# Informed and Uninformed Investors

# in an Experimental Ponzi Scheme

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**Abstract**

We study subject behavior in a laboratory Ponzi scheme. Two types of investors exist: informed and uninformed. Besides having a first mover advantage, the informed have specific knowledge about the viability of the scheme, *i.e.*, they know when it is time to withdraw. We derive theoretical predictions for this experimental game. Our experiments study three treatments, to wit, group size, interest rate and the relative number of informed. The results show that group size does not matter in our case but that both the interest rate and the number of informed affect behavior. Especially the behavior of the uninformed is affected in a way that is not predicted by theory: they tend to show a kind of 'herd' behavior by reacting to the choices of the informed.

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# 1. Introduction

In the summer of 1920, Massachusetts was shocked by a tremendous financial scandal that affected thousands of innocent investors. The Italian born immigrant Charles Ponzi offered investors a 50% return on their investment in 90 days. He claimed that he himself was making a 400% return on the money. In fact, he was using the money invested by others to pay out the interest owed. The system did not collapse before ten thousand people invested almost ten million dollar. This fraud lead to a jail sentence for Ponzi (who allegedly died owning only 75 dollar) but also made his name famous.[1] Nowadays, it is known as a Ponzi scheme. *Ponzi schemes are games where individuals or companies pay out funds to some parties by borrowing funds from others*.

Ponzi schemes existed before 1920 and many have existed since then. Bhattacharya (1998) reports on one in France, in 1719. Very famous are the recent cases in Albania. In 1997, the Albanian economy suddenly collapsed after four years of rapid growth following decades of communist dictatorship and central planning. The main reason for the collapse was the unraveling of a series of what was commonly -but incorrectly- referred to as 'pyramid schemes'. A large number of Albanians invested and lost their life savings in funds that went bankrupt. This led to a political and economic chaos that is still paralyzing the country today. More information about the economy in Albania and the effect of the Ponzi schemes is given by Gërxhani and Schram (1999), Sadiraj, Van Wijnbergen and Van Ewijk (1997), Shala (1997), and the references therein.

Pyramid schemes are a specific kind of Ponzi schemes. A classic pyramid operates on the assumption that some individuals (at the 'top') will earn money from the investments of others. As time progresses, more and more people are needed to support those in the upper levels. These pyramid schemes can be either legitimate or illegitimate. In a legitimate pyramid structure, the primary purpose is to sell a product (*e.g.*, encyclopedias, soaps or cosmetics). The return to the upper levels of the pyramid are from both the sale of the product and the recruitment of new salespersons. The return is generated from both one's own commission on sales and the commissions on sales of those one recruits. In an illegitimate pyramid, the return is typically derived from investments by others and not from sale commissions. They offer

[1] For more information about Charles Ponzi, see the web site 'The Ponzi Scheme' by Mark C. Knutson (www.usinternet.com /users/mcknutson/pscheme.htm).

investment returns which sound better than what is offered in the marketplace. The investors are encouraged to reinvest the profits rather than take a payoff.

The distinguishing feature of the pyramid type of Ponzi schemes is that old victims are paid back with funds received from new victims. As long as the pyramid continues to grow, the investors are not usually aware that their money has been misappropriated. Most of these schemes unravel when new 'investors' can no longer be found. Generally, illegal pyramid schemes collapse of their own weight. The schemes often are not reported and, therefore, not prosecuted because individuals are embarrassed to admit that a con artist fleeced them. The illegitimate recruiter can be anyone: a friend, relative, neighbor, work peer, church member, academic economist, journal editor, or someone unknown.

As mentioned, Ponzi schemes are more general than only the pyramid type. All share some of the characteristics of the pyramid schemes but also have some different dynamics.[2] The kind of Ponzi scheme observed in Albania, is characterized by the promotion of what starts out to be, or appears to be, a real investment opportunity. Therefore, contrary to common understanding, the Albanian schemes were not pyramids but another kind of Ponzi scheme.[3] From here onward, we will use the term 'Ponzi scheme' to refer to the non-pyramid type of scheme observed in Albania. The important thing that all Ponzi schemes have in common, however, is that to survive, they need to use invested funds to pay other investors. When there is insufficient money left (e.g., because investors start to withdraw), they collapse.

The Ponzi schemes under consideration often involve the development of a valuable resource such as oil, gas, minerals or real estate. What is being promoted often actually exists. In this case, the promoter does own a mine, or some investment property. However, the promoter typically grossly overvalues its worth. In other cases, the asset or resource, which is the basis for the investment opportunity, is a figment of the promoter's imagination. In either scenario,

[2] See Gerald P. Nehra's web site: mimstartup.com/articles/ponzi.htm.

[3] There are several distinctions between the Albanian type of Ponzi schemes (like the one developed by Ponzi himself) and pyramid schemes. First, a pyramid scheme involves a person making an investment for the right to receive compensation for introducing new participants. There is a clear understanding that the success of the opportunity is dependent upon attracting additional participants. A Ponzi scheme participant believes that the investment is dependent upon the successful development of a productive asset such as a mine or real estate complex. Second, pyramids must fail because, by their nature, they depend upon endless exponential participation growth to succeed. Ponzi schemes eventually fail because the underlying asset upon which the investment was based either never existed, or was grossly overvalued. Contrary to pyramid schemes, Ponzi schemes can flourish even with passive investors. Finally, pyramid scheme participants 'go for gold' by attracting others to the scheme. Ponzi scheme participants 'go for gold' by increasing their investment and hopefully their share of the profits from the successful development of the productive asset.

the promoter convinces investors that the asset can be further developed with more capital, and the promoter will share the profits with the investors.

In these Ponzi schemes, substantial dividends are paid out to the investors early on. The representation is that these dividends are ‘profits’ coming from the successful development of the investment assets. What is actually happening is that the promoter is merely returning a portion of the investors' money to them. These early and substantial dividends induce early investors to increase their share of the operation, while additional investors are attracted to the scheme. The driving force for the scheme to survive is that the amount of money invested must always be higher than the amount of money needed to be paid out. The process of paying dividends continues and (sometimes) more investors come forward until the fraud is uncovered because investors want to withdraw more money than is available or the promoter disappears with the investment proceeds.[4]

Typically, two types of investors participate in these Ponzi schemes: informed and uninformed (Sadiraj, Van Wijnbergen, and Van Ewijk, 1997). In Albania, for example, informed investors were governmental influential people trying to maximize their earnings while they had influence. Uninformed investors were the ‘common people’. The informed investors control the main sources of information dissemination, the media. They give positive information about the existence of these schemes giving the impression, for example, that government supports it and it is a secure investment with high returns. The advantage for informed investors is that their informational advantage typically allows them to get out of the scheme on time.

In this paper, we will study the non-pyramid type Ponzi schemes. Note that it is generally very difficult to obtain field data on these schemes. Apart from the fact that many are illegal and therefore do not have public records, the records that are available will generally have very noisy data. They have typically flourished in countries where reliable data on variables like inflation or interest rates offered by different institutions are difficult to find.

Therefore, in order to get a better understanding of individual behavior in such schemes, we will study them in a controlled laboratory setting. We will observe the behavior and decisions of individuals in an experimental investment project with the main characteristics of Ponzi schemes. These include an unrealistically high interest rate, the possibility of keeping the scheme alive by using invested funds to pay out interest and an increasing probability of bankruptcy as time passes**.** In addition, as in Sadiraj, Van Wijnbergen and Van Ewijk (1997) we distinguish informed from uninformed investors. How we do so is explained in the following section. Finally, our controlled Ponzi scheme allows for a real return to investments. This return is insufficient to cover the interest paid, however. Only the informed investors know the real return. We are mainly interested in comparative statics. In particular, we will consider the effect of an increase in the interest rate paid and in the relative number of uninformed investors.

As far as we know, Ponzi schemes have not been studied in a laboratory setting before. There is a related phenomenon that has been studied experimentally, however. Bubbles in financial markets have some characteristics similar to Ponzi schemes. Rationally, they should not occur. Nevertheless, it is generally believed that they do occur, and there is a vast theoretical literature trying to explain why (*e.g.*, Brock, 1982, Tirole, 1985, O'Connell and Zeldes (1988), and Gilles and LeRoy, 1992). In addition, they have been observed in laboratory markets (*e.g.*, Smith et al., 1988, King et al., 1990, Sunder, 1995).

Though Bhattacharya (1998) argues that Ponzi schemes are a subset of the bubbles literature, we believe that the relationship is more subtle. There are similarities and differences between Ponzi schemes and bubbles in financial markets. The similarity is obvious: in both cases there is an overvaluation of fundamental asset prices and the market could go down or up. At any point in time, a rational investor will calculate the expected value of the payoff taking both scenarios into account. At the beginning of the life of the scheme or financial bubble, the expected value of investing is thought to be positive. As time passes, the consensus among investors is that the chance that the scheme or the financial bubble might collapse is increasing. However, even if there is consensus that prices are too high, many investors stay in the market for fear of missing out on a golden opportunity, or simply, because they think they can outsmart other investors.

One difference between financial bubbles and Ponzi schemes is that in the bubble, there is a fundamental asset value that the asset price is based on. In case of Ponzi schemes the fundamental asset value is almost 0 since it is based on an asset or resource that is either grossly overvalued by the promoter or it is a figment of his (her) imagination. An important other distinction is given by the institutions they show up in. Bubbles may occur when assets

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[4] Not all Ponzi schemes start out as frauds. Sometimes a promoter really believes the asset will prove profitable.

are traded in a 'double auction' institution where all traders can buy and sell as they wish. The Ponzi schemes occur in institutions where the individual decision is whether or not to participate. Though it would be an interesting topic for future research to compare these institutions and their effect on behavior, this is not an issue addressed in the present paper. Our analysis is restricted to Ponzi games.

In the following section, the game used to study Ponzi schemes is presented in more detail. Section 3 provides a theoretical analysis of the game. The experimental procedures and design are presented in section 4 and the results are discussed in section 5. Section 6 discusses implications and concludes.

## 2. The Ponzi-Game

In the game used to describe Ponzi schemes, investors have to decide whether or not to invest a fixed sum Y (equal across investors) in an investment fund (IF). Investors j, $j \in I \cup U$, are either *informed* ($j \in I$) or uninformed ($j \in U$). We use the notation 'I' ('U') both to denote the set of informed (uninformed) investors and the number of informed (uninformed) investors. The total number of (potential) investors is then given by N=I+U.

Before individual investment decisions are made (i.e., at time t = 0) there is an initial investment $\chi$ in IF, reflecting real returns. We assume that nature draws $\chi$ from a known set of number between p and q, with equal probabilities, i.e. $\chi \in \{p,\ldots,q\}$ where q>p>0. Next, informed investors are told the realization of $\chi$. They may either invest Y in IF or invest nothing. Hence, their strategy space in any period is {0,Y}.[5] As long as bankruptcy does not occur (see below), the game moves on to the uninformed.

The uninformed players do not know the exact value of $\chi$ but they know that $\chi$ is a stochastic variable with a known distribution. After the informed made their decision in a period, and if bankruptcy did not occur, the uninformed choose a strategy from {0,Y}. Again, if bankruptcy does not occur (see below), a return rdY is paid to every $j \in I,U$ where d is a dummy denoting whether or not j invested in IF. Interest payments are paid out of the funds in IF and therefore diminish the amount of money available for the future. Hence, if the amount

[5]In fact, the decision to be made if a subject in our experiments previously invested is whether or not to withdraw this investment. Formulating it in the way we have done in the analysis allows us to assume a constant (and symmetric) strategy space.

of interest payments previously paid were larger than $\chi$, the amount remaining in the scheme would be insufficient to pay back the investments of all investors, if they simultaneously wished to withdraw. This makes the game a Ponzi scheme.

There is a restriction in the strategies allowed. If an investor has previously withdrawn money (i.e., she has invested zero after previously investing Y), she is not allowed to invest again. This implies that withdrawal is final. As will become clear below, this restriction simplifies the analysis considerably.

In any period, the informed have the option of withdrawing their funds before the uninformed make their decision. The decision by the informed is not made public until the end of the period. At that point, the aggregate investment decisions of the informed and the uninformed are made public and a new round is started. Hence, when the informed make their decision, they know what the (aggregate) most recent decision of the uninformed is (and, knowing the realization of $\chi$, they know the exact amount of funds in the scheme). On the other hand, the uninformed know neither the realization of $\chi$, nor the most recent investment decision of the informed when they decide what to do.

In every round, there are two points in time where bankruptcy may occur. First, when the informed make their investment decision, some might want to withdraw their investment. If the amount of money they wish to withdraw is less than the funds available in IF, the withdrawals are realized. If not, bankruptcy occurs. Second, at the end of the round, money is needed to pay for the withdrawals of the uninformed participants plus all interest payments. If there is enough money available in IF, these are realized. If not, bankruptcy occurs. In case of bankruptcy, the funds remaining in IF are equally split across all remaining investors.

Denote the amount of money available in IF in period t by $x_t$ and let $d^t_i$ be a dummy equal to 1(0) if i invested (did not invest) in period t. The following overview summarizes the structure of the game.

| | |
|---|---|
| Period 0 | nature invests $\chi$ in X; $x_0=\chi$. |
| | if $j \in$ I, j is informed of the value of $\chi$. |
| Period 1 | a) all $j \in$ I choose a strategy from {0,Y} |
| | b) all $j \in$ U choose a strategy from {0,Y} |

c) total investment is $\chi + \Sigma_{j\in I,U}d^1_jY$

d) Payoffs to $j \in I,U$ is $rd^t_jY$

e) investment left in $X \equiv x_1 = \chi + (1\text{-}r)\ \Sigma_{j\in I,U}d^1_jY$

Period t

a) all $j \in I,U$ are informed of $\Sigma_{j\in I}d^{t-1}_j$ and $\Sigma_{j\in U}d^{t-1}_j$

b) all $j \in I$ choose a strategy from {0,Y}, unless they have previously withdrawn

c) if the decisions of $j\in I$ were to be implemented , the amount invested would be: $x_{ta} \equiv \chi + \Sigma_{j\in U}d^{t-1}_jY + \Sigma_{j\in I}d^t_jY - r\Sigma^{T-1}_{\tau=1}\Sigma_{j\in I,U}d^\tau_jY$. One must then check whether $x_{ta}$ is sufficient to cover the withdrawals in period t by $j\in I$. Because we define strategies as a decision from {0,Y}, a withdrawal is an investment of 0 following a previous investment of Y. In fact, a bankruptcy occurs when $x_{ta} < 0$.

d) all $j \in U$ choose a strategy from {0,Y}, unless they have previously withdrawn.

e) This would make current investment $x_{tb} \equiv \chi + \Sigma_{j\in I,U}\ d^t_jY - r\Sigma^{T-1}_{\tau=1}\Sigma_{j\in I,U}d^\tau_jY$. Bankruptcy occurs when $x_{tb}$ is insufficient to cover interest payments in period t, for which one needs $r\Sigma_{j\in I,U}\ d^t_jY$.

## 3. Theoretical Analysis

Before turning to game theoretic aspects of this game, consider efficiency. Note that the initial investment $\chi$ (the 'real return') can only be realized (earned by the subjects) if sufficient investments are made. Any other (interest) earnings are effectively a redistribution of income. Therefore, any outcome where there are sufficient investments to have $\chi$ paid out as interest is efficient.

In this multi-stage game, a strategy is a complete plan of action. First, consider the case where every player invests Y in every period. As a consequence, bankruptcy occurs and the remaining funds are distributed evenly. It is easy to see that each investor earns $Y + \chi/N$ in this case. In general, this is not a Nash equilibrium, however. Assume that bankruptcy occurs in period T. Hence, T is implicitly determined by the conditions that

(1) the available funds were sufficient for interest payments in T-1, implying

$\chi + NY \geq (T\text{-}1)rYN$;

(2) the available funds are insufficient for interest payments in T, implying

$\chi + NY < TrYN$, or $\chi < TrYN - NY$.

Next consider an investor that withdraws her investment in T-1. She earns (T-2)rY + Y. Comparing this to the bankruptcy payoff , we find that withdrawal in T-1 is profitable when

$$(T-2)rY + Y > Y + \chi/N, \text{ or } \chi<N(T-2)rY = TNrY - 2NrY.$$

Given the second condition for bankruptcy in T, a sufficient condition for profitable withdrawal in T-1 is NY > 2NrY, or r < 0.5. In that case, the situation where everyone stays in until bankruptcy is not a Nash equilibrium.

Similarly, no outcome can be a Nash equilibrium if all investments are withdrawn and more than rY is left in IF (because a single investor can increase her earnings by investing one more period). For example, no investments in IF at all is not an equilibrium.

Next, consider quasi-symmetric strategies, i.e., symmetric strategies within the group of informed traders and symmetric strategies within the group of uninformed traders (*e.g.,* Palfrey and Rosenthal, 1983). A first thing to note is that in equilibrium, an investor will not postpone investing until a period t>1. In this case, she can unilaterally increase earnings by investing in periods 1..t-1 and, if necessary, moving the period of withdrawal forward. Therefore, we only consider strategies where subjects invest in period 1 and withdraw in period t. If t=1 this implies not investing at all. A strategy is then characterised by the period in which the investment is withdrawn.

Therefore, assume that uninformed investors all follow the strategy that they withdraw in period t*, unless they observe the informed withdrawing in t<t*-1. In the latter case, the informed withdraw in period t.[6] We will (A) first determine the best reply of the informed. Next, (B) we will argue that this best reply does not affect the t* chosen by the uninformed.

[6]If the uninformed observe the informed withdrawing, this indicates that the amount of money left from $\chi$ is insufficient to pay interest. We will argue below that, in equilibrium, the informed will not withdraw in any t<t* for certain parameters.

Then (C) we will discuss the incentives for individual investors to deviate from the optimal quasi-symmetric strategies. Finally, (D) we determine the optimal t*.

*(A) The best reply to t**

Let $R_t$ denote the total amount of money paid as interest in the periods 1,..,t-1. Thus, $R_t = r\Sigma^{T-1}_{\tau=1}\Sigma_{j\in I,U}d^{\tau}_{j}Y$.

Also, let $t_\chi$ be the number of periods that interest can be paid out of $\chi$ to all N investors, given the realized value of $\chi$. Hence, $t_\chi$ is such that $R_{t\chi}\leq\chi$ and $R_{t\chi+1}>\chi$. Next, if $t_\chi > t^*-1$, let t** > t* be the lowest number of periods for which $\chi$ is insufficient to pay interest if all N investors receive interest for t*-1 periods ($R_{t^*}=(t^*-1)NrY$) and only the I informed investors receive interest thereafter. In this case, the uninformed leave the scheme before $\chi$ has been paid out completely as interest and the informed can stay in longer (until period t**-1) without risk. Thus, if $t_\chi > t^*-1$, t** is such that:

$$\chi - R_{t^*} -(t^{**}-t^*)rIY > 0 \text{ and } \chi - R_{t^*} -(t^{**}+1-t^*)rIY < 0.$$

The final thing to consider before describing the best reply of the informed to the uninformed strategy t* is the fact whether interest payments in excess of $\chi$ are being paid out of the investments of the uninformed or of the informed. We will choose parameters in a way that insures that $\chi$ plus the investments by the uninformed are sufficient to pay interest to all investors until t*. We will call this the Ponzi-condition. If it is not fulfilled, the informed are in fact playing a game of chicken amongst themselves that is not relevant for the Ponzi scheme.

Now, assuming that the Ponzi condition is fulfilled, if the uninformed play the strategy t*, the best reply by the informed is to play the strategy:

| | | |
|---|---|---|
| withdraw in | t* | if $t_\chi \leq t^*-1$ |
| | t** | if $t_\chi > t^*-1$ . |

The intuition underlying this strategy is that the informed will withdraw at the last chance before the uninformed do, if the latter are ‘overestimating’ the amount of money available. In this case, the informed will draw interest from the investments by the uninformed. If the uninformed are underestimating the amount available, the informed will stay in until $\chi$ is (almost) depleted.

It is easy to see that this is a best reply to t* if all informed are forced to use the same strategy. If $t_\chi \leq t^*-1$ no informed investor has a reason to withdraw at a different time than t*. If $t_\chi > t^*-1$, all informed investors will stay in as long as the amount of money left in excess of investments is enough to pay interest to all informed (note that the uninformed will have withdrawn at the earlier stage t*. If the amount remaining is enough to pay interest to a subset of the informed investors, a game of chicken occurs between the informed players (similar to the situation described in Sadiraj, van Wijnbergen, and Ewijk 1997). We will not discuss this ‘subgame’ in the present analysis.

*(B) Effect on t**

Next, we consider whether this best reply will affect the t* chosen by the uninformed. This is not the case. The structure of the strategy by the informed is such, that an uninformed cannot derive any information about the value of $\chi$ from it. Therefore, the uninformed will not update their beliefs about $\chi$’s value and stick to their originally determined t*.

*(C) Individual deviation from t**

Are there reasons for individual uninformed investors to deviate from the quasi-symmetric t*? As with the informed, the only reason for individual deviation would be that there is enough money (expected) for interest payments to some uninformed but not enough for all. Again, the consequence is a game of chicken between the uninformed, which we will not focus on.

*(D) Determining t**

Therefore, we now determine the optimal t*. To do so, we determine the withdrawal period that maximizes the expected return for the uninformed investor. Recall that $\chi$ is drawn from a distribution on the domain {p,…,q}, with equal probabilities. Let $t_p$ ($t_q$) be the number of periods that all N participants can receive interest payments, if $\chi$=p ($\chi$=q).

First note that there are $t_q$-$t_p$+1 discrete periods in the interval [$t_p$,$t_q$]. The probability that $\chi \in$ [p,q] is large enough to pay interests to all I+U participants for exactly $t_p$+n periods, $0 \leq n \leq t_q - t_p$, is equal to $1/(t_q-t_p+1)$. If the uninformed stay in for $t_p$+n periods, the probability that $t_\chi \geq t_p+n$ (hence, the uninformed do not lose money to the informed) is equal to $(t_q - (t_p+n) +1)/(t_q-t_p+1)$. The probability that any of the outcomes that $t_\chi = t_p$, $t_p+1$ … $t_p+n-1$ occurs is $1/(t_q-t_p+1)$. Note that the probabilities over all $t_\chi$ (=$t_p$..$t_q$) sum up to 1.

Assume risk neutrality. Define $Pr \equiv 1/(t_q-t_p+1)$ and denote money earnings by $\pi$. Recalling that we are still assuming that the Ponzi condition is fulfilled, the expected payoff from staying in for $t^*=t_p+n$ periods ($n\in\{0,1,\ldots,t_q-t_p\}$) is given by:

$$E(t_p+n)= \pi( t_p+n \mid t_\chi \geq t_p+n)\, P(t_\chi \geq t_p+n) + \pi( t_p+n \mid t_\chi < t_p+n)\, P(t_\chi<t_p+n)$$

$$= \{(rY\,(t_p+n)+Y)\,(t_q-(t_p+n)+1)\}\,Pr + \sum_{i=tp}^{tp+n-1} (\{UY-(t_p+n - i)rIY\}/U + riY)\,Pr$$

$$= \{(rY\,(t_p+n)+Y)\,(t_q-(t_p+n)+1)\}\,Pr + \sum_{i=tp}^{tp+n-1} [riY(1+I/U) -(t_p+n)rIY/U+Y]Pr$$

The first part of this expression gives the expected (net) interest earnings in case when $t_\chi > t^* = t_p+n$. The summation gives the expected net interest earnings for $t_\chi < t^*$. In this case, bankruptcy will occur when the uninformed try to withdraw in t*. The net earnings are determined by what the uninformed player gets before bankruptcy minus interests that are paid to the informed from the investments of the uninformed.

Because p,q and Y are independent of n, maximization (over n) of E is equivalent to maximization of $E'\equiv E/(YPr)$ over n. Rewriting gives:

$$E' = (r\,(t_p + n) +1)(t_q - (t_p + n) + 1) + \left(r(1 + I/U) \sum_{i=tp}^{tp+n-1} i\right) - (t_p + n)\, r\, n\, I/U +n$$

$$= (r\,(t_p + n) +1)(t_q - (t_p + n) + 1) + (r(1 + I/U)\,(nt_p+n(n-1)/2) - (t_p n+ n^2)\, r\, I/U+n$$

Taking the derivative:[7]

$$dE'/dn = 0 = r(t_q- 2t_p +1)-1 -2nr +r(1-I/U)n - (r/U)(U/2+I/2\, Ut_p) +1$$

[7] Formally, we cannot take the derivative to n, because n is discrete, of course. The function is such, that we can optimize for continuous n, however. If the optimum is for non-integer n, we need to check which of the adjacent integers is optimal. If the optimum is 'out of bounds', the corresponding corner solution is the optimum.

Note that the second derivative is equal to -r(1+I/U), i.e. negative. So, we are dealing with a maximum. Hence, $n = [t_q - t_p + (1-I/U)/2]\ U/(U+I)$ and $t^* = t_p + n = t_q + I/N\ t_p + (U-I)/2N$. Hence, for given parameters, we can easily calculate the quasi-symmetric equilibrium. In the next section, we will do so for the parameters used in the experiments.

## 4. Procedures and Parameters

The experiments were run at the CREED laboratory of the University of Amsterdam in May-September 1998. Subjects were recruited from the undergraduate population.[8] In total, 224 subjects participated. This experiment lasted about 1 hour. On average, participants earned 35 guilder. [9]

In all sessions we chose Y=250 Dutch cents We used a complete 2x2x2 design, varying the number of participants (N=16 versus N=12), the interest rate r (r=0.1 versus r=0.2), and the relative number of informed, (I=1, U=N-1 versus I=U=N/2). The values chosen for p and q (the boundaries for the distribution from which $\chi$ was drawn) depend on the number of participants. For N=12, we chose p=1200, q=3600 and for N=16, the values are proportionally higher: p=1600, q=4800. For all combinations of the numbers chosen it can be shown that the Ponzi condition is fulfilled. We shall refer to the high (low) interest sessions as Hi (Lo) and to the sessions with 1 informed subject(s) as 1. We will refer to all sessions (N=12 or N=16) with half of the subjects informed by “8”. Because we ran a full between subject design, we have the following eight kinds of sessions: Hi1-12; Hi8-12; Lo1-12; Lo8-12, Hi1-16; Hi8-16; Lo1-16; Lo8-16. We ran each of these sessions twice, for a total of 16 sessions. In each session, 8 independent rounds with the parameter configuration concerned were run.

The values of $t_p$ and $t_q$ depend on r. In Hi1 and Hi8, the value of $\chi$ was chosen from the set {1600, 2400, 3200, 4000, 4800} when N=16 and 3/4 of the values of this set when N=12. In Lo1I and Lo8I the set was {1600, 2000, 2400, 2800, 3200, 3600, 4000, 4400, 4800} when N=16 and again 3/4 of the values of this set when N=12. The integer values were chosen such, that that interest could be paid from $\chi$ to all subjects for exactly an integer number of periods, if all invested. This explains why the set is larger with the low interest rate and why the

[8] In some sessions, subjects were invited to stay for a second experiment, unrelated to the one reported here.

[9] At the time of the experiments, 100 cents = $0.50.

numbers are lower for N=12. With the parameters chosen, we have $t_p$=2, $t_q$=6 for Hi1 and Hi8 and $t_p$=4, $t_q$=12 for Lo1 and Lo8, irrespective of N.

Because the Ponzi condition is fulfilled, we can use the calculations of the previous section to determine the quasi-symmetric equilibrium strategies t*. Again, the values chosen for the distribution underlying $\chi$ imply that t* is equal for N=12 and N=16. The values for the various combinations of r and I are given in table 1.

| I | 1 | 6/8 |
|---|---|---|
| R = 0.1 | 12 | 8 |
| R = 0.2 | 6 | 4 |

**Table 1: Quasi-symmetric equilibrium t*.**

Hence, in this equilibrium, all subjects will keep their money invested in the fund until t*=$t_q$ in Hi1 ($t_q$=6) and Lo1 ($t_q$=12). In Hi8 and Lo8 the uninformed will withdraw halfway between $t_p$ and $t_q$ and the informed will do the same for low draws of $\chi$ but stay in longer for high draws.

The random draws of $\chi$ were made once for all sessions to minimize noise in the data analysis. Nevertheless, the distinct parameter configurations implied that we needed to adapt the numbers for various sessions. We decided to adapt $\chi$ in such a way, that $t_\chi$ (the number of periods in which there was enough 'outside' money in the fund to pay interest to all participants) was comparable across sessions. For example, in round 1 of the sessions with N=16 and an interest rate of 10%, the value $\chi$=2400 was used. In this case, 400 is paid in interest in each period when all participants invest. This implies that $t_\chi$=6. To adapt for N=12, we used the value $\chi$=0.75*2400=1800. For these sessions, 300 is paid in interest in each period when everyone invests, and once more $t_\chi$=6. For an interest rate of 20%, 800 (N=16) or 600 (N=12) is paid per period when everyone invests, implying $t_\chi$=3. Here, we did not adjust the value, in order to avoid income effects. In the following section it will be argued that a simple rescaling of time makes the sessions with high and low interest rates comparable.[10] Table 2 gives an overview of the random draws of $\chi$ in the 8 rounds and the corresponding $t_\chi$ values.

[10] In some cases, the value drawn for $\chi$ was not dividable by 600 (800) and therefore not in the set used for the random draw in case of a high interest. In these cases we adjusted the value in the way discussed in the notes of table 2.

| Round | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| $\chi$ | 2400 | 4800 | 1600 | 1600 | 3600[1] | 4000 | 2000[2] | 3600[1] |
| $t_\chi$(low interest) | 6 | 12 | 4 | 4 | 9 | 10 | 5 | 9 |
| $t_\chi$(high interest) | 3 | 6 | 2 | 2 | 4 | 5 | 3 | 4 |

**Table 2: Random draws of $\chi$**
[1]Adjusted to 3200 for the high interest sessions.
[2]Adjusted to 2400 for the high interest sessions.

# 5. Experimental Results

## General Results

A first question is, of course, whether the Ponzi schemes in the laboratory collapse like they do in the outside world. The answer is a clear 'yes'. In all rounds of every session a bankruptcy occurred: in the late periods of every round $\chi$ was completely depleted and money invested by players was used to pay out interest.[11] In this respect, the outcome in the laboratory is no different than that in Massachusetts in 1920, Albania in 1997, or numerous other places around the world in the past century. An important difference, however, is that the laboratory allows us to carefully study the development of the Ponzi scheme and the individual choices underlying it.

We start with an overview of aggregate participation in the schemes. In figure 1, we show the 'survival function'. This shows the raw data by giving the percentage of subjects investing in the scheme as a function of the period. In order to make all sessions directly comparable, we multiple the survival time of the sessions with a high interest rate by 2. This can be interpreted as a rescaling of time. Basically, we are treating the investment decision as if it lasts for two periods, in these sessions. With this adjustment, for all sessions, the quasi-symmetric equilibrium derived above is for everyone to withdraw in period 12 in case of 1 informed player and for at least all uninformed to leave in period 8 when there are 6 or 8 informed players. Note in figure 1 that we do not observe such a step-function. Instead, investors start withdrawing as soon as investing becomes risky (period 4) and many keep their

[11] Recall that bankruptcy occurs in the quasi-symmetric equilibrium when $t_\chi<t^*$.

money invested even when it is sure that interest is being paid out of subjects' investments.[12] This observation is not a consequence of aggregating across rounds with varying values of $\chi$. We observe the same in individual rounds as well. Nevertheless, the major decline in investment takes place between period 8 and 12 in all sessions. Hence, in aggregate, behavior looks somewhat similar to that in equilibrium.[13]

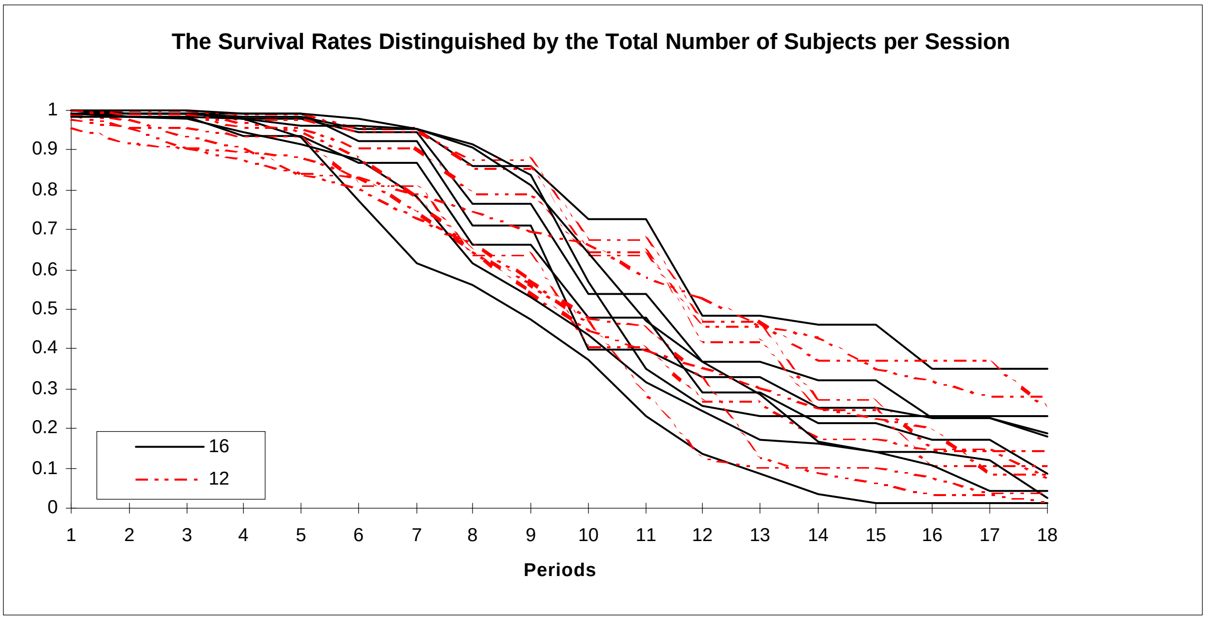


Figure 1. The survival rates for N = 16 and N = 12

In figure 1, we have distinguished the sessions with 12 and 16 subjects. At first sight, the number of subjects does not affect participation in the scheme. This is supported by Renyi test (Q=1.86,p=0.13).[14] Therefore, from here onward we pool our data for N=12 and N=16 and continue the analysis with 4 sessions for each of the combinations of the other two treatments (interest rate and number of informed).

We now turn to a straightforward graphical overview of the four combinations of our treatments. Figure 2 compares the low interest sessions with 1 and 8(6) informed investors. Figure 3 does the same for the high interest sessions. At first sight, investors appear to keep their money in the fund longer, when there is 1 informed investors than when there are 8(6).

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[12] Obviously, both observations make the risk neutrality assumption underlying our theoretical analysis questionable. We will return to this matter in the concluding discussion.

[13] In figure 1, we have deleted observations beyond period 18. In some cases, the fund remained 'alive' for a number of periods longer. In general this was the case when two or three investors were involved in a game of chicken and did not withdraw. In all cases, the funds ended in bankruptcy, either because withdrawals or because interest payments could not be paid from the fund.

[14] The Renyi test is the analogue of a Kolomogorov Smirnov test that corrects for censored data. In addition, we conducted all of the test presented below for our other two treatments and find no evidence of a group size effect.

This seems to hold a bit stronger for the low interest sessions than for the high interest ones. We use a two-sample Renyi test to test the null hypothesis that the survival functions are the same for the two different treatments. The alternative hypothesis is that they are significantly different for different treatments. In both the low and high interest cases we reject the null hypothesis (Q=7.23, p<0.01; Q=6.30, p<0.08, respectively). Therefore we conclude that the number of informed traders affects the investment decisions.

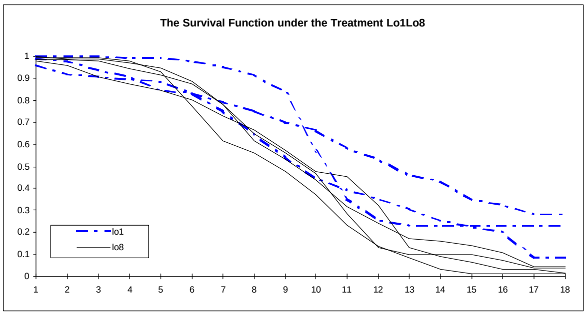


Figure 2. Survival functions for Lo1, Lo8 treatments

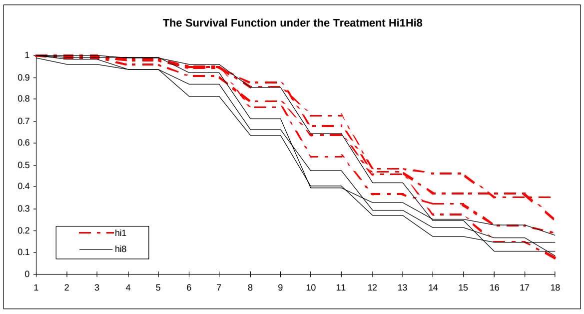


Figure 3. Survival functions for Hi1, Hi8 treatments

Next, we compare the high and low interest sessions (rescaling time in the former case). Figure 4 compares the high and low interest sessions where 1 informed investor participated. Figure 5 does the same for the sessions with 8(6) informed investors. It appears that there is an effect in case there are 8(6) informed investors, with higher interest leading to longer survival. The effect seems less clear for the cases where there is 1 informed, except perhaps in later periods. However, Renyi tests show that the difference is significant for both 1 informed (Q=4.68, p<0.01) and 8 informed (Q=5.15, p<0.01).

Next, we briefly compare investments to what predicted by the quasi-symmetric equilibrium. Recall that in this equilibrium, the uninformed invest until period t*=12 for all sessions with 1 informed (after rescaling time for the high interest sessions), and until t*=8 for all sessions with 8(6) informed. The informed should all withdraw in period 12 as well, in the

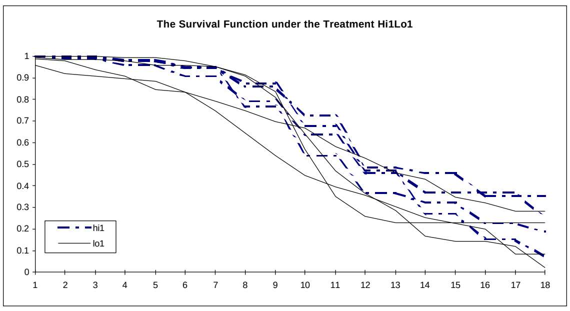


Figure 4. Survival functions for Lo1, Hi1 treatments

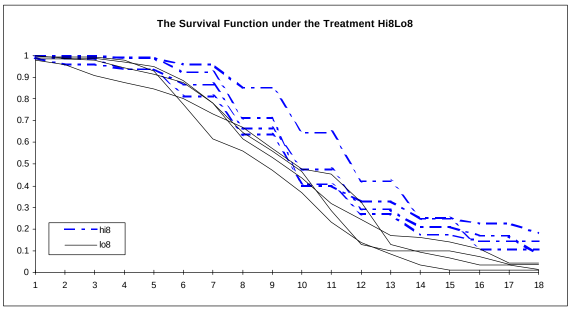


Figure 3. Survival functions for Lo8, Hi8 treatments

sessions with 1 informed (because $t^*=t_q$). Hence, with 1 informed, total investment should be 0% in period 12, irrespective of the interest rate. We observe 38.5% participation in the low interest cases and 47.7% with high interest. When there are 8(6) informed, participation by these informed in period $t^*=8$ depends on the actual value of $t_\chi$. At any rate, it should be below 50% (because all uninformed withdraw) and it should not be affected by the interest rate. For these sessions, we observe 60.4% participation in period 8 with low interest and 70.3% with high interest.

Hence, the comparative statics for participation in t*, when comparing 1 or 8(6) informed (*i.e.*, higher participation in the latter case) are confirmed. There is also a higher participation for higher interest rate, however, which is not predicted. All in all, the quasi symmetric equilibrium is not a good predictor of behavior.[15] In addition, we do not observe any development of behavior towards this equilibrium across the 8 rounds of play. To get a better understanding of individual choices, we now turn to a more detailed analysis of behavior in our laboratory games. This will also allow us to test the game theoretical predictions more formally.

## Analysis of Investment decisions

To obtain a better understanding of the experimental results, we describe the observations in each session by using a discrete hazard model to study the decision to withdraw money from the scheme. This model describes the probability of leaving the scheme in period t conditional on participating in t-1. This probability is called the hazard rate. It is a function of the period and of a set of covariates (which may or may not be time dependent). Details can be found in Lancaster (1990).

To estimate this model, we apply a parameterization using the exponential distribution. The covariates we use in our estimations denoted by Z. The hazard rate $\theta_t$ is then given by:

(1) $\theta_t = 1 - \exp(-\exp(\gamma_t + \beta' Z))$,

where $\gamma_t$ is a term allowing the so-called 'baseline hazard' to vary across periods. This allows for the fact that the probability of withdrawing (given that one is still investing) increases over time, independent of other variables. When estimating the coefficients $\gamma_t$ and $\beta$, we correct for the fact that we have censored data (*i.e.*, subjects cannot participate after bankruptcy even though they had chosen to).

For $\gamma_t$, we estimate 4 distinct coefficients by dividing the periods in (1) the risk free periods where $\chi$ is always large enough to pay interest to all subjects for 4 periods (periods 1-4 with low interest and periods 1-2 with high interest); (2) the 'low risk' periods 5-8 (low interest) or 3-4 (high interest); (3) the risky periods 9-12 (5-6; (4) the high risk periods where it is certain that $\chi$ is not large enough to cover interest payments to all subjects (beyond 12 for low interest and beyond 6 for high interest). Each of these sets of periods is represented by a binary variable in our regressions.

We use the coefficients estimated by this model to summarize the data per session. In fact we estimate three versions of the model per session. These differ in the group of subjects involved and the variables used for Z. In version one, we study the basic characteristics in the structure of individual behavior. This model uses all choices (across 8 rounds) by all participants. In this case, Z consists of two binary variables, indicating the player type (informed or uninformed) and the actual value of $\chi$ drawn. The latter is set equal to zero for the uninformed, because they do not know the actual value, of course. Hence, in this model, the data of a session are summarized by six numbers, the four coefficients $\gamma_t$ and the coefficients concerning player type and the value of $\chi$.

The second and the third versions of the model are meant to test particular game theoretical predictions. The second version considers (only) the choices (in 8 rounds) of the uninformed in each session and the third (only) the choices of the informed.

An important characteristic of the quasi symmetric equilibrium, is that the uninformed should not react to the investment decisions of the informed, unless the latter withdraw before t*, which will not happen in equilibrium. Therefore, it is interesting to study the extent to which the uninformed do follow the informed. We will refer to this as 'herding'. This is what we test in the second version. In this case, Z only consists of a variable describing the fraction of informed investors that withdrew in the previous period. Note that Z is now time dependent, which we indicate by adding a subscript. The hazard model we estimate is then given by:

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[15] Naturally, other equilibria may exist. We are more interested in studying behavior in Ponzi schemes than in a detailed

(2) $\theta_t = 1- \exp(-\exp(\gamma_t+\alpha Z_t))$.

The data of a session are summarized by the corresponding coefficient and the four coefficients $\gamma_t$.

In the third version of the model we test the game theoretical prediction that the hazard rate of the informed will be different for the cases (1) when the actual number of risk free periods $t_\chi$ -determined by the value of $\chi$- is smaller than the equilibrium exiting time of the uninformed, t*, and (2) when it is larger. In this case, Z consists of two variables, $\chi_l$ and $\chi_h$. In both cases the variables consist of the actual value of $\chi$ or 0. In $\chi_l$, the value of 0 is attributed to those draws where $t_\chi > t^*$, and for $\chi_h$ the value is 0 when $t_\chi < t^*$. Hence, the game theoretical prediction is that there will be no effect of $\chi_l$ (the informed stay in until t* is reached, independent of $\chi$) and a negative effect of $\chi_h$ (the informed are less likely to withdraw for higher $\chi$, once t* has been reached).

Note that we do not estimate any of the three hazard models simultaneously for all choices across sessions. One reason is that choices within a session are not independent observations. A similar problem exists for individual choices across rounds in a session, however. Therefore, we will not discuss statistical properties of the estimated hazard coefficients *per se*. Instead, we compare the coefficients across sessions.

Table 3 gives the average values of the coefficients estimated for the first version of the model. The binary variable ‘Type’ is defined to be 1(0) for the (un)informed.

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game theoretic analysis, however.

| | Lo1 | Lo8 | Hi1 | Hi8 | All |
|---|---|---|---|---|---|
| $\gamma_1$ | -4.82 | -4.74 | -5.19 | -5.60 | -5.09 |
| $\gamma_2$ | -3.44 | -2.59 | -3.30 | -3.12 | -3.11 |
| $\gamma_3$ | -1.76 | -1.35 | -2.21 | -1.88 | -1.80 |
| $\gamma_4$ | -1.52 | -0.67 | -1.83 | -1.59 | -1.40 |
| Type | 0.66 | 0.28 | 0.46 | 0.59 | 0.50 |
| $\chi$ chosen | -0.52 | -0.88 | -0.64 | -0.57 | -0.65 |

**Table 3: Average coefficients, model version 1**

The estimates in $\gamma_1$ - $\gamma_4$ are the estimates of the $\gamma_t$ coefficients. These represent a 'pure time' effect. Given that time is represented by binary variables grouping periods, the negative numbers themselves have no specific meaning. Comparing the numbers for the four groups of periods does have a meaning however. In fact, the coefficients increase almost monotonically in all sessions, implying an increasing probability of leaving the scheme as time passes by. For each of the time coefficients, we have 16 observations. To check whether these coefficients differ significantly, we use Wilcoxon signed ranks test on these 16 observations. It turns out that the differences $\gamma_1/\gamma_2$ (Z=-3.51), $\gamma_2/\gamma_3$ (Z=-3.51), and $\gamma_3/\gamma_4$ (Z=-2.02) are all significant at the 5% level.

The positive coefficients for Type indicate that, *ceteris paribus*, the hazard rate is higher for the informed than for the uninformed. In other words, the informed are more likely to withdraw. This counterintuitive result may be due to the fact that (as we will see below) uninformed follow the behavior of the informed. The structure of the game is such that there is a one period delay between the moment an informed withdraws and the moment this is noticed by the uninformed, however. The negative value for $\chi$ means that there is a negative relationship between the actual value of $\chi$ and the hazard, i.e. a higher random draw of $\chi$ means a lower probability of withdrawal. Because we defined this variable only for the informed, this means that the informed stay in longer when there is more external money in the fund. This is in line with intuition. Whether the behavior of the informed is in line with the model is tested in more detail in the third version of the model, below.

We can use the estimates of the first version of the hazard model to test for treatment effects. Once again using the 16 estimates per coefficient as the unit of observation, we use a

Mann-Whitney test for testing the hypotheses whether or not the $\gamma_t$, type and chi coefficients under two treatments (Hi versus Lo and 1 versus 8(6) informed) are identical. Table 4 gives the results.

| | $\gamma_1$ | $\gamma_2$ | $\gamma_3$ | $\gamma_4$ | *Chi* | *Type* |
|---|---|---|---|---|---|---|
| **Hi vs. Lo** | -1.16 | -0.945 | -1.94 | -1.47 | -1.05 | -0.99 |
| p-value | 0.27 | 0.38 | 0.05 | 0.16 | 0.33 | 0.33 |
| *Reject H0* | *No* | *No* | *Yes* | *No* | *No* | *No* |
| **1 vs. 8** | -0.26 | -1.99 | -1.47 | -1.26 | -1.57 | -0.21 |
| p-value | 0.79 | 0.05 | 0.16 | 0.23 | 0.13 | 0.87 |
| *Reject H0* | *No* | *Yes* | *No* | *No* | *No* | *No* |

**Table 4: Treatment effects (Mann Whitney test results)**

Given that the null hypothesis is that there is no treatment effect, we only find significant differences (at the 5% level) for $\gamma_3$ when testing for an interest rate effect and for $\gamma_2$ when testing for an effect of the relative number of informed. In high risk periods the exit rate for players facing a high interest rate is lower than for those facing a low interest rate. During the low risk periods, more informed players in the game increases the exit rate compared to the case when there is only one informed. It is difficult to draw conclusions from these results, however. Partly it is because we are considering all participants together. We therefore turn to the second version of the hazard model, where we only consider the choices of the uninformed.

The second version of the model only considers the choices of the uninformed and tests whether herding takes place. When estimating, we again correct for the fact that we have censored data. The estimation results per session are presented in table 5.

The coefficient in the last column is concerned with the herd behavior discussed above. The positive numbers indeed indicate herding in all sessions (except the Lo1 session where we have no estimate). Hence, the uninformed are more likely to withdraw if (some of) the informed did so previously. The size of the coefficients in some sessions (especially when there are 8(6) informed) and the standard deviations indicate a strong effect. The dependency problems mentioned above imply that we cannot test significance in the standard way, however. A simple t-test of the 15 (non-missing) observations in the last column of table 5 rejects the hypothesis that the average coefficient is equal to zero, however ($t=5.41$; $p<0.001$).

| | γ1 | γ2 | γ3 | γ4 | Herd |
|---|---|---|---|---|---|
| Lo1 | -7.50 (0.57) | -6.51 (0.36) | -3.96 (0.13) | -3.67 (0.26) | 1.23 (0.27) |
| Lo1 | -8.58 (1.01) | -6.26 (0.32) | -3.66 (0.13) | -2.16 (0.71) | 1.48 (0.25) |
| Lo1 | -6.55 (0.45) | -5.63 (0.29) | -4.94 (0.22) | -4.36 (0.27) | -10 (0.00)** |
| Lo1 | -6.06 (0.36) | -4.96 (0.22) | -4.39 (0.21) | -3.98 (0.29) | 0.79 (0.36) |
| Lo8 | -8.79 (1.02) | -5.25 (0.27) | -4.60 (0.28) | -4.59 (0.54) | 3.74 (0.31) |
| Lo8 | -7.71 (0.61) | -5.61 (0.28) | -4.91 (0.29) | -4.31 (0.38) | 4.32 (0.31) |
| Lo8 | -6.04 (0.43) | -5.27 (0.32) | -5.07 (0.36) | -2.65 (0.32) | 2.23 (0.39) |
| Lo8 | -8.56 (1.03) | -5.89 (0.36) | -4.61 (0.34) | -4.27 (0.73) | 3.74 (0.40) |
| Hi1 | -6.56 (0.71) | -4.44 (0.25) | -3.21 (0.17) | -4.08 (0.38) | 0.69 (0.29) |
| Hi1 | -5.99 (0.58) | -3.76 (0.20) | -2.71 (0.15) | -2.90 (0.33) | 0.45 (0.28) |
| Hi1 | -6.90 (1.00) | -4.67 (0.34) | -2.92 (0.18) | -3.29 (0.38) | 0.55 (0.33) |
| Hi1 | -5.42 (0.50) | -4.28 (0.29) | -3.00 (0.19) | -1.84 (0.24) | 0.37 (0.31) |
| Hi8 | -6.89 (1.02) | -4.37 (0.36) | -3.47 (0.33) | -5.52 (1.01) | 1.35 (0.43) |
| Hi8 | -5.07 (0.40) | -4.27 (0.32) | -3.69 (0.32) | -4.07 (0.62) | 2.52 (0.37) |
| Hi8 | -10 (0.00)* | -4.51 (0.39) | -3.53 (0.37) | -2.54 (0.59) | 2.56 (0.44) |
| Hi8 | -10 (0.00)* | -6.79 (0.68) | -5.18 (0.59) | -4.30 0.69) | 4.44 (0.66) |
| | | | | | |

**Table 5: Coefficients for model version 2: only uninformed**

Standard deviations are in parentheses. *No coefficient estimated because no uninformed investor withdrew in the first 4 periods. **No coefficient estimated because the informed always withdrew so early that no uninformed followed.

We can summarize the effect per treatment by determining the average herding coefficients. Excluding the missing value for the Lo1 session, the average coefficient is 0.51, 1.17, 2.72, and 3.51, for Hi1, Lo1, Hi8, and Lo8, respectively. Hence, herding appears to be stronger for low interest rates than for high interest rates and for sessions with 8(6) informed than sessions with 1 informed. We formally test these treatment effects using Mann-Whitney tests. The effect for high versus low interest rate does not show up as significant ($Z=-1.27$; $p=0.23$), the difference for 1 versus 8 informed does ($Z=-3.12$; $p=0.001$). Hence, herding by the uninformed is stronger when there are eight informed than when there is one.

Finally, the third version of the model tests the prediction that the informed will (will not) adjust to variations in $\chi$ as long as $t_\chi$ is high (low) enough. We test this by introducing the variables $\chi_l$ and $\chi_h$ described above. Table 6 presents the results per session. Note that for the sessions with 1 informed, the parameters imply that $t_\chi \leq t^*$, for all $\chi$. Hence, there are no observations for $\chi_h$.

| | $\gamma1$ | $\gamma2$ | $\gamma3$ | $\gamma4$ | $\chi_l$ | $\chi_h$ |
|---|---|---|---|---|---|---|
| Lo1 | -5.11 (0.58) | -3.98 (0.33) | -1.48 (0.12) | -0.94 (0.25) | -0.06 (0.11) | |
| Lo1 | -6.21 (1.00) | -3.87 (0.32) | -1.17 (0.11) | -1.30 (0.15) | -0.24 (0.15) | |
| Lo1 | -4.04 (0.36) | -3.26 (0.27) | -2.46 (0.22) | -2.24 (0.26) | 0.83 (0.16) | |
| Lo1 | -3.61 (0.32) | -2.58 (0.21) | -1.87 (0.19) | -2.29 (0.28) | 0.14 (0.15) | |
| Lo8 | -4.22 (0.38) | -2.24 (0.17) | -1.20 (0.17) | -0.94 (0.25) | 0.17 (0.11) | -0.19 (0.06) |
| Lo8 | -3.81 (0.34) | -2.99 (0.27) | -1.83 (0.27) | -0.73 (0.20) | 0.76 (0.19) | -0.20 (0.08) |
| Lo8 | -5.03 (0.59) | -2.46 (0.21) | -1.04 (0.19) | -1.71 (0.54) | 0.55 (0.18) | -0.14 (0.08) |
| Lo8 | -5.44 (0.59) | -2.16 (0.18) | -1.33 (0.23) | -0.27 (0.05) | 0.58 (0.12) | -0.17 (0.05) |
| Hi1 | -4.84 (0.71) | -2.71 (0.25) | -1.31 (0.15) | -1.58 (0.34) | 0.01 (0.12) | |
| Hi1 | -4.42 (0.58) | -2.13 (0.19) | -0.93 (0.14) | -0.97 (0.33) | -0.12 (0.13) | |
| Hi1 | -4.61 (0.71) | -2.94 (0.32) | -1.18 (0.16) | -0.90 (0.32) | 0.21 (0.16) | |
| Hi1 | -3.91 (0.50) | -2.42 (0.25) | -1.56 (0.26) | -0.57 (0.17) | 0.24 (0.15) | |
| Hi8 | -6.24 (1.01) | -2.50 (0.23) | -0.95 (0.18) | -1.55 (0.40) | 0.72 (0.12) | 0.11 (0.06) |
| Hi8 | -3.50 (0.37) | -1.83 (0.19) | -0.96 (0.22) | -0.40 (0.20) | 0.24 (0.11) | -0.13 (0.05) |
| Hi8 | -3.88 (0.47) | -1.86 (0.22) | -0.82 (0.24) | -0.39 (0.27) | 0.60 (0.18) | -0.09 (0.09) |
| Hi8 | -5.44 (1.00) | -2.79 (0.30) | -1.29 (0.26) | -0.36 (0.21) | 0.48 (0.18) | -0.09 (0.09) |

**Table 6: Results for model version 3: only informed**

The coefficients in the last two columns are of interest here. Note that 13 of the 16 coefficients for $\chi_l$ (where the predicted value is zero) are positive and 7 out of 8 coefficients for $\chi_h$ (predicted to be negative) are negative. T-tests on the 16 (8) observations show that both are significantly different from zero. The negative values for the coefficient concerning $\chi_h$ are in line with the game theoretical prediction for the equilibrium strategy of the informed, but the positive coefficients for $\chi_l$ are not. The latter shows that the informed respond to higher values of $\chi$ by a higher conditional probability of leaving the scheme, as long as $\chi$ is such that $t_\chi < t^*$. This result is somewhat surprising.

As for treatment effects, we find that neither $\chi_l$ or $\chi_h$ differs significantly between high and low interest rates (Z=-0.105, p=0.959; Z=0.00, p=1.00, respectively). Whereas we have no observations for $\chi_h$ in case of 1 informed, the number of informed does significantly affect the coefficient observed for $\chi_l$ (Z=-2.26, p=0.026). This result indicates that the positive effect observed is only found in case of 8 informed subjects. Hence, the surprising result mentioned above might have to do with the way in which the informed interact amongst themselves and not with the way they interact with the uninformed. This is a topic for future research.

# 6. Conclusions

Behavior in outside the laboratory Ponzi schemes is almost impossible to study. Not only are people often ashamed to admit that they participated, there is generally no real bookkeeping. Therefore, to study the basic elements of this behavior, the laboratory provides a useful tool. In this paper, we have focused on the effect that the rate of interest and the number of informed investors have on investments in these schemes.

The Ponzi schemes we created in the laboratory appear to work as such. They started almost immediately in every round of every session. Moreover, bankruptcy was always observed. Hence, we believe our experimental data allow us to get a first grasp at the behavior of participants in Ponzi schemes. It appears that the quasi symmetric equilibrium we derive does not fit the data too well. Of course, this could be due to the fact that we assume risk neutrality. Nevertheless, the fact that we often observe investments in periods when everyone can be certain that the initial investment $\chi$ has been depleted completely, means that a model assuming complete rationality cannot explain the data. As argued by Tirole (1982), it is not rational to participate in a Ponzi scheme (in our case, after a certain period of time).

An important conclusion from our data is that the distinction made between informed and uninformed investors that has been hypothesized elsewhere makes sense. We find that the uninformed investors follow the movements of the informed and can therefore potentially be taken advantage of by the informed. Note that rationally, the uninformed should consider that it is in the interest of the informed to mislead them. The fact that the uninformed can be misled in this way is often considered as a major reason for the occurrence of these schemes (see Sadiraj, van Wijnbergen, and Ewijk 1997, or Bhattacharya, 1998 for examples and references).

We also find that behavior is affected by the interest rate and the number of informed. The latter provides a dilemma to the informed wanting to start such a scheme. On the one hand, they would like to restrict the information to a 'happy few'. On the other hand, our results show that an increase in their number will make the uninformed more susceptible to their behavior and therefore will increase the potential for making money off of the uninformed.

We believe that our experiments provide interesting insights into behavior in Ponzi schemes. Nevertheless, they also open possibilities for complete research programs. For example, it would be interesting to see whether or not experienced subjects are less likely to lose money in these schemes (though the behavior we observe across rounds does not indicate this). More fundamentally, we have not addressed the possibility of starting such schemes, or even of different participants starting competing schemes. In our view, this is an interesting topic deserving future attention. However, there is much we can learn from simple environments like the one discussed in this paper, before turning to more complicated ones.

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