# Bubbles and Information: An Experiment *

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**Abstract**

Asymmetric distribution of information, while omnipresent in real markets, is rarely considered in experimental economics. We study whether information about imminent future dividends can abate bubbles in experimental asset markets. We find that markets with asymmetrically informed traders have significantly smaller bubbles than markets with symmetrically informed or uninformed traders. Hence, fundamental values are better reflected in market prices – implying higher market efficiency – when some traders know more than others about future dividends. This suggests that bubbles are abated when traders know that a subset of them have an edge (in information) over others.

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## 1 Introduction

In the wake of the bursting of the U.S. housing bubble 2007 and the global financial crisis it caused, bubbles and especially the role that insiders – i.e., subjects with information advantages – play in the formation of such bubbles have come under increasing scrutiny by regulators and academics alike. In this paper, we examine how bubble formation and asymmetric information – where some traders know more about an asset's fundamental value than others – are related to each other. Whenever traders know that a subset of them have an edge over the others (in terms of knowledge about an asset's fundamental value), strategic behavior of informed traders (who compete to make profitable trades, thus revealing their information) and uninformed traders (who might delay trade in order to avoid exploitation) should lead to more efficient prices. The main hypothesis of our paper is therefore the conjecture that asymmetric information on asset markets can abate bubbles.

We will test this conjecture in an experiment that allows to control carefully for traders' information about the fundamental value of an asset – a condition that can never be met in real markets, as traders will be unwilling to disclose or unable to properly assess the quality of their information relative to that of other traders. Our main finding is that asymmetric information of traders about an asset's imminent future dividends (one or two periods ahead) reduces the magnitude of bubbles significantly. This result is mainly driven by traders anchoring their willingness to buy and sell more closely on the expected future dividend payments and hence pushing the market price in the direction of an asset's fundamental value.

Our main hypothesis is largely motivated by a debate in the law-and-economics literature on insider regulation that forbids insiders to trade on their supreme information.[1] Generally speaking, this debate addresses the issue of asymmetric information and market outcomes.

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[1] Interestingly, until 1933 insider trading was legal on all major stock markets. However, in the wake of the great Depression the Securities Exchange Act of 1934 outlawed insider trading in the U.S. Other nations followed suite and today insider trading is illegal on all major markets.

The trade-off discussed with respect to insider-trading, in particular, is between efficiency and fairness (see Easterbrook and Fischel, 1991, or Scott, 1998, for surveys). One camp of the debate, mainly based in the field of law, argues to keep up the ban on insider trading, as otherwise the market would be unfair, i.e., allegations of fraud could flourish. Proponents of the "efficiency-camp" point out that when insiders are allowed to trade on their information prices will be closer to reflect a fair value of the stock, which would benefit especially the less informed, since information would be introduced more quickly into the market in this situation.[2] While we will not be able to finally resolve this long-standing dispute, our more modest goal is to provide controlled laboratory evidence on the impact of asymmetric information on bubbles in asset markets.

Our experimental design builds on the seminal paper of Smith, Suchanek, and Williams (henceforth SSW, 1988). Their design has the convenient property of persistently producing bubbles, i.e., serious mispricing, when inexperienced subjects trade. The abatement of bubbles can thus be linked to treatment changes. Despite the fact that the development of the traded asset's fundamental value over time is common knowledge in such experimental asset markets, the literature that followed SSW (1988) has documented that bubbles are robust to a plethora of modifications of the original SSW-design.[3] To date, trader experience has been

[2] Milton Friedman, Daniel Fischel, Henry Manne, and Thomas Sowell have been among the most outspoken supporters of the "efficiency-camp". They claim that insider trading based on material nonpublic information benefits investors, in general, and therefore also less informed traders.

[3] None of the following factors has been found to prevent bubbles: short selling (King et al., 1993; Haruvy and Noussair, 2006); buying on margin (King et al., 1993); using call markets instead of continuous double auctions (van Boening et al., 1993); adding a parallel market with a short-term asset that exists only for one period (Lei et al., 2001); keeping the fundamental value constant over time instead of letting it decline as in SSW (Noussair et al., 2001); precluding speculation by prohibiting buyers to resell the asset and sellers to buy it (Lei et al., 2001); asking participants for expectations about future prices (Haruvy et al., 2007); or running the experimental markets with professional business persons (SSW, 1988; King et al., 1993). The evidence is mixed for introducing a futures market alongside the spot market (see Porter and Smith, 1995, and Noussair and Tucker, 2006).

identified as the only robust factor that moderates bubbles in these markets. Exposing traders repeatedly to a stationary market environment reduces bubbles to the extent that prices track fundamentals very closely when traders are twice-experienced with a given market setting. Dufwenberg et al. (henceforth DLM, 2005) have shown that even a small fraction of experienced traders in relation to inexperienced ones suffices to reduce bubbles considerably, such that prices in markets with a mixture of experienced and inexperienced traders are not different from markets with twice-experienced traders only. This result provides a second motivation for our main hypothesis, namely that bubbles might be abated whenever traders know that a subset of them have an edge over others. While in DLM (2005) the edge concerns the level of experience in such markets, we hypothesize that asymmetric information about imminent future dividends can have the same effect. Both situations seem to capture realistic features in markets. Similar to the claim of DLM (2005) that real financial markets are characterized by a mixture of experienced and inexperienced traders, we argue that there is heterogeneity across traders on real markets with respect to their knowledge about the future development of an asset’s fundamental value.

While the influence of asymmetric information has not been explored in the SSW-design, so far, insider trading has been studied experimentally in different contexts, of course. Plott and Sunder (1982) have examined the predictive power of rational-expectations models in markets where some traders knew the return of a one-period security before trade opened, while other traders did not. In a rational expectations equilibrium, trading prices are expected to reveal the return also to uninformed traders because in equilibrium prices must be consistent with individuals’ expectations about the actual return when they face those prices. In fact, Plott and Sunder (1982) find that the five markets considered in their paper converge relatively quickly to the prices implied by a rational expectations equilibrium. However, Plott and Sunder (1982) do not examine the formation of bubbles and whether or not asymmetric information distribution leads to larger or smaller bubbles, as will be the focus of our study.[4]

Schnitzlein (2002) has explored the influence of asymmetric information on market efficiency and trader profits in an experiment that has been motivated by a theoretical model of Kyle (1985). In this model noise traders and informed traders interact with dealers who can bid in a first-price sealed-bid auction for traders' buy or sell orders. Schnitzlein (2002) finds that when the presence of insiders is not disclosed to dealers then insiders use the timing and size of orders to hide their information from them and thereby generate positive trading profits. When the presence of insiders is known competition between them drives prices quickly to the efficient level. A key difference to our setting concerns the fact that in Schnitzlein's (2002) experiment dealers (the uninformed traders) are not allowed to submit buy and sell orders. Hence, it is impossible in his design to examine how informed and uninformed traders differ in their limit and market orders and how uninformed traders might try to avoid exploitation through informed traders by placing cautious orders only. Furthermore, since noise and informed traders only make orders that can be accepted by uninformed dealers in Schnitzlein (2002), it is also not possible to analyze how informed traders accept other traders' orders, and which types of orders they place. Since real markets can be expected to have informed and uninformed traders interacting with each other in both submitting and accepting orders, our design will allow for that.[5]

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[4] In principle, Plott and Sunder (1982) also have data on how quickly prices converge to (rational expectations) equilibrium when all traders in a market know the current period's returns. However, they are not reporting any comparison of the speed of convergence with symmetric or asymmetric information (which would also be much harder in their design since it is a within-subjects design and they have only five markets altogether, making it hard to control properly for possible order-effects).

[5] A recent paper by Bloomfield et al. (2009) has also looked at the interaction of uninformed and informed traders in experimental markets. Their design is based on a model by Hong and Stein (1999) and they are particularly interested in whether uninformed traders are responsible for short-term momentum trading and long-term reversals. In fact, this seems to be the case, however for different reasons than in Hong and Stein's

As a short preview, our design has the following characteristics and yields the following results: Based on a control treatment of the SSW-type, where no trader has advance knowledge of a stochastic dividend's realization in the future, we set up one treatment in which we inform each trader at the beginning of a trading period about the asset's dividend realization at the end of the period. We find that bubbles – i.e., the difference between market prices and fundamental values – are reduced in this treatment. In three additional treatments we implement asymmetric information distributions. In the first of these, half of the traders have no information, while the other half know the dividend realization of the current period. In the second one we increase the asymmetry by providing one third of traders with the next two dividends, one third of traders with the next dividend, while one third of traders do not know any future dividend in advance. The asymmetry is public knowledge in these two treatments. The third treatment with asymmetric information is a replication of the second one, except that traders are not informed about the asymmetries, but are only told their own information level and that other traders might have the same or a different level, without specifying that further. This latter treatment serves as a check whether public knowledge about the degree of asymmetric information has any impact on bubble size. We find that all three treatments with asymmetric information reduce bubbles to the same degree and that asymmetric information causes market prices to be significantly closer to fundamental values than in the control treatment or the treatment with symmetric advance information.

In section 2 we introduce the experimental design in more detail. Section 3 presents the experimental results and analyzes the reasons for the smaller bubbles if information is asymmetrically distributed. Section 4 concludes the paper.

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(1999) model, since uninformed traders turn out to be rather contrarian traders than traders that are chasing trends. Bloomfield et al. (2009) do not focus, though, on the determinants of bubbles in particular and on the effects that the symmetric or asymmetric distribution of information might have.

## 2 Experimental design

### 2.1 Basic market structure

We set up an experimental asset market in which assets of a virtual company can be traded.[6] Holding an asset generates a stochastic dividend stream. In each period the asset pays a dividend of either 0 or 20 experimental currency units (ECU) with equal probability. The actual dividend in a particular period is the same for all assets that can be traded. Each *market* consists of three rounds, and each *round* in turn has ten trading *periods*. A trading period lasts 120 seconds. Trading is organized as a continuous double auction with open order book. Subjects can buy and sell any quantity of assets, given the limitations of their asset inventory and cash endowment, i.e., neither are loans provided nor is short selling allowed. Cash and stock holdings are carried over from one period to the next within a given round. At the beginning of a new round of ten periods the inventories are reset to the initial starting levels. This means that an asset's life-span is ten periods. Since no "buy-out" is provided for holding an asset at the end of period 10, assets are worthless at the end of a round. This feature of the experimental design implies a declining fundamental value within each round. The expected dividend is 10 ECU per period. Assuming risk neutrality, the fundamental value is given by $k \times 10$ ECU, where $k$ indicates the number of periods remaining. An asset's fundamental value is, therefore, declining from 100 ECU in period 1 to 10 ECU in period 10.

Each experimental market consists of six traders. Three of these traders are endowed with 3,000 ECU and 10 units of the asset at the beginning of each of the three rounds. The other three traders receive 1,000 ECU and 30 stocks at the start of each round. Hence, traders' endowments are identical in expected value. All traders are accurately informed about the dividend generating process of the asset (see the experimental instructions in Supplement A),

[6] The design of the market and the parameterization were adopted from DLM (2005).

in particular about the expected value (in terms of dividends) of holding the asset for a given number of periods.

### 2.2 Experimental treatments

Our five treatments differ with respect to the traders' knowledge about future dividends:

1) Treatment *CONTROL*. None of the six traders in a market knows any future dividend. Hence, when trading in period *t* starts, the realization of the asset's dividend for period *t* is unknown. Only when trading stops after 120 seconds the dividend becomes known to all traders and traders receive the dividend for each asset they hold at the end of period *t*. In the following, we speak of information level *I0* for traders in *CONTROL*.

2) Treatment *SYMM*. When trading in period *t* starts, all traders already learn the dividend that the asset will pay at the end of period *t*. Yet, traders have no information about the actual dividends in periods $z > t$. The information about period *t*'s dividend is symmetrically distributed in this treatment, and we refer to information level *I1* for all traders in *SYMM*, because they know one dividend realization in advance.[7]

3) Treatment *ASYMM1*. This treatment is characterized by an asymmetric distribution of information. Specifically, each market consists of three traders with information level *I0* and three traders with information level *I1*. Hence, three traders know the dividend of period *t* at the beginning of period *t*, while the other three traders have no such information. Information levels are randomly assigned to traders at the beginning of the experiment and remain fixed for the entire 30

[7] This treatment may be reminiscent of Porter and Smith's (1995) design where each asset paid a fixed amount for sure after each period, implying that traders are also symmetrically informed by knowing *all* future dividends with certainty. We have a much more limited, and probably more realistic, case in mind where traders know at best the short-term future cash flows of a longer-lived asset.

trading periods. Traders know their own information level and the distribution of information levels, but they do not know the information level of a particular trader who has posted a bid or ask.

4) Treatment *ASYMM2*. Here we increase the information asymmetry by introducing three different types of traders with respect to their information about the asset's future dividends. The distribution of information is common knowledge. Two traders get to know the dividends in periods *t* and *t*+1 before trading in period *t* begins. We call this information level *I2*. Two other traders have information level *I1*, while the remaining two traders have information level *I0*, knowing only that the asset will pay with equal probability 0 ECU or 20 ECU in period *t*.

5) Treatment *ASYMM2_ni*. This is exactly as *ASYMM2*, except that traders are not informed about the distribution of information levels. Each trader is informed about his information level and is told that the other traders might, but need not, have different information levels. Hence, traders know that asymmetric information might be present in the market, but they don't know more than that.

Table 1 summarizes the distribution of information levels in the five treatments.[8] Comparing the relation of prices to fundamental values in *CONTROL* and *SYMM* will allow examining whether bubbles can be abated if traders know an asset's dividend already when they are buying and selling it in a given period. In both *CONTROL* and *SYMM* traders are symmetrically informed, though. Comparing *CONTROL* to *ASYMM1* allows examining whether some informed traders in the market influence bubble formation. A comparison between *SYMM* and *ASYMM1* should be especially interesting, as in *SYMM* all traders have

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[8] In the *ASYMM2*- and *ASYMM2_ni*-treatments it is ensured that one of the two traders with a given information level has an endowment of 3,000 ECU and 10 stocks, and the other one of 1,000 ECU and 30 stocks. Hence, the endowment is balanced within and across information levels. Recall that the different endowments are identical in expected value.

information that is known to only half of the traders in *ASYMM1*. Furthermore, keeping the median information level (*I1*) constant, a comparison of *SYMM* to *ASYMM2* (*ASYMM2_ni*) and of *ASYMM1* to *ASYMM2* (*ASYMM2_ni*) will reveal whether the stronger asymmetric information distribution implemented in *ASYMM2* (*ASYMM2_ni*) has an effect on bubble formation. Finally, comparing *ASYMM2* to *ASYMM2_ni* allows examining whether common knowledge about the distribution of information is important for the size of bubbles.

*[Table 1 about here]*

### 2.3 Experimental procedure

Before conducting the experiments, we drew randomly a sequence of 30 realizations of the dividend (of either 0 ECU or 20 ECU). We then created a second sequence by "mirroring" the randomly drawn sequence, such that in each period the dividends in both sequences were different.[9] Finally, we fixed these two sequences of dividends and used them in six markets each in each treatment (see Supplement B). This procedure of pre-determining dividends in single markets was chosen in order not to confound possible differences across treatments by different realizations of the dividends in the five treatments.

Traders' computer screens were also identical across treatments. During a trading period traders were informed about their endowment in cash and stocks, the future dividends (if applicable), the current period's trades, and the open order books for bids and asks. The prices of trades were also shown in a graphical chart (see the trading screen in the instructions, given in Supplement A). At the end of each period, traders saw a history screen with details on their

[9] If the dividend in period *t* was 0 ECU (20 ECU) in sequence 1, it was 20 ECU (0 ECU) in period *t* of sequence 2.

endowment, this period’s closing prices and the actual dividend, a trader’s total dividend earnings from this period and the mean prices of all previous periods in a particular round.

We ran 12 markets in each treatment, yielding a total of 60 markets, in which 360 undergraduate students at the University of Innsbruck participated. None of the students had any prior experience in market experiments and none had been introduced to the literature initiated by SSW (1988). The recruitment of participants was done with ORSEE (Greiner, 2004), and the experiment was computerized with zTree (Fischbacher, 2007). Each experimental session was run with 18 participants (yielding three independent markets per session), and the average duration of a session was approximately 90 minutes. Average earnings were 24 Euro (about 36 Dollars at the time of the experiment).

## 3 Results

### 3.1 Bubbles and (a)symmetric information

Figure 1 presents the main insight from our experiment by showing the development of average prices in the five treatments. Recall that each market consists of three rounds with 10 periods each. The broken grey line represents the average price in the 12 markets of *CONTROL*. As is typical for the SSW-design, there is a marked difference between the average trading price and the fundamental value, and the difference is typically increasing within a given round of 10 periods, but decreasing across rounds. The solid grey line represents treatment *SYMM*. Bubbles are slightly smaller in *SYMM* than in *CONTROL*. Most importantly, all three treatments with asymmetric information (*ASYMM1*, *ASYMM2*, *ASYMM2_ni*) have considerably smaller bubbles, meaning that prices track the fundamental value process much better than in *CONTROL* and *SYMM*. The difference between *SYMM* and *ASYMM1* is particularly interesting since the information set of all traders in *SYMM* is a strict superset of traders’ knowledge in *ASYMM1*. Despite this fact, prices in *ASYMM1* are much closer to the fundamental value than in *SYMM*. It is also noteworthy that the median information level in *SYMM* and *ASYMM2* (*ASYMM2_ni*) is identical, but bubbles are much smaller in *ASYMM2* (*ASYMM2_ni*). Thus, the asymmetric distribution of information seems the crucial source for the smaller bubbles.

*[Figure 1 and Table 2 about here]*

We measure bubbles by the asset's overvaluation and follow Stöckl et al. (2010) who have introduced the Relative Deviation (*RD*) as a robust measure that can be used for comparison across different treatments.[10] The relative deviation is defined as follows:

$$RD_{m,t} = \left(\overline{P_{m,t}} - FV_{m,t}\right) / \overline{FV_m} \tag{1}$$

*RD* in period *t* of market *m* is the average difference between the average market price of period *t* $\left(\overline{P_{m,t}}\right)$ and the respective fundamental value $FV_{m,t}$, normalized by the average fundamental value of market m $\left(\overline{FV_m}\right)$. For example, an *RD*-value of 0.2 indicates that prices are on average 20 percent above the fundamental value in the respective period *t*.

For the regressions reported in Table 2 we use *RD* in percent as the dependent variable, with positive values indicating overvaluation, and *CONTROL* as the benchmark treatment.[11] We employ a linear panel regression model with market clusters *m* = 1,…, 60. In addition to the treatment effects, we correct for autocorrelations (by including the dependent variable,

[10] The measure is robust, among others, to variations in the number of periods, the determination of the fundamental value and the variation in dividends. For details see Stöckl et al. (2010).

[11] Note that all results and significances would remain the same when alternatively the difference of prices and fundamental values had been taken, because *RD* only makes a linear transformation. Furthermore, the regression in Table 2 uses the average trading price within a given period for calculating *RD*. Using the weighted average price instead (weighted by the number of stocks traded for a particular price) yields qualitatively identical results.

lagged by one period, *RD(-1)*), a time trend (period taking values $t = 2,\ldots,10$), and dummies for rounds 2 and 3. The model is estimated by ordinary least squares (OLS), pooling all observations. To account for potential correlations within each market and potential heteroskedasticity across markets, the robust standard errors of Beck and Katz (1995) are employed throughout this analysis.

One can see from model "Base" of Table 2 that overvaluation is weakly significantly smaller in *SYMM* than in *CONTROL*. The effects of asymmetric information about the dividend realization on the level of overvaluation are highly significant, however. Overvaluation is about 8 to 11 percentage points lower in these treatments than in *CONTROL*, where it is on average 27.4 percent of the average fundamental value. Comparing overvaluation in each asymmetric treatment to overvaluation in *SYMM* shows that it is (weakly) significantly smaller in the asymmetric treatments in two of three cases (two-sided Wald-tests comparing *SYMM* against *ASYMM1* ($p = 0.044$), *ASYMM2* ($p = 0.249$), and *ASYMM2_ni* ($p = 0.085$)). However, the more refined "Extended" model in Table 2 will provide evidence that – when controlling in more detail for dividend realizations and autocorrelation – the overvaluation in *SYMM* is significantly larger than in each single treatment with asymmetric information. In the next subsection we will discuss the Extended model more extensively.[12]

The other independent variables included in the "Base"-model of Table 2 show qualitative results that are fully consistent with previous findings (e.g., DLM, 2005). Overvaluation decreases across rounds, i.e., with an increase in experience. There is also

[12] Note that there is no significant difference in overvaluation between the three treatments with asymmetric information. If, as a consequence, one would use one dummy for asymmetric information in the Base-model of Table 2 (instead of three dummies for each treatment with asymmetric information), this would yield a significantly larger overvaluation in *SYMM* than in the asymmetric treatments. The extended model confirms this main difference between the set of all asymmetric treatments and *SYMM* on the level of each single asymmetric treatment.

strong path dependence, as overvaluation in the previous period has a positive effect on overvaluation in the current period.

### 3.2 Further details on trading behavior

In order to explain our main result established in the previous subsection, we examine in this subsection trading volume and trading times on the market level as well as contingent on single traders' information level, and ultimately we analyze how single traders' knowledge about future dividends is reflected in prices, thus revealing information to uninformed traders.

Table 3 presents data on trading times across treatments. The average time to trade (averaged over the timing of all trades within a given period) is shortest in *CONTROL* (64 seconds), but longest in *ASYMM2* (68 seconds). Similarly, the average time until the first trade within a period is shortest in *CONTROL* (18 seconds) and longest in *ASYMM2* (29 seconds). Hence, the asymmetric information seems to make traders more cautious in striking deals, especially at the beginning of a period. This calls for a closer examination of trading behavior contingent on traders' information levels.

*[Table 3 and Table 4 about here]*

Table 4 presents key trading data for traders with different information levels in the three treatments with asymmetric information. First, we note that there is a difference with respect to the number of posted bids and asks across information levels (see panel [A]). In general, traders with information level *I0* post more limit orders than the informed traders. The better informed traders make significantly more market orders, meaning that they accept standing bids and asks more often than the less informed traders, as can be seen in panel [B]. The volume of trades shows no clear pattern and hardly any significant results (see panel [C]). The evidence presented in Table 4 thus suggests that the better informed traders are the most aggressive ones, trying to exploit their informational advantage as quickly as possible by placing market orders.[13] If this is, in fact, the case, then we should observe a significant reaction of prices to the information available to traders who know the current (or next) period's dividend realization.[14]

In the specification "Extended" of Table 2 we examine whether the information about period *t*'s dividend affects overvaluation (*RD* in percent) in the treatments differently. Therefore, we fit a panel regression that includes all effects from the basic model and additionally treatment-specific dividend information and treatment-specific autocorrelations. In particular, we include dummies for each treatment, measuring the effect of dividend realizations of zero (see the interaction terms with *DUM_DIV0*) on overvaluation *RD*. We expect a strong decrease in overvaluation in periods of a dividend of zero, since especially traders who are informed about the dividend realization in treatments *SYMM, ASYMM1*, *ASYMM2* and *ASYMM2_ni* may have a dampening effect on prices.

One can see that there is no dividend effect (dummy *DUM_DIV0*) in the *CONTROL* treatment while all interaction terms with *DUM_DIV0* are significantly negative in the other four treatments. This indicates that market prices react strongly to dividend information, especially in the negative direction when the dividend of the current period is zero. Furthermore, the autocorrelations differ clearly across treatments: In the control treatment, prior deviations are propagated into the next period much more strongly than in all other treatments. In particular, the asymmetric information treatments have a significantly smaller autocorrelation than *CONTROL* and *SYMM* ($p < 0.05$; two-sided Wald-tests). Using joint Wald tests of all three treatment-specific effects, we can, first, show that the size of

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[13] Similar findings have been reported by Bloomfield et al. (2005).

[14] In addition to prices reflecting information, we would expect traders with better information to react in the quantity of their stocks to their information about the dividend, and this is what we find. When traders with

overvaluation is significantly smaller in *SYMM* than in *CONTROL*, meaning that advance knowledge about this period's dividend reduces bubbles ($p < 0.05$). However, in a second step we can show that the overvaluation in each single treatment with asymmetric information is significantly smaller than in *SYMM* (two-sided Wald-tests against *ASYMM1*: $p = 0.005$, *ASYMM2*: $p = 0.052$, *ASYMM2_ni*: $p < 0.001$). This latter result confirms the central insight of our paper, i.e., that asymmetric information about assets reduces bubbles. Consistent with this main finding is the fact that there is no significant difference in overvaluation across the three treatments with asymmetric information ($p = 0.18$; Wald-test).

Given that informed traders try to exploit their information (which is then reflected in prices), a final look at traders' behavior conditional on their information level seems warranted. Uninformed traders try to protect themselves against the informational advantage of the better informed ones, e.g., by posting more bids and asks themselves, as we have seen above. If the informed traders reveal their private information and if uninformed traders learn to infer this information from prices, this should be visible in the difference between opening and closing prices in each period. Whenever the dividend is 20 the closing price should be higher than the opening price and vice versa when the dividend is zero.

*[Table 5 about here]*

In a final analysis we explore this relationship with the results presented in Table 5. We set up a panel regression model for each treatment separately with 12 cross-sections (markets) and 30 observations over time (periods) each. The difference between the closing and the opening price in each period serves as dependent variable and *PERIOD* and a dummy for the

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information level *I1* or *I2* know that period *t*'s dividend is 20 ECU, they increase their stock holdings significantly, but decrease it when the dividend is known to be zero.

periods with a dividend realization of zero (*DUM_DIV0*) serve as dependent variables.[15] Hence, with *DUM_DIV0* we measure the difference of closing to opening prices in relation to periods with a dividend of 20 (constant). From the positive constant in treatment *CONTROL* one can see a general trend of increasing prices in the course of a period when no dividend information is revealed during a period. However, in all treatments with asymmetric information the impact of precise dividend information for a subset of traders is visible, since all coefficients of *DUM_DIV0* are significantly negative with a magnitude ranging from -3.4 to -9.8. This indicates that informed traders go short when they see a dividend of zero at the beginning of a period which has a dampening effect on prices. Hence, closing prices are lower than opening prices when a dividend of zero is paid out in treatments with asymmetric information. We can thus conclude that the private information of better informed traders becomes publicly known through trading over the course of each period, leading to more efficient prices in settings with asymmetric information.[16] This pattern of decreasing intra-period prices with a dividend of zero is also visible in *SYMM*, but when looking at the intercept of the regression one can see the major difference to the treatments with asymmetric information. With a value of 7.8 the intercept in *SYMM* is much larger than in the other treatments as traders compete for high dividend payments and thus drive prices up in the course of a period. This effect is much weaker in treatments with asymmetric information, since only a subset of traders competes for the high dividends.

[15] All other independent variables which are included in Table 2 are excluded from this analysis since they are insignificant.

[16] In line with this finding, we find no significant differences in returns between traders with different information levels in the three treatments with asymmetric information (Wilcoxon signed ranks tests).

# 4 Conclusion

This paper has focused on the question whether asymmetric information about imminent dividends can abate bubbles in experimental asset markets. We have found that experimental markets with asymmetrically informed traders have, in fact, significantly smaller bubbles than markets where all traders have the same information. This holds even when the overall amount of information in the market is larger in the symmetric distribution case (*SYMM* versus *ASYMM1*). Hence, fundamental values are better reflected in market prices – implying higher market efficiency – when some traders know more than others about the future prospects of an asset. This is even true when the exact distribution of information is not common knowledge (in *ASYMM2_ni*), a condition that reflects most real-world markets most appropriately.

We think that our main result offers an interesting link to an earlier result by Dufwenberg et al. (2005) on how bubbles can be abated in the SSW-design. They have shown that bubbles decrease when traders know that some of them have already gained experience in such a market setting. Thus, it seems that bubbles are abated whenever traders know that some of them have an edge over the others, be it in prior experience or more information about the current dividends. In our case, we argue that our main result can be attributed to strategic behavior of traders in our *ASYMM*-treatments: Traders with no information trade more cautiously to avoid exploitation by informed traders. Therefore, they frequently post limit orders to earn the bid-ask spread. Informed traders try to hide their information by acting mostly through market orders. However, better informed traders are the more aggressive ones and they react to dividend information, which yields intra-period prices to go up (down) when the dividend is 20 (zero). Therefore, information of the informed traders gets revealed over time and prices track fundamentals much closer than in *CONTROL*. In contrast, in Treatment *SYMM* all traders know the dividend realization of the current period and hence compete for the dividends by bidding up prices when the dividend realization is 20.

If these results are somewhat indicative for what happens in real markets, they can be taken as evidence that bubbles are probably less likely in real markets than in SSW-style markets with symmetric information, as real markets are always characterized by asymmetry in information and opinions – otherwise no trade would happen. Our result also contributes to the debate in the law-and-economics literature on the pros and cons of insider regulation. In general, our results support the position of researchers who question very strict insider regulation. Asymmetric information seems to mitigate bubbles, supporting the line of argumentation of, e.g., Milton Friedman and Daniel Fischel who claimed that letting insiders trade freely is beneficial to market efficiency. This is not to say that disclosure requirements on real markets should be reduced to create more asymmetric information and thus mitigate bubbles – since providing information is key to markets being efficient (Fama, 1970) – but that asymmetric information itself is good rather than bad for market efficiency. It is unlikely that stricter disclosure requirements would create perfectly symmetric information across all traders, and hence our results should not be misinterpreted as favoring less disclosure. Given that the asymmetry in information has been found to be the key factor in abating bubbles in our result, it remains a (tough, but in case of success surely rewarding) question for future empirical research whether bubbles in real markets have been related to the degree of asymmetry in the distribution of information among market participants. For instance, it could be possible that the degree of asymmetry would differ between developed and emerging markets, and that this could have consequences for the likelihood and size of bubbles in such markets. However, as we have argued in the introduction, it seems very hard to quantify asymmetric information on real markets, and therefore we have resorted to a controlled experiment to provide evidence on the influence of asymmetric information on bubbles in experimental asset markets.

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# Tables and Figures

*Table 1. Summary of treatment conditions*

| | # traders with information level | | |
|---|---|---|---|
| Treatment | *I0* | *I1* | *I2* |
| *CONTROL* (*N* = 12) | 6 | - | - |
| *SYMM* (*N* = 12) | - | 6 | - |
| *ASYMM1* (*N* = 12) | 3 | 3 | - |
| *ASYMM2* (*N* = 12) | 2 | 2 | 2 |
| *ASYMM2_ni (N* = 12) | 2 | 2 | 2 |

Notes: *I0* stands for traders with information level zero who have no information on the realization of the dividend in the current period. Traders with *I1* already learn the dividend of the current period *t* at the beginning of period *t*, whereas traders with I2 are informed about the dividend in periods *t* and *t*+1. *N* indicates the number of markets run for each treatment. In each market we have 6 traders in a fixed matching.

*Table 2. Differences in overvaluation conditional on treatment and dividend information*

| Dependent variable: *RD* (relative deviation) in percent | Base | Extended |
|---|---|---|
| Constant | 27.43*** | 22.66*** |
| | (8.87) | (5.80) |
| *SYMM* | –4.99* | 9.88** |
| | (–1.74) | (2.29) |
| *ASYMM1* | –10.83*** | 3.07 |
| | (–3.68) | (0.72) |
| *ASYMM2* | –8.36*** | 11.88*** |
| | (–2.84) | (2.71) |
| *ASYMM2_ni* | –9.97*** | 8.88** |
| | (–3.42) | (2.04) |
| *DUM_DIV0* | | 0.39 |
| | | (0.09) |
| *DUM_DIV0 * SYMM* | | –21.22*** |
| | | (–3.35) |
| *DUM_DIV0 * ASYMM1* | | –14.61** |
| | | (–2.30) |
| *DUM_DIV0 * ASYMM2* | | –26.29*** |
| | | (–4.20) |
| *DUM_DIV0 * ASYMM2_ni* | | –20.75*** |
| | | (–3.26) |
| *RD(-1)* | 84.28*** | 99.20*** |
| | (43.24) | (32.33) |
| *RD(-1) * SYMM* | | –9.79** |
| | | (–2.48) |
| *RD(-1) * ASYMM1* | | –25.50*** |
| | | (–4.45) |
| *RD(-1) * ASYMM2* | | –21.10*** |
| | | (–4.27) |
| *RD(-1) * ASYMM2_ni* | | –30.71*** |
| | | (–5.87) |
| *PERIOD* | –1.63*** | –1.74*** |
| | (–5.01) | (–5.23) |
| *ROUND2* | –3.73*** | –4.70*** |
| | (–4.64) | (–5.06) |
| *ROUND3* | –6.68*** | –7.65*** |
| | (–5.62) | (–6.15) |
| $R^2$ | 72.23 | 77.11 |
| AIC | 195.48 | –93.72 |
| *N* | 1590 | 1590 |

Notes: Panel regression with markets as cross sections (60) and periods (30) as observations over time. Dependent variable: *RD*: is the average difference between the average market price of period *t* of market *m* and the respective fundamental value $FV_{m,t}$, normalized by the average fundamental value of the market. *SYMM*, *ASYMM1*, *ASYMM2* and *ASYMM2_ni* (where the realization of the dividend of the current period is known to all traders, half of the traders, and two thirds of the traders, respectively) serve as treatment dummies – hence, the effect of the baseline treatment *CONTROL* is incorporated into the intercept. *DUM_DIV0* indicates periods with a dividend of zero. *RD(-1)* is the dependent variable lagged by one period. *PERIOD* runs from 1 to 10 within each round and *ROUND2* and *ROUND3* are dummies for rounds two and three, respectively. AIC is the Akaike information criterion with lower values indicating a better goodness of fit of the model.

The model is estimated by ordinary least squares (OLS). To account for potential correlations within each market and potential heteroskedasticity across markets, the robust standard errors of Beck and Katz (1995) are employed throughout this analysis.

*, **, ***: significant at 10%-, 5%-, 1% level;

z-values are included in parenthesis

*Table 3. Average trading time and time of first trade*

| | *CONTROL* | *SYMM* | *ASYMM1* | *ASYMM2* | *ASYMM2_ni* |
|---|---|---|---|---|---|
| Avg. trading time (in sec.) | 63.8[a] | 65.1 | 67.4 | 67.9[a] | 65.3 |
| Avg. time of first transaction (in sec.) | 17.8[b,c,d] | 23.5[b] | 24.3[c] | 29.2[d] | 22.8 |

[a] pairwise comparison yields $p = 0.05$ (Mann-Whitney U-test, two-sided, $N$=24).
[b] pairwise comparison yields $p = 0.07$ (Mann-Whitney U-test, two-sided, $N$=24).
[c] pairwise comparison yields $p = 0.05$ (Mann-Whitney U-test, two-sided, $N$=24).
[d] pairwise comparison yields $p = 0.00$ (Mann-Whitney U-test, two-sided, $N$=24).
All other pairwise comparisons yield $p$-values larger than 0.1, and are not reported in detail.

*Table 4. Trading behavior conditional on information level in treatments with asymmetric information*

| | | Information level | | |
|---|---|---|---|---|
| | | I0 | I1 | I2 |
| [A] Average number of posted bids and asks per period and trader | *ASYMM1* | 4.1[a] | 3.0[a] | - |
| | *ASYMM2* | 3.1 | 2.7 | 2.7 |
| | *ASYMM2_ni* | 3.8[b] | 2.7[b] | 3.5 |
| [B] Average number of market orders per period and trader | *ASYMM1* | 1.8[c] | 2.2[c] | - |
| | *ASYMM2* | 1.2[d] | 1.6[e] | 1.9[d,e] |
| | *ASYMM2_ni* | 2.0 | 2.4 | 2.1 |
| [C] Average number of assets traded per period and trader | *ASYMM1* | 6.5 | 7.1 | - |
| | *ASYMM2* | 5.4[f] | 5.7 | 6.3[f] |
| | *ASYMM2_ni* | 9.0 | 6.9 | 7.8 |

[a] pairwise comparison yields $p = 0.03$ (Wilcoxon, two-sided, $N$=24).
[b] pairwise comparison yields $p = 0.06$ (Wilcoxon, two-sided, $N$=24).
[c] pairwise comparison yields $p = 0.06$ (Wilcoxon, two-sided, $N$=24).
[d] pairwise comparison yields $p = 0.08$ (Wilcoxon, two-sided, $N$=24).
[e] pairwise comparison yields $p = 0.06$ (Wilcoxon, two-sided, $N$=24).
[f] pairwise comparison yields $p = 0.06$ (Wilcoxon, two-sided, $N$=24).
All other pairwise comparisons yield $p$-values larger than 0.1, and are not reported in detail.

*Table 5. Regression on the intra-period difference between closing and opening prices*

| Dependent variable: Closing price minus opening price | | | | | |
|---|---|---|---|---|---|
| | *CONTROL* | *SYMM* | *ASYMM1* | *ASYMM2* | *ASYMM2_ni* |
| Constant | 4.51 | 7.77*** | 1.62 | 4.47*** | 2.16 |
| | (1.118) | (3.008) | (0.727) | (3.057) | (0.628) |
| *DUM_DIV0* | 0.54 | –7.90*** | –3.43*** | –8.23*** | –9.82*** |
| | (0.447) | (–3.333) | (–3.264) | (–5.141) | (–4.037) |
| *PERIOD* | –1.35*** | –1.62*** | –0.71** | –0.81*** | –0.21 |
| | (–2.862) | (–2.545) | (–2.279) | (–2.740) | (–0.573) |
| $R^2$ | 0.05 | 0.08 | 0.04 | 0.06 | 0.09 |
| AIC | 8.52 | 8.97 | 8.08 | 8.67 | 8.35 |
| *N* | 360 | 357 | 358 | 347 | 357 |

Notes: Panel--regression for each treatment separately. Dependent variable: Closing price minus opening price in period *t*. *DUM_DIV0* indicates periods with a dividend of zero. *PERIOD* runs from 1 to 10 within a round. AIC is the Akaike information criterion with lower values indicating a better goodness of fit of the model.
The model is estimated by ordinary least squares (OLS). To account for potential correlations within each market and potential heteroskedasticity across markets, the robust standard errors of Beck and Katz (1995) are employed throughout this analysis.
*, **, ***: significant at 10%-, 5%-, 1% level;
z-values are included in parenthesis

*Figure 1. Average trading prices of each treatment in comparison to the fundamental value (FV)*