Monetary Policy and Asset Price Bubbles: A Laboratory Experiment

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May 2020

Abstract

Advocates of a Leaning-Against-the-Wind monetary policy have claimed that such a policy can moderate asset price bubbles. On the other hand, there are compelling theoretical arguments that the policy would have the opposite effect. We study the effect of monetary policy on asset prices in a laboratory experiment with an overlapping generations structure. Participants in the role of the young generation allocate their endowment between two investments: a risky asset and a one-period riskless bond. The risky asset pays no dividend and thus capital gains are its only source of value. Consequently, its price is a pure bubble. We study how variations in the interest rate affect the evolution of the bubble in an experiment with three treatments. One treatment has a fixed low interest rate, another a fixed high interest rate, and the third has a Leaning-Against-the-Wind interest rate policy in effect. We observe that the bubble increases (decreases) when interest rates are lower (higher) in the period of a policy change. However, the opposite effect is observed in the following period, when higher (lower) interest rates are associated with greater (smaller) bubble growth. Direct measurement of expectations reveals a Trend-Following component.

1 Introduction

The Global Financial Crisis of 2007-2008 and the subsequent Great Recession, commonly attributed to the bursting of housing bubbles in a number of countries, has shown how damaging the effects of a collapse in asset prices can be to the real economy. This episode has renewed the debate regarding the stance that central banks should take in response to a growing asset bubble. The common view among policy makers before the crisis was that central banks should

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restrict their mandate to the stabilization of inflation and the output gap. This view, however has not gone unchallenged in the aftermath of the crisis, with many authors and policymakers arguing for a more active role for central banks in preventing overinflated asset prices by means of "Leaning Against the Wind" (henceforth, LAW) monetary policies. A policy of this type specifies that the interest rate be raised in response to asset price increases that are viewed as purely speculative, i.e. not justified by fundamentals, in order to attenuate the growth of a bubble. The rationale for LAW is that higher (lower) interest rates increase (decrease) the opportunity cost of the speculation that generates price bubbles.

The use of LAW policies in response to asset price bubbles has been criticized on several grounds. Firstly, it is argued that in practice it is difficult, if not impossible, to establish whether or not asset prices reflect their fundamental values, given the difficulty in measuring the latter. Secondly, such a policy is viewed as potentially having undesired consequences on sectors of the economy not affected by the bubble. Thirdly, Galí (2014) calls into question, on theoretical grounds, the notion that a higher interest rate would reduce the size of the bubble. He argues that, if agents are rational, the bubble component must grow in expectation at the rate of interest. As a result, a LAW policy could end up increasing, rather than decreasing, the size of the bubble.[1] On the other hand, Miao et al. (2019) point to the existence, under certain conditions, of equilibria in which a bubble decreases in size in response to an increase in the interest rate.

In this paper, we study the relationship between interest rate policy and bubble dynamics in the laboratory. The use of laboratory experimental methods provides a controlled environment, in which we can isolate the impact of different interest rate policies on the size and evolution of an asset price bubble. The bubble component within the asset price can be observed with precision. Interest rate policies can be made completely credible. Different interest rate policies can be studied and their effects compared, while keeping all other aspects of the environment constant.

Our experimental environment has an overlapping generations structure. Each participant plays the role of *young* and *old* consecutively over the two periods in which she is active. When young, participants decide how to allocate their cash endowment between a single-period riskless bond, yielding a known interest rate, and a long-lived asset that pays no dividends. The only incentive to purchase the long-lived asset comes from the possibility of realizing a capital gain when the asset is resold. A positive price for that asset indicates a pure bubble. When they are old, participants collect the principal plus interest from their bonds, as well as the proceeds from the sale of the asset to the current young generation.

Within this environment, we implement three different monetary policies, each specifying a particular rule determining the interest rate on bonds. Each

[1] Galí and Gambetti (2015) provide some empirical evidence based on U.S stock market data in support of that hypothesis.

of these policies represents a treatment in our experiment. In the first two treatments, the interest rate remains constant at either a "low" (3%) or a "high" (15%) level, over the entire experimental session. In the third treatment, the interest rate varies as a function of the change in the price of the long-lived asset in the previous period. The economy begins with a 9% interest rate, which we raise (lower) by 3% each time that the asset price increases (declines) by more than 10% from one period to the next. We interpret this third treatment as a LAW policy.

For an asset that pays a dividend and is priced at its fundamental value, a higher interest rate lowers the asset's present discounted dividend stream and thus its price. A LAW policy thus has the effect of lowering asset prices when interest rates are raised and increasing prices when rates are lowered. Higher rates increase the opportunity cost of committing capital to an asset. The attraction of using LAW policies to combat asset prices that seem too high appears to be based on this logic. However, as argued by Galí (2014) , if agents have Rational Expectations, an asset whose price has a bubble component may behave in the opposite manner. While the initial effect of a change of interest rate on price is indeterminate, the bubble component would subsequently grow at the rate of interest (and at a greater rate if traders are risk averse and the asset carries some risk), meaning that higher interest rates may lead to larger bubbles, all else equal. In our experiment, we study the behavior of an asset that has *only* a bubble component, a favorable scenario for a LAW policy to be counterproductive. If we observe that the policy is effective in stabilizing asset prices in our study, it provides evidence that the theoretical arguments against the use of a leaning against the wind policy rely on assumptions that are not satified in our environment, and that may not be satisfied in the outside world.

Our experiment is designed to consider the following questions. (1) Do bubbles grow more quickly under high or low interest rates? This is an implication of a no-arbitrage condition between the bond and the asset, but at odds with the hypothesized relationship under a LAW policy. (2) What is the initial effect of an interest rate change on the size of a bubble? The immediate effect of an interest rate increase (decrease) on asset prices is indeterminate in the Galí (2014) model, though presumed to be negative (positive) under LAW. (3) What is the effect of a LAW policy on bubbles in the period after the rate change? Under the Galí (2014) model, an interest rate increase (decrease) serves to increase (lower) the asset price relative to its trend.

Our main findings can be summarized as follows. First, the average price increase for the risky asset is close to that predicted when the interest rate is low and constant, but significantly smaller than predicted when the interest rate is high. Second, a LAW policy of increasing (decreasing) interest rates in response to asset price increases (decreases) has two effects. There is an immediate effect in the current period of decreasing (increasing) the size of the asset price bubble. However, in the subsequent period, the result is reversed and the higher (lower) interest rates tend to exacerbate (mitigate) asset price bubbles. Our results thus suggest a means of reconciling the apparent success of LAW policies in guiding asset price bubbles in the short run with the theoretical claims arguing that they would be counterproductive afterward. Increasing interest rates reduces a bubble in the short-run, but increases it thereafter. The pattern we observe is consistent with the model of Galí (2014) , who predicts that the short-run response to a rate hike is indeterminate and the later response is larger bubbles, and we obtain the additional finding that the indeterminate portion of the response has a strong tendency to be in the direction intended by LAW policies.

Some of the asset pricing patterns suggest that the assumption of Rational Expectations may not be appropriate. To study this possibility, we conduct a follow-up experiment. This experiment assesses how participants form their expectations about future asset prices. We find that expectations are backward-looking, with adaptive and trend extrapolating elements, rather than rational, suggesting that the source of the departures from the theoretical framework lies in the manner that agents form expectations. We then argue that assuming Trend-Following or Adaptive Expectations can account for a number of patterns in our data.

The paper is structured as follows. In Section 2, we review the related literature. In Section 3, we describe the experimental design and state our hypotheses The results are reported in Section 4. We discuss the role of expectations in Section 5 conclude with a discussion in Section 6.

2 Related literature

The three most closely related lines of experimental literature are (1) the work on asset market bubbles in experimental finance, (2) experimental studies of the effect of monetary policies on asset market behavior, and (3) the literature considering the behavior of economies with an overlapping generations structure.

The bulk of experimental research on asset bubbles builds on the seminal paper of Smith, Suchanek and Williams (1988). In the markets that they study, participants trade units of a single asset. The asset has a finite lifetime and pays a random dividend in each period. The dividend payment and (in some cases) a fixed terminal buyout value are the only sources of intrinsic value of the asset. The distribution of the dividend process is common knowledge to all traders. This means that the fundamental value is unambiguous, provided that traders are risk neutral. All cash not invested in the asset yields an interest rate of zero. Smith et al. (1988) find, however, that a price bubble tends to emerge and prices become decoupled from fundamental values. Much of the subsequent work has implemented changes to the Smith et al (1988) environment in order to consider the robustness of the bubble phenomenon and to search for ways that could prevent or eliminate it. Some approaches that have been taken include the introduction of short selling (Haruvy and Noussair (2006)), the presence of futures markets (Noussair and Tucker (2006), Porter and Smith (1995)) and the presence of experienced traders (Dufwenberg, Linqvist and Moore (2005)). A number of studies have considered traders' beliefs about future prices (Smith et al., 1988; Haruvy et al., 2007; Carle et al., 2019), and have found that they tend to extrapolate prior trends. For recent overviews of this literature see Palan (2013), Powell and Shestakova (2016) or Nuzzo and Morone (2017).

We are aware of four papers that study the effects of monetary policies on asset markets (Fischbacher, Hens and Zeisberger (2013), Giusti, Jiang and Xiu (2016) Bostian and Holt (2009), and Fenig, Mileva and Petersen (2017)). The environments in these studies have the common feature that agents have access to an alternative asset (bonds or deposit accounts) paying an interest rate each period. None of the environments in these papers, other than that of Fenig et al., allow for a rational bubble. All of these studies find that the presence of the alternative investment is not sufficient to completely eliminate asset bubbles. Fischbacher et al. (2013) implement a policy where the interest rate on cash is varied to try to push prices toward fundamentals, in effect implementing a Leaning-Against-the-Wind interest rate policy. They found that doing so did not have an appreciable effect on bubbles. Fenig et al. (2017) observe that introducing binding leverage constraints or raising the interest rate effectively contracts asset prices. [2]

Finally, our paper relates to a literature that studies the behavior of overlapping generations economies in the laboratory. In the first paper in this line of research, Aliprantis and Plott (1992) find that prices converge to a stationary competitive equilibrium. Marimon and Sunder (1993) observe convergence to a low-inflation steady-state in a setting with multiple equilibria, and Marimon and Sunder (1994) observe convergence to expectationally-driven cycles. Bernasconi and Kirchkamp (2000) investigate the effect of different monetary policies on inflation volatility and expectations using an overlapping generation framework. They find a tendency for oversaving and that monetary policies affect outcomes. Our paper differs from those in the previous literature in that neither production nor price-setting decisions are involved in our experiment, with our focus restricted to asset prices.

3 Experimental Design

We conducted a total of nine sessions for our main experiment. Sixteen subjects participated in each session for a total of 144 subjects.[3] The sessions were conducted at the LEEX laboratory at Universitat Pompeu Fabra, in Barcelona, Catalonia, Spain. Subjects were undergraduate students in business and economics. The Ztree platform (Fischbacher, 2007) was used to program the computerized environment. A session took approximately two hours and the

[2] Other experimental paradigms have been used to investigate the effects of monetary policies in general equilibrium economies. Assenza et al. (2013) and Pfajfar and Zakelj (2016) study the interaction between the formation of inflation expectations and the use of monetary policies within a New Keynesian framework. Assenza et al. (2013) find that an interest rate rule that reacts more than one-for-one to inflation has a stabilizing effect on prices. Pfajfar and Zakelj (2016) find that a forward-looking Taylor rule with a high reaction coefficient contributes to the reduction of inflation variability.

[3] This total of sessions and participants does not include the *Prediction* sessions described in section five.

average payment was 23€ per subject.[4] The earnings received by each subject were proportional to her payoff in the experimental economy, in keeping with conventional procedures in experimental economics.

The experimental environment has an overlapping generation structure. Each participant is active for two consecutive periods, in which he plays the role of a member of the "young" and "old" cohorts sequentially. Each period, a cohort of four young participants interacts with an old cohort that also has four members. [5]

When entering the economy, each young participant receives an endowment that she has to allocate between two assets: (i) a riskless one-period bond in perfectly inelastic supply, yielding a pre-announced interest rate and maturing in the next period, and (ii) an infinitely-lived risky asset. This asset does not yield a dividend at any time, but it can be sold in the following period, thereby possibly leading to capital gains or losses. The fundamental value of the risky asset is zero, and therefore we can think of it as a "bubble asset". If the asset trades at a positive price, it is a pure bubble. The participant allocates endowment to the bubble asset by purchasing it in a market that is operating in all periods. More precisely, "young" participants make bids on the existing units of the bubble asset held by the "old," with the cash endowment not used to purchase the asset automatically allocated to purchase of the bond at the end of the young period.

At the end of the period in which a participant is young, she earns interest on her holdings of the bond, and her holdings of the bubble asset are carried over into her old period. In her old period, she can sell units of the bubble asset to young agents. The lifetime payoff of each subject is realized at the end of her old period, and is made up of the principal plus interest on her bonds, plus the proceeds from the sale of her bubble asset. Her holdings of bond and asset then disappear.[6]

Each experimental session consists of several horizons, where each horizon refers to an entire multi-period economy. At the beginning of each horizon, all endowments are reinitialized at the same starting level. Each horizon, in turn,

[4] At the beginning of each experimental session we provided written instructions to all subjects and read them aloud. This took approximately 20 minutes.

[5] The implementation of the overlapping generations environment follows Marimon and Sunder (1993), with several differences. As in Marimon and Sunder (1993), we have a fixed number of subjects for each experimental session. In each period, a subset of them, composed of 4 subjects, enters the market as "young" participants and remains in the market for two consecutive periods, consisting of a young, followed by an old, period. An agent is then reborn as a new young agent in the period immediately following her old period.

[6] The aggregate supply of the long-lived asset (i.e. the number of units available for purchase every period) always remains unchanged. In order to guarantee this condition, units that are unsold by current old agents at the end of a given period through the auction mechanism are automatically and randomly allocated to current young buyers who are forced to pay 1.5 times the average transaction price in the period. For such transactions, the price received by the old sellers is .5 times the average transaction price. In this way, we maintain a constant supply of shares while incentivizing trade. In the event of no trade in a given period, the average transaction price is set at 0. Thus, a zero price equilibrium, which does exist in our laboratory environment, is a feasible outcome in the experiment, though it is never observed.

consists of a random number of periods, with a constant probability (equal to .1) that the horizon would end after any given period.[7] Each experimental session includes as many horizons as we could conduct in two hours and 30 minutes. We do not start a new horizon unless there remained at least 20 minutes left until the scheduled end of the session.

In each of the nine sessions, there are two horizons and thus two markets operating concurrently, each with 8 participants. At the end of each horizon, before starting a new market, participants in both markets are randomly regrouped. This is common knowledge.

There are three treatments, LOW, HIGH, and LAW, with the treatments differing only in the interest rate policy that is in effect. The policy defines the interest rate to be paid on the bond in each period.

LOW Treatment: A constant interest rate of 3% prevails throughout the entire experimental session.

HIGH Treatment : A constant interest rate of 15% is in force throughout the entire session.

LAW Treatment: A Leaning-Against-the-Wind policy is in effect, whereby the interest rate is adjusted as a function of the percentage change in the price of the bubble asset in the previous period. Specifically, the interest rate starts at 9% at the beginning of each horizon. It is increased (reduced) by 3% whenever the price of the bubble asset rises (declines) by more than 10% from one period to the next. Otherwise, the interest rate is left unchanged. Furthermore, we set upper and lower bounds for the nominal interest rate of 3% and 15%, respectively. The resulting interest rate rule can be written as:

$$R_t = \begin{cases} \min\{R_{t-1} + 0.03, 0.15\} \text{ if } (P_{t-1} - P_{t-2})/P_{t-2} \geqslant 0.1 \\ \max\{R_{t-1} - 0.03, 0.03\} \text{ if } (P_{t-1} - P_{t-2})/P_{t-2} \leq 0.1 \\ R_{t-1} \text{ otherwise} \end{cases}$$

Only one treatment is in effect in a given session. In the LAW treatment, participants are not explicitly informed about the policy rule nor given any reason for the changes in the interest rate. In all cases, the interest rate prevailing in any given period is communicated to participants at the beginning of the period.

The trading mechanism is a continuous double auction with an open order book (Smith, 1962). In each trading period, subjects can initiate a potential transaction by posting offers to buy or to sell the bubble asset. Each offer is for a single unit of asset, but subjects can post multiple offers to buy or sell. Active buy and sell orders are ranked and displayed in two separate columns, with the best available offers listed at the bottom. Subjects execute a trade by

[7] As discussed in Duffy (2014) this is theoretically equivalent to an infinite horizon with a discount factor $\beta = .9$.

selecting the best order available at any point in time and clicking on the “buy" or “sell" button located at the bottom of the order book. Short sales or buying on margin are not permitted

Each trading period lasts for 150 seconds. At the end of a trading period, a summary screen appears, showing relevant information, such as the participant's current quantity of risky asset and bonds held, and the interest they receive in the period.

Young participants are endowed with 5000 ECU in cash at the beginning of period 1 of each horizon. The size of the endowment of each new young generation increases at a 15% rate per period. The reason for this increase is the theoretical requirement of an interest rate at or below the growth rate of the economy's resources for a rational bubble to exist in equilibrium. Since our highest possible interest rate is equal to 15% per period, our strategy guarantees that this requirement would be satisfied. In period 1, each current “old" participant is endowed with 3 units of the bubble asset in order to initialize the market. Therefore, in any period, 12 units are exchanged between the old and young generations.

The payoff for each subject over each two-period lifetime is calculated at the end of the old period. It was given by the initial endowment, plus interest on bonds plus the capital gains (or minus the losses) from the purchase and sale of the bubble asset. Since each subject typically plays several “lives" in each horizon and there are several horizons in each experimental session, the program randomly selects one of the “lives" to count as a partipant's earnings from the experiment. The experimental currency is converted into Euros at a fixed, pre-specified exchange rate.

4 Results

4.1 The LOW and HIGH treatments

Figure 1 shows the average price in each of the three treatments. In the figure, the horizontal axis indicates the market period. All horizons are included in the figure. Periods beyond seven are not shown because they have fewer observations since relatively few horizons reach them. The vertical axis is the average price in a period. The figure shows that the average price in the HIGH treatment, 278, is slightly greater than under the LOW treatment, 251, though the difference is not significant (t = -0.78 , p=0.44; Mann-Whitney rank-sum test z=-1.16, p=0.24). Thus, higher interest rates exert neither a dampening nor an exacerbating effect on average asset prices.

The average return of the asset is given by:

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}} \tag{1}$$

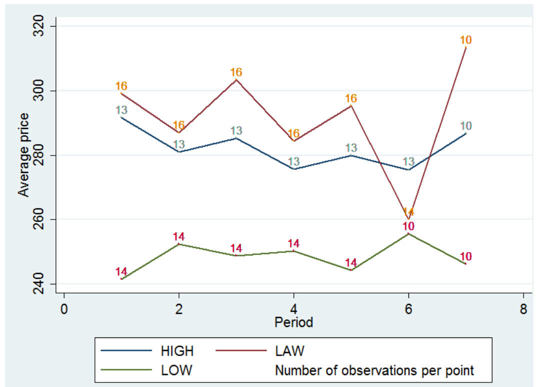

Figure 1: Asset prices in treatment by period, averaged over all horizons

The figure gives the impression that there is at most a modest tendency for the price of the bubble asset to rise over time, suggesting that returns average close to zero. Statistcal tests confirm this impression. The average return of the asset in the LOW treatment, 1.98%, is not significantly different from the risk free rate of 3% (t=-0.39, p =0.70; z=-1.791, p =0.073) . However, it is also not significantly different from 0% (t=0.76, p=0.46; z=0.47, p=0.637). The average return for the asset in the HIGH treatment, -0.7%, is significantly lower than the risk free rate of 15% (t=-12.24, $p < 0.01$; z=-3.18, p=0.0), though not different from zero (t = -0.53, p = 0.60, z = -0.45, p = 0.64). The returns are also not significantly different between the LOW and HIGH treatments at conventional levels of significance (t=0.89, p = 0.37; z= 0.72, p = 0.46) [8]

Thus, we do not observe significantly different bubble size or growth in the LOW and HIGH treatments. While the rate of bubble growth is close to the interest rate under LOW, and significantly lower than the interest rate under HIGH.

4.2 Leaning against the wind

In this section, we first consider the association between interest rates and prices in the LAW treatment. Figure 1 gives the impression that LAW treatment

[8] The volatility of prices is similar in the two treatments. We distinguish between *within-horizon* dispersion of returns from period to period within a horizon. and between-horizon dispersion, a measure of the variance in average return across different horizons. We define the within-horizon dispersion as $\sum_{t=1}^{T}(R_t - R_{t-1})^2$, where R_t is the return of the asset in period t and R_{t-1} is the return in the preceding period. This measure averages 0.09 for the LOW, and 0.12 for the HIGH treatment, respectively. The difference between the two treatments is not significant (t= -0.37, p=0.71; z= -1,26, p= 0.21). We define between-session dispersion as $(\sum_{j=1}^{J}(\bar{R}_j - \bar{R})^2)$, where $\bar{R}_j$ represents the average return in a horizon of a given treatment and $\bar{R}$ is the average return in the treatment. The values of this measure are 0.0088 in LOW, and 0.0019 in the HIGH, treatment, suggesting more between-session heterogeneity in the LOW treatment.

exhibits large oscillations. The claim of advocates of Leaning Against the Wind policies is that an interest rate increase (decrease) in period t would reduce (increase) the price in period t. In our experiment, a LAW policy takes the form of an interest rate change in period t being enacted in response to a price change between periods t-1 and t. That is, $r_t > r_{t-1} + .03$ if $P_{t-1} > 1.1 * P_{t-2}$ and $r_t < r_{t-1} + .03$ if $P_{t-1} < .9 * P_{t-2}$. This change in r_t would affect the return from holding bonds between periods t and $t+1$, changing the demand for the bubble asset. A higher interest rate would increase the opportunity cost of holding the asset, leading to lower demand and consquently a lower price. A lower interest rate would have the opposite effect.

We consider this relation with two measures. The first is a test of whether interest rate increases (decreases) correlate with a contemporaneous decrease (increase) in asset price. That is, we test whether

$$(P_t - P_{t-1}) * (r_t - r_{t-1}) < 0 | r_t \neq r_{t-1} \tag{2}$$

in a significant majority of instances. We also evaluate the effect of interest rate changes on the current price trend. Since the price trend is $P_t - P_{t-1}$, the test is:

$$(P_t - P_{t-1} - (P_{t-1} - P_{t-2})) * (r_t - r_{t-1}) < 0 | r_t \neq r_{t-1} \tag{3}$$

However, as noted by Gali (2014), there may be an offsetting effect of interest changes on subsequent price trends. The interest rate in period t affects the return of a bond held from period t to $t+1$. Therefore, the return of the bubble asset between periods t and $t+1$ should be affected in a similar direction as the interest rate change. In our experiment, we measure this effect as a positive relationship between a change in interest rate in period t and a change in the price of the bubble asset between periods t and $t+1$. That is, we test whether:

$$(P_{t+1} - P_t) * (r_t - r_{t-1}) > 0 | r_t \neq r_{t-1} \tag{4}$$

after a signifcant majority of interest rate changes. We also consider how interest rate changes affect the change in the return of the asset compared to the prior trend. That is, we test whether:

$$(P_{t+1} - P_t - (P_t - P_{t-1})) * (r_t - r_{t-1}) > 0 | r_t \neq r_{t-1} \tag{5}$$

Table 1 shows the percentage of observations that are consistent with each of the measures. The first column of the table is the measure being considered, the second column indicates the total number of periods, in which there were interest rate changes, and for which the test can be evaluated. The third column contains the number of periods in which the relationship in the first column was observed. The table shows that the large majority of observations are consistent with all four measures. This indicates that the immediate effect of a leaning against the wind policy is to push asset prices in the intended direction. Interest rate increases have the effect of lowering prices, while rate reductions increase them in the current period. However, the effect one period ahead is very different. In the overwhelming majority of cases, the price bubble in the asset is increased by a rate hike and lowered by a rate decrease.

Measure	Observations	Consistent
$(P_t - P_{t-1}) * (r_t - r_{t-1}) < 0$	54	51
$(P_t - P_{t-1} - (P_{t-1} - P_{t-2})) * (r_t - r_{t-1}) < 0$	48	47
$(P_{t+1} - P_t) * (r_t - r_{t-1}) > 0$	45	39
$(P_{t+1} - P_t - (P_t - P_{t-1})) * (r_t - r_{t-1}) > 0$	41	38

Table 1: Effects of Leaning Against the Wind Policy on Current and Future Prices of the Risky Asset

5 The Role of Expectations

In section 4.1, we observed that the price of the asset under LOW tends to increase modestly, but at a rate that was not significantly different from zero. The price of the asset in the HIGH treatment also did not change at a rate significantly different from zero. However, it was negative in sign, despite the positive interest rate. The price trend in HIGH is significantly different than that predicted by a no arbitrage condition between the bond and the bubble asset. In this section, we explore what might be behind this unanticipated pattern. We consider the potential connection between the price trend and the expectations individuals hold.

Much prior experimental evidence supports the notion that people have backward-looking expectations of some form. Indeed, in experimental tasks that involve predicting market prices, prior studies consistently find that the majority of subjects use Trend Extrapolation, which depends only on previous price data, or Adaptive Expectations, which involves basing current predictions on past prices and past own predictions (e.g.(Haruvy, Lahav & Noussair 2007); (Hommes, Sonnemans, Tuinstra & Van de Velden 2008)). Indeed, one should only hold Rational Expectations if it is common knowledge that others do so as well. Therefore, the failure to observe Rational Expectations prices does not necessarily mean that there is any irrational behavior, only that it be believed to be possible. That is, a lack of common knowledge of rationality can make expectations of prices, and in turn prices themselves, depart from fundamentals, even when all traders are rational.

5.1 A follow-up experiment to elicit expectations

To establish what might be the appropriate assumptions on expectations to describe behavior in our experiment, we conducted additional experimental sessions with a different cohort of participants than those in the prior treatments. The new participants were randomly selected from the same subject pool, students in business and economics from Universitat Pompeu Fabra. A total of 60 subjects, divided among four laboratory sessions, participated in this experiment.

In these sessions, subjects received information about prices in sessions of the three main treatments of the experiment. Specifically, participants had available (1) the asset price in the current period P_t, (2) the prior interest rate on the bond r_{t-1}, and (3) the interest rate that would prevail between the current period and the next, r_t. They were asked to forecast the price of the asset in the next period, P_{t+1}. After that, they observed the actual data from the period that they had forecast, and we asked to forecast the next period. The sequences of realized prices and interest rates for the forecastiing task were randomly taken from the market data of the three treatments. A total of 22 sequences (out of a total of 43) were used for this experiment, and each of the sequences was used once.

Participants received a monetary payment based on the accuracy of their forecasted prices compared to the actual realizations. Following Haruvy et al. (2007) the incentive scheme for correct predictions was established through a simple payment schedule (reported as Table 1B in the instructions in Appendix B). The experiment took on average 70 minutes, including instruction, and the average payment was 25€. In total, we obtained 2642 price predictions from these sessions.

5.2 What expectations do participants have?

We begin our analysis of the data by considering how well predictions conform to Rational Expectations. There are two senses in which we can view expectations as rational. The first notion of rationality is that expectations are unbiased predictors of the subsequent price. To test this, we estimate

$$R_{t+1} = \alpha + \beta R^e_{t+1} + \varepsilon_{t+1}, \quad (6)$$

where $R^e_{t+1} = (P^e_{t+1} - P_t)/P_t$. P^e_{t+1} is an individual's prediction of the price in period $t+1$ and R^e_{t+1} is the predicted return for that period. If expectations are unbiased, we would observe that $\alpha = 0$ and $\beta = 1$.

However, as shown in the middle column of Table 2, the estimated β coefficient is equal to 0.139, significantly different from 1 (p-value < 0.01). The estimate of α is significantly different from 0 (p-value < 0.01) and equal to 0.029. A F-test of the hypothesis that the two coefficients are as predicted yields a statistic of F $= 261.59$ (p $< .0001$). The reported R^2 is equal to 0.0057, so that the model explains a very small amount of variation. The data are inconsistent with the hypothesis that expectations are unbiased predictors of upcoming prices.

Another notion of Rational Expectations is that individuals apply a theoretical model that assumes common knowledge of rationality to the data that they observe to form their expectations. Under this assumption, an agent expects the return on the asset to equal the rate of interest on bonds. To test this, we can estimate the following model:

$$R^e_{t+1} = \alpha + \gamma r_t + \varepsilon_{t+1} \quad (7)$$

If agents have Rational Expectations, $\alpha = 0$ and $\gamma = 1$. The estimates are shown in the last column of Table 2. the estimated γ coefficient is equal to -0.043, significantly different from 1 (p-value < 0.01). The estimate of α is 0.009, significantly different from 0 (p-value < 0.01). A F-test of the hypothesis that the two coefficients are equal to the predicted values yields F = 529.34 (p < .0001). The reported R^2 is essentially 0. Thus, the data are inconsistent with the hypothesis that individuals have Rational Expectations.

	R_{t+1}	R^e_{t+1}
R^e_{t+1}	0.139***	
	(0.038)	
r_t		-0.043
		(0.062)
Constant	0.029***	0.009
	(0.006)	(0.007)
N	2323	2323
R^2	0.0057	0.0002

Table 2: Estimates of Models of Rational Expectations

In view of the fact that our incentivized observers do not employ Rational Expectations, we ask if they employ rules that have been widely observed in other experimental paradigms. We consider three alternative models in the regressions reported in Table 3. In the second and fifth columns of the table, we report estimated parameters of a simple Trend Extrapolation rule, given by:

$$P^e_{t+1} - P_t = \beta_0 + \beta_1(P_t - P_{t-1}) + \varepsilon_{t+1}. \tag{8}$$

We also estimate an Adaptive rule:

$$P^e_{t+1} - P^e_t = \beta_0 + \beta_1(P_t - P^e_t) + \varepsilon_{t+1} \tag{9}$$

and the estimates are given in columns 3 and 6. Both the Trend Following and the Adaptive models are estimated with and without the interest rate r_t as a control.

The simple Trend Extrapolation rule that we consider assumes that individuals use only prior price data and assume that the most recent trend will continue. There has been support for models with this feature in the asset market experiments of Haruvy et al. (2007). Adaptive rules have been proposed and supported in Learning-to-Forecast experiments, often in combination with Trend Following rules (Anufriev et al., 2018). The simple Adaptive rule we evaluate compares one's prediction in the preceding period with the actual outcome, and updates the prediction for the subsequent period in the direction of the outcome.

There is also the possibility that expectations are governed by a mix of the two types of rule. We also estimate a Hybrid rule, including Trend Following and Adaptive Expectation components:

$$P^e_{t+1} - P_t = \beta_0 + \beta_1(P_t - P_{t-1}) + \beta_2(P_t - P^e_t) + \varepsilon_{t+1} \tag{10}$$

Table 3 shows that the Trend Following and Hybrid rules, which incorporate past trends, describe predictions better than Rational Expectations. The R^2

of regressions that include the trend are between .2 and .42, while those that include only an Adaptive component explain less variation. In Appendix A, we also report the same analysis separating the LAW treatment, in which the interest rate is subject to frequent changes, from the LOW and HIGH treatments. Each of the two subsets of the data displays the same overall pattern as the pooled data.

Interestingly, the estimated coefficients on the recent trend $P_t = P_{t-i}$ in equations (8) and (10) are negative. This means that individuals expect prices to exhibit a form of negative autocorrelation or mean reversion, in that the larger the change in a given direction, the less in the same direction the next change is expected to be. Similarly, the coefficients on $P_t - P_t^e$ in equations (9) and (10) are also negative. This means that the more prices have exceeded (been lower than) an individual's expectations in period t, the less she adjusts her predictions upward (downward) in the next period. This also is consistent with the idea that individuals expect mean reversion to occur. This pattern holds even in the treatments with no LAW monetary policy, in which such expectations might be held due to an anticipated policy response.

	Trend Follow	Adaptive Exp.	Hybrid	Trend Follow	Adaptive Exp.	Hybrid
$P_t - P_{t-1}$	-0.34***		-0.40***	-0.34***		-0.39***
	(0.01)		(0.01)	(0.01)		(0.01)
$P_t - P_t^e$		-0.14***	-0.23***		-0.14***	-0.21***
		(0.02)	(0.01)		(0.02)	(0.01)
r_t				-224.10***	-38.32***	-207.30***
				(10.53)	(14.83)	(9.83)
$Cons$	-11.21***	0.82	-8.23***	10.97***	4.57***	12.01***
	(0.62)	(0.82)	(0.59)	(1.18)	(1.67)	(1.10)
N	2323	2323	2323	2323	2323	2323
R^2	0.20	0.03	0.31	0.33	0.04	0.42

Table 3: Parameter Estimates for Backward-Looking Expectational Rules

5.3 Expectations and price dynamics

As described in section four, the behavior of the LOW and HIGH treatments shows some unexpected patterns. The first is that the price of the asset does not exhibit a significant increase over time. Indeed, in the HIGH treatment the price actually decreases over time on average, though the effect is not significant. The second is that the price changes between one period to the next, $P_t - P_{t-1}$, in the HIGH and LOW treatments are not significantly different from each other. Indeed, the trend is actually lower under HIGH than under LOW. While these patterns are inconsistent with Rational Expectations, we argue here that they are consistent with expectation of the form in either equations (8) or (10).

We show how under appropriate assumptions on expectations, the two following counterintuitive patterns can arise: (1) a downward trend in prices, and (2) smaller (larger) price appreciation (depreciation) under higher interest rates. While these patterns are extreme caricatures of what we have observed, the arguments can be easily refined to capture the more modest effects that we have obtained. Consider a trader with expectations as in equation (10), and for simplicity assume that $\beta_0 = 0$. Denote the expectation the agent holds at the beginning of period s about the price of the asset in period t as P_t^{es} Before period 1, there is no basis to form expectations, because there is no past data. Thus, we assume that a young agent's expectations for the price in periods 1 -3, P_1^{e1}, P_2^{e1}, P_3^{e1} are arbitrary. However, for a given expected price for period 1, we assume that $P_1^{e1} = P_2^{e1} = P_3^{e1}$.[9]

If the return on the bond between periods 1 and 2 is the interest rate r, then the willingness-to-pay of traders for the long-lived asset in period 1 is $\frac{P_2^{e1}}{R}$, where $R = 1 + r$, since the return on bonds is r, to equalize the return on the asset and the bond. Therefore, the period 1 price must be $\frac{P_2^{e1}}{R}$, It is clear that if all traders approch the valuation of the asset in this manner, the price in period 1 will be below the level traders predicted, so that $P_1 = P_1^{e1}/R < P_1^{e1}$. This means that prior period 1 predictions are incorrect, in line with the relaxation of the assumption of Rational Expectations.

Now consider period 2. An agent with Hybrid Expectations will now update her predictions for period 2 downward, in view of the fact that the price in period 1 was lower than expectations, so that $P_2^{e2} < P_2^{e1}$. Because there is not yet enough data to establish a trend, she will also have the expectation that $P_3^{e2} = P_2^{e2}$ Thus, in period 2, the current young will value the asset at $P_2 = \frac{P_3^{e2}}{R}$. Notice that this price is lower than R times the observed price in period 1, so that $P_2 < R * P_1$, since $P_2 = \frac{P_3^{e2}}{R} < P_2^{e2} < P_2^{e1} = R * P_1$. This means that the asset appreciates at a rate less than R, and may even depreciate.

In period 3, agents will lower their expectations of the current price for period 3 in light of the fact that $P_2 < P_2^{e2}$, so that $P_3^{e3} < P_3^{e2}$. A similar effect will occur in subsequent periods $t > 3$ and any increase in price will be strictly less than the risk-free rate and may even be negative. The trend-following effect will lead to anticipation of a continuation of the price trend, and the Adaptive Expectations component will continually push agents to update their beliefs in the direction of lower prices.

Example 1: Suppose that $P_1^{e1} = P_2^{e1} = P_3^{e1} = 250, R = 1.09$, and agents have the expectations given in (10) with $\beta_1 = \beta_2 = 1/2$. In period 1, the price would equal $P_1 = \frac{P_2^{e1}}{R} = 250/1.09 = 229.36$. Then, a young agent's expectation in period 2 of the upcoming period 2 price would be $P_2^{e2} = P_1 + \beta_2(P_1 - P_1^{e1})$

[9] The assumption that the expectations of individuals who are just entering a new asset market are that the price trajectory will remain constant is strongly supported by the results of Haruvy et al. (2007), who observed a strong tendency for flat expectations among inexperienced agents in their markets, even though all agents knew that the fundamental value of the asset was decreasing over time.

= 229.36 + 0.5*(229.36 - 250) = 219.03. She would have the same expectation for period 3, that $P_3^{e2} = P_2^{e2} = 219.03$. Therefore, the price that a young agent would be willing to pay in period 2, $P_2 = 219.03/1.09 = 200.95$.

In period 3, an agent's expectation for the upcoming period $P_3^{e3} = P_2 + \beta_1(P_2 - P_1) + \beta_2(P_2 - P_2^{e2})$ = 200.95 + 0.5*(200.95 - 229.36) +0.5* (200.95 - 219.03) = 200.95 - 14.21 - 9.04 = 177.7. If agents hold the same expectation for period 4, so that $P_4^{e3} = P_3^{e3}$, then $P_3 = 177.7/1.09 = 163.03$.[10] Since $P_3 < P_2 < P_3$, the example illustrates how a negative trend in the valuation of a risky asset can arise, even in an environment with positive interest rates, when the assumption of Rational Expectations is replaced by those beliefs that are held by our participant pool.

Example 2: This example demonstrates, when contrasted with Example 1, that the price decline is steeper, the higher the interest rate. Consider the behavior of a similar market when the interest rate $r = .03$ instead of $r = .09$ as in the example above. Then, $P_1^{e1} = P_2^{e1} = P_3^{e1} = 250$, and $P_1 = 250/1.03$ = 242.72. Consequently, $P_2^{e2} = 239.08$. and $P_2 = 232.12$. In period 3, $P_3^{e3} = 232.12 - 5.3 - 3.48 = 223.34$ and $P_3 = 216.83$. The downward trend is more modest than under the higher interest rate.

Example 3: This example shows that the same general pattern is observed if $\beta_1, \beta_2 < 0$. Continue to assume that $P_1^{e1} = P_2^{e1} = P_3^{e1} = 250, R = 1.09$, and agents have the expectations given in (10), but with $\beta_1 = \beta_2 = -0.5$ The β coefficients are negative as we have estimated and initial expectations are of a flat trajectory. In period 1, the price would equal $P_1 = \frac{P_2^{e1}}{R}$ = 250/1.09 = 229.36, and $P_2^{e2} = P_1 + \beta_2(P_1 - P_1^{e1})$ = 229.36 - 0.5*(229.36 - 250) = 239.68. Since $P_3^{e2} = P_2^{e2} = 239.68$, $P_2 = 239.68/1.09 = 219.89$. In period 3, $P_3^{e3} = P_2 + \beta_1(P_2 - P_1) + \beta_2(P_2 - P_2^{e2})$ = 219.89 - 0.5*(219.89 - 229.36) - 0.5* (219.89 - 239.68) = 219.89 + 4.73 + 9.90 = 233.91. If $P_4^{e3} = P_3^{e3}$, then $P_3 = 233.91/1.09 = 214.59$. Prices decline over time.

Example 4: The example shows how, with different long-term expectations, the price trend can be flat regardless of the signs of the coefficients β_1 and β_2. Suppose, for example, that short term expectations for the next period are those in (10), while the price is expected to appreciate by the rate of interest in period $t + 1$. That is, assume that $P_1^{e1} = 250, P_2^{e1} = R * P_1^{e1}$, and $P_3^{e1} = R * P_1^{e2}$, and $R = 1.09$. Then, we have that $P_1 = P_2^{e1}/R = 250$. As a consequence, $P_2^{e2} = P_1 + \beta_2(P_1 - P_1^{e1})$ = 250 + 0.5*(250 - 250) = 250, and $P_3^{e2} = P_2^{e2} * R$ = 250*1.09 = 272.5. Then the price in period 2, $P_2 = P_3^{e2}/R = 250$, and $P_3^{e3} = P_2 + \beta_1(P_2 - P_1) + \beta_2(P_2 - P_2^{e2})$ = 250 + 0.5*(250 - 250) + 0.5*(250 - 250) = 250, and so on. The price stays constant at 250 despite the positive interest rate. The prices would remain constant for any values of β_1 and β_2

[10] Note that the downward trend remains, though is less pronounced, if there is no trend-following component in agents's expectations. Suppose that $\beta_2 = 0$. Then $P_3^{e3} = 186.75$ and $P_3 = 171.33$.

under the expectations assumed.

6 Discussion

In this paper, we have reported on an experiment to study the effects on an asset market of a Leaning-Against-the-Wind monetary policy. The asset has no intrinsic value, and can only be held for the purpose of speculation. It is widely thought within the central banking community that a tight interest rate policy can be used to mitigate asset market bubbles, while an accomodative policy can help alleviate asset price declines. However, as pointed out by Gali (2014), higher interest rates have the effect of raising the return on all assets, so that an asset in a bubble can expeience a more rapid run-up in price, the higher is the interest rate. Indeed, this is an unavoidable consequence of assuming Rational Expectations.

Our experimental data show the way to a reconciliation of the two viewpoints. We find that there is an immediate, short-term decrease in the price of the risky asset following an interest rate hike and similar increases following an interest rate cut. This effect appears to be behavioral in origin and is not anticipated by received theoretical models, which allow for the effect only when the asset pays dividends in the future. The response to the interest rate change occurs presumably because the return of the alternative, safe asset is directly affected by the policy, resulting in changes in demand for the bubble asset. The increase in return in the bond resulting from a rate hike draws investment out of the risky asset, and the decrease in return induced by a rate cut has the opposite effect. We also observe that the effect predicted by Gali (2014) appears strongly in the data. When a higher interest rate is in effect, the bubble asset appreciates more than under a lower interest rate. Thus, the typical effect of a rate hike is to decrease a bubble in the current period, and magnify the bubble in the next period. It appears to us that a central bank policy of leaning against the wind must have very frequent adjustments, before the second effect can appear, in order to be effective in moderating asset prices.

We also conducted two treatments, HIGH and LOW, in which the interest rates were constant. Under Rational Expectations, the bubble asset would appreciate at a greater rate in the HIGH than in the LOW treatment, since the interest rate is greater under HIGH. In our data, we observe that the two assets exhibit similar average price changes. The changes average close to zero. In section 5, we have argued that such a pattern can arise if individuals have Adaptive or Trend Following, rather than Rational, Expectations, even without the mean-reverting property that we reserve in our expectations. The experiment demonstrates that unanticipated price trends can be observed among inexperienced market participants. Follow-up work can investigate whether this is a realistic possibility in markets populated with sophisticated investors who have very high stakes in the market.

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7 Appendix

	Trend Following	Adaptive Exp.	Hybrid	Trend Following	Adaptive Exp.	Hybrid
$P_t - P_{t-1}$	-0.15***		-0.21***	-0.17***		-0.22***
	(0.02)		(0.02)	(0.02)		(0.02)
$P_t - P_t^e$		-0.20***	-0.30***		-0.20***	-0.28***
		(0.02)	(0 .01)		(0.02)	(.013)
r_t				-195.29***	-17.02	-172.26***
				(12.30)	(17.76)	(10.85)
$Cons$	-16.08***	0.72	-11.42**	5.79***	2.59	7.56***
	(0.74)	(1.04)	(0.68)	(1.53)	(2.22)	(1.35)
N	1567	1567	1567	1567	1567	1567
R^2	0.04	0.06	0.26	0.17	0.06	0.36

Table 4: Parameter Estimates for Backward-Looking Expectational Rules - Constant Interest Rate

	Trend Following	Adaptive Exp.	Hybrid	Trend Following	Adaptive Exp.	Hybrid
$P_t - P_{t-1}$	-0.543***		-0.56***	-0.52***		-0.54***
	(0.02)		(0.02)	(0.02)		(0.02)
$P_t - P_t^e$		-0.04	-0.08***		-0.04	-0.09***
		(0.03)	(0.02)		(0.03)	(0.02)
r_t				-146.54***	-77.16**	-149.55***
				(24.38)	(36.76)	(23.99)
$Cons$	-0.82	2.08	-0.21	9.67***	7.64***	10.52***
	(0.86)	(1.31)	(0.86)	(1.94)	(2.95)	(1.91)
N	756	756	756	756	756	756
R^2	0.60	0.003	0.61	0.62	0.008	0.63

Table 5: Parameter Estimates for Backward-Looking Expectational Rules - LAW treatment

8 Appendix B

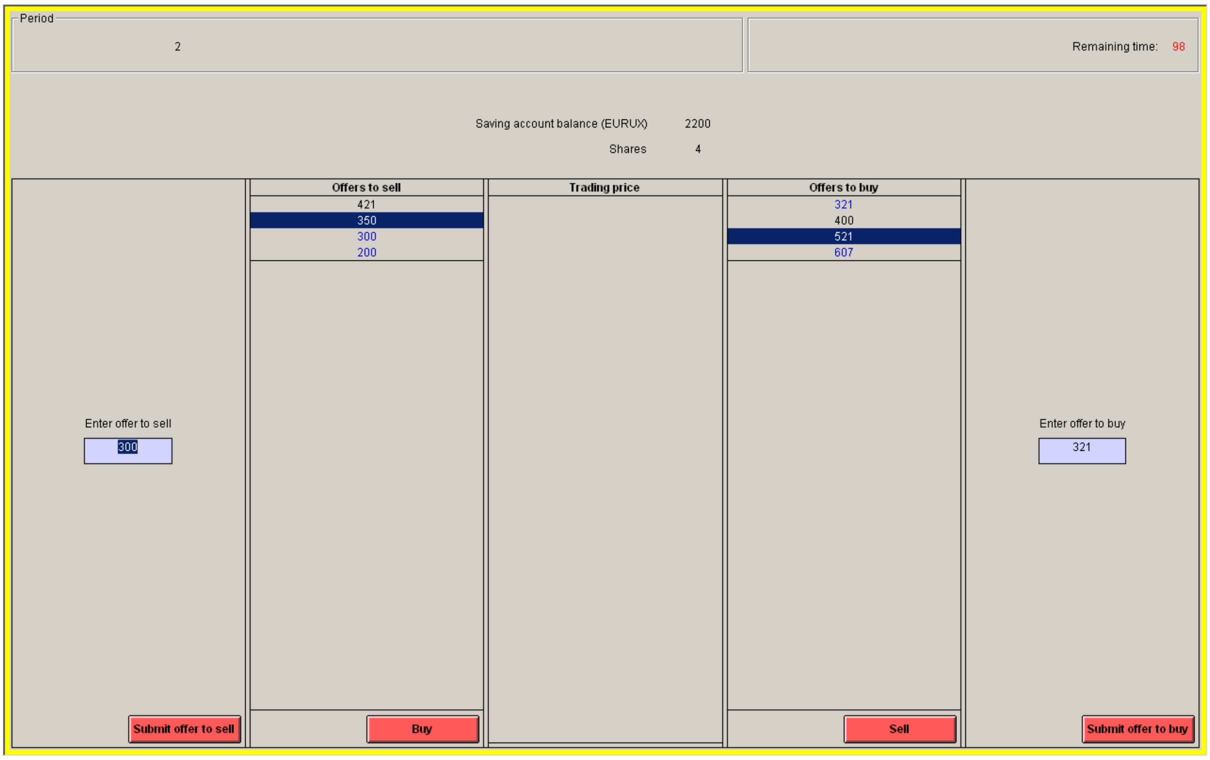
Instructions

You are taking part in an experiment involving financial decisions. The instructions are simple and if you follow them carefully and make good decisions, you can earn some money, which will be paid to you after the experiment. The currency used in this experiment is called “eurux”. The amount of eurux you accumulate will be converted at the end of the experiment into “real” euros. The exchange rate is 150 eurux for 1 Euro. If anything is unclear at any time, feel free to raise your hand and ask the experimenter any question you may have. Please do not talk to other participants during the entire experiment.

a. Main characteristics of the experiment

In this experiment, you will play several “lifecycles.” A **lifecycle** consists of two periods: In the **first period** of a lifecycle, you are “**Young**.” In the **second period** of a lifecycle, you are “**Old**.”
Once the second period ends, you will play again in a new lifecycle until the end of the experiment for a certain number of periods.
In each lifecycle, you can earn money (Eurux). The amount of money you earn will depend on your investment decisions when “Young” and “Old” as well as on other participants’ decisions.
When the lifecycle starts and you are “Young”, you will receive a budget in EURUX that will be deposited in your bank account and that earns a preannounced interest rate paid to you at the end of the lifecycle (when you are “Old”).
You can use theis money to trade (i.e. buy and sell) units of an asset with the other participants.
Depending whether you are “Young” or “Old”, you will be able to “buy” or “sell” shares, respectively.
In the following we will explain you how to buy and sell shares in each period of the experiment.

b. Trading Interface



This is the trading interface you will use during the entire experiment.
In the top left corner you can see in which period you are participating. The top right corner shows how much time (in seconds) is left in the current period.
If your role for this period is of **Young** (Old), you will only be able to **buy** (sell) shares.
In order to buy shares you need money, while if you want to sell shares you need to own them.
The quantity of money and the number of shares you currently have for trading is reported at the top of the screen. Both are instantly updated each time you buy or sell a share.
In the following, the experimenter will explain you how to buy and sell shares by using the trading interface.

Young Role – Buying shares

If you are "Young" you will only be able to buy shares. You can do it in two ways.

First, you can **initiate a purchase** of a share by **submitting** an **offer to buy**.
If you have money (eurux) in your bank account and would like to buy a share, you can initiate the purchase by submitting an offer to buy.
Try submitting an offer to buy a share now. Write a number in the text area "Enter offer to buy." Then press the red button labelled "Submit offer to buy". Immediately in the column labelled "Offers to buy", you will see a list of numbers ranked from low to high. These numbers are the prices at which traders are willing to buy a share in this period. The offers to buy will be executed once they are accepted.
Your own offers are marked in blue; others' offers are in black.

Second, you can **realize a purchase** of shares by **accepting** an **offer to sell submitted** by a participant in the "Old" role.
If you have enough money in your savings account, you can buy a share at one of the prices listed in the "Offers to sell" column, which contains all the offers to sell submitted by participants in the "Old" role. You buy a share by selecting one of the others' offers and then clicking on the red button "Buy".
If you click on the "Buy" button without selecting any offer, the program will automatically buy for you at the **cheapest (best)** price among the offers to sell currently posted by others. The best offer currently available is highlighted in deep blue.
Try buying a share now. Choose a price in the column "Offer to sell" and then click on the "Buy" button;
Whenever an offer is accepted, a transaction is executed. Immediately when you **accept** an offer to sell, you realize a purchase and the number of EURUX in your savings account goes down by the trading price; at the same time, your trading partner realizes a sale and the balance in his/her savings account increases by the trading price.

Old Role – Selling Shares

If you are "Old" you will only be entitled to sell shares. You will be able to do it in two ways.
First, you can **initiate a sale** of shares by **submitting** an **offer to sell.**
Try offering to sell a share now. Write a number (integer) in the text area labelled "Enter offer to sell" in the first column and then click on the button "Submit offer to sell". You can see that a set of numbers will appear in the column labelled "Offers to sell". Each number corresponds to an offer from one of the participants. Your own offers are shown in blue; others' offers are shown in black. The offers to sell are ranked from high to low. Each offer is to sell **one single** share. Note that by submitting an offer to sell, you initiate a sale, but the sale will not be executed until someone accepts it.
If you want to sell more shares, repeat this process.

Second, you can **realize a sale** of a share by **accepting** an **offer to buy.**
***Try selling a share now*.**
If you have shares in your account, you can sell them by selecting a price listed in the "Offers to buy" column, which contains all the offers to buy submitted by participants in the "Young" role. You sell a share by selecting one of the others' offers and then clicking on the red button "Sell".

If you click on the "Sell" button without selecting any offer, the program will automatically sell one share for you at the **highest (best)** price currently listed in the column of "Offers to buy", which is highlighted in deep blue.

A transaction is executed whenever an offer to buy is accepted. If you accept an offer to buy posted by others, you realize a sale and as a result, the amount of EURUX in your savings account increases by the trading price. In contrast, when your offer to buy is accepted by someone else, you realize a purchase and the number of EURUX in your savings account decreases by the trading price. The reverse happens to your trading partner.

One of the objectives when "Old" is to sell all the shares you previously purchased to the current "Young" participants. It can happen that the time period expires and you still have some units to sell.

If this happens, the program will automatically sell your remaining units to the "Young" participants for a lower price (later in the instructions we will explain how this price will be calculated).

c. Interest on Bank Account

The money (Eurux) that you have in your bank account earns interest. The interest rate you will receive is announced when you are "Young" and remains displayed on your trading screen. You will receive this money at the end of your lifecycle, when you are Old. The interest rate will be applied to the balance that you carry over to the next period at the end of your Young period.

Example: if you have 5000 eurux left in your account after buying shares as "Young and the current interest rate is 10%, your account will be credited with 500 eurux at the end of your "Old" period.

d. Report Screen

Once the trading market closes, after each period, you will see a screen summarizing your current situation.

The Young role screen contains the following information:


Period
1

Report

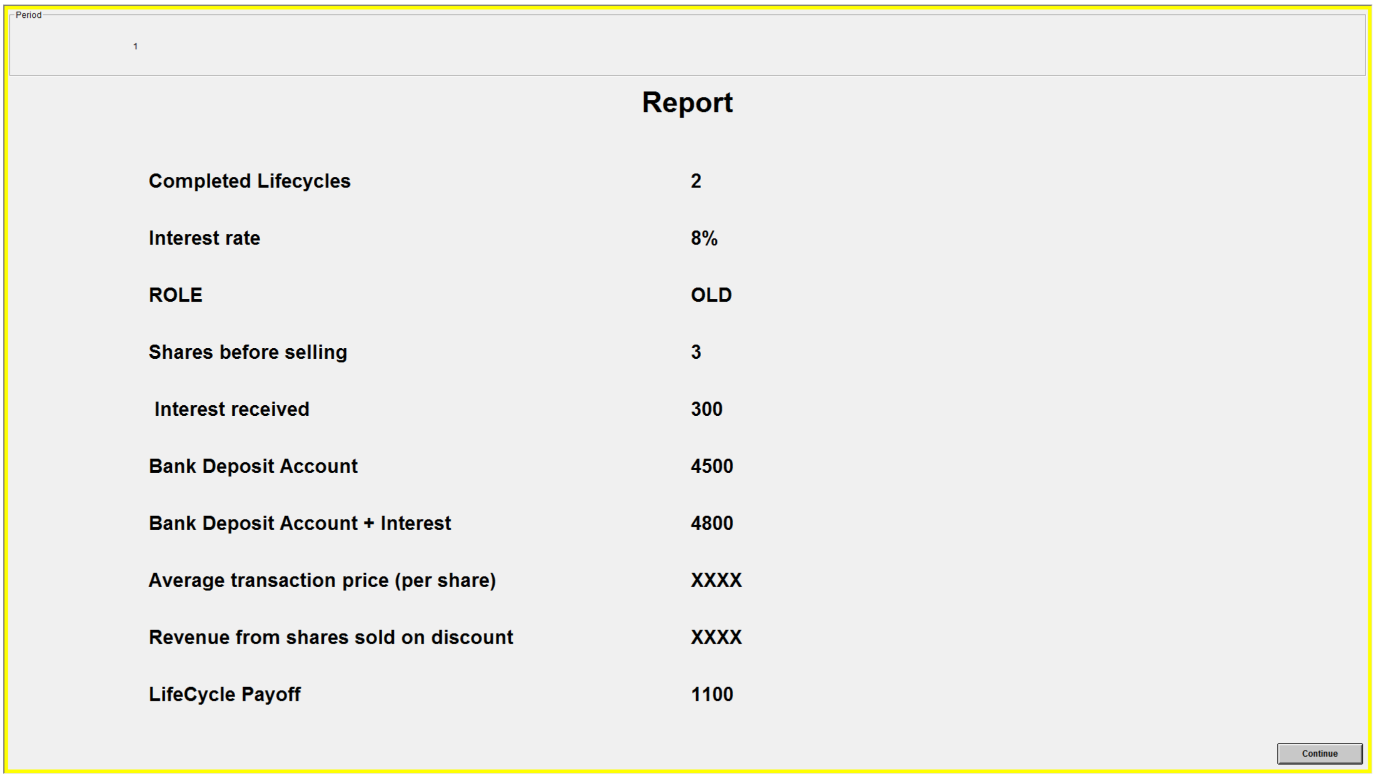
Current lifecycle	3
Interest rate	8%
Average transaction price (per share)	XXXX
ROLE	YOUNG
Number of shares purchased	2
Additional shares assigned	1
Total shares available to sell when OLD	3
Bank Deposit Account	3200

Continue

The Young role screen contains the following information:

- *Current Lifecycle*: The Lifecycle (i.e. a young period followed by an old one)
- *Interest rate*: The interest rate you will receive on the money you did not use to buy shares (i.e. Your Bank Deposit Account)
- *Average transaction price* (per share): The average transaction price resulting from all transactions.
- *Role*: Your Role in the period just finished
- *Number of shares purchased*: The number of units you purchased by trading with participants in the Old role
- *Additional shares assigned*: You might randomly receive some additional units. I will explain this later in the instructions.
- *Total shares available to sell*: The number of shares purchased plus the additional shares assigned
- *Bank deposit account*: The amount of Eurux you did not use to purchase shares and that will receive the announced interest.

The Old role screen contains the following information:



The Old role screen contains the following information:

- *Completed lifecycles*: the number of lifecycles that you played (i.e. a period you played as Young followed by a period you played as Old).
- *Interest Rate:* The interest rate you received on the money you did not use to buy shares when young.
- *Role*: Your role for the period just finished.
- *Shares before selling*: The number of shares you had (purchased when young) to sell at the beginning of your old period.
- *Interest received*: The quantity of money you receive as interest.
- *Bank Deposit account*: The total amount of Eurux you received by selling the shares + the money from the shares you sold on discount (I will explain this later in the instructions).
- *Bank Deposit account + interest*: Bank Deposit account + interest received.
- *Average transaction price* (per share): The average transaction price resulting from all transactions.
- *Revenues from shares sold on discount:* The amount of money you received from the shares you were not able to sell (see explanation below)

Important information for both roles

As a YOUNG participant one of your objectives is to purchase shares owned by the OLD participants in each period. Any shares not bought by YOUNG participants by the end of the period are sold to them automatically at a price equal to average trading price of the period times 1.5. Therefore, it is usually better to purchase units during the period than to be forced to do so afterwards.

As an OLD participant, one of your objectives is to sell shares to the YOUNG participants in each period. Any shares not sold by OLD participants by the end of the period are sold automatically to YOUNG participants at a price equal to average trading price of the period times 0.5. Therefore, it is usually better to sell units during the period than to be forced to do so afterwards.

e. Number of periods and composition of the market

You will be playing in several lifecycles, each one composed of two periods. A sequence of lifecycles forms a "market session". Each period, a "lottery" determines if the market session continues or comes to an end.
There is a 10 percent chance that any given period is the last one. Equivalently, there is a 90 percent chance that the current "market session" will continue beyond the present period.
An "experimental session" will usually involve several "market sessions." When a market session ends, a new one will start immediately with the same characteristics.

When a new market session ends, you will be randomly matched with different participants for the following session. Therefore you will typically playing with different people in each experimental session.

f. Lifecycle payoff and participant payment

The decisions you make in each of your lifecycles affect your earnings in this experiment.

Your lifecycle payoff is calculated as the total of (1) + (2), where

(1) Is the interest you receive in your bank account on the money you did not use to buy shares when Young.
(2) The price at which you have been able to sell the shares when you are Old that you purchased when you were Young. If you sell a share when you are Old at a higher price than you bought it for when you were young, you make a profit equal to the difference between the price you sold the share for and the price you paid for it. If you sell a share when you are Old at a lower price than you bought it for when you were young, you lose money equal to the difference between the price you sold the share for and the price you paid for it.

Therefore, when you are young and thinking about purchasing units and which price you should pay, you should consider the interest rate, which determines (1) and how you expect the price to change between the time you are young and old, which determines (2).

You will receive 5 Euro for participating in this experiment independently of your performance.
At the end of the experiment, **one lifecycle** will be **chosen randomly** and your total amount of Eurux will be transformed into Euro and paid out to you. The exchange rate is 150 Eurux for 1 Euro.

Instructions

You are taking part in an experiment involving financial forecasts. The instructions are simple and if you follow them carefully and make good decisions, you can earn some money, which will be paid to you after the experiment. The currency used in this experiment is called "eurux". If anything is unclear at any time, feel free to raise your hand and ask the experimenter any questions you may have. Please do not talk to other participants during the entire experiment.

During the experiment you will receive information regarding the price evolution of an asset across several periods.

You will participate in several independent sequences of periods. Each time that a sequence ends a new one starts. The length of the sequence may vary. The experiment will last a maximum of 90 minutes.

Information and forecast

For each period you have to insert your **best guess** about the price that the asset will have at the end of the current period.

Price sequences are the result of experimental asset markets played some months ago in the laboratory by real participants. Furthermore, you will receive information regarding the prevailing interest rate that participants were receiving on the money not used in the asset market.

Your objective is to forecast the evolution of the asset price across periods.

In order to make your guess, you have to pay attention **to three pieces** of information provided by the program:

1. The asset price of the past period. This is the last market price of the financial asset
2. The interest rate announced in the past period
3. The current interest rate for this period

With this information you have to insert your guess about the price that the asset will take at the end of the current period.

For example. Suppose you are in period 3 of the second sequence of periods. The program tells you that in period 2 the last realized price was of **200 Eurux**. Additionally it tells you that the interest rate for period 2 was **9%.** Finally, the program tells you that the current interest rate for period 3 is **6%.** You have to indicate the price you think the asset will take at the end of period 3.

Participant payment

After inserting your price prediction, the program will compute the distance between your prediction and the real market price at the end of the period.
Based on the following table, your earnings will be totaled up and communicated to you at the end of the experiment.

Level of accuracy	Earnings to individual submitting prediction
Within 5% of the real price	2.5€
Within 12.5% of the real price	1€
Within 25% of the real price	0.5€

Table 1B: Payment Schedule for the accuracy of predictions

Here is an example:

Suppose we are in period 4. You inserted a price of 300 Eurux as your prediction for the end of the current period. The price turns out to be equal to 350 Eurux.

Since your forecast was 16% above the real market price, for this period your earnings are equal to 0.5€.

The sum of your earnings per period will determine your total earnings in the experiment

Trial Periods

Before starting with the real experiment, we will practice for one sequence of 5 periods. This sequence will not count toward your earnings for the experiment.
During these trial periods, please raise your hand if you have any questions.
YOU ARE NOT ALLOW TO COMMUNICATE WITH ANY OTHER PARTICIPANT. The use of mobile phones is totally forbidden.