Soft landing of a stock market bubble An experimental study

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First version: February 2002
Current version: July 2007

This research has been carried out within the NCCR FINRISK project on “Behavioural and Evolutionary Finance”
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JEL classification: C92, E42, E44, E58.

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2 The authors gratefully acknowledge feedback and comments from seminar participants at the University of Zurich, Stanford's Graduate School of Business, the Swiss National Bank, the European Central Bank, the University of Frankfurt, the University of Tilburg, Bergen Business School, and from several traders of the Fixed Income Group of Goldman Sachs London. Most notably we are grateful to Urs Birchler, Driss Ben-Brahim, Jon Bendor, Jeremy Bulow, Philipp Hartman, Ernst Fehr, Chip Heath, Charles Noussair, Tunay Tunca, Mark Schindler, Bob Wilson, and Muhamet Yildiz. We thank Sally Gschwend for improving our English. Financial support by the Swiss National Bank and the national center of competence in research "Financial Valuation and Risk Management" is gratefully acknowledged. The national centers in research are managed by the Swiss National Science Foundation on behalf of the federal authorities.
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1. Introduction

The appropriate response of monetary policy to asset price bubbles is an issue that is currently under hot debate among central bankers and monetary economists. The collapse of the TMT bubble led a number of authors to argue that the central banks’ monetary policy should not only aim for inflation targets, but also incorporate asset price developments and other financial system stability indicators. Crockett (2003) has summarized this view as follows (italics in original):

“[I]n a monetary regime in which the central bank’s operational objective is expressed exclusively in terms of short-term inflation, there may be insufficient protection against the build up of financial imbalances that lies at the root of much of the financial instability we observe. This could be so if the focus on short-term inflation control meant that the authorities did not tighten monetary policy sufficiently pre-emptively to lean against excessive credit expansion and asset price increases. In jargon, if the monetary policy reaction function does not incorporate financial imbalances, the monetary anchor may fail to deliver financial stability.”

Corresponding with this view, both Borio and Lowe (2002) as well as Renaud (2003) suggest tightening monetary policy when policy makers believe an asset price bubble is developing, even though inflation may still be well under control. Refraining to do so might decrease the financial system’s future stability.

Other authors are skeptical of enforcing such a monetary policy. Simply raising interest rates in the hope of containing a speculative asset price bubble might result in exactly the economic collapse one was trying to avoid. The best response to an asset price bubble is to be prepared for action during its burst and if potential, undesired financial instabilities should arise from it. As one of those exponents, Greenspan (2002) states: “Such data suggest that nothing short of a sharp increase in short-term rates that engenders a significant economic retrenchment is sufficient to check a nascent bubble. The notion that a well-timed incremental tightening could have been calibrated to prevent the late 1990s bubble is almost surely an illusion. Instead, we

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need to focus on policies to mitigate the fallout when it occurs and, hopefully, ease the transition to the next expansion.”

The theoretical literature remains unclear on the feasibility of using an active interest rate policy to engineer a "soft landing" of the economy, in particular of stock markets. Much of this literature focuses on stochastic asset price bubbles (see e.g. Bernanke and Gertler (1999); Bernanke and Gertler (2001); Cecchetti, Genberg, Lipsky and Wadhwani (2000); Cecchetti, Genberg and Wadhwani (2002); and Gruen, Plumb and Stone (2003)). The bottom line of this literature seems to be that the results hinge on the particular stochastic assumptions regarding the asset price (as well as other shocks that might provide a fundamental explanation for the asset price movements) and, above all, on the information available to the policy maker. Gruen, Plumb and Stone, in particular, argue that policy makers need to know rather more about the nature of the bubble, and they need to know it early if a pre-emptive activist policy is to be effective.

The idea of our paper is to try to extract the essence of such arguments and test them in a laboratory setting. Asset price bubbles can be identified in a laboratory experiment, the information content of monetary policy can be controlled, and we can analyze with the use of control experiments how the bubble would have evolved without the policy! Of course the flip side of being able to isolate certain effects is that one should be careful when transferring the results from the experiment back to real world economies. However, our experiment gives at the very least new insights into the effectiveness of monetary policy in taming speculative behavior in asset markets. After all, only this speculative behavior can be the reason for any policy

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intervention since there is no role for monetary policy whatsoever in a rational market.

Our experiment is a further step in a tradition of laboratory stock market experiments. A typical laboratory stock market has the following structure: six to eight traders interact with each other using some electronic trading system over 12 or 15 periods. Trade usually takes place using a continuous double auction, the traded asset is a stock that pays a dividend at the end of each period, and the dividend is mildly stochastic and stationary over time. The fundamental value of the asset in such a market does not exceed the product of the number of remaining periods times the expected value of the dividend draw, assuming common knowledge of rationality and risk aversion. Traders begin the experiment with an endowment in stock and some experimental currency; final allocation will be exchanged at the end of all trading into dollars at a pre-specified rate. All this is common information. Although it is known that common information does not necessarily imply common knowledge because priors possibly differ, economic theory would still typically predict trading at or near the fundamental value of the stock.

Despite all this, laboratory trading deviates from the fundamental value in a "bubble" pattern. The following stylized facts characterize a typical experimental stock market bubble. Trade in early periods tends to be close to fundamental value, not infrequently even under it. People then bid the stock price up and eventually trade at prices that are significantly higher than the fundamental value – until a certain point in time (here about period 10 or 11) after which the stock price begins to crumble, sometimes in outright crashes (fast decline in price at high trading volume).

Naturally, economists are puzzled: "rational" people would not act this way because, when rationality is common knowledge, backward induction implies that prices cannot bubble (e.g. Tirole (1982)). A possible explanation for this puzzle is the "greater fool theory" (or Keynes' "beauty contest") – even if you are aware of the inherent value of an object, you are rationally willing to pay more as long as you believe that you will find another trader to buy the asset from you at an even higher and even less "rational" price, be it because this trader is a rookie or because she speculates even more aggressively. Until a short while ago, this was the hope that drove regular people, often rookies, to quitting their jobs in order to pursue full-time momentum trading (day trading).
The authors of the seminal paper in the literature (Smith, Suchanek and Williams (1988)) have already proposed this explanation. It is all the more surprising that Lei, Noussair and Plott (2001) have very convincingly debunked the speculation motive as a sole source of laboratory stock market bubbles. Briefly, they created a stock market structure that prevented speculation, and observed very little effect on any bubble measure.

Other papers have investigated the stability of the observed phenomenon with regard to different treatment parameters. King, Smith, Williams and Boening (1993) find none of the following having an impact on the occurrence or size of bubbles: the possibility of short selling stocks, buying on margin, identical endowments, transaction costs ("brokerage-fees"), professional traders as experimental subjects, nor price caps and floors. The only possibility they identify for reducing bubbles is first familiarizing some participants with the results of the Smith, Suchanek and Williams (1988) paper. Schwartz and Ang (1989) check the "house money" hypothesis by letting people trade with their own money, to little avail.

Smith, Suchanek and Williams (1988) also hypothesized that the described trading pattern might be due to risk aversion in early periods (trades under fundamental value), leading to price increases in subsequent periods subsequently creating momentum; but Porter and Smith (1995) rule out risk aversion as a major factor. Bubbles are also stable with respect to differences in market organization (van Boening, Williams and LaMaster (1993)).

There are few studies that show how bubbles can be moderated. Ackert, Charurat, Church and Deaves (2002) implement short selling by allowing players to hold a limited amount of negative assets. In their design, the average trading price over all periods was very close to the fundamental value. However, in a recent study, Haruvy and Noussair (2006) show that short selling may overshoot. If there are little constraints on short selling, prices even fall below fundamental value. Thus, short selling does not increase rationality but simply reduces the prices. Futures markets mitigate bubbles (Porter and Smith (1995), in particular, if futures for every period are available Noussair and Tucker (2006). Finally, experience is the most reliable method to reduce bubbles. Even the existence of only few experienced traders (e.g. 2 out of 6 in Dufwenberg, Lindqvist and Moore (2005) are sufficient to moderate bubbles significantly. The latter result was celebrated as a partial if not complete reconciliation of stock market bubble experiments with the predictions of economic
theory. We have our doubts. Even though in real markets a large share of the traders
consists of experienced traders, usually no one is experienced with the particular
situation when a bubble occurs. For instance, in the new economy bubble, it was not
clear how the fundamental value of dot-com companies should be determined.

Be that as it may, experimental stock market bubbles arise, and are stable with
respect to virtually all market parameters. Thus the question: what to do about them?
In the "real world", one crude response is to raise key interest rates, usually by 25
base points at a time, sometimes by 50. Indeed Alan Greenspan did raise interest rates
when the TMT-bubble (which he already attributed to “irrational exuberance” on
December 5, 1996) became quite obvious in the late 1990s. Increasing interest rates
creates higher opportunity costs of holding stock, and thereby directly discourages
investments as well.

Our paper focuses on this idea. Interest policy changes opportunity costs, thus
affecting prices. We introduce a portfolio alternative to trading in stocks: an interest-
bearing bond. We raise the interest rate in treatment groups using an endogenous
interest rate policy algorithm when we observe bubbles. Control groups – unknown to
them – face a fixed interest rate. We are interested in several questions. One, is it
possible to influence bubbles, in particular to reduce them based on one of the bubble
measures we propose? Two, does the participants' portfolio choice exhibit elements of
rational choice or present new puzzles? Given that no one has yet studied this market
structure, we also want to examine thoroughly how our results compare to those of
earlier experiments. We find some support for questions number one and two. We
observe only a small but positive impact of our interest policy on bubbles. On the
other hand, we find evidence in portfolio choice for value-driven (rational) investment
behavior. Direct measures to decrease liquidity seem preferable over interest rate
policy.

Section 2 describes the experiment in more detail. Section 3 presents the
research hypothesis and defines measures, which we use in our analysis. Section 4
analyzes the data and section 5 concludes. The appendix contains the experimental
instructions.
2 Experimental design and procedures

2.1 Basic design

Our experiment is based on the design of Smith, Suchanek and Williams (1988). In their experiment, as in ours, participants receive an initial endowment of stocks and experimental money in a fictitious currency (called "Gulden"). Subjects had the possibility of trading their stocks for 15 periods in a double auction for a given period of time. Stocks pay a dividend of 0, 8, 28, or 60 Gulden at the end of each period. All payoffs are equally likely, yielding an average of 24. There is no redemption value for the stocks at the end of the experiment; the experimental money is then exchanged into real money and paid to the subjects.

If subjects are risk neutral and rational, and if this is common knowledge, then trade should only occur at the fundamental value. In this case, the fundamental value equals to the expected sum of dividends which are going to be paid for the stock. This means that the fundamental value starts at a value of 360 in period 1 and declines linearly to 24 in period 15.

To study the impact of interest policy, we introduced an alternative investment possibility: interest-bearing bonds. Subjects had to decide at the beginning of each period how much of their current monetary endowment they wanted to invest into a one-period bond – framed as a bond account – and how much of their money they put into their trading account. The money invested in bonds could not be used for trading, i.e., it could not be used for buying stocks. Interest could also be introduced into this market environment in an alternative manner: Interest could be paid on all uninvested money at the end of the trading phase, i.e., on all the money not actually invested in stocks. We did not use this alternative implementation because the bond alternative allows investigating whether interest policy has an impact on the liquidity in the market. Without the bond alternative, the liquidity on the stock market would be completely exogenous – just all the money in the experiment. If money invested in bonds cannot be used to buy stocks in a given period, the money on the trading account is a measure for the liquidity of the stock market.

The interest rate was set to $r=0.05$ in the first period, but was variable in principle. The experiment thus consisted of three phases:

1. Participants decide how to split their total cash for the current period. Money put into bonds bears interest, but cannot be used to trade. Money in the trade
account does not bear interest, but can be used to trade stocks in phase 2 of this period.

2. Trade in stocks takes place. Trade is organized as a continuous double auction and lasts for 150 seconds each period.

3. The dividend for this period is determined. Income from dividends on shares of stock and interest on bonds is added to the participants' total cash accounts, together with the current amounts in their trade and bond accounts. At the beginning of the following period, participants only have money in their total cash accounts, and a number of shares in their stock accounts.

In Figure 1, we show the net present value (NPV) of the stock at an initial interest rate of \( r=0.05 \). In period \( t \in \{1,2,\ldots,15\} \), the NPV is defined as

\[
NPV_t = \sum_{j=t}^{15} \frac{E[\text{dividend}_j]}{(1+r)^{15-j}},
\]

using the obvious notation. Valuation of an asset using the NPV concept is standard practice and amounts to assuming risk neutrality.\(^6\) Note that this is the fundamental value from the point of view of a trader in the auction phase and not the fundamental value from the point of view from investor when he decides how much to invest into the bond and into the trading account.\(^7\) The naive fundamental value is the expected sum of all future dividends. It equals the NPV if the interest rate equals zero. The standard policy mentioned in Figure 1 will be explained later in the paper.

\(^6\) Assuming risk aversion would only reduce the fundamental value and therefore increase bubble sizes.

\(^7\) The fact that the two fundamental values are different can easily be seen when looking at period 15. In the auction, the value of a stock equals 24, independent of the interest rate. When the subjects decides how much money to use for buying stocks, the money has opportunity costs and therefore the value of stocks are lower in this case \((24/(1+r))\)
Figure 1: Naive fundamental value, net present value (NPV) for the no policy treatment and NPV for the standard policy treatment assuming static expectations.

Previous experiments (such as Lei, Noussair and Plott (2001), Porter and Smith (1995), Smith, Suchanek and Williams (1988), or Smith, Boening and Wellford (2000)) informed the participants about the current NPV of one share of stock in each period, to make sure that bubbles did not merely happen because of individual calculation errors. Because no interest-bearing alternative exists in their setting, the NPV is simply the sum of expected dividends. Given that our experiment is more complicated (even with no change in interest rates), we cannot expect everyone to immediately understand the concept of a discounted NPV. Explaining how a change in interest rates influences the NPV would almost certainly have confused some of our participants. For this reason, and because our focus was not on bubbles per se but on the impact of interest policy on bubbles, we decided to omit periodic reports of NPVs to the participants. Instead, we made sure through careful instructions and a set of test questions that the participants understood the dividend draw in each period completely – its impact on "expected" values, and best and worst possible cases. Although several of the participating students had previously attended classes in introductory statistics, we did not rely on any mathematical or statistical language. We provided calculators for those that wanted them. While the instructions pointed out that the interest rate might change, we did not indicate if, when, or by which amount it
would do so. Note also that students could neither trade on margin nor short sell assets.

A translation of the experimental instructions is in the appendix. They also contain screen shots of the experiment.

2.2 The experimental interest policy

Our interest rate policy algorithm aims to approximate the behavior of central banks such as the Federal Reserve Board (Fed). The basic idea is to raise rates when we see a positive bubble, and to lower them in the opposite situation (where "bubble" is defined as persistent trade at values significantly (more than 35 percent) different from the NPV of our stock). We do not change the interest rate more frequently than every four periods, and not before period four, for three reasons: one, to avoid introduction extra noise through continual adjustments; two, to keep participants from guessing when the next change would happen; and three, to approximate another "real" Fed policy – frequent changes are unusual because the market might perceive them as informative (usually negative) signals in themselves.8

After interventions in one direction, central banks will attempt to create some leeway for further interventions during times that are less problematic – e.g. by lowering interest rates to an intermediate level when markets cool off, after having raised them earlier. Because we restricted ourselves to only five different interest rates for statistical reasons (0.01, 0.05, 0.11, 0.15, 0.21), we actually faced the same problem. Therefore, after interventions in one direction, we intervened instantly into the opposite direction when mean contract prices hit the stock's NPV (which happened only once).

Subjects were not informed about the algorithm used. We did this for two reasons. First, investors also do not know the interest policy in reality. Second, we wanted subjects to get exactly the same information in the policy treatment as well as in the no policy treatment.

2.3 Procedures common to all experiments

Everyone initially received the same endowment in cash and stocks, but this was not told to the participants. There is sufficient evidence (see e.g. King, Smith,

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8 In this respect, 2001 was a very unusual year.
Williams and Boening (1993); Porter and Smith (1995); or Caginalp, Porter and Smith (1998)) that initial heterogeneity of cash or stock accounts does not significantly influence the results of bubble experiments. Because the same is not true for total (consolidated) endowments, we controlled for the latter by providing the same initial endowments in all experiments (10 shares of stock and 3,600 Gulden per participant\(^9\)).

All subjects were undergraduates from the University of Zurich and the Swiss Federal Institute of Technology in Zurich (ETH). We maintain a large database of about 3,000 – 4,000 students whom we recruit at the beginning of the academic year to participate in “economic experiments in decision making.” Experimental subjects are called upon for participation when needed, their participation and success recorded for future reference. The subjects had not previously participated in a bubble experiment; in particular, they only participated in one session of this study.

We divided each session into two markets of 7 or 8 participants who received the same dividends. One group served as the treatment (policy) group, the other as the control (no policy) group. The experiments lasted on average 2 hours and 30 minutes. In total, we conducted 8 sessions with 126 subjects.\(^{10}\)

After the experiment, the participants exchanged their Gulden into Swiss Francs at a rate known to them from the start. Although we calibrated the experiments so that the average participant received a compensation comparable (by hour) to a Swiss student salary, we also created incentives for the participants to trade to the best of their abilities. Final payoffs ranged from roughly SFR 13.00 (including a show up fee of SFR 10.00) to SFR 80.00 ($7 - $50) – a sizeable success-dependent spread. The experimenters were programmed and conducted with the experimental software z-Tree (Fischbacher (2007)). The interest policy was calculated in a spreadsheet. The resulting interest rate was entered on a dedicated terminal.

\(^9\) The numbers are from a recent experiment by Lei, Vivian, Charles N. Noussair, and Charles R. Plott, 2001, Nonspeculative bubbles in experimental asset markets: Lack of common knowledge of rationality vs. actual irrationality, *Econometrica* 69, 831-859. More precisely, they provide either 7,200 Gulden and 0 shares, or 0 Gulden and 20 shares of stock per participant. While this was in line with their research focus (bubbles without the possibility of speculative gains), we had to adjust it to our setting.

\(^{10}\) One session in Experiment 1 suffered from a software glitch and could not be used in the analysis.
3 Research Hypothesis

Starting with Smith, Suchanek and Williams (1988), many studies have shown that subjects create bubbles in experimental asset markets. Our study focuses on the question whether an appropriate interest rate policy can reduce bubbles. Bubbles are always defined relative to the fundamental value. The fundamental value is not obviously defined in our design since it depends on the expected future interest rates. An increase in the interest rate will affect the subjects’ beliefs about future interest rates. If interest rates go up, so does the belief about future interest rates and therefore the fundamental value decreases. A decrease in trading prices could simply reflect a rational decrease in the subjects’ belief about the fundamental value.

A second effect of higher interest rates could be a reduced liquidity on the stock market. If people earn higher interest, they reduce their money in the trading account. Since there is now less money in the market, demand for stocks decreases and therefore the trading prices also decrease. The effects could be caused in particular by a reduced demand from the noise traders. Experiments have indeed shown that an exogenous variation of liquidity affects the size of a bubble: (Caginalp, Porter and Smith (2000)) show for instance that initial cash endowment is positively correlated with the size of the bubble. Different from these previous studies, we are interested in the question whether interest rates actually influence liquidity, whether this endogenous reduction of liquidity has an impact on prices and therefore reduces the size of a bubble. We will now formulate the hypothesis based on this idea.

Hypothesis 1: Policy reduces bubbles. The interest policy raises reduces the intensity and the duration of bubbles.

To test this conjecture, we have to conceptualize the measurement of a bubble. Any measure has to be a deviation of prices from the fundamental value. We will use average trading prices throughout our analysis as a measure of the price in that period\textsuperscript{11}. We will use two measures for the fundamental value. One measure is the fundamental value assuming static expectations about the interest policy, i.e., the fundamental value if subjects assume the interest rate to remain constant until the end of the experiment. Since subjects will probably not be able to compute this value, we conjecture that subjects could use the "naive" fundamental value, which ignores the

\textsuperscript{11} Taking the median price does not change the results we obtain.
alternative investment possibility completely and equals just the sum of all future dividends. It is clear that it is much harder to reduce a bubble relative to the correct fundamental value with an interest policy. Since an increase in the interest rate reduces the fundamental value, it increases the bubble – if the decrease in price does not exceed that of the fundamental value. Furthermore, if subjects expect interest rates to return quickly to the initial value, the fundamental value would be the same in the policy treatment as in the control treatment. The naive fundamental value is a proxy for this case. We call the deviation from the naive fundamental value a "naive bubble" and that from the fundamental value assuming static expectations of interest rates a "sophisticated bubble".

The average deviation of trading prices from the fundamental value is the first measure of a bubble. It weights both duration (number of consecutive periods in which average price is above fundamental value) and amplitude (maximum deviation from fundamental value) of the bubble. We always consider signed differences (and not absolute values) because we were always in the situation of a positive bubble and we had to increase the interest rate. So if the prices undershoot as a result of increasing interest rates, this is also considered to be a reduction of the bubble. Finally, we define the relative bubble as deviation of the price from the fundamental value normalized by the fundamental value.

**Hypothesis 2: Increasing interest rates reduces liquidity in the stock market.** Since subjects choose their liquidity in the stock market, we can determine the impact of the interest policy on the liquidity and the impact of liquidity on the bubble. We use the absolute amount of money in the stock market and the individual share of money used in the stock market as variables for measuring liquidity. Note that the subjects have to make an explicit decision about their market liquidity in order to measure the impact of interest rates on liquidity and the impact of liquidity on prices. This means that the bond account is an indispensable feature of our design. A design in which subjects would get interest on money not invested in the stock market would not suffice.

**Hypothesis 3: Reduced liquidity is responsible for reducing a bubble.** There may be many different channels by which an increase in the interest rate reduces the bubble. We conjecture that one of the most important of these channels is that higher interest rates reduce liquidity in the stock market and, referring to the quantity theory of money, this in turn reduces trading prices. (Another channel could
be that subjects take the interest rate as an informative signal about the correctness of the price and reduce the price when the interest rate increases. We deal with this point later in the paper.)

**Hypothesis 4: Policy has no impact on trading volume and volatility.**

This hypothesis should be considered more as a question. We hope that interest policy has no impact on trade volume and volatility. Due to the liquidity constraint, a decrease in trading activity could result from an increase in interest rates; on the other hand, however, subjects who hold stocks might be much more willing sell them. We do not expect one of these effects to be larger than the other. We use the within period standard deviation of prices normalized with the average price as a measure volatility and the number of trades per period as a measure for turnover.

### 3.1 Standard interest policy

There are two ways for performing the correct comparison between the treatments with and without interest policy. One way is to compare all policy with all non-policy treatments. This includes comparing policy treatments with non-policy treatments that did not build up a bubble, however, i.e. in which policy would not have been applied. A better way is to include only those treatments in which the criterion to intervene was satisfied in the analysis. The latter has the advantage reducing heterogeneity and therefore increasing statistical power. Therefore, we only include those markets in the following analysis where an increase in interest rate would have been necessary in period 4. This is also justified because 11 of 14 markets could be included. Interest policy turned out to be the same in all these markets in which an interest policy was applied. Interest rate was increased to 11% in period 4, it was further increased to 15% in period 8 and again to 21 % in period 12. We call the policy the standard interest policy.

### 4 Analysis

#### 4.1 Impact of interest rate on bubble and liquidity

As explained above, we will analyze only those treatments in which an interest increase was necessary in period 4. This was the case in 11 of 14 markets. The standard policy was applied in 6 of these markets; 5 treatments are used as control treatment. In Figure 2, we present the naive and the sophisticated bubble for the
policy and the no policy treatments. First, the figure shows that the bubbles are of considerable size. In period 8 and 9, the bubble is roughly equal to the fundamental value, i.e., subjects pay twice the fundamental value.\footnote{Note, that we only report the treatment here which started early with a bubble. However, this occurs in about 80\% of the cases.} Our focus is not on the bubble per se but on the impact of the interest policy. We see that the naive bubble is reduced and that the reduction is considerable. However, the interest policy remains far from bringing prices back to even the naive fundamental. If we correct for the change of the fundamental value, i.e., if we look at the sophisticated bubble, the impact of the interest policy is almost negligible. At least, the policy reduces even the sophisticated bubble beginning in period 7.

![Figure 2: Bubbles in the basic experiment.](image)

<table>
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<th>3</th>
<th>4</th>
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</table>

Table 1: Average trading prices and one-sides test for Mann-Whitney-U tests comparing the 7 markets with policy to the 5 markets without policy.
Table 2: One-sided Mann-Whitney-U tests comparing the 6 markets with policy to the 5 markets without policy. Average: Average bubble in period 4 to 15; duration: duration of the bubble starting from period 4; max: maximum amplitude of the bubble starting from period 4; relative: average relative bubble in periods 4 to 15.

To investigate the statistical significance of the results, we first look at period averages. In Table 1, average trading prices\textsuperscript{13} are listed for the policy and the no policy treatment. Prices are only significantly different (at the 5%-level one-sided) between the two treatments in periods 9 and 10. It is not surprising that the difference is highest in these middle periods since it takes some time until the interest policy causes a reaction in markets, and all markets crash at the end, anyway.

Since it is not clear when the policy starts having an impact on the market, we use highly aggregated data for comparing the treatments. Market averages (starting in period 4) have the advantage that affects of the policy should show up even if they are not uniformly timed in all markets. Table 2 shows that no measure of the sophisticated bubble is statically different, but the interest policy (weakly) significantly reduces the duration, amplitude and relative measure of the naive bubble.

To conclude, although interest policy has some impact on the bubble, this impact is both weakly significant and very small when compared, for instance, with the size of the bubble.

Table 3: Two-sided test for Mann-Whitney-U tests comparing the 6 markets with the 5 markets without policy.

\textsuperscript{13} These are averages of the market period averages.
Does the interest policy have other effects on the market? Table 3 shows data on trading volume, market liquidity, and volatility. As we conjectured, market liquidity is lower in the policy treatments than in the no policy treatments, but the difference is not significant.\(^{14}\) Differences in trading volume as well as volatility are small and insignificant.

### 4.2 Control treatment without reinvestment of interest income

Our implementation of the interest policy has an unpleasant and unrealistic side effect: if the interest rate is increased, subjects have a higher income from this interest and therefore have more disposable income. While a higher interest rate increases opportunity costs for holding liquidity, it also produces much higher liquidity. The failure of the interest policy could be due to this effect. However, as shown in Figure 3, the interest policy could reduce liquidity in the market. The effect on the share of the income invested into the trading account is even more extreme since the disposable income is higher with higher interest rates.

![Figure 3: Liquidity in the stock market. The figure on the left shows the average amount of money in the trading account; that on the right shows the share of money in the trading account.](image)

\(^{14}\) The share of money in the trading account is statistically different on the 10% level if we apply a one sided test.
The argument that higher interest rates decrease trading liquidity is of course an incomplete argument for the claim that the increased total liquidity is not responsible for the failure of the policy treatment. For that reason, we conducted a series of experiments in which interest income was not available for trading. Interest was paid at the end of the experiment. Therefore, available money remained constant in the policy as well as in the control treatment. Note that the fundamental value in this situation equals

\[ NPV_t = \sum_{j=1}^{15} \frac{E[\text{dividend}_j]}{(1+(15-t)i)} \]

Because all of the interventions which we analyzed in the first series had the same policy, we decided to implement a completely exogenous interest policy in the second series. Thus, there was always one market in every of our 6 sessions with a no policy treatment with a fixed interest rate and a policy treatment with the standard interest rate policy. Aside from these two differences, this series did not differ from the first. All the parameters remained constant and the market size was still 8, i.e., a total of 96 subjects participated in this series.

Figure 4 shows the bubbles in this experiment. We also see that the policy was not able to reduce the bubble significantly in this treatment.

Figure 4: Bubbles in a series of experiments in which interest was paid at the end of the experiment and was not available to the subjects for trading.

4.3 Interest policy and information

Interest policy is often accompanied by information; one goal of interest policy is to keep the stock market on track. The uninformed traders could learn from an interest increase that the Fed – a much better informed agent – believes that stock
market prices are too high. However, the interest increase could also be interpreted as the Fed’s confidence in the strength of the economy which warrants higher stock prices. We did not tell the subjects what kind of policy we implemented in our experiment. Therefore, we had no control of whether subjects believed the interest policy conveys information. It could be that the effect of an interest policy is more due to this informational mechanism than to the liquidity manipulation, for example\textsuperscript{15}.

For that reason, we conducted an experiment in which we added information about the purpose of the interest policy in the instruction. We wrote:

\textit{The interest rate is only increased if the experimenters consider the stock prices to be too high. The interest rate is only decreased if the experimenters consider the stock prices to be too low. As a clue for this, the experimenters use the sum of the dividends, which are to be expected in the remaining periods. This means:}

\begin{itemize}
  \item \textit{When the experimenter assesses the prices to be correct, the interest rate will remain the same.}
  \item \textit{When the experimenter assesses the prices to be too high, the interest rate will remain the same or will be increased.}
  \item \textit{When the experimenter assesses the prices to be too low, the interest rate will remain the same or will be reduced.}
\end{itemize}

We took care that this policy was applied as stated in these instructions. For this reason, we had to apply an endogenous interest policy in this series of experiments and we compare only those markets in which intervention was or would have been necessary. There were 8 sessions with two markets each. Intervention was necessary in 6 policy markets and in 7 no policy markets.

\textsuperscript{15} Trichet, Jean-Claude, 2003, Asset Price Bubbles and Their Implications for Monetary Policy and Financial Stability, in William Curt Hunter, George G. Kaufman, and Michael Pomerleano, eds.: \textit{Asset Price Bubbles: The Implications for Monetary, Regulatory and International Policies} (MIT-Press, Cambridge Massachusetts, London), page 16 argues that the content of interest rate policy it is not opportune to introduce asset prices into the monetary policy rule of the central bank, due to this unclear information.
Figure 4: Naive and sophisticated bubbles in information treatment. Interest rate changes in this treatment were associated with information whether prices were too high or too low.

As Figure 4 reveals, giving more information on the interest policy does not help at all. The bubble in this treatment could also only be reduced marginally – at best. However, one problem with this design could be inferred. If subjects know that interest rates are raised if the prices are high, they could collude against the experimenter and trade at high prices to induce him to increase the interest rates. While this motive cannot be excluded, it does not seem very likely since there was no means to coordinate and the trader who bought at high prices had to provide a very uncertain public good. Indeed the total money earned in these treatments was not higher than in the other treatments\textsuperscript{16}.

4.4 Liquidity as a key mechanism

When we take all the data together, we find that the naïve bubbles (average difference between period price and naïve fundamental value for period 4-15) differ between policy and no policy treatments (two-sided Wilcoxon rank-sum test: p=0.062). Furthermore, the amplitude of the bubble (maximum difference of average period price from fundamental value) differs highly significantly between policy and

\textsuperscript{16} Note that one is concerned with a similar moral hazard problem in real stock markets, known as the “Greenspan hedge”. If traders know that the Fed protects them from crashes then they are more likely to bid up stock prices (cf. Mishkin, Frederic S., and Eugene N. White, Ibid.U.S. Stock Market Crashes and Their Aftermath, in., page 76). Our analysis would suggest that these collusion concerns are less important in a competitive market than one may infer from results in small scale principal agent models.
no policy treatment (two-sided Wilcoxon rank-sum test: p=0.009). In Table 5, we report also other bubble measures as investigated in Haruvy, Lahav and Noussair (2007). In this table, we use all markets in which intervention would have been necessary. We study market averages staring in period 4, when the first intervention was possible. Some of the averages are trade volume weighted. In these every trade has equal weight. In the other cases, we calculate an average over period averages. The table shows that policy has only an effect on naïve bubble measures, and also on the naïve bubble measures the effect is not very strong.

As shown above, higher interest rates cause lower investments in the trading account. In the following, we investigate whether this was a likely mechanism for the reduction of the naive bubble by the interest policy. Also for this analysis, we include the treatments from all three series of experiments in which intervention would have been necessary according to the rule in the corresponding series of experiments. We run OLS regression with bubble variables as dependent variables and with the policy dummy as regressor. Column (5) reports the corresponding coefficient. In these regressions the naïve bubbles are only weakly significant and only when we use a one-sided test. In column (6), we report the coefficient of the policy dummy in an OLS regression in which we include absolute liquidity (the amount of money used for trading) as a control variable. If the reduction of liquidity is the sole source why policy reduced the bubble, then these coefficients should be equal to zero. For most bubble measures this is indeed the case. This implies that the policy was not without impact on the market; it had a clear impact on liquidity and this in turn had a significant impact on the bubble. Besides the indirect effect via the liquidity, the interest policy had no effect – even on the naïve bubble. Hence, our analysis suggests that in order to tame a stock market bubble, direct measures which reduce liquidity, like decreasing credit limits, for example, are preferable to interest policy.
<table>
<thead>
<tr>
<th></th>
<th>(1) benchmark</th>
<th>(2) no policy</th>
<th>(3) policy</th>
<th>(4) Wilcoxon</th>
<th>(5) regression</th>
<th>(6) partial</th>
</tr>
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<tbody>
<tr>
<td><strong>Average difference between price and FV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naïve</td>
<td>131.9</td>
<td>99.6</td>
<td>0.062*</td>
<td>-32.30*</td>
<td>-5.31</td>
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<tr>
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<td>161.6</td>
<td>157.3</td>
<td>0.591</td>
<td>-4.21</td>
<td>21.06</td>
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<tr>
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<td>121.2</td>
<td>91.7</td>
<td>0.100*</td>
<td>-29.51*</td>
<td>0.93</td>
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<tr>
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<td>144.1</td>
<td>0.506</td>
<td>-6.54</td>
<td>23.78</td>
<td></td>
</tr>
<tr>
<td><strong>Average positive differences between price and FV</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>naïve</td>
<td>144.1</td>
<td>113.7</td>
<td>0.076*</td>
<td>-30.38*</td>
<td>-7.79</td>
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<tr>
<td>Real</td>
<td>179.8</td>
<td>176.4</td>
<td>0.776</td>
<td>-3.48</td>
<td>17.85</td>
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<tr>
<td>naïve, TVW</td>
<td>128.3</td>
<td>98.7</td>
<td>0.071*</td>
<td>-29.62*</td>
<td>-1.24</td>
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<tr>
<td>real, TVW</td>
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<td>146.9</td>
<td>0.429</td>
<td>-8.93</td>
<td>20.24</td>
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<tr>
<td><strong>Average absolute difference between price and FV</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naïve</td>
<td>148.1</td>
<td>118.7</td>
<td>0.067*</td>
<td>-29.32*</td>
<td>-8.81</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>182.4</td>
<td>178.2</td>
<td>0.681</td>
<td>-4.29</td>
<td>15.89</td>
<td></td>
</tr>
<tr>
<td>naïve, TVW</td>
<td>135.4</td>
<td>105.7</td>
<td>0.067*</td>
<td>-29.74*</td>
<td>-3.41</td>
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<tr>
<td>real, TVW</td>
<td>160.9</td>
<td>149.6</td>
<td>0.359</td>
<td>-11.31</td>
<td>16.70</td>
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<tr>
<td><strong>Amplitude of bubble</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naïve</td>
<td>264.3</td>
<td>207.6</td>
<td>0.009***</td>
<td>-56.77**</td>
<td>-43.56*</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>299.1</td>
<td>299.7</td>
<td>0.899</td>
<td>0.62</td>
<td>0.70</td>
<td></td>
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<tr>
<td><strong>Share of periods with price above FV</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Naïve</td>
<td>0.83</td>
<td>0.81</td>
<td>0.616</td>
<td>-0.02</td>
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<td>Real</td>
<td>0.87</td>
<td>0.88</td>
<td>0.856</td>
<td>0.01</td>
<td>0.07*</td>
<td></td>
</tr>
<tr>
<td><strong>Number of consecutive periods above FV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naïve</td>
<td>11.78</td>
<td>11.17</td>
<td>0.362</td>
<td>-0.61</td>
<td>0.52</td>
<td></td>
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<tr>
<td>Real</td>
<td>13.06</td>
<td>12.50</td>
<td>0.300</td>
<td>-0.56</td>
<td>0.46</td>
<td></td>
</tr>
<tr>
<td><strong>Share of periods with price increase relative to FV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naïve</td>
<td>0.59</td>
<td>0.50</td>
<td>0.050***</td>
<td>-0.08**</td>
<td>-0.07**</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>0.50</td>
<td>0.43</td>
<td>0.204</td>
<td>-0.07*</td>
<td>-0.05</td>
<td></td>
</tr>
<tr>
<td><strong>Number of consecutive periods with price increase relative to FV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naïve</td>
<td>5.44</td>
<td>4.17</td>
<td>0.101</td>
<td>-1.28**</td>
<td>-1.14*</td>
<td></td>
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<tr>
<td>Real</td>
<td>4.39</td>
<td>3.33</td>
<td>0.250</td>
<td>-1.06*</td>
<td>-0.62</td>
<td></td>
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<tr>
<td><strong>Absolute liquidity</strong></td>
<td>1065.1</td>
<td>698.7</td>
<td>0.000***</td>
<td>-366.45***</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Relative liquidity</strong></td>
<td>0.21</td>
<td>0.12</td>
<td>0.000***</td>
<td>-0.09***</td>
<td>-0.04***</td>
<td></td>
</tr>
<tr>
<td><strong>Trade volume</strong></td>
<td>191.7</td>
<td>180.8</td>
<td>0.056*</td>
<td>-10.89</td>
<td>34.57**</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Averages and statistical tests of different bubble measures. All data refer to averages after period 3 (periods 4 to 15). Column (1) reports whether the naïve or the sophisticated fundamental value is uses as a reference; TVW= trade volume weighted. Column (2) and (3) report the average in the policy or in the no policy treatment. Column (4) reports the p-value of a two-sided Wilcoxon rank sum test that compares market averages between policy and no policy treatment. Column (5) reports the coefficient of the policy dummy in a regression of the variable. The significance is reported one-sided. Column (6) reports the coefficient of the policy dummy in an OLS regression in which absolute liquidity is added as a control variable. In the statistical tests, we use the following notation *= significant at 10%-level, **= significant at 5%-level, ***= significant at 1%-level.
5 Conclusion

We conducted a series of experiments in which we investigated whether an active interest policy can mitigate bubbles in an experimental asset market. We showed that there is an effect of interest policy on trading prices. However, this effect is small and it is significant only when one does not take into account the fact that the fundamental value is modified by interventions. Although the bubble cannot be reduced clearly, subjects’ responses to changes in the interest rate were in the expected direction. They reduced their investment for trading and, therefore, liquidity was reduced in the stock market. Reduced liquidity in the stock market in turn had a significant effect on stock market prices. So, even though the effect is weak, the liquidity mechanism of an active interest policy works also in the lab.

In sum, we conclude that while it might be good to be the king (or Alan Greenspan), it is not easy. It is hard to calibrate an interest policy that deflates bubbles in a timely and controlled manner, even in a modestly complex setting (such as in our experiment) – how much harder must this have been in the American economy?
6 References


Gruen, David, Michael Plumb, and Andrew Stone, 2003, How should monetary policy respond to asset-price bubbles?, paper presented to the Reserve Bank of Australia annual conference (Sydney).


### 7 APPENDIX

Overview

You are now participating at an economic experiment that deals with trading in stock markets. Contingent on your decisions in this experiment, you can earn money in excess of your participation fee of 10 francs.\(^1\) Hence, it is important that you read these instructions very carefully. You will find some questions at the end of the document. Please answer them and tell us when you are done. **Please refrain from talking for the duration of the experiment.** If you have questions, please ask us. If you do not observe this rule, we will have to exclude you from this experiment and all payments, and ask you to leave. The experiment consists of 15 periods. The currency of the experiment is called Gulden\(^2\), not francs. You can earn Gulden in each period. We will exchange your Gulden to francs at the end of the experiment, at a rate of

\(^1\) The instructions are translated from German.

\(^2\) One dollar is about 1.8 francs.

\(^3\) A Gulden is a medieval coin.
1000 Gulden = 120 centimes\(^2\)

Basic structure of the experiment

This experiment is about the investment of money. You can buy either stocks or bonds. You can also trade in stocks. Bonds bear interest. Money you use for trading does not bear interest. Stocks pay a dividend each period.

At the beginning of the experiment, i.e. at the beginning of the first period, you receive an endowment in money and in stocks. Each period is structured in the same way. You first decide how much money to put into bonds and how much money to reserve for trade in stocks. You can then trade in stocks, i.e. sell them to other participants or buy them from other participants. You can only use the money you reserved at the beginning of the period for trade in stocks. After the trade phase, you receive a dividend for each stock in your possession, and interest on your bonds. You can use this money and the stocks again in the next period. Some details:

1. **The dividend:** Each stock pays a dividend at the end of every period. The dividend amount is determined by chance. It is either 0, 8, 28 or 60 Gulden for every stock in your possession at the end of the respective period. Each amount is equally likely and determined in each period with the aid of a die. In other words, on "average" (over many periods) you can expect to earn 24 Gulden per period per stock in your possession, if you are lucky 60, and if you are unlucky 0.

2. **The interest:** You receive interest on money invested in bonds. The original interest rate is 5 % per period. It is variable which means that it is possible, but not certain, that the interest rate will change in later periods. You do not receive interest for money on your trade account.

The accounts

1. **Stock account:** At every point in time, this account shows the current number of stocks in your possession.

2. **Cash accounts:**

\(^2\)100 centimes = 1 franc.
a. **Trade account**: You can use the money on this account to buy stocks during the trade phase (c. *periods*). It does **not** bear interest.

b. **Bond account**: This account contains the money that you declared as non-trade money for this period. It **does** bear interest.

c. **Total cash**: The sum of the previous two accounts.

Your profit

It is very easy to calculate your profit in Gulden (in addition to the 10 francs show up fee). It is:

Money on your total cash account at the end of period 15.

You do not receive anything for stock in your stock account at the end of the experiment. During the experiment, you have the following options for making a profit:

1. Buying and selling of stocks
2. Dividends on your stocks
3. Interest on cash in bonds

The periods

1. **Splitting your cash on the accounts**
At the beginning of each period, you receive an overview over the current state of your wealth (see above). This overview specifies:

(a) The average price at which stocks traded in each of the previous periods.
(b) The state of your total cash account and your stock account.
(c) The current interest rate that will be paid in this period on money in your bond account.

On the bottom of the page you notice the icon of a calculator. When you click it, a calculator appears on your screen. You can use it for calculations at this stage of each period.

You then have to make a decision before trade in stocks begins:

- Divide your cash between your trade account and your bond account. In the following trade phase of this period, you can use only money in your trade account to deal in stocks. You receive interest on money in your bond account. We added a button "calculate interest" to help you translate percentage points into Gulden. When you hit this button you see, under the bond account, the amount in Gulden you would receive at the end of this period at the current interest rate if you put as much money into the bond account as you currently do. You can try out different amounts in your bond account and compare the Gulden they pay you at the end of the period before you continue.

- When you are happy with how you split your cash on the two accounts, first press the "calculate interest" button and then the "OK" button on your screen. Even if you want to pass on the calculation of interest, you have to first hit the "calculate interest" button and only after that the "OK" button. The experiment switches to the (stock) trade phase of this period once the last participant has hit the "OK" button.

2. The (stock) trade phase
In each period you have 2 minutes and 30 seconds to trade stocks. Check the trade screen below. On top is the current period and time remaining. You see the number of stocks in your stock account and the Gulden in your trade account in the middle of the screen.

In the lower part of the screen, you trade:

(a) You make sales offers to the other participants in the window on the very left. Enter the price you are asking for in the blue field and press "sell". This price appears then on the screen of all participants right next to this field, in the field "sales offers." You can only enter integer, positive amounts, and your offer must be lower than the currently lowest offer.

(b) The next window contains the sales offers of all participants. You can buy one stock at one of these prices. The current best offer is highlighted. When you hit "buy", you automatically buy a stock from the participant who made this offer. The respective amount is debited to your trade account.

(c) The window in the center of the lower part of the screen lists all prices at which stocks were traded in this period.

(d) The fourth window contains the price bids of all participants. You can sell one of your stocks at one of these prices. The best bid is highlighted. When you hit "sell", you sell one of your stocks to the participant who made this offer. The resulting cash amount is credited to your trade account.
(e) You can make an offer to buy in the window on the very right. Enter the amount at which you are willing to buy a stock into the blue field and hit "buy". This price subsequently appears on all screens in the field "offers to buy." You can only enter integer, positive amounts, and your offer must be higher than the currently highest offer.

Some **trade rules for stocks:**

- Do not sell stocks that you do not yet own.
- Do not sell stocks to yourself.
- Do not buy stocks with debt, i.e. you are not allowed to offer more for a stock than you currently have on your trade account (You cannot access money in your bond account for trade in this period).

The computer will enforce these rules automatically. If ever you are astonished about problems with the execution of one of your orders, please check first whether you followed these rules.

### 3. Summary of this period

<table>
<thead>
<tr>
<th>Period</th>
<th>1 of 15</th>
</tr>
</thead>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Money in bonds</td>
<td>...</td>
</tr>
<tr>
<td>Revenue on money in bonds (Interest: %)</td>
<td>...</td>
</tr>
<tr>
<td>Trade account</td>
<td>...</td>
</tr>
<tr>
<td>Dividend per stock</td>
<td>...</td>
</tr>
<tr>
<td>Number of stocks</td>
<td>...</td>
</tr>
<tr>
<td>Revenue from dividends</td>
<td>...</td>
</tr>
<tr>
<td>New total cash</td>
<td>...</td>
</tr>
<tr>
<td>Number of stocks</td>
<td>...</td>
</tr>
</tbody>
</table>

At the end of each period, you receive a summary of your profits from dividends on your stock and interest on money in your bond account.
Additionally, this summary shows the current state of your accounts. Press the "continue" button once you are ready. Check the screen shot and the short description under it.

**Line 1:** The money you put into your bond account at the beginning of this period.

**Line 2:** Your profit in Gulden from the interest on the amount from line 1.

**Line 3:** Cash on your trade account at the end of this period, i.e. after the stock trade phase.

**Line 4:** This period’s dividend (per stock).

**Line 5:** The number of stocks you own at the end of this period, i.e. after the stock trade phase.

**Line 6:** The product of lines 4 and 5.

**Line 7:** The sum of lines 1, 2, 3 and 6.\(^{21}\)

---

\(^{21}\) The participants were then asked to answer several questions that followed the instructions. Their sole purpose was to make sure that the participants had correctly understood the instructions.
**Questionnaire**

Please answer all the questions. We will only start with the experiment when all participants have filled out their questionnaires correctly. False answers do not have any consequences for your profit (nor do correct answers). The questionnaire only fulfills the purpose of ensuring that all participants have understood the experiment correctly. The trading examples and amounts of the accounts are purely fictitious and are chosen in such a way that the calculations in the questions are simplified. If you have any doubts please don’t hesitate to approach us.

1. Participant A has 2500 Gulden on his trade account and 8 shares at the beginning of the trading period. He buys one share from participant B for 100 Gulden, one share from participant C for 300 Gulden and one share from participant D for 600 Gulden. He sells one share to participant E for 500 Gulden. The dividend at the end of the period is 28 Gulden. How many Gulden does A have at the end of the trading period on his trade account?

2. A situation for a participant at the beginning of the trading period:
   - Trade account: 2600 Gulden.
   - Interest: 5 %
   - Share account: 8
   The participant buys one share for 100 Gulden and another share for 500 Gulden in the following trading period, but executes no further transactions within the same period. The dividend is 60 Gulden. What are the participant's account balances at the end of the period? How much interest does A receive at the end of the experiment for this period?

   Share account:
   Trade account:

3. Another situation for a participant at the beginning of a trading period:
   - Trade account: 1200 Gulden.
   - Bond account: 2800 Gulden.
   - Interest: 5 %
   - Shares: 8

Which of the following transaction plans are possible for the next trading period (in this **chronology**), and if not, why not?

   a. Buy of a share for 600 Gulden, then one for 650 Gulden. Afterwards sell of a share for 700 Gulden.

   b. You state an offer to sell one share for 400 Gulden, that you cancel through a buy of your own offered share.
c. You see on your trading screen the following offers to sell: 700, 600, 500, 400. You state an offer to sell for 400 Gulden.

4. What average traded price do expect to see in the first period (there is no right or wrong answer, i.e. the answer does not follow from the experimental instructions. We are just interested in your opinion.)

When you are finished please raise your hand! I will come to look at your answers.