Unleashing Animal Spirits - Self-Control and Bubbles in Experimental Asset Markets

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June 11, 2014

Abstract

We exogenously vary the ability to exert self-control of traders in experimental asset markets. Markets with participants with lower self-control capacities exhibit substantially higher price bubbles. Not only does mispricing increase compared to the control condition, but also overpricing is larger when participants lack the resources to exert self-control. Our treatment effect cannot be explained by differences in cognitive capacities or risk attitudes, since measures for both seem unaffected by our treatment. This study therefore suggests that reduced self-control can contribute to the emergence of bubbles in experimental markets.

JEL codes: G02, G11, G12, D53, D84

Keywords: Behavioral finance, trader behavior, self control, experimental asset markets, bubbles

Very preliminary version. Do not quote.

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1 Introduction

In this paper we explore the effect of reduced self-control capacities and thus a larger reliance on the impulsive system in an experimental double auction market. Popular guidebooks on the psychology of (stock market) investing suggest to use self-control in order to suppress impulsive and emotion-driven behaviour. Typically, self-control is brought up as a means to guard against undue optimism, actions motivated by emotional responses and impulsive decisions. Furthermore, guidebooks stress, that self-control is needed in order to stick to plans. All of these are highly important abilities in a market environment where one's portfolio constantly fluctuates in value and sometimes temporary losses have to be accepted or running with the herd has to be avoided. Psychologists have defined self-control as the capacity to override or inhibit undesired behavioural tendencies, such as impulses, and to refrain from acting on them (Tangney et al., 2004). In recent years researchers have come to understand, that self-control is a limited resource that works like a muscle and thus can be temporarily exhausted (Baumeister et al., 1998). According to dual-systems perspectives of cognitive processing different systems of information processing underlie impulsive, largely automatic forms of behaviour on the one hand (system one) and deliberate, largely controlled forms of behaviour on the other (system two) (Hofmann et al., 2009). The deliberative controlling system is effortful and depends on control resources (i.e. self-control resources). If resources are low, reflective operations may break down leading to a dominance of impulsive reactions, which might be in conflict with objective reasoning. Psychologists have developed experimental methods of weakening self-control, thus leading to a dominance of the impulsive system one in decision making (Baumeister et al., 1998; Hofmann et al., 2009), which we rely on in this study.

Economic models of financial decision making have in recent years incorporated the trait self-control as an important individual contributor to the emergence of behavioural biases such as time inconsistent decision making. However, asset markets and auctions have not been connected to self-control so far. Often, self-control problems have been described as intrapersonal conflicts between 'multiple selves' starting with Thaler and Shefrin (1981). Self-control has also been modeled as quasi-hyperbolic discounting, i.e. relative overweighting of present utility (Laibson, 1997), and as cue-triggered temptation (Gul and Pesendorfer, 2001). A lack of self-control causes decisions which counteract long-run interests of individuals, e.g. addictive behavior, under-saving and procrastination (Bucciol et al., 2010). Furthermore, lack of self-control has been connected with overspending (Heidhues and Koszegi, 2010).

Empirical studies have on the one hand used survey responses to elicit the relationship between the trait self-control and outcomes of financial decisions as suggested by Ameriks et al. (2007) and on the other hand exogenously reduced the capacity of individuals for further self-control based on the experimental methods established by Baumeister et al. (1998). Using various tasks[1] people's capacity for further self-control can be reduced and the impact of this treatment in domains such as risk-taking (e.g. Bruyneel et al. (2009)), social preferences (e.g. Furtner and Kocher (2013)) and tendencies for cognitive biases (De Haan and Van Veldhuizen, 2012) have been considered.

So far, however, the influence of self-control in market settings has not been looked at empirically. In this paper we focus on the impact of a reduction of self-control resources on market outcomes in an experimental asset market, in particular on the emergence of bubbles. We thus take the concept of self-control, which has been mainly investigated in individual decisions without interactions, and transfer it to an incentivized asset market.

We use the double auction market setting which was inspired by the work by Smith et al. (1988) and in which bubble formation has been studied by many researchers.[2] So far, considering the role of psychological concepts, emotions and overconfidence have been studied as contributors to the formation of bubbles in double auction markets (e.g. in Breaban and Noussair (2013) and Michailova and Schmidt (2011) respectively). We are the first to exogenously reduce self-control resources in a double auction environment to consider its effects on aggregate market outcomes.

Our findings support the notion that self-control might play a role in markets with individual interactions. We deplete individuals using the Stroop task (Stroop, 1935) – one of the most widely used tasks in the psychological literature on ego depletion (Hagger et al., 2010). In order to control for possible channels via which reduced self-control might impact market outcomes, we elicit individual certainty equivalents for a lottery and use the cognitive reflection test (CRT), which has been shown to be a useful measure of cognitive skills (Frederick, 2005) and a good predictor for susceptibility towards cognitive biases (Toplak et al., 2011). In our experiment, reduced self-control resources significantly impact aggregate market outcomes. We find that asset bubbles are more pronounced in the sense that both mispricing as well as overpricing are increased. Neither of our control variables can account for the differences in market outcomes between our treatment and control groups. We interpret our findings as the result of participants' stronger reliance on their impulsive system 1 for decision making.

The structure of our paper is the following: Section 2 gives an overview about related literature, section 3 explains and motivates our design and section 4 presents the results from our experiments. In section 5 we discuss possible channels for our results. Section 6 contains our conclusion and possible directions for future research.

[1] See Hagger et al. (2010) for a survey on self-control exhaustion (commonly called 'ego depletion' and depleting tasks.

[2] For recent survey articles on experimental research on asset pricing in general and bubbles in particular see the surveys by Noussair and Tucker (2013) and Palan (2013) respectively.

2 Related Literature

Self-control if often defined as the capacity to override or inhibit undesired behavioural tendencies, such as impulses, and to refrain from acting on them (Tangney et al., 2004). According to recent psychological research self-control relies on limited resources and thus works like a muscle, i.e. the exertion of self-control depletes energy for further acts of self-control. This ability replenishes after rest, can be trained and is an individual trait that differs between people (Baumeister et al., 1998; Muraven et al., 1999; Muraven and Baumeister, 2000; Tangney et al., 2004; Muraven, 2010). Self-control can thus be regarded as the resource which is used up, when individuals try to control their impulses and initial acts of self-control might negatively impact subsequent decision making, if it also requires self-control. The paradigm of exogenously reducing self-control to consider its impact on people's decisions and performance in subsequent tasks goes back to the seminal work by Baumeister et al. (1998), which has sparked a lot of interest in social psychology. Self-control can be related to dual-systems perspectives of decision making. These perspectives of cognitive processing share the general assumption, that structurally different systems of information processing underlie the production of impulsive, largely automatic forms of behaviour on the one hand (system one) and deliberate, largely controlled forms of behaviour on the other (system two). The deliberative controlling system is effortful and depends on control resources (i.e. self-control resources). Thus if resources are low, reflective operations may break down leading to a dominance of impulsive reactions, which might be in conflict with objective reasoning (Hofmann et al., 2009). Psychologists have developed experimental methods of weakening self-control, thus leading to a dominance of the impulsive system 1 in decision making (Baumeister et al., 1998; Hofmann et al., 2009), which we rely on in this study.

There are some theoretical models in economics on self-control and willpower, however asset markets and auctions have not been connected to self-control so far. In the models at hand, a lack of self-control causes decisions which counteract long run interests of an individual, such as addictive behavior, under-saving and procrastination (Bucciol et al., 2010). Popular ways to model self-control are intrapersonal conflicts between multiple selves with diverging interests (Thaler and Shefrin, 1981; Fudenberg and Levine, 2006), models of quasi-hyperbolic discounting, i.e. relative overweighting of present utility (Laibson, 1997), and the temptation model of Gul and Pesendorfer (2001), which basically models self-control errors as cue-triggered mistakes (see also Benhabib and Bisin (2005); Bernheim and Rangel (2004); Kim (2006)). Lack of self-control has also been connected with overspending (Heidhues and Koszegi, 2010). In more recent models, willpower has been explicitly modeled as an internal depletable resource (see Ali, 2011; Fudenberg and Levine, 2012; Ozdenoren et al., 2012).

One strand of the empirical literature in economics has worked with survey evidence in order to determine the relevance of self-control for various economic decisions. Ameriks et al. (2003) look at the connection between wealth accumulation and self-control in a sample of US households. They attribute differences in savings among households to differing 'propensities to plan' – i.e. different inclinations to exert self-control. Gathergood (2012) conducts a similar study for a UK sample. He finds a positive association of lack of self-control and consumer over-indebtedness. Interestingly, an experimental study by Vohs and Faber (2007) shows, that the availability of self-control resources predicts whether people can resist impulse buying temptations, hinting at a causal relation from availability of self-control resources on savings and spending behavior of individuals.

Another strand of the empirical economics literature has used laboratory settings, where individuals' internal self-control resources can be exogenously depleted.[3] This research has mainly focused on the effects of reduced self-control resources on individual preferences and decisions, e.g. time preferences, and on tasks, in which biases are often observed. The effect of such treatments on risky decision making has been studied with mixed results: On the one hand, Bruyneel et al. (2009) find that 'ego depletion' caused by active mood regulation induces decision makers to take more risks. On the other hand, Unger and Stahlberg (2011) find an increase in risk aversion. Bucciol et al. (2011, 2013) show in field experiments with children and adults that self-control depletion leads to reduced productivity on subsequent task performance. De Haan and Van Veldhuizen (2012) find no effect of depletion via a repeated Stroop task on the performance in an array of tasks, in which framing effects are typically observed, such as anchoring effects and the attraction effect, where adding a dominated decoy option to the choice between two options makes people choose the option dominating the decoy more often. Furtner and Kocher (2013) find that individuals with reduced self-control free-ride more often in a public goods game.

Smith et al. (1988) were the first to use a very similar design of experimental double auction markets to the one present in this paper. They found bubbles in the majority of their markets and thus spawned a wide array of empirical papers analyzing the reasons for such bubbles. There are some results from these studies, which can be related to the present work. Subject confusion is one of the factors, which contribute to bubbles, since subjects do not fully understand instructions (Huber and Kirchler, 2012) and bubbles are significantly reduced when a stock with decreasing fundamental value – the usual fundamental value process of stocks in Smith et al. (1988) markets – is more intuitively explained as being the stock from a depletable gold mine (Kirchler et al., 2012). Another factor that has been found in the literature to contribute to bubbles, which is possibly related to our findings, is myopic adjustment of expectations. Some investors might form

[3]Building on the seminal work by Baumeister et al. (1998) various 'ego-depleting' tasks have been studied. For an overview see the meta study by Hagger et al. (2010).

beliefs backwards-looking taking past experiences as predictors for future price movements. Thus investors become momentum traders who buy after positive price changes expecting further upturns and similarly sell after negative price movements. De Long et al. (1990) show in their model, that such traders could drive rational speculation in a market and thus contribute to bubbles. Indeed, Haruvy et al. (2007) found myopic adjustment of expectations to be correlated with bubbles in double auction asset markets. Another factor affecting bubble sizes are emotions. Andrade et al. (2012) find that inducing excitement prior to the market stage induces bubbles higher in magnitude and amplitude relative to other emotions and a neutral condition. In a similar study, Lahav and Meer (2012) find that inducing positive mood leads to higher deviations from fundamental values and larger bubbles. The role of emotions in experimental asset market has also been evaluated using Likert scales (Hargreaves Heap and Zizzo, 2011) and face reading software (Breaban and Noussair, 2013). Results from these experiments indicate that excitement (Hargreaves Heap and Zizzo, 2011) and positive emotional state before market opening (Breaban and Noussair, 2013) are correlated with increased prices relative to fundamental values. Additionally, fear at the opening of the market is correlated with lower price levels (Breaban and Noussair, 2013).

3 Design

Our experiment consisted of four parts: Participants initally played one test period of the double auction market to become familiar with the computer program and market structure. Earnings from this test period did not count towards final earnings. Participants then started part two: the Stroop task, intended to reduce their ability to exert self-control. In part three we elicited a measure for risk aversion and cognitive skills. Part four was the actual asset market. We conducted the experiment in October 2013. 160 participants took part in ten experimental sessions at Munich Experimental Laboratory (MELESSA). We obtain 16 independent observations, eight for each of our conditions. The experiment was programmed using z-Tree (Fischbacher, 2007) and recruiting was done with ORSEE (Greiner, 2004). Experiments lasted about 90 minutes and participants earned 18.18 € on average. We only invited students who had never participated in an asset market experiment before. We also excluded students familiar with the CRT and Stroop task. Prior to the start of the experiment, subjects received written instructions for all parts of the experiment that were read aloud to ensure common knowledge.[4] Any remaining questions were answered in private.

In order to identify the causal effect of reduced self-control capacities on asset market trading behavior, we employ a single treatment variation. In our condition *TREATMENT* subjects were subject to ego depletion, whereas in condition *CONTROL* they were not. We achieved ego depletion

[4]The translated instructions can be found in Appendix A.1.

by implementing a version of the Stroop task (Stroop, 1935) which differed between *TREATMENT* and *CONTROL*. For a duration of five minutes, subjects were given a black screen on which words in different colors showed up, every word in turn being a color (e.g. the word ‘blue’ printed in red color). Subjects then had to select the color the word was printed in (not the written word itself) before the next item appeared. A conflict between the color of the word and the word itself is widely accepted to reduce self-control resources (Hagger et al., 2010). Therefore we ensured that our condition *TREATMENT* always exhibited a conflict between color and word. Our condition *CONTROL* instead did not incorporate a conflict except for every 70th item. By having a conflict every now and then, we were able to ensure that subjects in the *CONTROL* condition still took the task seriously. In both conditions, participants received a flat payment of 3 € in order to avoid wealth effects to confound our results and they were only presented one item at a time until the time of 5 minutes was over or they completed 255 items, whichever came first.[5] Since our only difference between *TREATMENT* and *CONTROL* is the amount of conflicting items in the Stroop task and conflict has been associated with reduced self-control capacities we feel confident to argue that our results stem from differences in ‘ego depletion’ and hence reduced self-control.

After completion of the Stroop task, we asked subjects how strenuous they perceived the task to be. Afterwards, subjects answered the three questions from the CRT. Since ego depletion is said to reduce cognitive skills (Schmeichel et al., 2003) we intended to employ a measure that accounts for differences in cognitive reasoning. The CRT is well suited for this purpose as we needed a reliable and not very time-consuming measure. Subjects were paid .5 € for every correct answer but did not learn their earnings and correct answers until after the end of the experiment. Then, we elicited individual certainty equivalents (CE) for a lottery using a multiple price list in order to obtain a measure for risk attitudes. The lottery paid either .20 € or 4.20 € with equal probability and the possible fixed amounts subjects could pick were equally spaced between the two outcomes. We allowed subjects to only switch once from the lottery to the fixed amount. In order to determine payment, the computer randomly picked one of the ten decisions and implemented the preferred option. Again, participants were not informed about their earnings from this part until after they had completed the ten period asset market in order to avoid wealth effects.

Subjects then immediately commenced the asset market. Participants can trade a single dividend-carrying asset over the course of ten periods in a continuous double auction market with open order books similar to Smith et al. (1988). The asset paid a dividend of either ten or zero points with equal probability at the end of every period and was worthless after the final period (declining fundamental value). The realized dividends were added to a players’ cash holdings (increasing

[5] Only two of the 160 subjects managed to complete all 255 items in less than five minutes, both of which were assigned to condition *CONTROL*. Both participants however did only have less than 30 seconds left when finishing all items.

cash-to-asset ratio). Each period lasted 120 seconds and each market consisted of ten traders. All subjects received an initial endowment of cash and assets and all assets and cash were always carried to the next period. Short selling and money borrowing was ruled out.

During a trading period, traders could make offers to sell or buy stocks as well as accept open offers. Inactive offers remained in the books until the beginning of the following period and partially executed deals continued to be listed with their residual quantities only. Before the first period, subjects received either 1000 points in cash and 60 assets or 3000 points in cash and 20 assets. In each market there were exactly five traders with each of these endowments. We explicitly stated that assets were worthless after the tenth period and provided subjects with a detailed table where they could retrieve the fundamental value of an asset at any point in time. After every period, subjects could see the average trading price as well as the realizations of current and all past dividends on a dedicated screen. Our design therefore perfectly resembles the baseline market used in Kirchler et al. (2012), a feature that enables us to compare our data to theirs. After the final period, we converted participants' cash holdings into Euros using an exchange rate of 500 points = 1 €.

Following the asset market part, subjects were asked to fill in a standard questionnaire eliciting demographics and background data. We also asked participants how tired they felt after the experiment and if they experienced the experiment to be strenuous. We then paid all subjects in private and dismissed them from the laboratory.

4 Results

4.1 Test measures

In order to appropriately measure our markets' tendencies to exhibit bubbles we do not only compare trading prices against the fundamental value of the asset, but also make use of bubble measures commonly used in the literature. Stöckl et al. (2010) discuss the advantages and disadvantages of several bubble measures. In the following we adopt their approach and check our market evolution using *Relative Absolute Deviation* (RAD) and *Relative Deviation* (RD) to identify miscpricing and overshooting respectively. RAD is constructed as a time average of the absolute difference between mean market prices and fundamental value in a given period relative to the absolute average fundamental value of the entire asset market. RD is a time average of the difference between mean market prices and fundamental value in a given period relative to the absolute average fundamental value over all periods. These two measures differ with respect to how the difference between mean price and fundamental value in a given period enters, either in absolute terms or not.[6] The advantage

[6]A formal representation would be: RAD = $\frac{1}{T}\sum_{t=1}^{T}\frac{|P_t - FV_t|}{|\bar{FV}|}$ and RD = $\frac{1}{T}\sum_{t=1}^{T}\frac{P_t - FV_t}{|\bar{FV}|}$, where P_t is the volume-adjusted mean price in period t, FV_t is the fundamental value of the asset in period t and $\bar{FV}$ denotes the

of this approach is that the measure is independent of the number of periods as well as the actual size of the fundamental value and that they increase in the difference between fundamental value and market prices. Both measures are easy to interpret. A RAD of .1 means that prices are on average 10 % off fundamental value, while a RD of .1 indicates that prices are on average 10 % above fundamental value.

4.2 Market evolution and bubbles

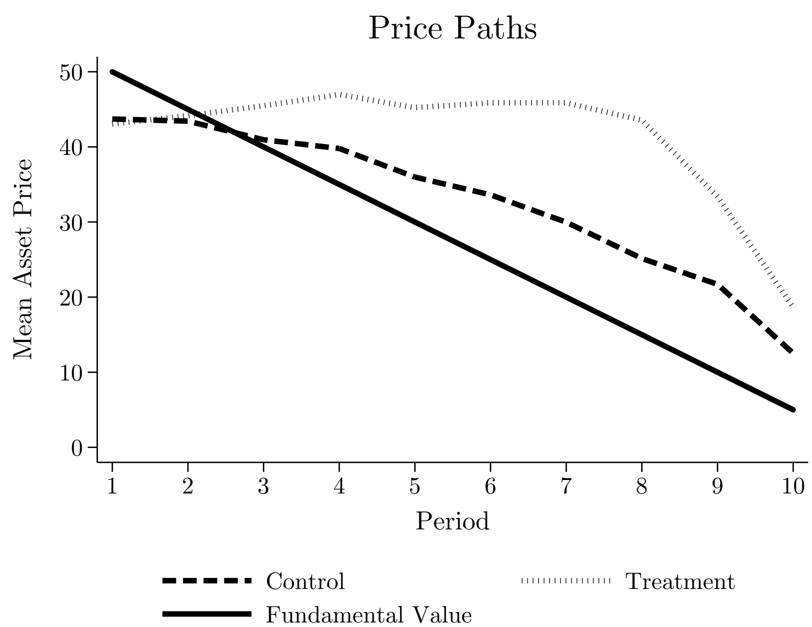


Figure 1: Mean (Volume Adjusted) Trading Prices across Treatments

Figure 1 shows how average market prices in *TREATMENT* and *CONTROL* evolve over time compared to the fundamental value of the asset market. In both conditions, mean market prices start out below the fundamental value but quickly exceed it, thus forming bubbles. Although the prices strongly decrease eventually, none of the average prices reaches the fundamental value again. Figure 1 suggests a stronger bubble for our *TREATMENT* condition and a Mann-Whitney test reveals that mean prices are in fact significantly different between our conditions ($z = -1.785$, $p = 0.0742$). A Wilcoxon signed-rank test confirms that both are systematically different from fundamental value (*CONTROL*: $z = 1.680$, $p = 0.0929$, *TREATMENT*: $z = 2.380$, $p = 0.0173$).[7]

average fundamental value of the market. See also table 1 in Stöckl et al. (2010).

[7] This pattern also holds if we do not look at quantity-adjusted mean prices but only at trade-adjusted mean prices, although the difference between the mean price and the fundamental value turns insignificant for the *CONTROL* condition ($z = 0.1540$, $p = 0.1235$). Since it is only marginally not significant, because of the large number of tests

With respect to our bubble measures we find that our *CONTROL* condition on average exhibits RAD=0.3253 and RD=0.1885, while in condition *TREATMENT* we observe RAD=0.5890 and RD=0.4990. Therefore, according to RAD in our *CONTROL* condition, prices deviate by about 33% from fundamental value, whereas they deviate by about 59% from fundamental value in our *TREATMENT* condition. This difference is significant (Mann-Whitney test, $z = -1.995$, $p = 0.0460$). A comparison of RD tells us that while in *CONTROL* prices are on average 19% too high, in *TREATMENT* they exceed fundamental value by almost 50%. A Mann-Whitney test suggests that these are also significantly different ($z = -1.785$, $p = 0.0742$). It goes without saying, that our bubble measures are significantly different from zero across all conditions and therefore we can neither reject substantial mis- nor overpricing.

It is interesting to observe that while the ratio of over- to mispricing of 50 % in *CONTROL* is already quite high, it becomes even higher in *TREATMENT* when it climbs to almost 85 % , suggesting that relatively more overpricing occurs when subjects lack the ability to restrain themselves.

4.3 Period-specific effects

We now turn towards individual periods. Because all markets start out on roughly the same price level and then quickly diverge, it is natural to look at each period separately. Table 1 reports the p and z-values (in parentheses) from Mann-Whitney tests, always comparing the variable of interest between *TREATMENT* and *CONTROL* for each period. While in the first periods we see almost no difference between our conditions, starting from period five, the market in *TREATMENT* exhibits significantly higher mean prices and hence more overshooting and mispricing. It is interesting to see, that the gaps in miscpricing and overshooting between our conditions widen at almost the same time, suggesting a strong treatment effect in the intermediate periods of our market. The gaps persists until almost the very end of our experiment apart from an endgame effect in the ultimate period.

Note that there is also huge endogeneity in market evolution and that there is a lot of heterogeneity between markets. Figure 2 displays the evolution of each market separately. The left panel represents the markets from our *CONTROL* condition, while the right panel shows our *TREATMENT* markets. It is interesting to see that average prices in *CONTROL* markets more often exhibit a downward slope, while in *TREATMENT* there are more markets exhibiting a hump-shaped price evolution. Furthermore, the emergence of bubbles can oftentimes be attributed to constant prices and decreasing fundamental values. This is exactly what we observe in many markets in *CONTROL* but we even see to some degree increasing prices in some markets of our *TREATMENT* condition.

performed and the resulting stability of the observed pattern we are not concerned that this result contradicts the strong findings we obtain throughout our analysis.

Period	volume-adjusted mean price	trade-adjusted mean price	RAD	RD
1	-0.67 (0.84)	-0.85 (0.735)	0.0143 (-0.63)	-0.0245 (0.84)
2	0.73 (0.105)	2.87 (-0.21)	-0.0749 (0.21)	0.0266 (0.105)
3	4.53 (-0.84)	3.38 (-0.525)	0.0006 (-0.105)	0.1646 (-0.84)
4	7.18 (-1.47)	7.64 * (-1.89)	0.1720 (-1.26)	0.2612 (-1.47)
5	9.24 * (-1.785)	9.03 * (-1.785)	0.2523 (-1.47)	0.3359 * (-1.785)
6	12.27 ** (-2.205)	12.01 ** (-2.31)	0.4186 ** (-2.205)	0.4461 ** (-2.205)
7	15.90 ** (-2.521)	15.84 ** (-2.415)	0.5703 ** (-2.521)	0.5781 ** (-2.521)
8	18.40 ** (-2.521)	19.00 ** (-2.521)	0.6573 ** (-2.521)	0.6693 ** (-2.521)
9	11.69 ** (-2.1)	11.78 ** (-1.995)	0.4249 ** (-2.1)	0.4249 ** (-2.1)
10	6.13 (-1.26)	6.48 (-1.26)	0.2007 (-1.05)	0.2228 (-1.26)

Differences between *TREATMENT* and *CONTROL* and z-values (in parentheses) for Mann-Whitney tests. Volume-adjusted mean price denotes the average price per asset, while trade-adjusted mean price denotes average price per trade.

Table 1: Period-specific Effects

We will come back to this in our discussion.

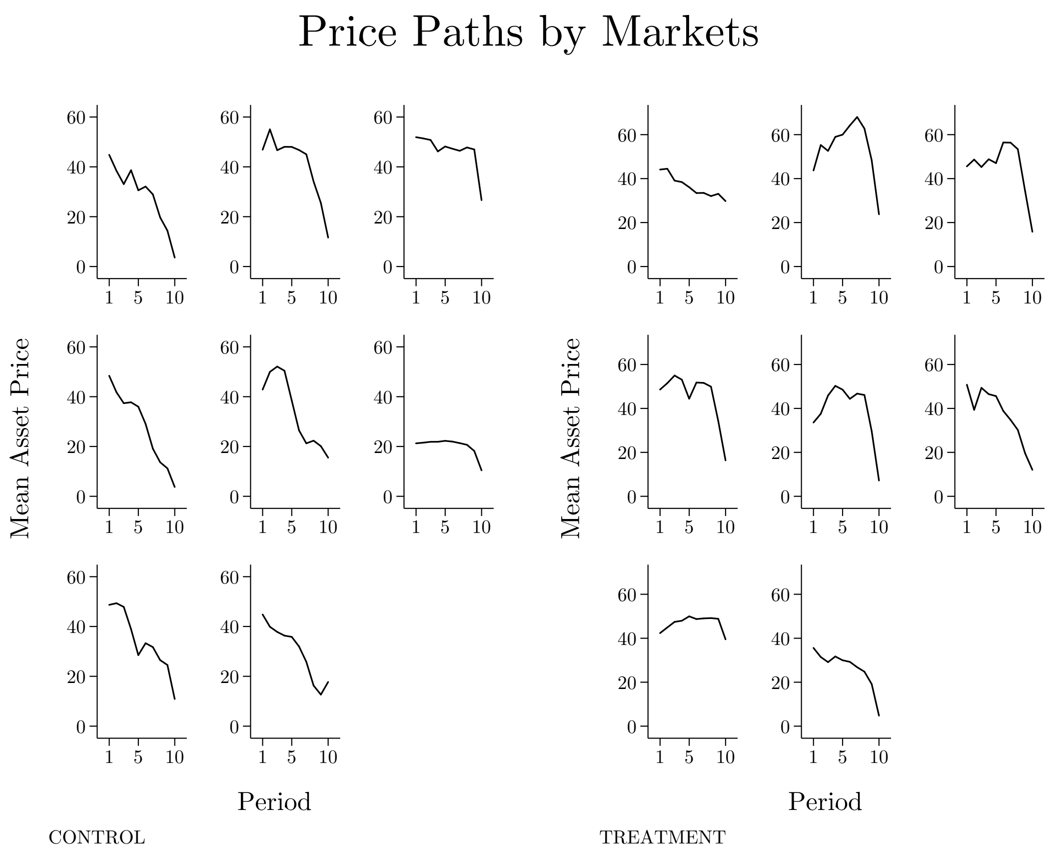


Figure 2: Evolution of Markets

4.4 Trading activity

Although our results seem to be pretty robust, one might still argue that differences in prices were driven by differences in market activities, for example caused by increased passivity (exhaustion) or overconfidence. To show that this is not the case, we look at the number of shares traded for each condition separately. While the average trader trades 13.02 shares per period in *CONTROL*, he would trade 11.39 shares per period in *TREATMENT*. According to a Mann-Whitney test, this difference is not significant ($z = 0.945$, $p = 0.3446$). Not only is there no observed difference in trading patterns, but also subjects do not report to be more tired in either of these conditions (2.8 vs. 2.99, Mann-Whitney test: $z = -0.686$, $p = 0.4926$), making exhaustion an unlikely explanation for our findings.

4.5 Risk attitudes and cognitive abilities

The results from the market suggest that there is a strong treatment effect due to 'ego depletion'. We now turn to other possible explanations for our results, changes in cognitive abilities and risk attitudes. The average number of correct answers in the CRT is 1.05 in *CONTROL* and 1.14 in *TREATMENT*. This difference is not significant according to a Mann-Whitney test ($= -0.355$, $p = 0.7223$). Furthermore, the certainty equivalent we elicitated is surprinsingly almost indistinguishable from the lottery's expected value, 2.2 in *CONTROL* versus 2.145 in *TREATMENT*. This difference is also not significant (Mann-Whitney test, $z = 0.827$, $p = 0.4083$).

We feel comfortable arguing that neither changes in risk attitudes nor changes in cognitive reasoning abilities can account for our findings.

4.6 Effectiveness of the Stroop task

One might have the concern that our placebo Stroop task in *CONTROL* might already have altered our results in an unpredictable way such that we can no longer compare it to a standard market like in Smith et al. (1988). We are confident that this is not the case. In the previous section, we discussed how we set up the experiment resembling the design by Kirchler et al. (2012). In their paper, they provide RAD and RD for their baseline market, namely RAD=0.414 and RD=0.297. Using a Wilcoxon Signed-Rank test we cannot reject the hypothesis that RAD and RD we obtain from our *CONTROL* condition are equal to these values ($z = -1.120$, $p = 0.2626$).[8]

In order to judge the effectiveness of our Stroop task, our data suggests that in *CONTROL* subjects tried to solve on average 194.55 word/color combinations, while they only tried 174.45 in *TREATMENT*. Correct answers in the task decrease from 191.65 to 170.31 in *TREATMENT* and when asked how strained subjects feel on a scale from 1 to 6, the average answer increases from 2.64 in *CONTROL* to 3.18 in *TREATMENT* suggesting that our 'real' Stroop task was indeed more strenuous. All these differences are significant at any conventional level.

4.7 Regressions

In order to detect any influence of our measure of risk attitude and cognitive skills on our market outcomes, we run linear dynamic panel regressions. OLS is not a feasible estimator in dynamic panel data models with a fixed time period as it creates a correlation between error and regressor (Nickell, 1981). Commonly used solutions to this problem however make it impossible to retrieve information about the time-invariant explanatory variables as they rely heavily on first-differencing. We therefore employ the two-step procedure by Kripfganz and Schwarz (2013). In a first step, we

[8]For our *TREATMENT* condition we find that RD and RAD are significantly different.

estimate only the coefficients of the time-variant variables, while in the second step we regress the residuals from our first step on the time-invariant variables.[9]

Table 2 shows the marginal effects for our regressions using a Quasi Maximum Likelihood (QML) estimator in the first step and a Generalized Method of Moments Estimator (GMM) in the second.

	(1) RD	(2) RD	(3) RD	(4) RD	(5) RD
Lag of RD	0.816***	0.800***	0.898***	0.885***	0.888***
	(0.0217)	(0.0203)	(0.0213)	(0.0211)	(0.0205)
Treatment	0.151***	0.150***	0.107***	0.0955***	0.0924***
	(0.0104)	(0.0109)	(0.0118)	(0.0111)	(0.0109)
Period		0.00438**	0.00162	-0.0173***	-0.0215***
		(0.00191)	(0.00184)	(0.00234)	(0.00243)
Period 2			0.124***	0.00903	-0.0123
			(0.0195)	(0.0229)	(0.0228)
Period 3			0.106***	0.0126	-0.00509
			(0.0182)	(0.0204)	(0.0203)
Risk Attitude				0.0470***	0.0415***
				(0.00584)	(0.00583)
CRT Performance				0.00644	0.0106**
				(0.00487)	(0.00490)
Male					0.0546***
					(0.00987)
Constant	0.0245**	0.00740	-0.00833*	0.0381***	0.0419***
	(0.0114)	(0.0107)	(0.00455)	(0.0143)	(0.0151)
AIC	-402.0	-405.3	-456.8	-575.2	-606.2
Observations	1600	1600	1600	1600	1600

Two-step dynamic linear panel regression using quasi-maximum likelihood estimation in the first stage and generalized methods of moments estimation in the second stage. Dependent variable is Relative Deviation. Treatment is a dummy where 1 stands for *TREATMENT* and 0 for *CONTROL*. Period 2 and Period 3 are dummies that turn 1 in the respective periods. Risk Attitude is an individual's certainty equivalent. CRT Performance denotes the number of correct answers on the CRT. Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 2: Regressions on Relative Deviation

In all five models we are interested in the effect on RD, our measure for overpricing. Throughout all specifications, we observe a strong autocorrelation in overpricing, but also a significant treatment effect: Being in *TREATMENT* increases overpricing by between 10 and 15 percentage points. Our measure for risk attitude is strongly significant, a higher certainty equivalent indicating lower risk aversion increases overpricing. Performance on the CRT only has an effect in our final specification

[9] We are very grateful to Sebastian Kripfganz for sharing his STATA code.

and is only significant after controlling for gender. Introducing our measure for risk aversion and cognitive skills however slightly decreases our treatment coefficient but it remains in the same ballpark and is still highly significant. This leaves us with confidence that our treatment was successful in decreasing participants' capacities to exert self-control and that neither changes in cognitive skills nor risk aversion are responsible for our results.

5 Discussion

In the following we would like to discuss possible channels, via which our treatment effect might come about or which might influence our results.

Some authors have speculated about a possible role of risk aversion for price bubbles (Porter and Smith, 1995; Miller, 2002) claiming that early underpricing might be due to risk aversion, leading to initial price increases sparking speculative bubbles. Market behavior has been found to be correlated with risk attitudes by Fellner and Maciejovsky (2007). They find that lower degrees of risk aversion, as measured by binary lottery choices, are connected with higher total market activity and a higher number of trades. As stated before, the literature exploring the effect of ego depletion on risk aversion has come to ambiguous results (Bruyneel et al., 2009; Unger and Stahlberg, 2011). We find no significant effect of ego depletion on risk aversion as measured by our certainty equivalent elicitation. Additionally, we find no effect of ego depletion on trading volume or prices in the first period, which have often been claimed to be affected by risk aversion. From the findings in our study it is therefore unlikely that the channel via which the ego depleting task increases bubbles is through an effect on risk aversion – irrespective of what the exact effect of risk aversion on outcomes in double auction markets might be.

Another channel via which our treatment might increase mispricing and bubbles are cognitive abilities. Schmeichel et al. (2003) found that ego depleting tasks reduce people's performance at information processing such as in logic and reasoning tasks, but not in tests of previously acquired knowledge. Thus, it might have been the case, that our treatment exogenously reduced participants' cognitive abilities. Dohmen et al. (2010) have previously shown, that both risk aversion and impatience vary systematically with cognitive ability in a representative sample of the German population. Similarly, Benjamin et al. (2006) show that small-stakes risk aversion and short-run discounting are less frequent among Chilean high school students with higher standardized test scores. Experimentally inducing cognitive load leads to similar results in their experiments. However, we found no significant effect of ego depletion on our measure of cognitive abilities – the CRT, which has been found to be a good predictor for heuristics-and-biases tasks (Toplak et al., 2011).

Subject confusion contributes to the occurence of bubbles in double auction markets of the kind studied in this paper. Both Huber and Kirchler (2012) and Kirchler et al. (2012) find that subjects have problems understanding the non-intuitive decreasing fundamental value process commonly present in double auction markets. However, as subject confusion might be correlated with cognitive abilities and since we did not find an effect of ego depletion on cognitive abilities, we find increased subject confusion to be an unlikely candidate for being responsible for our results.

Another question, which is closely related to understanding the fundamental value process of assets in a double auction market, is how price expectations are formed. De Long et al. (1990) have stressed the role of the way investors update their expectations for the emergence of speculative bubbles. The role of expectations in experimental asset markets has been studied by Haruvy et al. (2007) who found that unexperienced traders initially expect constant transaction prices and then come to believe in a continuation of past trends originating from both the current and prior markets. While traders adapt their expectations over repetitions of the market, bubbles become less and less pronounced. Expectations might have been formed in a more 'myopic' way in our treatment markets - i.e. people were basing their expectations more strongly on recent price changes in the treatment than in the control. The updating process could in fact be considered as an internal conflict between the previously acquired knowledge of the decreasing fundamental value process and the market signal represented by (positive) price changes. Positive changes in price contradict the decrease in fundamental value occuring every period. Potentially, depleted participants fail to resolve or even notice this conflict, in which knowledge should be given precendence over observation, and thus rely more heavily on what is at hand – i.e. the recent positive price changes – rather than on what they should know - i.e. the decreasing fundamental value process. Enlightening how formation of expectations is influenced by reduced self-control resources might be an interesting avenue for future research.

The results in Hargreaves Heap and Zizzo (2011), Lahav and Meer (2012), Andrade et al. (2012) and Breaban and Noussair (2013) suggest that emotions play an important role for the emergence of bubbles. Inducing excitement and positive affect before the experiment can lead to larger bubbles (Lahav and Meer, 2012; Andrade et al., 2012). Similarly, excitement and positive emotions are correlated with higher pice levels (Hargreaves Heap and Zizzo, 2011; Breaban and Noussair, 2013). Since the task we used for ego depletion (and in fact also for our control condition) is quite demanding and frustrating, it could be claimed that it is more likely that we induced a negative affective state before the experiment rather than positivity and excitement as in Lahav and Meer (2012) and Andrade et al. (2012). Additionally, studies from psychology which included measures of affect as a dependent variable generally have not found effects of ego depletion on (post depletion) affect (Baumeister et al., 1998; Bruyneel et al., 2006; Hagger et al., 2010). However, even if we can exclude initial differences in mood to be responsible for our bubbles, we cannot control for the possiblitiy and indeed looking at the psychological literature find it quite probable, that differential emotional responses to price changes, i.e. more impulsive behaviour, might occur due to ego depletion. Active mood regulation has been shown to deplete self-control resources and some common ego-depleting tasks draw on this idea (Baumeister et al., 1998; Hagger et al., 2010). As pointed out in the introduction, regulating affect or emotional responses to price changes requires individuals to control themselves. If the ability for self-control is reduced before the market stage, people might react more emotionally to price changes, e.g. they might get more excited about positive price movements, or act more often on the basis of affect, both of which might increase their reaction to these movements and thus support the formation of bubbles (Hargreaves Heap and Zizzo, 2011; Breaban and Noussair, 2013). Studies in marketing psychology (Bruyneel et al., 2006) have shown that people whose self-control has been reduced rely more on affective and less on cognitive features for product choice. Similarly, it could be the case in our setting that ego-depleted traders rely more heavily on the affective feature of the stock (i.e. the thrill from its recent price increase) than on the cognitive feature (i.e. the knowledge, that the fundamental value process of the stock is decreasing) and thus a bubble can arise. This line of argumentation provides an explanation of why price expectations might be more 'myopic' in the ego-depletion condition, i.e. investors might due to increased excitement rely more heavily on what is at hand than on previously acquired knowledge. The role of emotions for the formation of expectation might be a further interesting avenue for future research.

Reduced self-control might have an impact on inertia and passivity of people. In one of the experiments in Baumeister et al. (1998) it turned out that participants with reduced self-control capacities were more prone to be passive and remain in defaults. Similarly, it could be argued, that in our experiment depleted participants remained passive and in the default of holding on to their endowments more often, thus preferring not to trade the asset. This might have impacted market behavior and aggregate outcomes. Smith et al. (1988) pointed out the pattern that trading volume shrinks in the period prior to the bubble burst. However, to our knowledge there have been no systematic studies on the relation between market activity and the emergence of bubbles. Nonetheless, we do not find any differences in market activity between our treatment and control markets. Therefore we are confident to deny, that an effect of our treatment on the level of trading activity might have influenced prices in our markets.

Another factor potentially affecting price bubbles and their size is overconfidence. In the setting of Plott and Sunder (1988) Biais et al. (2005) find that overconfidence in the sense of miscalibration, i.e. too small confidence intervals, is negatively correlated with performance of subjects, while the psychological trait self-monitoring is connected with improved performance of traders. Michailova and Schmidt (2011) construct double auction markets based on subjects' overconfidence in the sense of overestimating own abilities, as measured in pre-experimental sessions. They find that prices in ‘rational’ markets, i.e. the markets with the least overconfident participants, tend to follow fundamental asset value more closely than prices in the most overconfident markets. Furthermore, ‘overconfident’ markets exhibit more tradings and larger bubbles than ‘rational’ markets (Michailova and Schmidt, 2011). Psychological studies have not found evidence, that the the effect of ego depletion works through self-efficacy (Wallace and Baumeister, 2002). In fact, it seems more likely that ego depletion would reduce one’s self-confidence, since the ego-depleting tasks are usually very demanding and frustrating. DeBono and Muraven (2013) find supporting evidence that ego depletion leads to more accurate and therefore less optimistic predictions of own future performance. Additionally, we find no increase in trading activity in our treatment markets, which can be interpreted as no sign of overconfidence. Thus, an increase in overconfidence is unlikely to be contributing to our findings.

6 Conclusion

In an experimental asset market setting, we have shown that exogenously varying the ability to exert self-control drastically increases an experimental market’s tendency to exhibit price bubbles. We used the Stroop task. According to psychological research, which found self-control to work like a muscle, this task inhibits the ability to exert further self-control in following tasks. In continouous double auction markets we observe significantly more mispricing and even more overpricing. To make sure these differences cannot be attributed to differences in cognitive skills or risk preferences our treatment might have induced, we elicit individual certainty equivalents and have subjects perform the CRT. We do not find any effects on either of these measures. To us increased impulsivitiy, i.e. from a dual systems perspective of human cognition dominance of the impulsive system one, seems most likely to be at the root of the increased occurrence and size of asset bubbles we find. We leave detecting the exact channel via which this ‘impulsivity’ works – be it via the process of adjusting price expectations, increased vulnerability and reactions to emotions or a combination of several of the mechanisms we have discussed – as an interesting avenue for future research.

Our findings have potentially far-reaching consequences: First, we have shown that self-control capacities might play an important role for participants in stock markets, especially with respect to the formation of short-term bubbles. Second, people should be aware of their fluctuations in self-control capacities and avoid participating in market settings during ‘depleted’ time periods or seek to ‘recharge’ their self-control resources beforehand. While we do not argue that self-control issues are responsible for the evolution of long-term bubbles like the 2008 real estate bubble, they can certainly be important contributing factors for short-term trading behavior.

Recent research has shown that carefully designing experimental asset markets can abate bubble formation, while we show that lack of self-control can actually increase asset bubbles. It would therefore be very interesting to further investigate the robustness of self-control issues with respect to market design. Additionally, the relevance of self-control in real-world markets would be an interesting area for future research.

A Appendix

A.1 Instructions

Welcome to the experiment and thank you for your participation!

Please do not talk to other participants of the experiment from now on

General information on the procedure

The purpose of this experiment is to investigate economic decision making. You can earn money during the experiment, which will be paid to you individually and in cash after the experiment has ended.

The whole experiment takes about 1.5 hours and consists of 3 parts. At the beginning you will receive detailed instructions for all parts of the experiment. If you have any questions after reading the instructions or at any time during the experiment please raise your hand. One of the experimenters will then come to you and answer your question in private.

During the experiment, you and the other participants will be asked to make decisions. In some parts, you will interact with other participants. Thus both your own decisions and the decisions of other participants can determine your payoffs. Your payoffs are determined according to the rules which are explained in the following. As long as you can make your decisions, a countdown will be displayed in the upper right corner of the screen which is intended to give you an orientation for how much time you should use to make your choices. In most parts you can exceed the time limit if needed; in some parts, however, you can only act within the time limit (You will be informed about this beforehand). Information screens not requiring any decisions will disappear after the time-out.

Payment

In some parts of the experiment we will not refer points instead of Euros. Points will be converted to Euros at the end of the experiment. You will be informed about the exchange rate at the beginning of the respective part.

For your timely arrival you will receive 4 € additionally to the income earned during the experiment.

Anonymity

We evaluate the data from the experiment only in aggregate and never connect personal information to data from the experiment. At the end of the experiment you have to sign a receipt, which we need for our sponsor. The sponsor does not receive any further data from the experiment.

Aid

On your desk you will find a pen. Please leave it on there after the experiment.

Part I

Task

The first part of the experiment consists of a task that will last 5 minutes. You will see a black screen on which words in different colors will appear. Here you can see an example:

You will be asked to click one of the buttons at the bottom of the screen. You will be asked to choose the button corresponding to the color the word is written in (**not** the word itself). In the example you should click on "yellow".

After clicked a button, the screen disappears and **another word in another color** appears. Please try to solve **as many word/color combinations** as possible within 5 minutes.

After 5 minutes the first part ends automatically and the second part begins.

Payment

You receive 3 € for part I.

Part II

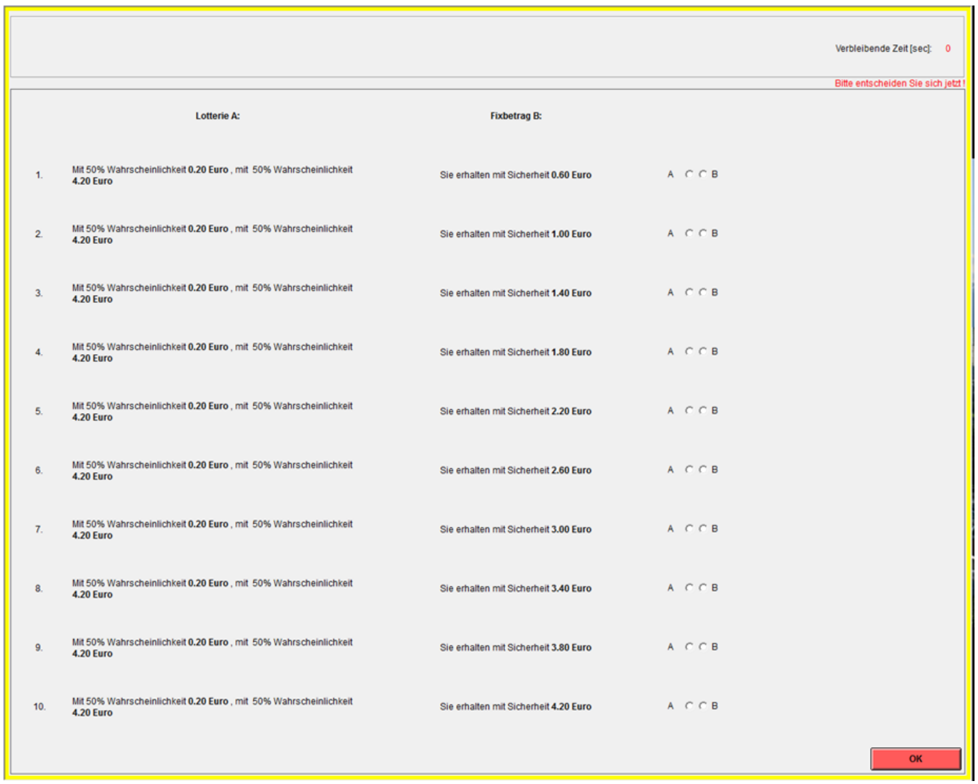
Task

In the second part you first have to answer three questions. For each question answered correctly you receive 0.5 € = 50 Cents.

Afterwards, you will be shown **10 decision problems**. In each of these problems you can choose between **a lottery and a safe amount of money**. The lottery remains unchanged within a period, whereas the safe amount of money increases with every additional decision problem. As the safe amount of money is strictly increasing from row to row, you should stay with the safe amount of money after you have switched to it once.

Your decision is only valid after you have made a choice for each problem and then confirmed it by clicking the OK-button on the bottom right of the screen. Take enough time for your decisions, as your choice – as described in the following – will determine your payoff from this part.

Here you can see what your screen will look like:



Your profit will be determined according to the following rules: First, **the computer chooses randomly and with equal probability one of the ten decision problems for payment**. If you selected the lottery in the relevant problem, the computer will simulate the outcome and you will receive it as payment. If you selected the safe amount in the relevant problem, you will receive it for sure.

For example: Assume the computer randomly chooses the first decision problem and you chose the lottery. Then the computer will simulate the outcomes of this lottery and you either receive 0.2 € (50% probability) or 4.2 € (50% probability).

Payment

The sum of your payoffs from the questions answered correctly at the beginning and your payoff from the decision problem chosen by the computer are your payment for part II of the experiment.

Please note: The computer will directly calculate the result. However, you will only learn about this at the end of the experiments, i.e. how many questions you answered correctly and which decision problem with which outcome the computer selected for you. That information will be presented to you on a separate screen at the end of the experiment.

After the end of part II, part III begins automatically.

Part III

Payment

In the third part of the experiment we refer to points rather than Euros. Points are converted to Euros at the end of the experiment according to the following exchange rate

500 points = 1 Euro (1 point = 0.002 Euros = 0.2 Cents)

Short Description

The third part of the experiment consists of a simulated stock market. The stock market lasts for 10 consecutive periods. Within these periods you can buy or sell shares of a single firm.

At the end of each period for every share that you own you receive either a dividend of 10 points (probability 50%) or 0 points (probability 50%).

During the 2 minutes trading period you can either offer to sell or buy shares or accept existing buying or selling offers by other participants.

Detailed description: Trading Period

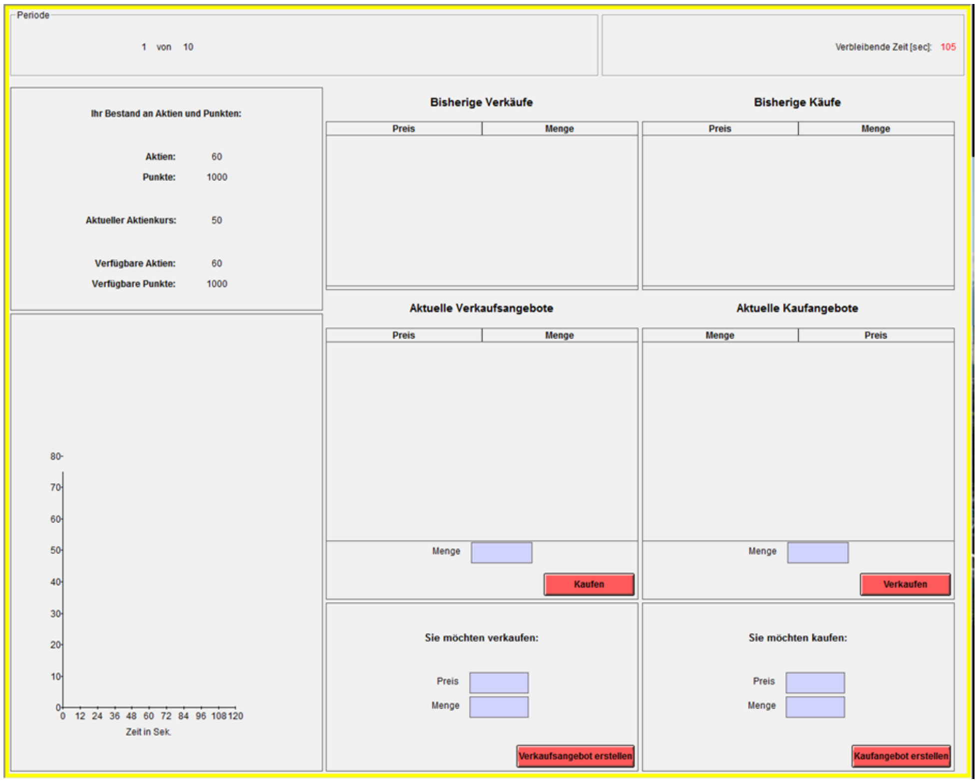
At the beginning of the first trading period you will receive an endowment of shares and points. Every participant receives either 20 shares and 3000 points or 60 shares and 1000 points. The distribution of endowments is random with a 50% probability of receiving each endowment.

Each period lasts exactly 120 seconds (= 2 minutes) and all screens disappear after the time out. You cannot make any trades or offers until he next trading period starts. During a trading period neither your amount of shares nor your amount of points can fall below zero.

During a trading period your screen will look like the following.

In the upper box you see the current period and how much time you have left in the current period. Below it to the left the box displays how many shares you currently own and how large your current wealth is expressed in points. Additionally the current share price and the amount of available shares and points are displayed.

Available shares are those of your shares that you have not offered for sale yet. If you offer to sell shares, you still own them, but they will be subtracted from your account as soon as someone else accepts your offer. Hence, you can only make sale offers that do not exceed your current amount of available shares.



Available points are those of your points that you have not used for buying offers yet. If you make an offer to buy shares, you still own the points, but they will be subtracted from your account as soon as someone else accepts your offer. Hence, you can only make buying offers that do not exceed your current amount of available points.

On the bottom left you can see a graph that shows the evolution of share prices in the current period. On the horizontal axis (the x-axis) you can see the time in seconds at which a trade was made. On the vertical axis (the y-axis) you can see the corresponding price.

In the upper part of the screen you see two lists that have the headlines "Previous Sales" and "Previous Purchases". Here, every trade that you made is listed. For each trade where you bought shares, price and quantity will be listed in "Previous Purchases". For each trade where you sold shares, price and quantity will be listed in "Previous Sales".

Below you find two lists with the headlines "Current Selling Offers" and "Current Buying Offers".

Accepting Selling Offers

In the list "Current Selling Offers" you find price and quantity of each offer, in which a participant offers to sell shares. Your own selling offers will also appear in this list. You can accept every offer in this list (except for your own offers) by marking the corresponding entry in the list, entering the quantity you want to buy into the field "quantity", and then confirming by clicking on the button "Buy". If you accept a selling offer, you will receive the number of shares that you have entered from the seller and the seller receives the corresponding price for each share he sold to you.

Please note: You can also buy less than the number of shares stated in the offer. In that case the offer of the seller will remain on display in the list after the trade, but the number of shares on offer will be reduced by your purchase. Example: A seller makes an offer to sell 10 shares at the price of 60 points each. A buyer buys 6 of those shares. Then an offer to buy 4 shares at the price of 60 points each will continue to be available to all other participants.

Please note that the computer automatically marks the best selling offer (i.e. the one with the lowest price) with a blue bar. You can recognize your own offers, as they are not displayed in black but in blue font.

Accepting offers to buy

In the list "Current Buying Offers" you find price and quantity of each offer, in which a participant offers to buy shares. Your own buying offers will also appear in this list. You can accept every offer in this list (except for you own offers) by marking the corresponding entry in the list, entering the quantity you want to sell into the field "quantity", and then confirming by clicking on the button "Sell". If you accept a buying offer, the other participant will receive the number of shares that you entered and you receive the corresponding price for each share you sold.

Please note: You can also sell less than the number of shares the buyer offers to buy. In that case the offer of the buyer will remain on display in the list after the trade, but the number of shares demanded will be reduced by your sale.

Please note that the computer automatically marks the best buying offer (i.e. the one with the highest price) with a blue bar. You can recognize your own offers according to their blue font.

Creating Selling or Buying Offers

In the bottom part of the screen you have the possibility to create your own selling or buying offers. If you want to create an offer to sell, enter the quantity of shares that you want to sell and the price per share which you demand for each unit in the field below "You Want to Sell" . After clicking the button "Create Selling Offer", your selling offer will show up in the list "Current offers to sell". Example: You want to sell 10 shares at a price of 55 points per share. Then you enter 10 into the field "Quantity" and 55 into the field "Price".

If you want to create a buying offer, enter the quantity that you want to buy in the field below "You Want to Buy" and the price per share for which you are willing to buy that quantity. After clicking the button "Make Buying Offer" your offer will show up in the list "Current Buying Offers". Example: You want to buy 20 shares at a price of 45 points per share. Then you enter 20 into the field "amount" and 45 into the field "price".

Please note: An offer to buy or to sell that has been made cannot be cancelled. Only if no one accepts an offer during the course of a trading period, it will not be displayed in the next period of trade.

Dividends

After the end of a trading period the following screen displays a summary of the previous period showing you how many shares and points you own, whether a dividend has been paid and if so, how large your overall dividend payments were.

In each period the dividend per share either amount to 10 points (with a probability of 50%) or to 0 points (with a probability of 50%) and is the same for all shares. After the end of period 10, all shares are worthless. All participants learn the realization of the dividend simultaneously on a separate screen at the end of the corresponding period.

The following table displays the value pattern of a share, i.e. the expected value of the remaining dividends. The first column indicates the current period, in the second column you find the number of remaining dividend payments. The third column shows the average expected dividend per share and period. The last column shows the average of remaining dividends per share in the corresponding period.

Current period	Remaining dividend payments	x	Average dividend value per period (0 or 10 with equal probability)	=	Average remaining dividends per share that you own
1	10		5		50
2	9		5		45
3	8		5		40
4	7		5		35
5	6		5		30
6	5		5		25
7	4		5		20
8	3		5		15
9	2		5		10
10	1		5		5

Assume for example that four trading periods remain. As the dividend per share is either 0 or 10 points with a probability of 50% each, this yields an expected dividend of 5 points per share and period. Assume you only own one single share which you intend to hold until the market closes. Then you can expect a total dividend payment for the four remaining periods of '4 remaining periods' x '5 points' = '20 points'.

Payoff

At the end of part III the shares no remaining value. Only your amount of points will be converted to Euros according to the exchange rate stated above of 1 point = 0.002 Euros = 0.2 Cents.

Afterwards, you will see a screen displaying your payoffs from the second part.

In the following, we will ask you to completely and honestly answer some questions concerning your person. On leaving the laboratory, we will pay you your profit privately and in cash. Please remain seated until we call you up in a random order. Please leave the instructions and the pen at your desk and take your numbered seat card with you.

Practice Period

Before you start today's experiment with part I, you will first play a practice period of part III to become familiar with the stock market. The payoff from this practice period will not influence your final payoff. Please note that the realization of the dividend and your endowment are not necessarily identical to the first period of part III as the realization is random and endowments will be randomly assigned.

After completion of the practicing period part I of the experiment begins.

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