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Anchoring of expectations: The role of credible targets in a game experiment

Bodo Herzog [a*]

[a] Professor of Economics, ESB Business School, Reutlingen University, Germany.
*Corresponding author's email address: Bodo.Herzog@Reutlingen-Universtiy.de

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ABSTRACT

This paper provides new evidence on the formation and anchoring of inflation expectations. I conduct a game experiment and analyze the adjustment as well as the impact of credible targets on expectations. In addition, I evaluate the idiosyncratic determinants on the formation of expectations. The analysis reveals six results: First, I find evidence that long-term inflation expectations are firmly anchored to a credible target. Second, a temporary deviation due to unexpected monetary policy might trigger a decline in credibility, and third a de-anchoring of expectations due to uncertainty. Fourth, I find that people change their expectations little if a credible target exists. Fifth, expectations exhibit a large degree of time-variance only in environments without a target. Sixth, the dynamic adjustment to an 'incomplete' equilibrium, which is theoretically unstable, is nevertheless rapid and persistent in case of credible targets. All in all, I demonstrate a unique game setup with contributions to both experimental and monetary economics.

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1.0 Introduction

Central bankers and academics emphasize the importance of low and stable inflation rates. It is needless to say that the European Central Bank's (ECB) primary objective is to maintain price stability according to the article 127(1) Treaty of the Functioning of the European Union (TFEU). Interestingly the TFEU does not provide an explicit definition of price stability, however, the ECB operationalizes this statement by "*A Harmonized Index of Consumer Prices for the euro area below, but close to 2% over the medium term.*" With regards to maintaining the price stability at 2 per cent, academic literature points out the requirement of both a credible target and firmly anchored expectations. In other words, central banks have to anchor the expected inflation rate at the official inflation target. However this requires independence and, even more importantly, credibility of monetary policy.

In this paper, I provide new empirical evidence on the formation and determinants of inflation expectations as well as the importance of target credibility. I conduct an experimental study and utilize a modified 'beauty contest game' to analyze the anchoring of expectations as well as the impact of credibility. I undertake this game experiment with 207 randomly selected students, staff members, and professionals from 2011 to 2012. This study is unique because it establishes a new empirical measurement approach for inflation expectations. Furthermore it is based on a novel game design that allows the analysis of the expectation process with unprecedented modifications. The results are of importance for monetary policy especially for central banks in particular in times of uncertainty.

The main findings are as follows: First, I have evidence that long-term inflation expectations remain well anchored to the definition of price-stability of below, but close to 2.0 per cent in the sample. Second, increasing uncertainty due to the euro area crisis, however, might trigger likely changes in inflation expectations. Even though only a few increases are found in short-run game expectations in general, the change of expectations is considerable if a higher level of uncertainty is introduced to the game setup. People lacking economic knowledge are at first exposed to inflation de-anchoring effects. Third, I find a measurable decline of target credibility that cannot be recognized in official surveys on inflation expectations during that time period. This finding is called an 'erosion of credibility below the surface'. It demonstrates the potential danger of highly accommodative monetary policy. The erosion of credibility may continue, and gets even more severe, provided that uncertainty increases due to interest rates at the zero lower bound, for instance. Given this ambiguous environment, I find in the experiment that increasing uncertainty (created via hidden cheating in the game) impairs credibility and finally de-anchors the inflation expectations. Fourth, people change their views and expectations only a little if the target is credible. Moreover there is evidence that non-economic participants on average expect higher inflation rates and they are less concerned about the impact of asset purchasing programs or balance sheet extensions. Fifth, expectations exhibit a larger degree of time-variance in case of an arrangement without a target. Sixth, it turns out that the convergence process towards the 'incomplete' target-equilibrium is incredibly fast, if there exists a credible (inflation) objective. Finally, there is evidence that a higher level of education produces both, lower levels and volatility in inflation expectations. All in all, my paper is the first which utilizes experimental game theory for research in monetary economics. I show new insights on the formation and convergence of expectations in an environment with and without credible (inflation) targets.

The remainder of the paper is structured as follows: Section 2 presents a literature review. In section 3, I describe the setup of the experimental game. The discussion of the results is devoted to section 4. Finally, Section 5 concludes the paper.

2.0 Literature review

In modern macroeconomics, particularly in monetary theory, rational expectations play an essential role. The idea of rational expectations imply that shocks or new information do not change the expectations at all, because current expectations contain all the past and future information. Thus agents' predictions are not biased or systematically wrong. In theory, economists use this assumption to determine the optimal inflation rate while central banks minimize their loss function. However, a couple of years ago, a debate has emerged regarding the proper modeling and understanding of (inflation) expectations in macroeconomics (Woodford, 2005; Sims, 2009). Among other problems, I see a proper modeling of expectations as the biggest challenge in today's sciences of economics.

There is already rich literature available with regards to inflation expectations. Orphanides and Williams (2005) develop a model in which inflation expectations are sensitive to economic shocks. Consequently, the current financial turmoil has the potential to alter inflation perceptions. In this line, there are also microfounded approaches (Brazier et al., 2008; Sims, 2009). They demonstrate, by utilizing an optimization problem, that agents are constrained in their ability to process news. Thus agents receive noisy signals of economic shocks that bias expectations in the end. Brazier et al., (2008) build a model on the formation of inflation expectations based on two heuristics: the lagged and targeted inflation rate. They find that agents switch between both regimes in the assessment of price stability. Similarly there are papers by Gul and Pesendorfer (2005) or Cargill and Parker (2004) that follow a behavioral economic approach. Both argue that a bias or overconfidence leads to temporary changes in expectations. This phenomenon was econometrically observed during the currency conversion in the euro area in 1999 (Schwarze et al., 2010).

The model by Demertzis et al. (2009) is close to the idea of my paper. According to that paper, individuals form their expectations based on all the available information which is noisy. Agents know that expectations depend on monetary policy and on the expectations of all the other agents. The relative weight assigned to these two factors is finally determined within the model. My game experiment enables me to experimentally study the formation process of expectations particularly in relation to the expectations of other agents and exogenous factors. The experimental game setup is a modified 'beauty contest game'. Overall I embed this unique game experiment to the literature of monetary policy.

A seminal paper by Nagel (1995) established an empirical literature on the implications of game theory with the usage of the 'beauty contest game'. She shows that the experimental results significantly deviate from the game-theoretic reasoning. The equilibrium process is rather iterative than an elimination of dominant strategies. The reasoning process follows finite and not infinite steps as supposed in the theory. She simply shows that ordinary people have either first or second-order beliefs. Nevertheless, over time, the numbers converge to the Nash equilibrium, which is due to learning-rules (Heinemann et al., 2009). These so-called guessing games have been a fruitful source to assess boundaries of human rationality (Heinemann et al., 2009; Nagel & Grosskopf, 1998). Given the results of such experiments, Camerer (2003) points out that human subjects play 'as if' they were considering no more than a few iterated steps of reasoning. I show that these games may also provide useful insights in the understanding of (inflation) expectations in monetary economics. Thus my paper brings forward a valuable approach in experimental economics to macroeconomics, and especially in monetary economics. In other words, I study how people build expectations subject to the expectations of others and exogenous factors. In particular, I elucidate the impact of target credibility on (inflation) expectations, which is vital in the literature of central banking.

To my knowledge, this is the first paper that applies an experimental approach to inflation expectations despite distinct complementarities in monetary economic literature. In addition, my approach significantly differentiates from the existing literature. The existing approaches are either based on surveys or on measures from financial markets. Until today, surveys have been the only direct measurement method of inflation expectations commonly used by central banks (ECB, 2006). On the contrary, my approach gathers information based on an experimental setup. The experimental setup has the advantage of mitigating the existing deficiencies of survey research. First, surveys are cross-sections with low frequencies, and are only suitable to analyze long-term properties. Second, surveys heavily rely on the willingness of the respondents to tell the truth. Third, the wording and understanding of the questions are sensitive to the result and people may perceive inflation quite differently (Mankiw & Reis, 2003). Due to these shortcomings, central banks started to analyze break-even inflation rates in financial markets (Swanson et al. 2007). The advantage of this measurement method is the higher frequency, especially during crises (Galati et al. 2011). But there are similar faults. The computation of expected inflation based on financial products require strong assumptions, such as the decomposition of the expected inflation rate, risk premium, liquidity premium, and other technical factors (Hoerdahl & Tristani, 2012).

Nonetheless both measurement approaches reveal stylized facts. Mankiw & Reis, (2003) find evidence that experts' opinions spread slowly from person-to-person, which leads to low variability of inflation expectations (Carroll, 2003; Capistran & Timmermann, 2009). Furthermore a study by Clark and Davig (2008) analyze the key determinants of inflation expectations and find a significant reliance on macroeconomic variables. Forsells and Kenny (2008) find the same for the euro area, and Levin et al. (2004) illustrate that expectations are highly correlated with the three-year moving average of the lagged inflation. They argue in line with Clark and Nakata (2008) that this is due to the so-called period of 'great moderation'. Consequently the existing literature confirms that firmly anchored inflation expectations do not respond to shocks or temporary crises. However, there is a doubt that these findings are biased due to the period of the 'great moderation'. Thus, my experimental study sheds light to this concern, and studies inflation expectations in times of crises and high uncertainty. Whether the 'old' stylized facts remain valid in a period of uncertainty is an up-to-date challenge.

3.0 Experimental design and rationale

The main source of my analysis on the formation and persistence of inflation expectations are gathered experimental game data, created via modifications of the beauty contest game. I carried out the experiments in the period of March 2011 to March 2012. The approach has the following unique features compared to the existing methods of measuring inflation expectations: First, the experiment allows studying of the formation and anchoring process of expectations in a dynamic setup (round I to round III). In addition, the idiosyncratic data of the questionnaire enables me to evaluate the determinants during the formation process. Second, the experimental design provides insight to the importance and role of credible inflation targets, which is unique to my knowledge. Third, I test the so-called group size effect that proposes greater strategic decision-making in larger groups. Fourth, I test and confirm the 'quarter law' of the so-called attraction factor in a quantum model of decision-making. Finally, I control the trustworthiness of the participants' expectations using pecuniary incentives. Overall the experiment evaluates the formation of expectations and demonstrates both the role and dynamics of credibility. Both issues are of importance for stable (inflation) expectations. But whose discovery via standard inflation surveys has been impossible up until today.

The benchmark game is designed as a beauty contest game in literature (Kocher & Sutter, 2005). On the one hand, this guarantees that each participant considers the best response in terms of (inflation) expectations (winning number) in comparison to the expectations of all the other people. On the other hand, I modify the game in a rather tricky manner by introducing a predefined target of 2.0, which serves as a credible (inflation) anchor. This should fasten the convergence towards the target value during the round I, but would likely slow down the adjustment to the Nash equilibrium at zero. At best, the predefined anchor attracts the majority of expectations around the target value at all times. I call such a situation an 'incomplete' subgame perfect Nash equilibrium (Gueth et al., 2002). The reasoning is as follows: the target level is neither a subgame perfect equilibrium nor a Nash equilibrium. It is incomplete because it is inherently unstable. This peculiar 'quasi' equilibrium rests in the fact that people are attracted to credible targets. Thus the result is a persistent but temporarily deviates from the Nash equilibrium. Without a target, I expect a gradual convergence towards the Nash equilibrium at zero in the subsequent rounds. Finally, I introduce a smart re-design of the previous game experiment. Here I test the convergence speed of expectations and the role of credibility towards the target. This is conducted within a new game environment, which I call a 'cheating game'. This is a novel idea even in experimental economics. It is explained in detail in the following paragraphs.

The game experiment is conducted involving 207 participants and then split into two subsamples. The first subsample contains N = 95 individuals. This group plays the benchmark 'beauty contest game' with a credible target as explained above. The second subsample has N = 112 members. This subsample plays the modified benchmark game. I label it as a cheating game in respect of the supposedly credible target. Each game experiment is played in three different sequential sessions and lasts about 90 minutes. Whether to play the benchmark or cheating game is randomly assigned to the groups. Consequently the results are not biased nor affected by learning effects because of game sequence. Each game session consists of at least three rounds and each round lasts about 10 minutes. In addition, at the start and at the end of every round, each participant has to answer a questionnaire. Here, I ask for comments on the game decision as well as the assessment of the target credibility in the respective game round. In addition, I ask for further socio-economic variables in the questionnaire, such as age, gender, years of education, economic background, work experience, and grades in school. In order to motivate participants to respond accurately and act as realistic as possible, I introduce pecuniary incentives – as usually done in experimental economics – offering money or other valuable gifts. The promised reward is assigned to the winner (defined by the best responses) during the overall experimental game.

In each game session, approximately 10 to 25 players seat far away from each other in a classroom so that communication is not possible. At the beginning the instructor announces the common information and explains the rules of the game. In addition, I provide a written statement with the rules. Then the group plays three rounds of game session number one. After that they play game sessions two and three, each of which consists of three rounds. Session two and three are based on new information but without the knowledge of whether it is the standard or cheating game. The players are identified with anonymous numbers. After each round, they write their estimate of the expected inflation rate (or inflation guess) on response cards. I request that individuals choose their own inflation expectations based on their judgment about the current central bank policy, the state of the economy, and other people's expectations in the game experiment. Thus each participant has to solve the trade-off of choosing a number based on his or her assessment in the game environment. Moreover the participants have to give a written explanation or comment in the questionnaire. Thereafter the response cards and questionnaires are collected and the computation of the mean is carried out. Then the game result, which is defined as mean value times a given parameter, is written on the blackboard. The expectation closest to this number wins the round. At the end, the winner (best choices in all rounds) gets the 1st prize. All other players receive a consolation gift.

In general, the reasoning of the beauty contest game, the benchmark setup, is straight forward. All participants simultaneously choose a number within the closed interval [0, 10]. It is possible to choose a number with one decimal place; for instance 4.2. The winner is the person whose number is closest to the mean of all the chosen numbers multiplied by the parameter p, where p is a predetermined positive number. In other words, p is common knowledge and always announced before playing the game. For $0 < p < 1$, a unique Nash equilibrium exists at which all players choose zero (Nagel, 1995).[1] In this case, game theory predicts an unambiguous outcome. But in reality, this happens slowly by iteration due to lower-order belief of ordinary people. In the first round, a player has no information about the behavior of the other players. Hereby each player has to form expectations about the choices of other players based on either objective evidence or subjective criteria. After the round one, all members reveal more but noisy information. The new information, however, is rather fuzzy due to the anonymity about the actual behavior of the group members.

Next, as mentioned above, I make two modifications on the standard 'beauty contest game'. The ultimate goal of the modifications is the creation of further fuzziness and uncertainty. As a consequence, the modified game setup disturbs people's formation process of expectations. The two modifications are as follows: (A) either credible or incredible inflation targets within the benchmark game, or (B) a cheating game. A cheating game irritates or fools people's reasoning process significantly due to the announcement of wrong mean numbers after each round. Both modifications allow me to elucidate the following issues: how players form belief; the role of credible and incredible targets; and how credibility affects the formation and persistence of expectations.

[1] In general, for p = 1 and more than two players, it is a coordination game and there are infinitely many equilibrium constellations in which all players must choose the same numbers (Ochs, 1995).

In the end, I identify whether players incorporate mental processes of the others, and study the role of credible targets in their (conscious) reasoning. The rationale behind the modified beauty contest game is as follows: First, I use the property of the credible inflation target of 2.0 (enforced by a central bank) and ask the participants what they would choose and what their inflation expectation would be in this game context. Consequently all participants face a trade-off of choosing between the credible target of 2.0 times the *p* parameter, i.e. 2*p, or winning the game by reasoning with higher-order belief ($2*p^2$ or $2*p^3$...), i.e. still choosing the Nash equilibrium at zero. A credible anchoring and/or persistence of expectations can be confirmed, if an outcome of about *2*p* results in the first and subsequent rounds in average. However, if I find a convergence to zero, similar to the benchmark setup, I would reject the hypothesis of a firm inflation anchor. This would imply that winning the game predominates, and thus the inflation target is incredible or the game incentives are too weak. Consequently I have to check the level of game incentives by playing the cheating game.

Suppose the game instructor always announces a wrong mean after each round, which is different to the 'true mean' played by the participants. Obviously this cheating induces an artificial incentive to play (equilibrium) numbers close to the target, even if the real numbers of the group members are far away. Thus there are two questions of interest: a) whether people would detect this cheating, and b) how long people would stick to the wrong numbers.

For instance, if people stick to the (inflation) target of 2.0 but, by doing so, persistently deviate from the winning cheating game target, I can explain this (sticky) behavior as an 'erosion of credibility below the surface'. Therefore, with this innovative modification, I disentangle the agent's motive and its impact on the formation process of expectations. This setup is a 'cheating game' because the game-instructor is systematically fooling the participants. Consequently the players have to deal with a threefold trade-off: a winning number close to the 'wrongly' announced equilibrium or following the 'incomplete' target equilibrium of 2.0 or playing the Nash equilibrium at zero.

It is noteworthy that the modification with a 'cheating game' is even more far-reaching in terms of the analysis of the persistence of expectations. The systematic agitation of the participants away from the 'true' target allows unique measurement of the persistence of inflation expectations over time. I expect a higher variance of results in the cheating game due to the higher level of uncertainty and fuzziness about expectation errors. The instructor communicates the results always with the statement that it is computed by him in full independence and under full transparency, such as by an independent agency or central bank. In other words, the instructor should be seen unbiased and independent. Without knowing that the instructor cheats, the participants have to form their expectations based on the announced numbers. Again this unique setup allows testing the idea of credibility and persistence of expectations over time. Overall both game modifications provide valuable insights about the formation process of (inflation) expectations.

In all samples, I set p = 0.5 in order to force people to solve the respective trade-off. Theoretically, with credible targets, I expect that the individuals rapidly converge to the equilibrium number of 1.0, which is in-line with the target of 2.0 (times the p-parameter of 0.5). Moreover I expect certain persistence around the target because this is a kind of focal point or behavioral anchor at least in the first round. Given people play truthfully, the game should illustrate a fast and persistent convergence towards 1.0 in the target game. Of course, credibility of the target is a prerequisite for both the convergence and persistence at 1.0. This issue remains to be studied in more detail in the cheating game setup. The cheating game forces the agents unambiguously away from the equilibrium or target of either zero or 1.0.

4.0 Results and discussion

I organize the findings as follows: First, I start with an overview of the average numbers and explain the bottom-line of the results. Thereafter I evaluate the specific features of every round: for instance, the adjustment speed from round to round, the credibility values in case of the cheating game, the adjustment speed of credibility, and the self-assessment of current and past inflation rates. In the second subsection, I study the econometric findings in regard to the idiosyncratic and socio-economic variables in relation to the revealed 'real' and 'experimental' (inflation) expectations. The final subsection is devoted to an empirical test of the quarter law assumed in a quantum model of decision-making (Herzog, 2015).

4.01 Results of the game experiment

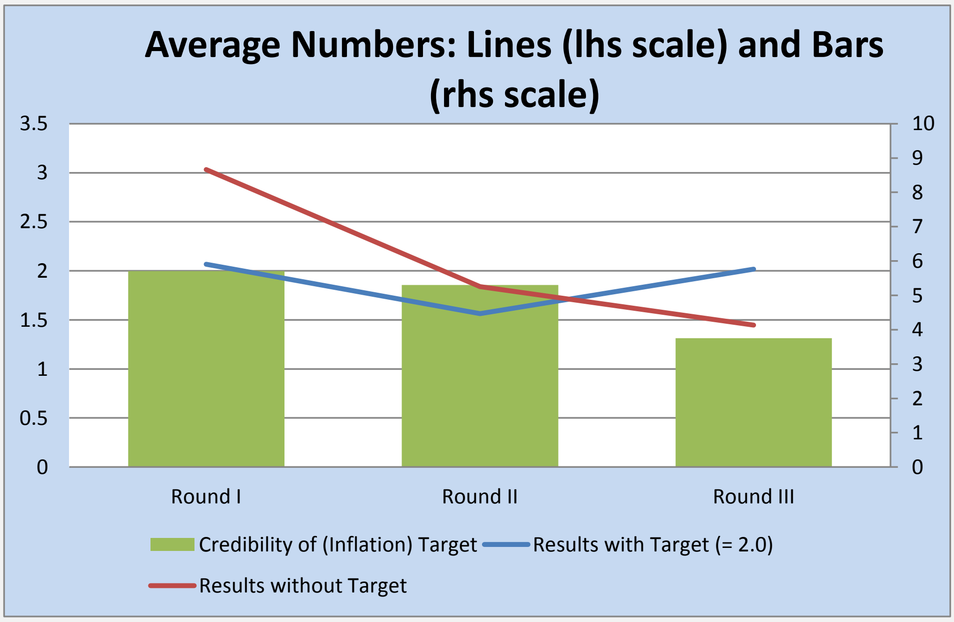
Figure (1) summarizes the main findings of the experimental game regarding the formation of expectations and the role of target credibility. The Figure depicts the inflation expectations from round I to round III. The red line reflects the average inflation guessed by all the participants in the game without an inflation target. In the first round, the value is close to 3.0, followed by a continuous decline to 1.4 in round III. The winning number in round III is close to 0.7, i.e. 1.4 times p = 0.5. Overall my experimental finding is in line with the literature of beauty contest games. There is a gradual convergence towards the Nash equilibrium at zero.

The solid blue line depicts the mean guesses of participants, however, in a game with an explicit and credible target of 2.0. Firstly and strikingly, there is a fast convergence towards 2.0 already in the first round. The average in round I equals 2.1. This demonstrates that participants expect the others' expectations to be close to the credible target. Thus a target stabilizes and anchors the expectations at the target level, even if the winning game number is lower. In the next two rounds, the average numbers remain almost constant. In round II, the average is 1.6 and surprisingly rebound to 2.0 in round III. Consequently the game results of round I and round III are significant at 1 per cent and they do not show any statistical difference to the target value of 2.0.

This confirms the hypothesis that a credible (inflation) target attracts people at least in the first place. Moreover it confirms a fast and almost persistent convergence around the target level over time. This is partly surprising based on the standard utility theory because the majority of people who choose a number at the credible target will definitely lose the game and thereby achieve lower economic utility. However the new idea of a quantum model of decision-making provides a reasonable explanation to this behavior: people are more attracted to the credible target, and thus the so-called attraction factor outweighs the utility factor (Herzog, 2015). People choose the target level despite losing utility in the game; overall they are better off.

It is remarkable that this pattern is almost always observable in all game experiments. The persistent deviation from the winning Nash equilibrium cannot be explained by the standard utility theory. Of course, the majorities of people have lower-order belief and they are more attracted to credible targets. There are only a few selfish agents who (always) choose to deviate in order to win the game.

Figure 01: Average expectation and average credibility per round



The bars in Figure (1) depict the main result of the cheating game; it reflects the participants' judgment of target credibility. The numbers range between ten, for very high credibility, and zero, for no credibility at all. Despite cheating in round I, most people trust the computed mean value. The average trust value is 5.4 out of 10 in round I (right-hand scale). The credibility remains almost constant in round II. There is only a small decline to 4.9 out of 10. However, surprisingly to me, this target credibility significantly erodes in round III. The credibility drops to 3.3 out of 10. This change is even significant at 1 per cent. It can be said that people are concerned about the target if they experience a mysterious disturbance after two subsequent rounds. The majority of agents still choose (inflation) expectations close to 2.0 in round III, even though they lost confidence in the target. This illustrates an ongoing erosion of credibility below the surface. Consequently, this erosion process starts long before the occurrence of any measurable change in (inflation) expectations.

I believe this finding shows how sensible inflation expectations are and how carefully central banks should monitor any change. I find that the erosion of credibility results in a partial de-anchoring of expectations. The standard deviation of the responses in round III is also significantly higher than in round I and II. Apart from the standard deviation of expectations, the standard deviation of credibility is continuously increasing (Table 1). Both effects are neither measured nor detected in any standard inflation survey methodology.

In addition, I find evidence that expectations, especially after a reassessment in the cheating game, spread slowly to those of other people, and display a low variability at the beginning. Both issues can be seen in Table (1). First the standard deviations in round I and II are 1.23 and 1.54 respectively, which are significantly lower than the one in the standard game, i.e. 5 per cent. The high kurtosis in the target game demonstrates the slow spread of expectations from people to people. These findings are similar to Swanson et al. (2007), Carroll, (2003) or Capistran & Timmermann, 2009. However, in contrast to literature, the variability significantly increases as soon as the erosion below the surface starts in the cheating game setup. In round III in particular, the standard deviation is 2.56, well above 1.83 in the benchmark game. These findings demonstrate that unanticipated events, shocks, or highly accommodative monetary policy may early increase uncertainty and create adverse undetected effects on expectations and the overall economy.

Even more astonishing is the fact that the majority of 207 participants expect 'real' inflation well above 2.0. In fact, my survey data reveal that the majority of people assesses – independently from the game – inflation expectation at 3.3 in five years with a standard deviation of 1.5. This is anecdotal evidence that people reveal rather short- to medium-run inflation expectations within the game setup; this was also noted by comments in the questionnaire. Nonetheless this observation strengthens the findings in the cheating game, because it makes the observed erosion below the surface even more dangerous in the long-run. Consequently my experimental game reveals vital short-run preferences. Of course, this result is in contrast to central bank surveys at that time (Galati & Poelhekke, 2011). Most surveys find firmly anchored expected inflation rates. My study, however, reveals the hidden effects in times of uncertainty which is undetected by standard surveys in central banking today.

Next, I proceed with a comparative look at the experimental results (Table 1). I distinguish between the two subsamples – with and without inflation targets. The 'real' inflation expectations of the members in both subsamples are almost the same. The average past and expected inflation rates are 2.1 and 2.9 respectively – and the same in both subsamples. The estimate of current inflation is, on average, 2.5 (and 2.4) and thus again significantly closes in both subsamples. The preferred inflation target of all the participants in the sample is close to 2.0. The cheating game demonstrates that a systematic cheating more likely impairs the credibility of the inflation anchor than the level of inflation expectations (Table 1 and Figure 1). Although I find a destabilization, measured by the loss of target credibility in round III, this finding does not imply a rapid de-anchoring of 'real' expectations. As already discussed, game expectations are rather short-run, and thus differ to 'real' inflation expectations.

Figure (2) illustrates the convergence process of expectations in both subsamples. The top (bottom) panel of Figure (2) depicts the convergence process without (with) a target. Furthermore the graphs on the left-hand side display the convergence process from round I to round II; and on the right-hand side from round II to round III respectively. Strikingly the bottom figure depicts fast convergence to the 'quasi' equilibrium. This process is faster than the convergence to the Nash equilibrium at zero in the top panel. The reason for this quick convergence is probably based on the explicit announcement of the credible target. Consequently participants immediately use the target as an anchor in round I. Of course, the anchoring effect only works if the majority believes that the target is credible. Henceforth, if almost everybody reasons in the same way and anticipates the target to be credible, the so-called anchoring effect appears. This anchoring effect is well-known in behavioral economics.

Furthermore, in case of a credible target, I find a cluster of expectations around the target level times the p parameter even in round III. There is no bijective convergence towards zero – the Nash equilibrium in the game setup. Generally this demonstrates the effectiveness of a credible target. However fooling the people and thereby losing credibility, as I show in the cheating game, suspends the effectiveness of a credible target with some time delay. Therefore it can be said that it is just a matter of time until the de-anchoring of expectations gets out of hand. Despite the explanation that a target gives an orientation in round I, I am surprised to see the effectiveness and persistence in all subsequent rounds. The anchoring at the target level seems to serve as a dominant strategy. A second objective of this experimental study is to enhance the understanding of the formation process of expectations. Therefore I compare my findings to real-world expectations by asking all the participants about their economic knowledge, the understanding of the ECB, and so on. I find evidence that most people in the sample know the current inflation target and define the target between 1.5 and 2.0. Nonetheless, there is a substantial number of participants (65 out of 207) who believe that the inflation target is between 0.0 and 1.0. The latter belief is prevalent under participants without economic knowledge. In contrast, participants with some economic background are more familiar with the inflation target and the functioning of central banks. However an unexpected result appears if you ask the participants what inflation target they would prefer. An overwhelming majority prefers a target of 2.0. This is astonishing because it is inconsistent with at least 65 peoples' responses who define the inflation target between 0.0 and 1.0.

Figure 02: Convergence Process of Expectations from Round to Round

The results above can be even strengthened by calculating the adjustment speed in both samples from round I to round III. I find that participants in the game without a target have – in terms of adjustment speed – high numbers. In case of a credible target, the adjustment is almost zero in all categories. This finding implies that people immediately use the credible target as an anchor in round I and thereafter stick to it in all subsequent rounds. Consequently there is nearly no shift or reassessment of the initial expectations. Again this confirms the anchoring and persistence of expectations in case of credible targets.

Finally I focus on the credibility issue in more detail. The right-hand panel in Table (1) shows the subjective assessment of credibility. The majority of the test persons judge the credibility at a mean of 5.4 in round I. The credibility assessment in round II is of 4.9. In round III, subjects start doubting the credibility and either suspect it to be incorrectly informed or become indifferent to the target. Consequently the average credibility drop to 3.3, which is significantly different from round I at 1 per cent. The standard deviation increases from 2.5 in round I and II to 2.8 in round III. I already labeled this case the erosion below the surface.

Table 01: Summary of Results

Game Design	Intervals	Expectations(choices)[a)]			Target Credibility Assessment		
		Round I	Round II	Round III	Round I	Round II	Round III
With	0.0-0.5	4	15	2	2	1	11
target	0.5-1.0	19	35	46	4	4	17
N=12	1.0-1.5	18	24	32	0	0	0
(Cheating)	1.5-2.0	32	22	16	6	5	12
	2.0-2.5	15	7	2	0	0	0
	2.5-3.0	7	3	2	9	11	16
	3.0-3.5	4	0	1	1	0	0
	3.5-4.0	7	2	1	13	7	4

	4.0-4.5	3	0	0	0	0	0
	4.5-5.0	0	0	0	8	12	15
	5.0-5.5	0	0	0	0	0	0
	5.5-6.0	0	0	0	0	0	0
	6.0-6.5	0	0	0	0	0	0
	6.5-7.0	0	0	0	17	7	7
	7.0-7.5	0	0	0	0	0	0
	7.5-8.0	1	1	0	17	9	5
	8.0-8.5	0	0	0	0	0	0
	8.5-9.0	0	0	0	4	2	0
	9.0-9.5	0	0	0	0	0	0
	9.5-10.0	0	2	10	7	6	6
Weigh Average		1.87***	1.46	1.94***	5.44	4.98	3.35
Median		3.88	2.88	2.13	4.00	3.88	4.12
Std. Dev.b)		1.23	1.54	2.56	2.56	2.57	2.80
Kurtosis		6.82	6.80	12.76	0.93	-1.03	0.20
N		110	111	112	88	64	93
Without	0.0-0.5	2	12	26			
target	0.5-1.0	3	24	26			
N=12	1.0-1.5	6	22	16			
	1.5-2.0	16	13	10			
	2.0-2.5	12	4	5			
	2.5-3.0	21	9	6			
	3.0-3.5	10	1	0			
	3.5-4.0	7	0	1			
	4.0-4.5	5	3	0			
	4.5-5.0	4	0	0			
	5.0-5.5	1	2	0			
	5.5-6.0	0	0	0			
	6.0-6.5	0	0	0			
	6.5-7.0	2	1	0			
	7.0-7.5	1	0	0			
	7.5-8.0	1	0	1			
	8.0-8.5	0	0	0			
	8.5-9.0	0	0	1			
	9.0-9.5	0	0	0			
	9.5-10.0	1	3	2			
Weigh Average		2.88	1.78***	1.39			
Median		3.88	3.13	3.00			
Std. Dev.b)		1.63	1.90	1.83			
Kurtosis		2.94	3.99	5.33			
N		92	94	94			

a) Numbers represent the number of responses in the respective intervals, b) Standard deviation is calculated on the basis of the respective game expectations.
Source: own.

T-test with Ho=2.0 vs. H1, Reading. ***=significant at 1%, **=significant at 5%, *=significant at 10%,

4.03 Evaluation of socio-economic data: Econometric study

The analysis of socio-economic data reveals the determinants of the formation process of expectations. The regression equation contains the following socio-economic variables: age, skill, grade, year of education, year of professional experience, credibility assessment in each round, and current and past individual's inflation expectations. In addition, I control gender, academic major, and some other features.

First, let me discuss the regression results of round I. Not surprisingly the regressions in round II and round III are insignificant. At the first view, this looks astonishing, but the game setting convincingly explains this issue. People have to form expectations independently only in round I. Thus, in round I, they utilize all idiosyncratic and socio-economic experience. The personal characteristics indeed affect the judgment in the first round. On the contrary, in round II and round III, people already obtain (game) information about the average numbers from the previous rounds and group members. Of course, that information is valuable, and influences the judgment of the people in the subsequent rounds. Accordingly the individual characteristics, such as grades or years of education, matter less in subsequent rounds. Moreover this finding proves the fact that people follow a learningrule (Heinemann et al., 2009). In summary, this explains the robustness and significance of the regression model in round I (Table 2).

In addition, it turns out that the 'real' expected inflation rate in five years is significant and positively related to the game expectations in round I. Therefore individuals with higher 'real-world' expectations choose higher numbers in the beauty contest game. This finding demonstrates that people use their 'real' expectations as an anchor in round I – if there is no other anchor available. However, as supposed by the game theories, the smarter the participant, the faster their convergence towards the equilibrium, and thus they tend to choose lower numbers. This is reflected in the positive sign of the 'School-grades' variable of 1.207. This variable is significant even at 1 per cent. Interestingly work experience is not significant. This result may be explained by the fact that the sample is dominated by students and other academics with low or no professional experience. It turns out that, in a subsample excluding students, the variable is almost significant at 10 per cent. Conversely age and past inflation are significant at 10 per cent. Both variables are negatively related to the expectations, i.e. the older the person and the higher the perceived past inflation, the lower the numbers they choose in round I. This is expected because older people are more exposed to inflation risks. Therefore they are usually more risk averse. Finally I find that women select lower numbers (expectation levels) than men. This might indicate that women are smarter or more risk-averse. The answer to this question is left to further research.

Table 02: Regression models

	Model 1 Dep. Round I	Model 2 Dep. Real exp. Inflation
Constant	2.968	7.618***
	(1.97)	(1.76)
Real expected	0.736***	
Inflation	(0.09)	
Gender	-1.194*	
	(0.40)	
School Gate	1.207***	
	(0.34)	
Work	0.015	
Experience	(0.01)	
Age	-0.142*	-0.108
	(0.07)	(0.05)
Past	-0.334*	-0.306
Inflation	(0.17)	(0.24)
Credibility	-0.345***	-0.385***
Assessment	(0.09)	(0.09)
Target Change		0.556*
		(0.32)
R squared	0.693	0.477
Adj. R squared	0.645	0.377
F- statistic	14.67	4.792
Prob. (F- statistic)	0.000	0.006
N	207	207

Std. error in parenthesis. And notion: *p<0.05, **p<0.01, ***p<0.001.

Furthermore I estimate the determinants of 'real' expected inflation in five years as a dependent variable (second column). As expected, I find that the older the people and the higher the perceived inflation, the lower the (preferred) expectations. This finding is in line with literature by Clark and Davig (2008), who find that the determinants of inflation expectations are macroeconomic variables and past inflation. Moreover Levin et al. (2004) illustrate that expectations are correlated with a moving average of the lagged inflation rate. However I cannot find evidence for the hypothesis that work experience and education stabilize expectations. Work-experience is always insignificant and therefore excluded from the model. This exclusion has no effect on the signs or significance of the other variables. The variable 'Credibility Assessment' reflects the participants' assessment of the credibility of the inflation target. I find that a high target credibility by the game participants imply lower inflation expectations. Of course, this relationship is as expected. In addition, it is in-line with my game result above. In the end, this finding echoes the erosion of credibility below the surface. In summary, the regression highlights the importance of target credibility for the anchoring of (inflation) expectations. Therefore it can be said that a firm anchoring of expectations is tough without target credibility. In the short-run, I need the credibility for a fast and persistent convergence. In the long-run, credibility is crucial to keep the expectations close to the target despite random disturbances or temporary policy deviations.

Next, I distinguish between the response of people with and without economic knowledge. I have participants in the sample among other scientific backgrounds, such as chemistry, engineering, design, art, and computer science. Overall, I find a decline in target credibility among people in this group. This might be triggered by the lack of economic knowledge combined with the uncertainty linked to the ongoing European sovereign debt crisis. The last point was noted by several people. Non-economic students are more concerned about the overall development of the economy, and less on the details of new monetary programs. This corresponds to findings in other scientific studies that confirm the importance of overall macroeconomic variables for inflation expectations (Clark & Davig, 2008). In my sample, people with non-economic majors reveal both higher 'real' and 'experimental' expectations than people with economic background. Interestingly economic students are virtually more concerned about the asset purchasing programs and the size of central banks' balance sheet in respect to the inflation expectations than the overall economy. This is in contrast to a study by Clark and Nakata (2008) who find that the period of 'great moderation' and the introduction of inflation targeting have inherently anchored expectations at low levels permanently.

Lastly I find that people who prefer higher inflation (proposal by Blanchard et al. 2010), also reveal higher 'real' and 'experimental' inflation expectations. This result is measured by the variable 'Target Change'. People in this group display a higher time-variance in expectations, despite a credible target. In average, the variance is of 106 per cent above the reference group. Furthermore the variance increases with the number of rounds. Once again, this indicates the importance of credible targets in central banking.

4.04 Further empirical results

The final subsection is devoted to the verification of the so-called quarter-law in a quantum model of decision-making (QMDM) (von Neumann & Morgenstern, 1953; Yukalov & Sornette, 2011; Herzog, 2015). The QMDM is a new alternative to existing behavioral economic models due to several decision-making paradoxes (Ellsberg, 1961; Kahneman & Tversky, 1976; Loomes & Sugden, 1982; Chew et al. 1991; Ariely, 2008). First of all, I evaluate the so-called group size effect. This means that groups process information more effectively than individuals. Thus groups act more strategically. In fact, I find that larger groups (sample) converge faster to the equilibrium. In addition, this finding confirms the error-attenuation hypothesis that decision-errors decline with increasing information and group size. In case of the first subsample (N=95), the relevant average numbers are 3.0 in round I; 1.8 in round II; and 1.4 in round III respectively. The same numbers for the full sample (N=207) are 2.6 in round I; 1.8 in round II; and 1.1 in round III respectively. This is first evidence for a faster convergence to zero for the larger sample. To my knowledge, this paper provides first empirical evidence to this phenomenon, which has been only a theoretical proposition up until today.

Furthermore I evaluate the quarter law, which is a property of the attraction factor in the QMDM. First I calculate the utility factor. Thereafter I calculate the attraction factor based on the game data. I use these values, as supposed in the model, to compute the mean-value of the attraction factor. Throughout the experimental data, I find evidence almost in-line with the quarter law (Table 3). But due to the small sample of just N = 207, this is not a rigorous verification. Therefore this topic leaves room for further research.

Table 3: Calculated means of attraction factor (= Quarter Law)

	Round I	Round II	Round III
Attraction Factor	0.264	0.295	0.268

Nevertheless there is evidence that the mean-value of the attraction factor is close to a quarter. Despite the fact that the law of large numbers is not fully applicable, I think the quantum model provides valuable insights to decision-making processes of both individuals and groups under high uncertainty.

5.0 Conclusion

Since the onset of the financial crisis, there has been a lively debate about the role of (rational) expectations in macroeconomic models and whether a change in the inflation target may help foster the recovery process. Both issues are closely related to my study. I experimentally analyze how agents form expectations, and demonstrate the role of credible (inflation) targets. Interest rates at the zero-lower bound and highly accommodative monetary policy in all major industrialized countries may create doubts and uncertainty on price-stability. The announcement of quantitative easing by the US Federal Reserve Bank, Bank of England, Bank of Japan, and the European Central Bank in 2015 demonstrates the abnormal situation. The economic implication of the current strategy in monetary economics is unknown even among economists. Yet recognizing the early warning signs requires a better understanding of the formation of (inflation) expectations. This paper sheds new light on this issue and identifies vulnerabilities and triggers.

This paper contributes to the literature with several distinguishing features: First, I have evidence that expectations remain well anchored as long as the target is credible. Second, cheating and uncertainty influence expectations rather little at the beginning but likely further after some time. This gradual erosion below the surface cannot be measured and recognized by the current survey techniques. Third, participants change their expectations rather little if they face a credible target and have economic knowledge. Fourth, expectations exhibit a high degree of time-variance in case of no target or an incredible one.

In line with Nagel (1995), I restate that people form second or third-order believe and remain well below the theoretical prediction of game theory. The fifth result, however, shows that convergence and persistence towards an ‘incomplete’ equilibrium is incredibly fast if there is a credible target. This establishes an almost stable anchoring effect in the human believe system. Finally I confirm that a ‘target’ change may affect the process of decision-making twofold: on the one hand, it increases the convergence towards the new target level, but on the other hand it increases the variance of expectations. The last finding impairs the credibility of the target. Consequently a credible target makes policy implementation more effective and enhances the internalization of future costs. However transparency cannot fully compensate the loss of confidence if the (inflation) target temporarily changes.

All in all, this paper shows novel insights on the formation process of expectations under uncertainty. Due to the gradual erosion below the surface in my cheating game, I would be very cautious with ideas, such as the one by Blanchard et al. (2010), which temporarily proposes a higher inflation target of 4 or 6 per cent. This will certainly increase uncertainty, and thus impair central banks’ credibility. Both uncertainty and lower credibility trigger a de-anchoring of (inflation) expectations. Even if smart economists understand the optimality argument of Blanchard's proposal, it is a risky business and probably opens the Pandora's Box in the overall society.

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Appendix

Table 04: Sample with target +Table 05: Sample without target							
Game Design	Intervals	Block A			Block B		Block C
		Current Inflation	Past Inflation	Real expected Inflation (5 y.)	ECB Target	Preferred Target	Adj. Speed[a)] Round I to Round III
With target N=112	0.0-0.5	0	0	0	19	3	-0.5
	0.5-1.0	1	3	0	11	0	1.4
	1.0-1.5	3	6	3	5	1	0.7
	1.5-2.0	6	1	20	17	27	-0.5
	2.0-2.5	9	7	10	5	4	-0.9
	2.5-3.0	19	6	39	4	4	-0.7
	3.0-3.5	3	2	7	0	1	-0.8
	3.5-4.0	3	1	6	2	2	-0.9
	4.0-4.5	0	0	1	0	0	-1.0
	4.5-5.0	1	1	16	0	0	0.0
	5.0-5.5	0	0	0	0	0	0.0
	5.5-6.0	0	0	0	0	0	0.0
	6.0-6.5	0	0	0	0	0	0.0
	6.5-7.0	0	0	1	0	0	0.0
	7.0-7.5	0	0	0	0	0	0.0
	7.5-8.0	0	0	1	0	0	-1.0
	8.0-8.5	0	0	0	0	0	0.0
	8.5-9.0	0	0	0	0	0	0.0
	9.0-9.5	0	0	0	0	0	0.0
	9.5-10.0	0	0	0	1	0	0.0
Weigh Average		2.52	2.18	2.97	1.38	1.90	
Median		2.88	2.13	3.13	3.00	2.13	
Std. Dev.		4.02	3.16	7.07	4.57	4.84	
Kurtosis		3.63	-1.07	12.62	2.36	12.74	
N		45	27	104	64	42	
Without target N=94	0.0-0.5	0	0	1	23	3	11.7
	0.5-1.0	1	3	0	12	5	7.5
	1.0-1.5	5	6	4	7	1	1.6
	1.5-2.0	8	1	11	31	14	-0.4
	2.0-2.5	11	7	12	3	1	-0.6
	2.5-3.0	16	6	27	5	6	-0.7
	3.0-3.5	4	2	7	0	0	-1.0
	3.5-4.0	2	1	7	2	4	-0.9
	4.0-4.5	0	0	1	0	2	-1.0
	4.5-5.0	2	1	9	0	2	-1.0
	5.0-5.5	0	0	0	0	0	-1.0
	5.5-6.0	0	0	0	0	0	0.0
	6.0-6.5	0	0	0	0	0	0.0
	6.5-7.0	0	0	0	0	0	-1.0
	7.0-7.5	0	0	0	0	0	-1.0
	7.5-8.0	0	0	1	0	0	0.0
	8.0-8.5	0	0	0	0	0	0.0
	8.5-9.0	0	0	0	0	0	0.0
	9.0-9.5	0	0	0	0	0	0.0
	9.5-10.0	0	0	1	1	0	0.9
Weigh Average		2.44	2.18	2.95			
Median		2.50	3.13	3.50			
Std. Dev.		3.88	3.16	5.10			
Kurtosis		0.82	-1.07	8.01			
N		49	27	81			

Table 6: Full sample without target, N= 207

Game Design	Intervals	Expectations(choices)[a)]		
		Round I	Round II	Round III
With target N=207 (Cheating)	0.0-0.5	5	22	27
	0.5-1.0	17	55	60
	1.0-1.5	19	41	43
	1.5-2.0	48	32	24
	2.0-2.5	25	9	7
	2.5-3.0	26	11	8
	3.0-3.5	11	1	1
	3.5-4.0	13	2	2
	4.0-4.5	7	3	0
	4.5-5.0	4	0	0
	5.0-5.5	1	2	0
	5.5-6.0	0	0	0
	6.0-6.5	0	0	0
	6.5-7.0	2	1	0
	7.0-7.5	1	0	0
	7.5-8.0	2	1	1
	8.0-8.5	0	0	0
	8.5-9.0	0	0	1
	9.0-9.5	0	0	0
	9.5-10.0	1	5	12
Weigh Average		2.38	1.63	1.77
Median		4.50	3.50	3.50
Std. Dev.[b)]		1.50	1.72	2.28
Kurtosis		9.52	9.07	10.67
N		182	185	186

a) Numbers represent the number of responses in the respective intervals, b) Standard deviation is calculated on the basis of the respective game expectations.