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# Thar She Bursts: Reducing Confusion Reduces Bubbles[†]

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*To explore why bubbles frequently emerge in the experimental asset market model of Smith, Suchanek, and Williams (1988), we vary the fundamental value process (constant or declining) and the cash–to–asset value ratio (constant or increasing). We observe high mispricing in treatments with a declining fundamental value, while overvaluation emerges when coupled with an increasing C/A ratio. A questionnaire reveals that the declining fundamental value process confuses subjects, as they expect the fundamental value to stay constant. Running the experiment with a different context ("stocks of a depletable gold mine" instead of "stocks") significantly reduces mispricing and overvaluation as it reduces confusion.* (*JEL* C91, D14, G11, G12)

We explore possible causes for the emergence of "bubbles" in experimental asset markets replicating the seminal design introduced by Smith, Suchanek, and Williams (1988), henceforth SSW. In particular, we separate the effect on market efficiency of a declining/constant fundamental value (FV) from the effect of an increasing/constant cash–to–asset value ratio (C/A ratio).[1] We observe that confusion in treatments with declining fundamental value is the main driver for mispricing and leads to overvaluation when coupled with a high C/A ratio.[2] This is supported by findings from a questionnaire and from two control treatments where the notion "stocks" is replaced by "stocks of a depletable gold mine." This change in context reduces subjects' confusion about the FV (elicited by a questionnaire) and leads to significantly smaller mispricing and overvaluation. The design is robust to treatment changes like

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[1] The C/A ratio is the ratio of all subjects' cash holdings and the total asset value, i.e., number of shares outstanding multiplied by FV.

[2] Overvaluation is present when average prices are above the respective fundamental value (FV). Mispricing measures deviations of prices from FVs, irrespective of whether they are positive or negative. Here we follow Stöckl, Huber, and Kirchler (2010) and measure mispricing by Relative Absolute Deviation (RAD) and overvaluation by Relative Deviation (RD).

a higher variance of the dividend process and a higher initial C/A ratio that have rekindled bubbles in earlier experiments.

In 1988, Smith, Suchanek, and Williams (1988) introduced a new and groundbreaking methodology to test the efficient market hypothesis (EMH) postulated by Fama (1970). While empirical studies testing the EMH suffer from the FV's being unobservable, fundamentals become perfectly observable in laboratory asset markets. SSW define the FV as the expected value of a finite stream of stochastic dividend payments generating a FV that *declines deterministically*. The key finding of SSW is that market prices deviate strongly from the FV, with prices being mostly too high—the authors talk of bubbles. Over the past two decades numerous studies have replicated and modified this setting, exploring how parameter changes, such as short selling, experience, futures markets, constant fundamental value, etc. influence bubble formation.[3]

When investigating the properties of SSW markets in more detail, one observes that the amount of cash grows due to dividend payments, while the FV of the asset declines to zero. Thus, the C/A ratio in the market increases several fold over the course of the experiment.[4] Hence, SSW markets are characterized by a declining FV combined with an increasing C/A ratio over time.[5]

We separate the effect of a declining/constant FV from the effect of an increasing/constant C/A ratio to provide explanations for the impact of each variable on mispricing and overvaluation. With a $2 \times 2$ design we test for each factor's impact, as, in addition to the replication of experiments with a declining FV and an increasing C/A ratio and experiments with a constant FV and a constant C/A ratio, we introduce one treatment with a declining FV and a constant C/A ratio and one treatment with a constant FV and an increasing C/A ratio. Table 1 provides an overview of the $2 \times 2$ design and related papers.

We observe (i) high mispricing in treatments with declining FVs and (ii) overvaluation when a declining FV is coupled with an increasing C/A ratio. A questionnaire reveals that (iii) the concept of a declining fundamental value generates confusion among subjects, with most subjects believing the FV to either stay constant or increase. (iv) In two control treatments with the different context "stocks of a depletable gold mine" we find significantly smaller mispricing and overvaluation than in the comparable treatment using the term "stocks." This holds even when the variance of the dividend process and the initial C/A ratio are increased several fold. This points to the importance confusion about the FV plays in bubble formation.

[3] Haruvy and Noussair (2006) investigate the impact of short selling and buying on margin. Van Boening, Williams, and LaMaster (1993) use call markets instead of continuous double auction markets, while Lei, Noussair, and Plott (2001) add a parallel market with a short-term asset that exists for only one period. Smith, van Boening, and Wellford (2000); Noussair, Robin, and Ruffieux (2001); and Oechssler, Schmidt, and Schnedler (2007) keep the FV constant over time. Lei, Noussair, and Plott (2001) preclude speculation by prohibiting buyers to resell the asset and sellers to buy it. In most of the aforementioned studies, bubbles still emerge. Instead, bubbles are less pronounced with experienced subjects trading in the same setting, and when special emphasis is put on a thorough understanding of the dividend process. This is reported in Dufwenberg, Lindqvist, and Moore (2005) and Lei and Vesely (2009), respectively.

[4] In most settings the C/A ratio increases by a factor of 15 to 50.

[5] Although unexplainable from a rational expectations perspective, Caginalp, Porter, and Smith (1998); Caginalp, Porter, and Smith (2001); and Haruvy and Noussair (2006) report that high initial C/A ratios drive bubble formation in experimental asset markets. Given these behavioral findings and the dramatic increase in the C/A ratio over time in markets with declining FVs the C/A ratio was chosen as one of the two treatment variables in this study.

TABLE 1—OVERVIEW OF THE TWO TREATMENT VARIABLES "C/A RATIO" AND "FUNDAMENTAL VALUE" (FV) AND RELATED LITERATURE

| | | Fundamental value (FV) | |
|---|---|---|---|
| | | Declining | Constant |
| C/A ratio | Increasing | Literature available[a] | Literature available[c] |
| | Constant | No literature | Literature available[b] |

[a] See, e.g., Smith, Suchanek, and Williams (1988); Caginalp, Porter, and Smith (2000); Smith, van Boening, and Wellford (2000), A2; Caginalp, Porter, and Smith (2001); Dufwenberg, Lindqvist, and Moore (2005); Haruvy and Noussair (2006); Noussair and Tucker (2006); Haruvy, Lahav, and Noussair (2007); Hussam, Porter, and Smith (2008); Sutter, Huber, and Kirchler (2010).
[b] See, e.g., Caginalp, Porter, and Smith (1998); Smith, van Boening, and Wellford (2000), A1; Noussair, Robin, and Ruffieux (2001); Oechssler, Schmidt, and Schnedler (2007).
[c] Camerer and Weigelt (1993).

The paper is structured as follows: Section I outlines the research questions and methodology; Section II provides details on market design, experimental treatments, and experimental implementation. Section III presents results from the experiments, and Section IV concludes.

## I. Research Questions and Methodology

### A. *Research Questions*

Exploring possible causes of bubbles Smith, van Boening, and Wellford (2000) investigate the impact of dividend timing on asset prices. In their Treatment A1 the asset pays a random dividend at the end of the experiment, while in A2 dividends are paid out each period. The former model leads to a constant FV with a constant C/A ratio while the latter is the classic SSW design with a declining FV and an increasing C/A ratio. The authors conclude that frequent dividend payments in Treatment A2 induce bubble formation in comparison to A1 where no bubbles occur. These findings serve as starting point for Noussair, Robin, and Ruffieux (2001) who conjecture that (i) frequent dividend payments increase the likelihood of bubbles and that (ii) changing (declining) FVs contribute to bubble formation, as prices need to adjust to the FV each period. They combine per period dividend payments (with an expected value of zero) with a constant FV (the asset is bought back at the end of the experiment at an ex ante known terminal value). Reporting moderate bubbles, they argue that a constant FV cannot eliminate bubbles completely. Again, the authors name frequent dividend payments as the main driver of bubble formation.

However, comparing treatments A2 to A1 in Smith, van Boening, and Wellford (2000), and the studies of Smith, Suchanek, and Williams (1988) to Noussair, Robin, and Ruffieux (2001) is problematic, since two parameters are changed simultaneously: The FV is constant, rather than declining, and the C/A ratio changes from increasing to constant. Consequently, it is impossible to exactly identify whether the larger bubbles in Smith, Suchanek, and Williams (1988) and in A2 of Smith, van Boening, and Wellford (2000) are due to a declining FV, an increasing C/A ratio, or both. With a $2 \times 2$ design we examine changes in each factor (FV process and C/A ratio) separately. We formulate the following research questions:

- RQ1: Does an increasing C/A ratio lead to mispricing and/or overvaluation?
- RQ2: Does a declining fundamental value lead to mispricing and/or overvaluation?

If the increasing C/A ratio proved to be the main driver of mispricing and/or overvaluation, the results of Smith, van Boening, and Wellford (2000) would be supported.

However, if the declining FV turned out to be the main driver, we focus on behavioral explanations, especially the influence of the experiment's context and potential confusion of experimental subjects. Two recent papers, Chou et al. (2009) and Smith (2010), stress the importance of context (the former talk of "recognition") in laboratory experiments. The latter argues that subjects interpret the task they face in an experiment against the background of their past experiences and personal knowledge. Summarizing his experiences with markets of the SSW type, Smith outlines that subjects seem to be "*confused*," and that they "*do not get the message*" (pp. 6 and 7, respectively, in Smith 2010; emphasis added). Following a similar line of reasoning, Oechssler (2010) argues that the SSW design is very different from real markets and may therefore be difficult to understand for subjects. Consequently, we conjecture that the term "stock" used in the instructions confuses subjects as it is commonly associated with stable or upward trending prices (Smith 2010, p. 6, talks of "*homegrown expectations of prices rising*"), in contrast to the deterministically declining FV paths in the experiment.[6] We therefore formulate the following research question:

- RQ3: If a declining fundamental value significantly contributes to mispricing and/or overvaluation, is confusion, i.e., the lack of understanding the FV concept, evident?

To test this research question, we run a questionnaire after each experiment on the understanding of the FV process, and we conduct two control treatments where we change one paragraph in the instructions, talking of "stocks of a depletable gold mine" rather than "stocks" in general.

### B. *Measuring Mispricing and Overvaluation*

Stöckl, Huber, and Kirchler (2010) point out some weaknesses of previously used bubble measures. Following them, we apply RAD (relative absolute deviation) for "mispricing" and RD (relative deviation) for "overvaluation." Table 2 outlines details on the two measures. The resulting numbers of RAD and RD are easy to

[6] Literature already provides hints that subjects may have difficulties in understanding the concept of a declining FV in the SSW design: Lei and Vesely (2009) put special emphasis on the protocol of the experiment and report that no bubbles emerge when they introduce a premarket phase to focus subjects' attention on the dividend structure. The results in Dufwenberg, Lindqvist, and Moore (2005) can be interpreted in a similar way, since experience in repeated SSW markets with identical settings, and thus a better understanding of the process governing the FV, eliminates bubbles. Note, however, that experience reduces bubbles only when the setting remains unchanged. Hussam, Porter, and Smith (2008) provide evidence that even among experienced subjects bubbles can be rekindled when the initial C/A ratio and the variance of the dividend process are increased several fold.

TABLE 2—BUBBLE MEASURES: RAD AND RD

| Measure | Calculation |
| --- | --- |
| Relative absolute deviation | $RAD = (1/N)\sum_{p=1}^{N} \lvert \overline{P_p} - FV_p \rvert / \lvert \overline{FV} \rvert$ |
| Relative deviation | $RD = (1/N)\sum_{p=1}^{N} \left(\overline{P_p} - FV_p\right) / \lvert \overline{FV} \rvert$ |

*Note:* $P_p$ = (volume-weighted) mean price in period $p$; $FV_p$ = fundamental value in period $p$; $\overline{FV}$ = average fundamental value of the market.

interpret—a RAD of 0.1 means that prices on average differ by 10 percent from the average fundamental value. RD provides additional information whether the asset is overvalued—e.g., with a RD of 0.1 (−0.1) prices are on average 10 percent higher (lower) than the average fundamental value. A combination of RAD = 0.1 and RD = 0 indicates that prices are on average 10 percent off the fundamental value, but phases of over- and undervaluation cancel out. In this case, mispricing would be present, but nonsystematic as far as its direction is concerned.[7]

## II. The Experiment

In each of our laboratory markets, ten subjects trade a dividend paying stock for experimental currency (Taler) in a sequence of ten periods. Dividends are paid out at the end of each period or are deferred and paid out at the end of the experiment. The realized dividend payments are not known in advance, but at the end of each period subjects learn the dividend of the respective period.

To determine the asset's FV, subjects know the possible dividend realizations, their probability of occurrence, the total number of trading periods, and the terminal value of the asset (if any).

$$FV_k = E(\text{dividend}) \cdot \text{remaining periods} + \text{terminal value}. \tag{1}$$

Given this information set, the FV in period $k$ is the product of the expected dividend payment per period and the number of periods remaining plus any terminal value (zero in SSW). This is public knowledge (see experimental instructions in the online Appendices B, C, and D).

### A. *Markets with a Declining Fundamental Value*

In markets with a declining FV, the dividend is either 0 or 10 with equal probability. The FV in period 1 is therefore 50 and decreases by 5 each period. After ten periods the asset expires worthless; no terminal value is paid to subjects.

[7] We additionally include results of some of the more familiar measures used in earlier studies on the SSW model, like share turnover (ST), price amplitude (PA), total dispersion (TD), and average bias (AB) in Table A2 of the Appendix. See Table A1 for details on the formulae.

### B. *Markets with a Constant Fundamental Value*

In markets with a constant FV the dividend per period is either −5 or 5 with equal probability. Thus, dividends have an expected value of zero. In these treatments assets have a positive terminal value of 50. Hence, the FV is constant across periods with a value of 50.

### C. *Experimental Treatments*

At the beginning of each experimental session half of the subjects are endowed with 60 shares and 1,000 Taler (the experimental currency), while the other half are endowed with 20 shares and 3,000 Taler. Valued at the initial FV of 50, which is identical in all treatments, each subject starts with an initial wealth of 4,000 Taler. At the beginning of each market the total cash amount in the market $(5 \cdot 1{,}000 + 5 \cdot 3{,}000 = 20{,}000)$ equals the value of all stocks in the market $(5 \cdot 20 + 5 \cdot 60 = 400 \text{ stocks} \cdot 50 = 20{,}000)$. Thus, the initial ratio between cash and asset value (the C/A ratio) is 1.[8]

We implement a $2 \times 2$ design with the treatment variables FV (either constant or declining) and C/A ratio (either constant or increasing). Table 3 presents an overview of the different treatment abbreviations and properties. The treatment abbreviations are to be read as follows: The symbols "\" and "—" specify whether the FV is declining or constant. "=" and "+" indicate whether the C/A ratio is constant or increasing.[9]

The first treatment, T1(\+), replicates the classic experiment of the SSW type with declining FV and increasing C/A ratio. Dividend payments generate frequent inflows of cash into the market, which increases the available cash in the market on average by 2,000 (either 0 or 4,000 with equal probability) in each period.[10] Over the course of the experiment the "monetary base" therefore doubles. This increase in cash is accompanied by a declining fundamental value, which falls by 90 percent from period 1 to the start of period 10. Thus, the C/A ratio increases nineteenfold over the course of the experiment.[11]

Treatment two, T2(—+), is designed with a constant FV and an identical increase in the C/A ratio as in T1(\+). Subjects receive increasing exogenous cash inflows in each period which mimic the development of the C/A ratio in T1(\+). This requires quite substantial cash inflows in each period—e.g., total cash inflow into the market is 200,000 in the last period. Dividends are collected in a separate dividend account.

In the third treatment, T3(\=), characterized by a declining FV and a constant C/A ratio, dividend payments are displayed but collected in a separate account

[8] Different values are used in round 2 of Treatment T6(\+$_{\text{G\_re}}$).

[9] Tables A1 and A2 in online Appendix A provide further details on each treatment.

[10] In SSW markets dividend yields (ratio of dividends to FV) are extremely high, starting at 10 percent in the first period of a ten-period setting and reaching 33, 50, and 100 percent, respectively, in the last three periods. In real markets, however, dividend yields (ratio of dividends to prices) are very low—the dividend yield of stocks on the NYSE 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 NYSE pay dividends. Source: http://www.indexarb.com.

[11] Smith, Suchanek, and Williams (1988) use different parameters, e.g., in their Treatment "Design 1" (nine traders, 30 periods) they implement a C/A ratio in period 1 of 1.2 which increases to 48.9 in period 30.

TABLE 3—TREATMENT PARAMETERIZATION

| | T1(\+)[a] | T2(—+) | T3(\=) | T4(——=) | T6(\+$_{G\_re}$), R2 |
|---|---|---|---|---|---|
| Exp. dividend | 5 | 0 | 5 | 0 | 6 |
| Periods | 10 | 10 | 10 | 10 | 10 |
| $FV_0$ | 50 | 50 | 50 | 50 | 60 |
| $FV_{10}$ | 0 | 5 | 0 | 50 | 0 |
| Number stocks | 400 | 400 | 400 | 400 | 200 |
| Total asset value$_0$ | 20,000 | 20,000 | 20,000 | 20,000 | 12,000 |
| Initial cash | 20,000 | 20,000 | 20,000 | 20,000 | 40,000 |
| Cash in/outflow | 2,000 | + | −2,000 | 0 | 1,200 |
| Dividend account | No | Yes | Yes | Yes | No |
| Source of in/outflow | Dividend | Exogenous cash flow | Saving account | No cash inflow | Dividend |
| FV process | \ | — | \ | — | \ |
| C/A ratio | +(1–19) | +(1–19) | =(1) | =(1) | +(3.33–42.33) |

[a] The parametrization is identical in T5(\+$_G$) and in round 1 (R1) of T6(\+$_{G\_re}$).

and paid out at the end of the experiment. However, this would still lead to a tenfold increase in the C/A ratio until period 10, as the FV declines by 90 percent. Consequently, we additionally reduce the monetary base by deducting 200 Taler from each subject's cash account at the end of each period. If a subject has less than 200 Taler, her money holdings become negative, and she is not allowed to buy assets or post bids until her money holdings are positive again. Therefore, the C/A ratio of 1 remains constant over time, as the "monetary basis" in the market is reduced by 90 percent from period 1 to period 10 as well.

Treatment four, T4(——=), features a constant FV and a constant C/A ratio. Dividends are collected in a separate dividend account.

Treatment five, T5(\+$_G$), is an exact replication of T1(\+). We change only one paragraph in the instructions, talking of "stocks of a depletable gold mine" rather than "stocks."

Treatment six, T6(\+$_{G\_re}$), serves as a robustness check for T5(\+$_G$) and is inspired by Hussam, Porter, and Smith (2008), who rekindle bubbles with twice-experienced subjects by increasing the C/A ratio and the variance of the dividend process. The treatment consists of two rounds (R1 and R2) of ten periods each. The first round is an exact replication of Treatment T5(\+$_G$). In the second round the number of stocks is reduced, while both cash holdings and the variance of the dividend process are increased.[12]

## D. *Market Architecture*

Subjects trade in a continuous double auction with open order books with all orders 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.

[12] Details on the parameters follow in Section IIIC.

The trading screen provides subjects with current information on their stock and Taler holdings. All transaction prices with the corresponding trading time are shown in a real time chart on the left side of the screen.[13] Each market consists of ten trading periods of 120 seconds each. Taler and stock holdings are carried over from one period to the next. No interest is paid on Taler holdings, and there are no transaction costs.

### E. *Experimental Implementation*

Six markets were run for each of the six treatments. All 36 experimental markets were conducted between December 2009 and October 2010 at the University of Innsbruck with a total of 360 students (bachelor and master students in business administration and economics). Most subjects had already taken part in other experiments in economics, but each subject participated in only one market of this study. We especially took care that the subjects did not participate in earlier asset market experiments of comparable design. The markets were programmed and conducted with z-Tree 3.2.8. by Fischbacher (2007). Subjects were recruited using ORSEE by Greiner (2004).

At the beginning of each session subjects had 15 minutes to read the instructions on their own. This was done to eliminate any possible experimenter bias. We set up the instructions in an identical way to the papers of Dufwenberg, Lindqvist, and Moore (2005) for markets with declining FVs, and Noussair, Robin, and Ruffieux (2001) for markets with constant FVs to ensure comparability to existing literature. Afterwards, the trading screen was explained in detail, followed by two trial periods to allow subjects to become familiar with the trading screen. After the main experiment, subjects had to complete a questionnaire testing their understanding of the FV process and asking for demographic data.

In markets with a declining FV the traded asset is worthless after the last period. Thus, only Taler holdings are converted at a known exchange rate of 400 Taler = 1 euro (The exchange rate is 520 Taler = 1 euro in T6(\+$_{G\_re}$), R2). In markets with a constant fundamental value, the final wealth (units of the asset multiplied by FV of 50 plus Taler holdings) is converted at an exchange rate of 400 (4,000) Taler = 1 euro in T4(—=) (T2(—+)).

Each session lasted around 60 to 80 minutes and average earnings for treatments T1(\+) to T5(\+$_{G}$) were 10 euro while average earnings in Treatment T6(\+$_{G\_re}$) were 20 euro. Before the main experiment we ran a standard lottery experiment to measure risk aversion similar to Holt and Laury (2002). Subjects earned on average 4 euros from the lottery experiment in addition.

## III. Results

### A. *Overview*

Figure 1 provides an overview of mean prices (bold lines with circles), price paths of individual markets (gray lines), and the FVs (bold lines) in treatments T1(\+)

[13] See online Appendix B for a screenshot.

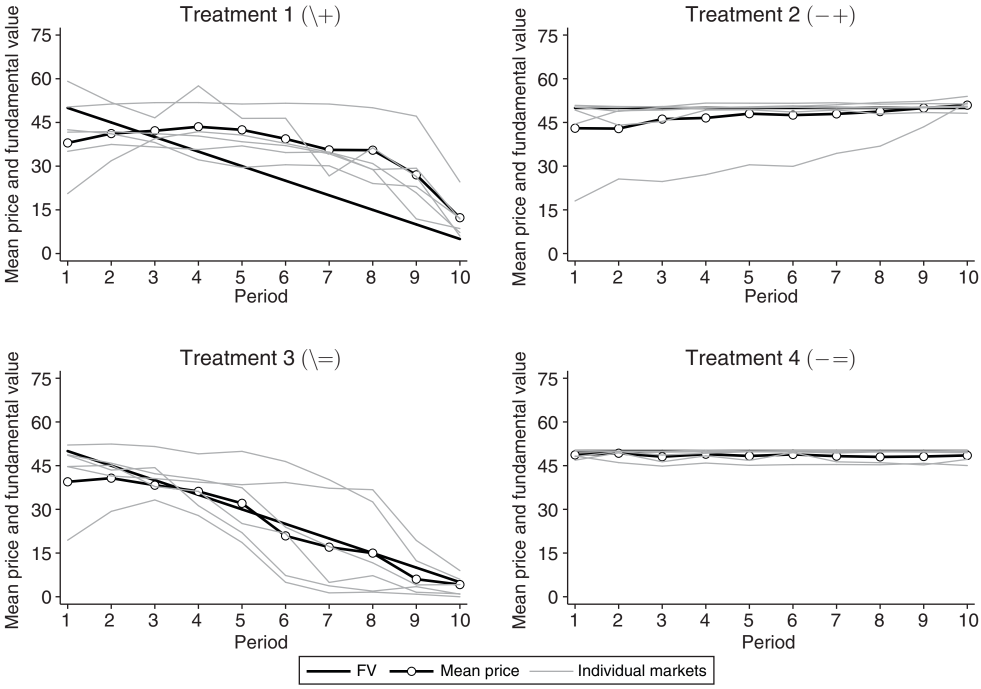


FIGURE 1

*Notes:* Fundamental Value (*FV, bold line*), Mean Treatment Prices (*bold line with circles*), and Volume-Weighted Mean Prices of Individual Markets (*gray lines*) as a Function of Period. Left panels: Treatments T1(\+) and T3(\=) featuring declining FVs. Right panels: Treatments T2(—+) and T4(——=) with constant FVs.

TABLE 4—TREATMENT AVERAGES FOR RAD AND RD

| Treatment | RAD | RD |
|---|---|---|
| T1(\+) | 0.414 | 0.297 |
| T2(—+) | 0.079 | −0.060 |
| T3(\=) | 0.306 | −0.040 |
| T4(——=) | 0.027 | −0.027 |

*Note:* We provide values of RAD and RD and values of some previously used bubble measures ST, PA, TD, AB for each market in Table A2 in Appendix A.

to T4(——=). One can see that treatments with declining FVs are characterized by a high variability of price paths in individual markets. On aggregate, mean prices are well above the FV in T1(\+), while mean prices track the fundamental value in T3(\=). In treatments with constant FVs, mean prices track fundamentals quite accurately.

Turning to mispricing (RAD) and overvaluation (RD) one can see patterns in Table 4. In T1(\+), in which the fundamental value declines and the C/A ratio increases (top left panel of Figure 1), a RAD of 41.4 percent documents high mispricing and a RD of 29.7 percent marks strong overvaluation. This is in line with earlier literature on the SSW design. Mispricing still remains high, but overvaluation

Table 5—Overview of the pairwise Mann-Whitney-U-Tests to answer RQ1 and RQ2

| | T1(\+) | T4(—=) |
|---|---|---|
| T2(—+) | RQ2 (FV) | RQ1 (C/A) |
| T3(\=) | RQ1 (C/A) | RQ2 (FV) |

is no longer present (on average) as soon as the C/A ratio is kept constant over time in markets with declining fundamental value (bottom left panel of Figure 1, Treatment T3(\=)). Due to the constant C/A ratio of 1 in T3(\=), individuals lack the buying power to bid prices up or keep them high when others want to sell. Prices decline along with overall money supply, but confusion about the declining FV process is still evident in the huge dispersion of prices (measured by RAD).

In contrast, both treatments with constant FVs (right panels in Figure 1) display very efficient prices.

## B. *Statistical Tests on Research Questions 1 and 2*

To test for differences between treatments we conduct Mann-Whitney-U-tests. We consider markets with an increasing C/A ratio (declining FV) and test them against markets with a constant C/A ratio (constant FV) to answer RQ1 (RQ2). We run this analysis for the pooled dataset and for pairwise comparison of treatments (see Table 5).

It is evident from Table 6 that on aggregate markets with declining fundamental values are characterized by strong mispricing compared to markets with constant FVs as the *Z*-value of RAD is highly significant with a difference in means of 30.7 percentage points (see line 1 in the bottom panel of Table 6). While the results for overvaluation look similar on the aggregate level (with a significant difference of 17.1 percentage points), a closer inspection of Table 6 reveals that overvaluation is very strong in T1(\+) compared to T2(—+) and T3(\=). Though not significant due to the small sample size and the high variance in individual market realizations when comparing T1(\+) with T3(\=), an increasing C/A ratio in markets with declining FVs seems to be necessary to lead to overvaluation as well.[14]

Summarizing our results so far, we find high mispricing in treatments with declining FVs, while overvaluation emerges only when a declining FV is coupled with an increasing C/A ratio. This is not in line with Smith, van Boening, and Wellford (2000), as frequent dividend payments in treatments with constant FV do not lead to bubbles.

[14] Risk-averse subjects might act more cautiously in treatments with potentially negative dividend payments (those with a constant FV) compared to treatments with strictly nonnegative dividends (those with a declining FV). This would result in less speculation and consequently in lower turnover. Therefore, we run the Mann-Whitney-U-tests of Table 6 with share turnover (ST) as the variable of interest. We find no statistical difference in all specifications, i.e., trading volume is not different between treatments. We thank an anonymous referee for pointing us to this idea. See Table B1 in the Appendix for a related analysis.

TABLE 6—TESTS ON RESEARCH QUESTIONS 1 AND 2

| RQ1 (C/A-ratio) | | RAD | RD |
|---|---|---|---|
| T1(\+) & T2(—+) versus T3(\= ) & T4(—=) | Δ mean | 0.080 | 0.152** |
| $N = 24$ | Z | −0.751 | −2.078 |
| T1(\+) versus T3(\=) | Δ mean | 0.109 | 0.337 |
| $N = 12$ | Z | −0.801 | −1.601 |
| T2(— + ) versus T4(—=) | Δ mean | 0.052 | −0.033 |
| $N = 12$ | Z | −0.641 | −1.121 |
| **RQ2 (FV)** | | **RAD** | **RD** |
| T1(\+) & T3(\=) versus T2(—+) & T4(—=) | Δ mean | 0.307*** | 0.171** |
| $N = 24$ | Z | −3.753 | −1.963 |
| T1(\+) versus T2(—+) | Δ mean | 0.335** | 0.357 *** |
| $N = 12$ | Z | −2.402 | −2.882 |
| T3(\=) versus T4(—=) | Δ mean | 0.278*** | −0.014 |
| $N = 12$ | Z | −2.882 | −0.160 |

*Notes:* The values represent the differences in means (Δ *mean*) of the treatments under investigation and Z-values from a Mann-Whitney-U-Test ($Z$). To test whether results are driven by outliers we run a robustness check by excluding the markets with the highest RAD in each treatment from the analysis. Results do not change (see Table B1 in the online Appendix).

***Significant at the 1 percent level.

**Significant at the 5 percent level.

### C. *Research Question 3: Behavioral Reasons for the Impact of the FV Process*

In a recent paper Smith states that subjects may be "*confused*" and "*do not get the message*" in SSW-type markets (Smith 2010, pp. 6 and 7, respectively). Furthermore, Smith highlights the importance of the context an experiment is presented in. This might be an important factor here: the term "stock" in the instructions may call to subjects' minds associations of stable or upward trending FV paths—this is supported by the fact that even professional traders produce similar price patterns compared to other subject pools: their daily experience is for stock prices to not decline deterministically, and this pattern is called to their minds when they read "stocks" in the instructions (see Oechssler 2010 for a similar line of reasoning and Smith, Suchanek, and Williams 1988 for experimental results with professional traders).

To test the impact of context and of subjects' confusion, we run a questionnaire and two control treatments with different context.

*Questionnaire*.—After each experimental session, we ask the following question: *"The fundamental value in period p is 50. What will the fundamental value most likely be in the next period?"* Subjects were asked to choose among values of 40, 45, 50, 55, or 60.[15]

The right panel of Figure 2 provides the distribution of subjects' deviations from the correct forecast in both treatments with constant FVs. Nearly 70 percent estimate

[15] The questionnaire was not incentivized.

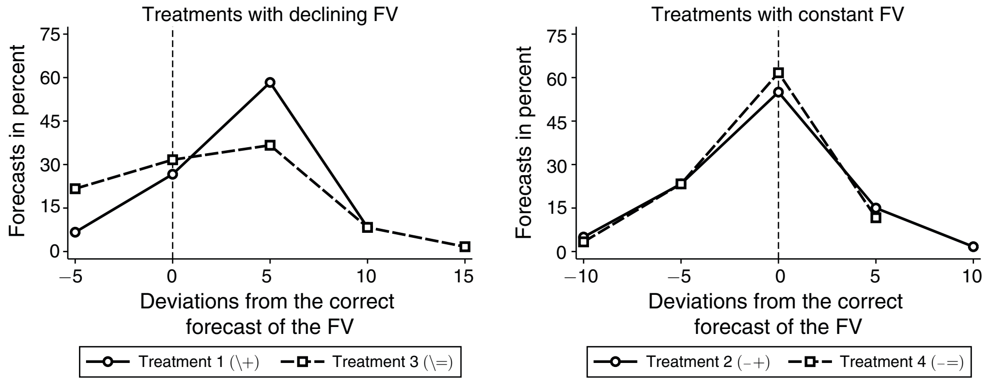


FIGURE 2

*Notes:* Errors in forecasting the FV in the questionnaire. Left panel: treatments T1(\+) and T3(\=) with declining FV. Right panel: treatments T2(—+) and T4(——=) with constant FV.

the FV correctly, and the remaining 30 percent are symmetrically distributed around the correct estimation.

In contrast, in markets with declining FVs (left panel in Figure 2), around 57 percent of subjects expect the FV to remain constant or increase, and less than 30 percent of all subjects forecast the FV correctly.[16]

Subjects obviously are confused by the concept of a declining FV, even after having traded in the market for ten periods. As most subjects in SSW-style markets believe that the FV will stay constant, prices do not decline, producing a "bubble" as the FV declines. This holds especially when an increasing C/A ratio provides enough liquidity to the market.

*Control Treatment with Context "Gold Mine*."—If subjects' confusion about the FV process is a main driver behind bubble formation in SSW markets, a more intuitive context in the instructions should reduce confusion and abate bubbles. Our control treatment T5($\backslash +_G$) is an exact replication of T1(\+), i.e., the classic SSW setting, but with a different context used in the instructions. Instead of "stocks" we label the assets as "stocks of a depletable gold mine." We do this, as we assume that subjects easily grasp that a gold mine can be exploited for a finite time span (e.g., ten periods), sometimes gold is found (dividend = 10), while in some periods no gold is found (dividend = 0). Specifically, we replace the paragraph in the instructions that explains the FV process (see online Appendix B, fourth paragraph, starting with "At the end of each trading period...") with the following paragraph:

> *The stocks are of a depletable gold mine, in which gold is mined for 10 periods. In each period the probability of finding (not finding) gold is 50 percent. If gold is found in period p, a dividend (profit) of 10 Taler for each unit of the stock will be paid. If no gold is found, the dividend will be zero. After 10 periods the gold mine is depleted and the value of the stock is zero.*

[16] The deviations from the correct forecast of the FV are significantly different between markets with constant and markets with declining FVs, Mann-Whitney-U-test, $p$-value of 0.000, $N = 240$.

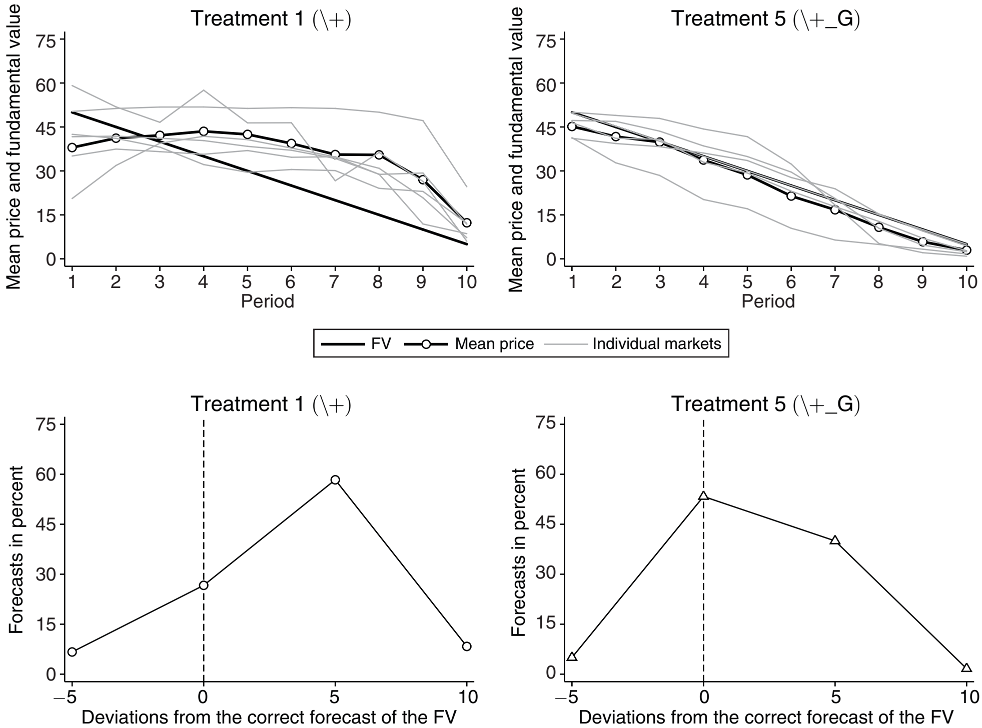


FIGURE 3

*Notes:* Fundamental Value (*FV, bold line*), Mean Treatment Prices (*bold line with circles*), and Volume-Weighted Mean Prices for Individual Markets (*gray lines*) as a Function of Period (*top panels*). Errors in Forecasting the FV in the Questionnaire (*bottom panels*). Left Panels: Treatment T1(\+). Right Panels: Treatment T5(\+G).

What might seem like a small change provides subjects with a different context: instead of trading an abstract stock, calling to their minds stock prices following a random walk or trending upwards, they have an easy-to-grasp example of a depletable asset where declining prices supposedly become easier to imagine.

The results, presented in the right panel of Figure 3, show markedly smaller deviations of prices from FVs, compared to T1(\+), which is shown in the left panel. RAD (0.16) and RD (–0.07) in T5($\backslash +_G$) are significantly smaller than the respective values in T1(\+), demonstrating that the minor change in the instructions is sufficient to significantly reduce mispricing and overvaluation (Mann-Whitney-U-test, $p$-values of 0.025 ($N = 12$) and 0.004 ($N = 12$) for RAD and RD, respectively). Further evidence that subjects' confusion about the declining FV is reduced in T5($\backslash +_G$) compared to T1(\+) is given in the bottom right panel of Figure 3. In particular, 55 percent of subjects answered the questionnaire correctly, compared to 28 percent in T1(\+) (bottom left panel).[17]

[17] The deviations from the correct forecast of the FV are significantly different between T1(\+) and T5($\backslash +_G$), Mann-Whitney-U-test, $p$-value of 0.009, $N = 120$.

*Robustness Check: Rekindling Bubbles in the Control Treatment with Context "Gold Mine*."—Treatment T6( $\backslash +_{G\_re}$) serves as a robustness check for Treatment T5( $\backslash +_G$). We increase both the C/A ratio and the variance of the dividend process of T5( $\backslash +_G$), as these changes in the parameters rekindled bubbles even among twice-experienced subjects in Hussam, Porter, and Smith (2008).[18] In particular, the six markets of Treatment T6( $\backslash +_{G\_re}$) consist of two rounds of ten periods each. The first round is an exact replication of Treatment T5( $\backslash +_G$) with inexperienced subjects. In the second round these once-experienced subjects face a very different setting. They are randomly shuffled into new cohorts of ten traders each, the number of stocks in the market is reduced by 50 percent, the amount of cash is doubled and the variance of the dividend process is multiplied by a factor of 2.44. In particular, the dividend in each period is drawn from the realizations 0, 1, and 17 with equal probabilities, which increases the expected dividend from 5 to 6 and the variance from 25 to almost 61. Consequently, the FV declines from 60 to zero toward the end of round 2.

The results of RAD and RD of both rounds (the respective individual and mean market prices are displayed in the upper panels of Figure 4) are perfectly in line with Treatment T5( $\backslash +_G$) and do not exhibit increased mispricing and overvaluation in round 2. The respective values of RAD (R1: 0.20; R2: 0.16) and RD (R1: 0.07; R2: $-0.06$) are again significantly smaller than the respective values in T1( $\backslash +$) and are not significantly different from the respective values in T5( $\backslash +_G$).[19] In fact, RAD and RD are even slightly lower in R2 than in R1 of Treatment T6( $\backslash +_{G\_re}$), though not significantly.

Additional and more direct evidence that subjects' confusion about the declining FV in T6( $\backslash +_{G\_re}$) remains low compared to T1( $\backslash +$) even in the "rekindle" setting of R2 is given in the lower panels of Figure 4. One can see that in both rounds 65 to 70 percent of subjects answered the questionnaire correctly.[20]

Following Hussam, Porter, and Smith (2008), our markets with only once-experienced subjects should be even more prone to rekindled bubbles, but as the data show, they are not, as the different context "gold mine" clearly reduces confusion about the FV process.

## IV. Conclusion

In this paper we explored reasons for the frequent emergence of "bubbles" in experiments replicating the market design first presented in Smith, Suchanek, and Williams (1988). We observed (i) high mispricing in treatments with declining fundamental value, and (ii) overvaluation when the declining FV is coupled with an increasing C/A ratio. By running a questionnaire after the experiments we found that (iii) subjects are confused by the concept of a declining fundamental value,

[18] We thank one referee for pointing us to the idea of this robustness check. We set up this robustness check in an almost identical way to the "rekindle" experiments in Hussam, Porter, and Smith (2008).

[19] T6( $\backslash +_{G\_re}$) versus T1( $\backslash +$), Mann-Whitney-U-test, $p$-values of 0.037 (R1), 0.007 (R2) and 0.078 (R1), 0.004 (R2) for RAD and RD, respectively. T6( $\backslash +_{G\_re}$) versus T5( $\backslash +_G$), Mann-Whitney-U-test, $p$-values of 0.522 (R1), 0.631 (R2) and 0.150 (R1), 0.631 (R2) for RAD and RD, respectively. $N = 12$ for all tests.

[20] The percentage deviations from the correct forecast of the FV are significantly different between T1( $\backslash +$) and T6( $\backslash +_{G\_re}$) (Mann-Whitney-U-test, $p$-values of 0.000 and 0.004 for R1 and R2, respectively) and insignificant between T5( $\backslash +_G$) and round 2 of T6( $\backslash +_{G\_re}$) (Mann-Whitney-U-test, $p$-value of 0.255). $N = 120$ for all tests.

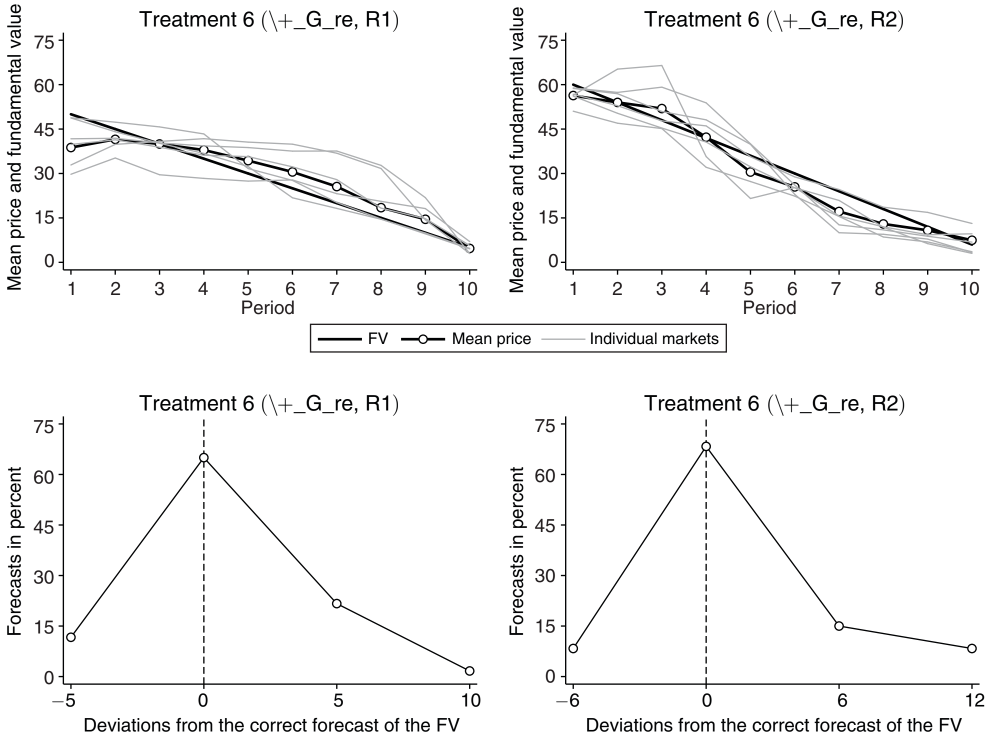


FIGURE 4

*Notes:* Fundamental Value (*FV, bold line*), Mean Treatment Prices (*bold line with circles*), and Volume-Weighted Mean Prices for Individual Markets (*grey lines*) as a Function of Period (*top panels*) of the Robustness Check T6(\+$_{\text{G\_re}}$) (*top panels*). Errors in Forecasting the FV in the Questionnaire of T6(\+$_{\text{G\_re}}$) (*bottom panels*). The left plots present results for the first round (R1), the right ones those for the second round (R2).

since most believed that the FV would stay constant or increase. Finally, (iv) results from two control treatments with the different context "stocks of a depletable gold mine" showed significantly smaller mispricing and overvaluation than the comparable treatment with the term "stock." This finding is robust to treatment changes like increasing the initial C/A ratio and the variance of the dividend process that had previously led to rekindling of bubbles even with experienced subjects.

Previous studies invariably report that only experience in the same setting (Dufwenberg, Lindqvist, and Moore 2005) and a very careful explanation and demonstration of the FV process (Lei and Vesely 2009) were able to eliminate bubbles in SSW-type markets. We have shown that a different context can achieve the same. In our view all three ways to abate bubbles have the same underlying origin: they all help to reduce or eliminate "confusion" about the FV process among subjects that otherwise leads to bubbles. Following and adapting the argumentation of Chou et al. (2009), Oechssler (2010), and Smith (2010), the likely reason for the confusion is that a declining FV process is not in line with subjects' past experiences and personal knowledge of real stock markets. We provide twofold evidence for this claim: (i) in the questionnaire conducted after the experiments the majority of subjects in markets with declining FVs expected the FV to stay constant or increase. (ii) We observed significantly smaller mispricing and overvaluation when the tradable asset was labeled as "stocks of a depletable gold mine," since subjects' confusion about the underlying fundamental value process was reduced (two-thirds answered the questionnaire correctly).

Hence, this paper emphasizes the importance confusion plays in bubble formation. Confusion present in a market with declining fundamental value can lead to large mispricing (T1(\+) and T3(\=)) unless abated by a reduced level of confusion about the FV (T5(\+$_{\text{G}}$) and T6(\+$_{\text{G\_re}}$)). When combined with ample liquidity (T1(\+)) this leads to overvaluation as well. When the FV is easier to estimate (e.g., when it is constant in T2(—+) and T4(—=)) or more intuitively graspable in T5(\+$_{\text{G}}$) and T6(\+$_{\text{G\_re}}$), confusion is reduced, mispricing is small, and thus overvaluation usually nonexistent.

Concluding, our results demonstrate that (i) reducing liquidity in times of confusion sufficed to prevent strong overvaluation, but not mispricing. (ii) Reducing confusion—in our case by an intuitive depiction of the FV process—suffices to reduce mispricing and overvaluation, even when liquidity is high.

## Appendix A: Individual Market Results including Alternative Measures

Table A1—Bubble Measures and Formulae for Calculation

| Measure | Formulae |
|---|---|
| Relative absolute deviation | $RAD = (1/N)\sum_{p=1}^{N} \lvert \overline{P_p} - FV_p \rvert / \lvert \overline{FV} \rvert$ |
| Relative deviation | $RD = (1/N)\sum_{p=1}^{N} (\overline{P_p} - FV_p) / \lvert \overline{FV} \rvert$ |
| Share turnover[a] | $ST = \sum_{p=1}^{N} VOL_p / TSO$ |
| Price amplitude[b] | $PA = \max(\overline{P_p} - FV_p)/FV_1 - \min(\overline{P_p} - FV_p)/FV_1$ |
| Total dispersion[c] | $TD = \sum_{p=1}^{N} \lvert MedianP_p - FV_p \rvert$ |
| Average bias[c] | $AB = (1/N)\sum_{p=1}^{N} (MedianP_p - FV_p)$ |

*Notes:* $\overline{P_p}$ = volume-weighted mean price of period $p$; $FV_p$ = fundamental value of period $p$; $\overline{FV}$ = mean fundamental value in the market; $MedianP_p$ = the median price in period $p$; $N$ = total number of periods; $VOL$ = number of shares traded in period \$ to \$; $TSO$ = total shares outstanding.

[a] Van Boening, Williams, and LaMaster (1993).

[b] Hussam, Porter, and Smith (2008); Lei and Vesely (2009); Noussair, Robin, and Ruffieux (2001); Porter and Smith (1995). Varying computation in Haruvy and Noussair (2006), Haruvy, Lahav, and Noussair (2007), and Van Boening, Williams, and LaMaster (1993).

[c] Haruvy and Noussair (2006), Haruvy, Lahav, and Noussair (2007).

Table A2—Individual Market Results for RAD, RD, and Alternative Measures

| Treatment | Market | RAD | RD | ST | PA | TD | AB |
|---|---|---|---|---|---|---|---|
| T1(\+) | 1 | 0.223 | 0.103 | 1.498 | 0.410 | 54.00 | 2.90 |
| | 2 | 0.356 | 0.168 | 2.940 | 0.684 | 103.25 | 4.33 |
| | 3 | 0.467 | 0.467 | 1.843 | 0.431 | 130.21 | 13.02 |
| | 4 | 0.262 | 0.179 | 1.628 | 0.452 | 74.60 | 5.23 |
| | 5 | 0.426 | 0.112 | 2.115 | 0.906 | 139.25 | 2.36 |
| | 6[a] | 0.750 | 0.750 | 2.340 | 0.737 | 206.67 | 20.67 |
| Mean | | 0.414 | 0.296 | 2.060 | 0.603 | 118.00 | 8.08 |
| T2(—+) | 1 | 0.004 | −0.001 | 2.790 | 0.029 | 1.44 | −0.06 |
| | 2 | 0.007 | 0.007 | 1.425 | 0.014 | 6.39 | 0.64 |
| | 3 | 0.041 | −0.041 | 2.528 | 0.106 | 10.90 | −1.09 |
| | 4[a] | 0.362 | −0.355 | 1.925 | 0.673 | 187.00 | −18.10 |
| | 5 | 0.025 | 0.025 | 3.415 | 0.027 | 11.90 | 1.19 |
| | 6 | 0.035 | 0.005 | 1.825 | 0.190 | 11.46 | 0.72 |
| Mean | | 0.079 | −0.060 | 2.318 | 0.173 | 38.18 | −2.78 |
| T3(\=) | 1[a] | 0.501 | −0.501 | 2.275 | 0.512 | 181.76 | −14.18 |
| | 2 | 0.190 | −0.180 | 0.993 | 0.325 | 58.00 | −5.80 |
| | 3 | 0.113 | 0.002 | 2.843 | 0.267 | 30.76 | 1.37 |
| | 4 | 0.279 | −0.247 | 0.808 | 0.441 | 78.30 | −5.63 |
| | 5 | 0.427 | 0.427 | 0.848 | 0.408 | 122.50 | 12.25 |
| | 6 | 0.323 | 0.258 | 0.845 | 0.542 | 86.80 | 6.88 |
| Mean | | 0.305 | −0.040 | 1.435 | 0.416 | 93.02 | −0.85 |
| T4(—=) | 1 | 0.003 | −0.003 | 3.518 | 0.008 | 0.60 | −0.06 |
| | 2 | 0.009 | −0.009 | 1.620 | 0.029 | 4.49 | −0.45 |
| | 3 | 0.008 | −0.008 | 1.118 | 0.035 | 2.53 | −0.25 |
| | 4 | 0.002 | 0.002 | 1.113 | 0.006 | 1.30 | 0.13 |
| | 5[a] | 0.086 | −0.086 | 1.880 | 0.069 | 43.14 | −4.31 |
| | 6 | 0.056 | −0.056 | 3.315 | 0.084 | 25.50 | −1.45 |
| Mean | | 0.027 | −0.027 | 2.094 | 0.039 | 12.93 | −1.07 |
| T5(\+$_{G}$) | 1 | 0.232 | 0.061 | 1.768 | 0.429 | 69.45 | 2.01 |
| | 2 | 0.125 | 0.014 | 1.388 | 0.205 | 35.79 | 0.52 |
| | 3 | 0.082 | −0.076 | 4.265 | 0.093 | 13.81 | −1.38 |
| | 4 | 0.003 | 0.000 | 1.410 | 0.012 | 0.15 | −0.01 |
| | 5 | 0.105 | −0.021 | 1.605 | 0.256 | 28.80 | −0.60 |
| | 6 | 0.394 | −0.394 | 2.733 | 0.229 | 113.09 | −11.31 |
| Mean | | 0.157 | −0.069 | 2.195 | 0.204 | 43.51 | −1.80 |
| T6(\+$_{G\_re}$), R1 | 1 | 0.166 | 0.058 | 2.640 | 0.362 | 43.95 | 2.20 |
| | 2 | 0.260 | −0.101 | 2.128 | 0.568 | 73.55 | −2.65 |
| | 3 | 0.085 | 0.068 | 2.255 | 0.191 | 25.27 | 1.84 |
| | 4 | 0.045 | −0.013 | 2.543 | 0.111 | 7.98 | −0.50 |
| | 5 | 0.346 | 0.170 | 1.670 | 0.679 | 81.65 | 5.89 |
| | 6 | 0.315 | 0.217 | 1.408 | 0.520 | 86.30 | 5.63 |
| Mean | | 0.203 | 0.066 | 2.107 | 0.405 | 53.12 | 2.07 |
| T6(\+$_{G\_re}$), R2 | 1 | 0.115 | −0.115 | 1.690 | 0.079 | 42.16 | −4.22 |
| | 2 | 0.241 | −0.039 | 2.390 | 0.548 | 78.00 | −2.20 |
| | 3 | 0.214 | −0.214 | 1.640 | 0.125 | 68.76 | −6.88 |
| | 4 | 0.071 | 0.034 | 3.485 | 0.173 | 20.57 | 1.65 |
| | 5 | 0.175 | 0.014 | 1.565 | 0.387 | 57.61 | 1.02 |
| | 6 | 0.162 | −0.066 | 1.510 | 0.335 | 59.20 | −1.92 |
| Mean | | 0.163 | −0.064 | 2.047 | 0.275 | 54.38 | −2.09 |

[a] Market dropped in robustness check, see Appendix B.

## Appendix B: Robustness Check

Table B1—Robustness Checks for Research Questions 1 and 2

| RQ1(C/A-ratio) | | RAD | RD |
|---|---|---|---|
| T1(\+) & T2(—+) versus T3(\=) & T4(—=) | Δ mean | 0.043 | 0.084 |
| $N = 20$ | $Z$ | −0.605 | −1.890 |
| T1(\+) versus $T$3(\=) | Δ mean | 0.080 | 0.154 |
| $N = 10$ | $Z$ | −0.940 | −0.940 |
| T2(— + ) versus T4(— = ) | Δ mean | 0.006 | 0.014 |
| $N = 10$ | $Z$ | −0.731 | −1.567 |
| RQ2(FV) | | RAD | RD |
| T1(\+) & T3(\=) vs T2(—+) & T4(—=) | Δ mean | 0.288*** | 0.137** |
| $N = 20$ | $Z$ | −3.780 | −1.965 |
| T1(\+) versus T2(—+) | Δ mean | 0.324*** | 0.207*** |
| $N = 10$ | $Z$ | −2.611 | −2.611 |
| T3(\=) versus T4(—=) | Δ mean | 0.251*** | 0.067 |
| $N = 10$ | $Z$ | −2.611 | −0.313 |

*Notes:* Markets with the highest RAD in each treatment are dropped from the sample. The values represent the differences in means (Δ *mean*) of the treatments under investigation and $Z$-values from a Mann-Whitney-U-Test ($Z$)

***Significant at the 1 percent level.

**Significant at the 5 percent level.

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