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Abstract

For the past two decades a market model introduced by Smith, Suchanek, and Williams (1988, henceforth SSW) has dominated experimental research on financial markets. In SSW the fundamental value of the traded asset is determined by the expected value of a finite stream of dividend payments. This setup implies a deterministically falling fundamental value with a predetermined end of the life-span of the asset and extremely high dividend-payouts. We present a new market model in which we implement the fundamental value by adopting a random walk process. Compared to SSW-markets, prices in the new markets (SAVE) are more efficient and end-of-experiment imbalances common in SSW-markets are not observed. Our results demonstrate, that implicit features of the SSW market model contribute to bubble formation.

JEL classification: C92, D83, D84, G12

Keywords: Experimental economics, asset market, bubble, market efficiency

1 Introduction and Related Literature

Whether and to what degree prices "*fully reflect all available information*" as defined by Fama (1970) for a market to be "efficient", is one of the most hotly debated issues in economics and finance. Understanding whether and when markets are (in)efficient is crucial for market participants and regulators alike. However, empirical studies in the field suffer from the need to estimate the fundamental value of an asset. Unfortunately, decades of research have so far failed to produce a reliable and universally accepted model to calculate the fundamental value of a risky asset like a stock.

In 1988 Vernon Smith, Gerry Suchanek, and Arlington Williams (henceforth SSW, Smith et al. (1988)) introduced a new market model to tackle the question: they used laboratory markets to explore whether prices reflect available information in a simple market setting. This pioneering work was ground-breaking, as the fundamental value of the traded asset was known, and thus deviations of prices from fundamental values could be calculated without the estimation problems that classical empirical studies have to overcome. In SSW the fundamental value of the traded stock is determined by the expected value of a finite stream of stochastic dividend payments. The SSW model requires three parameter sets that have to be public knowledge: the possible dividend realizations, their probability of occurrence and the total number of periods in the experiment. Given these information sets the fundamental value declines *deterministically* towards zero at the end of the experiment. The key finding of Smith et al. (1988) is that trading prices substantially deviate from the fundamental value, as usually prices are too high – the authors talk of "bubbles". In the two decades since then numerous studies have replicated and modified the setting, exploring how parameter changes influence bubble formation.[1]

Real stock markets are characterized, among other things, by prices (and supposedly the underlying fundamental values) following a random walk process, no pre-determined life-span of a listed company, and low dividend-payouts. For example, the dividend yield on Wall Street is currently around 2 percent, and even lower at 0.49 percent on NASDAQ, where 73 of the top-100 companies did not pay any dividend in 2007. Only one third of companies listed on Wall Street pay dividends.[2] Some features of the SSW design were more justified when it

[1]Seminal studies and what they explore include: King et al. (1993) and Haruvy and Noussair (2006) looked at short-selling and buying on margin. Van Boening et al. (1993) used call markets instead of continuous double auctions, while Lei et al. (2001) added a parallel market with a short-term asset that exists only for one period. Noussair et al. (2001), Oechssler et al. (2007) and Noussair and Powell (2008) kept the fundamental value constant over time, and Lei et al. (2001) precluded speculation by prohibiting buyers to resell the asset and sellers to buy it. SSW; King et al. (1993) ran the experimental markets with professional business persons. Only experience proved to reliably abate bubbles.

[2]Source: http://www.indexarb.com. The dividend yield on a company stock is the company's annual dividend payments divided by its market cap, or the dividend per share divided by the price per share.

was set up, than today: then dividend yields on Wall Street were in the range of 6 percent per year. In SSW the fundamental value *deterministically* falls to zero within a predetermined number of periods, i.e. the stock ceases to exist. In addition it features extremely high dividend yields, starting at 10 percent in the first period of a 10-period setting and reaching 33, 50, and 100 percent in the last three periods. Considering these extreme payout rates, subjects face a disproportionate accumulation of cash over the course of the experiment. This feature itself may account for a part of the observed bubbles as excess cash was shown to produce bubbles (Caginalp et al. (2000), Haruvy and Noussair (2006)). These are significant deviations from real market – significant enough to justify the question whether the model can be considered a valid description of real stock markets and thus about the applicability of the results reported. This holds even more, as it may be difficult for experimental subjects to grasp what kind of asset they are trading. A SSW-"stock" combines features of bonds (pre-defined life-span) with features of a stock (uncertain payments), but it is neither.

In this paper we compare the dividend-based SSW approach to an alternative market model in which we implement the fundamental value as a random walk process. The new design (called SAVE for "Stochastic Asset Value Experiment") features a random-walk fundamental value process without dividend payments and without a pre-determined end to the life of the asset. Hence, there are no cash inflows and even when trading ends the asset still has a positive fundamental value and is bought back at this value by the experimenter.

In our experiments we let the same human subjects trade in SAVE-markets and in SSW-markets sequentially. While the SSW-markets produce the "usual" bubbles, SAVE markets exhibit efficient prices with no significant deviations from fundamental values. Strong end-of-experiment effects present in SSW markets, e.g. increasing bid-ask-spreads and a growing imbalance between bids and asks, are not present in SAVE markets, which remain 'balanced' until the very end.

The paper is structured as follows: Section 2 provides details on the market models and the experimental implementation. Section 3 presents the results and provides potential explanations on the different findings in SSW and in SAVE markets. Section 4 summarizes and concludes the paper.

2 The Experiment

In each experimental session ten subjects trade a risky asset for money (Taler) on two markets (SSW and SAVE) which are run sequentially.[3]

2.1 Fundamental Value (FV) in SSW Markets

In SSW markets subjects trade a dividend paying asset, where dividends are paid out at the end of each period. To determine the asset's FV subjects have to know the possible dividend realizations, their probability of occurrence and the total number of trading periods in the experiment. Given these information sets the FV in period k is determined as the number of remaining periods multiplied with the expected dividend payment.

$$FV_{SSW,k} = E(\text{dividend payment}) \cdot \text{remaining periods} \tag{1}$$

Each market (run) consists of 10 periods where the dividend is either 0 or 10 with equal probability. The FV in period 1 is therefore 50 and decreases by 5 Taler each period.[4] Note that the (linearly decreasing) FV for the whole market is known already at the start of the experiment. A detailed table included in the instructions provides subjects with all relevant information for each period. Hence, subjects already know the exact realization of the FV in SSW markets at the beginning of the experiment. At the end of the market the asset expires worthless, no terminal value is paid to subjects. The realized dividend payments

[3] In half of the cases SAVE-markets are run first, in the other half subjects trade in SSW-markets first.

[4] Declining and constant fundamental values are easy to implement in SSW. Increasing fundamental values would require negative expected dividend payments that have to be paid by subjects, or other (hard to understand) mechanisms, see e.g. Noussair et al. (2008).

are not known in advance, but at the end of each period subjects learn the dividend paid for the period.

2.2 FV in SAVE Markets

In SAVE-markets the FV is determined by a random walk process.[5] We use a random walk process frequently used in models of asset pricing, namely a Geometric Brownian motion without drift, to implement FV changes:

$$FV_{SAVE,t} = FV_{SAVE,t-1}e^{\alpha} \tag{2}$$

where α is a normally distributed variable with mean zero and standard deviation of 20%.[6] The starting value of the process is 50, to be comparable to the SSW markets. Although a positive drift term is often assumed for real world markets, we refrain from using it to keep the design easily understandable.[7] This setup mitigates undesirable noise that might be caused by cash inflows or asset values approaching zero.

Subjects do not know the exact FV but they receive a quite precise signal about the FV in each period. At the beginning of each period when the FV takes a new value, signals are updated. Their precision changes randomly from period to period and is distributed around the FV with a mean of zero and a standard deviation of 5%. The sum of deviations within a period is zero, as we balanced deviations. Specifically, we generate normally distributed random deviations for one half of the subjects and "mirrored" these deviations for the other half.[8]

[5] SAVE-markets are easily implementable with dividend payments, as e.g. done by Huber (2007).

[6] This corresponds to a standard normal error term (ε) and a standard deviation (σ) of 20% in terms of common notation. The implications of these parameters are carefully explained to subjects with examples and a figure.

[7] See Huber (2007) and Kirchler (2009) for implementations of SAVE-markets with a positive drift.

[8] See Appendix B for detailed instructions.

2.3 Shared Characteristics of Both Treatments

2.3.1 Experimental Implementation

At the beginning of each experimental session subjects are informed that they will take part in two separate experimental markets, named "Experiment A" and "Experiment B" and that there will be a separate introduction for each experimental market before it starts. Each market is preceded by two trial periods, which do not count toward subjects' payout. To model the SSW markets similar to those already existing in the literature, we use identical instructions as Dufwenberg et al. (2005).

The trading screen provides subjects with current information on their stock and Taler holdings, and their current wealth.[9] All transaction prices with the corresponding trading time are shown in a real time chart on the left side of the screen.

The dividend realizations (SSW) as well as the FV changes (SAVE) used in the experiment are randomly generated but determined in advance to ensure comparability. To avoid order effects (i.e. SSW markets conducted as experiment A influence SAVE markets that follow as experiment B) we start with the SSW type markets in half of the cases and with SAVE type markets in the other half.[10] To reduce effects that might be caused by the stochastic realizations of the dividend payments in SSW and the FV changes in SAVE we generate one process randomly each. We then create a second sequence by "mirroring" the randomly drawn sequence, such that in each period the dividends/FVs in both sequences are different.[11] Thus we use a total of four stochastic processes – called A and B for the SSW markets and C and D for SAVE markets. Combining the two dividend paths of SSW with the two process realizations in SAVE in all reasonable ways leads to eight sessions (consisting of two markets each) to implement.

[9] See Appendix B and C for screen shots.

[10] We do not find evidence for the presence of order effects.

[11] If the dividend in period k is 0 (10) in sequence 1, it is 10 (0) in period k of sequence 2. If the FV in the SAVE-markets in period k is 65 (35) in sequence 1, it is 35 (65) in sequence 2.

We conducted all eight experimental sessions in July 2008 at the University of Innsbruck with a total of 80 students (bachelor and master students in business and economics). All subjects already took part in other experiments in economics but each took part in only one session of this experiment. We especially took care that the subjects did not participate in earlier asset market experiments of comparable design. Each session lasted between 80 to 90 minutes, and the average earnings were 20 EUROs. The markets were programmed and conducted with z-Tree 3.0.6. by Fischbacher (2007). Subjects were recruited using ORSEE software by Greiner (2004).

2.3.2 Market Architecture

Subjects trade in a continuous double auction with open order book with all orders being executed according to price and then time priority. Market orders have priority over limit orders and are always executed instantaneously. Any order size and the partial execution of limit orders are possible. Shorting stocks and borrowing money is not allowed. Each market consists of 10 trading periods of 120 seconds length each. Taler and stock holdings are carried over from one period to the next, but not between markets. No interest is paid on Taler holdings.

2.3.3 Initial Endowments

At the beginning of each market one half of the subjects is endowed with 60 shares and 1000 Taler, the other half is endowed with 20 shares and 3000 Taler. Valued with the initial FV of 50, which is identical in both market settings, each subject receives an initial wealth of 4000 Taler.

2.3.4 Earnings and Payment

In SSW markets the traded asset is worthless after the last period and no terminal value is paid. Thus, Taler holdings are converted at a known fixed exchange rate into EURO and paid out privately in cash at the end of the session.

In SAVE markets asset holdings are bought back at their fundamental value (in Taler) by the experimenter after the last period. Then the Taler holdings are converted into EURO at a known fixed exchange rate. In our experiments the exchange rate was 400 Taler = 1 EURO in both treatments. An experimental session lasted approximately one and a half hour and payment averaged 20 EUROs.

3 Results

3.1 Descriptive Overview

Figure 1 presents the development of average transaction prices per period (solid line with circles) and fundamental values (solid line) over time in the two different market models.

Insert Figure 1 about here

One can see the typical pattern of price deviations from FVs in the SSW markets (bottom panel). Overvaluation (difference of market prices and fundamental values) is very high and on average amounts to 50.5% of the FV. In contrast, SAVE markets (top panels) present a different picture: prices track FVs nicely and the average overvaluation of 5.4% is modest.[12] Similar to Kirchler (2009) prices seem to underreact to changes in the FV in the SAVE-markets. Thus, markets with fluctuating FVs provide also better insights compared to markets with constant FVs (Caginalp et al. (1998) and Smith et al. (2000)), since in the latter prices can only overreact or track the fundamental values.

Figure 2 goes into further detail and displays the difference of average transaction prices per period and the respective fundamental value in absolute values

[12]The results are even more astonishing given the fact that traders already know about the FV in each period in advance in SSW markets, as we use almost identical instructions compared to Dufwenberg et al. (2005). In SAVE markets they are only informed about the FV in the current period and still prices are much more efficient.

(left panel) and in percent of FV (right panel). For the SSW markets we observe the typical pattern of increasing overvaluation as a function of time. Note that this is not caused by increasing prices, but by a falling fundamental value, while prices stay constant for most of the experiment. In SAVE markets the deviations are negligible compared to what we see in SSW markets. To get a more refined picture of mispricing in both treatments we introduce in Table 1 bubble measures which are frequently used in experimental bubbles literature.

Insert Figure 2 about here

Insert Table 1 about here

Price amplitude (PA) measures the difference between the highest and the lowest deviation of prices from the fundamental value within a session divided by the fundamental value. For the average bias (AB) the per period difference between the median market price and the fundamental value is calculated. Total dispersion (TD) measures the absolute difference of median prices per period from the FV in period k and sums it up across all periods (Haruvy and Noussair, 2006). Relative duration (RDUR) is an indicator for the 'length' of a bubble. It is the maximum number of consecutive period within a complete market that exhibit increasing deviations of prices from FV minus one and than divided by the total number of periods minus two. The formula ensures that RDUR falls in the [0,1] interval.

Note that TD is dependent on the number of periods and the general level of the FV as no benchmarking on these variables is done – to resolve this problem we introduce the new measure RAD_p: it measures in each period the absolute deviation of the mean market price from the FV, divided by $\overline{FV}$ (the average FV within the experiment).[13] To obtain one measure for each market we sum up over all periods to get a proxy of the average percentage of the asset's mispricing of market m. RAD_t is calculated similarly with the difference that

[13]We divide by $\overline{FV}$ to control for disproportional high contribution that are triggered by the low FV in late SSW periods.

all transaction prices are used instead of mean prices per period. With RD_p we modify the calculation of RAD_p by replacing the absolute deviation of the mean price and the FV with the difference of both variables. With this measure we are able to make statements about whether the markets show positive or negative mispricing.

Insert Table 2 about here

Table 2 provides details for each market in each sessions and on market model aggregates. One can see that each measure presents a similar picture. Much higher value are shown in the SSW than in the SAVE markets. Thus, we confirm the frequent occurrence of bubbles in SSW markets, while in SAVE markets prices mostly track fundamentals closely.

3.1.1 Statistical Tests on Mispricing

To measure whether the observed mispricing and the difference between the two treatments are statistically significant we set up the following SUR (seemingly unrelated regression) model:

$$y_m = \beta_1 \text{SSW}_m + \beta_2 \text{SAVE}_m + \epsilon_m. \quad (3)$$

Here, SSW and SAVE are binary dummy variables representing the two different market types and m stands for market.[14] With a Wald-coefficient test we check whether the difference in coefficients is statistically significant. As dependent variable, y_m, we use the bubble measures presented in Table 1.

Insert Table 3 about here

Table 3 provides the results. All measures report significant "bubbles" for the SSW markets, while only PA shows a weakly significant result for SAVE markets. Even here the magnitude is three times larger for SSW markets.

[14]We refrain from using an intercept as with this specification we test for each independent variable on the null hypothesis of being different from zero.

Also with RAD_p and RAD_t, in our view the two most meaningful measures of mispricing, we observe major differences between SSW and SAVE markets. Whereas SSW markets show strong and highly significant mispricings of more than 72.2% of the FV, the price paths in the markets of type SAVE track the FV much closer with mispricings of roughly 13.2% which are not significantly different from zero. Not surprisingly, the differences between the mispricings in both market types are significant on the 1%-level (Wald coefficient test). Thus, the price paths of SAVE markets are significantly more efficient than those of the SSW type. RD_p provides evidence that in both treatments prices are higher than fundamentals. Whereas the overvaluation in the SSW markets is highly significant with roughly 50.5%, the bias in the markets of type SAVE is quite moderate with 5.4%, which is not significantly different from zero.

3.2 Explanations for Differences in Bubble Formation

As mentioned above SSW- and SAVE-markets differ in their fundamental value process. This generates a new market model with two major differences: In the SSW markets (i) the end of the asset is predetermined whereas it is not in SAVE markets. Furthermore, (ii) the dividend yields in SSW-markets are very high with the consequence of massive cash inflows, whereas the asset in SAVE-markets does not pay any dividends. Consequently, we investigate whether these two differences may contribute to bubble formation in the two market models. Additionally, we report on subjects' understanding of the market models as explored by a questionnaire that was run after each market.

3.2.1 End-of-Experiment Effect

The dividend structure in SSW-markets has an important implication: the fundamental value declines deterministically to zero with the consequence that the end of the experiment (asset) is predefined by the time the asset's value reaches zero. However, real listed companies aim to prosper without a pre-specified end of their activities. We calculate the following proxies to test for end-of-experiment effects in both market models:

OPENASK_k and OPENBID_k stand for the number of open asks and open bids at the end of period k. In the top panel of Figure 3 we divide each time series by the sum of (OPENASK_k+OPENBID_k) and calculate the mean across all markets in each treatment. Large values of this proxy indicate an imbalance between the buy and the sell side of the market. The SSW markets exhibit a striking difference between the number of limit asks and limit bids towards the end of the experiment as most traders try to sell their assets. In SAVE markets no persistent pattern and no end-of-experiment effects are visible (see right panel of Figure 3).

Insert Figure 3 about here

BESTASK_k and BESTBID_k define the price of the best ask and the price of the best bid at the end of period k. In the bottom panel of Figure 3 we divide both time series by the mean market price in each period and calculate the respective mean across all markets. In well-functioning and liquid markets the difference between these numbers is very small. One can see major differences in the bid-ask spread proxy between both treatments: Whereas it is narrow and constant throughout all periods in the SAVE markets, it is much larger and shows time-dependent patterns in the SSW markets. Beginning with period six the asymmetry between BESTASK and BESTBID increases with BESTBID dropping significantly to values of roughly 60% in period 10. In contrast, BESTBID in period 10 of the SAVE markets still exhibits values of above 95%. The increase of the percentage spread in SSW markets can probably be compared to the situation briefly before a company files for bankruptcy on real markets (see e.g. Serednyakov (2002)).

To statistically test whether the observed time series within and between the treatments are statistically significant we apply the following SUR-regression,

$$y_k = \alpha + \beta_1 \text{SSW} \cdot \text{PERIOD}_k + \beta_2 \text{SAVE} \cdot \text{PERIOD}_k + \epsilon_k \quad (4)$$

with SSW · PERIOD and SAVE · PERIOD measuring the time trend of both treatments separately. As dependent variable, y_k, we apply the following variables which are based on the time series presented in Figure 3:

$$\text{DIFFOPEN}_k = \frac{1}{M}\sum_{m=1}^{8}\frac{\text{OPENASK}_{m,k} - \text{OPENBID}_{m,k}}{\text{OPENASK}_{m,k} + \text{OPENBID}_{m,k}}, \quad (5)$$

$$\text{SPREAD\%}_k = \frac{1}{M}\sum_{m=1}^{8}\frac{\text{BESTASK}_{m,k} - \text{BESTBID}_{m,k}}{P_{m,k}}.$$

If end-of-experiment effects are present we expect to observe positive time trends in the independent variables SSW·PERIOD and SAVE·PERIOD. Table 4 presents the results. We see strong end-of-experiment effects in the SSW-markets as both proxies exhibit highly significant positive coefficients, while SAVE markets display no significant results. All these results corroborate our notion that SSW-markets are not a typical representation for stock markets in general.

Insert Table 4 about here

3.2.2 Cash Endowment and Cash Inflow

At the beginning of each market in each treatment the total cash amount (20000 Taler) equals the number of stocks multiplied with its initial FV (400 stocks · 50 Taler = 20000 Taler). The relationship between cash and asset value equals 1. In SAVE-markets this relationship does not change a lot as it is only affected by fluctuations in the FV. Depending on the FV realizations the relationship between asset value and cash is narrow compared to SSW-markets. For the lowest and highest FV in SAVE-markets the cash to asset ratio takes the values 1.81 and 0.69 respectively.

In contrast, in SSW-markets the FV and the available cash amount vary much more over time. Dividend payments generate frequent inflows of cash into the market, which increase the available cash for subjects period for period. Depending on the dividend realization, in each period either zero or 4000 additional Taler flow into the market, i.e. 2000 on average per period. Over the course of the experiment the "monetary basis" therefore doubles. This increase in cash is accompanied by a declining fundamental value, which falls by 90% from period 1 to period 10. Thus, the relationship of available cash and asset value increases almost twentyfold. However, massive cash inflows or extraordinary high initial cash endowments have been shown to contribute to the formation of bubbles (see e.g. Caginalp et al. (1998, 2000) and Haruvy and Noussair (2006)).

The "basic" SSW-design is a treatment in which massive cash inflows occur, as dividend payments present subjects with additional cash to compete for the remaining dividend payments which keeps prices high. Thus, the bubbles observed in SSW-markets may be caused by high cash endowments and/or the changing ratio of cash to asset value over time.

3.2.3 Further Behavioral Observations

SSW-markets rely on the capability of subjects to correctly use backward induction and to trade accordingly. Lei et al. (2001), p. 832 state: "*Because of the finite time horizon, backward induction implies that risk neutral agents must trade at the fundamental value*".[15] Psychological literature provides strong evidence that subjects are bad at using backward induction and instead apply other heuristics on which they base their decisions. Johnson et al. (2002) show that subjects use a limited look-ahead heuristic instead of backward induction.

To get an impression of whether subjects were able to understand the design of the fundamental value process of the two treatments, we ran a questionnaire after each market. The subjects were asked the following question: "*The fundamental value in period t is 45. What will the fundamental value most likely be in the next period?*" To answer this question, subjects were able to check values from 35 to 55 with steps of five. Figure 4 provides the percentage of

[15] See Dufwenberg et al. (2005), Noussair and Tucker (2006), Porter and Smith (1995) and Smith et al. (2000) for similar arguments. Backward induction is possible in SSW-markets as the asset deterministically expires worthless at the end of a pre-defined number of periods.

votes as a function of the deviations from the correct estimation (45 for SAVE- and 40 for SSW-markets). We find that nearly 55% of the subjects estimated the FV correctly in the SAVE-markets (solid line with circles) and the remaining 45% are symmetrically distributed around the correct estimation. In strong contrast, in markets of the SSW-type (dotted line with crosses), more than 60% of all traders expect the FV to remain constant or increase and only 35% of all subjects forecasted the FV correctly. The average overestimation was more than 10% in SSW-markets, whereas average overestimation in SAVE-markets was less than 1%. Thus, we conclude that subjects have problems in realizing that the fundamental value of the asset declines deterministically.

Insert Figure 4 about here

Consequently, it might be that the strong price deviations from fundamental values detected in SSW-markets are less due to speculation, biases, or heuristics – as usually assumed in the literature – but that at least some of the deviations are caused by subjects' lack of understanding of the design. This view is also supported by findings of Lei and Vesely (2008) who took extreme care to explain the SSW-setting carefully to subjects and did not find any bubbles.

SAVE-markets differ from SSW as they do not rely on subjects capability to use backward induction, as prices change stochastically from period to period. Also note that in SSW-markets the theoretically calculated FV of the asset does not have much importance for subjects payment as the asset expires worthless. Therefore, subjects have little reason to focus on fundamentals. In SAVE-markets assets are bought back at their fundamental value after the last period, thus attributing a higher importance to fundamentals.

4 Conclusion

In this paper we provided evidence that the market model is crucial for bubble formation in laboratory asset markets. We ran two alternative models: the first is based on the design of Smith et al. (1988) (SSW) which follows a dividend based approach to determine the fundamental value of the asset. Keeping all other parameters constant (e.g. trading mechanism, initial endowments, number of traders, etc.), we adopt another model (SAVE) by changing the fundamental value process to measure its impact on bubble formation. Instead of a dividend driven process, we implement a random walk fundamental value process. With respect to SSW-markets this implies that (i) the fundamental value of the risky asset in SAVE-markets does not decrease deterministically to zero and thus has no predefined life-span; (ii) the high dividend payments compared to real world markets are eliminated. When measuring the impact of model design on bubble formation we find that the SSW-markets produce the "usual" bubbles, while SAVE-markets produce efficient prices with no significant deviations from fundamental values. Furthermore, strong end-of-experiment effects are present in SSW-markets (e.g. increasing bid-ask-spreads and a growing imbalance between bids and asks) whereas no such effects are found in SAVE-markets, which remain "balanced" until the very end. Furthermore, we found that subjects had problems in correctly understanding the fundamental value process of the SSW-markets. Specifically, only one third of all subjects estimated the fundamental value correctly in a simple questionnaire and the average overestimation was more than 10% of the fundamental value. In contrast, average overestimation in SAVE-markets was less than 1%.

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Figures and Tables

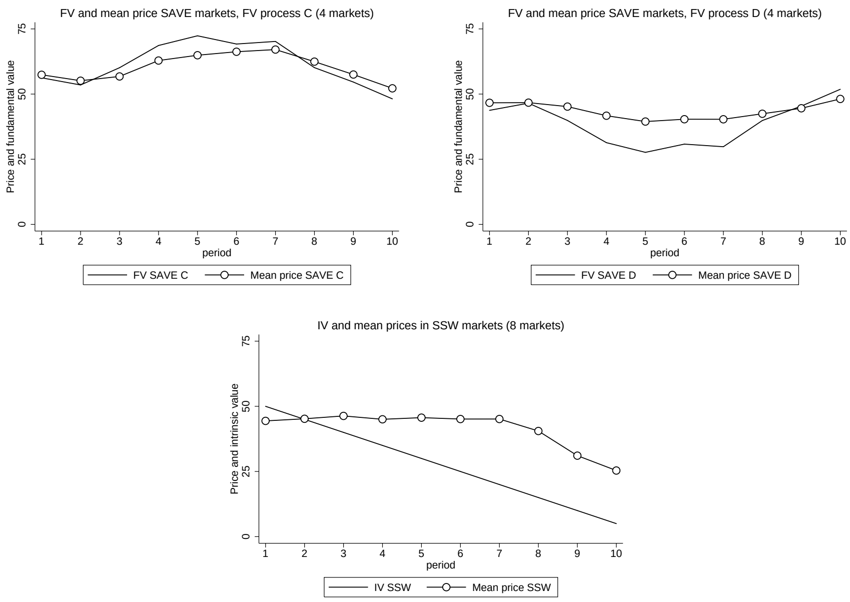


Figure 1: Fundamental values and average transaction prices for the SAVE markes, processes C and D (top panels) and the SSW markets (bottom panel).

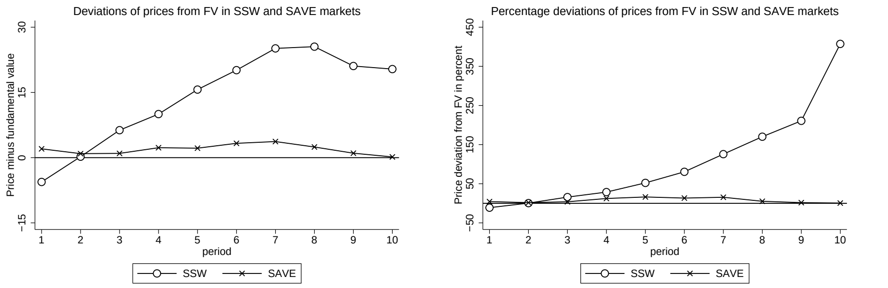


Figure 2: Overvaluation in absolute values (left panel) and in percent (right panel) of the SSW- and the SAVE-markets.

Table 1: Bubble measures: PA (price amplitude), AB (average bias), TD (total dispersion), DUR (duration), RAD_p (relative absolute deviation per period), RAD_t (relative absolute deviation per transaction), RD_p (relative deviation per period).

Measure	**caluclation**
Price amplitude [a]	$PA = max_k(P_k - FV_k)/FV_1 - min_k(P_k - FV_k)/FV_1$
Average bias [b]	$AB = \sum_{k=1}^{K}(MedianP_k - FV_k)/K$
Total dispersion [b]	$TD = \sum_{k=1}^{K} \lvert MedianP_k - FV_k \rvert$
Relative duration [c]	$RDUR = \frac{1}{(K-2)} * (DUR - 1)$
Relative absolute deviation per period	$RAD_p = \sum_{k=1}^{K} \lvert P_k - FV_k \rvert / \overline{FV}$
Relative absolute deviations per transaction	$RAD_t = \sum_{k=1}^{K} \sum_{t=1}^{S} \lvert P_{tk} - FV_k \rvert / (\overline{FV} * K * T)$
Relative deviation per period	$RD_p = \frac{1}{K} \sum_{k=1}^{K} (P_k - FV_k)/\overline{FV}$

Notes: P_k = mean price for period k; P_{tk} = price of the t^{th} transaction in period k; FV_k = fundamental value per period; $\overline{FV}$ = average fundamental value over all periods of the experiment k; $MedianP_k$ = the median price in period k; K = total number of periods; T = total number of transactions per period.

[a] Hussam et al. (2008)

[b] Haruvy and Noussair (2006)

[c] DUR is the maximum number of *consecutive* periods that *relative* price deviations from $\overline{FV}$ increase.

Table 2: Descriptive statistics for the different markets. PA (price amplitude), TD (total dispersion), AB (average bias), RDUR (relative duration), RAD_p (relative absolute deviation per period), RAD_t (relative absolute deviation per transaction), RD_p (relative deviation per period).

market	**type**	**process**	**PA**	**TD**	**AB**	**RDUR**	**RADp**	**RADt**	**RDp**
1	SSW	A	1.08	378.0	37.8	0.63	141.2%	141.3%	141.2%
2	SSW	B	1.76	283.5	10.7	0.63	93.8%	98.8%	24.7%
3	SSW	A	0.22	32.5	-2.1	0.25	11.1%	12.1%	-8.0%
4	SSW	B	0.84	121.2	-7.1	1.00	46.9%	46.9%	-28.7%
5	SSW	A	0.63	239.5	23.9	1.00	79.4%	81.8%	79.4%
6	SSW	B	0.52	115.4	11.5	0.75	40.8%	42.8%	40.8%
7	SSW	B	0.92	239.4	23.3	0.88	86.2%	86.5%	83.5%
8	SSW	A	0.57	197.9	19.8	0.75	70.9%	70.9%	70.9%
1	SAVE	C	0.29	35.3	-1.9	0.38	6.7%	7.3%	-2.4%
2	SAVE	D	0.54	138.7	13.5	0.38	34.7%	34.8%	33.5%
3	SAVE	D	0.15	21.0	-0.5	0.13	4.9%	6.1%	-1.2%
4	SAVE	C	0.16	23.8	-0.3	0.13	3.8%	4.0%	-0.7%
5	SAVE	C	0.40	68.6	0.7	0.25	9.5%	14.7%	-4.6%
6	SAVE	D	0.35	84.2	6.6	0.25	20.6%	23.1%	17.0%
7	SAVE	C	0.16	27.3	0.5	0.38	3.6%	5.2%	0.7%
8	SAVE	D	0.26	33.3	0.6	0.38	8.9%	10.1%	1.1%
Mean SSW			0.82	200.9	14.8	0.73	71.3%	72.7%	50.5%
Mean SAVE			0.29	54.0	2.4	0.28	11.6%	13.2%	5.4%

Table 3: SUR-regression on overvaluation. The independent variables SSW and SAVE are binary treatment dummies. As dependent variables we use: PA (price amplitude), TD (total dispersion), AB (average bias), RDUR (relative duration), RAD_p (relative absolute deviation per period), RAD_t (relative absolute deviation per transaction), and RD_p (relative deviation per period).

		PA	AB	TD	RDUR	RADp	RADt	RDp
SSW		0.818***	14.753***	200.926***	0.734***	0.713***	0.727***	0.505***
SAVE		0.290*	2.386	54.028	0.281***	0.116	0.132	0.054
		(0.113)	(3.629)	(27.239)	(0.063)	(0.095)	(0.096)	(0.132)
N		16	16	16	16	16	16	16
R^2		0.79	0.51	0.78	0.91	0.78	0.80	0.48
Wald test	F(1,98)	10.84	5.81	14.54	25.98	19.56	19.35	5.85
	p-value	0.0014	0.0178	0.0002	0.0000	0.0000	0.0000	0.0174

Notes: Wald coefficient tests are used to test on the differences between the independent variables; standard errors in parenthesis; * and ** represent the 5% and the 1% significance levels.

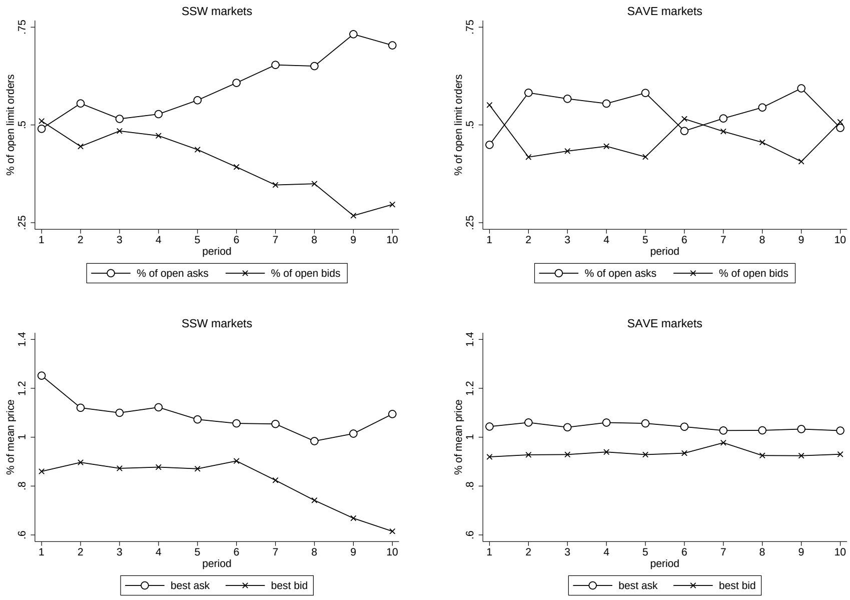


Figure 3: BESTASK_k and BESTBID_k at the end of period k relative to the mean market price in SSW (left) and SAVE (right) markets for each period (top panel). Share of open bids (OPENBID_k) and asks (OPENASK_k) relative to all open limit orders in SSW (left) and SAVE (right) markets at the end of period k (bottom panel).

Table 4: Time series analysis - SUR regression

		SPREAD%	DIFFOPEN
SSW · PERIOD		0.016**	0.041**
SAVE · PERIOD		-0.010	0.012
		(0.006)	(0.007)
α		0.175**	-0.010
		(0.033)	(0.040)
N		20	20
R^2		0.60	0.67
Wald test	F(1,51)	29.41	23.58
	p	0.0000	0.0000

Notes: Wald cofficient tests are used to test on the differences between the independent variables; standard errors in parenthesis; * and ** represent the 5% and the 1% significance levels.

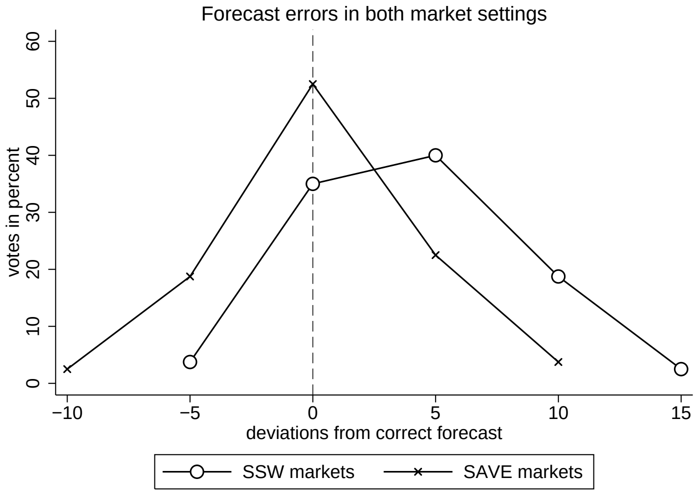


Figure 4: Questionnaire: "The fundamental value in period t is 45. What will the fundamental value most likely be in the next period?" The graph provides the percentage of votes as a function of the deviations from the correct estimation (45 for SAVE- and 40 for SSW-markets).

Appendix

Appendix A: Market Results

SSW Markets

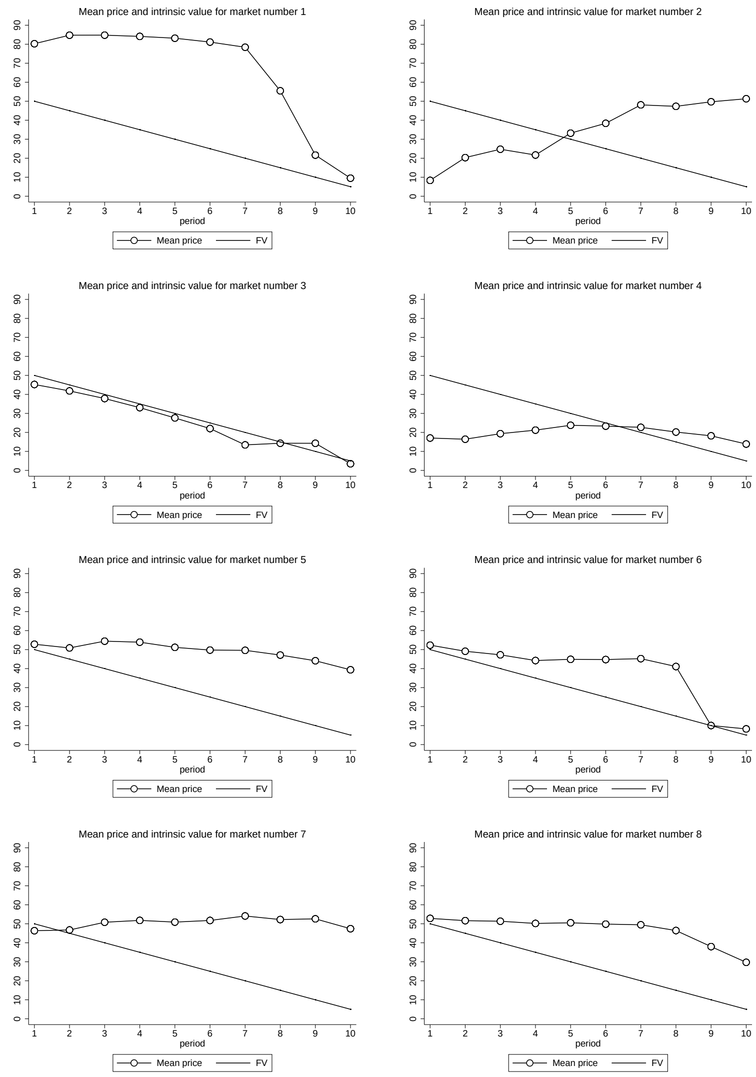


Figure A1: Fundamental values and average transaction prices for each market of the SSW-type.

SAVE Markets

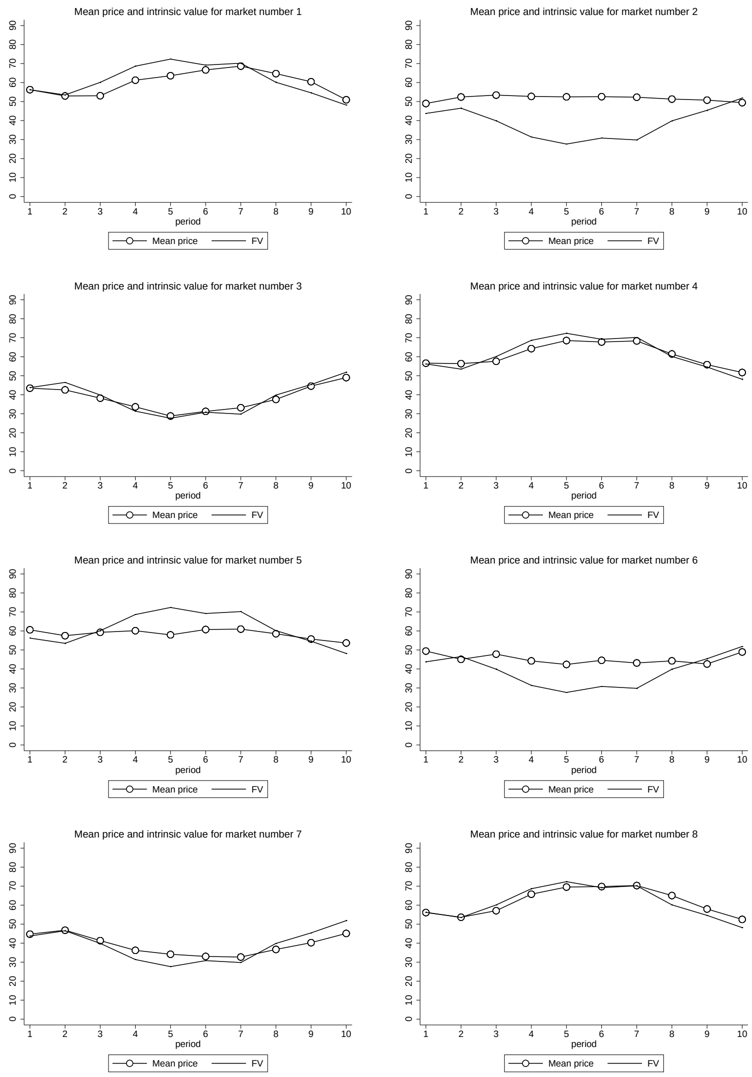


Figure A2: Fundamental values and average transaction prices for each market of the SAVE-type.

Appendix B: Experimental Instructions for the SSW markets[16]

Dear Participant! We welcome you to this experimental session and kindly ask you to refrain from talking to each other for the duration of the experiment. If you face any difficulties, contact one of the supervisors.

During this experimental session your take part in **two** experiments (Experiment A and Experiment B). At the beginning of each experiment the instructions applying to the respective experiment will be handed out and read out loud be the supervisors.

Instructions for Experiment A

General Information

This experiment is concerned with replicating an asset market where traders can trade the stocks of a fictitious company for 10 consecutive periods.

Market Description

The market consists of ten subjects. Five of the ten traders get an initial endowment of 20 assets and a working capital of 3000 Taler, another five are endowed with 60 assets and 1000 Taler at the outset. At the beginning of the experiment the asset has a fundamental value (FV) of 50. Evaluating the asset at its initial FV yields that each subjects' wealth adds up to 4000 Taler. In every period you can sell and/or buy assets, and your asset and Taler inventories are transferred to the next trading period, respectively. Each trading period automatically terminates after two minutes.

Trade is accomplished in form of a double auction, i.e., each trader can appear as buyer and seller at the same time. You can submit any quote of assets with prices ranging from 0 to a maximum of 200 Taler (with at most two decimal places). For every bid you make, you have to enter the number of assets you

[16] To mimic closely already existing SSW markets, we use almost identical instructions asDufwenberg et al. (2005). Note also, that in an earlier version of this paper we had a translation mistake (from German to English) in the instructions of the SSW market as the "Fundamental Value" was mistakenly called "Average Holding" Value".

intend to trade as well. Note that your Taler and asset inventory cannot drop below zero.

At the end of each trading period, every asset pays a dividend (profit) which gets summed up to your Taler holding. The dividend (for one asset) amounts either 0 or 10 Taler, given equal probability. Thus, an asset's average dividend amounts 5 Taler for every period. Assets feature a life-span of 10 trading periods, i.e., after dividends are paid out at the end of period 10, assets are worthless.

You do not get any information about the dividend realization of the current period, i.e. you do not know the dividend payment for the current or the coming periods. The only thing you know is that the dividend either takes the value of 10 or 0 (per asset) in each period. *At the end of a period* you will be informed about the dividend realization of the expired period.

Fundamental Value (FV)

The subsequent table might help you to make your decisions. The first column, labeled "Ending Period", indicates the last trading period of the market. The second column, labeled "Current Period", indicates the period during which the FV is being calculated. The third column gives the number of holding periods from the period in the second column until the end of the market. The fourth column, labeled "Average Dividend Value Per Period", gives the average amount that the dividend will be in each period for each unit held in your inventory. The fifth column, labeled "Fundamental Value Per Unit of Inventory", gives the expected total dividend earnings (per asset) for the remainder of the experiment. That is, for each unit you hold in your inventory for the remainder of the market, you receive in expectation the amount listed in column 5, which is the defined as the FV of the current period. The number in column 5 is calculated by multiplying the numbers in column 3 and 4.

Fundamental Value Table

Suppose for example that there are 4 periods remaining in a market. Since the dividend on a unit of asset has a 50% chance of being 0 and a 50% chance of being 10, the dividend is in expectation 5 Taler (per period for each asset). If you hold one asset for 4 periods, the total dividend paid on the unit over 4 periods is in expectation 4 * 5 = 20.

Ending period	Current period	Number of Holding Periods	x	Average Dividend Value per Period	=	Fundamental Value per Unit of Inventory
10	1	10		10		50
10	2	9		10		45
10	3	8		10		40
10	4	7		10		35
10	5	6		10		30
10	6	5		10		25
10	7	4		10		20
10	8	3		10		15
10	9	2		10		10
10	10	1		10		5

Calculate Your Earnings

At the end of the market (after 10 periods), assets have a value of zero. Solely your Taler holding serves the determination of your total earnings.

Your earnings for a period are calculated as follows:

Your EARNINGS FOR A PERIOD = dividend per unit * number of units in inventory (at the end of the period) + revenues/− expenditures (accruing in the course of trading).

If you *buy* assets, your Taler holding is diminished by the respective expenditures (price * volume). Inversely, if you *sell* assets, your Taler holding will be increased by the respective revenues (price * volume). Your total profit in the market results from the initial Taler endowment (1000 or 3000 Taler), plus the sum of earnings acquired in all 10 trading periods.

Your TOTAL EARNINGS in the market =
Initial Taler endowment + earnings for period 1 + earnings for period 2 +
earnings for period 3 + earnings for period 4 + earnings for period 5 +
earnings for period 6 + earnings for period 7 + earnings for period 8 +

earnings for period 9 + earnings for period 10.

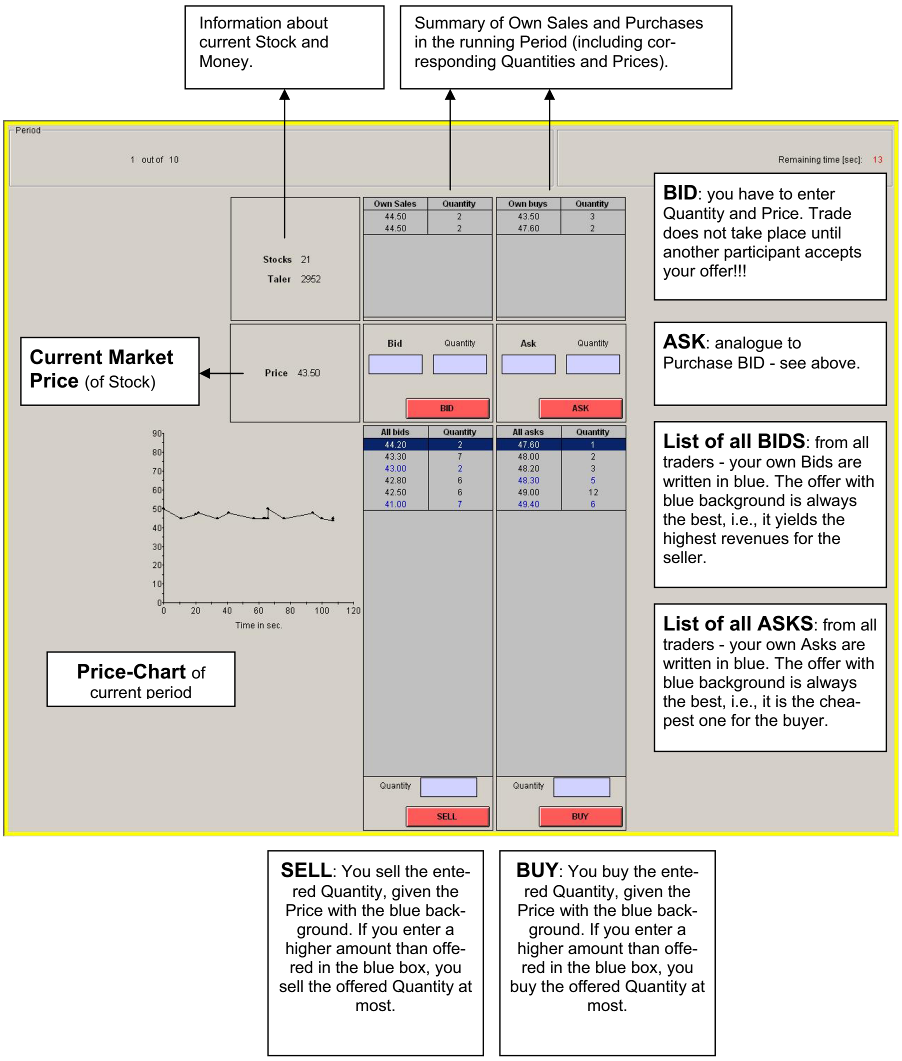
Your total earnings in this experiment are converted into Euro at a rate of

400 Taler = 1 Euro

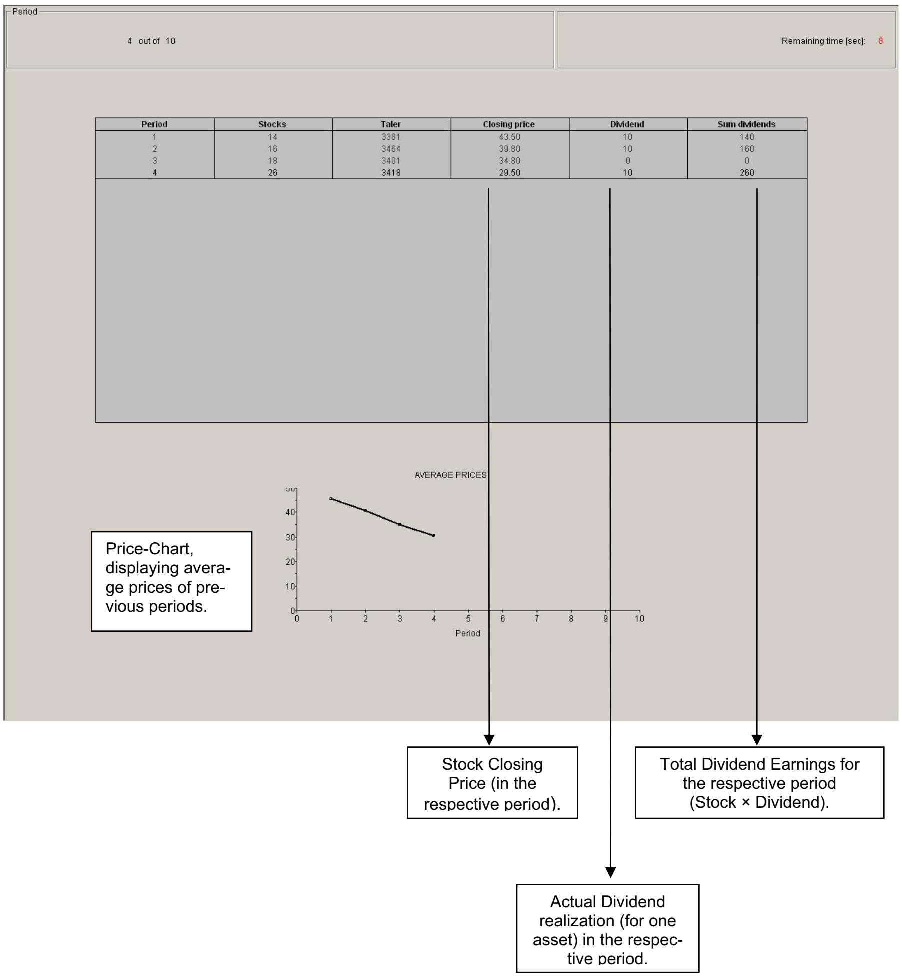
Important information

- No interest is payed for Taler holdings.
- Each trading period lasts for 120 seconds.
- The experiment ends after 10 periods.
- Use the full stop (.) as decimal place.

Trading screen: By means of the following graphics, the procedure of trading (buying and selling) will be illustrated.



History screen: appears after every trading period (for 10 seconds), providing you with vital information:



Appendix C: Experimental Instructions for the SAVE markets

Dear Participant! We welcome you to this experimental session and kindly ask you to refrain from talking to each other for the duration of the experiment. If you face any difficulties, contact one of the supervisors.

During this experimental session your take part in **two** experiments (Experiment A and Experiment B). At the beginning of each experiment the instructions applying to the respective experiment will be handed out and read out loud be the supervisors.

Instructions for Experiment B

General Information

This experiment is concerned with replicating an asset market where traders can trade the stocks of a fictitious company for 10 consecutive periods.

Market Description

The market consists of ten subjects. Five of the ten traders get an initial endowment of 20 assets and a working capital of 3000 Taler, another five are endowed with 60 assets and 1000 Taler at the outset. At the beginning of the experiment the asset has a fundamental value (FV) of 50. Evaluating the asset at its initial FV yields that each subjects' wealth adds up to 4000 Taler. In every period you can sell and/or buy assets, and your asset and Taler inventories are transferred to the next trading period, respectively. Each trading period automatically terminates after two minutes.

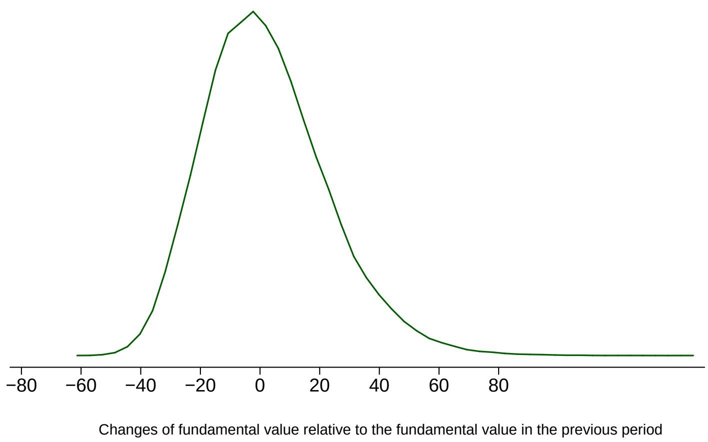
Trade is accomplished in form of a double auction, i.e., each trader can appear as buyer and seller at the same time. You can submit any quote of assets with prices ranging from 0 to a maximum of 200 Taler (with at most two decimal places). For every bid you make, you have to enter the number of assets you intend to trade as well. Note that your Taler and asset inventory cannot drop below zero.

Fundamental value (FV) of the asset

The fundamental value ($\neq$ the price) of the stock is the value at which the assets are bought back at the end of the experiment. In reality the FV depends on company specific as well as general economic variables. In the experiment the FV is modeled according to the following random process:

$$FV_{(t)} = FV_{(t-1)}e^{\alpha}$$

The current FV corresponds to the FV one period ago altered by a change parameter (α). This α is drawn from a normal distribution with mean 0 and a standard deviation of 20 %. The graphic below illustrated possible changes of the fundamental value relative to the fundamental value one period ago. Modest changes occur at higher probabilities than large changes do.



Information about the fundamental value

In each period you receive a signal about the fundamental value of the stock. At the market level the majority of the signals is close to the true fundamental value but large deviations are possible. The signals vary with a standard deviation of 5% around the true FV. The precision of the signal changes every period and does not follow any systematic pattern. Positive and negative deviations of the signals sum up to 0 each period.

Total wealth

Your wealth is the sum of your Taler holdings and the number of your stocks multiplied by the current price. Generally, for evaluation of your wealth the current price on the market is being used, so your wealth will change even if you did not participate in the last transaction.

$$Wealth = (StockHoldings * Price) + TalerHoldings$$

Your earnings

Your earnings at the end of the experiment depend on your total wealth at the end of the experiment. Stock holdings are evaluated with the true **fundamental value** in period 10. Your wealth in Taler is transfered into Euro according to the following exchange rate:

400 Taler = 1 EUR.

Example:

At the end of the experiment you hold 45 stocks and 1,607.35 Taler. The stocks are evaluated at their true fundamental value of 63.17 in period 10. Calculating your wealth at the end of the experiments yields:

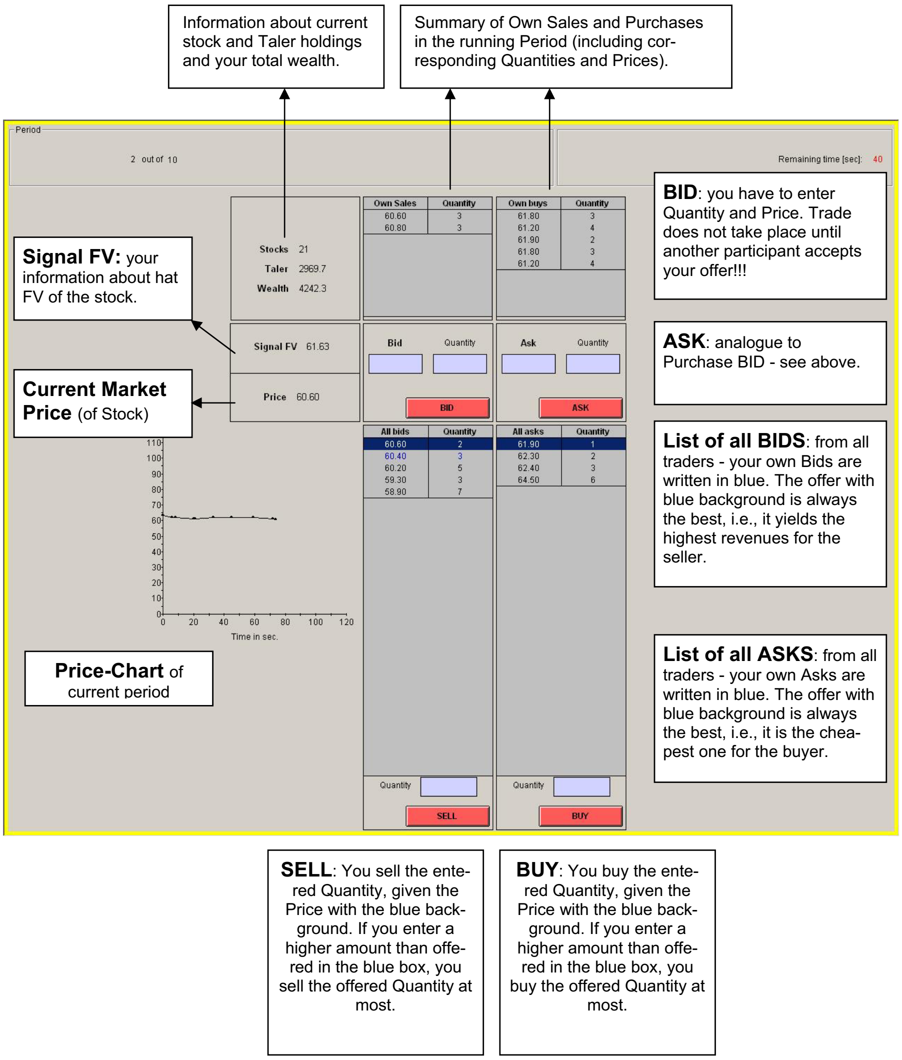
1,607.35 Taler + 45 stocks * 63.17 Taler = 4,450 Taler

Your payment is calculated a follows: 4.450/400 = EUR 11.13 (Payment: EUR 11)

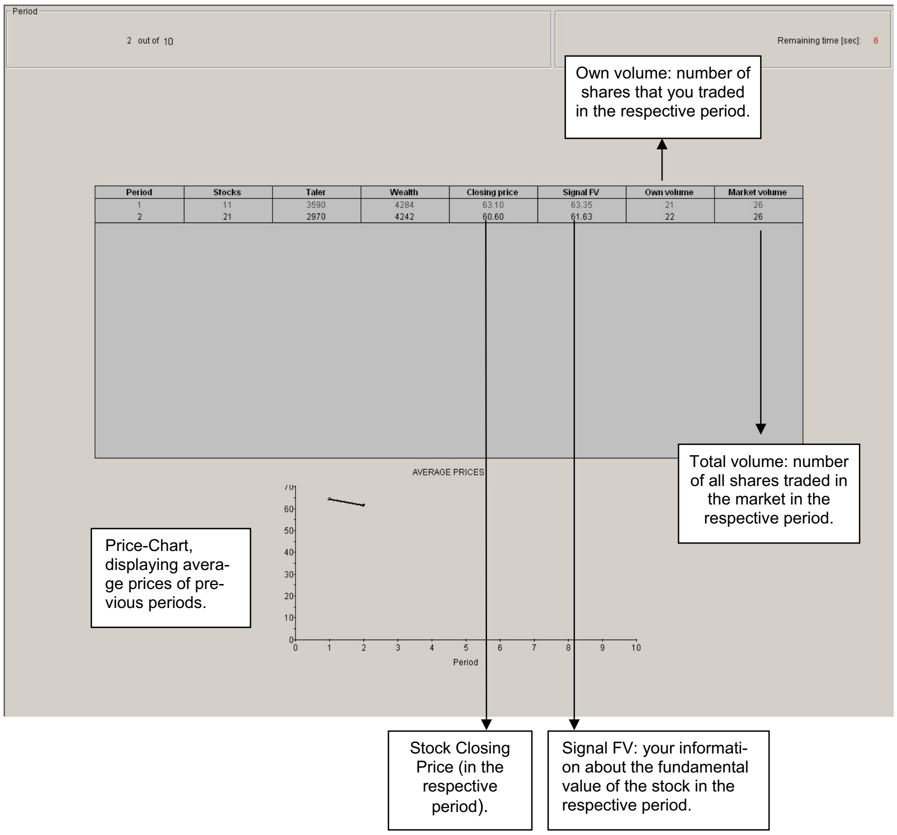
Important information

- No interest is payed for Taler holdings. Assets do not pay any dividends.
- Each trading period lasts for 120 seconds.
- The experiment ends after 10 periods.
- Use the full stop (.) as decimal place.

Trading screen: By means of the following graphics, the procedure of trading (buying and selling) will be illustrated.



History screen: appears after every trading period (for 10 seconds), providing you with vital information:



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Michael Kirchler, Jürgen Huber and Thomas Stöckl

Bubble or no Bubble - The Impact of Market Model on the Formation of Price Bubbles in Experimental Asset Markets

Abstract

For the past two decades a market model introduced by Smith, Suchanek, and Williams (1988, henceforth SSW) has dominated experimental research on financial markets. In SSW the fundamental value of the traded asset is determined by the expected value of a finite stream of dividend payments. This setup implies a deterministically falling fundamental value with a predetermined end of the life-span of the asset and extremely high dividend-payouts. We present a new market model in which we implement the fundamental value by adopting a random walk process. Compared to SSW-markets, prices in the new markets (SAVE) are more efficient and end-of-experiment imbalances common in SSW-markets are not observed. Our results demonstrate, that implicit features of the SSW market model contribute to bubble formation.

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