spent until the retirement phase starts. Besides obligatory savings, people can still make additional pocket savings. The third pension system provides an additional option: voluntary pension savings. The difference between voluntary pension savings and pocket savings is that voluntary savings can be accessed before retirement.

Overall, it has been observed that voluntary saving option made subjects to save more. There is no evidence that obligatory contributions and stochasticity of income motivates people to make larger savings. In addition, experimental results show that better cognitive abilities lead to better performance in the saving task.

Regardless the difference in topics of all three papers, the conclusions reached in each of them are based on the experimental results. Thus, the experiment is used as one of the main tools of the research in all three works. The remainder of the thesis is structured as the collection of three papers presented in the order stated above. The appendixes and the relevant list of references are placed at the end of each of the papers for the matter of convenience.

Bank runs as a coordination problem within a two banks set-up: who will survive?*

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Abstract

The paper presents an extended version of the Diamond and Dybvig model, where depositors of one bank besides keeping and withdrawing are given an option to redeposit the money to another bank. I find that the frequency of bank runs becomes disproportional: being given an opportunity to choose among banks, depositors tend to relocate deposits leaving their bank more often, which keeps clients of a recipient bank calm. The number of simultaneous bank runs decreases although insignificantly. The most commonly played equilibrium is when all the subjects keep the money in the corresponding bank. Besides that, in the treatment with the redepositing option, subjects actively use it under the condition that the subjects of the bank-recipient keep the money. Subjects learn how to coordinate and play equilibria more frequently in the second than in the first half of the game. Also, the history of previous experiences matter: the more runs a subject has witnessed, the less he keeps the money in the bank in the future.

Keywords: bank runs, experiment, coordination problem

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1 Introduction

The first bank run documented in the literature happened in the 16th century in England, causing economic damages to the country. Since then, bank runs tend to occur with a persistent regularity having severe consequences for the economies all over the world (Kindleberger, 2015; Laeven and Valencia, 2013). Several factors influence the emergence as well as the propagation of bank runs. Among them are the level of deposit insurance (Schotter and Yorulmazer (2009), Boyle et al. (2015), Madies (2006)), availability of information and its completeness (Arifovic and Jiang (2014), Schotter and Yorulmazer (2009)) as well as personal characteristics of depositors (Kelly and Gráda (2000), Iyer and Puri (2012)).

In the current paper, I investigate another factor that is important for bank runs propagation, although has not been considered in the literature. I analyze how the existence of several (two) banks together with a possibility to relocate a deposit from one bank to another at no cost may change the withdrawal behavior of subjects. To my knowledge, in none of the theoretical and experimental studies on bank runs, a subject is given a possibility to change the initial deposit allocation. However, there is some empirical evidence that the option to leave one bank for another may be crucial for the stability of the banking system, especially on the moments of panics.

Saunders and Wilson (1996) analyze the behavior of depositors in the US in 1929-1933 and find that depositors were not withdrawing but reallocating the money to other banks which seemed to be solvent. The recent empirical study by Brown et al. (2014) shows that almost 80% of households that withdrew their deposits from a distressed swiss bank (UBS), redeposited the money to another non-distressed one. According to Iyer and Puri (2012), depositors were likely to redeposit funds with government banks in case of panics. Schumacher (2000) shows that during the currency crisis in Argentina, depositors relocated the money from banks that were not likely to survive the crisis to more resilient banks. Thus, whether a depositor has a choice among banks or not may be crucial for the withdrawal behavior as well as for emergency and propagation of bank runs.

Furthermore, understanding whether depositors withdraw or redeposit is essential for the regulators of a banking sector, because these two actions have a different effect on the banking system's liquidity. Withdrawals cause a contraction in the money supply (Friedman and Schwartz (2008), Kaufman (1994)) and slow down the aggregate economic activity (Mishkin (1992)). Whereas if a client redeposits, the money still stays in the banking system thus does not lead to the liquidity shortage. In other words, the same action of withdrawal may have different consequences for the banking system with only one bank and several banks. In the first case, the bank run means the collapse of the entire banking system. Whereas in the latter case, if all subjects leave one bank for another, there is one severe bank run, although the banking system still preserves the overall level of liquidity. Introduction of a model with more than one bank, as well as the possibility to redeposit, may be a good starting point to understand what may keep the money of depositors within the banking system which is vital in times of economic turbulence.

Overall, the paper seeks to answer two main research questions: (1) How does the introduction of a costless redepositing option changes withdrawal behavior as well as the propensity of an individual bank to fail?; (2) When subjects can relocate their deposits, do simultaneous bank runs occur more/less often?

To answer these questions, I develop an extended version of the Diamond and Dybvig (DD) model. I consider two banks such that depositors of one of the banks can relocate money to another bank at no cost. I assume that banks have the same fundamentals to exclude the possibility of one bank being initially "healthier" than another. There is no guarantee that a subject will not experience a bank run changing initial bank allocation. However, due to the fact that new clients may join one of the banks, it may be perceived as more stable in the eyes of depositors. The banks have the same number of initial clients, the same fundamentals and provide the same interest rates on deposits - the banks do not compete for clients setting different interest rates. Hence, there are no monetary incentives, only the availability of choice among banks that may influence the depositors' behaviour.

To understand whether the introduction of an option to relocate a deposit leads to more bank runs, I find theoretically optimal behavior in the extended model and compare it with the one in the classical model without redepositing. Then I check my conclusions experimentally by running two versions of the game: with and without a redepositing option. I construct the experiment in the form of a game that is being played 20 times. I apply a fixed matching of subjects, which allows me to study learning effects and to see how withdrawal behavior changes across time[1]. According to the literature, there is no consensus reached regarding this topic. Arifovic et al. (2013) do not find any learning effects, whereas Schotter and Yorulmazer (2009) show that subjects do learn over the game. One may claim that learning effects in bank - run games are not informative per

[1] The initial matching of subjects within a bank and a system of two banks stays through the entire game.

se as far as people go through the bank run situation at most ones in their lives (Schotter and Yorulmazer (2009)). However, retail bank customers rarely change their main bank relationship (Kiser (2002)), which means that they are dealing with the same bank for most of the time. In this case, learning effects can be useful for explaining the changes in the withdrawal behavior of individuals even if no bank runs occur.

I find that the costless possibility to change initial deposit allocation has a twofold effect on bank runs. On the one hand, provided with a redepositing option, depositors tend to leave their bank more often than when such an option is not available. On the other hand, the bank which receives new clients experiences fewer runs. Overall, in a banking system where subjects can relocate their deposits, there are more cases of at least one bank run happening, and insignificantly less simultaneous bank runs. In both treatments, I observe better coordination in the second half of the game than in the first one. Besides that, risk averse subjects are more reluctant to keep money in a bank than risk neutral and risk seeking individuals.[2] I find that negative experience of going through a bank run leads to more cases of subjects leaving the bank in the future. Thus, bank runs are contaminating: if they happened in the past, it increases the chance of them occurring again later.

The remainder of the paper is structured as follows. First, I analyze the main literature on the topic. Then, I describe the Diamond and Dybvig model and the proposed theoretical extension. Next, I provide a numerical simulation which is used for the experiment as well as state the main hypotheses. Finally, I analyze the data and conclude.

2 Literature

There is an immense number of theoretical, empirical and experimental literature on the topic of bank runs. Usually the object of studies is either a *bank run* (Arifovic and Jiang (2014), Madies (2006), Schotter and Yorulmazer (2009)) or a *banking panic* (Chakravarty et al. (2014), Brown et al. (2016), Duffy et al. (2016)). The main difference between these two notions is that a bank run happens in one bank whereas a banking panic overwhelms many banks. Studies on individual bank failures usually assume the existence of only one bank in the banking system. As far as I consider deposit movements across banks, I focus mainly on research works that model (or can be easily applied to) several banks operating within the banking system.

[2] I use the same notions of different risk attitudes (risk aversion, risk loving and risk neutrality) as Crosetto and Filippin (2013).

2.1 Theoretical Literature

The problem of bank runs has been considered in the theoretical literature from different angles. Bryant (1980) introduces an overlapping-generations model in which people can borrow from banks to finance their consumption. He shows that demand deposits backed by fractional currency reserves and public insurance can be beneficial to prevent bank runs. Temzelides (1997) analyzes whether the average size of a bank in the system affects the panic propagation. The author introduces several banks of equal size, assuming that the number of its clients defines the size of a bank. All people know the size of the representative bank in the system, but do not know how big is the bank where they keep a deposit. Temzelides (1997) shows that clients panic more the smaller is the representative bank. Besides that, the local interaction between clients triggers bank runs in the neighboring banks.

As Temzelides (1997), Allen and Gale (2000) investigate how contagion can spread among banks. Subjects are assigned to one of the banks that hold interregional claims on each other. In case there are too many withdrawals from one of the banks, another bank lends its funds which are the money of its depositors. The authors show that financial linkages of this kind can turn out to be a disaster: in the end, interbank relations can lead to an economy-wide financial crisis.

Iori et al. (2006) analyze how heterogeneity in average liquidity of banks influences bankruptcies. They find that in a system with heterogeneous banks the risks of contagion are higher. Also, Acharya and Yorulmazer (2008), Acharya (2009) claim that in such a banking system, financial institutions have an incentive to make similar investments, which in the end undermines the financial stability of the financial system as a whole.

Freixas et al. (2011) consider that bank panics may happen if the interbank market rate is not set correctly. If it is too high, it may be not enough liquidity in the interbank market as banks will be obliged to pay high returns to the clients. As a consequence, it may lead to massive failures to meet obligations in front of the depositors and cause bank runs. Zhu (2005) proposes a model in which bank runs are closely related to the state of the business cycle. He finds that interest-cap deposit insurance scheme can prevent bank runs, although he admits that the model misses essential features such as information asymmetry among agents and idiosyncratic shocks faced by banks.

Goldstein and Pauzner (2005) show that not only overall economic conditions and interbank relations but also the conditions of a deposit contract affect the occurrence of bank runs. The authors find that banks become more vulnerable when they offer more risk sharing. Cañón and Margaretic (2014) extend the model of Goldstein and Pauzner (2005) by showing that the introduction of reserve requirements by a central bank can decrease the probability of a bank run.

Wang (2013) contributes to the existing literature by analyzing how the announcement of bailouts affects depositors' behavior. The author finds that availability of the bailout policy helps to prevent clients from leaving the bank, however, when it is announced that there will be a bailout, clients immediately run on the bank. The role of information has also been studied by He and Manela (2016). The authors are interested to know how availability and precision of signals about bank's solvency effects the propagation of bank runs. They find that less informative signals make subjects wait to withdraw, whereas private information acquisition shortens the survival time of illiquid banks.

2.2 Empirical Literature

Empirical studies on bank runs are scarce (Bikhchandani and Sharma (2000)). The main research works are by Kelly and Gráda (2000), Gráda and White (2003), Iyer and Puri (2012), Ramirez and Zandbergen (2014), Ziebarth (2013), Saunders and Wilson (1996).

Kelly and Gráda (2000), Gráda and White (2003) investigate whether there is any link between social knits and a banking contagion. Considering the panics of 1854 and 1857 in the United States, they analyze the behavior of Irish immigrants living in New York in the 1850's. The authors find that immigrants who were originally from the same province of Ireland were panicking together provoking bank runs. Besides that, the authors study whether the banking crises of 1854 and 1857 were caused by bad banks' fundamentals or massive panics. They claim that both crises were not driven by the immediate panic. Also, the panic of 1857 was an informed contagion as it was caused by business leaders and banking clerks and only then was supported by withdrawals of less educated and less informed clients.

Whether bank runs are the result of bad economic conditions or panicking behavior is additionally investigated by Ramirez and Zandbergen (2014) and Saunders and Wilson (1996). Ramirez and Zandbergen (2014) consider the banking crisis that happened in the United States in 1893. They are interested in analyzing deposit withdrawals from four national banks that operated in Helena and Montana. The authors find that the runs are driven by panic, not by bad bank fundamentals. Also, there is a strong correlation between withdrawals which proves the existence of contagion. The authors claim that bank runs in Helena and Montana are an excellent example of how depositors' behavior can trigger a massive banking panic. Saunders and Wilson (1996) analyze bank runs that happened during the Great Depression. The authors find the evidence of contagion for 1930–1932, while none seems to have existed in 1929 or 1933.

As far as information plays a vital role in the propagation of bank runs, Ziebarth (2013) investigate the influence of media on their severity. The author tests whether radio penetration rates correlate with the levels of banking stress during the period of the Great Depression. Finally, he finds that 10% increase in radio penetration rates caused a 4.3 percentage drop in the number of bank deposits between 1930 and 1933. It proves that information translated by the media can affect the behavior of depositors during bank runs.

2.3 Experimental Literature

Individual bank runs have been extensively researched over the last years (Arifovic and Jiang (2014), Garratt and Keister (2009), Kiss et al. (2014), Madies (2006)), whereas experimental literature on banking panics is scarce. According to my knowledge, there are only 3 experimental studies by Chakravarty et al. (2014), Brown et al. (2014) and Duffy et al. (2016) in which banks are considered not in isolation, but as a part of one banking system.

Chakravarty et al. (2014) run an experiment in which two banks (Left and Right) are functioning within the same banking system. Each bank has 10 depositors. Depositors of the Left Bank know the level of liquidity in their bank before they make a decision, whereas Right Bank depositors can guide themselves only knowing the decisions of the Left Bank depositors and the liquidity level of the Right Bank in the previous period. Depositors of the same bank make their decisions simultaneously. The authors are interested in analyzing whether the decisions of the Left Bank depositors influence withdrawal behavior of the Right Bank depositors. They show experimentally that this influence is present both when banks' liquidity levels are assumed to follow independent Markov processes and when they are identical. Thus, the authors cannot conclude that the runs are caused only by the fundamentals of the bank (the level of liquidity). Indeed, bank runs are also triggered by the pure panic of players.

A similar experiment is conducted by Brown et al. (2014). The authors consider a banking system with two banks. Each bank has two depositors. The pair of participants assigned to the first bank is called "Leaders", whereas the depositors of the second bank are named

"Followers". Depositors from the same pair simultaneously decide whether to keep or to withdraw a deposit. "Leaders" know the quality of their bank assets, which can be weak or strong with the same probability, whereas "Followers" are uncertain about their bank assets' quality. Each subject in a couple of "Followers" decide after "Leaders" have made their choices.

There are three experimental treatments. In the first treatment (the No-Linkages treatment) the number of withdrawals that occurred in the leaders' bank is communicated to the followers and becomes common knowledge. The followers are informed that the leaders knew the asset quality of their bank before they made their decisions and that the realization of the actual asset quality of their bank is independent of that of the leaders' bank. In the second treatment (the Linkages treatment) followers are informed that the asset quality of their bank is identical to that of the leaders' bank they observe, whereas all other features of the first and the second treatments are identical. In the third treatment (the Baseline treatment) the followers are not informed about the behavior of the leaders. As in the other two treatments, followers are uncertain about the asset quality of their bank. The third treatment serves as a benchmark for two others.

Brown et al. (2014) analyze whether deposit withdrawals are highly contagious across banks when depositors know (do not know) that there are or there are no economic linkages between banks. The authors show that the contagion is likely in linkage games but only when the players know that the link exists. Both Chakravarty et al. (2014) and Brown et al. (2014) assume that depositors have no choice among banks: subjects are assigned to one of the banks by the experimenters and can either keep or withdraw the money. Thus, players cannot change their initial bank allocation. The main difference between two experiments is that Brown et al. (2014) measure explicitly the beliefs of depositors in the followers' by using the baseline treatment, which is absent in the work of Chakravarty et al. (2014).

Compared to Brown et al. (2014) and Chakravarty et al. (2014), Duffy et al. (2016) consider a larger network of banks. They assume the existence of four banks in the network that may have four possible symmetric structures. According to the first structure, banks do not have any linkages. Regarding the second one, banks are connected pairwise. In the third structure, the connection is incomplete: every bank is related only with two other banks, whereas, in the complete structure (the fourth one), all banks are linked. Duffy et al. (2016) find that financial contagions are possible both in incomplete and complete network structures, but they are significantly less likely to occur under a complete interbank network structure. It happens because complete interbank network structures facilitate more efficient risk sharing among banks.

2.4 Summary

There is a variety of theoretical, empirical and experimental literature devoted to the analysis of withdrawal behavior during bank runs. However, in all the studies subjects can either keep or withdraw the money from a bank; there is no possibility to relocate the deposit from one bank to another (Temzelides (1997), Allen and Gale (2000), Acharya and Yorulmazer (2008), Chakravarty et al. (2014), Brown et al. (2014), etc.). Such an assumption limits the number of available options for subjects and distorts the overall picture, as far as in reality people can and do choose among banks (Saunders and Wilson (1996), Iyer and Puri (2012)).

Because the model where subjects can change their initial deposit allocation is empirically motivated and theoretically appealing (He and Manela (2016)), I propose a theoretical model with two banks such that clients of one of the banks can redeposit the money to another bank. As far as most of the theoretical and experimental literature is based on the model of Diamond & Dybvig (Green and Lin (2003), Cavalcanti (2010), Gu (2011), Cañón and Margaretic (2014)), I use it as the baseline for my experiment.

The DD model is constructed as a game in which depositors must decide whether to keep or to withdraw the money from a bank.[3] If too many subjects decide to withdraw, a bank may not be able to pay to all of them thus goes bankrupt. The bank is assumed to be financially stable by default; thus the model considers bank runs as a consequence of a panic not related to the bank's fundamentals.[4] I extend the model of DD for the two banks' case. To avoid a situation when a healthier bank attracts a weaker bank's depositors (Kaufman (1994), Diamond and Rajan (2012), Demirgüç-Kunt et al. (2006)), I assume that two banks are identical with regard to their fundamentals. Consequently, depositors' decisions are influenced only by information about other clients' withdrawals and are not affected by banks' fundamentals. It allows me to preserve the original idea of the DD model that bank runs are the result of a pure coordination game.

The extension of the DD model that I suggest contributes to the existing literature in sev-

[3] Here I provide only the intuition behind the model leaving all the details for the theoretical framework section.

[4] Some authors claim that depositors' beliefs about the bank's fundamentals play an important role in bank runs (Jacklin and Bhattacharya (1988), Calomiris and Mason (2003)). I acknowledge this point of view and think that the introduction of fundamentals' heterogeneity could be a promising extension of my model. For more details see "Conclusions and discussion" section.

eral ways. First, it replicates the functioning of a banking system more realistically as far as depositors are allowed to change the bank. Second, it is built on the widely-accepted theoretical model, which makes possible comparability of the current and previous research results. Lat but not least, it seeks to check whether theoretically found optimal behavior (Nash equilibria) for the two banks' case is observed in the experiment.[5]

All the details regarding the model are provided in the following section. To make it easier to follow, I start with the DD model and then introduce its extension with two banks where players of one of the banks can redeposit the money to another. After that, I provide numerical examples for both versions of the model and find Nash equilibria. Lastly, I elaborate on how the option to redeposit should influence the optimal decision-making of people and consequently change a possibility of bank runs to happen.

3 Theoretical framework

3.1 Diamond and Dybvig model

Consider a game with a single bank and several depositors. The bank invests in a long-term project using deposited amounts. Deposits are of the same maturity as the investment project. However, the depositors may withdraw the money earlier - before the due date. The bank knows how many "early" withdrawals may happen and sets the deposit interest rate accordingly. If due to the panic more depositors withdraw too early, the bank goes bankrupt. Thus, the model explains bank runs as a consequence of excessive withdrawals driven by the pure panic of depositors.

Bank

The time is discrete: T=0,1,2. At T=0, the bank collects money in the form of deposits that mature at T=2.[6] To be able to pay interest on deposits the bank invests all the funds in a project which at T=2 gives a return of R>1 per unit invested. Although deposits are due in two periods, depositors may withdraw the money earlier - at T=1. In this case, the bank has to take out some part of its investment at a salvage value of 1, because the

[5] In this regard, it contributes to the studies of Madies (2006) and Garratt and Keister (2009) who analyze the frequency of equilibria. I add to these conclusions analyzing corresponding frequencies for the two banks' case.

[6] The original model assumes the infinite number of depositors, but it can be applied to the case when their number is finite. Please, see Section 3.3.

project is interrupted and the money withdrawn earns no interest. Depositors who always withdraw at T=1 are called "impatient". An impatient depositor always withdraws at T=1, because consumption at T=2 gives him no utility (Diamond and Dybvig (1983)), whereas a patient depositor may withdraw at T=1 or at T=2 because he consumes at T=2.[7]

Based on the known fraction of impatient depositors (t) and assuming that they are utility-maximizers, the bank derives the optimal level of interest rates r_1^* and r_2^* to be paid to the depositors withdrawing at T=1 and T=2 respectively:[8]

$$\begin{cases} \underset{r_1,r_2}{\underset{max}{U}} = t \times \mathrm{U}\ (r_1) + (1-t) \times \mathrm{U}\ (r_2) \\ t \times r_1 + (1-t) \times r_2 \times \frac{1}{R} = 1 \end{cases} \tag{1}$$

It may be proved that $1 < r_1^* < r_2^* <$ R (see Appendix I). Thus, there are monetary incentives for patient depositors to keep the money for two periods instead of withdrawing it "early" (at T=1). If only impatient depositors withdraw, the return on the project is just enough to pay r_1^* and r_2^* to impatient and patient depositors correspondingly. The main target of a bank is to meet its obligations in front of depositors who are assumed to be the owners of a bank.

Depositors

The objective of depositors is to maximize utility that they get from consumption. Depositors spend everything they earn, so how much they consume, depends on how much interest they earn on deposits. They learn their types (patient or impatient) at T=1. Impatient depositors always choose to withdraw early, whereas patient ones decide on the moment (T=1) whether to withdraw or to keep the funds deposited. The game is simultaneous thus expectations of the behavior of others drive the decision of each one. If a patient depositor expects others to withdraw, it may become optimal for him to withdraw as well for the reason explained below.

As shown before, the bank sets the optimal interest rates such that only impatient depositors should withdraw. However, if there is a panic and not only impatient but also

[7] The model assumes no discounting. The same assumption is applied in the experimental literature (Brown et al. (2012), Kiss et al. (2014), Chakravarty et al. (2014))

[8] According to Diamond and Dybvig (1983) utility function should be twice continuously differentiable, increasing, strictly concave (players are risk averse) and should satisfy the Inada conditions. The coefficient of relative risk aversion should always be greater than 1.

some patient depositors decide to withdraw, the bank will not be able to pay off to all, but only to a fraction of them. In reality, a depositor gets the money in case of a bank run if he is among the first $\frac{1}{r_1^*}$ withdrawers in the line. Because the game is simultaneous, it is defined randomly how many depositors are in front in the line (F_j).

If a depositor withdraws at T=1, he can receive what was promised - r_1^* or nothing (see Equation 2). The probability of getting r_1^* is defined as the number of depositors that the bank can pay off divided by the number of depositors that are in a queue to withdraw. If a depositor keeps the money until T=2, he gets a pro rata share of the bank's assets at T=2 (see Equation 3). If there is a massive panic, he will get nothing. On the other hand, if only impatient depositors withdraw, the patient ones get the highest interest possible: r_2^*. Intrinsically, there is no reason for a patient depositor to withdraw unless he expects others to do so. In the latter case keeping the money till T=2, he will get nothing with certainty, whereas withdrawing, he has a chance to get r_1^* even if everyone else withdraws.

To conclude, the depositor's choice depends on his expectations regarding the actions of others. If he thinks that massive withdrawals are highly probable, he should also withdraw; otherwise, he should keep.

$$V_1 = \begin{cases} r_1^*, f_j < \frac{1}{r_1^*} \\ 0, f_j \geqslant \frac{1}{r_1^*} \end{cases} \tag{2}$$

,where V_1 - the payoff per unit withdrawn at T=1; $f_j = \frac{F_j}{N}$ - the fraction of total demand deposits serviced before agent j

$$V_2 = \max\,(0; \frac{R \times (1 - f \times r_1^*)}{1 - f}) \tag{3}$$

,where V_2 - the payoff per unit kept till T=2, f=$\frac{F}{N}$ - the total fraction of withdrawals.

Since the number of early withdrawals is not known with certainty and subjects decide simultaneously, there are two symmetric Nash equilibria in pure strategies. Which of two equilibria occurs depends on depositors' expectations regarding the fraction of those who will withdraw: $\tilde{f}$

1. When $\tilde{f} = t$, there is a *good equilibrium* in which only impatient depositors with-

draw while patient keep money in a bank.[9]

2. When $\tilde{f} > \frac{R-r_1^*}{r_1^* \times (R-1)}$, there is a *bad equilibrium* (a bank run case) when everyone withdraws the money at T=1.[10]

3.2 Diamond and Dybvig model with redepositing

The model of DD can be easily extended for a case of two banks functioning independently. If each of the banks has different depositors and banks don't have anything in common, we are still dealing with the DD model, but applied twice. Making one step forward, I modify the model with two independent banks (Bank I and Bank II) by allowing depositors of Bank I to relocate money to Bank II.[11]

Besides using more realistic assumptions, the model with redepositing is important from a theoretical point of view. Depositors of Bank I are provided with three options (keep, withdraw and redeposit) instead of two. It gives them an additional incentive to leave Bank I in case they believe Bank II is safer and worth to redeposit the money there. As far as money redeposited can be used by Bank II to meet its obligations in case of massive withdrawals, the bankruptcy of Bank II becomes more difficult to happen compared to the case when redepositing is not possible.

Overall in a model with redepositing, the subject's decision depends on his expectations of what depositors of his as well as of another bank will do, which is not the case when two banks are functioning independently. Thus the introduction of a possibility to redeposit changes the complexity of a coordination problem, which makes it interesting to analyze whether bank runs are more or less likely to occur in this case.

Banks

There are two banks - Bank I and Bank II. Each has the same number of initial (different) depositors and the same fraction of impatient depositors (t). At T=0, Bank I collects money in the form of deposits that mature at T=2. To be able to pay interest on deposits, Bank I invests all the money collected in a long-term project which at T=2 gives a return

[9] When $\tilde{f} = t$ the payoffs that are received by depositors coincide with the optimal ones and are the highest possible for each of the types (patient and impatient) correspondingly. That is why none of the depositors have an incentive to deviate from the chosen strategy: an impatient one withdraws while a patient one keeps).

[10] For the proof see Diamond and Dybvig (1983).

[11] A model may be extended further by allowing depositors of both banks to redeposit, although it is left for the future research.

of R>1 per unit invested. As before, in case of many early withdrawals, the bank has to liquidate some part of its investment at a salvage value of 1 to pay off to the depositors.

Bank II makes an investment in the long-term project (a different one) that gives the same level of return: R>1. It obtains the funding for it from its initial depositors. Besides that, Bank II can make an additional investment in the short-term project that lasts from T=1 till T=2 and provides a return – r per unit invested.[12] To get money for the short-term project, Bank II offers an additional deposit contract that lasts from T=1 until T=2. The contract is aimed at those depositors of Bank I who do not trust the bank and consider Bank II to be better to keep a deposit there. Thus at T=1 they withdraw the money from Bank I and bring it to Bank II.

Banks have to define the optimal interest rates to be paid to those who keep (r_2^*), withdraw (r_1^*) and redeposit the money (r_3^*). I make three assumptions that are important for the derivation. First, I assume that all the interest earned by Bank II on the short-term project is equally shared among those who redeposited, that is why r=r_3. As far as the short-term contract does not bring any additional return to the initial depositors of Bank II, r_2^* and r_1^* stay the same as in the model without a redepositing option, which makes possible the comparison of the results for two versions of the model.[13] Second, in case of redepositing a subject withdraws a deposit together with interest and relocate all of it (r_1^*) to Bank II. Third, I follow Allen and Gale (1998) and He and Manela (2016), by assuming that $r_3 = \frac{r_2}{r_1}$. This assumption is important, because its violation (for instance, $r_3 > \frac{r_2}{r_1}$) makes by default depositors of Bank I better-off redepositing to Bank II than keeping money in Bank I. In this case, a decision to redeposit is driven not by sentiments or beliefs but by objectively better monetary conditions provided by Bank II, which is not the focus of the current paper. The target is to analyze withdrawal behavior which is a clear consequence of mis-coordination, which the third assumption allows achieving.

Therefore, it is possible to derive the optimal interest rates as follows:

$$\begin{cases} \underset{r_1, r_2}{\underset{max}{U}} = t \times \mathrm{U}\ (r_1) + (1-t) \times \mathrm{U}\ (r_2) \\ t \times r_1 + (1-t) \times r_2 \times \frac{1}{R} = 1 \\ r_3 = \frac{r_2}{r_1} \end{cases} \tag{4}$$

[12] Following Allen and Gale (2000) and Uhlig (2010), I assume the return on the short-term project to be higher than one, but less than the return on the long-term project, thus: 1<r<R.

[13] This assumption is intuitive and follows the logic of the DD model that a bank earns a zero profit sharing all its earnings among the owners (depositors).

Solving the system of equations one can find the optimal interest rates (r_1^*, r_2^*, r_3^*) that are guaranteed to be paid to the players if in both banks only impatient depositors withdraw. As it is in the DD model, $1 < r_1^* < r_2^* <$ R. If only impatient depositors withdraw, a patient one gets more keeping the money thus there is no reason for him to withdraw. Also there is no incentive for him to redeposit as the maximum he can get: $r_1^* \times \frac{r_2^*}{r_1^*} = r_2^*$ is the same he would receive keeping the money in Bank I. As far as the game is simultaneous and the number of early withdrawals is not known with certainty, it may become optimal for a depositor to withdraw/redeposit instead of keeping if too many depositors are expected to withdraw. The possibility of such is described below.

Depositors

Bank I

The depositors of Bank I may withdraw, keep or redeposit the money to Bank II. The set of available actions is common knowledge among all. If a depositor withdraws at T=1 he can get what was promised - r_1^* or nothing (see Equation 5). The probability of getting r_1^* is defined as the number of withdrawals that the bank can pay off divided by the number of depositors that claim to withdraw. Depositors who keep the money till T=2, get an equal share of funds remaining in the bank by that time (see Equation 6). Thus, their payoff depends on the total number of withdrawals from Bank I, which ranges from 0 to r_2^*.

If a subject decides to redeposit, his payoff depends on: (1) the number of withdrawals from Bank I; (2) how many depositors withdraw from Bank II. As far as he may get either r_1^* or 0 withdrawing and then up to r_3^* per unit redeposited, his final payoff varies from 0 to r_2^*. In case not only impatient but also patient depositors withdraw from Bank I, one's attempt to redeposit may be unsuccessful as he may get nothing to redeposit. Besides that, the payoff of a depositor to a large extent depends on the number of withdrawals from Bank II. If only impatient ones withdraw, the subject who redeposits gets what was promised: $r_1^* \times r_3^* = r_2^*$. Otherwise, a depositor receives what is left in Bank II at T=2 equally divided among all the depositors who were keeping the money there until that time. If too many depositors withdraw early, Bank II will use all the funds available (including those he got from redepositors) to survive. Thus there is a risk that a subject who redeposits will get nothing at the end.

$$V_1^I = \begin{cases} r_1^*, f_j^I < \frac{1}{r_1^*} \\ 0, f_j^I \geqslant \frac{1}{r_1^*} \end{cases} \tag{5}$$

,where V_1^I - the payoff per unit withdrawn from Bank I at T=1, f_j^I - the fraction of total demand deposits of Bank I serviced before agent j

$$V_2^I = \max\,(0; \frac{R \times (1 - f^I \times r_1^*)}{1 - f^I}) \tag{6}$$

,where V_2^I - the payoff per unit kept in Bank II till T=2, $f^I = \frac{F^I}{N}$ - the total fraction of withdrawals from Bank I.

$$V_3^I = \begin{cases} r_2^*, t \leqslant f_j^I < \frac{1}{r_1^*}, f^{II} = t; \\ \frac{(N - F^I \times r_1^*) \times R + K \times r_2^*}{N - F^{II} + K}, t \leqslant f_j^I < \frac{1}{r_1^*}, t < f^{II} \leqslant \frac{1}{r_1^*}; \\ max(\frac{(K - (F^{II} \times r_1^* - N)) \times r_2^*}{K + N - F^{II}}; 0), t \leqslant f_j^I < \frac{1}{r_1^*}, f^{II} > \frac{1}{r_1^*}; \\ 0, f_j^I \geqslant \frac{1}{r_1^*} \end{cases} \tag{7}$$

,where V_3^I - the payoff per unit redeposited; $f^{II} = \frac{F^{II}}{N}$ - the total fraction of withdrawals from Bank II; K - the total number of Bank I depositors who have redeposited the money to Bank II.

To conclude, what a depositor chooses is dictated by his expectations regarding the actions of all others. If a depositor believes that his counterpart from Bank I will keep the money, he should do the same. If he thinks that his counterpart will withdraw, whereas a bank run for Bank II is unlikely, he should redeposit the money. If he forecasts massive withdrawals from both banks, the redepositing option is worthless; the best strategy, in this case, is to withdraw.

Bank II

The depositors of Bank II may withdraw the money at T=1 or keep it till T=2. If a depositor withdraws at T=1 he can get what was promised - r_1^* or nothing. The amount that the depositor of Bank II receives if he keeps the funds there depends on the total number of withdrawals from the bank as well as on the number of redepositors. The final payoff of a depositor who keeps varies from 0 to r_2^*. As before, the decision is driven by expectations. If a depositor expects others to withdraw, he should do that as well. As long as there are some depositors of the first bank relocating the money to the second bank, Bank II can survive more withdrawals compared with the case when redepositing is not available. Thus, if redeposits of funds are expected, it may become reasonable for a player of Bank II to keep even if some of his counterparts withdraw.

$$V_1^{II} = \begin{cases} r_1^*, f_j^{II} < \frac{N+K\times r_1^*}{r_1^*\times(N+K)} \\ 0, f_j^{II} \geqslant \frac{N+K\times r_1^*}{r_1^*\times(N+K)} \end{cases} \tag{8}$$

,where V_1^{II}- the payoff per unit withdrawn from Bank II at T=1; $f_j^{II} = \frac{F_j^{II}}{N}$ - the fraction of total demand deposits of Bank II serviced before agent j

$$V_2^{II} = \begin{cases} r_2^*, f^{II} = t \\ \frac{R\times(N-F^{II}\times r_1^*)+K\times r_2^*}{N-F^{II}+K}, t < f^{II} \leqslant \frac{1}{r_1^*} \\ max(\frac{(K-(F^{II}\times r_1^*-N))\times r_2^*}{K+N-F^{II}}; 0), f^{II} > \frac{1}{r_1^*} \end{cases} \tag{9}$$

,where V_2^{II}- the payoff per unit kept in Bank II till T=2.

To prove that stated above intuitions are theoretically valid and optimal, I provide a numerical example for two versions of the model: with and without an option to redeposit. I find the Nash equilibria for each of the cases and elaborate on the differences observed.

3.3 Numerical Example

Consider a bank that has 3 depositors, out of which 1 is impatient: N=3; t=1/3. From this point onwards, I consider only patient subjects' decisions, because an impatient one always withdraws. Every depositor has 100 ECU as a deposit in the bank.[14] The bank invests in the project that gives a return of R=2.8. Assume that the utility function is U(C)=$\frac{C^{1-\rho}}{1-\rho}$, where ρ=3.06.[15] Applying stated above optimality conditions (Equation 1) the bank sets interest rate: r_1^*=1.5; r_2^*=2.1. So, if a depositor withdraws the money at

[14] ECU stands for experimental currency units

[15] The chosen functional form has been widely used in the literature (Temzelides (1997), Ennis and Keister (2009), Green and Lin (2003))

T=1, he is promised to receive 150 ECU, while keeping till T=2 brings him 210 ECU. However, this is guaranteed in case only the impatient depositor withdraws early. Clearly, the bank can satisfy the maximum of 2 early withdrawals.[16]

Let's call patient depositors as Player I and Player II. Each of them may either keep or withdraw. If none of the patient players withdraws: $f=\frac{1}{3}$. In this case, each of them will get: V_2=210 ECU. If one of patient depositors withdraws: $f=\frac{2}{3}$, the depositor that keeps, will get: V_2=0 ECU, the depositor that withdraws, will get V_1=150 ECU. If both of them withdraw: f=1. In this case, a depositor will get: V_1=150 ECU if he is the first or the second in a queue, and V_1=0 ECU if he is the third. There are two Nash equilibria in pure strategies: when all patient depositors are keeping the money and only impatient withdraws, and when everybody withdraws the money (see Table 1).

Table 1: Diamond and Dybvig model: a numerical example

	Keep	Withdraw
Keep	(U(210);U(210))	(U(0);U(150))
Withdraw	(U(150);U(0))	($\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0))

Now assume there are two identical independent banks like the one described above. Let's call them Bank I and Bank II for convenience. In this case, we apply the standard DD model but applied twice. That is why there are four Nash equilibria in pure strategies:

Eq I: Patient depositors of both banks keep (KKKK)
Eq II: Patient depositors of both banks withdraw (WWWW)
Eq III: Patient depositors of Bank I keep, patient depositors of Bank II withdraw (KKWW)
Eq IV: Patient depositors of Bank I withdraw, patient depositors of Bank I keep (WWKK)

Now let's assume the same two banks as before, but besides keeping and withdrawing, depositors of Bank I can redeposit the money to Bank II at T=1. It can be found that r_1^*=1.5, r_2^*=2.1, r_3^*=1.4 (see Equation 4). As before, everyone has 100 ECU as a deposit, thus withdrawing at T=1 a depositor receives 150 ECU, whereas keeping till T=2 as well as redepositing brings him 210 ECU.[17]. In this case, there are the following four Nash equilibria in pure strategies (for a proof see Appendix II):[18]

[16] It has 300 ECU in total and has to pay 150 ECU at T=1 per person
[17] Withdrawing from Bank I, a client will get 150 ECU. Then redepositing this amount to Bank II will give him the final payoff of 150 × 1.4=210 ECU
[18] It can be easily shown that the stated above equilibria remain such for the N players' case, although

Eq I: Patient depositors of both banks keep (KKKK)
Eq II: Patient depositors of both banks withdraw (WWWW)
Eq III: Patient depositors of Bank I keep, patient depositors of Bank II withdraw (KKWW)
Eq IV: Patient depositors of Bank I redeposit, patient depositors of Bank II keep (RRKK)[19]

Comparing equilibria for two models, you can see that when there is an option to redeposit the money from one bank to another, depositors are supposed to use it (RRKK) instead of merely withdrawing (WWKK). In other words, the possibility to choose among banks makes depositors to keep money within a banking system instead of keeping it "under the pillow", which should lead to fewer cases of simultaneous bank runs (banking panics). As far as the optimal behavior differs across two versions of the model, it strengthens the motivation to conduct experimental research to test whether the behavior of real subjects also changes following theoretical predictions.

4 Experimental Design and Procedures

The experiment was conducted at the University of Milan among the bachelor, master and PhD students who study economics, politics or law. When selecting the participants, there were no preferences regarding their gender or age. After entering the lab, subjects were randomly assigned to the computers and given paper instructions that were also read out-loud. The instructions had the description of the experimental procedures, as well as the description of the game (see Appendix III, IV) including the payoff matrices to reduce the complexity of computations to a minimum. After the clarification questions were answered in person, the experiment started.

There were two experimental treatments conducted. Each of the treatments began with the incentivized version of the Bomb Risk Elicitation Task (Crosetto and Filippin (2013)) to control for the level of risk aversion of individuals. Then the bank run game was played 20 times. After the game was completed, each subject was asked about one's

as the number of players increases, the new equilibria may arise. The focus of the current research is not only to find an optimal theoretical solution for the game but mainly to check whether it is being understood and applied by the subjects of the experiment. As far as there are three subjects per game, we are interested in finding Nash equilibria for the three-players' case.

[19] It is important that depositors of Bank II play "keep" in equilibrium. In case they withdraw, the second bank goes through a bank runs, so the money of redepositors is used to pay off to early withdrawers. Thus, subjects who redeposit never get what was promised.

gender, age, and educational background. Then the subjects were paid according to their performance. The final payoff was calculated as the sum of three components: the show-up fee, the payment for the BRET task and the payoff of one randomly chosen periods of the bank-run game multiplied by 0.02 (for more details, see Appendix III,IV).[20]

The only difference between two treatments was the structure of the bank run game. At the core of the first treatment lies the model of DD with one bank. The results of Treatment I were extrapolated for the case of two independent banks which allowed the comparison between treatments. For Treatment II, the model of DD with a redepositing option was used. Subjects were randomly assigned to Bank I or Bank II at the beginning of the game and dependent on the bank could keep/withdraw or redeposit.[21]

In both treatments, I have applied the same parameters of the model as provided in the numerical example above. Each subject has 100 ECU as a deposit. There were three depositors per each bank: two of them were the participants, and one more (an impatient depositor) was replicated by the computer.[22] At the beginning of the game, each player was randomly matched with another player to be depositors of the same bank. For the second treatment, there were cohorts of 4 players formed (two players of Bank I and two players of Bank II). Initial matchings within and across banks stayed for the whole game of 20 rounds.[23]

At the end of each round, there was some feedback provided to the subjects. In accordance with the literature (Arifovic et al. (2013), Madies (2006), Brown et al. (2016)) a subject from each of the treatments could observe: (1) the entire history of his and all other players' decisions; (2) the history of earnings; (3) his position in a queue for every round when he withdrew or redeposited.

Considering the literature, I have formulated the following three hypotheses. All of them

[20] The same approach is applied by Brown et al. (2016), Kiss et al. (2012), Kiss et al. (2014). An alternative is to pay the total earnings made during the game (Garratt and Keister (2009), Madies (2006), Arifovic et al. (2013)). However, the latter approach suffers from possible wealth effects thus was not used in the paper.

[21] In case of withdrawals, the position in a queue (being 1st, 2nd or 3rd among withdrawers) was decided randomly by the computer.

[22] As far as the impatient player always withdraws the money, substituting it with an automaton doesn't seem to have any influence on the results. The same way of reasoning is applied in the literature. See Kiss et al. (2014).

[23] There are two approaches regarding the way players are coupled in the bank-run games. The first way is to reshuffle the group of players every time a new round starts (Kiss et al. (2014), Garratt and Keister (2009)). The second approach is to keep the initial matching of players over the game (Arifovic et al. (2013), Madies (2006), Brown et al. (2016), Chakravarty et al. (2014)). The latter approach was chosen to be applied because it allows studying learning effects which is one of the points of interest for the current research.

are tested in the next section of the paper.

Hypothesis I - Bank runs and Banking Panics

Introduction of a possibility to redeposit leads to significantly different frequencies of withdrawals and bank failures across banks. Overall, simultaneous bank runs should happen less often in Treatment II than in Treatment I.

Comparing equilibria across treatments, you can see that the only difference is the fourth equilibria according to which subjects of Bank I are better of redepositing rather than withdrawing from Bank I when depositors of Bank II are keeping the money in the bank. Due to that, subjects of Bank I should redeposit rather than withdraw, which should lead to less simultaneous bank runs in the second treatment. Overall, I expect that in Treatment II depositors of Bank I leave it more often than in Treatment I, being provided with a choice among banks. Consequently, there are more withdrawals and bank runs in Bank I. At the same time, depositors of Bank II should withdraw and panic less in expectation of depositors from Bank I joining their bank.

Hypothesis II - Equilibria and Learning

In both treatments, among all the equilibria possible, I expect the ones that give the highest payoffs to be played more often.[24] *In the second treatment, subjects tend to play equilibria less frequently than in the first one. However, in both treatments, subjects learn how to coordinate with time.*

As far as in the second treatment subjects of Bank I have to choose from two instead of three actions, the coordination problem gets more complicated. That is why I expect equilibria to occur less frequently in the second than in the first treatment. At the same time, I forecast subjects to learn and get better at coordinating. In the first treatment, subjects get more if they all keep the money in the corresponding bank. Thus, I expect the good equilibrium (KKKK) to be played more often. In the second treatment, there are two equilibria (KKKK, RRKK) that give the highest payoffs possible. That is why I expect them to be played more times than the other equilibria in the game.

Hypothesis III - Personal Characteristics and Withdrawals

The decision to keep the money in a bank depends not only on the treatment but also on the subject's risk aversion and previous experiences with the bank. Risk averse subjects are more reluctant to stay with the bank than risk neutral and risk seeking subjects. Besides

[24] The majority of experimental literature which applies the DD model shows that subjects tend to play the payoff-dominant equilibrium Garratt and Keister (2009),Madies (2006),Chakravarty et al. (2014).

that, if a person has experienced bank runs in the past, he will be more reluctant to keep the money in this bank in the future.

Garratt and Keister (2009), Kiss et al. (2014) conclude that the fraction of previous rounds in which a subject witnessed a bank run has a significant effect on his withdrawal behavior. The higher is the fraction, the bigger is the probability of him withdrawing in the future. That is why, I consider the history of previously occurred bank runs to be relevant to the subject's choices. Although, Kiss et al. (2014) experimentally show that risk aversion has no predictive power, theoretical an empirical literature claims the opposite. Using the DD model, it is easy to show that subjects with constant relative risk averse utility function should panic earlier the higher is their level of risk aversion.[25] In other words, if subject A is more risk averse than subject B and the latter one withdraws when M subjects are expected to do so, subject A should withdraw even earlier - when M-L subjects are expected to run on the bank. Thus, in case subjects are highly risk averse, they will withdraw in expectation of even a small number of withdrawals, which proves that withdrawals may be partially explained by the high level of risk aversion of depositors (Saunders and Wilson (1996)). That is why, I expect risk aversion to play an important role on withdrawal behavior.

5 Results

In total 108 subjects participated in the experiment: 36 subjects participated in Treatment I and 72 subjects (36 subjects per bank) participated in Treatment II. The actual average payment for the BRET task and the bank-run game are 4.2 Euro and 2.8 Euro correspondingly.

In Table 2, I provide some averaged statistics on overall data sample as well as compare data distributions across treatments with the help of the Chi-squared test. As you can see, more women than men took part in the experiment. Most of the subjects are not more than 26 years old. The sample is spread almost evenly concerning the educational background of subjects. The participants are mainly risk averse, whereas less than 15% are risk seekers. Overall, the sample is quite homogeneous: based on the results of the Chi-squared test, the age, gender, risk aversion and educational background of subjects do not vary significantly across experimental treatments.

One of the key research questions of the paper is whether the availability of an option

[25] For the detailed proof see Horváth and Kiss (2016).

Table 2: Data Sample Structure

Parameter	Description	Fraction	Prob. chi2
Gender	Female/Male	56% / 44%	0.89
Major of Studies	Economics /Politics /Legal Studies	33% / 35% / 32%	0.19
Risk Attitudes	Averse/Neutral/Lover	81% / 6% / 13%	0.98
Age	Below 20 / 20-25 / Above 25	42% / 54% / 4%	0.42

to redeposit leads to less bank runs in the economy. To analyze that, for each cohort of subjects that formed a system of banks, I have calculated the number of times during the game (out of 20 possible) a group experienced a bankruptcy of none, one or two banks in a system.[26] I analyze the frequency of full bank runs across treatments, considering a bank run to be full (or "pure-panic" run as it is called by Madies (2006)) when all its initial depositors withdraw. With the help of Mann-Whitney U test, I test whether the differences in the number of runs are significant across treatments and banks (see Table 3).

As you can see, there are more cases of at least one bank run in a system with a possibility to redeposit. In the first treatment, there are no runs in 13 rounds on average, whereas in the second treatment only in 9 rounds on average none of the banks experience a run. Besides that, for the second treatment, the frequency of individual runs significantly varies across banks. If we consider the bank from the first treatment as a baseline for the comparison, there are 2.5 more cases of Bank I runs and 4 times fewer cases of Bank II runs in the second treatment. In other words, provided with a choice among banks, depositors of Bank I leave it more often causing additional bank runs, but at the same time the bank-recipient (Bank II) experience fewer bankruptcies. Indeed, there are fewer cases of simultaneous bank runs in the second treatment, although the difference is not significant. It leads to the partial rejection of the first hypothesis ("Bank Runs and Banking Panics") since only the number of individual bank runs is significantly different across treatments.

The additional evidence of how a redepositing option influences the stability of each bank and the system as a whole comes from the net cash flow analysis. In order to see whether subjects use an option to redeposit and how does it affect banks' stability, I have estimated the average net cash flows for each of the banks[27] and for the system as a whole (see Table 4). Withdrawn amounts were considered as cash outflows, whereas

[26] Each cohort consisted of 4 subjects. For the first treatment, I have extrapolated the results for one bank (2 subjects) to the two banks' case assuming two banks being identical and independent.

[27] The bank from the first treatment was used as the baseline for Mann-Whitney U test comparison.

Table 3: The average number of full bank runs across treatments and banks (Mann-Whitney U test)

<table>
<tr><th></th><th>Treatment I</th><th>Treatment II</th><th>p - value</th></tr>
<tr><td>None</td><td>13
(65%)</td><td>9
(45%)</td><td>0.04</td></tr>
<tr><td>Bank I</td><td rowspan="2">4
(20%)</td><td>9
(45%)</td><td>0.00</td></tr>
<tr><td>Bank II</td><td>1
(5%)</td><td>0.08</td></tr>
<tr><td>Two banks</td><td>3
(15%)</td><td>1
(5%)</td><td>0.71</td></tr>
</table>

redeposited amounts as cash inflows. I have conducted Mann-Whitney U test to check whether net cash flows are significantly different across banks and systems. The bank in the first treatment experienced the net cash outflow (-83.73), whereas Bank II had a positive net balance due to subjects of Bank I reallocating their deposits. At the same time, Bank I experienced a more substantial net cash outflow (-136.25) than the bank in the first treatment (-83.73).[28] Overall, the cash outflow from the system of banks with a redepositing option is on average lower than from a system without such an opportunity, although the difference is not statistically significant.

Table 4: The net cash flow (Mann-Whitney U test)

<table>
<tr><th></th><th>Treatment</th><th>Mean (ECU)</th><th>p-value</th></tr>
<tr><td>Bank I</td><td>I
II</td><td>-83.73
-136.25</td><td>0.02</td></tr>
<tr><td>Bank II</td><td>I
II</td><td>-83.73
56.12</td><td>0.00</td></tr>
<tr><td>System</td><td>I
II</td><td>-167.46
-80.13</td><td>0.17</td></tr>
</table>

Result I: In a banking system where subjects can relocate their deposits, there are more cases of at least one bank run happening. As long as subjects use a redepositing option, it is Bank I that mostly suffers from bankruptcies, whereas Bank II gets more stable due to additional funds from depositors of the first bank. Overall, the net amount withdrawn from the system does not vary significantly across treatments, which explains almost the same number of simultaneous bank runs.

To contribute to the analysis, I study how often depositors play each of the possible

[28] All stated above differences are significant at 5% level.

actions during the game (see Table 5). In the first treatment, almost two-thirds of the times players keep the money in a bank, whereas in the second treatment, players of Bank I do it only 35% times on average (see Table 5). Considering it together with a decrease in withdrawals (23%), it becomes clear that the possibility to redeposit makes subjects to keep the money in Bank I less often. Besides that, players of Bank II withdraw less than players in the first treatment: they keep the money in a bank 76% of the times compared with 62% in Treatment I.

In the second treatment, there is a clear tendency by subjects of the first bank to keep less whereas withdraw and redeposit more over time. Also, subjects of the second bank keep the money much more often (83%) in the second half than in the first half of the game. The same does not hold for the subjects of the first treatment, although in the first round of the game they show a similar pattern in behavior (keep around two-thirds of the times). One may claim that an increasing tendency to keep may be explained by the fact that depositors of the second bank experience better outcomes in the first half of the game due to redepositing. However, I do not find the evidence for that: the average payoff of Bank II subjects who keep and subjects from the first treatment who keep are not significantly different.[29] It proves that an increase in the number of times depositors of the second bank keep the money, is driven not by better outcomes of the game in its first half, but rather by subject's expectations that: (1) the counterpart will not withdraw; (2) players of the first bank will redeposit.

Table 5: Actions played by subjects across treatments and banks

Time	Treatment I: Bank		Treatment II: Bank I			Treatment II: Bank II	
	Keep	Withdraw	Keep	Withdraw	Redeposit	Keep	Withdraw
First 10 Rounds	61%	39%	39%	20%	41%	69%	31%
Second 10 Rounds	63%	37%	30%	26%	44%	83%	17%
All Rounds	62%	38%	35%	23%	42%	76%	24%

Result II: When there is a choice among banks, subjects tend to redeposit the money from one bank to another rather than to keep it "under the pillow". Subjects of the bank-recipient mainly keep the money in the bank; such a tendency grows with time.

Besides observing individual decisions of subjects, it is interesting to analyze how well the players coordinate their moves. For the reasons of comparability, I extrapolate experimental results of the first treatment on the two banks' case. I estimate ex post what

[29] This conclusion is based on the results of Mann-Whitney U test. The corresponding p-value is 0.59.

would be the fraction of equilibria played in the first treatment assuming two banks functioning independently. Comparing the results, I find that in both treatments the most commonly played equilibrium is a "good equilibrium" when all the depositors keep the money in a bank (see Table 6). In the second treatment, there is one more equilibrium that is played as often: when players of Bank I redeposit their money to Bank II while all the subjects of that bank are keeping their deposits. All of that supports my second hypothesis ("Equilibria and Learning"). WWWW and KKWW are played much less frequently in Treatment II than in Treatment I: in less than 5% of the cases in total. Besides that, in Treatment II there are more cases when none of the equilibria is played. Because players of Bank I are provided with three rather than two options, it gets more difficult to coordinate.

Table 6: Equilibria across treatments

	KKKK	WWWW	KKWW	WWKK	No
Treatment I	24%	6%	12%	12%	45%
	KKKK	WWWW	KKWW	RRKK	No
Treatment II	14%	2%	2%	14%	68%

Subjects play equilibria more often as time elapses, which goes hand in hand with my second hypothesis ("Equilibria and Learning"). Figure 1 and Figure 2 show how frequently each of the equilibria happens in the first 10 and in the last 10 rounds of the game. In both treatments, subjects tend to coordinate better in the second than in the first part of the game. In the first treatment, subjects play each of the equilibria more often as the game evolves. Whereas in Treatment II, only KKKK and RRKK equilibria are played more frequently. Such an increase is driven by the significant rise in the number of times subjects of Bank II play "keep" in the second half of the game and better coordination among the players.

Result III: In both treatments the most commonly played equilibrium is a good one. Besides that, in Treatment II subjects of Bank I tend to redeposit the money while players of the second bank keep (RRKK). In Treatment I subjects learn how to coordinate and play all possible equilibria more often with time. In Treatment II only KKKK and RRKK are becoming more recurrent, which is the result of both better coordination and the second bank' subjects keeping the money more often.

Previously, it has been shown that subjects learn over time how to coordinate their actions. However, it is even more important to understand what triggers which action, mainly the decision to keep or not to keep money in a bank. To study which factors influence the

Figure 1: Equilibria in time - Treatment I

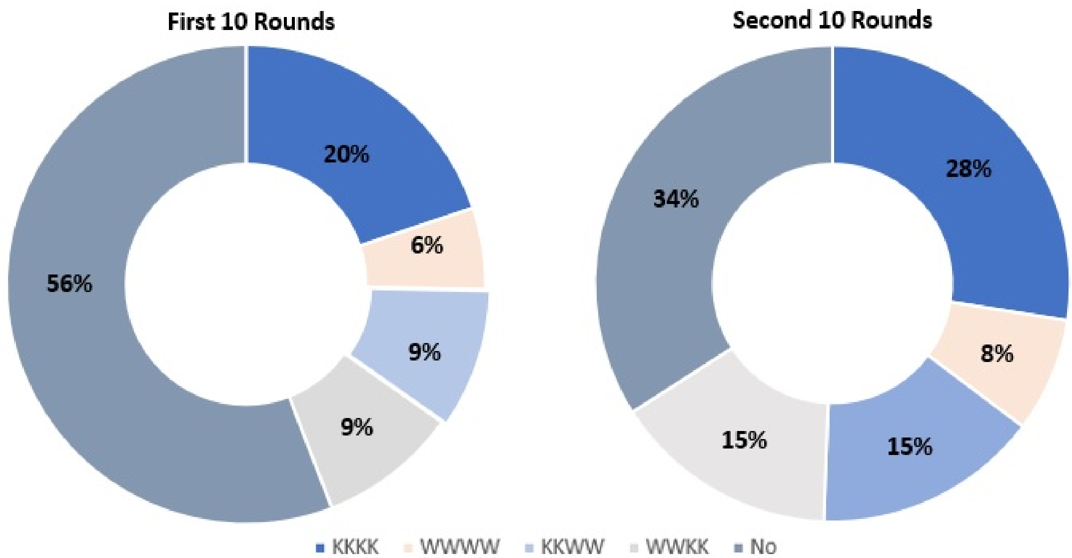
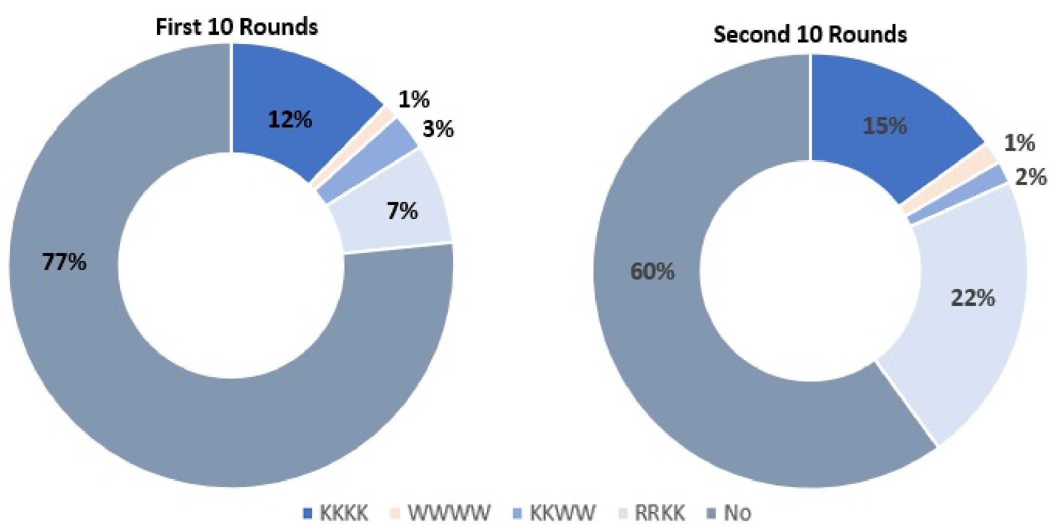


Figure 2: Equilibria in time - Treatment II



subject's choices, I am using the following regression model:

$$K_{i,t} = \beta_0 + \beta_1 \times Treatment\_II\_Bank\_II_i + \beta_2 \times Treatment\_II\_Bank\_I_i + \\ + \beta_3 \times Previous\_Ratio\_Runs_{i,t} + \beta_4 \times Male_i + \beta_5 \times Risk\_Averse_i + \beta_6 \times Round_t \tag{10}$$

, where $K_{i,t}$ - a dummy variable which is equal to 1 if a player keeps and 0 if a player withdraws/redeposits the money; $Treatment\_II\_Bank\_II_i$ - a dummy equal to 1 for the players of the second bank of the second treatment; $Treatment\_II\_Bank\_I_i$ - a dummy equal to 1 for the players of the first bank of the second treatment [30]; $Previous\_Ratio\_Runs_{i,t}$ - the ratio of previous full bank runs lived by the agent; $Male_i$ - a dummy equal to 1 for males; $Risk\_Averse_i$ - a dummy equal to 1 for risk averse players; $Round_t$ - the round of the game

I test for the treatment effects as well as check whether subjects' choices vary across banks. Besides that, I control for the subject's previous experiences as well as for the gender and risk aversion, because one's personal characteristics may play a role in his/her decisions. As far as the game is played several times, I have included the time trend in the model. In Table 7, I report the coefficients for the OLS regression model.[31] The standard errors provided in the brackets are bootstrapped due to the presence of heteroscedasticity.[32] The model was checked for multicollinearity and omitted variables, none of that was identified.[33] Considering subjects of the first treatment as a baseline category, it is clear that depositors of the second bank keep less whereas depositors of the first bank keep more in the second treatment. The previous experiences of a subject play a significant role: going through more bank runs in the past, a subject gets cautious keeping less in the future. The gender of a participant does not play a significant role, whereas his risk-attitudes are essential. Risk averse subjects keep significantly less than all others. Lastly, subjects play "keep" less with time, although this result is not significant. Overall, my

[30] In here I consider initial bank allocation

[31] Based on the results of Breusch and Pagan Lagrangian multiplier test for random effects; there is no significant evidence of the panel effects, thus simple OLS seems to be an appropriate choice. A fixed-effects model is not suitable mainly due to the specification of the model, but also based on the results of the Durbin–Wu–Hausman test.

[32] Heteroscedasticity was identified with the help of the Breusch-Pagan/Cook-Weisberg test.

[33] To test for multicollinearity and omitted variables, I used the VIFs factors and the Ramsey test correspondingly.

Table 7: Decision to keep: what does it depend on?

	$K_{i,t}$
$Treatment\_II\_Bank\_I_i$	-0.348***
	(0.028)
$Treatment\_II\_Bank\_II_i$	0.189***
	(0.027)
$Previous\_Ratio\_Runs_{i,t}$	-0.275***
	(0.063)
$Male_i$	-0.010
	(0.020)
$Risk\_Averse_i$	-0.147***
	(0.026)
$Round_t$	-0.001
	(0.002)
$Constant$	0.960***
	(0.063)
N	2052
R^2	0.147

Bootstrapped standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

predictions regarding the effect of risk aversion and previous experiences of the subject on withdrawal behavior are correct.

Result IV: The subject's decision to keep the money in a bank depends on one's risk-attitudes and previous experiences. Overall, bank runs are contaminating: if they happened in the past, it increases the chance of them occurring in the future. Risk averse subjects are more reluctant to keep money in a bank than risk neutral and risk seeking individuals.

6 Conclusions and discussion

In the current paper, I propose a unique extension of the Diamond and Dybvig model in which a subject is given a possibility to change the initial deposit allocation. To avoid a situation when a healthier bank attracts a weaker bank's depositors, I assume that two banks have the same fundamentals. It allows me to preserve the original idea of the Diamond and Dybvig model that bank runs are the result of a pure coordination problem and to test how the availability of choice among banks influences subjects' withdrawal behavior. Whether depositors withdraw or redeposit is essential for the regulators of a banking sector, because these two actions have a different effect on the banking system's liquidity. That is why I consider the results of the current research to be of particular interest to the policymakers and the regulators of the banking sector.

I find both theoretically and experimentally that the introduction of a redepositing option leads to more cases of individual bank runs. Being provided with the redepositing option, depositors tend to change their initial deposit allocation more often than when such an option is not available. At the same time, the bank which receives new clients experiences significantly less bank runs. In both experimental treatments (with and without redepositing) the most commonly played equilibrium is the good one when all the subjects keep the money in the corresponding bank. Besides that, in the treatment where the redepositing option is available, subjects actively use it under the condition that the subjects of the bank-recipient keep the money. Subjects learn how to coordinate over time and play equilibria more frequently in the second than in the first half of the game. The subject's choice to keep or not the money in a bank depends on one's previous experiences with the bank. Bank runs are contagious: if they happened in the past, they are more likely to occur in the future. Besides that, I find that risk attitudes affect subjects' decisions: risk averse subjects are more reluctant to keep money in a bank than all others.

Overall, I find that in the banking system where subjects can relocate their deposits from one bank to another, the rate of bank runs differs across banks. I find that in this case, the number of simultaneous runs gets less although insignificantly. However, I expect this conclusion to change in case banks have different fundamentals. Besides that, in the current version of the model, there are no transaction costs in case of redepositing. Introduction of heterogeneity across banks as well as transaction costs may be considered as a promising extension which may shed light on the problem of banking panics.

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Appendix I - Diamond and Dybvig model - optimality conditions

From equation (1), it can be derived:

$$MRS_{1,2} = \frac{MU_1}{MU_2} = \frac{U'_{r_1}}{U'_{r_2}} = \frac{t \times U'_{r_1}}{(1-t) \times U'_{r_2}} = \frac{R \times t}{1-t} \tag{11}$$

Finally:

$$\begin{cases} U'(r_1) = \mathrm{R} \times U'(r_2) \\ t \times r_1 + (1-t) \times r_2 \times \frac{1}{R} = 1 \end{cases} \tag{12}$$

It is assumed that U=U(C) is risk averse, so U'(C) is decreasing. Thus from the system (14) and an assumption that R>1, the conclusion is that $r_1^* < r_2^*$. Besides that, from the system (14), it is cleat that:

$$U'(r_1) = R \times U' \ (\frac{\text{1-t}\times r_1}{1-t} \times \mathrm{R}) \tag{13}$$

If r_1=1, equation (15) can be rewritten:

$$U'(r_1) = U'(1) = R \times U'(R) \tag{14}$$

According to the model U=U(C) should have the coefficient of RRA>1, ∀ C ∈ [1;R], so ∀ γ ∈ [1;R] the following holds:- $\frac{\gamma \times \text{U''}(\gamma)}{U'(\gamma)}$ >1, thus:

$$R \times \text{U'(R)} = 1 \times \text{U'(1)} + \int_{\gamma=1}^{R} \frac{\partial}{\partial \gamma}(\gamma \times \text{U'}(\gamma))\partial\gamma = \text{U'(1)} + \int_{\gamma=1}^{R} (\text{U'}(\gamma) + \gamma \ \text{U''}(\gamma))\partial\gamma < U'(1) \tag{15}$$

Thus, when r_1=1, U'(r_1)=U'(1) and R×U'($\frac{\text{1-t}\times r_1}{1-t}$ × R) < U'(1). U'(r_1) is decreasing, whereas U'($\frac{\text{1-t}\times r_1}{1-t}$ × R) is increasing with respect to r_1, so r_1^* >1.

From equation (14) one can derive that $r_2 = \frac{\text{1-t}\times r_1}{1-t}$ × R. Because r_1^*>1, $\frac{\text{1-t}\times r_1}{1-t}$ < 1, so r_2^*<R. At the end, 1<r_1^*<r_2^*<R.

Appendix II - Nash equilibria in pure strategies for the model with redepositing: a numerical example

Let's call the clients of Bank I as Player I, Player II and Player III. They can decide whether to keep (K), withdraw (W) or redeposit the money to Bank II (R). Let's name clients of Bank II – Player IV, Player V and Player VI. They can either keep (K) or withdraw (W) the money from Bank II. Let's assume that Player III and Player VI are impatient

Then using the payoff functions provided above the game can be represented in the normal form and four equilibria can be found (see Tables below):[34]

Equilibrium I: all patient players in each of the banks keep the money (KKKK)
Equilibrium II: all players of both banks withdraw their deposits (WWWW)
Equilibrium III: all patient depositors of Bank I keep the money while the ones of Bank II withdraw (KKWW)
Equilibrium IV: all patient players of Bank II redeposit the money while all patient depositors of Bank II keep (RRKK)

[34] The payoffs for the impatient players are not in the table for the matter of convenience as far as impatient subjects always withdraw. Thus the payoffs are represented in the form: (Payoff of Player I; Payoff of Player II; Payoff of Player IV; Payoff of Player V)

Table 8: Normal form of the game: Player IV and Player V keep

	Keep	Withdraw	Redeposit
Keep	(U(210);U(210);U(210);U(210))	(U(0);U(150);U(210);U(210))	(U(0);U(210);U(210);U(210))
Withdraw	(U(150);U(0);U(210);U(210))	($\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0);U(210);U(210))	($\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(210) + $\frac{1}{3}$ × U(0);U(210);U(210))
Redeposit	(U(210);U(0);U(210);U(210))	($\frac{2}{3}$ × U(210) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0);U(210);U(210))	($\frac{2}{3}$ × U(210) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(210) + $\frac{1}{3}$ × U(0);U(210);U(210))

Table 9: Normal form of the game: Player IV withdraws and Player V keeps

	Keep	Withdraw	Redeposit
Keep	(U(210);U(210);U(150);U(0))	(U(0);U(150);U(150);U(0))	(U(0);U(105);U(150);U(105))
Withdraw	(U(150);U(0);U(150);U(0))	($\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); U(150); U(0))	($\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(105) + $\frac{1}{3}$ × U(0); U(150); $\frac{2}{3}$ × U(105) + $\frac{1}{3}$ × U(0)
Redeposit	(U(105);U(0);U(150);U(105))	($\frac{2}{3}$ × U(105) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0);U(150);$\frac{2}{3}$ × U(105) + $\frac{1}{3}$ × U(0))	($\frac{1}{3}$ × U(140) + $\frac{1}{3}$ × U(105) + $\frac{1}{3}$ × U(0); $\frac{1}{3}$ × U(140) + $\frac{1}{3}$ × U(105) + $\frac{1}{3}$ × U(0); U(150); $\frac{2}{3}$ × U(105) + $\frac{1}{3}$ × U(140))

Table 10: Normal form of the game: Player IV keeps, and Player V withdraws

	Keep	Withdraw	Redeposit
Keep	(U(210);U(210);U(0);U(150))	(U(0);U(150);U(0);U(150))	(U(0);U(105);U(105);U(150))
Withdraw	(U(150);U(0);U(0);U(150))	($\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); U(0); U(150))	($\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(105) + $\frac{1}{3}$ × U(0);$\frac{2}{3}$ × U(105) + $\frac{1}{3}$ × U(0);U(150))
Redeposit	(U(105);U(0);U(105);U(150))	($\frac{2}{3}$ × U(105) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0);$\frac{2}{3}$ × U(105) + $\frac{1}{3}$ × U(0); U(150))	($\frac{1}{3}$ × U(140) + $\frac{1}{3}$ × U(105) + $\frac{1}{3}$ × U(0); $\frac{1}{3}$ × U(140) + $\frac{1}{3}$ × U(105) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(105) + $\frac{1}{3}$ × U(140); U(150))

Table 11: Normal form of the game: both Player IV and Player V withdraw

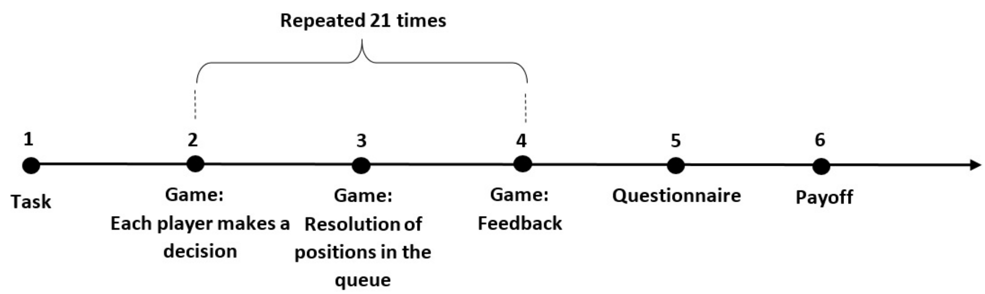
	Keep	Withdraw	Redeposit
Keep	(U(210); U(210); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0);$\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0))	(U(0); U(150); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0);$\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0))	(U(0); U(0); U(150); U(150))
Withdraw	(U(150); U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0))	($\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0);$\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0))	($\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(105) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0))
Redeposit	(U(0); U(0); U(150); U(150))	(U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0);$\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0); $\frac{2}{3}$ × U(150) + $\frac{1}{3}$ × U(0))	($\frac{2}{3}$ × U(0) + $\frac{1}{3}$ × U(105); $\frac{2}{3}$ × U(0) + $\frac{1}{3}$ × U(105); U(150); U(150))

Appendix III - Experimental Instructions: Treatment I

Welcome to the Experiment!

The current experiment is devoted to economic decision-making. It consists of a small task followed by a game. In the end, you will be asked to fill in a small questionnaire. If you have any questions or need help, please raise your hand. An experimenter will come to your place and answer your questions in private. Communication with other participants is prohibited. At the end of the experiment, you will be paid for participation.

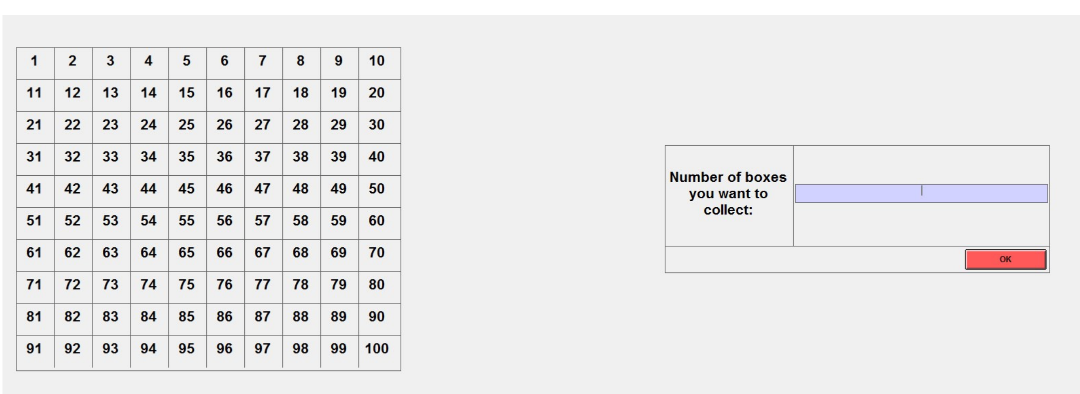
Figure 3: The timeline of the game



Description of the task

First, you will be asked to do a small task. On the computer screen, you will see a field composed of 100 numbered boxes. Behind one of these boxes hides a mine; all the other 99 boxes are free from mines. You do not know where this mine lies. You only know that the mine can be in any place with equal probability. Your task is to choose how many boxes to collect. Boxes will be collected in numerical order. So, you will be asked to choose a number between 1 and 100. You confirm your choice by hitting 'OK'.

Figure 4: BRET task



At the end of the experiment, we will randomly determine the number of the box containing the mine by means of a bag containing 100 numbered tokens. Every participant will have its own position of a bomb. If you happen to have harvested the box where the mine is located – i.e., if your chosen number is greater than or equal to the drawn number – you will earn zero. If the mine is located in a box that you did not harvest – i.e., if your chosen number is smaller than the drawn number – you will earn in euro an amount equivalent to the number you have chosen divided by ten. You will know how much have you earned only at the end of the experiment. After the task is done, you will proceed to the next stage of the experiment which is the game.

Description of the game

There is a bank that has 3 clients. Each of them has 100 ECU, so in total 300 ECU, that is initially kept in a bank in the form of a deposit. Deposit contract lasts for one experimental period, but the client has the right to withdraw his money during the period. The bank has 300 ECU invested in a project that gives a return of R=280% only if the money stays invested during all the period. For instance, if the bank invested 300 ECU, but during the period had to take part of it out (if needed): X ECU, the interest will be paid only on the amount that stayed the entire period invested: on (300-X) ECU. The amount is taken from the project during the period: X ECU doesn't bring any return, thus being considered at a nominal value. All the return earned is shared among the clients that stay with the bank at the end of the period. The bank knows with certainty that 1 out of 3 players will withdraw the money before the period ends. Regarding other 2 clients, it assumes that they will stay with the bank until the end of the period. Making this assumption the bank promises in the deposit contract to pay 210 ECU per client that stays with the bank and 150 ECU to the client who withdraws. So, the bank expects to take 150 ECU out of the project to pay to the withdrawer. Indeed, if the assumption of the bank turns out to be not correct and less than 2 clients in total stay with the bank (more than 1 withdraws), the bank must use more funds to pay to those who are withdrawing. As far as the funds need to be taken out during the period, there is no return on the investment yet. That is why the maximum amount that the bank can take out is 300 ECU. Thus, the bank has enough money only for a maximum of 2 withdrawals if happen (150 ECU per each). If 2 clients withdraw, each will get 150 ECU whereas the third who decided to stay with a bank will get 0 ECU as far as the bank will run out of money after two withdrawals. If 3 clients withdraw, the first and the second withdrawing get 150 ECU, whereas the third one gets 0 ECU. If the player withdraws, his/her position in the queue is defined randomly at the end of the period.

Your task

You will play a role of a depositor in a bank. Before the game starts, all the participants will be randomly divided into groups of 2. So, apart from you, there will be one more player randomly assigned to your bank. You will always play the game with the same person, that is initially matched with you. In total, there will be 3 depositors per bank: 2 depositors that are real people (you and another person) and 1 more depositor that will be generated by the computer (from now on, called automaton).

Remember that the automaton always withdraws the money.

You and your counterpart will be asked whether you want to KEEP your money in a bank or to WITHDRAW it. You don't know what your counterpart will do, but your payoff depends on his decision.

If you **KEEP:**

	Counterpart KEEP	Counterpart WITHDRAW
You get	210 ECU	0 ECU

If your counterpart keeps, the assumption of the bank that only automaton withdraws holds and you get as promised 210 ECU. If your counterpart withdraws, the bank needs all 300 ECU to pay two withdrawers, so you get 0 ECU.

If you **WITHDRAW:**

<table>
<tr><th>Position</th><th>Counterpart KEEP</th><th>Counterpart WITHDRAW</th></tr>
<tr><td>You get if 1st:</td><td rowspan="2">150 ECU</td><td rowspan="2">150 ECU</td></tr>
<tr><td>You get if 2nd:</td></tr>
<tr><td>You get if 3rd:</td><td>-</td><td>0 ECU</td></tr>
</table>

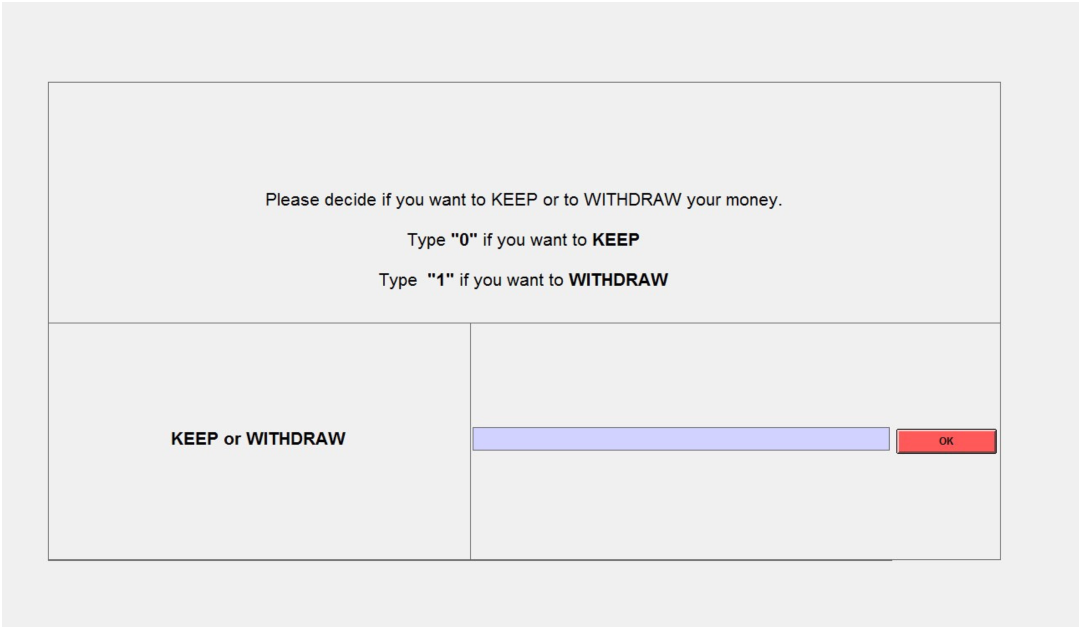
If your counterpart keeps, you and automaton withdraws, you will get 150 ECU anyway, as far as the bank has money for two withdrawers. If your counterpart withdraws, only the first two will get 150 ECU, the third will get 0 ECU.

Keep in mind that your position in the "queue" will be defined randomly after both participants decided.

Feedback

After both players decided, you will be provided with a short statistic for the game(s) played. The game will be played 21 times (rounds). The first time will be a TRIAL, so

Figure 5: Decision screen



will NOT influence your final payoff, whereas all others may influence your final payoff. You will know how much have you earned only at the end of the experiment: we will choose the number randomly from 1 to 20 which will tell us the payoff of which round of the game will be used for your final payment calculation.

Questionnaire

After you finished the game, you will be asked to fill in a small questionnaire regarding your age, gender and the major of your studies. All the information will be used only for the current research.

Final payoff

For the calculation of the final payoff, we will consider both what you have earned doing the first task and the payoff of one round of the game, chosen randomly.

Task I:

If you collected a bomb: Payoff Task I (Euro)=0

If you did not collect a bomb: Payoff Task I (Euro) = Number of boxes collected $\times$ 0.1

Task II:

Payoff Task II (Euro) = Payoff of one of the randomly chosen rounds $\times$ 0.02

Final:

Show-up fee = 2.5 Euro

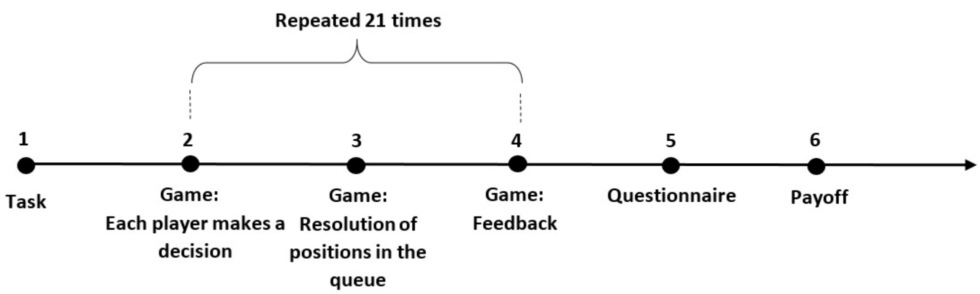
Final payoff = Show-up fee + Payoff Task I + Payoff Task II

Appendix IV - Experimental Instructions: Treatment II

Welcome to the Experiment!

The current experiment is devoted to economic decision-making. It consists of a small task followed by a game. In the end, you will be asked to fill in a small questionnaire. If you have any questions or need help, please raise your hand. An experimenter will come to your place and answer your questions in private. Communication with other participants is prohibited. At the end of the experiment, you will be paid for participation.

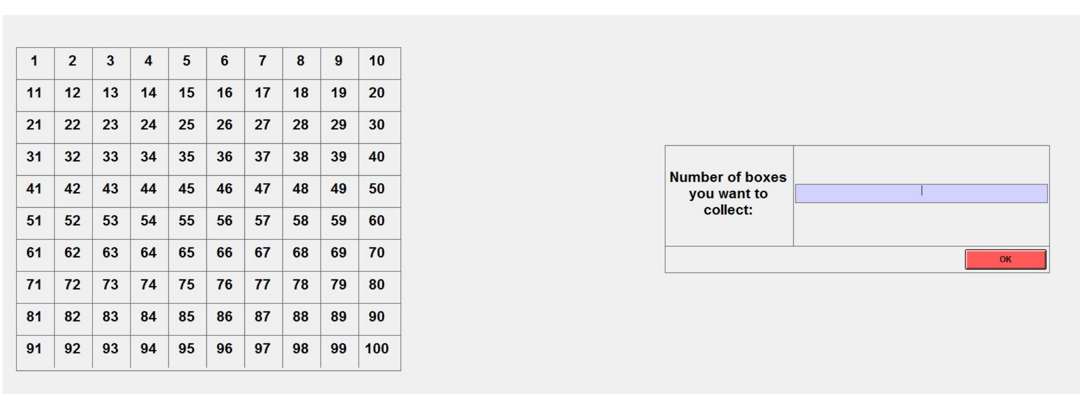
Figure 6: The timeline of the game



Description of the task

First, you will be asked to do a small task. On the computer screen, you will see a field composed of 100 numbered boxes. Behind one of these boxes hides a mine; all the other 99 boxes are free from mines. You do not know where this mine lies. You only know that the mine can be in any place with equal probability. Your task is to choose how many boxes to collect. Boxes will be collected in numerical order. So, you will be asked to choose a number between 1 and 100. You confirm your choice by hitting 'OK'.

Figure 7: BRET task



At the end of the experiment, we will randomly determine the number of the box containing the mine by means of a bag containing 100 numbered tokens. Every participant will have its own position of a bomb. If you happen to have harvested the box where the mine is located – i.e., if your chosen number is greater than or equal to the drawn number – you will earn zero. If the mine is located in a box that you did not harvest – i.e., if your chosen number is smaller than the drawn number – you will earn in euro an amount equivalent to the number you have chosen divided by ten. You will know how much have you earned only at the end of the experiment. After the task is done, you will proceed to the next stage of the experiment which is the game.

Description of the game

There are two banks: Bank I and Bank II. Each of the banks has 3 clients (different ones). Each of the clients has 100 ECU, so in total 300 ECU, that is initially kept in each bank in the form of a deposit.

Bank I

Each client of Bank I has a deposit contract that lasts for one experimental period, but the client has the right to take his/her money out of the bank during the period. The same as Bank I, Bank II has 300 ECU invested in a project that gives a return of R=280% only if the money stays invested during all the period. For instance, if the bank invested 300 ECU, but during the period had to take part of it out (if needed): X ECU, the interest will be paid only on the amount that stayed the entire period invested: on (300-X) ECU. The amount is taken from the project during the period: X ECU doesn't bring any return, thus being considered at a nominal value.

The bank knows with certainty that 1 out of 3 players will withdraw the money before the period ends. Regarding other 2 clients, it assumes that they will stay with the bank until the end of the period.

Making this assumption the bank promises in the deposit contract to pay 210 ECU per client that stays with the bank and 150 ECU to the client who withdraws. So, the bank expects to take 150 ECU out of the project to pay to the withdrawer.

Indeed, if the assumption of the bank turns out to be not correct and less than 2 clients in total stay with the bank (more than 1 withdraws), the bank must use more funds to pay to those who are withdrawing.

As far as the funds need to be taken out during the period, there is no return on the investment yet. That is why the maximum amount that the bank can take out is 300

ECU. Thus, the bank has enough money only for a maximum of 2 withdrawals if happen (150 ECU per each).

If 2 clients withdraw, each will get 150 ECU whereas the third who decided to stay with a bank will get 0 ECU as far as the bank will run out of money after two withdrawals. If 3 clients withdraw, the first and the second withdrawing get 150 ECU, whereas the third one gets 0 ECU.

Players of Bank I have a choice whether to KEEP the money in Bank I, WITHDRAW the money from it or REDEPOSIT the money to Bank II. The player can REDEPOSIT conditional on whether he can WITHDRAW. If the player decides to redeposit the money to Bank II, he first needs to take the money from Bank I and can get 150 ECU (if the 1st or 2nd in the queue) or 0 ECU (if the 3rd in the queue). If he gets 0 ECU– he/she has nothing to redeposit. If he gets 150 ECU, all the amount of money: 150 ECU is redeposited. If the player decides to withdraw/redeposit his position in the queue is defined randomly at the end of the period. So, the player learns only at the end of the period if his claim for redepositing was successful.

Bank II

The same as Bank I, Bank II has 300 ECU invested in a project that gives a return of R=280% only if the money stays invested during all the period. For instance, if the bank invested 300 ECU, but during the period had to take part of it out (if needed): X ECU, the interest will be paid only on the amount that stayed the entire period invested: on (300-X) ECU. The amount is taken from the project during the period: X ECU doesn't bring any return, thus being considered at a nominal value. All the return earned is shared among the clients that stay with the bank at the end of the period.

Bank II knows with certainty that 1 out of 3 initial clients will withdraw the money before the period ends. Regarding other 2 clients, it assumes that they will stay with the bank until the end of the period.

Making this assumption the bank promises to its initial clients in the deposit contract to pay 210 ECU per client that stays with the bank and 150 ECU to the client who withdraws.

Apart from that, Bank II has an additional project in which it invests money that is redeposited within the period by players of Bank I. The project gives a return only at the end of the period. Still holding an assumption that only 1 initial player will withdraw, Bank II proposes an additional deposit contract for "redepositors": it promises to pay 210

ECU at the end of the period.

Indeed, if the assumption of the bank turns out to be not correct and less than 2 initial clients stay with the bank (more than 1 withdraws), the bank must use additional funds during the period to pay to those who are withdrawing.

In this case, the bank (if needed) can use all the money available: from the first projects at a nominal value and what is redeposited.

The maximum amount that the bank can take out is 300 ECU from the first project and up to 300 ECU (depends on how many people will decide to redeposit - maximum two) from redepositors.

In this case, the amount invested in the second project will be less than initially expected as far as part of the funds that came from redepositors will be used to pay to withdrawers.

In this situation, those, who withdraw from Bank II get the money (150 ECU or 0 ECU) upon availability and dependent on the position in the queue, which is defined randomly at the end of the period.

And those who stay with the bank till the end of the period (depositors of Bank II who keep and depositors of Bank I who redeposited), get an equal share of all the money left at the end of the period (see details below).

Your task

You will play a role of a depositor in Bank I or in Bank II. Before the game starts, all the participants will be randomly divided into groups of 4. Then two out of four players will be assigned to Bank I, other two – to Bank II. In total, there will be 3 depositors per bank: 2 depositors that are real people (you and another person assigned to you) and 1 more depositor that will be generated by the computer (From now on, called automaton). You will be assigned either to Bank I or to Bank II. Apart from you, there will be one more player randomly assigned to your bank. Being assigned to Bank I/ Bank II keeps till the end of the experiment. This holds for every player. Also, you will always play the game with the same three people that are initially matched with you.

Player of Bank I:

You and your counterpart (another player of Bank I) will be asked whether you want to KEEP, WITHDRAW or REDEPOSIT your money.

Remember that the automaton always withdraws the money.

If you KEEP:

	Counterpart KEEP	Counterpart WITHDRAW	Counterpart REDEPOSIT
You get	210 ECU	0 ECU	

If your counterpart keeps, the assumption of the bank that only automaton withdraws holds and you get as promised 210 ECU. If your counterpart withdraws, the bank needs all 300 ECU to pay two withdrawers, so you get 0 ECU.

If you WITHDRAW:

	Counterpart KEEP	Counterpart WITHDRAW	Counterpart REDEPOSIT
You get if 1st	150 ECU	150 ECU	
You get if 2nd			
You get if 3rd	-	0 ECU	

If your counterpart keeps, you and automaton withdraws, you will get 150 ECU anyway, as far as the bank has money for two withdrawers. If your counterpart withdraws, only the first two will get 150 ECU, the third will get 0 ECU.

Keep in mind that your position in the "queue" will be defined randomly after both participants decided.

If you REDEPOSIT:

Both players of Bank II: KEEP

	Counterpart KEEP	Counterpart WITHDRAW	Counterpart REDEPOSIT
You get	210 ECU		

In this case, an assumption made by Bank I (only automaton withdraws) DOES hold, thus if you redeposit, you will get as promised 210 ECU.

One player of Bank II: KEEP another WITHDRAW

In this case, the assumption made by Bank I (only automaton withdraws) DOES NOT hold - two depositors withdraw (automaton and one more), so Bank II has to take 300 ECU out of the project, which is all the money invested. Thus, if you redeposit, your money is invested in the additional project and the return: 210 ECU is shared among you and the player of Bank II who keeps. So, each of you gets 105 ECU. Keep in mind that if not only you but also your counterpart will redeposit to Bank II, 420 ECU will be shared among you, your counterpart and the player of Bank II who keeps.

	Counterpart KEEP	Counterpart WITHDRAW	Counterpart REDEPOSIT
You get	105 ECU	105 ECU	140 ECU

Both players of Bank II: WITHDRAW

<table>
<tr><td></td><td>Counterpart KEEP</td><td>Counterpart WITHDRAW</td><td>Counterpart REDEPOSIT</td></tr>
<tr><td>You get</td><td colspan="2">0 ECU</td><td>105 ECU</td></tr>
</table>

In this case, the assumption made by Bank I (only automaton withdraws) DOES NOT hold - three depositors withdraw, so Bank II needs 450 ECU to pay all of them. Thus, it will take all 300 ECU out of the project and will use your money (150 ECU). Thus, nothing will be left and you will get 0 ECU at the end. Keep in mind that if not only you but also your counterpart will redeposit to Bank II, 150 ECU will be left after all the withdrawals and invested in the additional project. In the end, 210 ECU will be shared among you and your counterpart thus you will get 105 ECU.

Player of Bank II:

You and your counterpart will be asked whether you want to KEEP your money in a Bank II or to WITHDRAW it.

Remember that the automaton always withdraws the money.

Your payoff depends on what your counterpart (another player of Bank II: Player V) does: KEEP or WITHDRAW; as well as on whether players of Bank I REDEPOSIT the money to Bank II or not.

If you KEEP:

And NO ONE redeposit:

	Counterpart KEEP	Counterpart WITHDRAW
You get	210 ECU	0 ECU

If your counterpart keeps, the assumption of the bank that only automaton withdraws holds and you get as promised 210 ECU. If your counterpart withdraws, the bank needs all 300 ECU to pay two withdrawers, so you get 0 ECU.

If you WITHDRAW:

And NO ONE redeposit:

Position	Counterpart KEEP	Counterpart WITHDRAW
You get if 1st:	150 ECU	150 ECU
You get if 2nd:		
You get if 3rd:	-	0 ECU

If your counterpart keeps, you and automaton withdraws, you will get 150 ECU anyway, as far as the bank has money for two withdrawers. If your counterpart withdraws, only the first two will get 150 ECU, the third will get 0 ECU.

Keep in mind that your position in the "queue" will be defined randomly after both participants decided.

If you KEEP:

And ONE redeposit:

	Counterpart KEEP	Counterpart WITHDRAW
You get	210 ECU	105 ECU

If your counterpart keeps, the assumption of the bank that only automaton withdraws holds and you get as promised 210 ECU. If your counterpart withdraws, the bank still has the money that was redeposited. It is invested and at the end of the period 210 ECU the is shared among redepositor and you, so each get 105 ECU.

If you WITHDRAW:

And ONE redeposit:

Position	Counterpart KEEP	Counterpart WITHDRAW
You get if 1st:	150 ECU	150 ECU
You get if 2nd:		
You get if 3rd:	-	

When one player redeposits to Bank I, it can survive up to 3 withdrawals (300 ECU+150 ECU). Thus if you withdraw, you get 150 ECU anyway.

If you KEEP:

And TWO redeposit:

If your counterpart keeps, the assumption of the bank that only automaton withdraws holds and you get as promised 210 ECU. If your counterpart withdraws, the bank has the

	Counterpart KEEP	Counterpart WITHDRAW
You get	210 ECU	140 ECU

money of two redepositors that give 420 ECU which is shared among 3 players (you and two redepositors). So, you get 140 ECU.

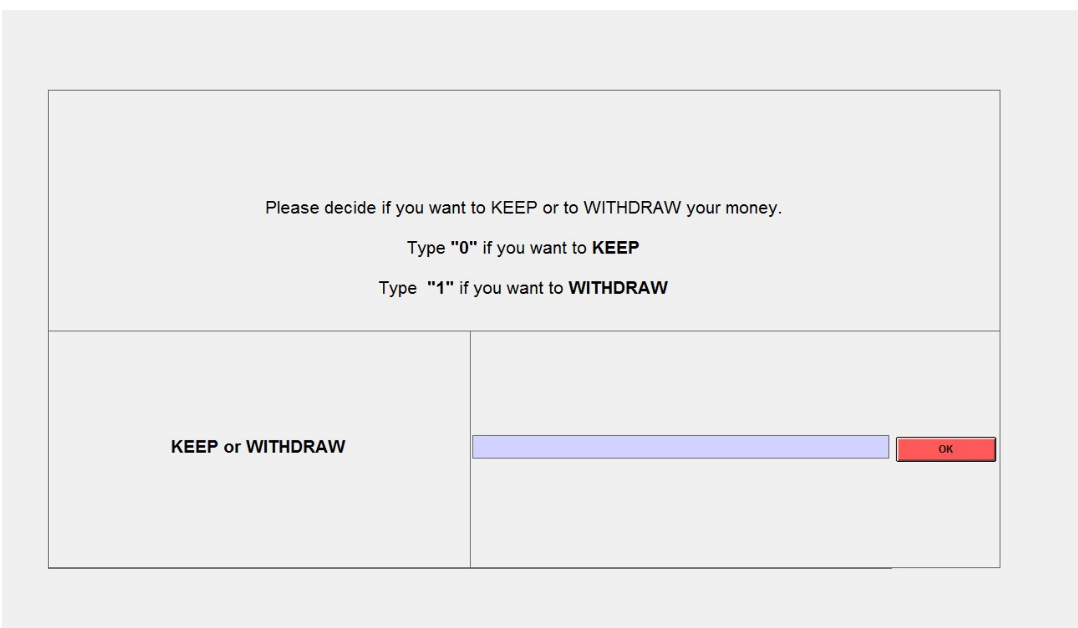
If you WITHDRAW:

And TWO redeposit:

<table>
<tr><th>Position</th><th>Counterpart KEEP</th><th>Counterpart WITHDRAW</th></tr>
<tr><td>You get if 1st:</td><td rowspan="2">150 ECU</td><td rowspan="3">150 ECU</td></tr>
<tr><td>You get if 2nd:</td></tr>
<tr><td>You get if 3rd:</td><td>-</td></tr>
</table>

When two players redeposit to Bank I, it can survive up to 4 withdrawals (300 ECU+300 ECU). Thus, if you withdraw, you get 150 ECU independently of what your counterpart is doing.

Figure 8: Decision screen



Feedback

After both players decided, you will be provided with a short statistic for the game(s) played. The game will be played 21 times (rounds). The first time will be a TRIAL, so will NOT influence your final payoff, whereas all others may influence your final payoff. You will know how much have you earned only at the end of the experiment: we will choose the number randomly from 1 to 20 which will tell us the payoff of which round of the game will be used for your final payment calculation.

Questionnaire

After you finished the game, you will be asked to fill in a small questionnaire regarding your age, gender and the major of your studies. All the information will be used only for the current research.

Final payoff

For the calculation of the final payoff, we will consider both what you have earned doing the first task and the payoff of one round of the game, chosen randomly.

Task I:

If you collected a bomb: Payoff Task I (Euro)=0

If you did not collect a bomb: Payoff Task I (Euro) = Number of boxes collected $\times$ 0.1

Task II:

Payoff Task II (Euro) = Payoff of one of the randomly chosen rounds $\times$ 0.02

Final:

Show-up fee = 2.5 Euro

Final payoff = Show-up fee + Payoff Task I + Payoff Task II

Coordination and communication during bank runs*

Ekaterina Shakina[†]& Martin Angerer[‡]

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Abstract

We analyze the withdrawal behavior of bank depositors in times of economic crisis. In our experimental model, we do not impose restrictions on the number of times subjects can withdraw or redeposit money. Additionally, there is no specific order in which subjects decide, and therefore, subjects have a variety of possible strategic moves (e.g., waiting, reacting to others, contacting peers, etc.) that are also available in reality. The experiment supplements existing theoretical models and examines the influence of the possibility to communicate, the culture of subjects, deposit insurance and the liquidity of the bank in tense economic times. Communication helps to stabilize banks, whereas information about the worsening of economic conditions together with irrational behavior increase the incidence of withdrawals. Communication helps to slow down withdrawals. An increase in the liquidity problems of a bank and a larger share of deposits not secured by deposit insurance cause larger withdrawals.

Keywords: withdrawal behavior, experiment, bank run, economic crisis, intercultural, communication

JEL classification: C90, D83, G14

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1 Introduction

Financial crises have occurred quite regularly over the last 400 years: Kindleberger (2015) shows that they occur in roughly ten-year intervals. In a study of the International Monetary Fund, Caprio and Klingebiel (2002) indicate that there were a total of 112 systematic banking crises in 93 countries and 51 borderline crises in 46 countries between 1975 and 1995. Since then, several other banking crises have taken place in other countries, such as Russia, Argentina and Turkey. In a more recent study, Laeven and Valencia (2013) show that 147 banking crises occurred between 1970 and 2011. The global financial crisis of 2007-2009 is just the latest evidence that bank runs remain persistent and are an important topic worldwide. When bank runs happen, they often entail disastrous consequences for the whole financial system. Kaminsky and Reinhart (2000) argue that bank runs can be blamed for "twin crises", meaning that a banking crisis also often causes a currency crisis. According to Kaufman (1994), a bank contagion can trigger a domino effect not only in the entire banking system, but even beyond it – in the entire financial system and the macroeconomy. Bonfim and Kim (2012) calculate that during major crises from 1970 to 2007, when collective behavior changed the micro-prudential nature of banking risk into a macro-prudential one, historical total losses for the economy were 13% of GDP and even averaged 20% of GDP (Laeven and Valencia (2013)). Therefore, most economists such as Fisher (2006), Brown et al. (2016), Rochet (2008), and Boyle et al. (2015) agree that bank runs have a significant negative influence on the banking system and the economy as a whole.

We study the withdrawal behavior of bank depositors, focusing on the effect of information and its exchange through communication on subjects' decisions. It has been shown both theoretically (Chwe (2000)) and empirically (Kelly and Gráda (2000)) that information plays an important role in economic and financial decision-making. Cohen et al. (2008) claim that social networks may be important mechanisms for information flow into asset prices. Hong et al. (2004) find that players enter a stock market after observing their peers participating. Ivković and Weisbenner (2007) conclude that word-of mouth communication between peers leads to an increase in stock purchases. Thus, communication seems to have a positive impact on financial trading. The conclusion that communication helps players to coordinate is also supported by the literature on bank runs. Kiss et al. (2014a) show that a communication node between patient players can help to prevent bank runs. We contribute to the existing literature by studying the coordination and communication behavior of subjects in a setting with changing economic conditions. To this end, we introduce not only private imperfect information about banks' fundamentals but also public information about general economic conditions in order to see how both types of information influence depositors' withdrawal behaviors. In a second step, we allow subjects to exchange information via an anonymous chat window in order to study whether communication helps to prevent bank runs.

In our model, we try to incorporate the two most common perspectives on bank runs. The first theory argues that changes in economic fundamentals drive bank runs - Gorton (1988) states that banking panics are related to the business cycle. Using the liabilities of failed businesses as a leading economic indicator, he concludes that whenever this indicator reached a certain threshold, a panic ensued. Zhu (2005) shows that a bank run is a business-cycle-related and state-related phenomenon; he documents the failure of the risk-sharing mechanism provided by the banking sector. The opinion that bad bank fundamentals drive bank runs is shared between Calomiris and Mason (2003), Allen and Gale (1998), Schumacher (2000), Acharya and Yorulmazer (2008).

The second theory argues that bank runs are the result of a pure panic of individuals. Saunders and Wilson (1996) analyze bank runs during the Great Depression times and find empirical evidence of depositors withdrawing even from financially stable banks. Also, Friedman and Schwartz (2008) claim that the run on the Bank of the United States in 1930 was not caused by bad fundamentals. The idea of bank runs being caused by panics is supported by Kindleberger and O'Keefe (2001), Kelly and Gráda (2000), Brown et al. (2012).

We do not argue for one theory or the other but highlight the potential importance of both. We propose a new experimental approach to examine the dynamics of depositor withdrawal behavior. To this end, we provide subjects with information regarding banks' fundamentals and, depending on the treatment, we allow them to communicate. We run two treatments of the experiment: in one of them subjects can communicate via chat in another - cannot. We compare experimental results with a theoretically optimal behavior that we find by running a simulation. This approach allows us to learn more about the withdrawal behavior of depositors in times of crisis: how far is it from being rational as well as to understand how does it depend on the possibility to communicate.

We choose an experimental approach for two main reasons. On one hand, existing theoretical models rely on assumptions that are often not fulfilled in real market situations and therefore exhibit low external validity.[1] On the other hand, there is a lack of ex-

[1] Usually, agents do not communicate during the game, thus making any kind of information-sharing

perimental analysis in the field because the environment of a banking crisis is difficult to model. We argue that the often-favored model introduced by Diamond and Dybvig (1983) is not suitable for tackling our research questions, and we propose an alternative approach as a result.

Summarized, we analyze withdrawal behavior that may lead to bank runs caused by the (irrational) behavior of depositors (as a result of a coordination game) within a scenario of worsening economic conditions. Like Schotter and Yorulmazer (2009), we are interested in seeing how bad fundamentals of a bank change the propensity to withdraw. We study not only whether depositors withdraw or not, but also analyze how much they withdraw which, to the best of our knowledge, has been neglected by the literature by now. Also we check whether communication helps prevent bank runs. We show that the opportunity to chat decreases withdrawals and is therefore helpful for bank survival in difficult macroeconomic times. Our third and final contribution is an in-depth analysis of the behavior of subjects who actually withdraw. Specifically, we analyze how the information provided about the bank, the level of deposit insurance, and the nationality, gender and the opportunity to communicate influence individual withdrawal decisions.

In a nutshell, we find that macroeconomic information is not the only factor to influence withdrawals; communication and coordination also play a big role. In general, communication helps to slow down withdrawals but is highly dependent on mood: many negative messages may cause larger individual withdrawals, but positive ones lead to smaller average withdrawals. Additionally, we find evidence that an increase in the liquidity problems of a bank and a larger share of uninsured deposits significantly trigger withdrawal behavior by increasing withdrawal sizes. We also find that women withdraw more often than men but do so in smaller amounts. Regarding cultural differences, we report first exploratory results that Russians withdraw higher amounts but do so less often than Germans.

2 Literature review

The common theoretical model used to examine the dynamics of bank runs even when the bank is not in financial turbulence was introduced by Diamond and Dybvig (1983). To be more concise, we will use abbreviation "the DD model" from this point on. In this two-period game, depositors decide whether or not to withdraw money from a bank. There are only two types of economic agents: those who prefer to consume (spend their

impossible. Additionally, depositors are allowed to withdraw only a fixed number of times, generally once and simultaneously with other players.

money) in the first period and those who are willing to wait until the second period to consume. In this setting, it is important that economic agents do not know to which "type" of consumers they belong until Period 1. In the case of a panic, a bank can absorb only a limited amount of withdrawals before it becomes insolvent. One finding of the model is that bank runs can occur even if it is known that there are no problems with the fundamentals of the bank. The model by Diamond and Dybvig (1983) is applied by the majority of researchers in the field[2] because it has many advantages, such as simplicity, clear mathematical reasoning, and optimal solutions. According to our knowledge, there are now more than 20 mainly theoretical, published modifications of the model, although most of the aforementioned features remain.

We propose an alternative model with another goal. The experimental approach presented aims at greater external validity. While we must sacrifice a precise theoretical solution, in exchange, we offer a simulation with rational agents as a theoretically motivated benchmark, which allows us to measure deviations from purely rational behavior and examine the influence of our treatment conditions. The following reviews the literature on influencing factors that we consider important for the setup of our experiment.

2.1 Communication

Communication plays a crucial role in decision-making. Cason et al. (2014) analyze how repetition and communication may facilitate coordinated resistance in deterring divide-and-conquer games. They find that is it more effective to communicate than to observe the history of past resistance. Cooper et al. (1992) study two-way preplay communication and find that this communication helps to overcome the coordination failures observed in the game without communication.

The form of communication has an effect on its efficiency. Bochet et al. (2006) study three forms of communication and find that verbal communication through a computer chat room substantially increases cooperation and efficiency. In contrast, communication by sending numerical messages has no significant influence on efficiency.

A bank's depositors usually communicate verbally or with the help of social networks. The influence of social networks on the speed of panics spreading among depositors is a rather new point of investigation. Iyer and Puri (2012) show that if other people in a depositor's network run, the depositor himself is more likely to run. Kiss et al. (2014a) develop an environment to investigate whether the connection to network nodes helps to

[2] See Green and Lin (2003), Cavalcanti (2010), Gu (2011), Cañón and Margaretic (2014).

prevent bank runs. They find that if patient depositors are connected through the node, the probability of a bank run decreases. The pure existence of the node is not sufficient, but observing other subjects' actions determines depositors' behavior.

In our experiment, we allow subjects to communicate in a chat treatment. One novelty of our setup is that subjects may communicate whenever they want during each of the periods; thus, they can talk both before and after making a decision. This setup allows us to consider both pre-play and after-play communication during bank runs. In contrast to Kiss et al. (2014a), subjects are not restricted to observing decisions of a specific counterpart but are allowed to chat with whomever they want and to exchange information of any kind. This setup gives complete freedom to the subjects to better replicate the communication process in reality.[3]

2.2 Gender and Culture

There is a great deal of evidence that gender differences affect financial decision-making. According to Kagel et al. (2016), gender differences while significant are sometimes small, but there are cases when even small differences may result in significant effects. Risk attitudes are empirically found to vary across genders: Gneezy and Potters (1997), Charness and Gneezy (2010). Also, the experimental literature on gender differences shows clear evidence that women are more risk-averse than men (Croson and Gneezy (2009), Bertrand (2011)).[4] Consequently, men and women behave differently when making risky investment decisions (Dwyer et al. (2002), Felton et al. (2003), Martenson (2008)). As far as withdrawal behavior is directly related to the propensity toward risk, an interesting question is whether one's decision to keep or to withdraw a deposit depends on gender. Kelly and Gráda (2000) analyze whether men or women are affected more by the panic on financial markets by studying two bank runs in New York in 1854 and 1857. They find that gender did not play a crucial role in explaining panic behavior. The same conclusion is reached by Kiss et al. (2014b). Although there is no evidence of gender being an important driver of withdrawal behavior in the existing experimental literature, we are still interested in analyzing gender effects. We argue that the level of risk aversion is a potential factor influencing withdrawal behavior; therefore, due to different risk attitudes among men and women, we believe that male and female depositors may behave differently.

[3] The assumption of a complete network is sometimes not fulfilled in reality.

[4] Although this finding seems very robust in the financial literature, there is also some current studies like Filippin and Crosetto (2016) and Kagel et al. (2016) doubting it's generality.

Additionally, there is a great deal of evidence that culture influences individuals' economic behavior. Guiso et al. (2006) claim that cultural variables are essential for understanding cross-country differences in national savings rates. Henrich et al. (2001) state that the degree of market integration can vary between societies. Research on the influence of different cultures on bank runs is scarce. For the same two panics in the 1850s, Kelly and Gráda (2000) examine the behavior of Irish depositors in a New York bank. As recent immigrants, their social network was determined largely by their place of origin in Ireland and where they lived in New York. During both panics, this social network became the prime determinant of behavior. Iyer and Puri (2012) use unique depositor-level data for a bank that faced a run and define the ethnicity of all the depositors into Muslims and Hindus. They find that depositors from the minority community (Muslims) are more likely to run. Given that there is almost no research in the field, we are interested in analyzing how cultural differences affect withdrawal behavior.

2.3 Information

The role of information during bank runs is crucial. Two main kinds of information affect withdrawals: (i) the financial stability of a bank and (ii) knowledge about other clients' withdrawals. Some models highlight that bank runs may be caused by depositors' beliefs about the solvency of their banks rather than beliefs about the actions of other depositors (Jacklin and Bhattacharya (1988), Calomiris and Mason (2003)). Others state that information about withdrawal behavior is essential: during times of economic instability and uncertainty, depositors are quite sensitive to the decisions of other clients (Chakravarty et al. (2014)). Brown et al. (2016) claim that players' fundamentals and behavior are influential and thus need to be considered together. They experimentally study the role of information during bank runs, finding that withdrawals are contagious when depositors know that there are economic linkages between banks.

We follow the ideas of Brown et al. (2016) making subjects (imperfectly) aware of the financial state of a bank at any time. During our experiment, subjects can see on the screen an indicator (the Default Score), which reflects the bank's distance from bankruptcy. The indicator worsens when the bank's fundamentals worsen and when subjects withdraw money. Thus, without communication subjects face an uncertainty regarding the behavior of other depositor which mimics real-life situation and goes hand in hand with the study of Garratt and Keister (2009). As the Default Score changes in real time, a subject may have an idea whether others are withdrawing or not. In this way, we allow other depositors'

Default Scores and behavior to be influential for withdrawal decisions. We conduct two treatments of the game: one with and one without a possibility to communicate. When subjects can communicate, they may not only guess that withdrawals are happening but also even find out how many depositors withdraw.

Additionally, whether information is public or private has an important role in withdrawal behavior. Indeed, it is still unclear how the privacy of information influences bank runs. Goldstein and Pauzner (2005) claim that when depositors do not have common knowledge about fundamentals, there is a unique Bayesian equilibrium in which a bank run occurs if and only if the fundamentals are below some critical value. On the other hand, Heinemann et al. (2004), who study global games, do not find evidence that an equilibrium becomes unique in coordination games with several equilibria if some information regarding payoff functions becomes private. They observe only small differences between sessions with common and private information. He and Manela (2016) find that depositors with less informative signals often wait before running. They claim that the public provision of solvency information helps to prevent bank runs. The timing of the public release of information regarding solvency is important, especially when a bank will be bailed out. Wang (2013) finds that before the announcement, the possibility of a bank being bailed out reduces investors' withdrawal incentives; however, after the announcement, investors may withdraw even more extensively. Overall, the influence of information becoming public or remaining private is a key question with regard to bank runs.

We acknowledge the importance of these approaches, and although it is not our main focus, we introduce imperfect private information about bank fundamentals (the Default Score) and public information about general economic conditions into our setup. To this end, every subject is provided with an estimate of the Default Score, which may deviate from the actual Default Score of the bank. Therefore, each subject has some (potentially noisy) information regarding the bank's stability (He and Manela (2016)). Additionally, subjects are given the same general information about the state of the economy. As a result, our setup will generally allow us to analyze how imperfect private information and perfect public information are used.

2.4 Types of Agents

As in the DD model, Temzelides (1997), Green and Lin (2000), Zhu (2005), Ennis and Keister (2009), Gu (2011), Smith and Shubik (2014) assume that there are only two types of economic agents: "patient" and "impatient". Impatient depositors always withdraw early, whereas patient ones choose in the moment whether they stay with a bank till the end or withdraw early. This assumption limits external validity because people often behave heterogeneously and, even more importantly, not necessarily in a time-consistent way. Sometimes, they are consistent and patient, while other times, they are impulsive and impatient. Azrieli and Peck (2012) show that with a continuum of agent types (between patient and impatient types), socially efficient outcomes cannot be achieved, underlining the possible influence of the type assumption. In the current experiment, we do not prescribe any types to the subjects.[5]Because there are no pre-defined impatient subjects, the coordination problem in our experiment is different from the one in the DD model. In their setup, a subject does not know whether a patient depositor withdraws (and then, it is possibly a bank run, and he should run as well) or if it is an impatient player and he should not worry. In our setup, there are no pre-defined impatient subjects, which is a different decision situation. The "type" of the other subjects, as well as how many are more or less patient, is unknown, which increases uncertainty. In our experiment, subjects observe the DS

in real time, which is an indicator for both the macroeconomic situation and the amount of withdrawals of other subjects. For one subject, it is hard to figure out (at least in non-chat sessions) whether other people withdraw or banks' fundamentals worsen at the beginning of the period. However, not pre-defining types allows us to claim that subjects' decision-making is not exogenously restricted.

2.5 Deposit Insurance

The DD model has two versions: one with and one without deposit insurance, emphasizing the role of insurance coverage for withdrawal decisions. Diamond and Dybvig (1983) make clear that deposit insurance is an effective measure to prevent bank runs. Although theoretically evident, based on the empirical data, the effect of deposit insurance on withdrawals is controversial. For instance, Schotter and Yorulmazer (2009) conclude that even the minimum coverage of 20-50% can help to slow down bank runs; however, explicit deposit insurance may lead to the moral hazard problem. Whereas Madies (2006) claim that partial insurance coverage does not prevent the occurrence of bank runs, full deposit insurance may help. Kiss et al. (2012) investigate correlation between the observability

[5] Arifovic et al. (2013) also do not impose any agent types. Thus, subjects play a coordination game between themselves without knowing with certainty who will withdraw. The authors do not consider bad fundamentals to be a reason for a bank run. Compared to Arifovic et al. (2013), we model an experiment such that not only the moves of other people, but also the fundamentals influence subjects' choices.

of the previous decisions of depositors and the amount of insurance coverage that should be provided in order to prevent bank runs. They find that if decisions are not observable, higher levels of deposit insurance decrease the probability of bank runs. However, when decisions are observable, this need not be the case. Overall, there remains no consensus concerning the amount of deposit insurance coverage that must be provided to prevent bank runs. For this reason, we implement deposit insurance in our experiment in order to analyze its effect on withdrawal decisions. Subjects are given different initial deposits, which allows us to check whether they withdraw more when a larger part of deposit is above the deposit insurance threshold.

2.6 Simultaneous vs. Sequential Decisions

Another assumption of the DD model mentioned by Jacklin and Bhattacharya (1988) and later researched by Lin (1996) is that depositors are able to act only simultaneously. Kinateder and Kiss (2014) provide a sequential-move version of the DD model in which they assume that depositors contact the bank in an exogenously given fixed order to communicate whether they withdraw or keep money. Both versions neglect the fact that in reality, people might strategically choose to react to the moves of others, acting both simultaneously and in sequence. Gu (2011) proposes a theoretical model that corrects for this issue, allowing players to choose a withdrawal time; however, the author still uses liquidity types in her analysis.

We believe that time of withdrawal is crucial regarding bank runs. Thus, in our model, subjects are not obliged to make a decision at the same time or in a specific order: they choose on their own when they want to make a decision within a 60-second time interval. Additionally, we allow subjects to make not one (as it is in the DD model) but several decisions within each experimental period. Subjects can withdraw and bring the money back to the bank as many times as they want, which is empirically motivated and theoretically appealing (He and Manela (2016)) and allows us to better replicate reality within a chosen experimental framework. Besides that, our assumption goes hand in hand with the latest experimental literature in the field. According to Garratt and Keister (2009), subjects are more likely to withdraw when given multiple chances to do so than when presented with a single decision.

2.7 Summary

We have analyzed the literature to establish several properties that our experimental approach will have to fulfill. Essential characteristics include that roles are not pre-assigned to the subjects and that all subjects begin the experiment under equal conditions, which allows them to behave in their own natural "role". The bank's operations follow a very realistic setting built on a balance sheet perspective. The experimental environment is repetitive, and subjects have the opportunity to partially observe the decisions of others. They also make their choices in a continuous time environment and can act both simultaneously and in sequence.

We propose an alternative that satisfies all these criteria and differentiates our model from the DD model. To our knowledge, it will be the first experiment to tackle the majority of "classical" restrictions. We trade a clear theoretical solution against a simulation benchmark for the sake of higher external validity. Therefore, we see our approach not as competing with the DD model, but as complementing it. We expect that withdrawal behavior in times of crisis is not always purely rational because people behave emotionally or even driven by panic. Our proposed model is a starting point for supplementary research that aims to find and observe deviations of real-world behavior from theoretically expected behavior.

To this end, we attempt to shed light on the following main questions: (1) Do subjects withdraw on a rational basis during difficult macroeconomic times? (2) Does the possibility to directly communicate via chat influence withdrawal behavior? (3) Can the behavior of depositors during bank runs be explained by their personal characteristics, such as gender and cultural differences, or by the amount of the deposit that is insured?

The remainder of the paper is structured as follows: in Section 3, we describe and explain our experimental approach, and in Section 4, we formulate the hypotheses that we want to test in the experiment. The results are presented in Section 5, and Section 6 concludes.

3 Methodology

3.1 General Description of the Experiment

We propose a new approach with a very realistic bank setup, which naturally comes at the cost of being rather complex. We therefore describe only the important parts of the experiment here and provide more details in the Appendix. We believe that our approach secures good external validity and sheds light on relevant aspects that have yet to be researched. The experiment consists of a bank and its depositors. The bank is automated and has the main objective of making profits by making investments, providing loans, and using deposits. Depositors are interested in earning as much interest as possible by keeping money in a bank account. We examine the withdrawal behavior of depositors while the economic situation of the bank worsens. The economic situation changes in an identical way across all the sessions and treatments. If depositors start to panic and run, the bank might default.

3.2 The Bank's Operations

The bank performs active and passive operations. As assets, the bank holds cash, short-term loans, long-term loans, investments in government debt securities, investments in corporate debt securities, property, and other assets. The liabilities side of the bank's balance sheet consists of deposits to clients and equity capital.

We have deliberately chosen this arguably complex balance sheet with multiple types of assets. Instead of making artificial assumptions and introducing an artificial solvency path, we decided to concentrate on external validity and mirror the real world and (i) propose a model for bank runs that can be used in the future to research other influencing factors, such as changes in regulation. (ii) Without such a sophisticated approach, we would also have a problem in terms of defining when a bank is insolvent and therefore defaults. We use the approach of the Bank for International Settlements, which defines in Basel III that a Liquidity Coverage Ratio (LCR) of 100% is the minimum requirement for a bank to be seen as solvent.

The likely most important feature for this study is that (iii) the solvency of the bank is highly influenced by the structure of the bank's assets and liabilities and by the way the liquidity ratio is calculated. Therefore, the solvency of a bank in times of crisis is not linear but highly dependent on the quality of liquidity of the assets currently held on the balance sheet. Hence, initial withdrawals do not harm the bank too much, but once the bank has to sell assets at a discount (because of lower market liquidity), the bank's financial situation worsens rapidly. This situation is a key problem banks face in real life. Additionally, our measure of default, the LCR, which we will present next, can be calculated only with the respective balance sheet details.[6]

[6] See Appendix I for details on the balance sheet.

3.3 The Liquidity Coverage Ratio as a Measure of Default

A default in our experiment is a consequence of a liquidity shortage;[7] for this, we apply the LCR as a main indicator of the bank's current solvency. LCR measures whether the bank has enough liquidity to cover its possible cash outflows, which may occur within the next 30 calendar days. According to The Basel Committee on Banking Supervision, LCR must be calculated as follows:

$$\mathrm{LCR} = \frac{\text{Stock of High-Quality Liquid Assets}}{\text{Total net cash outflows over the next 30 calendar days}} \tag{1}$$

As the LCR increases, the bank has to hold more liquidity to cover potential cash outflows and vice versa. Next, a new variable called the Default Score (DS) is created. Table 1 displays the relationship regarding how the DS is directly linked to the LCR values. During the experiment, all subjects can see the current DS on their screens in real time, allowing them to react to its changes immediately. It is important to note here that every subject sees his own estimation of the DS, which is similar to the real DS most of the time, but might be one number too high or one number too low at times that mirror noisy signals in the real world. The DS is an aggregate signal of the bank's current liquidity situation.

Table 1: The relationship between the Liquidity Coverage Ratio and the Default Score

LCR	DS
$\mathrm{LCR} \geqslant 3.4$	1
$2.9 \leqslant \mathrm{LCR} < 3.4$	2
$2.2 \leqslant \mathrm{LCR} < 2.9$	3
$1.8 \leqslant \mathrm{LCR} < 2.2$	4
$1.4 \leqslant \mathrm{LCR} < 1.8$	5
$1.2 \leqslant \mathrm{LCR} < 1.4$	6
$1 \leqslant \mathrm{LCR} < 1.2$	7
$\mathrm{LCR} < 1$	8

Each of the subjects has a deposit that is kept in a bank, and every subject may decide whether to leave money in a bank account or to withdraw. The following section sheds light on the bank functioning in the intertemporal environment of the experiment.

[7] In real life, the bank could contact the central bank as a lender of last resort. We do not include this possibility in our approach.

3.4 Bank Functioning in the Intertemporal Setting

Each period differs from the previous one because macroeconomic changes take place between each of the periods. On one hand, these changes are reflected in the macroeconomic variables provided to the subjects. Subjects can see the economic changes occurring through the dynamics of inflation and unemployment. On the other hand, macroeconomic changes influence the calculation of the High Quality Liquid Assets (HQLA). We implement the scenario of the global financial crisis of 2007-2009 by creating an economic factor from 0.1 to 0.7, in accordance with the stage of the crisis (see Table 2)[8]. In every period, the amount of HQLA is multiplied by this factor, thus reducing the stock of HQLA. As the economy drifts towards a recession, the factor becomes larger. Consequently, the bank can pay to fewer depositors in case they withdraw. The implementation of this factor incorporates market and credit risks alongside the liquidity risk.[9]

Table 2: Economic situation across periods

Period	Economic Factor
1	0.1
2	0.15
3-4	0.2
5	0.3
6-7	0.4
8	0.5
9-10	0.3
11-12	0.4
13-15	0.7

The dynamics of the crisis are also reflected in changes in interest rates: interest rates on short-term and long-term loans, on government debt securities, and on deposits were adjusted to their historical values. Although the values of interest rates do not fully coincide with the corresponding historical values, their dynamics are the same as they were from August 2008 to September 2009[10]. We have chosen this period because the

[8] We have created stages of the crisis based on the report by BIS (2009). Considering the period of time from July 2007 till May 2009 on a monthly basis, the authors define five of the financial crisis. The definition of stages is based on the values of GDP, inflation rate, unemployment rate etc. We use the same description of the stages for the experiment assuming that every experimental period has a length of one month and set the value of the economic factor correspondingly to the stage of the crisis.

[9] The subjects do not know this process precisely but know that the bank has more liquidity problems when macroeconomic conditions are poor.

[10] The historical values of interest rates on deposits, short-term loans, long-term loans and government debt securities were taken from the webpage of the Organization for Economic Cooperation and Development. All the values are taken as averages for the euro area countries. For details, please see:

crisis reached its peak during this time, and therefore, subjects would be most prone to run.

3.5 Details of the Experimental Implementation

The experiment consists of 15 periods (or less in the case of default). To avoid endgame effects, subjects are told that the experiment stops randomly between periods 12 and 17. Each period begins with an information screen, on which information concerning the economic situation in the upcoming period is displayed.[11] Each subject is provided with the same information about the expected rate of inflation and the expected rate of unemployment in the economy and their historical values as "external indicators" of the macroeconomic situation. Additionally, news concerning the situation in the banking sector and in the stock market is provided.

We ensure that the subjects understand the link between the macroeconomic situation and the solvency of the bank by (i) stating in the instructions that the economic factors "influence the bank in a way that it loses liquidity and may run into financial troubles" and (ii) stating above that the bank then might not be solvent enough to cover all of its obligations, (iii) providing them with the inflation rate and unemployment, which should give them real-life intuition behind the economic factor, and (iv) provide them with the written economic forecast, which, e.g., says "As a result losses occur causing banks to have liquidity shortages".

The next screen is the decision screen, which shows subjects how much money they currently have in their accounts, how much money is withdrawn, what amount of their deposit is insured, and how much interest on deposited and not-deposited amounts they have earned so far.[12] Subjects also observe the current DS in real time, which is individually derived for every subject and can be equal to, or one number higher or lower than the actual DS. The subjects are warned that if the real DS reaches "8", the game will stop and they will lose all deposited money that is not insured. It is also stated that the default may occur due to the actions of depositors, because of bad economic conditions, or a combination of both. Therefore, without communication, it is not possible for a subject to derive what exactly makes a DS worse: subjects' withdrawals or the economic situation. However, by using the chat, subjects can determine what other subjects did and find out the actual DS by sharing the Default Scores that each observed on the screen.

http://sdw.ecb.europa.eu/browse.do?node=bbn2891

[11] See Screen 1 in Appendix III.

[12] A calculator is also provided.

During the period, subjects can do three things: withdraw money, deposit money or simply wait and do nothing. With the exception of short selling, there are no limitations on withdrawing and depositing money.[13] Interest on deposits is paid proportionally to the time that money is kept in an account. Interest (constant at 0.1%) earned on not-deposited money depends on the time the money was not in the bank. At the end of the experiment, a subject's payoff depends on the percentage increase in wealth.

There are four treatments in total with four sessions each, and each session includes ten subjects, for a total of 160 subjects. These subjects differ in terms of the countries in which the studies are conducted and the availability of chat communication. The experiment was conducted in Russia, Austria, and Liechtenstein. In Russia, it was conducted at the National Research University, Higher School of Economics. In the German-speaking area, most of the experiments were conducted at the laboratory of the Vienna Center for Experimental Economics, others - at the University of Liechtenstein. The subjects were all students and had Swiss, German, Austrian or Russian nationalities and different educational backgrounds. We run a set of 4 markets for each treatment with Russian subjects and the same set with German-speaking subjects, which allows us to examine how culture impacts withdrawal behavior. The experiment was implemented in Z-tree (Fischbacher, 2007), and all sessions were conducted in English. Before the start of the experiment, subjects could ask clarification questions in private. In general, the task was properly understood, and subjects raised few questions. The treatments are summarized in Table 3.[14]

Table 3: Summary of Treatments

Cul.\Commun.	Chat	No chat
German	German-Chat	German-Non-Chat
Russian	Russian-Chat	Russian-Non-Chat

3.6 Benchmark Simulation

Theoretically, the bank could default in every period in which enough subjects withdraw a substantial amount of money, or it could never default. The amount that needs to be withdrawn for a default situation is not constant over time because of the bank's additional dependence on the macro-economic situation.

[13] See Screen 2 in Appendix III.
[14] For detailed instructions, see Appendix III.

We use simulations to derive the expected period of default for simple rational agents. Our rational agents follow some simple rules, which we assume to mirror rational behavior: (i) We assume that subjects have a critical DS (withdrawal score); if the DS[15] of the bank reaches this level, the agent withdraws; (ii) if the agent withdraws, he only withdraws the uninsured amount of money; (iii) if the decision to withdraw is made, all uninsured money is withdrawn; and (vi) if the status of the bank improves, a subject re-deposits all money. We run seven sets of simulations (each set has 100 iterations) altering the level at which agents withdraw and report the results in Table 4.[16]

Table 4 presents the results for various levels of the DS. Every column is one simulation setting. The values in the first line represent the critical DS at which all agents withdraw. In the second line, the corresponding average periods of the bank's default are stated. The value of a critical DS can be interpreted as a measure of overall risk aversion. As an agent becomes more risk averse, the earlier he will withdraw.

We find that the bank defaults already in Period 1 when the level of withdrawal is set to 2 (which is a very high level of risk aversion). Looking at the default periods of the simulation, we observe two things: (i) the bank should either default in period 6 if a very high risk aversion for all subjects is assumed or in period 13 for reasonable levels of risk aversion. If withdrawal happens in between, it follows that subjects do not behave rationally in our definition and withdraw as a result of either panic or poor coordination. (ii) We see that it is unlikely but possible that the bank never defaults, e.g., subjects refrain from withdrawing even when a DS of 8 is shown.

We conclude that if (i) subjects behave rationally, (ii) do not try to coordinate their actions with other subjects and (iii) do not individually panic, the bank should default in period 13.

Table 4: Simulation results

Withdrawal Score	2	3	4	5	6	7	8
Average period of default	1.0	5.1	6.0	13	13	13	–

Naturally, a default happens later as the critical DS increases (or the risk aversion lowers). At reasonable levels of average risk aversion, the simulation shows that the bank should always default in period 13. Thus, we have chosen a scenario in which, from period 12 to period 13, the macroeconomic situations change quite strongly and the DS of the

[15] Note that presented DS to the agent is not necessarily the real DS but might be one number too high or one too low, mirroring the exact same decision situation as in the experiment.

[16] More details regarding the simulation can be found in Appendix II.

bank changes to "6" even if no agent withdraws because of the changing macroeconomic situation alone. Simulations with purely rational agents therefore predict a default in Period 13.

4 Hypotheses

We have discussed earlier that bank runs are often considered mainly as the result of bad fundamentals or a coordination failure. We first test if subjects are acting according to the macroeconomic situation only. If they do, the bank should, as has been shown in the simulations, always default exactly in period 13, assuming reasonable levels of risk aversion and rational behavior. If the bank survives longer or shorter than period 13, than either coordination or irrational panic are also factors influencing withdrawal behavior. We formulate our first hypothesis as follows:

Hypothesis I: Information regarding the state of the economy is the only factor influencing withdrawal behavior. The bank always defaults in Period 13.

In a second step, we add the possibility to actively communicate, which could be of help for the coordination of depositors. Therefore, with Hypothesis II, we test if communication between the subjects allows for (better) coordination and lower withdrawals:

Hypothesis II: The possibility to communicate slows down the propagation of a panic: depositors withdraw less on average, and a bank run happens later or not at all.

Next, we analyze driving factors of subjects who do actually withdraw. To this end, we consider another subset of data and look into withdrawal/deposit transactions. We test if (a) the current situation about the liquidity of the bank, (b) the amount of deposited money not covered by deposit insurance, (c) gender influences and (d) cultural backgrounds explain withdrawal behavior. We conduct experiments with gender-mixed groups in two different regions: Russia and the German-speaking area (Austria and Liechtenstein). Only for the reason of brevity, we refer to subjects from that area as "German subjects" or "Germans". We expect increasing liquidity problems and higher uninsured deposits to increase withdrawals because they obviously increase risk. It is an often-observed finding in financial decision making that women behave more risk aversely than men. We therefore expect them to withdraw more and to do so more often. As far as cultural differences matter, we apply the widely known theory of Hofstede (2011) who defines six main dimensions of culture. We will consider one of the dimensions, which we believe to be applicable, called 'uncertainty avoidance index', which shows how much people try to avoid uncertainty in their daily lives. The score is significantly higher for Russia (95 out of 100) than for Austria and Germany (51, 65 correspondingly). Thus, we expect that Russian subjects will withdraw more than German-speaking subjects and be less trustful of the banking system. We formulate the following hypotheses:

Hypothesis IIIa: Increased liquidity problems of the bank trigger higher withdrawals.
Hypothesis IIIb: The larger is the uninsured part of a deposit, the bigger is a withdrawal.
Hypothesis IIIc: Women withdraw more and more often than men.
Hypothesis IIId: Russians withdraw more and more often than Germans.

5 Results

5.1 Sample Analysis

The age of subjects lies between 18 and 41, with an average of 23 years. Most of the subjects (78%) are students specializing in economics/business. The total number of German subjects (GS) and Russian subjects (RS) is 80 each. More than half of the total sample (56%) consists of male subjects. German subjects are more balanced with respect to gender: nearly half of their total number (45%) are men, whereas more than 60% of Russians (68%) are male (see Table 5). There is no clear evidence that subjects of a specific culture or gender significantly outperform others across markets. The final payoffs vary, although not significantly (see Table 6).[17]

Table 5: Gender distribution of GS and RS sub-samples

Gender	GS	RS	Total	Percent
Male	36	54	90	56.25%
Female	44	26	70	43.75%
Total	80	80	160	100%

5.2 Hypothesis I

We analyze whether information regarding the state of the economy is the only factor influencing withdrawal behavior. Table 7 reports the periods in which banks defaulted for

[17] For a balanced comparison of treatments, the payoffs in euro and rubles are adjusted with the purchasing power parity.

Table 6: Average Final Payouts

	Male		Female		Average	Minimum
	Chat	Non-chat	Chat	Non-chat		
GS (Euro)	14.7	15.1	16	13.8	14.9	8
RS (RUB)	477.2	475.6	358	452.0	424.9	180

each market. If hypothesis I were true, we would expect the bank in the no-communication treatment (*Non-chat*) to survive until Period 13, assuming reasonable levels of risk aversion. Focusing on the *Non-chat* column, we see that this is not the case in five out of eight markets. Thus, we find some evidence that information regarding the state of the economy is not the only factor influencing withdrawal behavior.

Table 7: Periods in which the bank defaults

	Period of default	
Culture	Chat	Non-Chat
RS	13	13
RS	13	12
RS	13	12
RS	13	7
GS	no (15)	13
GS	13	13
GS	13	12
GS	14	8
Average	**13.38**	**11.25**

The same conclusion can be reached by analyzing the average amount and number of withdrawals for non-chat sessions.[18] As seen in Figure 1 and Figure 2, changes in the number and size of withdrawals in the non-chat treatment do not usually correspond to fluctuations of the economic factor. The correlation coefficient between the number of withdrawals and the value of the economic factor is 0.07. The average size of withdrawals is related to the value of the economic factor only in first half of the game (0.79). Starting from Period 9, the correlation between these two indicators becomes negative and much lower (-0.18). These findings provide additional evidence that subjects' withdrawals are not caused solely by fundamentals. They are also driven by subjects' expectations of

[18] The average number of withdrawals per period per chat/non-chat session is calculated as the total number of withdrawals in corresponding sessions divided by their number. The average amount of withdrawals per period per chat/non-chat session is calculated as the sum of all withdrawn amounts in corresponding sessions divided by the number of sessions. We take into account that sessions ended in different periods; thus, in our calculation, only sessions that reached a specific period were considered.

Figure 1: The Average Number of Withdrawals

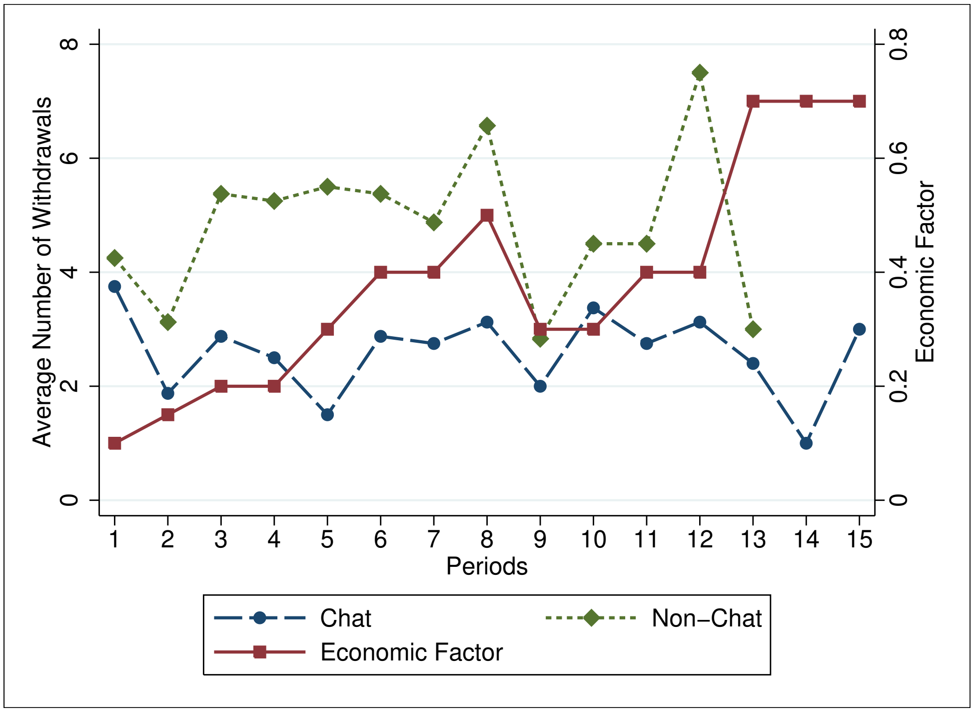
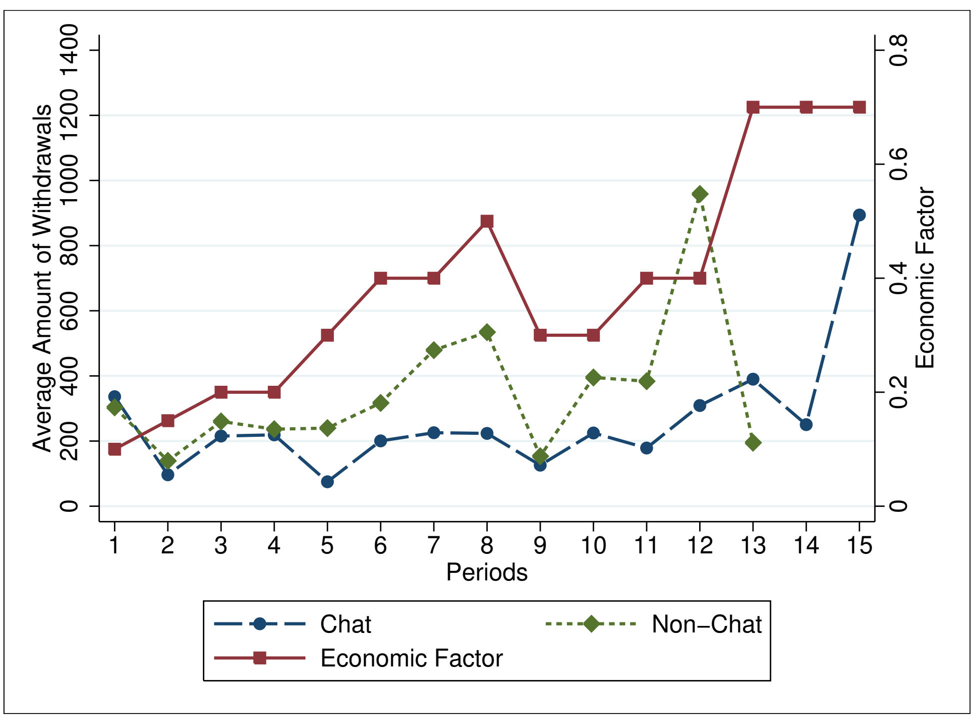


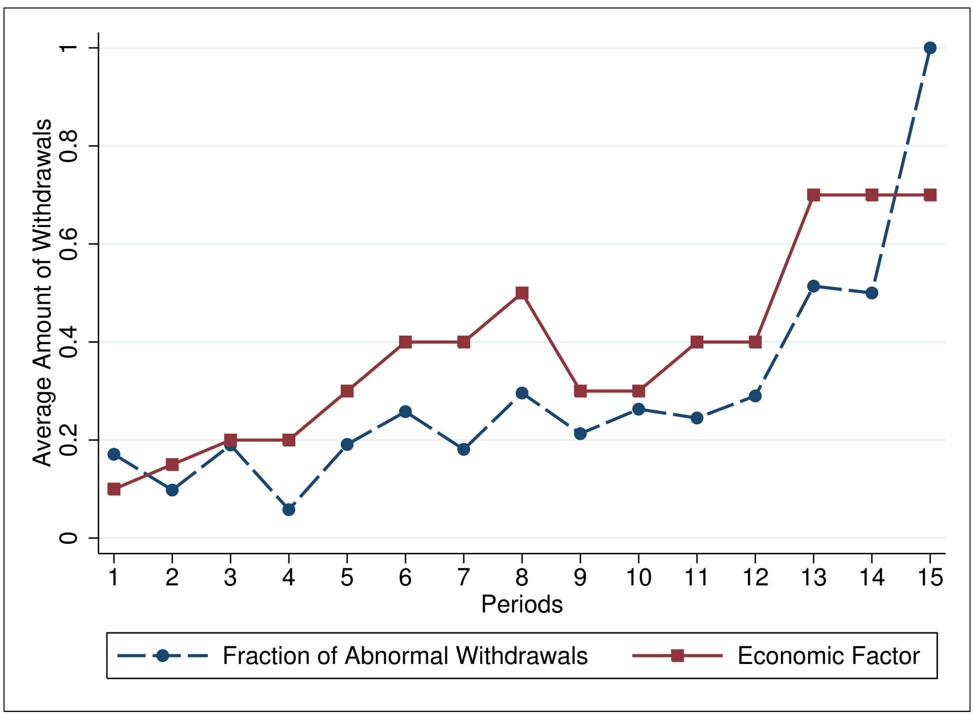
Figure 2: The Average Amount of Withdrawals



others being irrational or by their own irrational behavior. Thus, we reject the first hypothesis.

Besides that, we analyze the fraction of panic-driven withdrawals. We assume that abnormal withdrawals are such that a subject withdraws even parts of the deposit that are protected by deposit insurance, which is not rational, independent of the bank's fundamentals. We calculate the fraction of abnormal withdrawals in the total number of withdrawals and take it as a proxy of irrational behavior. Figure 3 shows that, after Period 10 there is a large growth in the fraction of abnormal withdrawals: it is 0.18 on average before Period 11, but significantly larger (0.27) for the remaining periods.[19] All these findings are an additional evidence that the economy is not the only factor influencing withdrawal behavior; this behavior is also driven by panics or poor coordination among depositors. It shows that panic bank runs exist, which goes hand in hand with the results of (Kiss et al. (2018)), who claim that panic bank runs may occur even in the absence of problems with fundamentals.

Figure 3: The Fraction of Abnormal Withdrawals



Result I: We find that not only fundamentals, but also panicking influences withdrawal decisions. The fraction of panic-driven withdrawals increases when economic conditions get worse.

[19] We check it with the help of the Wilcoxon signed-rank test. The result is significant at 5% level.

5.3 Hypothesis II

Looking at Table 7 again, we find that in sessions with the possibility of communication, the bank survives longer[20] on average, even for more than 13 periods. As shown in Figure 2, the largest withdrawals for non-chat sessions happen in Period 12, whereas for chat sessions, the largest withdrawals occur in Period 13, which explains why in the non-chat treatment, the bank defaults earlier. We conclude that not only the macroeconomic situation but also the coordination between subjects influences withdrawal behavior. In non-chat sessions, the average number and amount of withdrawals are always not less than those in chat sessions (see Figure 1, Figure 2). Thus, communication seems to have a positive influence, causing fewer withdrawals and runs.

An alternative explanation could be that chat treatments may have fewer withdrawals – and therefore fewer runs – due to a time constraint, as subjects could be occupied by typing messages and thus do not have enough time to withdraw. In fact, subjects do not type that much – around three words on average – and thus, chatting is not time consuming. Additionally, withdrawing is very easy. Only a few seconds are needed to type the amount to be withdrawn and to click enter. Thus, we do not believe that time limitations drive our results.

Result II: The possibility of communication among depositors has a positive effect leading to fewer withdrawals and runs.

In the following sections, we attempt to analyze how the chat opportunity enhances coordination. To this end, we will analyze the mood of messages, the ratio of positive to negative messages and their timing.

5.3.1 Positive and Negative Messages

We investigate whether and how the mood of communication influences withdrawal behavior. All messages are grouped into three categories: negative, neutral and positive. The evaluation has been performed subjectively by the authors by analyzing the chat protocols.[21] For example, a message such as 'There is no reason to withdraw' is considered to be positive, whereas a message such as 'I want to withdraw' is evaluated as negative. If a message lacks any mood or is not related to the game, such as 'How are you?', it is

[20] The difference is significant, tested with a Mann-Whitney-U-Test at the 5% level.

[21] The evaluation has been performed independently by each of the authors and the results were discussed to avoid any possible disagreements.

assessed to be neutral. We consider only positive and negative messages for the analysis. Additionally, these messages are called "early", "mid" and "late" depending on whether they happen in the first, second or third 20-second intervals, respectively.

Table 8 shows that subjects send more positive than negative messages during the experiment, with the number of positive messages being two times greater on average than the number of negative messages. German subjects are more active and chat approximately 80% more than Russian subjects.

Table 8: Distribution of positive and negative messages with respect to time

	GS	RS	Total	GS	RS	Total
	Positive Messages			Negative Messages		
Early	54	28	82	25	15	40
Mid	44	32	76	27	11	38
Late	30	14	44	19	10	29
Total	128	74	202	71	36	107

We also analyze how the number of positive and negative messages sent in a period affects withdrawal behavior. There are two ways withdrawals can change. One is the size (volume) of withdrawals, and the other is the number of withdrawals. We analyze them while controlling for the average DS per period as a proxy for the bank's liquidity status. We formulate the models in Equation 2 with *Av. Withdrawal Size*$_t$ in one period t being the dependent variable (Y_t). *Av. Withdrawal Size* is the sum of all withdrawals and deposits within a period divided by their number.

$$\mathrm{Y}_t = \alpha + \beta_1 \times \text{Positive\_Messages}_t + \beta_2 \times \text{Negative\_Messages}_t + \beta_3 \times \text{DS\_Average}_t + \mathrm{u}_t \tag{2}$$

,where *Positive (Negative)_ Messages* is a dummy variable which is equal to 1 when the number of positive (negative) messages in that period is greater or equal to 3 and equal to 0 otherwise[22]; *DS_ Average* is the average DS in that period.[23]

Table 9 reports that having more than 3 positive messages per period leads to lower sized per period withdrawals than otherwise. The same conclusion does not hold for negative

[22] We found that a threshold of 1/2 messages per period is not critical, whereas sending more or less than 3 messages has an effect on withdrawals.

[23] We use clustered standard errors on the period level for all regressions throughout the paper.

Table 9: The influence of messages on withdrawal behavior

	Av. Size of Withdrawal
Constant	−9.142
	(19.986)
Positive_Messages	−39.057**
	(16.012)
Negative_Messages	6.933
	(18.654)
DS_Average	16.023*
	(7.467)
Observations	103
R^2	0.208
Adj.R^2	0.184
Prob > F	0.003

Note: *p<0.1; **p<0.05; ***p<0.01

messages: sending more or less than 3 messages per period does not have a significant effect on withdrawals. Obviously, chat does more good than harm and therefore helps depositors to coordinate their actions.

Result III: The possibility to chat allows depositors to coordinate their decisions. The mood of conversation matters - having more than 3 positive messages per period leads to lower sized per period withdrawals than otherwise. Although, the same conclusion doesn't hold for negative messages.

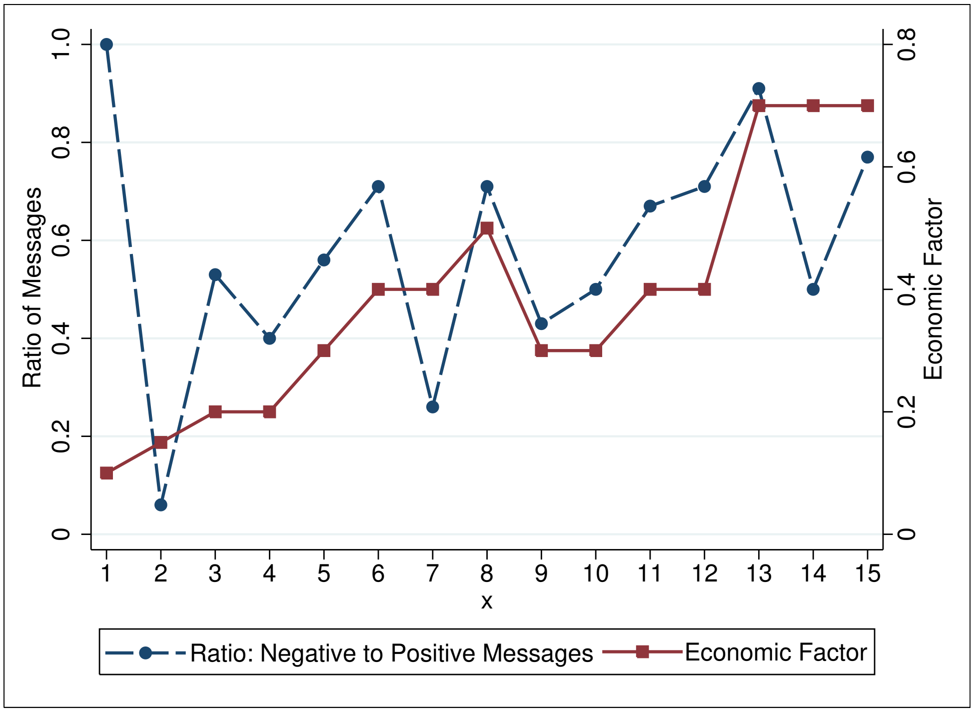
5.3.2 Message Ratio

Naturally, one would expect that as the ratio of negative to positive messages during a session increases, the probability of withdrawals or a default increases. Figure 4 plots the ratio of messages (defined as the total number of negative messages divided by the total number of positive messages sent within a period) and the economic factor. We find that once the messages' ratio approaches one (Period 13), meaning that there are as many negative as positive messages, 9 of 16 banks run into default (see Table 7).

Thus, we conclude that the mood of conversation predicts withdrawal behavior to some degree and may be a signal of upcoming withdrawals. However, as we found earlier that there is no general relationship between negative messages and withdrawals, this finding should be treated with caution.

It seems natural that the mood of conversation is potentially related to the economic conditions. As one can see from Figure 4, subjects are more negative than positive in their discussions when the economic situation becomes worse. In general, the relative mood of chatting is quite responsive to changes in the economy: in 8 out of 16 periods there is a co-movement of the ratio of messages and the economic factor.

Figure 4: The ratio of messages and the economic factor



Result IV: The mood of communication is sensitive to changes in economic conditions and may be a signal of upcoming withdrawals: once the ratio of positive to negative messages approaches one, withdrawals increase sharply.

5.3.3 Messages and Time

Looking again at Table 8, we find that the most chat activity occurs during the first 40 seconds, when subjects discuss information about the current economic conditions, the current DS and what to do in that period. The fewest messages are sent during the last 20 seconds of a period. This finding is another piece of evidence that subjects evaluate the situation as a coordination game problem based on the current market conditions. In Table 10, we report withdrawals in the same logic by grouping them into (i) early withdrawals (during the first 20 seconds of the period), (ii) mid withdrawals (between 20 and 40 seconds) and (iii) late withdrawals (after 40 seconds). As you can see, in chat treatments, people talk mainly at the beginning while they withdraw mainly at the end of the period. It makes us think that people first discuss (if they can) and decide later on about withdrawals, although this conclusion seeks additional experimental evidence.

Comparing the frequency of withdrawals for chat and non-chat treatments, we find it to be much higher for non-chat markets.[24] In non-chat treatments a subject withdraws 10 times per period, whereas in chat treatments it happens only 6 times on average. A tentative explanation of such behavior is that people face more uncertainty when they do not know the opinions of others, leading them to overreact when it comes to withdrawals. While in non-chat treatments, withdrawals are comparable over the first, second, and last 20 seconds, the amount of early withdrawals is much lower than the amount of mid and late withdrawals in chat treatments. This change in behavior points at the importance of the coordination aspect. The absence of communication leads to higher levels of uncertainty, creating more tension in the market as a result. We find no significant difference between the frequency of withdrawals for German and Russian subjects[25], even though German subjects withdraw money from the bank in the middle of a period, while Russian subjects withdraw mostly at the end.

Table 10: Distribution of withdrawals with respect to the time of a withdrawal

	Chat	Non -Chat	GS	RS	Total
	Total number of withdrawals				
All	277	435	361	351	712
Early	58	122	101	79	180
Mid	95	147	140	102	242
Late	124	166	120	170	290

5.4 Hypotheses III

We analyze how the current economic situation of the bank, the personal characteristics of a subject and market mood explain the size of withdrawals. To this end, we use OLS regressions, with the log of withdrawal size, number of withdrawals, number of abnormal withdrawals as dependent variables. The three dependent variables are each measured on the deepest level of data available. While the size of one withdrawal can be measured with

[24] This conclusion is based on the results of Mann-Whitney-U-test and is significant at 1% level.
[25] We make this conclusion based on the results of Mann-Whitney-U-test.

one withdrawal as one separate observation, the number of (abnormal) withdrawals can be measured only on a per-subject per-period level. We formulate two regression equations – one for the withdrawal size and one for the number of (abnormal) withdrawals:[26]

$$\begin{aligned}\text{Log Withdrawal Size}_i = \alpha + \beta_1 \times \text{Cur. Default Score}_i + \beta_2 \times \text{Log Uninsured}_i \\ + \beta_3 \times \text{Male}_i + \beta_4 \times \text{German}_i + \beta_5 \times \text{Chat} + \text{u}_i \quad (3)\end{aligned}$$

Here, *Log Withdrawal Size*$_i$ denotes the log of the size of a withdrawal of a subject i, *Cur. Default Score* denotes the DS shown to the subject i immediately before the moment of withdrawal, and *Log Uninsured*$_i$ denotes the log of the amount of money not covered by the deposit insurance in a subject's account immediately before withdrawal. *Male* and *German* are dummy variables that are 1 when a subject is male and German; *Chat* is a dummy variable indicating treatments in which chat was allowed.

$$\begin{aligned}\text{Num.Ws. (Num.Ab.Ws.)}_i = \alpha + \beta_1 \times \text{Average Default Score}_i + \beta_2 \times \text{Male}_i \\ + \beta_3 \times \text{German}_i + \beta_4 \times \text{Chat} + \text{u}_i \quad (4)\end{aligned}$$

Here, *Num.Ws. (Num.Ab.Ws.)* is the count of (abnormal) withdrawals of subject i within a period, and *Average Default Score* is the equally weighted arithmetic mean of the Default Scores during the period. All other variables are equally derived as in Equation 3. The results for the regressions from Equations 3 and 4 are displayed in Table 11.[27]

Regarding withdrawal size, we test several models, numbered (1) to (4). When first looking at model (4), we find that an increase in the DS by "1" leads to an increase of the size of a withdrawal by roughly 14%. When the amount of deposit not covered by insurance grows by 1%, withdrawals correspondingly grow by 0.5%. Looking at the other models and their corresponding R^2, we find that the main increase in explanatory power comes from the amount of money uninsured. It appears that the amount of money at risk is the main trigger for withdrawals. This finding highlights the importance of strong deposit insurance systems for system stability. Thus, we cannot reject Hypotheses IIIa

[26] We use the same model specification to analyze the number of withdrawals and the number of abnormal withdrawals

[27] We check for correlation between independent variables for all regressions. It is always less than 0.25.

Table 11: Driving factors of individual withdrawal behavior: all sessions

Dep. Var.:	*Log Withdrawal Size*				*Num.Ws.*	*Num.Ab.Ws.*
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	3.378***	0.916***	0.688***	0.927***	1.145***	1.189***
	(0.110)	(0.169)	(0.142)	(0.195)	(0.059)	(0.187)
Cur. Default Score	0.087*	0.148**	0.147**	0.142**		
	(0.040)	(0.042)	(0.042)	(0.042)		
Av. Default Score					0.008	0.040
					(0.019)	(0.087)
Log Uninsured		0.487***	0.510***	0.514***		
		(0.029)	(0.026)	(0.030)		
Male			0.337**	0.429***	−0.045	−0.326**
			(0.083)	(0.084)	(0.039)	(0.101)
German				−0.470***	0.184***	0.333***
				(0.088)	(0.041)	(0.079)
Chat	0.232	0.308*	0.312*	0.196	−0.126	−0.207
	(0.122)	(0.114)	(0.121)	(0.131)	(0.047)	(0.121)
Observations	712	687	687	687	602	362
R^2	0.016	0.179	0.195	0.227	0.054	0.153
$Adj.R^2$	0.013	0.175	0.190	0.221	0.048	0.143
Prob > F	0.007	0.000	0.000	0.000	0.002	0.005

Note: *p<0.1; **p<0.05; ***p<0.01

and IIIb regarding the withdrawal size. Looking at the number of withdrawals, we find no effect of the DS. We refrain from testing the average amount of money that is not insured, as this measure does not provide a good proxy for money at risk when averaged.

Table 11 also shows that the size of withdrawals for male subjects is 43% higher than for females. We find no statistically significant effect on the number of withdrawals. However, when we simply count the frequency of withdrawals, we find that women on average withdraw 44% more often than men.[28] Besides that, we find that the number of abnormal withdrawals is lower for men than for women (see Table 11). Thus, there is some evidence that women withdraw more quickly as well as irrationally but in smaller amounts, while men tend to wait to make a decision but then withdraw more at one time. We therefore report mixed evidence regarding Hypothesis IIIc and find that women withdraw less money but do so more often.

Hypothesis IIId states that Russians withdraw more and more often. Indeed, we find that the size of withdrawals by Germans is lower than that of Russians. However, looking at the number of withdrawals, we see that Germans withdraw more often than Russians and the same holds for the frequency of abnormal withdrawals. Therefore, again, we report mixed findings that Russians withdraw more money but less often, we find only partial support for Hypothesis IIId. As far as we do not find clear evidence for one or another group of subjects withdrawing smaller amounts and less frequently, we suggest this topic for future research. We believe that policymakers and banks would be interested in knowing what kind of depositors depletes the liquidity of the bank more slowly.

Result V: The size of withdrawals for male subjects is higher than for females. There is no evidence of a gender effect on the number of withdrawals. However, women make abnormal withdrawals more often than men. Besides that, women withdraw more quickly but in smaller amounts, while men tend to wait to make a decision but then withdraw more at one time. Russians withdraw more money, but less often then Germans.

6 Conclusion

We use an experiment to analyze the withdrawal behavior of bank depositors during times of economic crises. We make a strong case for the use of an experimental approach with higher external validity to analyze withdrawal behavior during times of economic crisis. The approach we offer allows for strategic behavior and communication and therefore

[28] On average, each woman withdraws 5.1 times in a market session and every man 3.6 times.

increases the set of possible strategic moves (e.g., waiting, reacting to others, contacting peers, etc.), which are also available in reality. We provide a benchmark simulation to compare the behavior of the subjects in the experiment to what we believe to be rational behavior.

In a nutshell, we find that information regarding the state of the economy is not the only factor to influence withdrawals. Subjects do take the macroeconomic situation into account, but coordination also plays a big role. In general, communication helps to slow down withdrawals, much depending on the mood of it. We find no significant evidence that negative messages may cause higher individual withdrawals, but strong evidence that many positive ones lead to smaller average withdrawals per period. We show that an increase in the liquidity problems of a bank (a higher DS) and a larger share of deposits not secured by deposit insurance trigger withdrawal behavior by increasing withdrawal sizes. We conclude that deposit insurance is a powerful instrument to decrease withdrawals in times of crisis. Interestingly, women make (abnormal) withdrawals more often than men but withdraw smaller amounts. Regarding cultural differences, we can report only preliminary exploratory results. We find that Russians withdraw higher amounts but less often than Germans.

Our analysis contributes to the understanding of withdrawal behavior, but further research is needed. We believe it is important to study how cognitive and cultural characteristics of depositors trigger withdrawals to understand what type of depositors depletes the liquidity of a bank more slowly.

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Appendix I - Experimental settings

The Balance Sheet of the Bank

Liabilities: Focusing on the liabilities first, we distinguish between deposits into subjects' deposits and other deposits. Only subjects' deposits are controlled by the subjects of the experiment. Other deposits are (virtual) loyal depositors of the bank, are not under subjects' control, and can therefore not be withdrawn by subjects. This information is needed to balance the experiment by decreasing the influence of a single depositor on the solvency of the bank. The capital of the bank consists of common shares and retained earnings. The amount of the bank's capital is based on existing Basel III regulations (Cournede and Slovik, 2011), and the 2015 amount of common equity must be set at a minimum level of 4.5% of all risk-weighted assets, while the amount of total capital should be at least 8% of all risk-weighted assets.

Assets: According to the Banking Commission on Basel Supervision (BCBS), there are two main approaches for the calculation of assets weighted with risk: the standardized approach (SA) and the internal rating-based approach (IRB approach). SA uses external credit ratings to define risk-weights for each of the asset classes, whereas IRB is based on a bank's own estimations. Each calculation method of risk-weighted assets has its advantages and disadvantages. On one hand, the IRB approach has a good level of sensitivity, allowing the necessary amount of capital to be calculated more precisely. On the other hand, the implementation of the IRB approach is potentially difficult because the method assumes the availability of sufficient historical data to make estimations. We calculate risk-weighted assets based on the various credit risk parameters of the IRB approach and the SA. The risk-weights for the assets of the bank are shown in Table 12.

Table 12: Risk weights for different asset classes

Asset	Risk-weight (%)
Cash	0
Short-term loans	75
Long-term loans	75
Government Debt Securities	30
Corporate Debt Securities	30
Property and Other Assets	17

Bank Operations During the Experiment: A bank's balance sheet changes from period to period in accordance with its activities. The bank performs the following operations every period:

- **Provides long-term loans:** Long-term loans are kept on a bank's accounts for longer than one period. At the end of each period, 50% of the received interest is turned into cash that the bank keeps. The other 50% are paid out to the hypothetical shareholders of the bank. Thus, the principal amount of long-term loans remains constant during the experiment.

- **Provides short-term loans:** Short-term loans have a maturity of one period. At the end of a period, 50% of the interest gained is kept to be reinvested in short-term loans in the next period. The bank extends its loans during the game. The other 50% are kept as cash by the bank.

- **Invests in government and corporate debt securities:** Investments in government and corporate debt securities are done every period. The interest income gained from these securities is not reinvested but paid out to the hypothetical shareholders.

- **Invests in property and other assets:** At the beginning of the game, the bank already has some real estate. During the game, we assume that there are no operations with these types of assets, so their value remains constant throughout the experiment.

- **Pays dividends to bank shareholders:** These are calculated as the sum of interest earned over the period on all securities and 50% of interest income earned over the period on long-term and short-term loans.

Liquidity Coverage Ratio Calculation

The LCR is calculated as follows:

$$\text{LCR} = \frac{\text{Stock of High-Quality Liquid Assets}}{\text{Total net cash outflows over the next 30 calendar days}} \tag{5}$$

High-quality liquid assets (HQLA) consists of three main groups: Level 1, Level 2 (A) and Level 2 (B) assets. Each of the HQLA are weighted with a special factor that defines how easily an asset can be converted into cash in order to cover losses. Level 1 assets can be fully transferred into cash. Level 2 (A) assets must be weighted with the factor of 85%, while a maximum 75% and minimum 50% of Level 2 (B) assets can be considered for LCR calculations. We consider cash to be a Level I asset (Factor: 100%), government debt securities in which the bank invests as Level 2 (A) (Factor: 85%), and assets and corporate debt securities as Level 2(B) (Factor: 50%). Taking into account the balance sheet structure of the bank, the formula for HQLA calculation is

$$\text{HQLA} = \text{Cash} + \text{Government Debt Securities} \cdot 0.85 + \text{Corporate Debt Securities} \cdot 0.5 \tag{6}$$

All other assets are considered to be the main source of cash inflows. According to BCBS regulations, double counting is not permitted on LCR, so if an asset is considered part of the "stock of HQLA," then it cannot be a source of cash inflows at the same time. The bank also has cash outflows at the end of every period with the interest payments on deposits.

All deposits with a maturity of less than 30 days can be divided into three main groups: stable deposits that meet additional criteria, stable deposits and less stable retail deposits. The main difference between stable and less stable deposits is that stable deposits are covered by insurance, whereas less stable deposits are too large to be covered by insurance. Therefore, if a deposit is larger than the deposit insurance, the part of it that is covered is considered stable, while the remaining part is unstable. LCR regulations weight them with specific factors of 5% and 10%, respectively. Unstable deposits are considered more likely to be withdrawn because they are not covered by insurance and people are more afraid of losing this part of their money in the case of default. Thus, total net cash outflow (TNCO) over the next 30 calendar days is calculated as described in Equations 7, 8 and 9:

$$\text{Total Cash Inflow over the next 30 calendar days (TCI)} = \text{SL} \cdot \text{r}_{sl} + \text{LL} \cdot \text{r}_{ll} \tag{7}$$

, where SL is the amount of short-term loans and LL for long-term loans and r_{sl} - monthly for the interest rate on short-term loans and r_{ll} - for long-term loans.

$$\text{Total Cash Outflow o.t.n. 30 cal. days (TCO)} = \text{Stable Part} \cdot 0.05 + \text{Unstable Part} \cdot 0.1 + \text{Other Deposits} \cdot 0.03 \tag{8}$$

$$\text{Total Net Cash Outflow o.t.n. 30 cal. days (TNCO)} = \text{TCO} - \min(\text{TCI}; 75\% \cdot \text{TCO}) \tag{9}$$

Some deposits (other deposits) are made by loyal clients and are likely not to be withdrawn at all. We assume that these deposits are kept in transactional accounts. For this reason, a percentage of monetary withdrawals will be on the low side:- 3%. These other deposits do not belong to the subjects and cannot be withdrawn or re-deposited by them. See Table 13 for a detailed overview of initial deposits.

Table 13: Initial deposited amounts at the beginning of the experiment

Before Withdrawal		Stable Deposit 5%	Less Stable Deposit 10%	Other Deposits 3%
Deposit 1	200	80	120	
Deposit 2	100	80	20	
Deposit 3	350	80	270	
Deposit 4	300	80	220	
Deposit 5	200	80	120	
Deposit 6	250	80	170	
Deposit 7	300	80	220	
Deposit 8	250	80	170	
Deposit 9	200	80	120	
Deposit 10	250	80	170	
Other Deposits	3270			98.11

Interest earnings gained from credit holders are considered cash inflow, whereas interest payments on deposits are cash outflow. Interest income on securities and cash are HQLA that play the role of "liquidity buffer" and can be used in the case of liquidity problems.

Calculating LCR allows an estimation of whether the bank has enough HQLA to meet its short-term liquidity needs. This information is reflected in the DS that is visible to subjects during the game.

Procedure to pay out depositors withdrawing deposits: The first asset class used by the bank to make payments to the depositors is cash. If the bank runs out of cash but withdrawals continue, it begins to sell Level II assets (first government debt securities, then corporate debt securities) to meet its obligations. If the amount of HQLA becomes less than that of TNCO, the bank has reached the point of bankruptcy. At the beginning of each period, the LCR is recalculated based on the amount of HQLA kept at the respective moment in time. It is important not only to adjust LCR at the beginning of each period but also to recalculate all balance sheet items in case some changes had occurred by the end of the previous period (for instance, accumulation of interest).

Appendix II - The details of the simulation

The proposed theoretical model has been simulated in MatLab. For each critical Default Score level, the simulation model has been run 100 times. For the simulation, we assume that if a player withdraws, he/she withdraws only the part of a deposit that is not covered by the deposit insurance as far as an insured amount is guaranteed in any case. In our theoretical model, players have an unlimited number of attempts within a period to withdraw/re-deposit the money. However, in our simulation, we assume that the maximum number of attempts is equal to three for several reasons. The first is time constraints, as it takes time to make a decision. The second reason is that the interest earned on a deposit becomes negligible if the number of attempts to keep/withdraw grows, thus making it unreasonable to decide too often. All other assumptions of the model not mentioned above, and the values of the parameters are kept as they are in the theoretical model.

Appendix III - Experimental instructions (translated)

Dear participant!

We would like to warmly welcome you to this experiment. From now on, you are asked not to speak to anyone except the tutors. If you have a question, please raise your hand and wait at your seat until a tutor approaches you. Please read carefully all the information provided below, as it is important for participation in the experiment.

Background information

In the experiment, a bank exists that, on one hand, keeps deposits of clients and, on the other hand, provides loans and holds securities. You are a depositor at the bank, so you must decide if you want to deposit money at the bank or not and if you do deposit, how much. It is your decision whether to keep money or to take it from the bank.

The bank

The bank is controlled by the computer and operates automatically. It receives deposits from clients and pays interest on these deposits. It also provides short- and long-term loans to other clients (not you) and invests in government and corporate debt securities, receiving interest payments for these activities. The bank operates for 12 to 17 periods. The experiment stops randomly after one of these periods, and all periods (12-17) have the same probability of being the last one. If the bank fails to meet its obligations to clients at any point during the experiment, it must default (more on this later). The decision phase in each period is 60 seconds long.

Actions of the participant

You and all other subjects each hold an account as a depositor at this bank. At the beginning of the game, all of your money is in the bank account. Your goal is to maximize your wealth at the end of the experiment. You increase your wealth by earning as much interest as possible. It is now your decision whether to keep all or part of the money in the account or to withdraw it from the bank. At the end of each period, you will earn an interest payment, which is calculated based on the amount deposited, the time that it was in the account during the period and the current interest rate. In other words, if you decide to withdraw money from the account during the period, you will earn an interest payment only at the end of the period proportional to the time you had the money in the account. The interest rate on your deposits will change from period to period. The current interest rate will always be provided on the screen. Non-deposited money also earns a very small, risk-free interest payment proportional to the time this amount was not kept in the bank during the period. However, the risk-free interest rate is substantially lower (i=0.1%) than the initial rate on the deposit. At the end of each period, both types of interest are added to your deposited money. The more money (deposited and not-deposited added together) you have at the end of the experiment, the higher your real payment.

Potential bank default

It is possible that in specific situations, the bank is not solvent enough to cover all of its obligations. This case is especially true in unfavorable economic situations where many depositors simultaneously withdraw a lot of money. Therefore, whether the bank defaults or not depends on the actions of all depositors and on economic factors, which influence the bank in such a way that it loses liquidity and may run into financial troubles. In this case, the Default Score (described below) increases. However, as long as the bank does not default, it will be able to fully pay its obligations, especially the interest payments on deposits, regardless of how high the Default Score is. If a default occurs, all the money that is currently deposited is lost, except for some part (max. 80 units of money) that is insured against bank default. (Note: you can see how much is insured on the decision screen). Therefore, as long as the bank is still in operation, each depositor earns the interest payments, but once the bank defaults, you lose the entire amount currently deposited (!), except for the insured part of it, and the game is over.

The information screen

To reach a decision on how much money you want to deposit, you can use the information provided to you at the beginning of each period and the information provided during the period. On the screen below, you can see how the information is provided at the beginning of each period. You receive information about the current economic situation that the bank is operating. This situation has an influence on the bank's assets and therefore influences the "health" of the bank. Information from the previous periods is repeated in the lines to provide an overview of economic development.

The decision screen

On this screen, you are provided with several pieces of information and the possibility to deposit and withdraw money. In each period, this screen is shown for 60 seconds. In the top window, you can deposit and withdraw money. You can withdraw only the amount that is left in the deposit account, and you can deposit only money that has not been deposited yet.

The information provided covers

Figure 5: Screen 1 Macroeconomic Information for the upcoming period

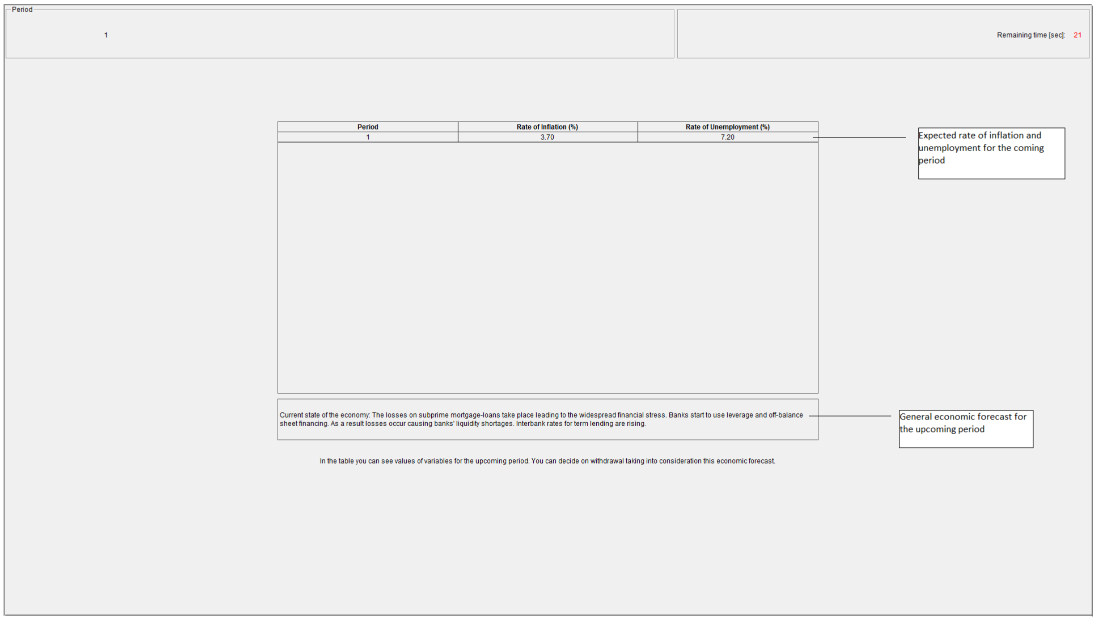
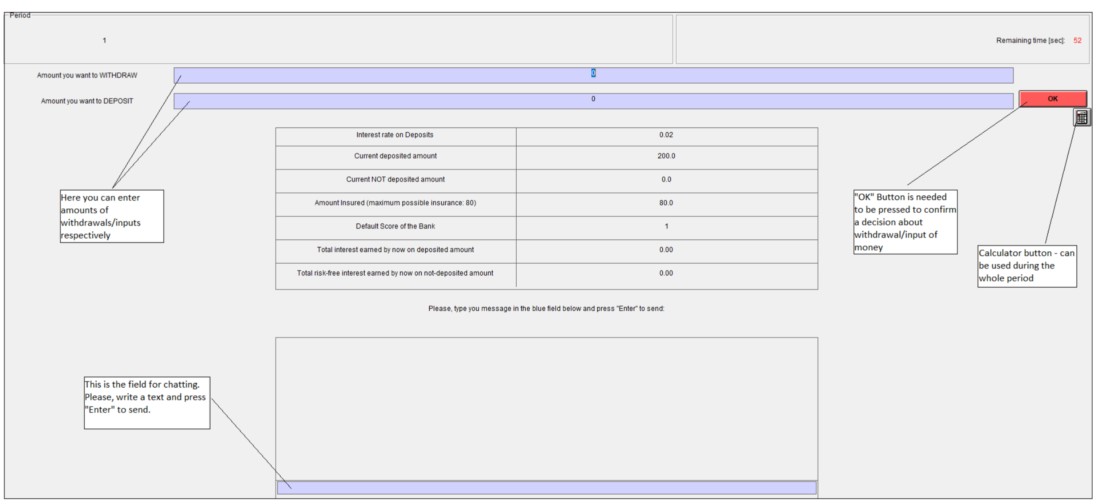


Figure 6: Screen 2 Decision Screen



Interest Rate on Deposits - interest rate on deposits for the current period.
Current Deposited Amount - amount of money kept in the bank at this moment.
Current Non-Deposited Amount - amount that you can still add to the amount in your account.
Amount Insured - amount that will be returned to you by the bank if it defaults. The maximum amount insured is 80.
Interest Earned by Now - amount that you have earned in the previously elapsed periods of the game on the deposited amount of your wealth (in units).
Total Risk-Free Interest - amount that you have earned in the previously elapsed periods of the game on the non-deposited amount of your wealth (in units)
The Current Default Score - how financially stable the bank is at the current moment using a number between 1 and 8. As the Default Score increases, the risk that the bank will not be able to pay back its liabilities increases. If the Default Score is equal to 8, the bank is already in default or very close to it. Once the bank has defaulted, no additional transactions will be executed, and the experiment stops at the end of the period.

Important: The default score shown to you is only an estimation of the real situation of the bank. The estimation is correct most of the time but has a random error with a mean of 0 and a standard deviation of 0.5. This figure means that in 65% of all cases, the estimation is correct. In all other cases, it is either one number too high or one too low (e.g., 5 or 7 instead of a 'real' 6). Each subject receives his/her own independent estimation. During the period, you can withdraw and deposit money as much and as often as you want.

Communication with other subjects is possible via the chat box. You can see the messages of all other depositors, and they can see all of yours.[29]

The end of the game and your final profit (for Russian players)
The game randomly ends between periods 12 and 17 with the same probability or when the bank defaults. Your payout in rubles will be calculated using the following rule:

*400 rubles + (% change in wealth) * 12*

*% change in wealth = 100 * (FinalWealth - InitialWealth) / InitialWealth*

where:
Final Wealth = Deposited money and non-deposited money at the end of the experiment,

[29] Communication was possible only in chat treatments. The instructions of non-chat treatments made clear that any kind of communication is forbidden.

including all interest payments
or in the case of bank default:
Final Wealth = Deposited insured money and non-deposited money at the end of the experiment
The minimum payment is 180 rubles.
Example 1: *Initial Wealth was 100. At the end, the Final Wealth is 114 % change in wealth = 100 * (115 - 100) / 100 = +15%*
Payment = 400 rubles + 12*15= 580 rubles
Example 2: *Initial Wealth was 100. At the end, the Final Wealth is 95 % change in wealth = 100 * (95 - 100) / 100 = -5%*
Payment = 400 rubles - 12*5 = 340 rubles

The final profit (for German players)

Your payout in euros will be calculated using the following rules:

15 Euro + (% change in wealth) / 3.5

*% change in wealth = 100 * (FinalWealth - InitialWealth) / InitialWealth*

where:
Final Wealth = Deposited money and non-deposited money at the end of the experiment, including all interest payments
or in case of bank default:
Final Wealth = Deposited insured money and non-deposited money at the end of the experiment
The minimum payment is 8 euros.

Income uncertainty and retirement savings in different pension systems: An experimental study*

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Preliminary Version

Abstract

We analyze how people's saving decisions vary across three different pension systems and income profiles. In the first pension system there is no mechanism to save, subjects make "pocket savings" and use them whenever they want. In the second system, subjects are forced to save 10% of their income in every period and still can make pocket savings. In in addition to that, in the third system people can make voluntary savings that cannot be spent before retirement. Theoretically, saving alternatives should not influence the amount saved, however we observe that voluntary saving option makes subjects to save more. We do not find any evidence that obligatory contributions, as well as stochasticity of income cause larger savings, although subjects use different "rules of thumb" depending on whether the future income is known or unknown. Better cognitive abilities lead to better performance in a saving task, whereas risk aversion does not seem to have a significant effect.

Keywords: pension systems, experiment, income uncertainty, saving behavior

JEL classification: C90, D91, H55

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1 Introduction

In most countries, the expected number of years that individuals will spend in retirement is still on the rise (Ersner-Hershfield et al., 2008). This demographic change leads to an increase in the old-age dependency ratio, which is commonly defined as the ratio of the number of persons aged 65+ to those aged 20–64. The old-age dependency ratio is an important factor for the viability of pay-as-you-go pension systems, and is rising sharply in many countries. For the EU, Eichhorst et al. (2011) forecast an increase in this ratio from 25% in 2007 to 50% in 2050.

At the same time, people save too little for the retirement (Hurd et al., 2012; Poterba et al., 2012). There are several reasons for that. First, people over-consume at early stages of their lives (Miron, 2001; Duffy and Li, 2016), which prevents them from starting to save early enough. This behavior has been described as "myopic" or "inattentive" (Lusardi, 1999; Reis, 2006; DeVaney et al., 2007). Besides that, subjects may lack the necessary willpower, postponing an unpleasant activity like saving (Thaler, 1994; Harris and Laibson, 2001). In addition, cognitive abilities may play a role as optimal saving over the lifetime is a complicated decision-making process (Ballinger et al., 2011). Last but not least, subjects may have dynamically inconsistent preferences (Brown et al., 2009).

The increasing age of population together with insufficient personal savings may threaten the sustainability of pension systems in the long run (Fatás et al., 2013). Thus, it is essential to understand what motivates people to save more for the retirement as well as to make them think about their own saving decisions (Tam and Dholakia, 2011).

In this paper, we analyze how people's saving decisions vary across different pension systems (with one, two or three saving options). According to Wärneryd (1996), the action of saving is usually passive. At the same time, the "default" arrangements for pension plan participation may have relatively large effects on saving behavior (Card and Ransom, 2011). For instance, Choi et al. (2004) and Carroll et al. (2009) find that savings under "default" plans are significantly lower compared to the case when an employee has to make an "active decision" regarding his savings.[1]

Our primary goal is to find what kind of pension system structure provides the best incentives for subjects to "actively" save for their retirement. We contribute to the scarce experimental literature by testing the effect of different pension system structures on

[1] By "default" plans we mean that employees are automatically prescribed a pension plan and do not decide on its features. Thus, they do not actively choose but rather passively accept the pension plan features.

saving behavior. As a benchmark, we use the optimal consumption path that we find within a theoretical model of life-cycle saving and consumption. We check whether the behavior observed in the lab is close to the optimal one.

The theoretical model design is based on recent empirical results regarding economic behavior (Marshall, 2005; Brown et al., 2009), which differs from the classical setup in several ways (Modigliani and Brumberg, 1954). First, the proposed utility function depends not only on current consumption but also on how much a subject consumed in the past - his level of habit. Besides that, habits are modeled to grow in a non-linear manner. Using dynamic optimization, we derive optimal consumption paths for decisions under income certainty and uncertainty. Then, we conduct an experiment to see what kind of saving mechanism (mandatory, voluntary, or their combination) incentivise people to save more for the retirement. In addition, we examine the effect of income stochasticity on saving decisions. Last but not the least, we test whether personal characteristics of subjects such as risk-aversion, gender, and cognitive abilities influence their saving decisions. The experimental approach allows us to measure the effect of a specific parameter within the controlled experimental environment (Falk and Fehr, 2003; Hurd et al., 2012; Dufwenberg, 2015). This distinguishes our approach from an analysis of empirical data, which may be affected by spillover effects (Wagner, 2005; Hurd et al., 2012) and cross-country differences in pension systems (Antolín and Whitehouse, 2009).

In a nutshell, we find that people fail to consume optimally. They spend too much before retirement, thus do not have sufficient funds to consume after retirement. In some treatments, subjects tend to consume less in the second than in the first part of the game. Although saving options' design should not cause differences in total savings across systems, we find that people save significantly more when they are provided with an option to make voluntary contributions. Stochasticity of income does not change the amount of total savings drastically. When the income is known, subjects tend to use the "rule of thumb" increasing their savings linearly over time. Whereas when income is stochastic, they tend to mimic its moves in their saving decisions. Overall, subjects demonstrate the worst performance in the treatment with only pocket savings. Better cognitive abilities help them to perform better in the task, whereas risk-attitudes do not seem to have a significant effect on choices.

The outline of the paper is as follows. In Section 2, we summarize the main literature. The methodology is explained in Section 3. The experimental design and procedure as well as the main hypotheses are detailed in Section 4. In Section 5, we report the main results. Section 6 concludes.

2 Literature review

One of the key elements of a sustainable pension system is an appropriate mix of three pension pillars (Eichhorst et al., 2011). The first pillar is usually based on the pay-as-you-go principle where contributions and taxes of current workers are used to finance pensions of current pensioners. The second pillar comprises voluntary or mandatory occupational pension schemes, while the third pillar consists of mostly voluntary contribution plans.

There is no single, empirically-supported conclusion regarding the optimal structure of a pension system (Orszag and Stiglitz, 2001). According to Advisory Council (1997), the first pillar serves a useful purpose, which should be salvaged and enhanced, whereas Cuevas et al. (1997) stress the negative impact of pay-as-you-go systems on national savings. Feldstein (1997) states that mandatory second-pillar contributions would add to national savings. Orszag and Stiglitz (2001) mention that the second pillar may not be an appropriate part of the pension system for many countries. Lately, there has been a shift towards funded pensions, not only by the increasing emphasis on the second pillar and the shift from defined benefit to defined contribution schemes, but also by promoting additional voluntary (third pillar) pension savings (Le Blanc et al., 2011; Holzmann, 2013). Nevertheless, pension policy cannot be universal: "one-fits-all countries" policy does not exist. It requires a more nuanced approach than implied by a single "optimal" constellation of pillars (Orszag and Stiglitz, 2001). Understanding what kind of saving mechanism (mandatory, voluntary, or some combination of both) stimulates people to save is a key step towards implementation of a successful system. Given that empirical analysis is not always possible, we study experimentally what kind of saving option(s) may induce people to save more for retirement.

Literature on experiments investigating saving decisions in simulated financial environments is scarce (Koehler et al., 2015). Carbone and Duffy (2014), Feltovich and Ejebu (2014) analyze how consumption choices are influenced by the degree of observability of peers' decisions. Ballinger et al. (2003) studies the effect of communication on savings. Fehr and Zych (1998) and Brown et al. (2009) try to relate insufficient savings to addictions and preferences for immediacy. Carbone and Hey (2004) finds that people's saving decisions are highly responsive to the current level of income. Anderhub et al. (2000) studies how uncertainty regarding life duration influences consumption choices. Hey and Dardanoni (1988) relates differences in saved amounts with cognitive abilities of subjects. Fatás et al. (2013) is interested in finding the effect of lump-sum payments on savings.

To our knowledge, there is only one experimental study by van der Heijden et al. (2015) that is close to ours. The authors study how the freedom to choose a pension scheme affects subjects' saving behavior. There are 4 possible schemes, which differ by the variability of income: a person can get all the income during the working life or spread it across the life span. The authors examine whether pension schemes that bring the income profile closer to the optimal consumption path lead subjects to save more. Although the authors study an interplay of saving decisions and income streams, they do not relate assumed streams' distributions with how the income is allocated in reality.

In our experiment we use a different setup to analyze subjects' savings. We provide individuals with the same income paths, but with different saving options. Subjects have complete freedom to allocate their income between the working and retirement stages of life. Besides analyzing which option (or their combination) leads to higher savings, we study the effect of income streams on savings by running two versions of the experiment, which differ by income streams being either deterministic or stochastic. We study whether the stochasticity of income influences saving behavior, because existing empirical and experimental evidence is inconclusive or even contradictory. Most of the literature shows that people save more in the presence of uncertainty. Skinner (1988), Zeldes (1989), Gourinchas and Parker (2002) find that when faced with income uncertainty, people consume less because they feel a higher need to save for retirement. Hahm and Steigerwald (1999) claim that consumers are forward-looking, gradually adjusting their precautionary savings to changes in income. In contrast, Fulford (2015) shows that income uncertainty is not a primary saving motive and does not necessarily drive precautionary savings. Moreover, estimates of precautionary savings range from 60% (Carroll and Samwick, 1998) to less than 10% (Guiso et al., 1992) of total wealth, casting additional doubt on any positive correlation between precautionary savings and income uncertainty.

We control for cognitive abilities and risk aversion of subjects because these factors are well-known to affect savings. According to the literature, risk-averse individuals save more. Hey and Dardanoni (1988) state that subjects who over-consume and under-save are mainly risk-lovers. Koehler et al. (2015) claim that more risk-averse participants save more in response to a lengthening retirement period. Fatás et al. (2013) argue that risk-averse subjects demonstrate a persistent precautionary saving behavior. Based on the literature, cognitive abilities play a role in a subject's performance in a saving task. Hey and Dardanoni (1988), Ballinger et al. (2003) and Brown et al. (2009) agree on people being boundedly rational, which prevents them from saving enough. Moreover, Ballinger et al. (2011) claim that cognitive abilities are the best predictors of saving performance.

Overall, we study how different pension schemes, as well as stochasticity of income and personal characteristics of subjects, influence their decisions in saving for retirement. As a theoretical framework, we use a modified version of a standard additive consumption model. All the relevant literature related to the model design choices is provided in the following section.

3 Methodology

Our theoretical framework builds on the standard additive consumption model proposed by Browning and Lusardi (1996). According to this model, people save during their working lives to have enough money to spend on consumption after retirement. Subjects maximize the total utility over the lifetime under the budget constraint. To find the optimal consumption path, we make the following assumptions. First, we assume that subjects do not have any inherited assets and there are no cash inflows apart from earnings during their lives, so any spending has to be financed from these earnings. Second, the fraction of total income that a person spends on consumption is scale-independent, i.e., it is defined only by their preferences and does not depend on the amount of available income. In this way, we control for the habit formation function and utility function to be homogeneous such that consumption choices are independent of the income level. Third, there is no mortality risk, i.e., subjects know exactly for how many years they will work and live.[2] Fourth, we assume zero discount rates to simplify the saving decisions for subjects, because, as shown experimentally, people fail to consume optimally even in the absence of utility discounting (Brown et al., 2009; Ballinger et al., 2011).

Despite being based on a well-known consumption and saving model, our framework differs in two ways. We follow the latest literature on intertemporal consumption (Bowman et al., 1999; Carroll, 2000; Brown et al., 2009) and assume that: (1) subjects' utility depends both on consumption and habit level; (2) the habit level grows non-linearly.

3.1 The Habit Formation Function

Habit plays a crucial role in consumption choices (Fuhrer and Klein, 1998; Marshall, 2005). There is empirical evidence that people tend to adjust their current consumption depending on past consumption levels. Constantinides (1990) analyzes monthly, quarterly

[2] There is almost no theoretical literature on the effect of mortality risk on savings (Yao et al., 2014). Thus, including it into the model seems to be an interesting extension, which is left for future research.

and yearly consumption in the US and finds significant evidence for habit formation at all levels of data. Winder and Palm (1996) confirm habit persistence in the Netherlands for quarterly consumption. Braun et al. (1992) observe the effect of habits on consumption in Japan. Carroll et al. (2000) show that habit formation can lead to a positive short-run response of savings to a favorable shock, even when there is no long-run effect of such a shock on savings. Fuhrer (2000) claims that the hypothesis of no habit formation can be rejected with a high level of confidence because the habit formation model captures the gradual hump-shaped response of real spendings. In a nutshell, habit formation finds clear empirical support and is accounted for in many intertemporal consumption-savings models (Alessie and Lusardi, 1997; Carroll, 2000; Brown et al., 2009).

Typically, the habit formation process is assumed to be linear, with the future level of habit depending on the previously formed habit and previous consumption (Fehr and Zych, 1998; Carroll, 2000; Brown et al., 2009). Linear habit formation has been supported by (Sheeran, 2002; Ajzen, 2002), but is lately refuted by Lally et al. (2010), who instead claim that habit changes in a non-linear way. Also, Hull (1943) studies how people develop their habits while doing simple routines: exercising after breakfast and before dinner. He shows that after several repetitions the habit grows asymptotically increasing steadily, but by a smaller amount with each repetition. According to Chen and Ludvigson (2009), nonlinear habit specifications are used in most of the recent research works (Li, 2001; Wachter, 2006; Yogo, 2008) as far as there is no theoretical reason to discard their validity.

We consider the latest theoretical and empirical literature and assume that a subject's habit grows in a non-linear way with respect to the previous habit and consumption levels (Lally et al., 2010). Following Carroll et al. (2000), Lally et al. (2010), Havranek et al. (2017), we assume habit to increase at a decreasing speed (see Equation 5):[3]

$$H_t = \sigma \times (\frac{\lambda \times H_{t-1} + (1\text{-}\lambda) \times C_{t-1}}{\sigma})^{\alpha}, \tag{1}$$

where C_t and H_t denote the levels of consumption and habit at time t, and λ, α, and σ are parameters.

According to the literature, λ ranges from 0.1 (Fehr and Zych, 1998) to 0.7 (Brown et al., 2009). We take an intermediate value of λ=0.5, assuming equal contribution of the previous habit and consumption to the new habit value.[4] Besides that, we make the habit

[3] For the technical proof, see Appendix I.

[4] There is no unique value for the initial level of habit. In Fehr and Zych (1998) it is 0, whereas in

non-linear, growing exponentially (α=0.85). By doing so, we incorporate two important properties of the habit formation function. First, we make it sluggish and imperfectly updating to the changes in consumption (Carroll et al., 2000). Second, we preserve the idea of saturation, assuming that the marginal effect of a rise in the standards of living (habit) is decreasing (Tinbergen, 1960). Last but not the least, we set σ=66.67, which plays the role of a scaling parameter responsible for the homogeneity of both - habit and utility functions and does not influence our results in any other way.

3.2 The Utility Function

Bowman et al. (1999), Duesenberry et al. (1949), Shea (1995b), and Shea (1995a) find an asymmetric response of consumption to anticipated changes in income. They state that people resist decreasing their standards of living even when they foresee a decrease in future earnings. According to Shea (1995b), people spend more when their future wages are supposed to rise, but they do not cut back when their future wages are expected to be cut. This is additional empirical evidence for consumption being "sticky downward" due to two reasons: (1) loss aversion of individuals; (2) reflection effects. Both features are captured in the utility function provided by Bowman et al. (1999), which is why we use the latter model as a benchmark for our experiment.

$$U(H_t, C_t) = \begin{cases} \alpha \times \frac{H_t}{\sigma} + \sigma \times (\frac{C_t - H_t}{\sigma})^{\alpha}, C_t > H_t \\ \alpha \times \frac{H_t}{\sigma} - \beta \times \sigma \times (\frac{H_t - C_t}{\sigma})^{\alpha}, C_t \leq H_t \end{cases}, \tag{2}$$

where α and β are parameters for risk and loss aversion, respectively

According to the chosen functional form (see Equation 2), we expect individuals to be loss-averse and more sensitive to the fall in consumption below the current level of habit than to an equal rise above it (Bowman et al., 1999). Uneven responses to up and down moves in consumption relative to habit resemble the value function proposed by Tversky and Kahneman (1992). That is why we apply the same structural form of the utility function as Bowman et al. (1999), but use parameter values from Prospect Theory. Because the values of α and β differ across experimental studies (Camerer and Ho, 1994; Tversky and Fox, 1995; Wu and Gonzalez, 1996), we choose the closest ones to the original values proposed by Tversky and Kahneman (1992): α=0.85, β=2.

Brown et al. (2009) it is 10. We assume H_0 being equal to 50.

3.3 The Optimal Consumption Path

In addition to analyzing subjects' behavior, we want to investigate how their choices differ from the theoretically optimal ones. In the experiment, each subject knows in advance that he will "live" for 15 periods. The first 10 periods correspond to the working career, during which a subject earns an income of Y_t per period. During the last 5 periods, which correspond to retirement, a subject does not earn anything (Y_t=0). We introduce a borrowing constraint such that subjects cannot spend their future income on current consumption - it can only be financed by savings and current income.[5] Subjects maximize their total utility over the lifetime with respect to consumption:[6]

$$\begin{cases} \underset{C_1,..,C_{15}}{\overset{}{f}}{}_{max} \quad (C_1, H_1, ..., C_{15}, H_{15}) = \sum_{t=1}^{15} U(C_t, H_t) \\ C_t \leq Y_t + \sum_{i=1}^{t-1} (Y_i - C_i) \end{cases} . \tag{3}$$

Because in our theoretical model subjects make decisions sequentially at different points in time, we are dealing with a multi-stage decision problem (see Equation (3)). This type of optimization problems can be solved by using backward iteration and search (Ballinger et al., 2011). Thus we use dynamic programming to find the optimal consumption path by sub-optimizing consumption in reverse sequential order (Rao, 2009).[7] We consider two cases, distinguishing deterministic and stochastic income. In case the income is deterministic, each subject receives $Y_t = 100$ per working period. If the income is stochastic, subjects know that they will get either $Y_t = 80$, $Y_t = 100$ or $Y_t = 120$ with equal probability. This leads to two different optimal consumption paths, one for deterministic and one for stochastic income (see Table 1).

To check the robustness of our results, we compare the utility from consuming optimally with the utility received by subjects when following a "rule of thumb". Empirically, many people follow simple rules ("heuristics") instead of solving an intertemporal optimization problem. The main reason for that is their inability to apply backward induction to find the optimal solution (Pemberton, 1993; Hey, 2005). Thus, heuristics or rules of

[5] We make this assumption because subjects significantly under-consume when they have an option to borrow (Meissner, 2016). As our main goal is to compare different pension schemes, we exclude an option to borrow to avoid misidentification of what causes higher savings – a possibility to borrow or the pension system design.

[6] The utility function depends both on the levels of consumption (C_t) and habit (H_t). When $H_t(H_{t-1};C_{t-1})$ and H_0 are known, we can express the utility function only through consumption.

[7] The calculations were carried out using R.

Table 1: Optimal Consumption vs. Rules of Thumb

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Utility
Deterministic	53.75	55.68	58.91	59.75	61.25	63.75	64.67	66.75	66.75	69.75	70.25	75.68	73.18	75.25	84.50	84.25
Stochastic: I	54.50	55.50	57.50	58.50	62.26	61.50	65.50	64.25	64.25	64.25	77.50	74.50	75.50	79.50	85.00	79.41
Stochastic: II	50.50	53.19	59.50	60.50	61.26	62.50	65.50	70.50	70.50	69.50	71.50	72.50	73.50	75.50	84.00	84.00
Rule I	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	-197.34
Rule II	50	50	50	50	50	50	50	50	50	50	100	100	100	100	100	38.42
Rule III	20	20	20	20	20	20	20	20	20	20	160	160	160	160	160	15.88

thumb have been recognized as important approaches to decision-making (Camerer, 1995; Conlisk, 1996; Rabin, 1998).

In our context, there are several heuristics discussed in the literature. According to Keynes (2016) people tend to consume all their available income thus do not save anything for retirement, whereas Lettau and Uhlig (1999) find that people tend to consume (only) 20% - 50% of their income. We look at three main rules: (1) consume all income at each moment in time (Keynes, 2016); (2) consume 50% of income in every working period, and dividing equally the savings for retirement (Campbell and Mankiw, 1989); (3) consume 20% of income in every working period, and dividing equally the savings for retirement (Lettau and Uhlig, 1999). Table 1 illustrates the utility loss arising from following these rules compared to following the optimal decision path.

4 Experimental Design and Procedures

The experiment was programmed in O-tree and conducted at WiSo Experimental Laboratory in Hamburg in June - August 2018.[8] Upon entering the laboratory, subjects were randomly assigned to the computers and provided with necessary instructions. They could ask clarification questions in person before the experiment started. There are 6 experimental treatments (see Table 2), each of them consists of five main parts: (1) questions to test cognitive abilities; (2) the BRET task; (3) questions to control for understanding of the pension task; (4) the pension task; (5) the questionnaire.

The cognitive abilities of the participants were checked using the questions made as proposed by Conway et al. (2005). To control for risk aversion, we used the incentivized 10x10 dynamic version of the BRET task (Crosetto and Filippin, 2013). Before running the main part of the experiment, the pension task, we asked subjects multiple-choice questions to control for their understanding of the main features of the game (the habit formation process, the utility function, etc.). If subjects answered incorrectly, they were

[8] You can find a demo version of the experiment at https://experiment-uni-li.herokuapp.com/demo/

Table 2: Description of Treatments

	Treatment Name	Income (ECU)	Pension System	Pocket Savings	Obligatory Savings	Voluntary Savings
1	S1Cons	always 100	I	+		
2	S2Cons	always 100	II	+	+	
3	S3Cons	always 100	II	+	+	+
4	S1Stoch	80, 100 or 120	I	+		
5	S2Stoch	80, 100 or 120	II	+	+	
6	S3Stoch	80, 100 or 120	III	+	+	+

asked to rethink their answers.[9] After finishing the pension task, subjects went through a short questionnaire providing information about their age, gender, and educational background. When the experiment was over, subjects were paid for the participation. For every box collected in the BRET task, a subject got 0.1 euros (in case there was no bomb), and zero otherwise. Besides that, we multiplied by 10 the number of total points that the subject earned in one of the rounds of the game.[10] That was the corresponding payment for the pension task.

The pension task was conducted twice to study learning effects. The task was modeled in the form of a game that lasted for 15 periods. In each period people had to make a decision regarding their consumption and savings. In the first 10 periods, they received some income, whereas in the last 5 periods they lived only on their savings. The amount of per period income as well as the way in which people could make savings depended on the treatment of the experiment (see Table 2). In S1Cons, S2Cons, and S3Cons, the income is constant and equal to 100, whereas in the other three treatments (S1Stoch, S2Stoch, S3Stoch), it is either 100, 80 or 120 with equal probability.[11] To make the final results comparable, we randomly generated two income paths (Path I and Path II) before the experiment was conducted. Some of the subjects were given Path I in the first and Path II in the second round of the game, and vice versa for the others. This allows us to analyze the behavior of subjects knowing that all of them have had the same realizations of income across the experiment. We introduce different income streams to check whether stochasticity of income influences subjects' saving decisions (see Table 3).

[9] We provided the subjects not only with the instructions (see Appendix II), but also with handout material which included the habit formation and the utility tables (see Appendix III). Using these tables, subjects could easily find the level of habit/utility corresponding to different (although not all) values of consumption without making any calculations. Moreover, during the game, subjects were allowed to use a calculator that was provided on the screen.

[10] There were two rounds, we selected one randomly.

[11] All the amounts were expressed in experimental currency units (ECU) to avoid any anchoring effects.

Table 3: Dimensions of Comparison

Dimension	Treatments
Stochasticity of Income	S1Cons vs. S1Stoch / S2Cons vs. S2Stoch / S3Cons vs. S3Stoch
Different Pesion Systems	S1Cons vs. S2Cons vs. S3Cons / S1Stoch vs. S2Stoch vs. S3Stoch

The second dimension of comparison is the type of pension system. The first pension system has no particular mechanism that would oblige people to save. Everything that is not spent on consumption becomes "pocket" savings, which can be used by the subjects at any moment in time. In a pension system of the second type, people are obliged to save 10% of their income in every working period. The total obligatory saved amount cannot be spent until Period 11, when the retirement phase starts. Besides obligatory savings, people can still make additional pocket savings. The third pension system provides an additional option: voluntary pension savings. The difference between voluntary pension savings and pocket savings is that voluntary savings cannot be accessed before retirement. Theoretically, the type of a saving option should not affect the total amount being saved. However, we do expect differences in saving behavior across pension systems. Based on the existing literature, we formulate the following hypotheses:

Hypothesis I

Subjects consume significantly more than they should during their working lives, i.e., they do not save enough for retirement. With repetition of the task, they learn to consume significantly less.

Hypothesis II

People save better (significantly more) when they are supposed to do so than when there is no obligatory contribution to be made. Also, the option to save voluntarily induces higher total savings.

Hypothesis III

Subjects save more when their income is stochastic than when it is deterministic.

Hypothesis IV

Subjects apply "rules of thumb" when making savings. The choice of rule depends on whether the future income is known or unknown.

Hypothesis V

The overall performance of subjects depends not only on the treatment but also on their cognitive abilities and risk aversion.

First, we expect that subjects will not save sufficiently for the retirement as it is observed in the majority of the empirical and experimental studies. Also, we believe that the obligation to make periodical contributions will increase subjects' awareness of the necessity to save. As a consequence, people will save "actively", thus will save more. Besides that, we suppose that in treatments with stochastic income, subjects will have a higher incentive to think about future risks. That is why they will make larger savings. The overall performance will depend on personal characteristics, such as attitudes towards risk and cognitive abilities. Due to the complexity of the task, we forecast people to use "rules of thumb" that we expect to vary depending on the income path.

5 Results

We have conducted one session of each experimental treatment. The number of subjects per treatment varies from 26 to 30 people.[12] In total, 171 people took part in the experiment. The average payoff was 11 Euro. There are more male than female participants (see Table 4).[13] Most of the subjects are quite young (not more than 30 years old) and have a bachelor or master degree. The results of the BRET task show that subjects are mainly risk-lovers: less than half of a sample (43%) are averse or neutral to risk. Only 3% of subjects have at least some prior knowledge about the topic of the experiment. Most of the people demonstrate good cognitive abilities: almost all (94%) answered more than 50% of logical questions correctly. Overall, based on the results of a Chi-squared test (see

[12] It was planned to get 30 participants per treatment, however due to no "show-ups" the number of participants is less than 30 for some of the treatments: S1Stoch, S3Cons - 26; S1Cons - 29; S2Cons, S2Stoch, S3Stoch - 30

[13] Background: No - "No, I have not attended any classes about either topic"; A bit - "Yes, I have attended at least one class on saving decisions"; Some - "Yes, I have attended at least one class on pension finance"; Sufficient - "Yes, I have attended classes on both pension finance and saving decisions".

Table 4), the data sample seems to be similarly distributed across treatments concerning gender, risk-aversion, cognitive abilities, education and the professional background of subjects.

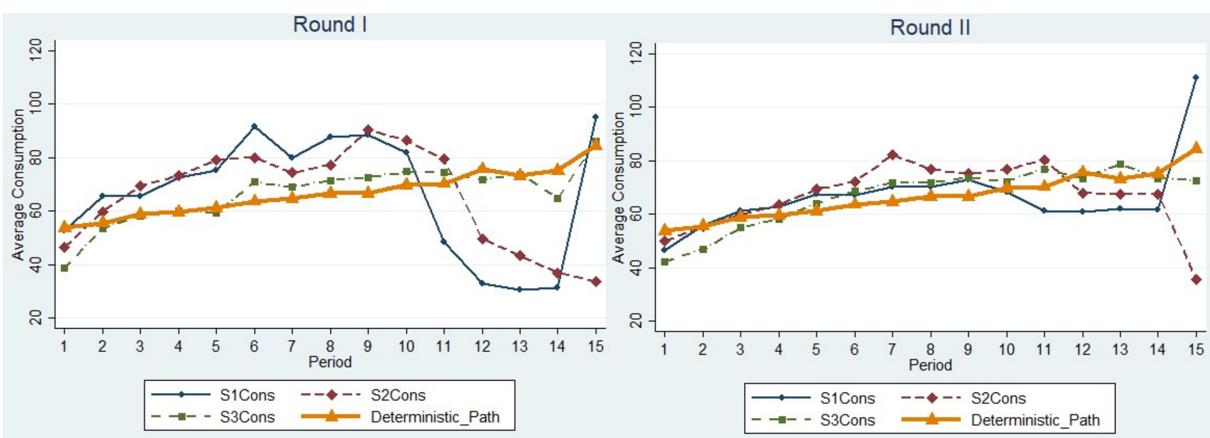
Table 4: Data Sample Structure

Parameter	Description	Fraction	Prob. chi2
Gender	Female/Male	56% / 44%	0.80
Education	High School/Bachelor/Master/PhD/Other	5% / 54% / 33% / 8% / 0%	0.47
Risk-Attitudes	Averse/Neutral/Lover	37% / 6% / 57%	0.21
Age	Below 20 / 20-25 / 25-30 / Above 30	3% / 60% / 26% / 11%	0.60
Cognitive Abilities	Less than 4 answers / 4-8 / 8-16	0% / 6% / 94%	0.45
Background	No /A bit / Some / Sufficient	87% / 10% / 1% / 2%	0.78

5.1 Consumption

The amount of savings is directly linked to how much a subject consumes during his working life. Thus, we start the analysis by comparing the optimal and observed in the lab consumption paths. On Figures 1, 2 and 3 we show the average level of consumption in each period and the corresponding optimal amounts to be consumed. In all the treatments subjects consume too much during their working lives, thus have to restrict themselves in consumption during the retirement. The tendency to overconsume is not as pronounced in Round II as in Round I, which means that people learn and adjust their consumption choices towards the optimal ones.

Figure 1: Consumption in S1Cons S2Cons S3Cons (ECU)



Looking at the graphs, it is not easy to see whether in the first, second or third pension system subjects overconsume least of all. Due to that, we have calculated the total amount

Figure 2: Consumption in S1Stoch S2Stoch S3Stoch: Round I - Path I, Round II - Path II (ECU)

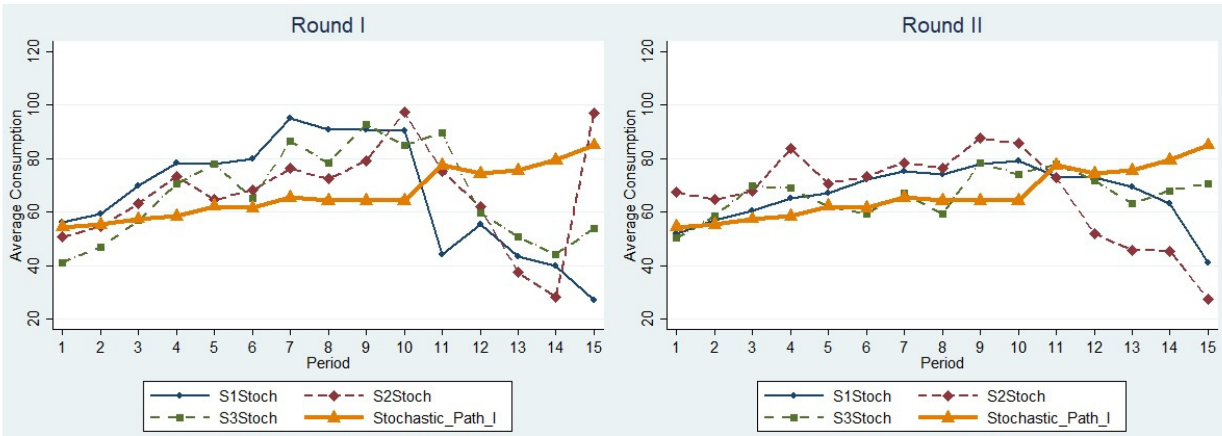
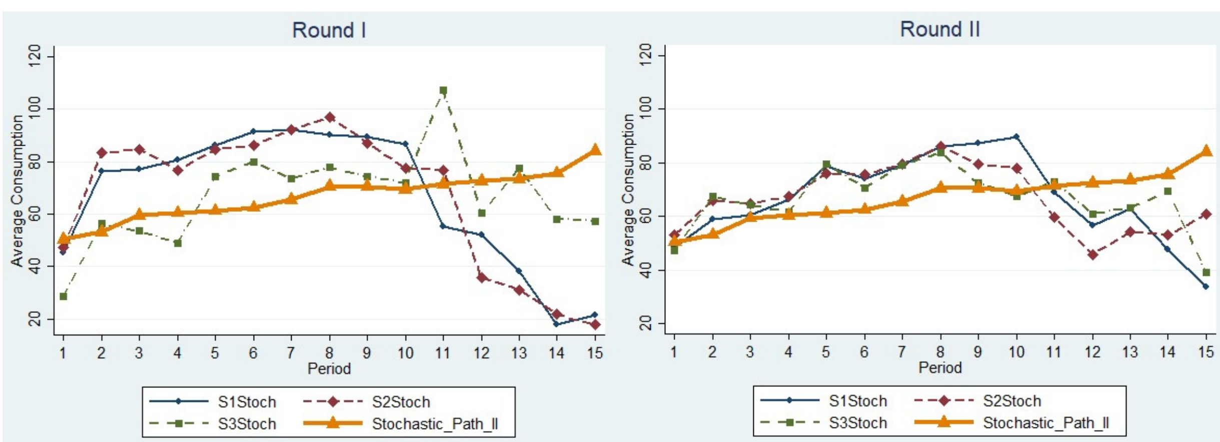


Figure 3: Consumption in S1Stoch S2Stoch S3Stoch: Round I - Path II, Round II - Path I (ECU)



of consumption over the first 10 periods for each of the subjects and found the averages across treatments (see Table 5). Besides that, for each of the treatments, we estimated the standard deviation of consumption per working period. As you can see from Table 5, in all treatments subjects consume more than they should, although in the third pension system subjects consume least of all per period and in total.[14] The variation in per period consumption is the smallest for the first pension system when the income is constant, and for the second, when it is stochastic.

Table 5: Consumption: averaged across two rounds (ECU)

	Deterministic Income				Stochastic Income			
	S1Cons	S2Cons	S3Cons	Opt	S1Stoch	S2Stoch	S3Stoch	Opt
Total	702.21	708.95	626.87	621.00	753.60	749.73	670.82	615.73
Period St.Dev.	9.88	11.14	11.10	8.35	12.08	9.24	11.49	9.15

To support the conclusions made above, we provide the results of the Mann-Whitney test in Table 6. We compare the amount of total consumption over the first 10 periods across experimental rounds. Besides that, we analyze whether subjects consume significantly more than they would following the optimal path.[15]

We support our previous conclusions and find that at 1% level of significance, subjects consume more than they should in all pension systems except the third one. Subjects of the first and second systems (except for S2Stoch) tend to adjust their behavior consuming significantly less (at 5%) in the second than in the first round of the game. Overall, we cannot reject the first hypothesis that subjects do not reach the optimal consumption path because they overconsume during their working lives. Although, we can only partially accept that over time people learn to consume significantly less.

Table 6: Statistical Tests: Total Consumption (p - values)

		Deterministic Income			Stochastic Income		
Test	Comparison	S1Cons	S2Cons	S3Cons	S1Stoch	S2Stoch	S3Stoch
Mann-Whitney U	Real vs. Optimal	0.01	0.00	0.61	0.00	0.00	0.02
Wilcoxon Signed-Rank	First vs. Second Round	0.01	0.04	0.79	0.00	0.27	0.86

Result I: People fail to consume optimally. They spend too much before retirement and consequently do not have sufficient money for consumption after retirement. In some of

[14] Consumption per working period can be estimated as total consumption from Table 5 divided by 10.
[15] For the comparison of real and optimal paths, we use the consumption values averaged across two rounds.

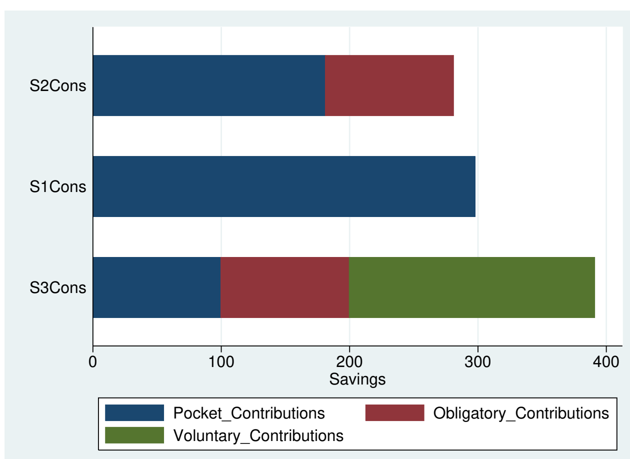
the treatments, subjects tend to adjust their behavior consuming significantly less in the second than in the first round of the game.

5.2 Savings

One of our key research questions is how the pension system design influences savings. There are different ways to save for the retirement. The largest number of savings options are available in the third pension system: pocket, obligatory and voluntary savings. Only pocket and obligatory savings are possible in the second system, whereas in the first system there are no saving mechanisms besides pocket savings. In the current section, we investigate not only the total amount of savings but also in which ways it has been accumulated.

From the graphs below you can see the average amount of total contributions (savings) made in different experimental treatments.[16] As you can see from Figure 4 and Figure 5, the largest amount of total savings is made in the third pension system, whereas there is no clear evidence that people save more in the second than in the first pension system.[17] When income is deterministic, people save more in the first system, whereas when it is stochastic, they accumulate more in the second pension system.

Figure 4: Savings Structure: S1Cons, S2Cons, S3Cons (ECU)

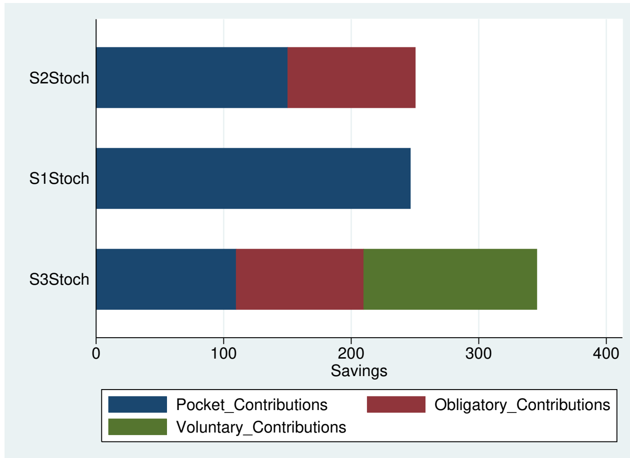


Another important aspect of savings is their structure. In the first pension system, people make only pocket savings. It is interesting to see whether in the second system subjects

[16] The average amount of savings is calculated as the total amount of savings accumulated within the first 10 periods averaged across two rounds of the game.

[17] For the more detailed information, please see Appendix IV.

Figure 5: Savings Structure: S1Stoch, S2Stoch, S3Stoch (ECU)



make pocket savings as before plus obligatory savings, that is why save more in total. In reality, subjects save almost the same total amount in both systems, reducing their pocket savings in the second system by the amount they are obliged to save. Thus, the introduction of an obligatory pension contribution does not stimulate subjects to save more than otherwise. Whereas the introduction of an option to make voluntary savings leads to higher total savings. As you can see from Figure 4 and Figure 5, the pocket savings in system 3 are smaller than in system 2. However, in system 3 people save additionally in the form of voluntary savings and the corresponding amount is much larger than a decrease in pocket savings. Overall, the introduction of a voluntary pension contribution stimulates subjects to save more in total than otherwise.

Table 7: Mann-Whitney U Test: Savings (p - values)

	Deterministic Income		Stochastic Income	
	S1 / S2	S2 / S3	S1 / S2	S2 / S3
Pocket	0.04	0.00	0.00	0.37
Pocket + Voluntary	-	0.01	-	0.00
Total	0.73	0.01	0.57	0.00

Stated above conclusions are supported with the help of Mann-Whitney U test (see Table 7).[18] We compare whether: (1) pocket savings; (2) pocket and voluntary savings; (3) total savings differ across treatments. Independently of the income path, we do not find any significant evidence that total savings in the first and the second treatments vary. Subjects significantly reduce their pocket savings in the second system, making negligible the contribution of obligatory savings to the total accumulated amount.

[18] For Table 7 and Table 8 the total amount of savings is averaged across two rounds of the game.

In the second and third systems, total savings vary significantly. The pocket savings are larger in system 3 than in system 2 only when income is constant. However, independently of the income path, the voluntary savings are big enough to make the total accumulated amount higher for the third than for the second system. Overall, we have to partially reject our second hypothesis: the option of voluntary savings motivates people to accumulate more, whereas introduction of obligatory contributions does not seem to have a significant effect on total savings.

Table 8: Mann-Whitney: Savings in Deterministic vs. Stochastic Treatments (p-values)

	S1	S2	S3
Total Savings	0.53	0.11	0.27
Pocket Savings	0.53	0.11	0.86
Voluntary Savings	-	-	0.14

Besides that, we test whether savings in treatments with the stochastic income are significantly higher than in corresponding treatments with fixed income. It is evident from Table 8 that all three kinds of savings do not differ much across treatments. Thus, we can reject our third hypothesis that people save more when their income is stochastic than when it is deterministic.

Apart from the amount of savings and their structure, it is interesting to study the patterns or "rules of thumb" that subjects apply when making decisions. Analyzing saving patterns at the individual level, we conclude that in treatments with stochastic and deterministic income people apply different "rules of thumb". Thus we cannot reject our fourth hypothesis. In case the income is known, people tend to increase their savings linearly with time. Whereas if the income is stochastic, subjects form their consumption paths tracking the changes in income.

For each of the subjects who participated in treatments with the deterministic income, we have checked whether the savings' path is significantly different from linear. Then we have calculated the percentage of subjects for whom this difference was not significant at 5% level. In this way, we have found how frequently subjects use a linear trend in savings as a rule (see Table 9). Also, we have calculated the initial savings' rate as well as the marginal growth in savings.

As you can see from Table 9, at least 20% of subjects in each of the treatments use a linear rule of thumb. Most often it is applied by the participants of S1Cons, whereas least often it is used by players of S3Cons. Besides that, initial savings' ratio, as well as its growth, vary across treatments. Subjects of S1Cons treatment initially save only 50%

Table 9: Trend in Savings: Deterministic Income

	S1Cons	S2Cons	S3Cons
Frequency of Usage	52%	38%	20%
Initial Savings Ratio	50%	42%	71%
Marginal Growth Rate	48%	24%	18%

but raise it by 48% in every subsequent period. Whereas participants of S3Cons start saving 71% of their initial income increasing the savings' rate slowly with time (18%). Overall, the average growth rate of savings is significantly different from zero.[19] It means that subjects from our sample do not apply the common rules described in the literature (always to consume 100%, 50% or 20% of income). To conclude, the larger is the set of available saving options, the less frequently people rely on the "rules of thumb". In quantitative terms, the rules vary across systems. Making savings within the first pension system, subjects start at a lower rate but grow savings faster than in the third system.

Interestingly, less than 5% of people who participated in treatments with the stochastic income used a linear "rule of thumb", thus we do not report corresponding results in here. However, participants in those treatments use another rule - they changed savings mimicking the income moves. We have calculated how often changes in saving rates correlated with ups or downs in income and reported corresponding results in Table 10.[20] As you can see, most of the times subjects of S1Stoch and S2Stoch adjust their savings' rates mimicking income moves. In the third pension system, people rely on this "rule of thumb" least of all.

Table 10: Trend in Savings: Stochastic Income

	S1Stoch	S2Stoch	S3Stoch
Frequency of Usage	0.61	0.69	0.14

Result II: People save significantly more in the third than in the second pension systems, which is in large the result of considerably big voluntary contributions. We do not find any evidence that obligatory contributions lead to higher total savings than in their absence. Also, stochasticity of income does not seem to change the amount of total savings drastically. We find that subjects use "rules of thumb" when making savings decisions. When they know their future income, they tend to increase savings linearly over time. In case future income is unknown, subjects mimic its moves in their saving choices.

[19] The significance is tested with the help of t-test at 5% level

[20] All correlation coefficients are significant at 5% level.

5.3 Total Points

In our experiment, the overall performance of a subject depends not only on the total amount of consumption (savings) but also on pace at which it was accumulated over the game. The ideas of consumption smoothing and habit formation are the key elements of our model. We believe that saving 50 ECU every year over 10 years' horizon is not the same as to save 500 ECU at once. If the subject's habits are decent, to make a saving of 500 ECU, a subject has to consume way below his level of habit sharply reducing consumption. Consequently, his final utility is lower than if he would get making savings in smaller quantities but over a longer time horizon. In our game, the final payment to a subject depends on the amount of "total points" (total utility) he gains, which is estimated as the sum of all utilities over the lifetime. Thus, the number of total points reflects not only consumption choices, but also their development through the entire game. That is why we analyze the total number of points to understand which factors influence the subject's overall performance in the saving task. According to the literature, not only the level of income and the structure of the pension system but also cognitive abilities and risk-aversion of subjects influence their decisions. Thus we formulate our linear regression model as follows:

$$\begin{aligned} \text{Log\_Total\_Points\_I(II)} = \alpha + \beta_1 \times \text{I\_Stoch} + \beta_2 \times \text{II\_Stoch} + \beta_3 \times \text{II\_Cons} + \\ + \beta_4 \times \text{III\_Stoch} + \beta_5 \times \text{III\_Cons} + \beta_6 \times \text{Logic} + \beta_7 \times \text{RA} + \text{Cons} \end{aligned} \tag{4}$$

, where *Log_ Total_ Points_ I(II)* - the log of the number of total points collected by the subject in I(II) round of the game; *Logic* - the level of cognitive abilities of a subject; *RA* - equal to -1/0/1 if a subject is risk-averse, risk-neutral or risk-lover; *Cons* - constant; *I_ Stoch* - the dummy variable equal to 1 if a pension system is of the first type with the stochastic income (the same logic holds for all other variables).

We try different specifications of the model and present corresponding results in Table 11 and Table 12.[21] Using S1Cons as a base treatment, we want to see whether in other treatments subjects earn significantly more total points. Independently of the round,

[21] All regressions are checked for multicollinearity, misspecification, and omitted variables. None of that is identified. There is heteroscedasticity, thus we report the results with robust standard errors.

subjects earn 7% more in the stochastic than in the deterministic treatment of the first pension system. Around 10% more get subjects of S2Stoch than subjects of S1Cons. The largest difference in total points is observed for S3Cons treatment - subjects accumulate around 11% more on average than in the base treatment. Cognitive abilities of subjects significantly influence their overall performance in saving task: every question answered correctly leads to a 2% increase in total points. Lastly, risk-aversion does not seem to have any significant effect on subjects' performance. Thus we can partially reject our fifth hypothesis.

Result III: Subjects perform worst of all in the treatment with only pocket savings option and constant income. In all other treatments, they get significantly more points because of making more savings or (and) adjusting their amount evenly across time. The largest difference in total points is observed for S3Cons treatment - subjects accumulate on average around 11% more than in S1Cons. Better cognitive abilities of subjects lead to better performance, whereas risk-aversion does not seem to have any effect.

Table 11: Total Points, Round I: Different Regression Specifications

	(1) Log_Total_Points_I	(2) Log_Total_Points_I	(3) Log_Total_Points_I
I_Stoch	0.065	0.073^{*}	0.074^{*}
	(0.036)	(0.035)	(0.036)
II_Stoch	0.103^{**}	0.111^{**}	0.109^{**}
	(0.033)	(0.034)	(0.034)
II_Cons	0.156^{***}	0.146^{***}	0.144^{***}
	(0.030)	(0.030)	(0.030)
III_Stoch	-0.046	-0.037	-0.040
	(0.100)	(0.101)	(0.108)
III_Cons	0.178^{***}	0.173^{***}	0.170^{***}
	(0.034)	(0.033)	(0.033)
Logic		0.017^{*}	0.017^{*}
		(0.007)	(0.007)
RA			0.006
			(0.021)
Cons	6.832^{***}	6.605^{***}	6.606^{***}
	(0.022)	(0.104)	(0.105)
N	225	225	225
R^2	0.090	0.111	0.111

Robust standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 12: Log Total Points, Round II: Different Regression Specifications

	(1)	(2)	(3)
	Log_Total_Points_II	Log_Total_Points_II	Log_Total_Points_II
I_Stoch	0.065*	0.072*	0.068*
	(0.028)	(0.028)	(0.028)
II_Stoch	0.084**	0.091**	0.096**
	(0.030)	(0.029)	(0.030)
II_Cons	0.130***	0.121***	0.125***
	(0.028)	(0.028)	(0.028)
III_Stoch	0.078*	0.087**	0.095**
	(0.033)	(0.031)	(0.030)
III_Cons	0.141***	0.135***	0.141***
	(0.024)	(0.023)	(0.023)
Logic		0.016***	0.016***
		(0.004)	(0.004)
RA			-0.016
			(0.009)
Cons	6.920***	6.705***	6.703***
	(0.018)	(0.058)	(0.058)
N	225	225	225
R^2	0.133	0.192	0.203

Robust standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

6 Conclusions

We study how different pension schemes, as well as stochasticity of income and personal characteristics of subjects, influence their decisions to save for retirement. Our primary goal is to find what kind of pension system structure makes subjects to save more. As a theoretical benchmark, we provide a modified version of a standard additive consumption model. After finding the optimal consumption paths, we test whether the behavior leading to those optimal paths is observed in the experiment. Our overall conclusion is that people consume far above the optimal level. Due to that, they do not save enough and experience a severe fall in their utility during the retirement stage. Although in the second round of the game the fall is not that tremendous: subject learn to reduce their consumption with repetition of the task.

Besides that, we find that introduction of the obligatory saving option does not lead to higher total savings - people reduce their pocket savings correspondingly to the amount that is saved under obligation. Whereas in the system with the voluntary saving option people save significantly more in total. The total savings do not differ significantly for the treatments with stochastic and deterministic income. However, subjects use different "rules of thumb" when income is known and unknown. When the income is deterministic, they tend to increase their savings linearly over time. However, when the income is stochastic, subjects mimic its moves in their saving choices. Cognitive abilities significantly affect the subject's saving behavior.

Regarding policy implications, our research suggests that the introduction of a possibility to make voluntary contributions makes subjects aware of the necessity to save actively for the retirement. Thus, the policy-makers should pay more attention to this option although tailor it to the specific features of the pension-system of each country. Besides that, increasing the subject's awareness of the necessity to save in advance seem to be helpful. We show that with repetitions of the task, people learn to overconsume less. However, in life repetitions are not feasible, which means that subjects should get aware as soon as possible that their consumption choices *now* directly influence their consumption *in the future*. In this respect, it is important to increase the level of financial literacy among individuals such that their consumption decisions would not be careless and myopic.

Appendix I

$$H_t = \sigma \times (\frac{\lambda \times H_{t-1} + (1\text{-}\lambda) \times C_{t-1}}{\sigma})^{\alpha} \tag{5}$$

$$\frac{\partial H_{t+1}}{\partial H_t} = \sigma \times \alpha \times \lambda \times (\frac{\lambda \times H_{t-1} + (1\text{-}\lambda) \times C_{t-1}}{\sigma})^{\alpha-1} \tag{6}$$

$$\frac{\partial^2 H_{t+1}}{\partial H_t^2} = \sigma \times \alpha \times \lambda^2 \times (\alpha - 1) \times (\frac{\lambda \times H_{t-1} + (1\text{-}\lambda) \times C_{t-1}}{\sigma})^{\alpha-2} \tag{7}$$

$$\frac{\partial H_{t+1}}{\partial C_t} = \sigma \times \alpha \times (1 - \lambda) \times (\frac{\lambda \times H_{t-1} + (1\text{-}\lambda) \times C_{t-1}}{\sigma})^{\alpha-1} \tag{8}$$

$$\frac{\partial^2 H_{t+1}}{\partial C_t^2} = \sigma \times \alpha \times (\alpha - 1) \times (1 - \lambda)^2 \times (\frac{\lambda \times H_{t-1} + (1\text{-}\lambda) \times C_{t-1}}{\sigma})^{\alpha-2} \tag{9}$$

As far as $\sigma > 0$, $0 < \alpha < 1$, $0 < \lambda < 1$, we have: $\frac{\partial H_{t+1}}{\partial H_t} > 0$, $\frac{\partial H_{t+1}}{\partial C_t} > 0$, whereas $\frac{\partial^2 H_{t+1}}{\partial H_t^2} < 0$, $\frac{\partial^2 H_{t+1}}{\partial C_t^2} < 0$. In other words, the habit formation function is increasing in habit and consumption, but at a decreasing speed.

Appendix II

This is the version of the instructions for the treatment S3Cons. For all other versions, contact the authors.

Background and short summary

This experiment is about saving and consumption decisions. You will participate in a game that will last for 15 periods. You will face 15 subsequent decision situations about how much you want to spend on current consumption and how much you want to save for the future.

Every time you spend money for consumption, you earn points. How many points you earn in a period depends on two factors: (i) how much you money you spend on consumption in that period and your current habit (both will be explained in detail later). At the end of the experiment, all points that you have earned will be summed up, converted into EUR and paid out in cash. Thus, it is in your interest to collect as many points as possible.

Income

In the first 10 periods (your working life), you will receive some income which is denoted in the experimental currency "Taler". This income varies from period to period, and will be either 80, 100 or 120 Taler. The sequence of incomes was generated by a random draw, where each outcome was equally likely for each period. In Periods 11-15 (retirement), your income will be 0.

Savings

There are three ways how to save money: the obligatory contribution, the voluntary contribution and ordinary savings. During your working life (periods 1-10), 10% of your income will be automatically deducted as an **obligatory contribution** to the pension fund. This money will be blocked until period 11, from which on you can use it. Whatever is left after the obligatory contribution can be fully used for consumption or can be saved in two other ways:

• You can make a **voluntary contribution** amount of "X" to the pension fund. In this case you also cannot use this saved amount until retirement.

• You can do nothing with the amount not used for consumption. In this case it is kept on your account as **savings "Y"**. This money can be used at any period in the future.

You can do neither, only one of them but also both, the voluntary contribution and the ordinary savings.

Example:

Suppose your income is 100 Taler, the amount deducted for the obligatory contribution will be 10 Taler (the 10%). You then have 90 Taler left for consumption or further savings.

If you decide to make a **voluntary contribution** of X Taler, it means that you could consume 90-X today. Remember that you can use the X Taler only when you are on retirement: in periods 11 - 15.

Now suppose you decide not to spend the full 90 - X Taler in that period, but Y Taler less. Then these Y Taler will be automatically kept as **savings** on your account and can be spent at **any moment** in the future.

Note: All of your savings and money left by the 15th period will automatically be spent in this (last) period.

Points earned by consumption

The points you earn from consumption depend on the amount of Taler spend on consumption and your current consumption habit.

Habit

Intuition of the consumption habit: during a lifetime a person develops a habit of consumption depending on what he or she is used to spend.

For example, if you are a student, you might be willing to live in a small flat with little comfort. When you grow older you improve the living standard and spend more on living. In this example your consumption level has grown over time and so has your habit. Also in this experiment the level of consumption you are currently used to will be called Habit. We will assume that in Period 1, your first Habit is exogenously given and equal to 50 Taler, whereas in all subsequent periods it is defined by the consumption you made in former periods. In Table 1 you can check what will be your Next_Period_Habit for a specific amount of consumption and the current level of Habit.

In detail the habit of the next period in Table 1 is calculated as follows:

$$Next\_Period\_Habit = AF * (0.5 * Adj.Habit + 0.5 * Adj.\ Consumption)^{0.85}$$

"AF" is a constant adjustment factor of 66.67; *Adj. Habit* is the Habit divided by this factor AF and Adj. *Consumption* is the consumption divided by this factor.

As you can see, the higher your current *Consumption* is, the larger becomes your *Next_ Period_ Habit.*

Example:

If your Habit is 50 and your Consumption is 100, your Next_Period_Habit will be 74 Taler.

Whereas if your Habit is 50 and your Consumption is 30, your Next_Period_Habit will be 43 Taler. Thus the more you consume, the higher is your Next_Period_Habit.

Remember, in Table 1 you can see how your habit will change for any level of consumption you might choose.

Points earned:

You can check the number of points you will earn in a period for any level of consumption and habit with Table 2.

In detail, the number of points (from table 2) that you will earn is defined by the following formula:

$$Points = 100 * \begin{cases} 0.85 \times Adj.Habit + (Adj.Consumption - Adj.Habit)^{0.85}, C_t > H_t \\ 0.85 \times Adj.Habit - 2 \times (Adj.Habit - Adj.Consumption)^{0.85}, C_t \leqslant H_t \end{cases} \tag{10}$$

Be aware that the more you consume now, the more you will need to consume in the future to be as happy as you are currently. You do not need to calculate the points on your own. A points calculator will be available for you anytime during the experiment.

Intuition behind: most probably you will agree that it is harder to switch back from a luxury car to a cheap one than from a cheap one to a luxury one.

That is why, you receive less points if you consume below your current level of habit. From the formula above, you can see that you lose twice as many points consuming below as you gain consuming above your current level of habit.

Example:

If your Habit is 50 and you consume 100, you will get 142 points. Whereas if your Habit is 50 and your Consumption is 30, you will get -8 points. Thus, consuming below the habit causes you less or even negative number of points.

The decision screen:

You will be provided with a decision screen (see below) in every single period of the game. Once again, your task is to decide how much you want to save and how much you want to consume. Remember that voluntary contributions as well as obligatory contributions can be spent on consumption only after retirement.

Final Payoff

Your final payoff will be calculated as the total sum of all the points collected during the game divided by 100. You will play two full implementations (sets of 15 periods) of this experiment. Only one implementation will be paid. Which one is determined randomly.

Example:

If you got 1000 points in total, your final payoff will be 10 EUR.

The decision screen:
In each period a new line is added to the table. In this example you face the investing decision in period 2. The columns can be described as follows:

Period: In which period you are. Here, in this example period 2.

Gross income: Your income in this period. Here 100.

Obligatory Pension Account: The sum of all obligatory payments. You can only use this money for consumption from period 11 on when it will be transferred to Savings.

Voluntary Pension Account: The sum of all voluntary payments. You can only use this money for consumption from period 11 on when it will be transferred to Savings.

Savings: The number of savings always available for you for consumption. Here 40.

Available Money: The sum of your income from this period and your savings. Here 90+40=130. In period 11 the obligatory and the voluntary pension account will be transferred to the savings account and therefore will also be available.

Consumption: The consumption of a period. Here it is "none" because you have not decided yet on the consumption amount.

Habit: Your current habit which influences the points you earn with your consumption. Here 52.

Points: The number of points earned. Here "none" because you haven't consumed yet in this period.

Total Points: The sum of all points earned in the experiment after the specific period. Here "none" because you have not earned points in this period yet.

Choose your consumption for Period 2

Time left to complete this page: **1:03**

Overview

Period	Gross income	Obligatory pension account	Voluntary pension account	Savings	Available money	Consumption	Habit	Points	Total points
1	100	10	0	0	90	50	50.0	64	64
2	100	20.0	0	40	130.0	None	52	None	None

You can spend up to **130.0** Taler.

Here you enter how much you want to consume in this period. Once you click "Submit" the decision is final.

Consumption (Enter 0 if None):

Voluntary pension contribution (Enter 0 if None):

0

Here you enter how much you want voluntary save in this period. All money available but not consumed or voluntary savedwill be savings in the future period. Once you click "Submit" the decision is final.

Submit

Decision aid

The table in the instructions provides an estimate of the points and future habit resulting from a chosen consumption.

Enter a value to calculate the exact points and habit for a respective consumption in this period.

Calculate

Here you can pre-calculate the specific number of points you would achieve with the specific amount of habit and consumption. You can use it as often as you want.

Appendix III

Table 1: Next Period Habit

Consumption

Habit	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	250	300	350	400
0	0	7	13	19	24	29	34	39	43	48	52	57	61	65	69	74	78	82	86	90	94	114	133	151	170
10	7	13	19	24	29	34	39	43	48	52	57	61	65	69	74	78	82	86	90	94	98	118	137	155	173
20	13	19	24	29	34	39	43	48	52	57	61	65	69	74	78	82	86	90	94	98	102	121	140	159	177
30	19	24	29	34	39	43	48	52	57	61	65	69	74	78	82	86	90	94	98	102	106	125	144	162	180
40	24	29	34	39	43	48	52	57	61	65	69	74	78	82	86	90	94	98	102	106	110	129	148	166	184
50	29	34	39	43	48	52	57	61	65	69	74	78	82	86	90	94	98	102	106	110	114	133	151	170	187
60	34	39	43	48	52	57	61	65	69	74	78	82	86	90	94	98	102	106	110	114	118	137	155	173	191
70	39	43	48	52	57	61	65	69	74	78	82	86	90	94	98	102	106	110	114	118	121	140	159	177	195
80	43	48	52	57	61	65	69	74	78	82	86	90	94	98	102	106	110	114	118	121	125	144	162	180	198
90	48	52	57	61	65	69	74	78	82	86	90	94	98	102	106	110	114	118	121	125	129	148	166	184	202
100	52	57	61	65	69	74	78	82	86	90	94	98	102	106	110	114	118	121	125	129	133	151	170	187	205
110	57	61	65	69	74	78	82	86	90	94	98	102	106	110	114	118	121	125	129	133	137	155	173	191	209
120	61	65	69	74	78	82	86	90	94	98	102	106	110	114	118	121	125	129	133	137	140	159	177	195	212
130	65	69	74	78	82	86	90	94	98	102	106	110	114	118	121	125	129	133	137	140	144	162	180	198	215
140	69	74	78	82	86	90	94	98	102	106	110	114	118	121	125	129	133	137	140	144	148	166	184	202	219
150	74	78	82	86	90	94	98	102	106	110	114	118	121	125	129	133	137	140	144	148	151	170	187	205	222
160	78	82	86	90	94	98	102	106	110	114	118	121	125	129	133	137	140	144	148	151	155	173	191	209	226
170	82	86	90	94	98	102	106	110	114	118	121	125	129	133	137	140	144	148	151	155	159	177	195	212	229
180	86	90	94	98	102	106	110	114	118	121	125	129	133	137	140	144	148	151	155	159	162	180	198	215	233
190	90	94	98	102	106	110	114	118	121	125	129	133	137	140	144	148	151	155	159	162	166	184	202	219	236
200	94	98	102	106	110	114	118	121	125	129	133	137	140	144	148	151	155	159	162	166	170	187	205	222	239
210	98	102	106	110	114	118	121	125	129	133	137	140	144	148	151	155	159	162	166	170	173	191	209	226	243
220	102	106	110	114	118	121	125	129	133	137	140	144	148	151	155	159	162	166	170	173	177	195	212	229	246
230	106	110	114	118	121	125	129	133	137	140	144	148	151	155	159	162	166	170	173	177	180	198	215	233	250
240	110	114	118	121	125	129	133	137	140	144	148	151	155	159	162	166	170	173	177	180	184	202	219	236	253
250	114	118	121	125	129	133	137	140	144	148	151	155	159	162	166	170	173	177	180	184	187	205	222	239	256
260	118	121	125	129	133	137	140	144	148	151	155	159	162	166	170	173	177	180	184	187	191	209	226	243	260
270	121	125	129	133	137	140	144	148	151	155	159	162	166	170	173	177	180	184	187	191	195	212	229	246	263
280	125	129	133	137	140	144	148	151	155	159	162	166	170	173	177	180	184	187	191	195	198	215	233	250	266
290	129	133	137	140	144	148	151	155	159	162	166	170	173	177	180	184	187	191	195	198	202	219	236	253	270
300	133	137	140	144	148	151	155	159	162	166	170	173	177	180	184	187	191	195	198	202	205	222	239	256	273
310	137	140	144	148	151	155	159	162	166	170	173	177	180	184	187	191	195	198	202	205	209	226	243	260	276
320	140	144	148	151	155	159	162	166	170	173	177	180	184	187	191	195	198	202	205	209	212	229	246	263	280
330	144	148	151	155	159	162	166	170	173	177	180	184	187	191	195	198	202	205	209	212	215	233	250	266	283
340	148	151	155	159	162	166	170	173	177	180	184	187	191	195	198	202	205	209	212	215	219	236	253	270	286
350	151	155	159	162	166	170	173	177	180	184	187	191	195	198	202	205	209	212	215	219	222	239	256	273	289
360	155	159	162	166	170	173	177	180	184	187	191	195	198	202	205	209	212	215	219	222	226	243	260	276	293
370	159	162	166	170	173	177	180	184	187	191	195	198	202	205	209	212	215	219	222	226	229	246	263	280	296
380	162	166	170	173	177	180	184	187	191	195	198	202	205	209	212	215	219	222	226	229	233	250	266	283	299
390	166	170	173	177	180	184	187	191	195	198	202	205	209	212	215	219	222	226	229	233	236	253	270	286	302
400	170	173	177	180	184	187	191	195	198	202	205	209	212	215	219	222	226	229	233	236	239	256	273	289	306

Table 2: Points

	Consumption																								
Habit	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	250	300	350	400
0	0	20	36	51	65	78	91	104	117	129	141	153	165	176	188	199	210	222	233	244	254	308	359	409	459
10	-27	13	33	49	63	78	91	104	117	130	142	154	166	178	189	201	212	223	234	245	256	310	362	412	462
20	-46	-14	26	45	61	76	90	104	117	130	142	155	167	179	190	202	213	225	236	247	258	312	364	415	465
30	-63	-34	-2	38	58	74	89	103	117	130	142	155	167	179	191	203	215	226	237	249	260	314	367	418	467
40	-79	-50	-21	11	51	71	87	102	116	129	142	155	168	180	192	204	216	227	239	250	261	316	369	420	470
50	-93	-66	-38	-8	24	64	84	100	114	129	142	155	168	181	193	205	217	229	240	252	263	318	371	423	473
60	-106	-80	-53	-25	5	37	77	96	112	127	141	155	168	181	193	206	218	230	241	253	264	320	374	425	476
70	-119	-94	-67	-40	-12	17	49	89	109	125	140	154	168	181	193	206	218	230	242	254	266	322	376	428	479
80	-132	-106	-81	-55	-28	1	30	62	102	122	138	153	167	180	193	206	219	231	243	255	267	324	378	430	481
90	-143	-119	-94	-68	-42	-15	13	43	75	115	135	151	165	180	193	206	219	232	244	256	268	325	380	433	484
100	-155	-131	-106	-81	-55	-29	-2	26	56	88	128	147	163	178	192	206	219	232	244	257	269	327	382	435	487
110	-166	-142	-118	-93	-68	-43	-16	11	39	68	100	140	160	176	191	205	219	232	244	257	269	328	384	437	489
120	-177	-153	-129	-105	-81	-55	-30	-4	23	52	81	113	153	173	189	204	218	231	244	257	270	329	386	440	492
130	-187	-164	-140	-117	-92	-68	-43	-17	9	36	64	94	126	166	186	202	216	231	244	257	270	331	387	442	494
140	-197	-174	-151	-128	-104	-80	-55	-30	-4	22	49	77	107	139	179	198	214	229	243	257	270	332	389	444	496
150	-207	-185	-162	-138	-115	-91	-67	-42	-17	8	35	62	90	119	151	191	211	227	242	256	270	332	390	446	499
160	-217	-194	-172	-149	-126	-102	-78	-54	-30	-4	21	47	74	103	132	164	204	224	240	255	269	333	392	448	501
170	-226	-204	-182	-159	-136	-113	-89	-66	-41	-17	8	34	60	87	115	145	177	217	237	253	267	334	393	449	503
180	-236	-214	-191	-169	-146	-123	-100	-77	-53	-29	-4	21	47	73	100	128	158	190	230	249	265	334	394	451	505
190	-245	-223	-201	-179	-156	-134	-111	-87	-64	-40	-16	9	34	59	86	113	141	170	202	242	262	334	395	453	507
200	-254	-232	-210	-188	-166	-143	-121	-98	-75	-51	-27	-3	21	47	72	98	125	154	183	215	255	333	396	454	509
210	-263	-241	-219	-198	-175	-153	-131	-108	-85	-62	-38	-15	10	34	59	85	111	138	166	196	228	333	397	456	511
220	-271	-250	-228	-207	-185	-163	-140	-118	-95	-72	-49	-26	-2	22	47	72	98	124	151	179	209	331	397	457	513
230	-280	-259	-237	-216	-194	-172	-150	-128	-105	-83	-60	-36	-13	11	35	60	85	110	137	164	192	329	397	458	515
240	-288	-267	-246	-224	-203	-181	-159	-137	-115	-92	-70	-47	-24	-0	24	48	72	98	123	149	176	326	397	459	516
250	-296	-275	-254	-233	-212	-190	-168	-147	-124	-102	-80	-57	-34	-11	13	36	61	85	110	136	162	319	397	460	518
260	-304	-284	-263	-242	-220	-199	-177	-156	-134	-112	-89	-67	-44	-21	2	25	49	73	98	123	149	292	396	461	519
270	-312	-292	-271	-250	-229	-208	-186	-165	-143	-121	-99	-77	-54	-32	-9	15	38	62	86	111	136	272	395	461	521
280	-320	-300	-279	-258	-237	-216	-195	-173	-152	-130	-108	-86	-64	-41	-19	4	27	51	75	99	123	256	393	461	522
290	-328	-308	-287	-266	-245	-224	-203	-182	-161	-139	-117	-96	-73	-51	-29	-6	17	40	64	87	112	240	390	461	523
300	-336	-315	-295	-274	-253	-233	-212	-191	-169	-148	-126	-105	-83	-61	-38	-16	7	30	53	76	100	226	383	461	524
310	-343	-323	-303	-282	-261	-241	-220	-199	-178	-157	-135	-114	-92	-70	-48	-26	-3	19	42	66	89	212	355	460	524
320	-351	-331	-310	-290	-269	-249	-228	-207	-186	-165	-144	-122	-101	-79	-57	-35	-13	10	32	55	78	200	336	459	525
330	-358	-338	-318	-297	-277	-257	-236	-215	-194	-173	-152	-131	-110	-88	-66	-45	-22	-0	22	45	68	187	319	457	525
340	-365	-345	-325	-305	-285	-264	-244	-223	-202	-182	-161	-140	-118	-97	-75	-54	-32	-10	13	35	58	175	304	453	525
350	-373	-353	-333	-312	-292	-272	-252	-231	-210	-190	-169	-148	-127	-106	-84	-63	-41	-19	3	25	48	164	290	446	525
360	-380	-360	-340	-320	-300	-280	-259	-239	-218	-198	-177	-156	-135	-114	-93	-71	-50	-28	-6	16	38	153	276	419	524
370	-387	-367	-347	-327	-307	-287	-267	-246	-226	-206	-185	-164	-143	-122	-101	-80	-59	-37	-15	6	29	142	263	400	522
380	-394	-374	-354	-334	-314	-294	-274	-254	-234	-213	-193	-172	-151	-131	-110	-89	-67	-46	-24	-3	19	132	251	383	520
390	-400	-381	-361	-341	-322	-302	-282	-261	-241	-221	-201	-180	-159	-139	-118	-97	-76	-55	-33	-12	10	121	239	368	517
400	-407	-388	-368	-348	-329	-309	-289	-269	-249	-229	-208	-188	-167	-147	-126	-105	-84	-63	-42	-20	1	112	228	353	510

Appendix IV

Table 13: Savings' Structure (ECU)

	Deterministic Income			Stochastic Income		
	S1Cons	S2Cons	S3Cons	S1Stoch	S2Stoch	S3Stoch
Total Savings:	238.76	243.33	391.81	197.73	241.73	346.50
"Pocket" Savings	238.76	143.33	108.58	197.73	141.73	125.20
Obligatory Savings	-	100.00	100.00	-	100.00	100.00
Voluntary Contribution	-	-	183.23	-	-	121.30

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