Overconfidence and bubbles in experimental asset markets

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OVERCONFIDENCE AND BUBBLES IN EXPERIMENTAL ASSET MARKETS

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Abstract

In this paper relationship between the market overconfidence and occurrence of the stock-prices' bubbles is investigated. Sixty participants traded in ten experimental markets of the two types: rational and overconfident. Markets are constructed on the basis of subjects' overconfidence, measured in the administered pre-experimental psychological test sessions. The most overconfident subjects form overconfident markets, and the least overconfident – rational markets. Empirical evidence presented in the paper refines differences between market outcomes in the experimental treatments and suggests the connection between market overconfidence and market outcomes. Prices in rational markets tend to track the fundamental asset value more accurately than prices in overconfident markets, and are significantly lower and less volatile than the average overconfident prices. Strong positive correlation between market outcomes and overconfidence measures draws conclusion, that an increase in market overconfidence is associated with the increase in average price and trading activity. Large and significant correlation between bubble measures and measures of overconfidence provide additional evidence that overconfidence has significant effect on price and trading behavior in experimental asset markets.

Keywords: overconfidence, price bubbles, experimental asset market.

JEL Codes: C92, G12

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1 INTRODUCTION

Many different factors are continuously contributing to the changes in stock prices. As a consequence stock-prices' bubbles might occur. Although different definitions of the stock price bubble notion exist, one thing is common to all of them: bubbles are deviations from the fundamental value of an asset. Fundamental asset value equals the present value of the stream of dividends that owner expects to receive, and therefore dividend is the only driving force of the asset prices. There exist several problems in determining the fundamental value of an asset, namely estimation of dividends on the asset through the time period, determination of the terminal asset value and discount rates for calculation of the present value. All these components can be controlled in the laboratory asset market.

A question arises, why people pay for an asset a price that differs from its fundamental value? According to Scheinkman and Xiong (2003) overconfidence is the main factor which makes people pay higher prices, than the underlying fundamental value of an asset. Overconfidence is one of the psychological characteristics, stipulating deviations from rational behavior. The concept of overconfidence is based on the large body of evidence from cognitive psychological research, which suggests that human-beings overestimate their own knowledge, abilities and precision of their personal information. Although the beginning of overconfidence research lies in psychological works, the effect of overconfidence on financial decision making, functioning of financial markets and economic outcomes is a widely researched topic in behavioral economics.

Most of the theoretical overconfidence papers are based on the initial assumption of traders' overconfidence, which is modelled as overestimation of the precision of private information that manifests itself via underestimation of the variance of the private signal that subjects get. Theoretical models of overconfidence predict that overconfidence causes excess trading volume and excess price volatility, as well it induces occurrence of the speculative price bubbles. There are a few empirical and experimental studies designed to test whether cognitive bias of overconfidence affects financial decisions, market outcomes and subjects' performance. Market experiments which are the closest in spirit to mine are by Biais, Hilton, Mazurier, and Pouget (2005), Kirchler and Maciejovsky (2002), Deaves et al. (2009). All these experiments analyzed relation between measures of overconfidence and trading behaviour, however only Deaves et al. (2009) explore the impact of overconfidence on the market-level. Kirchler and Maciejovsky (2002) run a multi-period experimental market and analyze development of overconfidence of the participants in the course of the experiment.

Their results indicate that participants of the experiment were well-calibrated in certain periods, and under- or overconfident in other periods. Biais et al (2005), use psychological questionnaire to measure the degree of overconfidence via interval estimation tasks in a group of 245 students. The main conclusion of the authors is that miscalibration does not lead to an increase in trading activity. On the contrary, Deaves et al. (2009) in their paper report that greater overconfidence leads to higher trading volume. They found no evidence that overconfidence and trading activity are gendered.

My experiment was constructed with the following assumptions in mind. First, previous experiments were not aimed at discovering the connection between the phenomenon of overconfidence and occurrence of stock-prices' bubbles. Second, there were no papers that previously used the suggested procedure of markets' formation, based on the participants' inborn level of overconfidence, and have managed directly connect changes in markets' overconfidence to the experimental outcomes. Third, previous experiments provided participants by private information with differences in signal quality, which itself creates potential for trade; in my experiment all subjects are given the same information. Fourth, to measure subjects' overconfidence I use a specially tailored test, weighted for the inclusion of easy, hard and medium difficulty questions, which is also gender-balanced; none of the previous experiments makes use of such test. However, unbalanced to hard-easy effect tests might artificially create high levels of overconfidence; the same is valid for gender bias. Fifth, I use the second construct to measure markets' overconfidence: a price-prediction task (in each period subjects submit their forecast of the next period's average market price and their confidence in this prediction). This design also enables following the evolution of market's overconfidence in the course of experiment. Both pre-experimental test and price prediction assignment are financially rewarded.

In this paper results of the experiment, designed to investigate the role of market overconfidence in the occurrence of bubbles in the asset prices and in the emergence of other stylized facts of the financial market (excessive trade, excessive price volatility), are reported. Additional interest is paid to the examination of the extent to which such relationship exists, i.e. determination of the linear relationship between price bubbles and the prevailing degree of market overconfidence, measured as the bias score. The design of the experiment follows Smith, Suchanek and Williams (1988) and is extended by a new feature, in which markets are constructed on the basis of subjects' overconfidence, assessed in pre-experimental studies. For the participation in the experiment two types of subjects are invited: those who have low bias score (rational subjects) and those who have high bias score (overconfident subjects). Of them in the experiment two types of markets are formed: rational and overconfident. When there are no asymmetries in information and all traders have identical assets' and currency endowments, and all of them are "homogenous … with statistically rational dividend and price expectations" (Gilette et al., 1999) a theory predicts that either no trading should occur or some marginal trading at the prices around the fundamental value. I assume that overconfident traders overestimate the probability of the occurrence of the maximum dividend value, thus they erroneously perceive possible future dividend income and optimistically overestimate the probability of existence of other traders ("greater fools") ready to pay for the asset an even higher price. This results in that the participants are taking excessive risk and trade at prices above the fundamental asset value. Thus bubbles in the asset's price occur. These bubbles usually burst several periods before the end of the experiment; research on overconfidence showed that overconfidence is decreasing with the task repetitiveness. Thus my second focus is to investigate changes in markets' overconfidence towards the end of the game.

Main findings from my experiment can be summarized as follows. In the ten sessions of this experiment, it is observed that, higher market overconfidence is accompanied by the higher average market prices and larger deviations of the security prices from fundamental value. Prices in rational markets tend to track the fundamental asset value more accurately than the prices in the overconfident markets, and are significantly lower than the average overconfident prices. Moreover, bubble and burst pattern was observed in the aggregated overconfident market, whereas in the rational market no sudden drop of the aggregated market price to the fundamental value occurred. Volatility of the prices and trade volume proved to be significantly lower in the rational market, as it was hypothesized. Overconfidence measure of the first part of the experiment is, in most markets, lower than that of the second part and this difference is significant. This finding could serve as an explanation why bubbles burst close to the end (or in some cases middle) of the experiment. Analysis of the bubble measures revealed that in the markets formed of overconfident subjects bubbles are more likely to occur and that they are significantly larger in magnitude than in rational markets. Large and significant correlation between bubble measures and measures of overconfidence provide additional evidence that overconfidence has significant effect on price and trading behavior in experimental asset markets.

Paper proceeds as follows. In Section 2 a brief overview of the findings of psychological[1] and financial literature on overconfidence are given; along analysis of the similar work and

[1] A detailed discussion of the relevant literature is provided in the working paper "Development of the overconfidence measurement instrument for the economic experiment".

discussion of the paper's contributions is presented. In Section 3 the research hypotheses are listed. In Section 4 details of the pre-experimental overconfidence measurement are provided. Section 5 provides description of experimental design. In Section 6 data analysis is presented, and, finally Section 7 concludes.

2 OVERCONFIDENCE

2.1 OVERCONFIDENCE IN PSYCHOLOGICAL RESEARCH

The beginning of the overconfidence research in finance and economics lies in psychological works. In psychological research overconfidence is defined as a prevalent tendency to overestimate one's skills, prospects for success, the probability of positive outcomes or the accuracy of one's knowledge. Phenomenon of overconfidence has been found in many different samples of the population, e.g. students (Fischhoff et al.,1977; Koriat et al., 1980, Zakay and Glicksohn, 1992), members of the armed forces (Hazard and Peterson, 1973), CIA analysts (Cambridge and Shreckengost, 1978), entrepreneurs (Baron, 2000), clinical psychologists (Oskamp, 1962), bankers (Staël von Holstein, 1972), executives (Moore, 1977), negotiators (Neale and Bazerman, 1990), managers (Russo and Schoemaker,1992), lawyers (Wagenaar and Keren, 1986), and civil engineers (Hynes and Vanmarcke, 1976); overconfidence is already present in children (see Powel and Bolich, 1993; Allwood, Granhag, and Jonsson, 2006).

Confidence and uncertainty In our life, many decisions are based on beliefs concerning the likelihood of uncertain events (Tversky and Kahneman, 1982). These beliefs can be expressed in numerical form as subjective probabilities. Subjective probabilities are the probabilities that people generate in their own minds to express their uncertainty about the possibility of the occurrence of various events or outcomes (Bar-Hillel, 2001). If over the long run, for all predictions made with some specific confidence, the actual proportion of correct outcomes equals the probability assigned, a person is considered to be well calibrated. Overconfidence, or miscalibration, concerns the fact that people overestimate how much they actually know: when they are P-percent sure that they have answered the question correctly or predicted (the outcome) correctly, they are in fact right on average less that P-percent of the time (Bar-Hillel, 2001). Optimistic overconfidence is a specific form of overprediction, based on overestimation of the probability of events thought to be beneficial to the judge (Griffin and Brenner, 2005). Most of the people are not well-calibrated and demonstrate overconfidence. Overconfidence can also be defined with respect to subjective confidence intervals (Kirchler and Maciejovsky, 2002). The assessor has to state values of the uncertain quantity that are associated with a small number of predetermined fractiles of the distribution. The usual finding is that the subjects' probability distributions are too tight. In the study of Alpert and Raiffa (1982) fifty-percent intervals included the true quantity only about 30 percent of the time; 98 percent intervals, only 60 percent of the time.

The degree of overconfidence is connected to the complexity of the task, and is the highest with the tasks of high difficulty (e.g. Clarke, 1960; and Pitz, 1974). As tasks get easier, overconfidence is reduced (Lichtenstein et al., 1982). Russo and Schoemaker (1992) note that being well calibrated is a teachable, learnable skill, which is demonstrated by the example of weather forecasters, who significantly improved accuracy of their forecast predictions and became one of the best ever calibrated group of subjects. Lichtenstein et al., (1982) conclude that continuance, repetitiveness of the task and the fact that, the outcome feedback for weather forecasters is well defined and promptly received, have high impact on accuracy of their predictions. There are two ways to achieve better subjects' calibration, which according to Lichtenstein et al. (1982) are motivation through reward for their assessment to be more precise, and outcome feedback[2].

2.2 OVERCONFIDENCE IN FINANCIAL RESEARCH AND CONTRIBUTIONS

Following the psychological research in overconfidence, interest in the consequences of economic subjects' overconfidence on financial decision making, functioning of markets and economic outcomes has occurred in behavioral economics. Theoretical models of overconfidence predict that overconfidence causes excess trading volume (De Bondt and Thaler, 1985; Shiller, 2000; Benos, 1998; Caballé and Sákovics, 2003), and excess price volatility (Scheinkman and Xiong, 2003; Benos, 1998, Daniel et al., 1998); it induces occurrence of the speculative price bubbles (Scheinkman and Xiong, 2003) and increases market depth (Odean, 1999; Kyle and Wang, 1997; Benos, 1998); it makes markets underreact to abstract, statistical, and highly relevant information and overreact to salient, but less relevant information (Odean, 1998); it makes returns of financial assets predictable (Daniel et al., 1998, 2001; Scheinkman and Xiong, 2003); overconfidence increases investors' tendency to herd (Hirshleifer, Subrahmanyam and Titman, 1994) and makes them choose riskier and undiversified portfolios (Odean, 1998, 1999; Lakonishok, Shleifer and Vishny, 1992), overconfident investors trade more aggressively, i.e. their trading activity is too high (Odean, 1999; Gervais and Odean, 2001) and their expected utility is reduced (De Long et al.,

[2] Moreover, receiving outcome feedback after every assessment is the best condition for successful training (Lichtenstein et al., 1982).

1991; Odean, 1998). Most of these papers are based on the initial assumption of traders' overconfidence, which is modelled as overestimation of the precision of private information that manifests itself via underestimation of the variance of the private signal that subjects get, or, in other words, too tight confidence intervals for the value of the risky asset (Glaser and Weber, 2007).

There are a few empirical and experimental studies designed to test the impact of overconfidence on financial decisions, market outcomes and subjects' performance. Some of them present only an indirect evidence of such impact, as they measure overconfidence via different proxies and it is not always clear who of the subjects and how strong are overconfident. For example Statman, Thorley, and Vorkink (2006) test the hypothesis of interdependence between overconfidence and high trading volume for the USA stock market. As a proxy for the degree of overconfidence authors suggest using the high past returns, i.e. they argue that after high past returns posterior volume of trade will be higher, as successful investment increases the degree of overconfidence. These conclusions are supported by Kim and Nofsinger (2003) for the Japanese stock market. Barber and Odean (2001) proxy overconfidence by the gender of the trader, i.e. their proposition is that, based on the psychological literature, women are less overconfident than men, thus they are going to trade less than men. In their study men were actually found to trade more than women.

A much clearer results are obtained through test-studies, enabling direct observation whether an examined person overestimate their knowledge, or underestimate variance of sock returns etc. For example, Menkhoff, Schmidt and Brozynski (2006) surveyed 117 fund managers in order to detect an impact of experience on overconfidence, risk taking, and herding behavior. However, only experiments enable a direct test of the hypothesis that a certain degree of overconfidence leads to a specific market outcome, expressed as some of the market parameters, e.g. average price, or trade volume. Market experiments which are the closest in spirit to mine were conducted by Biais, Hilton, Mazurier, and Pouget (2005), Kirchler and Maciejovsky (2002), Deaves et al. (2009). All these experiments analyzed relation between measures of overconfidence and trading behaviour.

Kirchler and Maciejovsky (2002) run a multi-period experimental market and analyze development of overconfidence of the participants in the course of the experiment. Miscalibration of subjects was measured before each trading period, via the two price prediction tasks: point prediction and interval prediction. Their results indicate that participants of the experiment were well-calibrated in certain periods, and under- or overconfident in other periods. They also find that higher degree of overconfidence is negatively correlated with the earnings of the participants of the experiment.

Biais et al (2005), use psychological questionnaire to measure, among other psychological traits, the degree of overconfidence via interval estimation tasks in a group of 245 students. Several weeks later after the students' overconfidence was measured they participated in an experimental asset market. The main conclusions of the authors are, that although miscalibration does not lead to an increase in trading activity it reduces trading performance of the subjects, and miscalibrated traders show "excessive confidence in their assessment of the value of asset", which eventually causes mistakes in financial decision making. Miscalibration reduces profits for men, whereas has no significant effect on women.

Deaves et al. (2009), conduct their experiment in order to test premises that overconfidence leads to an increase in trading activity, and that gender influences trading activity through differences in overconfidence. Compared to the two abovementioned experiments Deaves et al. (2009), instead of a multi-period experiment, conduct a battery of 12 single-period markets per experimental session and they use an increased up to 20 questions test consisting of the interval estimation tasks. To some of their sessions subjects were assigned based on their gender, and to some based on the overconfidence measure (OC). The values of OC measure used in the experiment of Deaves et al. (2009) show that all their subjects were extremely overconfident[3]. The main finding reported in their paper is that greater overconfidence leads to higher trading volume and leads to reduced earnings, but there is no evidence that overconfidence and trading activity are gendered.

My experiment was constructed with the following assumptions in mind:

First of all, most of the previous experiments concentrate on the connection between overconfidence and high market trade volume, and none of them was aimed at discovering the connection between the phenomenon of overconfidence and the occurrence of the bubbles in asset prices.

Second, there were no papers that previously used suggested procedure of markets formation, based on the participants' inborn level of overconfidence, and have managed directly connect changes in traders' psychological characteristics to the experimental market outcomes. Although Deaves et al. (2009), as mentioned above, run several sessions to which subjects

[3] In the experiment of Deaves et al. (Deaves et al. (2004) OC measure is constructed so as to vary in the interval [0, 1], where 1 points at extreme overconfidence. A well-calibrated person's OC score is 0.1, and values below point at underconfidence. However none of their subjects comes close to 0.1, the lowest OC being equal to 0.45.

were assigned by the degree of overconfidence, the issue of association of overconfidence with price-bubble was not in their focus, and therefore not explored. Not to mention, that they utilized a different overconfidence measurement methodology, and opted for different market structure (a battery of one-period markets per session vs. one multi-period market).

Third, previous experiments provided participants by private information with differences in signal quality, which according to Glaser et al. (2007) already creates a potential for trade[4]. E.g. in the experiment of Kirchler and Maciejovsky (2002) half of the participants had no information about the dividend distribution, and the other half had complete information. Experimental approach of Biais et al. (2005) relies on the asymmetric information trading game, where traders observe different private signals: bullish, bearish, and neutral. Deaves et al. (2009), also supply their subjects with different, in terms of quality, signals that depend on the results of the pre-experimental test. Moreover they try to manipulate the subjects' beliefs so that they think that their signals are more accurate. I do not create artificial belief in being better or possessing a piece of a more qualitative information. Instead all subjects are given the same information and I believe that only such approach enables the refinement of the pure differences between the two experimental groups.

Fourth, economic experiments on overconfidence measure the inborn level of subjects' overconfidence via the different tasks and tests, and in previous experiments overconfidence might have been caused (to some extent) by other reasons than the imperfection of human nature, namely by mistakes in the development of tests/tasks. E.g. findings from the psychological research show that overconfidence is the most pronounced for the hard questions (few people know the right answer) and the least for the easy (most of the people give a correct answer) questions. However, none of the abovementioned papers makes use of the balanced to hard-easy effect tests. This could have artificially created high levels of under- or overconfidence. For example in the experiment of Deaves et al. (2009) none of the subjects gets even close to the perfect calibration measure, and even the best calibrated participants exhibit rather high degree of overconfidence[5]. I created the specially tailored test, weighted for the inclusion of easy, hard and medium difficulty questions (also accounting for the possible gender bias) that was pre-tested and used with students enrolled in different disciplines of the social sciences. Compared to some of the authors, my test is expanded to

[4] If investors receive different pieces of private information about the uncertain value of the risky asset, there is heterogeneity between investors and thus a potential for trade (Glaser et al, 2003).

[5] This also raises doubts in the validity of their division of subjects in low and high overconfidence markets.

include more questions. Both overconfidence test and price prediction assignment are financially rewarded, which increases reliability of the overconfidence measurements.

And last but not least, I use two constructs to measure subjects' overconfidence: a general knowledge based, and based on the stock-price prediction task. Biais et al. (2003) and Deaves et al. (2009) use only general-knowledge tasks, where overconfidence is being estimated via the interval estimation tasks. In the experiment of Kirchler and Maciejovsky (2002) a pre-experimental overconfidence measurement did not occur, but rather, overconfidence was measured in the course of the experiment via the price prediction task. My design makes possible not only the evaluation of the students' pre-experimental degree of overconfidence, and based on that, division of students into two different types of market, but also the construction of the measure of the change in the markets' overconfidence from the first half of the experiment to the second. This enables more confident inference about the connection between the development of overconfidence and the bubble burst.

3 HYPOTHESES

Investment decisions in the experimental market are based on beliefs concerning the likelihood of the two kinds of independent uncertain events: 1) size of dividend at the end of the period and 2) probability to resell to the party willing to pay even more. I assume that subjective probabilities generated by overconfident traders make them overestimate the probability of the occurrence of the maximum dividend value, thus traders erroneously perceive possible future dividend income and optimistically overestimate the probability of existence of the irrational traders ("greater fools") ready to pay for the asset an even higher price. This results in that the participants are taking excessive risk and trade at prices above the fundamental asset value, and are even higher than the maximum possible dividend value. Both these reasons create a fertile field for the occurrence of the bubble in the experimental asset's price. Following this discussion the first hypotheses is formulated:

H_1. Trade in the two types of constructed markets will follow such patterns:

1. Rational market:
   - No trade or trade around the fundamental value (average expected dividends)
   - Investors trade relatively infrequently (low trading volume)
   - Prices are not too volatile relative to fundamentals
   - No bubble-crash pattern observed

2. Overconfident (irrational market):

- Trade at prices around maximum possible dividend value and trade at irrationally high prices i.e. exceeding the maximum possible dividend value.
- Excessive trade volume.
- Observed bubble and burst pattern

The second hypothesis is based on the work of Smith, Suchanek, and Williams (1988) and findings from psychological literature. Experiments by SSW (1988) showed that bubble/burst pattern is persisting scenario in the markets with inexperienced agents. Usually bubbles burst several periods before the end of the trading game. Research on overconfidence showed that overconfidence is decreasing in experts or with the task repetitiveness (see Sieber, 1974; Pitz, 1974; Lichtenstein et. al., 1980; Russo and Schoemaker, 1992). Also optimism diminishes with experience (Fraser and Green, 2006). Thus a second hypothesis is postulated:

H_2: Reduction in overconfidence causes bubbles' crash. Overconfidence is reduced with experience.

As mentioned earlier subjects can be trained to be better calibrated by motivating them financially to be more precise in their predictions, and by giving them feedback on their predictions' results. These both conditions are fulfilled in the experiment. Thus in the course of the trading game participants gain experience in it, and supported by market information about the results of their repeated actions turn into being "experts" of the game. Expertise should improve calibration of the subjects and bring about changes in their trade patterns (e.g. decrease in trading volume and price), causing stock price bubble's crash. Thus bubble bursts as participants turn being better calibrated, and correct their subjective probabilities downwards.

4 PRE-EXPERIMENTAL OVERCONFIDENCE MEASUREMENT

Pre-experimental psychological test sessions were conducted during several lectures on economics at the Chriatian-Albrechts University of Kiel. In each of the chosen classes, students were announced that they had an opportunity to take part in the short experiment on the voluntarily basis, for which a general knowledge quiz had to be filled out. For this activity 15 minutes were given. Participants of each pre-experimental session competed for the three prizes of 30, 20 and 10 EUR, which were awarded to those who answered the most questions right. Before the students started with the tests, a planned market experiment was advertised, and those subjects who were eager to take part in the economic experiment were encouraged to mark their interest on the tests by ticking the "I'm interested in participation in further experiments" option and leaving their contact in the form of an e-mail address.

The pre-experimental quiz consisted of the 18 general knowledge questions unrelated to economics, financial markets or experiments[6]. Every question had three answer alternatives, only one of which was right. After answering each question participants had to state how confident they were that the answer was right. For this purpose they could use any number in the range from 33%, meaning complete uncertainty, to 100% - complete certainty.

The overconfidence (underconfidence) of each participant was measured as the bias score. The bias score of an individual was calculated as the difference between the mean confidence level across all questions and the proportion of correct answers:

$$\textit{bias score} = \textit{average \% confidence} - \textit{average \% correct} \qquad (1)$$

A positive bias score represented overconfidence, and a negative bias score represented underconfidence. A bias score of zero indicated accurately calibrated person (neutral person).

This pre-experimental procedure allowed the author to obtain a large pool of students with their estimated bias scores in her database, and to ensure that the two stages of the experiment were perceived by the students as two rather non-associated experiments. Based on the pre-experimental calibration test individuals were divided into two groups – the least and the most overconfident, which are further on called correspondingly rational and overconfident subjects. Students were addressed through the e-mails according to their overconfidence and invited to register for the suggested experimental sessions. All students of a specific type of the calibration were approached at the same time and were given several possible experiment days for their choice, thus subgroups participating in different experimental sessions differed in their average overconfidence within the two main groups (rational and overconfident).

More than two hundred students showed interest in the forthcoming economic experiment. A database of the interested persons included information on 222 students' name, age, nationality, direction of studies, semester and overconfidence score. Potential experimental subjects were undergraduate and graduate students of economics, business administration and other social science disciplines, aged from 19 to 43 years (M = 22.95, SD = 2.73). Of those

[6] Questions were not connected to economics, as otherwise it could cause biased results if the same questionnaire was used with the heterogeneous pool of subjects the experimenter had in her disposition. Deaves et al., (2008) also motivate their choice of non-economic questions by the attempt "to avoid giving either group of participants a relative advantage because of subject content".

only nine percent were of non-German nationality (19 non-German, and 203 German). Consistent with the previous research, subjects in the database on average were prone to overconfidence (M = 11.78, SD = 10.58).

Appendix A presents data on the bias scores of the various (pre-)experimental subgroups: all participants who were in the database, all students who participated in the experimental sessions (a subsample of those in the database), and their subsamples – men, women, participants of rational, and overconfident markets. All groups seemed to be extremely overconfident, except for the participants of the rational market. A hypothesis of the equality of the average overconfidence of different subgroups was tested against the alternative that different subgroups varied by their overconfidence levels. The mean equality hypothesis is failed to be rejected for the difference between overconfidence of male versus female subjects both in the whole sample of pre-experimental test participants, as well as among all experiment participants and overconfident/ rational participants. The bias score of the participants of the overconfident markets is significantly higher than of those of the rational markets.

5 Experimental Design

5.1 Participants

A set of ten experimental sessions was conducted at the Christian-Albrechts University of Kiel between November and May 2008-2009. For each session six participants were recruited from the undergraduate and graduate students in economics, business administration and other social science disciplines who had not previously participated in a similar asset market experiment[7]. Seventy four people took part in experimental sessions, of them 60 people actually traded in the experimental markets. Thirty five males and 25 females, aged 19 to 28 (M = 22.73, SD = 2.06) participated in the experimental sessions. 87% of the participants were of German nationality. Thirty five subjects studied economics, 18 – business management, and 7 were students of the other social science disciplines. Approximate time required to conduct the experiment was 1 hour and 40 minutes. Subjects earned on average 390.36 ECU (10.54 EUR) (SD = 197.89) on the asset market (without the reward for the forecasting activity). Men earned on average more ECUs than women: women 335 ECU and

[7] Inexperienced subjects were chosen, because Smith, Suchanek, and Williams (1988) found that, when participants had little or no previous experience in asset markets the markets exhibited price bubbles and crashes rather than tracked the fundamental value.

men 447 ECU. This difference is significant (Mann-Whitney $Z = -2.646$, $p < 0.01$, one-sided). Instructions familiarized participants with the rules of the experimental market. English translation of instructions is included in Appendix B.

5.2 EXPERIMENTAL PROCEDURE AND THE RULES OF THE GAME

All experimental sessions were conducted in the computer lab. Six players participated in each of the experimental asset markets. Subjects could take part in only one experimental session and only in that type of the market (rational/overconfident) to which they were appointed based on the results of the psychological test. The experiment was programmed and conducted with the software z-Tree (Fischbacher, 2007).

At the beginning of the typical session students were given time to read the detailed instructions and ask the questions. At the end of the time devoted for reading the instructions experimenter again repeated the most important information at which students should pay attention, to ensure that everyone understood the rules of the game. Two trial periods followed, during which students could familiarize themselves with the experimental software, and were allowed to ask questions if something was unclear to them. Both prior to the trial periods and after them subjects were informed that these periods had no impact on their results.

Experimental design followed the pioneering work of Smith, Suchanek, and Williams (1988) with slight changes in the price forecasting task, and was performed as a continuous anonymous double auction. Every experimental market consisted of the sequence of 15 trading periods lasting at most 180 seconds during which each trader could post her bid and ask price of the asset unit. Therefore each participant could purchase asset units for their inventory by spending an amount of their working capital equal to the purchase price, or sell the inventory units and increase their working capital by an amount equal to the unit's sale price. Prior to the start of the experiment each trader was endowed with an equal amount of experimental assets and cash: 300 units of experimental currency (ECU) and 3 units of the experimental asset. At the end of the trading period, each asset in the inventory of the participants paid a dividend with possible values of 0.0, 0.8, 2.8, or 6.0 ECU. Probability of each dividend value was 0.25. Thus on average, through many draws subjects could expect a 2.4 ECU value dividend. Fundamental value of the stock is found according to the formula $n \times 2.4$ ECUs, where n stands for the number of periods remaining to the end of the session. Thus in round 1, the expected fundamental value from the dividend stream was $15 \times 2.4 = 36$ ECUs per each share; in every subsequent period it fell by 2.4 ECUs.

As the trading period was over, participants were shown market summary information from the past trading periods, and were asked to predict the average market price for the next period as well as to state how confident they were that their price forecast was correct. To express their confidence subjects could use any value between 0% and 100%, where 0% meant complete disbelief that the forecast could be true, and 100% meant complete belief that the forecast was correct. Participants were paid for their predictions based on their accuracy. Each period subjects were given feedback on their accuracy and their reward for the price forecasting task. Point estimation form of price prediction task, e.g. used by SSW (1988), was chosen over price interval estimation form due to several reasons. First, overconfidence measure obtained through interval estimation in the article by Kirchler and Maciejovsky (2002) did not vary in time and remained in the area of overconfidence; however, their point-estimate measure varied in time and took values from overconfident, to well-calibrated, and underconfident. Second, this form of price prediction task enabled comparison between pre-experimental and post experimental overconfidence measures.

5.3 INCENTIVES

A typical experiment lasted 1 hour and 40 minutes, and at the end of it subjects were paid in cash the amount of money that was based on their final working capital converted at the predefined exchange rate to Euros. Final working capital (FWC) equalled:

FWC = (300 ECU starting capital) + (dividend earnings) + (stock sales revenue) - (stock purchase cost) (2)

In order to motivate students they were offered an hourly reward, which was comparable to what on average an hour of the "student-job" in Germany pays[8], thus the asset market offered participants on average 7 EUR per hour of the experiment; for the whole experiment participants could expect to get on average 11 EUR.

Reward for the accuracy of predictions was constructed to be an additional income source in order to reduce mechanical participation and encourage conscious engagement into this activity. The closer the prediction was to the actual average market price, the higher was the reward. The reward scheme used in the experiment was similar to the suggested by Haruvy, Lahav, and Noussair (2007)[9]:

[8] To author's knowledge in the job market students could get on average 7 to 8 EUR.

[9] This incentive scheme instead of a quadratic scoring rule was chosen for the sake of keeping the instructions simple (Haruvy et al., 2007).

Level of Accuracy	Reward
Within 10% of actual price	3 ECU
Within 25% of actual price	1 ECU
Within 50% of actual price	0.5 ECU

Both monetary reward and the feedback about their predictions' accuracy were used for improving the subjects' calibration in the price prediction task.

6 EXPERIMENTAL RESULTS

6.1 NUMERICAL CHARACTERISTICS OF THE TWO TYPES OF THE MARKET

In this section various numerical characteristics of the two types of the market are compared. Each session counts as one observation. Totally ten market sessions were conducted: five sessions for the overconfident market, and five sessions for the rational market. If not stated otherwise, all data for each type of the market are ranked from the lowest to the highest.

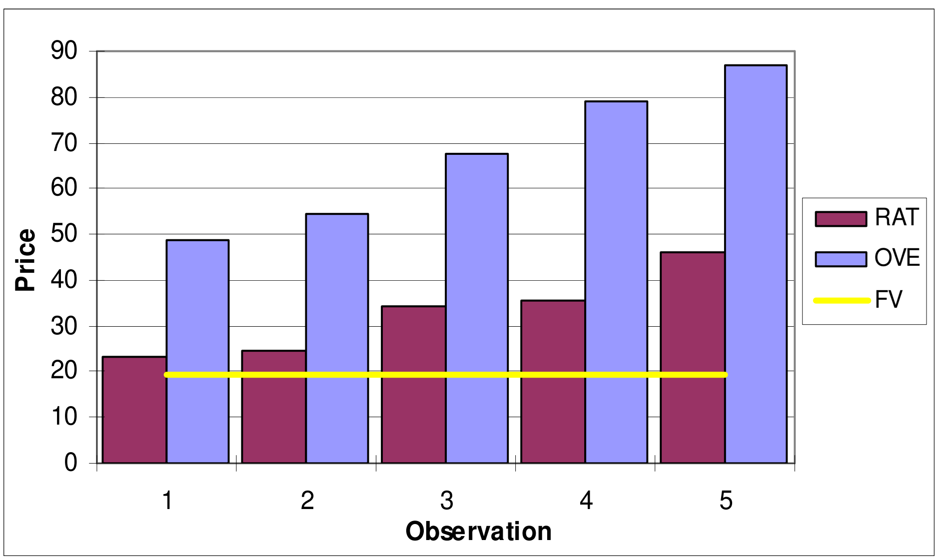


Figure 1: Average trade prices in both types of markets

I start by the comparison of the average contract prices in the rational and overconfident markets. Figure 1 demonstrates that on average prices in the overconfident market tend to be higher than in the rational market. The average market price for the rational markets was 33

ECUs (SD = 9.41[10]) and for the overconfident market 67 ECUs (SD = 16.02[10]). Statistical test of the difference between the average prices supports the initial conclusion from the visual analysis - average prices in the overconfident market are significantly higher than the rational market prices (Mann-Whitney $U = 0.0$, $p < 0.01$, one-sided). Now I turn to the comparison of the average prices obtained in the experiment to the average intrinsic value of the asset (fundamental value) 19.20 ECU. Figure 1 indicates that experimental average prices exceed the average fundamental value (from now on FV). Wilcoxon Signed Rank test supports that prices both in the rational and in the overconfident markets are higher than the fundamental value (Wilcoxon $T = 1.89$, $p < 0.05$, one-sided), i.e. prices in both types of the experimental market are shifted to the right from the fundamental value.

Evolution of the Average Price

Figure 2 presents the development of the joint average transaction prices for all five rational and all five overconfident markets. On the horizontal axis trading periods are indicated; vertical axis measures average price of the transaction for that period. Fundamental asset value, which is found as the sum of the expected dividends for the periods left till the end of the game, is presented alongside.

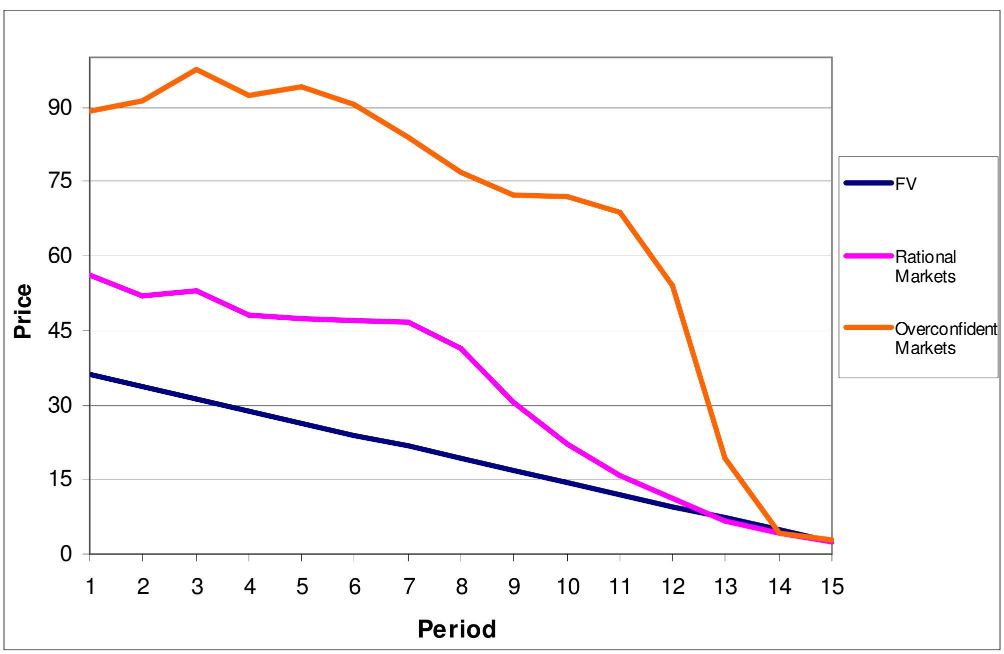


Figure 2: Development of the average market price

[10] Here aggregated average price and the standard deviation, which are based on the five average prices for each type of the market, are presented.

Visual data analysis suggests that prices deviate from the fundamental values in both types of the market. However prices in the rational market deviate from the fundamental value to a smaller extent than in the overconfident market. Although prices in both types of the market stay away from the fundamental value for almost the whole duration of the session, prices in the rational market tend to track the fundamental asset value more accurately than prices in the overconfident market. It can also be seen that in the aggregated overconfident market the bubble and burst pattern is more pronounced than in the aggregated rational market, where no sudden drop of the aggregated market price to the fundamental value is observed.

Volatility

Prior to the experiment I hypothesized that prices in the rational market would be less volatile than in the overconfident market. Figure 3 presents price variations in both types of the market, measured as standard deviations[11]. Initial analysis suggests that this intuition was right. The conducted Mann Whitney U test confirms that variation in prices in the overconfident markets is significantly higher than in the rational markets (Mann-Whitney U = 4, $p < 0.05$, one-sided). For both types of the market, Wilcoxon Signed Rank test enabled rejection of the null hypothesis that the volatility of the prices was not less than the volatility of the fundamental value at the significance level of 0.05 (Wilcoxon T = 1.89, $p < 0.05$, one-sided) in favor of the alternative hypothesis that the median volatility of rational/ overconfident market exceeded the volatility of the fundamental value (SD = 10.73).

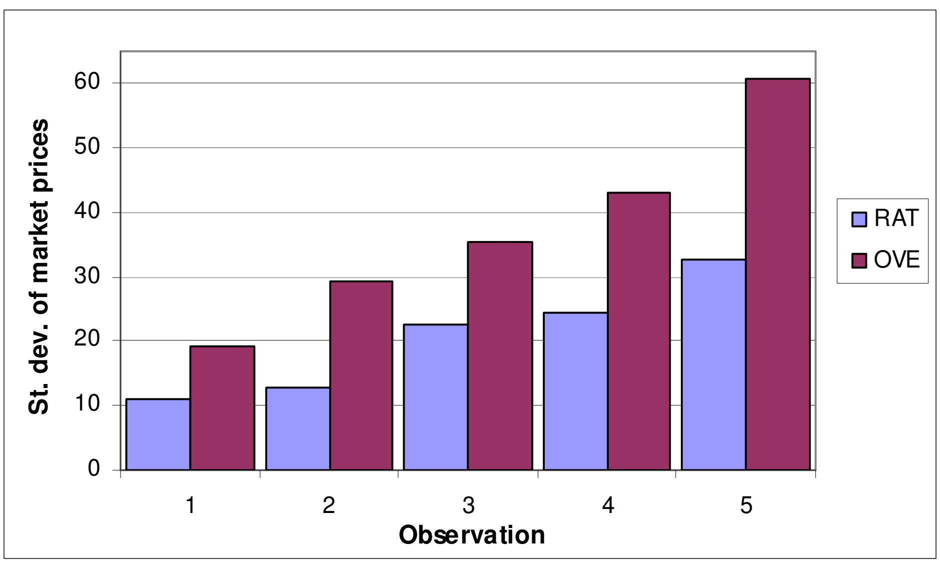


Figure 3: Volatility of asset prices in both types of markets

[11] Based on all prices of that market.

Trading Activity

In this subsection measure of market volume is introduced – average asset turnover rate (market turnover). Market turnover is obtained by dividing the number of the asset units traded in that market by the total number of the asset units in that market (18 units in our case).

I start by testing if the propositions of the No-Trade Theorem by Milgrom and Stokey (1982) applied in the conducted experimental markets. This theorem states that rational agents who differ from each other only in terms of information and who have no reason to trade in the absence of information will not trade (Milgrom and Stokey, 1982). Even though one type of the market was constructed so as to be on average rational and there was no private information Figure 4 suggests that trading activity in neither market is zero. Wilcoxon Signed Rank test of the hypothesis that there was no trading activity in the overconfident/rational market is rejected in favor of the alternative hypothesis that the trading activity is significantly higher than zero (Wilcoxon T = 1.896, $p < 0.05$, one-sided).

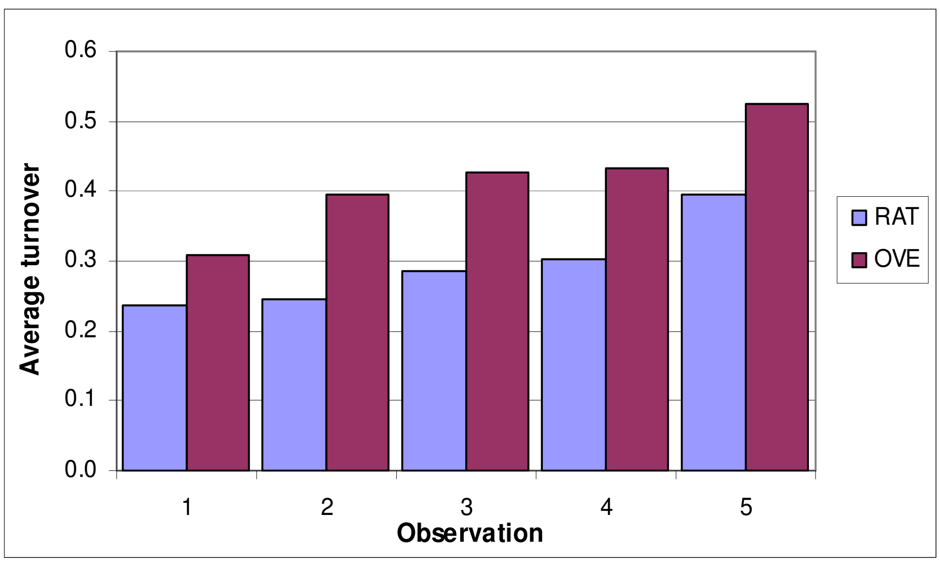


Figure 4: Average trading activity (turnover) in both types of markets

Trading activity in the rational market is lower than in the overconfident one: average market turnover in rational market sessions is 28% (5 units of asset) and 44% (8 units of asset) in overconfident. Mann-Whitney U Test was conducted to test if the average asset turnover rate in rational markets was the same as in overconfident markets, or whether alternatively market turnover in overconfident markets was higher. Trading in overconfident markets is found to be significantly higher than in rational markets (Mann-Whitney U = 1.5, $p < 0.05$, one-sided).

Evolution of the joint average market turnover for five experimental sessions of rational market and five overconfident markets is shown in Appendix C. It can be observed that the joint average market turnover decreased over the trade periods in both types of markets. Increase in trading activity in the last period can be attributed to the so-called end-game effect[12].

6.2 OVERCONFIDENCE MEASURE FROM THE FORECASTING TASK

Bias score (BS) from the price forecasting task was calculated for each session separately, as an average from all participants' forecasts about the next period's average price and their confidence in the answer. The score was calculated based on the "binary" methodology: if the average price was equal to the forecast it got a weight of 1, if not – 0. Overconfidence measure from the pre-experimental test is strongly correlated with the overconfidence measure from the forecasting task (Spearman's rho (8) = 0.65, $p < 0.05$, one-sided). According to Cohen, (1988) this correlation coefficient is considered to be large, thus I assume that both constructs measure the same phenomenon. This result also suggests that overconfidence is a robust phenomenon in our sample.

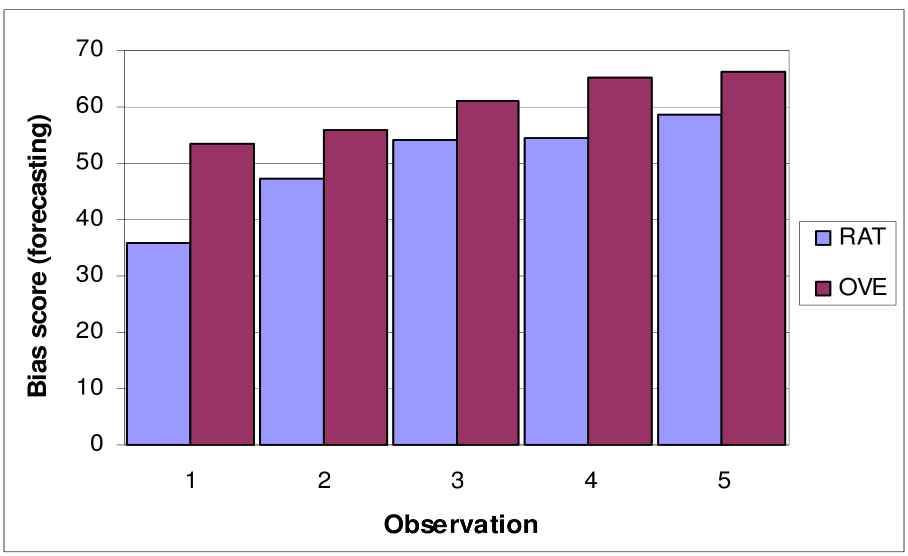


Figure 5: Average overconfidence in both types of markets

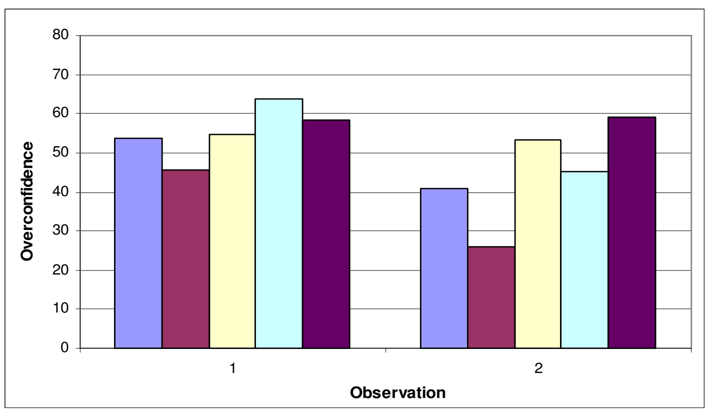
Figure 5 indicates that on average the bias score from the price forecasting task was higher in the overconfident markets than in the rational ones. On average overconfidence in price prediction task differed between the two types of market by 10 units (BS in rational markets

[12] The end-game effect occurs in repeated-round experiments, and is defined as the change in subjects' behavior that is attributed to the end of the experiment rather than being a part of subjects' behavior during the course of the experiment.

M = 50.08 (SD = 8.96); in overconfident markets M = 60.31 (SD = 5.02). BS value for the overconfident market is significantly higher than the BS for the rational market (Mann-Whitney U = 4.0, $p < 0.05$, one-sided).

Evolution of the Bias Score

To check if the proposition that overconfidence reduces to the end of the game compared to the beginning of the game holds true in the conducted experimental sessions, data on price prediction task were divided into two time intervals of seven periods in each, and two overconfidence measures for each market were calculated: one score for the first seven periods BS(2-8), and the second for the last seven periods BS(9-15). Figure 6 demonstrates that for most of the markets overconfidence measures calculated from the data on the price prediction for the first seven periods are higher than those calculated from the seven last periods. Wilcoxon Signed Ranks test confirms that BS(2-8) are significantly higher than BS(9-15) (Z = -2.429, $p < 0.01$, one-sided). This finding could serve as an explanation why bubbles burst close to the end (or in some cases middle) of the experiment.



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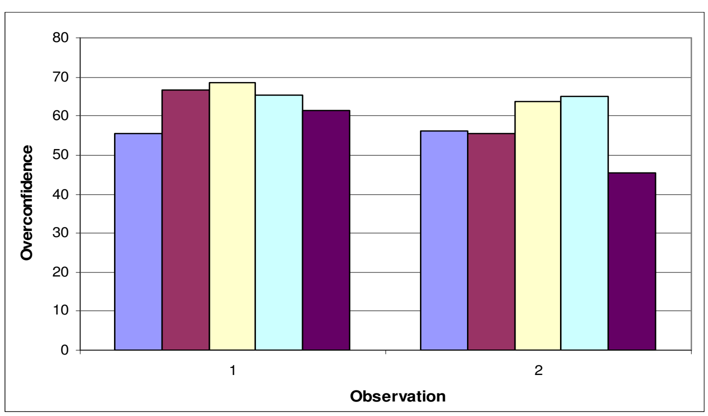


b.

Figure 6: Comparisons of BS(2-8) and BS(9-15): a. rational market; b. overconfident market

Relationship between Overconfidence and Market Parameters

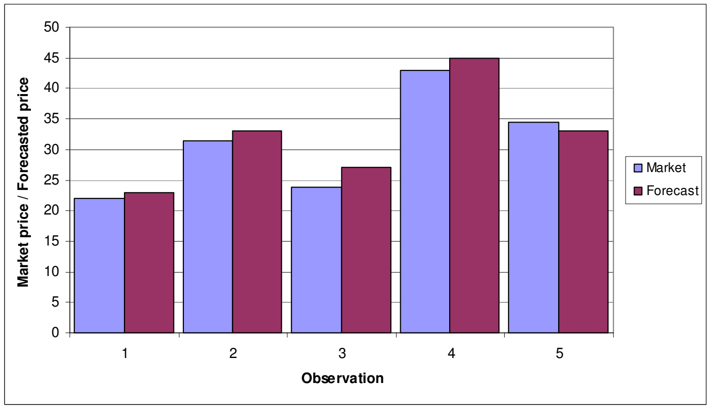
To check if the constructs that are used to measure overconfidence are related to the experimental results, analysis of correlation between the market parameters (specifically average market prices and the measure of trading activity) and the bias scores found from the pre-experimental overconfidence measurement and from the price prediction task is conducted. A positive significant linear relationship between the constructs and the average market price was found (pre-experimental BS: Spearman's rho (8) = 0.75, $p < 0.01$, one-tailed; forecasting BS: Spearman's rho (8) = 0.71, $p < 0.05$, one-tailed). These correlation coefficients are considered to be large. It can be concluded that an increase in overconfidence is associated with an increase in average prices.

Linear relationship between the bias scores found from the pre-experimental overconfidence measurement and found from price prediction, and average trade volume for the whole sample is found to be large (pre-experimental BS: Spearman's rho (8) = 0.69, $p < 0.05$, one-tailed; forecasting BS: Spearman's rho (8) = 0.58, $p < 0.05$, one-tailed). This is in line with the previous research, which found that the increase in overconfidence was paired with the increase in the trading activity, and the decrease in overconfidence was paired with the decrease in trading activity.

6.3 FORECASTING PRECISION

In this section precision of the forecasting activity for the two types of markets is analyzed. I start by graphical comparison of the average price predictions to the average market transaction prices to see whether any conclusions can be drawn about which type of the players (rational or overconfident) was better in forecasting. Figure 7 indicates that the differences between players' predictions and actual prices are small for both types of the markets, thus no clear conclusion can be drawn.

To conduct a statistical test of which group provided more accurate forecasts, differences between the average forecast and the average transaction prices are taken for the each type of the market. Then the hypothesis is tested, that the difference between the average forecast and the average market price equals to zero, versus the alternative one that the difference is not zero, or more than zero. After conducting the Wilcoxon Signed Rank test the null hypothesis cannot be rejected for the rational market ($Z = 1.079$, $p = 0.28$, two-sided). In the case of the overconfident market it is concluded that the forecasts tend to over-predict the real market price significantly ($Z = 1.89$, $p < 0.05$, one-sided).



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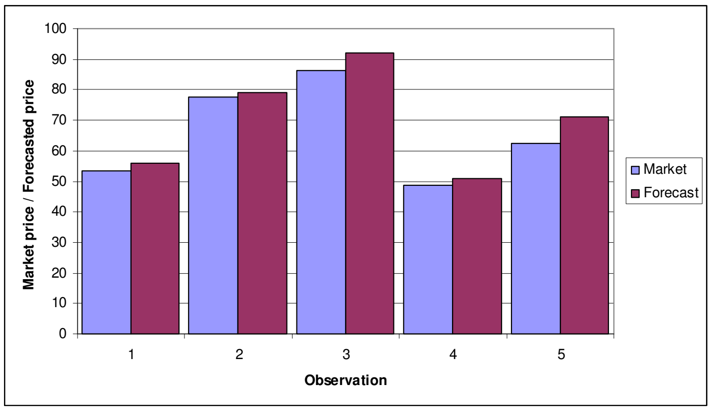

b.

Figure 7: Average forecast and market price: a. rational market; b. overconfident market

In a following step, a test is run if there is a linear relationship between the price prediction and the price. An almost one to one correspondence between the average forecast and the average market price is found (Spearman's Rho (8) = 0.997, $p < 0.001$, one-tailed), which could mean that on average the convergence of beliefs occurred, alongside with the "anchoring" of the subjects on their predicted price values while trading in the market in order to make more money.

6.4 BUBBLE MEASURES

From the previous analysis I obtained some evidence, that although prices, volatility and turnover in rational markets are significantly lower than in overconfident markets, they are still much higher than I have initially hypothesized, and that rational market might also be prone to bubbles, but of a smaller magnitude. Thus in this section experimental treatments will be analyzed in terms of their effect on the bubble's size. I use several measures of the magnitude of bubbles in laboratory markets that were developed by previous authors (e.g. King et al., 1993; Van Boening et al., 1993; Porter and Smith, 1995 as in Noussair and

Tucker, 2003; Dufwenberg et al., 2005). These measures are: Haessel-R2, Price Amplitude, Normalized Absolute Deviation, Normalized Average Deviation, and Velocity. Table 1 reports the values of the measures by session and treatment. Appendix D presents graphs of average market prices and turnover values per period in each of the ten markets.

The Hassel-R^2 (Haessel, 1978) measures goodness-of-fit between average market price per period and the intrinsic asset value. It determines how well the variation in actual market prices (around their mean) is accounted for by the variation in the fundamental value (around its mean), or, in other words, the proportion of the variation in market price which can be explained by variation in fundamental value. Hassel-R^2 converges to 1 if trading prices converge to fundamental values[13]. It is estimated by the R^2 associated to the regression of market prices on the fundamentals, where fundamental value is seen as an estimator for the average market price obtained from some linear model. A comparison of average contract prices obtained from the rational market with those obtained from the overconfident one, reveals that variation in the average prices in the rational market fit variation in the intrinsic value better in most of the sessions. Thus goodness of fit measure is significantly higher in rational markets (Mann-Whitney U = 3, $p < 0.05$, one-sided).

The Normalized (Average) Price Deviation is calculated by summing up all deviations of market contract prices from fundamental value and dividing this sum by the total number of stocks in the market (see Equation 3).

$$NPD = \frac{\sum_{i=1}^{q} \left[P_{ti} - FV_t \right]}{TSN} \tag{3}$$

Here, P_{it} is the price of the ith share in period t, FV_t is the fundamental value in period t, q is the number of contracts in period t, and TSN is the total number of shares in the market[14]. This measure is calculated for each period. Table 1 presents average value for each of the markets.

From the analysis of the NPD it can be determined whether stocks in that period were overpriced or underpriced relative to the fundamental value (a value of under- or overvaluation per-share). Average market value of the NDP can be treated as an indicator of the aggregated average under- or overvaluation per-stock in that market. Figure 8 depicts, for each of the two types of asset market, normalized price deviations from fundamental value per period. Results from rational markets are presented in the upper part of the panel, and from

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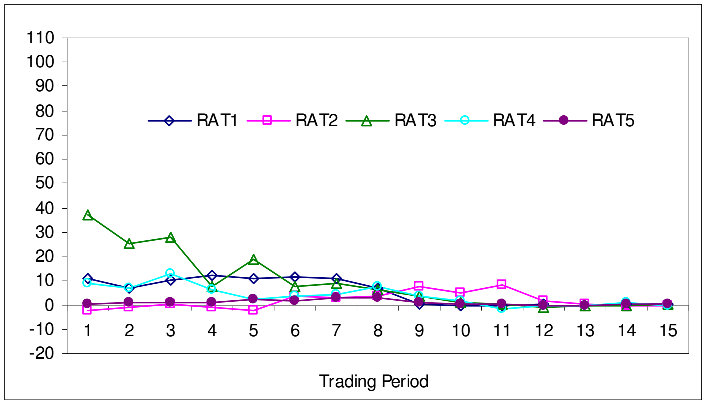
[13] See Dufwenberg et al. (2005) for an explanation why this measure is appropriate to experimental settings with known to the subjects last period.

[14] 18 in each of the ten experimental markets.

overconfident markets - in the lower part. From Table 1 one can see that prices are on average much more overvalued in the overconfident market than in the rational market and this difference is significant (Mann Whitney U = 1, $p < 0.01$, one-sided).



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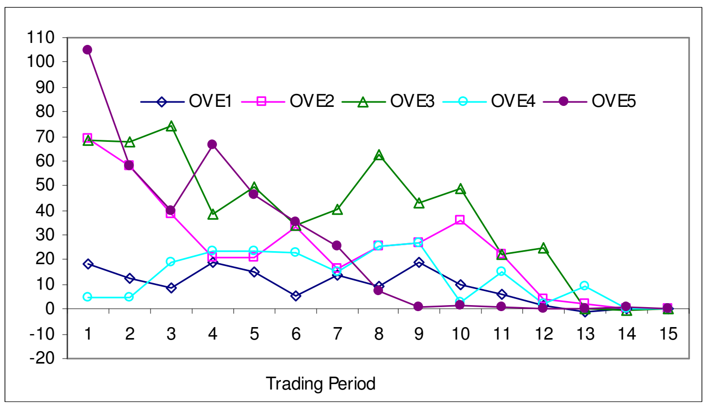


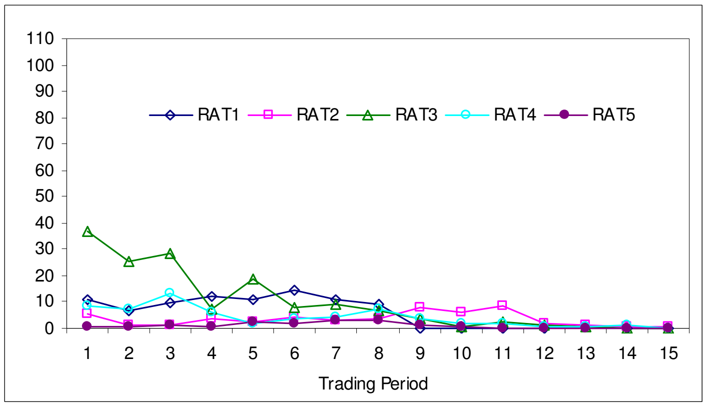
b.

Figure 8: Normalized price deviations from FV by trading period and overconfidence level: a. rational market, b. overconfident market

The Normalized Absolute Deviation is similar to the NPD, and is found as the sum, over all transactions of that period, of the absolute deviations of the market prices from fundamental value, divided by the total number of stocks in the market (see Equation 4). This measure is calculated for each of the periods. Table 1 presents the average value of NAD for each of the markets.

$$NAD = \frac{\sum_{i=1}^{q} \left| P_{it} - FV_t \right|}{TSN} \tag{4}$$

NAD measures the dispersion of the contract prices around the fundamental value, and high values of NAD point out that large number of transactions are being conducted at prices above the fundamental value. Figure 9 depicts absolute price deviations from fundamental value per period for each of the two types of asset market. Results from rational markets are presented in the upper part of the panel, and from overconfident - in the lower part. From the Table 1 one can say that on average contract prices in the overconfident market differ by more experimental units from the fundamental value (22.36 ECU) than in the rational market (4.92 ECU), and this difference is significant (Mann Whitney U = 1, $p < 0.01$, one-sided). Since there are not many cases of per-share undervaluation relative to fundamental value, there are no considerable differences in the values of NAD and NPD.



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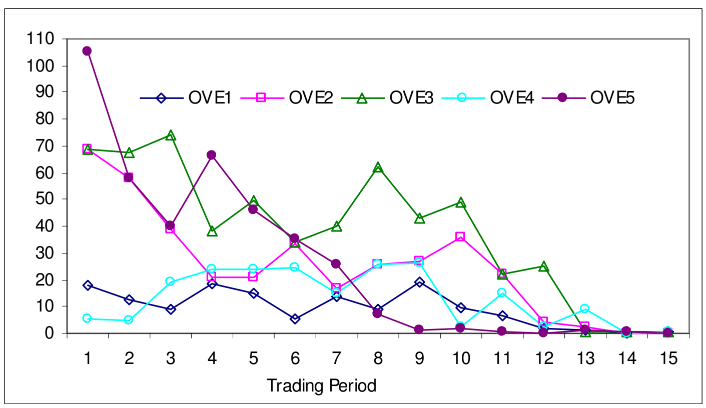

b.

Figure 9: Normalized absolute price deviations from FV by trading period: a. rational market, b. overconfident market

The Price Amplitude (APL) is the maximum value of the shift of average contract price from the fundamental value for an experimental session. It is found as the difference between the maximum positive and the maximum negative deviation of the average period price from the fundamental value of that period, normalized by the initial fundamental value (see Equation 5).

$$APL = \max\left\{\frac{(P_t - FV_t)}{FV_1}\right\} - \min\left\{\frac{(P_t - FV_t)}{FV_1}\right\} \quad (5)$$

Here, P_t is the average contract price and FV_t is the fundamental value in period t. Initial fundamental value FV_1 = 36 ECU.

Higher price amplitudes imply greater bubbles, and larger swings in the market price of the asset relative to fundamental value, evidence that prices have grown away from their fundamental values. From the Table 1 one sees that the price amplitudes in the overconfident market are on average more than twice higher than the amplitudes in the rational markets, and this difference is highly statistically significant (Mann-Whitney $U = 1.00$, $p < 0.01$, one-sided).

Velocity of the Asset is found by dividing the total number of transactions over the experimental session by the total number of stocks in the market. This is the measure of how many times an asset "turned over" the market. This measure is connected to the volume of trade: the higher is the velocity, the higher is the volume of trade, suggesting, according to Noussair and Tucker (2006), either heterogeneous expectations or biases in decision making prompting trade. From the Table 1 one can see that the velocity of stocks in the overconfident market is significantly higher than in the rational market: on average each stock "turned over" 6.27 times in the overconfident market, and only 4.38 times in the rational market. This difference is significant (Mann Whitney $U = 1.50$, $p < 0.05$, one-sided).

Correlation coefficients between bubble measures and measures of overconfidence (pre-experimental and forecasting bias scores) are large and significant (see Appendix E). This provides additional evidence that overconfidence has a significant effect on pricing and trade behavior in experimental asset markets.

Table 1: Bubble measures in each session

Session	Treatment	Hassel-R2	NPD	NAD	Amplitude	Velocity
1	OVE	0.581	9.144	9.308	1.69	4.61
2	OVE	0.535	24.908	24.939	2.25	5.94
3	OVE	0.414	38.257	38.380	2.87	7.89
4	OVE	0.288	13.008	13.196	1.32	6.50
5	OVE	0.877	25.874	25.961	3.33	6.39
6	RAT	0.906	5.745	6.133	1.09	4.56
7	RAT	0.571	1.769	3.412	0.67	5.94
8	RAT	0.944	9.593	9.924	1.67	4.28
9	RAT	0.805	3.781	4.099	1.15	3.56
10	RAT	0.942	0.983	1.017	0.30	3.67

Comparison to other experiments

Table 2 presents data[15] from several experiments which had similar structure to mine: in which 1) the asset market had duration of 15 periods, and 2) the fundamental value was declining each period. In the experiments of Smith, Suchanek, and Williams (1988), Porter and Smith (1995), Van Boening, Williams, and Le Master (1993) bubble and crash pattern in prices is widely observed. On the contrary, experimental sessions of Noussair and Tucker (2006) yield practically no bubbles. On average values of Normalized Absolute Deviation[16] and the Amplitude from the rational treatment are higher than the values from the "no-bubbles" experiment of Noussar and Tucker (2006) but are much lower than those obtained from the other three experiments, thus there is evidence of the smaller deviations from the fundamental value in the rational market treatment. However the turnover value is more than four times higher than that of Nourssar and Tucker (2006). Measures obtained from the overconfident market treatment are consistent with those observed in previous studies of markets of this type.

Table 2: Average values of some of the bubble measures from previous studies

Average values from my experiment	NAD	Velocity	Amplitude
Overconfident market treatment	2.24	6.27	2.29
Rational market treatment	0.49	4.40	0.98
Average values from previous research			
Noussair and Tucker (2006)	0.24	0.99	0.33
Smith, Suchanek, and Williams (1988)	5.68	4.55	1.24
Porter and Smith (1995)	--	5.49	1.53
Van Boening, Williams, and Le Master (1993)	5.12	5.05	4.19

Results presented in this section demonstrate that although bubbles in the rational markets are not completely eliminated, they are less severe in comparison to the bubbles in overconfident

[15] Data on the experiments of Smith, Suchanek, and Williams (1988), Porter and Smith (1995), Van Boening, Williams, and Le Master (1993) are taken from the paper of Noussair and Tucker (2006).

[16] For the comparison of NAD measure from my experiment to those of the other experiments, it has to be divided by 10. The reason is that, previous studies used an expected dividend equal to 0.24 ECU is each period; in my experiment it is 2.40 ECU.

markets: bubble measures calculated for the rational sessions are statistically significantly smaller than the ones obtained from the overconfident sessions. Moreover size of the bubble measures increases with the increase in market overconfidence.

7 CONCLUSIONS

In this paper results of the experiment, designed to investigate the role of market overconfidence in the occurrence of stock-prices' bubbles, are reported. The design of the experiment follows Smith, Suchanek and Williams (1988) and is extended by a new feature, in which markets are constructed on the basis of subjects' overconfidence, measured in pre-experimental studies. In the experiment two types of the markets are conducted: rational and overconfident. Empirical evidence presented in this paper refines differences between market outcomes in the experimental treatments and suggests the existence of the connection between market overconfidence and market outcomes.

When there are no asymmetries in information and all traders have identical assets' and currency endowments, and all traders are "homogenous … with statistically rational dividend and price expectations" (Gilette et al., 1999) a theory predicts that either no trading should occur or some marginal trading at the prices around the fundamental value. Findings from my experiment contradict this assumption. I find that trading activity in rational markets is significantly higher than zero; however it is significantly lower than in the overconfident ones. In the ten sessions of this experiment, it is observed that, higher market overconfidence is accompanied by the higher average market prices and larger deviations of the security prices from fundamental value. Although average prices in both types of markets significantly exceed the fundamental value, prices in rational markets tend to track the fundamental asset value more accurately than the prices in the overconfident markets, and are significantly lower than the average overconfident prices. Moreover, bubble and burst pattern was observed in the aggregated overconfident market, whereas in the rational market no sudden drop of the aggregated market price to the fundamental value occurred. Volatility of the prices and trade volume proved to be significantly lower in the rational market, as it was hypothesized.

Results show that both constructs that were used in the experiment to measure overconfidence (pre-experimental and price-forecasting task bias scores) are linearly strongly dependent, thus overconfidence is a robust phenomenon in my sample. Also it is taken as a proof that both constructs measure the same phenomenon. The strong positive correlation between market outcomes (average market price and trade volume) and overconfidence measures draws conclusion, that an increase in market overconfidence is associated with the increase in average price and trading activity. The reduction of the aggregated average market price and trade volume over the experiment's periods is observed. Thus hypothesis that overconfidence also reduces to the end of the game was tested. For that, based on the data from the first and last seven periods, two bias scores for each market were constructed. Overconfidence measure of the first part of the experiment is, in most markets, lower than that of the second part and this difference is significant. This finding could serve as an explanation why bubbles burst close to the end (or in some cases middle) of the experiment. Menkhoff, Schmidt, and Brozynski (2006) find similar results of decrease in overconfidence with experience; however Kirchler and Maciejovsky (2002) report that overconfidence increases with the experience.

Analysis of the five bubble measures (NPD, NAD, Amplitude, Hassel-R2, and Velocity) revealed that in the markets formed of overconfident subjects bubbles are more likely to occur and that they are significantly larger in magnitude than in rational markets. Large and significant correlation between bubble measures and measures of overconfidence provide additional evidence that overconfidence has significant effect on price and trading behavior in experimental asset markets. Comparison of the selected bubble measures, averaged over five rational and overconfident markets, to the measures obtained in other experiments in which bubble-crash pattern was observed (e.g. Smith, Suchanek, and Williams, 1988) and the experiment of Noussair and Tucker (2006) in which bubbles were practically eliminated, suggests that there is evidence of the smaller deviations from the fundamental value in the rational market treatment than those observed in previous studies of markets of this type. To conclude, the analysis of the bubble measures demonstrates that although bubbles in the rational markets are not completely eliminated, they are less severe in comparison to the bubbles in overconfident markets. Moreover bubble measures increase with the increase in market overconfidence.

Although results presented in this paper shed some light on the effect of overconfidence on the processes in experimental financial markets, further investigation of the topic is desirable. A promising direction in research is examination of what proportion of overconfident subjects in the market is sufficient to influence price departures from fundamental value. For this purpose mixed markets of overconfident and rational subjects should be introduced. It would also be interesting to study if the results obtained were not dependent on the other factors, e.g. risk aversion (if higher overconfidence is not correlated to higher risk aversion). Finally, one could investigate the differences in personal behavior and outcomes on the individual level of the two types of players (rational and overconfident).

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APPENDIX A: BIAS SCORE OF THE VARIOUS (EXPERIMENTAL) SUBGROUPS

Pre-experimental Test					
OBS	Group	Mean	SD	Min	Max
201	All	11.78	10.57	-11.33	43.5
93	Female	9.62	10.68	-11.33	38.89
108	Male	13.37	10.28	-10.28	43.50
	Male vs. female diff.	3.75 (0.57)	--	--	--
Experiments					
OBS	Group	Mean	SD	Min	Max
60	All	11.20	12.08	-5.89	43.50
25	Female	9.96	12.45	-5.89	38.89
35	Male	12.08	11.91	-4.72	43.50
30	Overconfident	21.33	8.26	10.17	43.50
30	Rational	1.06	4.03	-5.89	6.78
	Male vs. female diff.	2.13 (0.81)	--	--	--
	Overconfident vs. rational diff.	20.27 (0.00)	--	--	--
OVE market	Male vs. female diff.	-0.65 (0.64)	--	--	--
RAT market	Male vs. female diff.	0.68 (0.76)	--	--	--

APPENDIX B: TRANSLATION OF INSTRUCTIONS

INSTRUCTIONS

In this experiment we are going to create a market in which you will trade units of a fictitious asset (i.e. "shares" of a "stock") that earn a dividend over a series of trading periods. The instructions are simple, and if you follow them carefully and make appropriate decisions YOU MAY EARN A CONSIDERABLE AMOUNT OF MONEY which will be PAID TO YOU IN CASH at the end of the experiment.

The currency used in the market is called Gulden. All trading and earnings will be in terms of Guldens. At the end of experiment, the Guldens that you have accumulated will be converted to euros at the exchange rate of 0.27 EUR for each 10 Guldens and you will be paid in euros. Note that the more Guldens you earn, the more euros you get!

Duration of the experiment

The market will take place over a sequence of 15 trading periods. You may think of each trading period as a "business or trading day". Each trading period has a maximum length of 180 seconds at which time the market will close for that period. The remaining time left in each period will be shown by a clock on your computer screen.

The market period can be ended before the trading time expires by a UNANIMOUS vote of all participants in the market to end trading for that period. This alternative stopping rule allows the group as a whole to bypass the usual 180 second stopping rule. Each participant can vote by pressing the key labeled VOTE. Pressing VOTE and thus voting to end that market period does not eliminate you from participating further in trading for that period; it simply says that you are ready to end trading in the current period and move on to the next period.

Initial Endowments of Participants

Each trader at the beginning of the trading game is endowed by STARTING CAPITAL equal to 300 Guldens and 3 units of assets. During the experiment you may purchase or sell assets. At the END of each trading period you will receive a DIVIDEND on EACH UNIT asset unit in your inventory.

Dividend Process

You will not know the exact value of your dividend per unit prior to the end of each trading period. At the end of each trading period you will be told the value of your dividend per unit and your dividend earnings (dividend earnings = assets × dividend per unit). They will be added to your working capital.

Your dividends are drawn randomly each period. The possible values of your dividend per unit and the associated probability of occurrence are given below:

dividend	0.0 Gulden	0.8 Gulden	2.8 Gulden	6 Gulden
probability	1/4	1/4	1/4	1/4

Thus, the <u>average dividend</u> over many draws is 2.4 Gulden (=0.0*1/4+0.8*1/4+2.8*1/4+6*1/4)

Before each trading period information on potential income from holding your assets till the end of the experiment (15^{th} period) is provided to assist you in formulation of your market decisions. The following information is given to you: maximum, average and minimum possible dividends (the same in each period), and maximum, average and minimum earnings per inventory unit over the remaining experiment periods.

Reward scheme

Your decisions regarding the purchase and sale of asset units and your end-of-period inventory level (dividend earnings = dividend per unit × end-of-period inventory) should rest on the fact that at the end of the experiment your cash earnings are based on your final working capital which equals:

(300 Gulden starting capital) + (dividend earnings) + (asset sales revenue) - (asset purchase cost).

At the end of the game your assets have no value!

The rules of the Experimental Market

Suppose we open the market for Trading Period 1 and that you wish to enter your bid or offer. To enter bid (price at which you wish to buy an asset): type in the price for which you wish to buy an asset. Then click the box labeled "ENTER BID". To enter offer (price at which you wish to sell an asset): type in the price at which you wish to sell your asset and then click on the box "ENTER OFFER".

Notice that bids are going to be ranked in the decreasing order on the right side of the screen, and sale offers in the increasing order on the left-hand side of the screen.

Suppose now, that you wish to accept Seller's offer and purchase one unit of the asset. To do this first click the appealing price, standing in the column named "SALES OFFERS", and then click the button labeled “ACCEPT OFFER”. If you wish to accept Buyer’s bid click on the appealing price, standing in the column “BIDS” and then click the button labeled “ACCEPT BID”. Note that after a contract has been made, all bids and offers are erased and a new auction begins.

Upon buying/selling one unit of the commodity the transaction price (sales or purchase) will be added to (if you have sold), or subtracted from (if you have bought) your working capital immediately, same is valid for the assets’ inventory.

Your inventory at the end of a trading period is carried over to the beginning of the next trading period. At the end of each trading period your working capital will be increased by the amount of your dividend earnings (dividend earnings = number of units in your inventory × dividend per unit).

You can buy asset units as long as your working capital is greater than or equal to the purchase price. If you attempt to enter a bid or accept a seller’s offer that is greater than your working capital, the action will be ignored and you will receive an error message on your display screen. You can sell assets as long as your inventory is greater than zero. If you attempt to enter an offer or accept a buyer’s bid, when you have no assets in your inventory, the action will be ignored and you will receive an error message on your display screen.

Market Information

At the end of each trading period you will have the opportunity to see the market price summary information from the past trading periods, which will include such information as average market contract price, the highest, and the lowest market price, volume traded and dividend for that period.

__Additional Means to Earn__

At the end of each trading period you will be asked to enter a forecast of the average contract price in the next trading period. Information on the current period's mean price will be available for your inspection prior to entering a forecast. Information on your forecasting accuracy, consisting of the actual price, and your price forecast from the past periods will be available to your inspection after entering a forecast.

You will be paid for your predictions, based on their accuracy. The closer the prediction is to the actual average market price, the higher is the reward. Reward scheme for predictions' accuracy:

Level of Accuracy	Earnings
+/- 5% from the actual price	3 Gulden
+/- 12.5% from the of actual price	1 Gulden
+/- 25% from the actual price	0,5 Gulden

Your income from "forecasting part" will be converted to euros at the same rate as mentioned above and paid to you at the conclusion of the experiment.

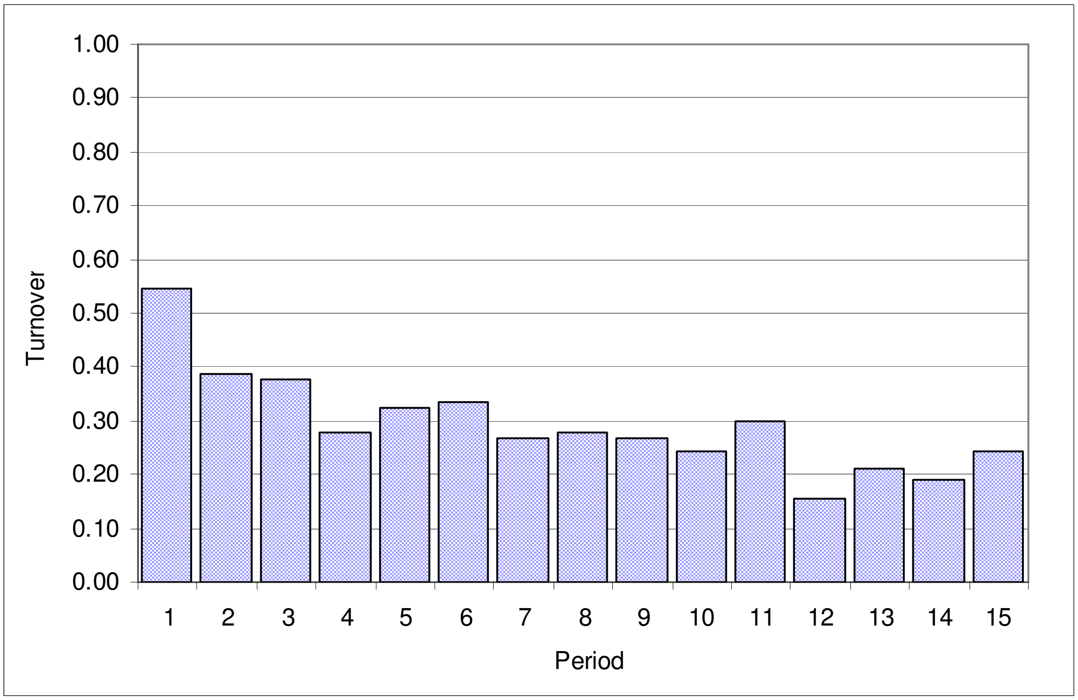
In the gap marked "Confidence level" you have to write how confident you are that your price forecast is correct! You can use any number between 0% and 100% to express your confidence, that your forecast is correct. Thus 0% means that you completely do not believe that your forecast can be true, and 100% means that you are completely sure that your Forecast will be correct.

This is the end of the instructions!

If you have a question that was not fully answered by the instructions please raise your hand and ask the experiment monitor before proceeding.

BEWARE! YOUR EARNINGS MAY SUFFER IF YOU PROCEED INTO THE MARKETPLACE WITHOUT UNDERSTANDING THE INSTRUCTIONS!

APPENDIX C: JOINT AVERAGE TURNOVER DEVELOPMENT (a. Rational market, b. Overconfident market)



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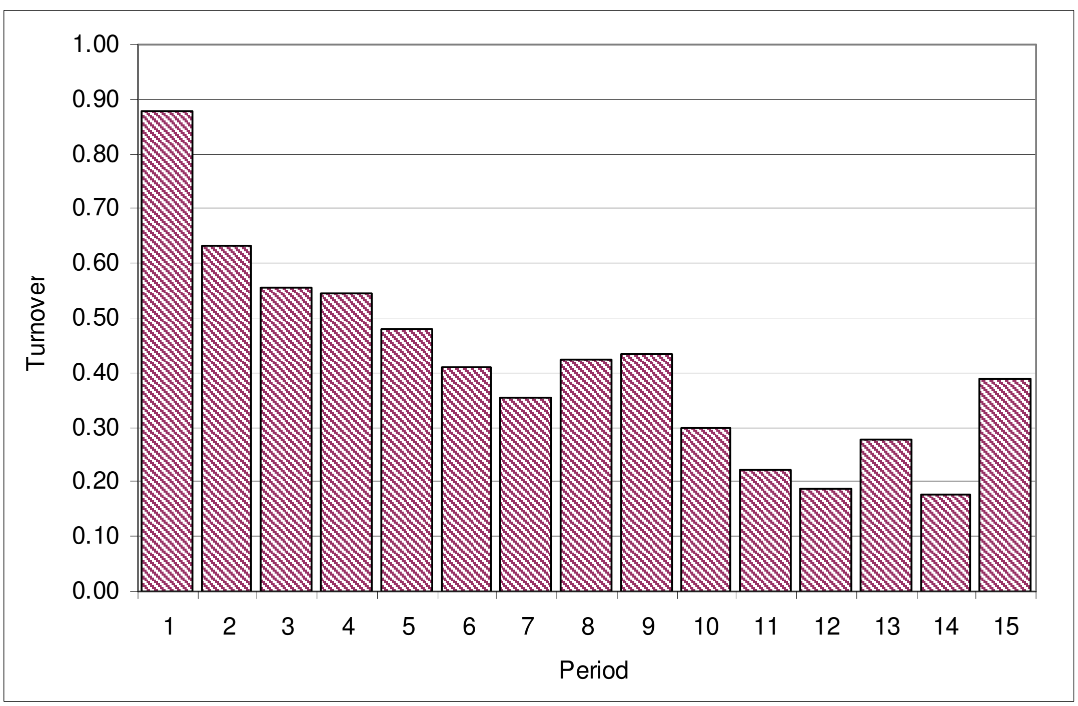
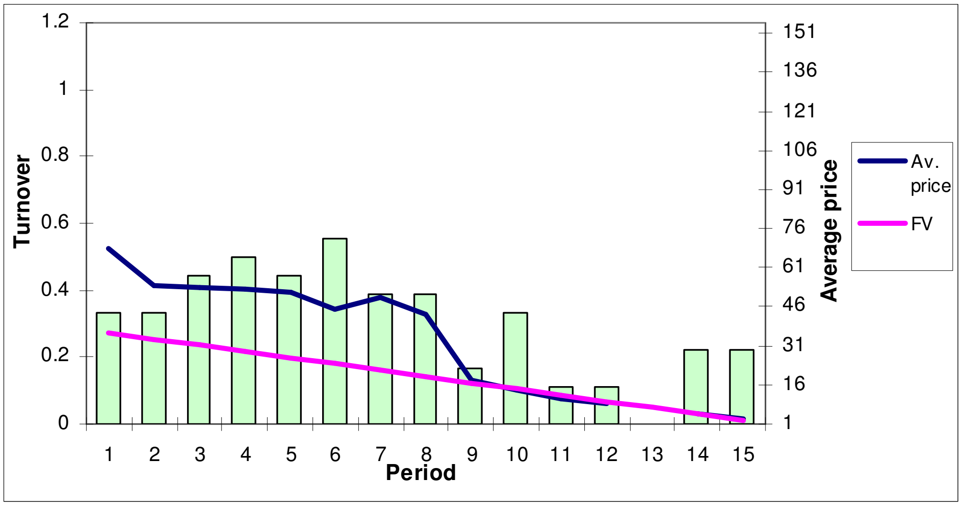
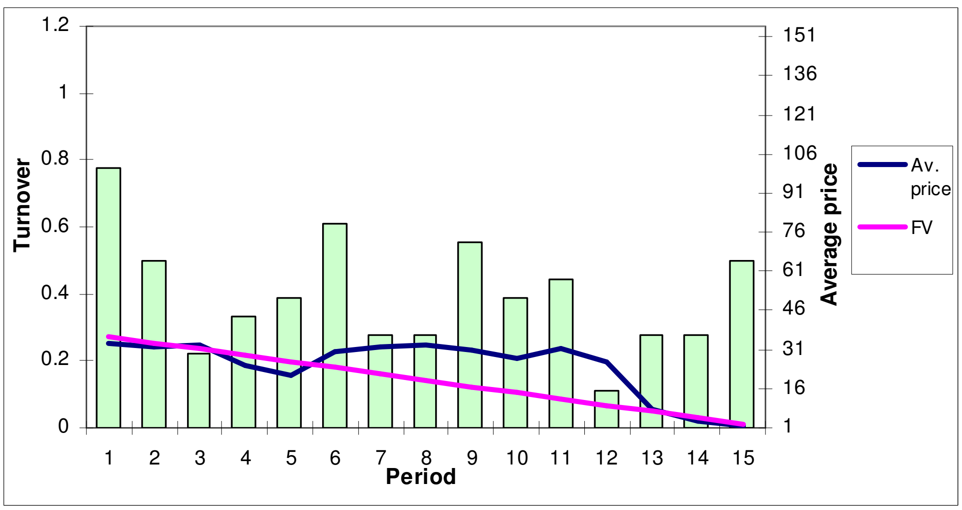


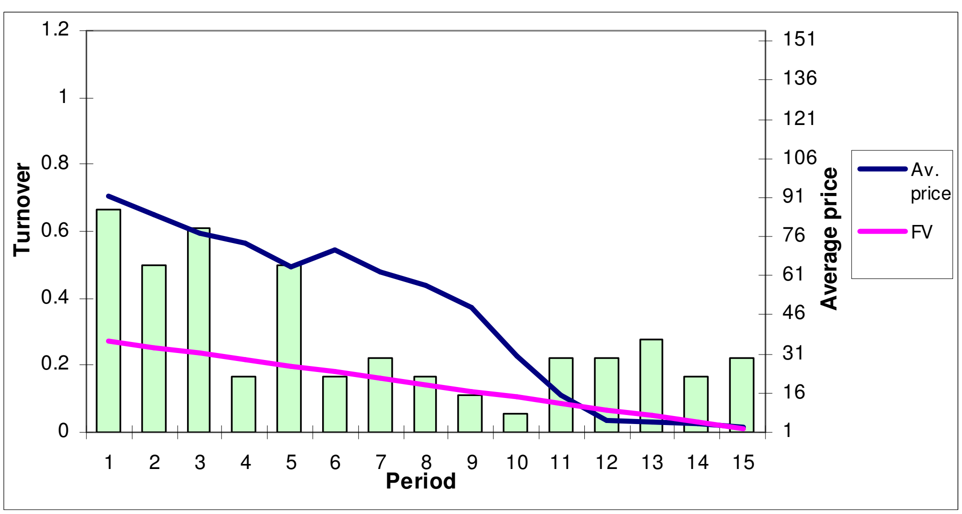
b.

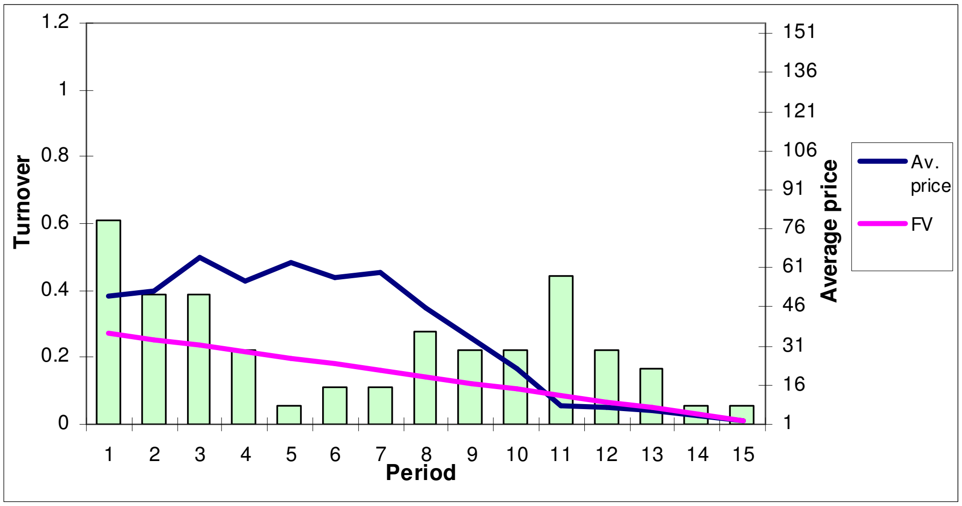
APPENDIX D: DEVELOPMENT OF AVERAGE PRICE AND TRADE VOLUME IN EACH MARKET

Rational Markets





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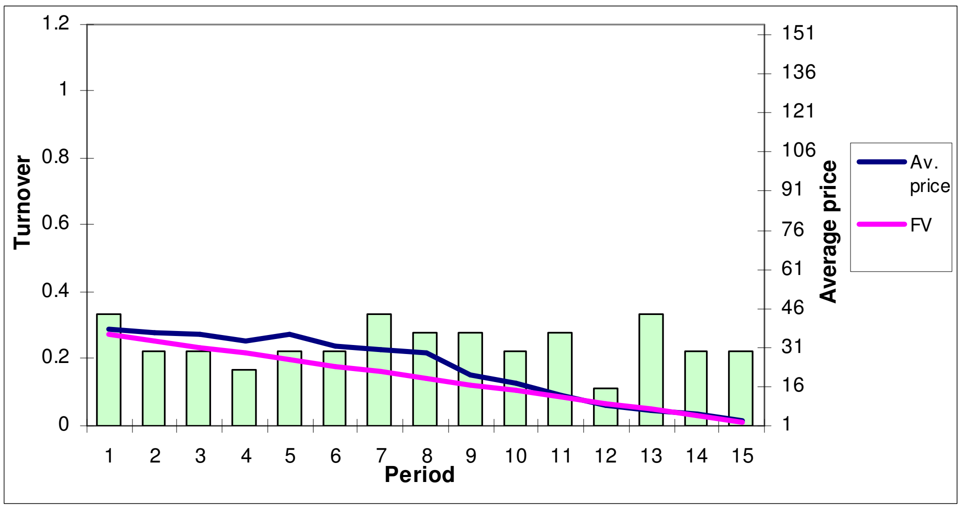
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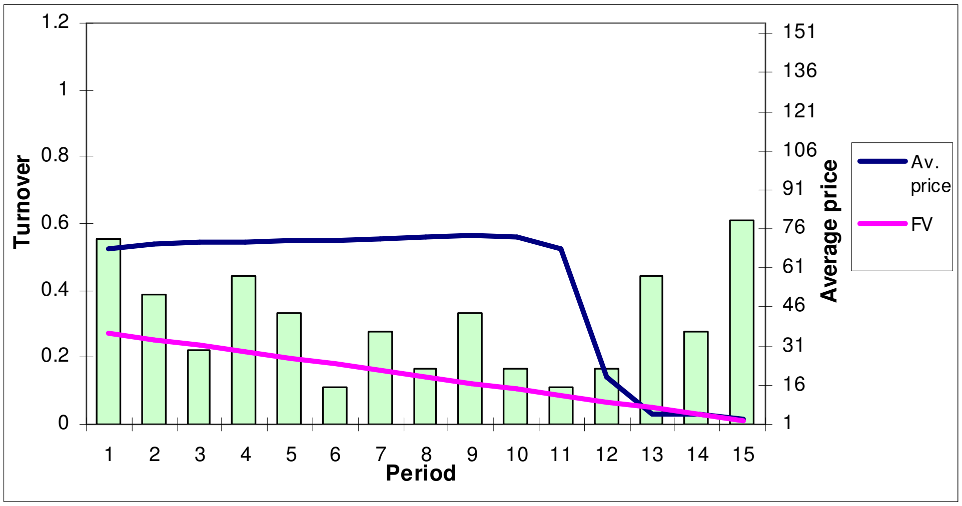
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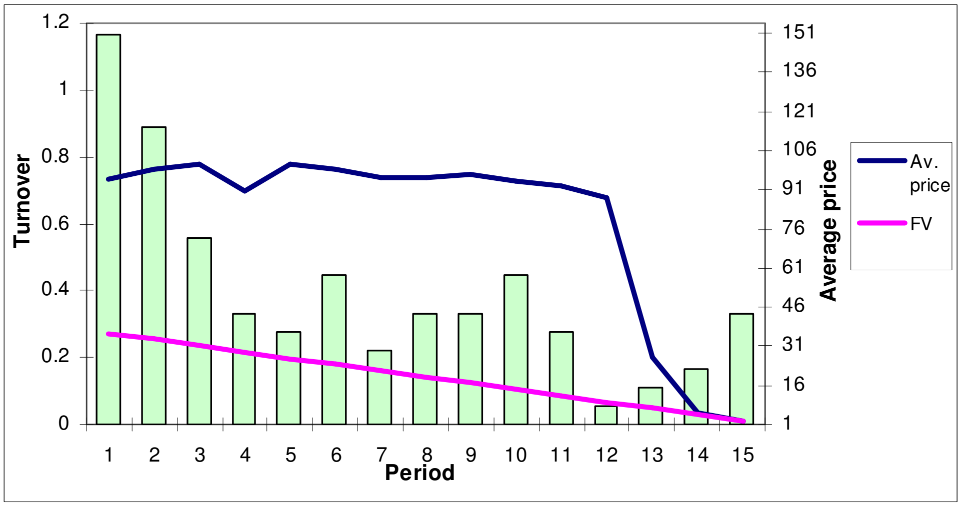
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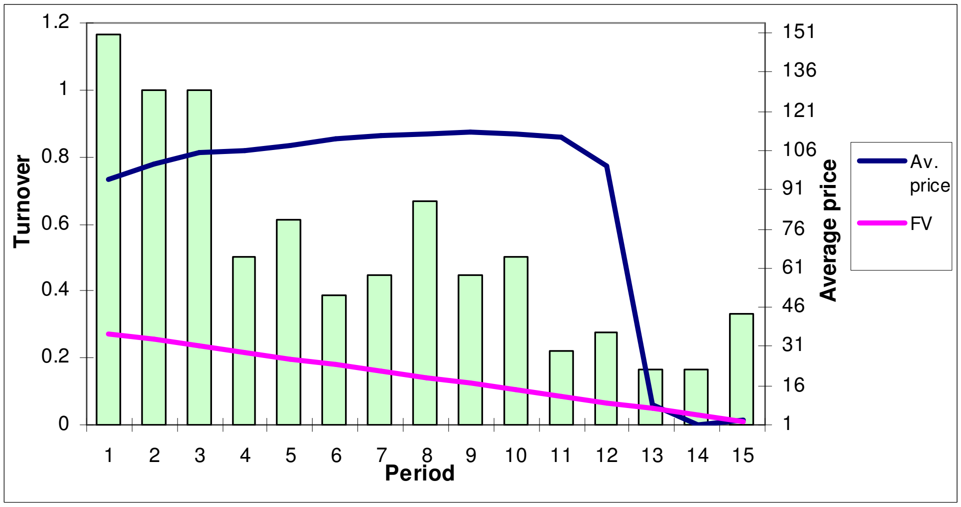
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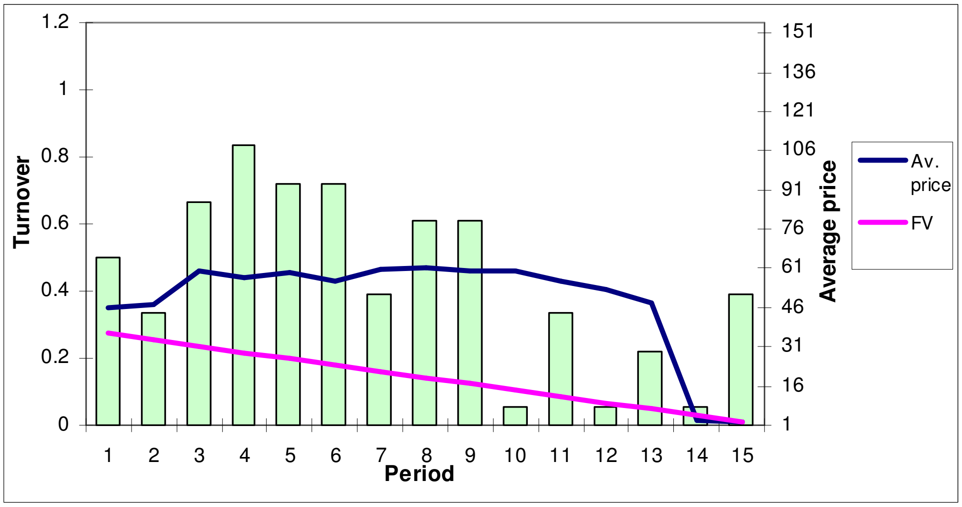
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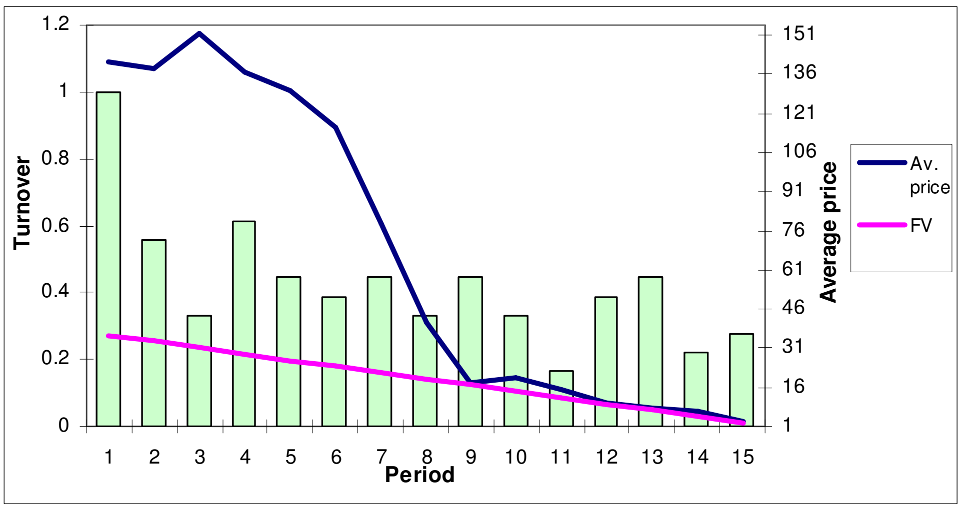
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Appendix E: Spearman's Rho Correlation Coefficient between Bias Scores and Bubble Measures

	BS (pre-experimental)	BS (forecasting)
Hassel R2	-0.770 (p<0.05, one-sided)	-0. 673 (p<0.05, one-sided)
NPD	0. 745 (p<0.01, one-sided)	0.636 (p<0.05, one-sided)
NAD	0. 745 (p<0.01, one-sided)	0.636 (p<0.05, one-sided)
Velocity	0. 717 (p<0.01, one-sided)	0.550* (p < 0.1, one-sided)
Amplitude	0. 661 (p<0.05, one-sided)	0.515 (p<0.1, one-sided)

* - based on 9 observations