Short sale constraints, divergence of opinion and asset values: Evidence from the laboratory*

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Abstract: The overvaluation hypothesis (Miller 1977) predicts that a) stocks are overvalued when there are short selling restrictions and that b) the overvaluation is increasing in the degree of divergence of opinion. We design an experiment that allows us to test these predictions in the laboratory. Our results support the hypothesis that prices are higher in the presence of short selling constraints. The overvaluation does not depend on the degree of divergence of opinion.

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1 Introduction

If traders have different opinions about the value of an asset, optimists will buy and pessimists will sell. Short sale restrictions prevent traders not currently owning an asset from selling it and thus exclude pessimistic traders from the market. The marginal traders' assessments of the asset value will thus be above average. If the price reflects these optimistic assessments the asset will be overvalued, and the overvaluation will increase in the degree of divergence of opinion. This is the overvaluation hypothesis first put forward by Miller (1977). Although it is obviously incompatible with a rational expectations equilibrium (Diamond and Verrecchia 1987) it has received much attention (and a fair amount of empirical support) in the literature. A first wave of empirical studies dates from the 1980s and early 1990s. Interest in the issue has been re-sparked recently, partially motivated by the question whether short-selling constraints have contributed to the internet bubble of the late nineties.

The empirical results, to be summarized briefly in section 2, are inconclusive. Papers relating short sale constraints for individual stocks to their valuation or their subsequent return on balance find evidence in favor of the overvaluation hypothesis (yet not unanimously). Charoenrook and Daouk (2005) who compare stock returns in countries with and without short sale restrictions reject the overvaluation hypothesis. A possible explanation for these contradictory results is the fact that empirical research into the issue is complicated by a number of impediments. Most importantly, neither the value of a stock nor the degree to which it is short sale constrained is directly observable. The same applies to the degree of divergence of opinion. Consequently, researchers have to rely on proxies for all variables of interest. These proxies may be noisy or even biased, and they may be correlated with other stock characteristics that affect valuation.

Our paper contributes to the literature in that it provides the first experimental test of the overvaluation hypothesis. None of the problems alluded to above is present in the laboratory. The experimenter controls the information structure and, consequently, the degree of divergence of opinion. Similarly, short sale constraints are imposed by the experimenter. As identical assets are traded with and without constraints, it is feasible to directly compare the market value of the assets, rather than inferring overvaluation from proxy variables or subsequent returns.

Although the impact of short sale constraints on valuation is easily amenable to experimental research, we know of only three papers that vary the level of short selling constraints in the laboratory (King et al. 1993, Ackert et al. 2002 and Haruvy and Noussair 2005). The design of these experiments differs from ours in a number of important ways. All three papers were inspired by experimental results suggesting that bubbles occur frequently in experimental markets for long-lived assets (Smith et al. 1988). Against this background they test whether allowing short sales has an impact on the frequency and magnitude of bubbles. The experiments of King et al. 1993, Ackert et al. 2002 and Haruvy and Noussair 2005 feature subjects with symmetric information. There is thus no divergence of opinion.[1] Consequently, none of these papers can be considered a test of Miller's (1977) overvaluation hypothesis because there, divergence of opinion is a necessary condition for overvaluation to occur. Further, the degree of divergence of opinion can obviously not be varied in a symmetric information setting.

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1 There may be differences of opinion due to strategic uncertainty, i.e., uncertainty with respect to the behaviour of other subjects. Strategic uncertainty is, however, not under the control of the experimenter.

The results of our experiments provide only partial support for the overvaluation hypothesis. Prices in the experimental markets are higher when short selling is prohibited. The overvaluation does, however, not depend on the degree of divergence of opinion.

The remainder of the paper is organized as follows. The next section presents a brief summary of the literature. In section 3 we describe the experimental design and procedures. Section 4 presents the hypotheses while the results are contained in section 5. In section 6 we summarize our results and offer concluding remarks

2 Literature

As noted in the introduction the overvaluation hypothesis was first put forward by Miller (1977). If traders in financial markets have different opinions, optimists will buy and pessimists will sell. Short sale constraints prevent those pessimists not currently owning the asset from selling it. Optimistic opinions will then be overweighted in market prices. Consequently, short sale restrictions lead to overvaluation and the overvaluation is increasing in the degree of divergence of opinion.

The overvaluation hypothesis as put forward by Miller (1977) is inconsistent with a rational expectations equilibrium.[2] Diamond and Verrecchia (1987) present a rational expectations model in which short sale constraints do not lead to overvaluation but reduce the speed at which new information, and bad information in particular, is incorporated into prices. Similar results, though in a very different context, are derived in Hong and Stein (2003). Recent theoretical research has revived the overvaluation hypothesis. Duffie et al. (2002) derive a model in which short sale constraints together with divergence of opinion (modeled by assuming different priors about the payoff distribution) may lead to overvaluation. In the model of Johnson (2004) higher degrees of divergence of opinion lead to lower subsequent returns in a fully rational context. In Scheinkman and Wei (2003) overconfidence creates divergence of opinion and may, in the presence of short sale constraints, lead to overvaluation. A similar result is derived in Jiang (2005).

Researchers have used various avenues in order to empirically test the overvaluation hypothesis. The most common approach is to consider a cross-section of stocks and to test whether stocks that are subject to short selling constraints are overvalued, and whether overvaluation depends on the degree of divergence of opinion. This requires (a) identification of stocks that are short sale constrained, (b) a measure for the degree of divergence of opinion[3] and (c) a measure of asset value to identify overvaluation.

Various measures have been employed to identify short sale constrained stocks. These include the short interest (Figlewski and Webb 1993, Asquith and Meulbroek 1996, Dechow et al. 2001, Desai et al. 2002, Asquith et al. 2005, Boehme et al. 2005, Cohen et al. 2005), institutional ownership (Asquith et al. 2005, Nagel 2005), the availability of options on the stock (Figlewski and Webb 1993, Danielsen and Sorescu 2001, Mayhew and Mihov 2004, Boehme et al. 2005), the inclusion of a stock in the "threshold list" (Diether et al. 2005) and the rebate rate (Jones and Lamont 2002, Reed 2003, Ofek et al. 2004, Boehme et al. 2005, Cohen et al.

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[2] It is fair to note that Miller (1977) was well aware of the limitations of his model. He explicitly refers to the winner's curse problem and argues (p. 1158) that "many investors are still following naive procedures".

[3] D'Avolio (2002) documents that a stock is more likely to be "on special" (i.e., to be expensive to short) when the degree of divergence of opinion is large. This suggests that the two explanatory variables of interest may not be independent.

2005). The most widespread proxy for the degree of divergence of opinion is the standard deviation of analyst forecasts (Diether et al. 2002, Boehme et al. 2005), but the standard deviation of returns and the turnover ratio have also been employed (Boehme et al. 2005).

Some researchers identify overvalued stocks by analyzing valuation ratios (Dechow et al. 2001, Desai et al. 2002, Jones and Lamont 2002) or by considering adjustments to analysts' earnings forecasts (Francis et al. 2005). The most widespread approach is to rely on subsequent returns to identify overvalued stocks. This approach is based on the implicit assumption that either short sale constraints are removed or the divergence of opinion is reduced (e.g. because new information is released), leading to a decrease of the level of overvaluation. Negative returns are thus taken as evidence of initial overvaluation.

Given the measurement problems and the different approaches to resolve them, it is not surprising that the conclusions are not entirely unanimous. A majority of papers find results that are supportive of the overvaluation hypotheses (e.g. Figlewski and Webb 1993, Danielsen and Sorescu 2001, Dechow et al. 2001, Desai et al. 2002, Diether et al. 2002, Jones and Lamont 2002, Gopalan 2003, Ofek et al. 2004, Boehme et al. 2005, Cohen et al. 2005 and Nagel 2005). Additional evidence in favor of the overvaluation hypothesis is provided by Aitken et al. (1998) and Chang and Yu (2004). Aitken et al. (1998) make use of the fact that in Australia short sales are transparent. Using intraday event study methodology they find that prices almost instantaneously decrease after a short sale. Chang and Yu (2004) use data from Hong Kong, where only stocks that are included on a short sale list can be shorted. The list is revised from time to time. Additions to and deletions from the list are associated with abnormal returns the sign of which is consistent with the overvaluation hypothesis.

Other papers support the overvaluation hypothesis only partially, e.g. when equally-weighted portfolios are considered (Asquith et al. 2005). Diether et al. (2005) find that returns of small stocks are negative after a period of increased short selling (which is consistent with the overvaluation hypothesis) but that returns after inclusion of small firms in the threshold list are, if anything, negative. The latter result is inconsistent with the overvaluation hypothesis because inclusion in the threshold list implies more binding short sale restrictions. Brent et al. (1990) report that returns are not smaller in the month after an increase in short interest, which is also inconsistent with the overvaluation hypothesis. Mayhew and Mihov (2004) present evidence suggesting that the negative returns around option listing that have been documented by others are not robust. They conclude by stating (p. 22) that "we now believe that there is no credible evidence from option markets that a marginal change in the cost of short selling can have an impact on prices."

Both Bris et al. (2004) and Charoenrook and Daouk (2005) compare stock return characteristics in countries with and without short sale restrictions. Both papers conclude that allowing short sales increases the efficiency of price discovery. Charoenrook and Daouk (2005) find that when countries start to allow short selling aggregate stock returns increase. This is clearly inconsistent with the overvaluation hypothesis.[4]

In summary, even though a majority of empirical papers finds results supportive of the overvaluation hypothesis, it appears fair to conclude that the issue is not yet finally settled. The measurement issues alluded to above suggest that an experimental approach may be warranted.

[4] Charoenrook and Daouk (2005) attribute their result to increased liquidity which, in turn, lowers expected returns and thus leads to an increase in stock prices.

Smith, Suchanek and Williams (1988) report results of experimental asset markets without short selling in which a long-lived asset is traded. They find that persistent bubbles occur very frequently. A number of subsequent papers have investigated into the reasons why these bubbles occur. Three of these papers (King et al. 1993, Ackert et al. 2002 and Haruvy and Noussair 2005) test whether lifting short sale restrictions reduces the frequency and / or the magnitude of the bubbles. The results are mixed. King et al. (1993) find that a relaxation of the short sale constraints does not have much impact on the occurrence of bubbles. Ackert et al. (2002), on the other hand, find prices closer to the fundamental value of the asset when short sale restrictions are relaxed. Haruvy and Noussair (2005) use a more differentiated experimental design and find that removing short sale restrictions reduces prices, but does not necessarily make them more efficient. In fact, when short sales are allowed prices may be significantly below the fundamental value.

Our experimental design differs in a number of important respects from former experiments. Most importantly, in all previous experiments subjects had symmetric information. Divergence of opinion can thus not be traced back to different information on the asset value.[5] Obviously, the degree of divergence of opinion can not be varied in a symmetric information setting. Another important difference is that all previous experiments used a long lived asset with a fundamental value that declined in the course of the experiment. Endowments were not re-initialized. Consequently, a subject exhausting her short selling capacity in one period is unable to sell in the next period. In contrast, our experiments consist of stationary replications of a one-period economy.

3 Experimental Design and Procedures

We conduct 18 experimental sessions in which a total of 180 subjects participate.[6] Participants are recruited among economics students at the university of Bonn using the online recruiting system ORSEE (Greiner 2004). Ten subjects are assigned to one cohort. Each cohort participates in one experimental session that consists of three distinct parts. . In order to allow the subjects to get acquainted with the computerized trading system, the sessions start with three training periods that are not included in the analysis. Subsequently there are 20 trading periods. In 10 of these periods short selling is prohibited and in ten periods it is allowed. We thus choose a within-subjects design, i.e. each cohort faces both the short selling condition and the no short-selling condition. To control for order effects half of the cohorts encounter the short selling condition first and the other half face the no short selling condition first.

Subjects receive a 20 € show-up fee for participation. In addition, at the end of the session two periods (one period of the no short selling condition and one period of the short selling condition) are determined randomly. The profit of these periods is converted into Euros at a rate of 20 ECU[7] = 1 € and added to (or subtracted from) the show-up fee.

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5 There may, however, be differences of opinion due to strategic uncertainty, i.e., uncertainty with respect to the behaviour of other subjects.

6 Four sessions are conducted with experienced subjects. We thus have 100 subjects who participate in one session and 40 subjects who participate in two sessions. Double-counting the latter group yields the number of 180 participants.

7 In the experiment all prices are denoted in Experimental Currency Units (ECU).

Asset value and private signals

Subjects in the experiment trade a risky asset against a numéraire (cash, denoted Experimental Currency Units, ECU). The value of the asset is a random variable denoted $\tilde{V}$. The value is high (H) or low (L) with equal probabilities. The realization is determined randomly at the beginning of each period but is only revealed after the end of the period. Draws in different periods are independent of each other.

At the beginning of the period each subject receives a private signal *s* that provides information on the value of the asset. The signal is either *h* (indicating a high value) or *l* (indicating a low value). The signal has precision *p* where *p* is the probability that the signal is correct, i.e.,

$$p = \text{Prob}\left(h \middle| H\right) = \text{Prob}\left(l \middle| L\right)$$

The signal is uninformative if p = 0.5, it is informative but noisy if 0.5 < p < 1 and it is perfectly accurate if p = 1. The conditional expectation of the asset value is

$$\begin{aligned} E\left(\tilde{V} \middle| s = h\right) &= pH + (1-p)L = L + p(H-L) \\ E\left(\tilde{V} \middle| s = l\right) &= pL + (1-p)H = H - p(H-L) \end{aligned}$$

Divergence of opinion

We wish to test the hypothesis that the overvaluation implied by the existence of short sale constraints increases in the degree of divergence of opinion among traders. We therefore vary the degree of divergence of opinion across (but not within) cohorts.

A reasonable measure for the degree of divergence of opinion is the cross-sectional variance of the conditional expected value of the asset. If the asset value is high (H), on average a fraction p of the traders receives the signal h and a fraction (1 - p) receives the signal l. The mean of the conditional expectations then is

$$E\left[E\left(\tilde{V}|s\right)\middle|\tilde{V}=H\right]=p\left[L+p\left(H-L\right)\right]+\left(1-p\right)\left[H-p\left(H-L\right)\right]$$
$$=H-2p\left(1-p\right)\left(H-L\right)$$

The cross-sectional variance of the conditional expected value of the asset then is

$$Var\left[E\left(\tilde{V}|s\right)\middle|\tilde{V}=H\right]=p\left\{\left[L+p\left(H-L\right)\right]-\left[H-2p\left(1-p\right)\left(H-L\right)\right]\right\}^{2}$$
$$+\left(1-p\right)\left\{\left[H-p\left(H-L\right)\right]-\left[H-2p\left(1-p\right)\left(H-L\right)\right]\right\}^{2}$$
$$=p\left(1-p\right)\left(4p^{2}-4p+1\right)\left(H-L\right)^{2}$$

The corresponding values for the case of a low asset value are

$$E\left[E\left(\tilde{V}|s\right)\middle|\tilde{V}=L\right]=\left(1-p\right)\left[L+p\left(H-L\right)\right]+p\left[H-p\left(H-L\right)\right]$$
$$=L+2p\left(1-p\right)\left(H-L\right)$$

and

$$Var\left[E\left(\tilde{V}|s\right)\middle|\tilde{V}=L\right]=p\left(1-p\right)\left(4p^{2}-4p+1\right)\left(H-L\right)^{2}.$$

Thus, irrespective of the realization of the asset value,[8] the cross-sectional variance of the conditional expectations of the asset value is proportional to $\theta\equiv p\left(1-p\right)\left(4p^{2}-4p+1\right)$. Therefore, we use θ to measure the degree of divergence of opinion. θ is zero when p = 0.5., because in this case the signals are uninformative and the conditional expectations of the asset value are equal to the unconditional expectation. θ increases when the signal becomes informative. θ approaches zero when the signal precision p goes to one. This is the case because the number of traders who receive a wrong signal goes to zero when p approaches 1. There exists a signal precision p that maximizes the degree of divergence of opinion. This maximum value is obtained for $p = 0.85$. Figure 1 graphs θ as a function of p.

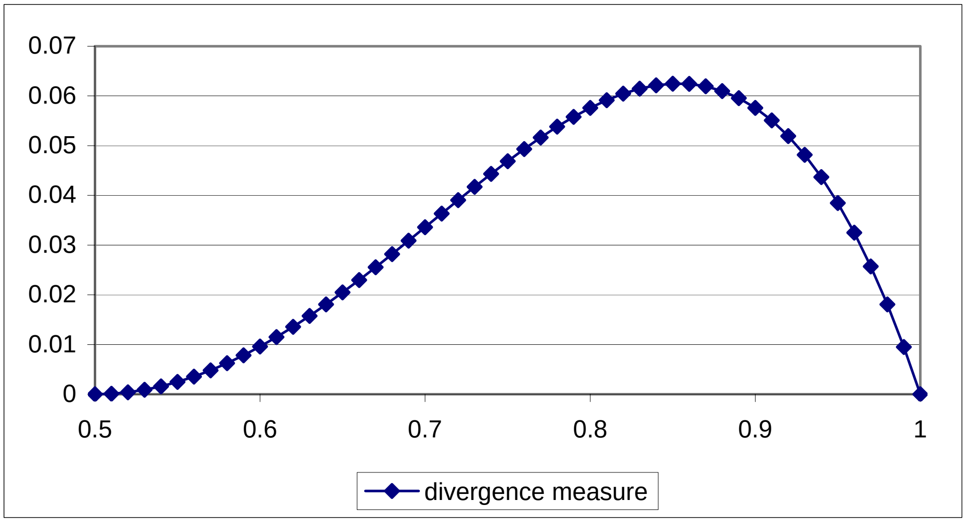

Figure 1: Divergence measure θ against the signal precision p

Parameter choice

We choose the following parameters: H is set equal to 200 and L is set equal to 100. To vary divergence of opinion, we choose two different signal precisions. In some sessions p equals 0.6 and in other sessions p is equal to 0.8. The two treatments are characterized by very different degrees of divergence of opinion. Table 1 shows the expectation of the asset value conditional on the realization of the signal and its precision. It further presents the expected number of traders with correct and incorrect signals and the measure θ for the degree of divergence of opinion.

Insert Table 1 about here

[8] This is an implication of our assumption that the asset value is equally likely to be high or low.

Previous experimental studies featuring a long-lived asset (e.g. Smith et al. 1988, King et al. 1993, Ackert et al. 2002 and Haruvy and Noussair 2005) have documented that without short selling possibility, overvaluation may even arise in the absence of asymmetric information. It is not clear that this result extends to our design because we analyze static repetitions of a one-period economy rather than a long-lived asset. Still, in order to test whether the same effect arises in our experiments, we conduct two sessions with symmetric information. In these sessions, subjects do not receive private signals. We use the results of these sessions as a benchmark to measure the impact of divergence of opinion.

Endowments and short selling restrictions

Subjects in each session are randomly and independently subdivided into two endowment groups at the beginning of each period. The different endowments create a rational motive for trade among subjects. Half of the subjects are endowed with four assets and 150 ECU (denoted the share endowment group). The remaining subjects are endowed with one asset and 600 ECU (denoted the cash endowment group). The (unconditional) expected values of the endowments are equal.

Subjects of both endowment groups have unlimited access to credit at a zero interest rate. Therefore, a situation where a subject would like to buy assets but is unable to do so can not arise.

In the no short selling treatment short sales are prohibited. The trading system rejects any offer that, if executed, would result in a short position. In the short selling treatment, on the other hand, short sales are allowed without any limitations and costs (e.g., lending fees).[9] Short positions are covered at the end of the trading period. For each share shorted, an amount equal to the true value of the asset is deducted from the subject's cash balance.

At the end of each period, the terminal wealth of each subject is calculated by adding the end-of-period cash balance and the value of the share portfolio (the product of the number of shares and their fundamental value). The profit is then calculated as the difference between the end-of-period wealth and the value of the endowment.[10]

<u>Market structure</u>

The market is a computerized continuous auction market with an open limit order book. We use the software zTree (Fischbacher 1999) to implement the trading system at the University of Bonn Experimental Economics Laboratory (BonnEconLab).

Each trading period lasts 150 seconds. At the beginning of each trading period the limit order book is empty. Traders can submit limit orders or accept standing limit orders submitted by others. Order execution is governed by price and time priority. Order size is restricted to one share. The minimum tick size is set to one ECU which amounts to 0.67% of the unconditional expected value of the asset.

Trading is anonymous; subject identification codes are thus not visible on the screen. There is full post-trade transparency, i.e., transaction prices (but not the identity of the traders)

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[9] This implies that shorting supply is infinite. Alternatively, we could allow short selling but restrict the amount of shares that can be shorted, or we could introduce short selling costs. Results in Cohen et al. (2005) suggest that it is shorting demand, rather than supply, that causes valuation effects. We therefore decided to (implicitly) vary the shorting demand by imposing different degrees of divergence of opinion, but to keep shorting supply constant.

[10] The share endowment is valued at the fundamental value of the shares. Thus, a subject who does not trade has a profit of zero irrespective of the realization of the asset value.

are visible to all traders. Subjects are not able to identify whether a trade they observe results in a short position.

Implementation issues

If the realizations of the signals were determined entirely randomly we would face two (related) problems. First, since the number of traders with correct and incorrect signals is determined randomly and thus changes, the effective degree of divergence of opinion may differ from the value shown in Table 1 and also changes across periods. Second, it may happen (particularly in the p = 0.8 treatment) that no trader obtains a wrong signal. In that case, however, there would be no informational asymmetry (although subjects would not be aware of that fact).

In order to avoid these problems, we choose a modified procedure by fixing the number of correct and incorrect signals at their expected values In the p = 0.6 [0.8] treatments, always six [eight] traders receive a correct signal and four [two] traders get an incorrect signal. Also, symmetry across the two endowment groups is imposed. Thus, in both endowment groups of the p = 0.6 [0.8] treatment there are three [four] traders with a correct signal and two traders [one trader] with an incorrect signal.

This procedure has the advantage that, from the point of view of the individual subject, signals are still determined randomly with known precision p = 0.6 [0.8] while at the same time the value of θ is held constant.

It may be the case that, with experience, subjects learn to avoid overvaluation. In principle this issue can be addressed by comparing misvaluation across periods and by comparing the results of those treatments where the sequence of short-selling and no short-selling is reversed. However, the 20 periods of an individual experiment may not be sufficient for learning to occur. In order to account for this possibility, we additionally conduct four sessions with experienced subjects, i.e., subjects that have already participated in a previous experimental session.

Treatment summary

Table 2 summarizes the treatments and introduces the notation that will be used in the sequel. "E" denotes a session with experienced subjects. All experiments were conducted in October and November 2005 in the BonnEconLab.

Insert Table 2 about here

4 Hypotheses

Binding short sale constraints prevent traders who are willing to sell from doing so and will thus lead to a lower trading volume. We thus state

Hypothesis 1: Trading volume

H1: Trading volume is lower under short-sale constraints

In the benchmark treatment (AP0 and PA0) traders only receive information about the unconditional expected value of the asset. We should thus expect prices to be equal to or (because of risk aversion) lower than 150. According to the overvaluation hypothesis both short sale constraints and divergence of opinion are necessary conditions for overvaluation to occur (for empirical evidence see Boehme et al. 2005). As there is no divergence of opinion in the benchmark treatment we do not expect short sale restrictions to affect valuation. We thus expect

Hypothesis 2: The benchmark treatment

H2a: In the benchmark treatment prices are equal to or (because of risk aversion) slightly lower than 150.

H2b: In the benchmark treatment there are no differences between the short-selling and the no short-selling conditions.

In those treatments with informational asymmetries (PA60, AP60, PA80 and AP80) there is divergence of opinion. The overvaluation hypothesis thus predicts that prices will be higher when short selling is prohibited. This yields

Hypothesis 3: Short selling

H3: In the presence of asymmetric information prices are higher when short selling is prohibited.

The overvaluation hypothesis predicts that prices are increasing in the degree of divergence of opinion. In the experiment we vary the degree of divergence of opinion yielding

Hypothesis 4: Divergence of opinion:

H4: The overvaluation due to short sale constraints is more pronounced when the degree of divergence of opinion is higher.

As noted previously the overvaluation hypothesis in its original form is inconsistent with a rational expectations equilibrium. A similar statement can be made for our experimental design. If all subjects behave rationally there will be no overvaluation. Even if subjects are not fully rational, they may learn and thus achieve outcomes closer to a rational expectations equilibrium in later periods. If learning occurs we should also expect overvaluation to be less pronounced in those sessions that use experienced subjects. This leads to

Hypothesis 5: Learning

H5a: The amount of overvaluation decreases over periods

H5b: The amount of overvaluation is smaller in the sessions that use experienced subjects.

5 Results

Table 3 reports figures on trading volume. The sessions for each treatment (PA0, AP0, PA60, AP60, PA80 and AP80) are pooled, and the mean and the median trading volume per period is calculated for the short-selling and the no-short-selling condition. Besides separate results for each treatment the table also contains (in the last line) the results pooled over all treatments. These aggregate results clearly confirm Hypothesis 1. Both the mean and the median trading volume are higher when short sales are allowed. The disaggregated data reveal a similar picture, though with exceptions. Trading volume is significantly higher when short sales are allowed in three out of six treatments. In the PA80 treatment the mean is significantly higher whereas there is no significant difference in the median. In the remaining two treatments (PA0 and PA60), there is no significant difference in trading volume. In summary, the results indicate that trading volume tends to be higher when short-selling is allowed.

<u>Insert Table 3 about here</u>

The hypotheses 2 - 5 make predictions about the asset prices in different treatment conditions. A test of these hypotheses requires a summary statistic of the asset prices. We use three such measures. The first is simply the mean price for each period. This measure assigns equal weight to each transaction within a given period. As the prices early in a period are less informative it may be preferable to use a weighting scheme that puts more weight on transactions occurring later in a period. We therefore use a digitally weighted average price as our second measure. It is defined as

$$p_j^{dig} = \frac{\sum_{i=1}^{T_j} ip_i}{\sum_{k=1}^{T_j} \sum_{i=1}^{j} i}$$

were T_j is the number of transactions in period *j* and p_i is the price of transaction *i* in period *j*. If there are five transactions in a period, the first one receives weight $1/(1+2+3+4+5)=1/15$, the second receives weight $2/15$ and so on. Our third measure is the mean of the bid-ask midpoints. The midpoint is not affected by the bid-ask spread and is therefore often considered to be a less noisy measure of asset value.

Hypothesis 2 relates to the benchmark treatment and predicts that prices in the benchmark treatment will be equal to or smaller than 150 (the unconditional expected value of the asset), and that, because of the absence of divergence of opinion, prices will not be higher when short selling is prohibited. We test this hypothesis by analyzing the three price measures described above. We treat the observations from different periods as independent.[11] We provide aggregate results and separate results for the PA and the AP treatments because the sequence in which subjects face the two conditions may have an impact on market outcomes.

[11] This is a common practice. It should be noted, though, that data from different periods of the same session are not, strictly speaking, independent because the same subjects interact with each other and share a common history.

In the benchmark treatment we do not have to differentiate with respect to the realization of the asset value because subjects do not receive information about the value and, consequently, can not condition their actions on the asset value.

The results are shown in Table 4. Panel A shows the results for the equally weighted mean price, Panel B those based on the digitally weighted mean and Panel C those based on the bid-ask midpoint. All three measures yield very similar conclusions. The only noteworthy difference is the fact that significance levels tend to be higher when the analysis is based on bid-ask midpoint. This corroborates our conjecture that the midpoint is a less noisy measure of asset value.

All three measures clearly indicate that prices for the benchmark treatments are significantly below 150 as shown in the first line of Table 4. We therefore conclude that our experimental design does not produce the "bubbles" that provided the starting point of previous experiments on short sales (King et al. 1993, Ackert et al. 2002 and Haruvy and Noussair 2005).

Prices are, however, significantly higher when short sales are prohibited (132.55 as compared to 127.96 with a t-statistic of 1.87, these figures are taken from Panel A). The disaggregated data show that this is mainly due to a large difference in the PA treatment (128.10 when short sales are prohibited and 120.04 when they are feasible, t-statistic 3.40) whereas the difference in the AP treatment is insignificant. The other two measures of asset value yield identical conclusions. The results thus suggest that prices tend to be higher when short selling is prohibited even in the absence of divergence of opinion. This contradicts Hypothesis 2b.

Insert Table 4 about here

In all non-benchmark treatments subjects receive signals about the value of the asset. We should therefore expect prices to depend on the realization of the asset value process. Consequently, the results are presented conditional on the asset value being low (100) or high (200), as shown in Table 4. In almost all cases prices are higher when short sales are prohibited. There are only two exceptions from this general pattern (in the AP60 treatment and in the PA80 treatment, respectively, when the value is high[12]).

Although the sign of the price difference generally conforms to our expectations the significance of the results is modest. Only three (Panel A) or four (Panels B and C) out of twelve t-statistics indicate significance at the 5% level (one-sided test). Taken together, these results do provide weak support for our Hypothesis 3. They also suggest that, in contrast to Hypothesis 4, the impact of short-selling restrictions on prices is not increasing in the degree of divergence of opinion. A more formal test of Hypothesis 4 will be presented later.

Table 5 addresses the learning hypothesis. Since the three price measures yield very similar conclusions we restrict the presentation to the equally weighted mean price. In Panel A of Table 5 we report separate results for the first half (periods 1-5) and the second half (periods 6-10) of each treatment condition. The results do not support the hypothesis that the impact of short selling restrictions on prices decreases with experience. Both in the first half and in the second half prices are higher when short sales are restricted in 6 out of a total of 10 cases. The most severe overvaluation is observed in the second half of the PA60 treatment when the true asset value is low. The average price is 174.93 when short sales are prohibited and 142.74 when they are allowed. Panel B of Table 5 compares the results from the sessions with inexperienced and experienced subjects. Again, there is not much evidence that the impact of short selling restrictions on prices decreases with experience. For both groups, prices are higher

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[12] In Panel C there is a third exception in the "all" column for p=0.8 and a high asset value.

when short selling is prohibited in six out of eight cases. The results in Table 5 thus suggest that the (weak) support for the overvaluation hypothesis documented earlier is not attributable to inexperienced subjects.

So far we have solely compared prices obtained under different treatment conditions. To obtain a more complete picture of the relation between short sale constraints and asset valuation we augment these univariate statistics with a pooled regression model. The dependent variable is the (equally weighted) average price[13] in each of 20 periods[14] of the 18 sessions. The price is likely to depend on the treatment and on the realization of the asset value process. For example, when $p = 0.8$ subjects have more precise information as compared to the case where $p = 0.6$. We should thus expect higher prices in the $p = 0.8$ treatments when the true value is high and lower prices when the true value is low. To capture these effects we include dummy variables for each treatment (except AP0 which is the base case) and interaction terms, defined as the product of the treatment dummies and a dummy variable that equals one when the realized asset value is high.

Besides these control variables we include a dummy variable that equals one when short selling is prohibited (model 1). The overvaluation hypothesis predicts a positive coefficient. In an additional model (model 2) we further add two interaction terms that interact the no-short-sales dummy with two dummy variables taking on the value one when $p = 0.6$ and $p = 0.8$, respectively. The coefficients on these interaction terms measure whether the overvalua-

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13 Using the digitally weighted average price or the bid-ask midpoint instead yields similar conclusions.

14 In period 14 of one session (PA60E) no transaction took place. The total number of observations in the regression is thus 359.

tion is more pronounced when the degree of divergence of opinion increases. The overvaluation hypothesis predicts a positive coefficient.

The results are presented in Table 6. The adjusted R^2 for both models is 0.5. The control and treatment variables thus explain about half of the variation in prices. Many of the treatment dummies and the interactions of the treatment dummies with the asset value dummy are significant, and most of the coefficients have the expected sign. Most importantly, prices are significantly higher when short sales are prohibited. The coefficient on the no-short-sales dummy is 4.51 (t-statistic 2.28) in model one and 4.14 (t-statistic 3.03) in model 2. These results are consistent with Hypothesis 3.

The coefficients on the additional interaction terms in model 2 are far from being significant. Thus, contrary to Hypothesis 4 (but consistent with our previous results), overvaluation does not increase in the degree of divergence of opinion.

6 Summary and conclusion

The overvaluation hypothesis first put forward by Miller (1977) predicts that assets will be overvalued when (a) short sale constraints and (b) differences of opinion exist. Numerous empirical studies have been conducted in order to test the overvaluation hypothesis. The results of these studies are not fully conclusive, partially due to measurement problems. Neither the existence (and degree, respectively) of short selling constraints nor the degree of divergence of opinion and the true value of a stock is observable, directly.

To avoid the shortcomings of previous empirical studies, we use an experimental approach. In the laboratory, trading of assets can be observed under ceteris paribus conditions with and without short selling constraints. We can thus examine the impact of short selling constraints on valuation. Our design further allows varying the degree of divergence of opinion across markets.

The results are only partially supportive of the overvaluation hypothesis. We find evidence of higher asset values in the presence of short sale constraints. We do not find, however, that overvaluation is increasing in the degree of divergence of opinion. We further document that trading volume is lower under short sale constraints, and that the overvaluation does not decrease when subjects are experienced.

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Table 1: Parameter choice

The table shows the parameters used in the individual experimental treatments. It further shows the expected value of the asset conditional on the signal and the expected number of traders with a correct and an incorrect signal. The full information benchmark is the expected value of the asset conditional on all 10 signals and under the assumption that the numbers of correct and incorrect signals are equal to their expected values. The last line shows the measure of divergence of opinion, θ.

	p = 0 (benchmark)		p = 0.6		p = 0.8	
	asset value		asset value		asset value	
	high	low	high	low	high	low
asset value	200	100	200	100	200	100
cond. expectation of trader with signal h	na	na	160	160	180	180
expected number of traders with signal h	na	na	6	4	8	2
cond. expectation of trader with signal l	na	na	140	140	120	120
expected number of traders with signal l	na	na	4	6	2	8
full information bench-mark	150	150	169.23	130.77	199.98	100.02
measure of divergence of opinion (θ)	0		0.0096		0.0576	

Table 2: Treatment summary

The table describes the treatments and shows the number of sessions that were conducted with each treatment condition.

Signal precision	sequence of treatments short selling prohibited - short selling allowed (PA)	short selling allowed - short selling prohibited (AP)
no signals (benchmark case)	PA0 - session 1	AP0 session 10
p = 0.6	PA60 - sessions 2-4 PA60E - session 5	AP60 sessions 11-13 AP60E - session 14
p = 0.8	PA80 - sessions 6-8 PA80E - session 9	AP80 sessions 15-17 AP80E - session 18

Table 3: Trading volume

The table shows the mean and the median trading volume per period for the different treatment conditions. Columns 5 and 8 report the t-statistic and the z-statistic for a test of the null hypothesis of equal means and medians, respectively. The last line shows results pooled over all treatment conditions.

Divergence of opinion	Order of treatments	mean volume per period			median volume per period		
		short sales allowed	short sales prohibited	t-statistic (p-value)	short sales allowed	short sales prohibited	z-statistic (p-value)
Benchmark	P-A	27.10	33.30	1.19	26.50	33.50	1.14
	A-P	10.60	8.00	2.29	11.00	8.00	1.99
p = 0.6	P-A	13.73	14.78	0.44	13.50	9.50	0.80
	A-P	27.85	13.25	5.03	26.50	12.00	4.88
p = 0.8	P-A	14.63	11.80	1.75	13.50	12.00	1.22
	A-P	23.60	9.63	4.24	16.50	8.00	3.97
pooled		19.83	13.28	4.89	15.50	10.50	5.04

Table 4: Price Levels

The table shows the mean price per period for the different treatment conditions. We report separate results for periods with low and high asset values, respectively (no such distinction is made in the benchmark treatment because there traders did not receive signals about the asset value). Columns 3-5 (6-8) report the prices for those periods where short sales were allowed (prohibited). We provide separate results for those sessions were the order of treatments was P-A and A-P, respectively, as well as aggregated results. Columns 9-11 show the t-statistics for the null hypothesis of equal means. The t-statistic in column 9 (10; 11) relate to a comparison of the prices in columns 3 and 6 (4 and 7; 5 and 8).

Panel A: Mean price, equally weighted

Diver-gence of opinion	Asset value	short sales allowed			short sales prohibited			t-statistic		
		P-A	A-P	all	P-A	A-P	all	P-A	A-P	all
Benchmark		120.04	135.88	127.96	128.10	136.99	132.55	3.40	0.95	1.87
p = 0.6	100	144.11	141.41	142.76	153.75	147.95	150.33	1.71	1.52	2.20
	200	156.11	148.69	152.30	157.09	147.42	153.08	0.21	0.23	0.21
p = 0.8	100	122.77	127.36	124.70	138.60	130.51	134.32	1.77	0.31	1.44
	200	184.79	168.74	175.95	181.50	175.07	178.42	0.63	0.96	0.56

Panel B: Mean price, digitally weighted

Diver-gence of opinion	Asset value	short sales allowed			short sales prohibited			t-statistic		
		P-A	A-P	all	P-A	A-P	all	P-A	A-P	all
Benchmark		119.84	136.18	128.01	127.94	136.91	132.43	3.14	0.60	1.73
p = 0.6	100	143.69	139.33	141.51	154.39	148.31	150.80	1.79	2.00	2.55
	200	155.38	148.77	151.98	157.01	147.79	153.19	0.33	0.16	0.31
p = 0.8	100	120.16	125.89	122.57	137.52	129.89	133.48	1.78	0.38	1.55
	200	187.30	169.91	177.72	184.78	176.23	180.69	0.49	0.94	0.67

Panel A: Bid-ask midpoint

Diver-gence of opinion	Asset value	short sales allowed			short sales prohibited			t-statistic		
		P-A	A-P	all	P-A	A-P	all	P-A	A-P	all
Benchmark		118.71	135.46	127.08	132.96	137.35	135.16	6.37	1.40	3.42
p = 0.6	100	141.92	144.13	143.03	153.22	147.88	150.07	2.23	1.12	2.40
	200	154.70	149.48	152.09	156.40	149.16	153.40	0.38	0.08	0.43
p = 0.8	100	118.97	128.54	122.98	134.50	134.57	134.54	2.16	0.81	2.25
	200	179.34	167.16	172.49	173.05	169.63	171.41	1.29	0.59	0.33

Table 5: Learning

Panel A shows average prices for the first half (periods 1-5) and the second half (periods 6-10) of the different treatment conditions. Results are differentiated with respect to the degree of divergence of opinion (p = 0.6 and p = 0.8), the realization of the asset value process (with the exception of the benchmark case), the order of treatments (P-A and A-P) and the short selling condition (allowed and prohibited). Panel B compares the results from the sessions with inexperienced and experienced subjects. There are no results for the benchmark treatment because there was no session with the benchmark treatment and experienced subjects. The structure of Panel B is similar to Panel A.

Panel A: First half versus second half

Divergence of opinion	Asset value	short sales allowed				short sales prohibited			
		P-A		A-P		P-A		A-P	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
benchmark		124.88	115.19	137.12	134.63	127.46	128.74	136.87	137.12
p = 0.6	100	146.09	142.74	144.28	139.02	144.13	174.93	147.80	148.10
	200	154.68	158.15	142.99	155.82	155.85	157.84	143.51	150.89
p = 0.8	100	126.35	118.30	127.72	126.94	146.24	130.96	123.60	144.33
	200	185.01	184.61	156.83	179.81	181.69	181.31	172.73	176.40

Panel B: Inexperienced versus experienced subjects

Divergence of opinion	Asset value	short sales allowed				short sales prohibited			
		P-A		A-P		P-A		A-P	
		inexp.	exp.	inexp.	exp.	inexp.	exp.	inexp.	exp.
p = 0.6	100	145.35	141.92	139.61	147.57	154.65	147.50	143.39	158.36
	200	156.18	155.00	144.74	158.97	158.63	154.01	144.85	159.41
p = 0.8	100	116.51	144.70	134.17	104.65	149.00	125.23	134.08	117.99
	200	185.86	181.93	173.15	156.17	181.43	182.02	178.23	166.63

Table 6: Regression results

The table shows the results of OLS regressions. The dependent variable is the average price of each period. We include control variables for the different treatment conditions and interactions between these control variables and a dummy that is equal to 1 whenever the asset value is high. In model 1 we include a dummy variable that equals 1 when short selling is prohibited. In model 2 we further include interactions between the short selling dummy and dummy variables that equal 1 in those sessions where p = 0.6 and p = 0.8 (denoted div 60 and div 80), respectively. The number of observations is 359 (18 sessions, each with 20 periods; in one period no transaction took place). t-values are based on heteroscedasticity-consistent standard errors.

	Model 1		Model2	
	coefficient	t-value	coefficient	t-value
constant	134.84	70.90	135.09	79.79
AP60	4.41	1.63	4.30	1.44
AP80	-3.36	-0.54	-3.83	-0.58
AP60E	16.39	3.77	16.31	3.40
AP80E	-25.15	-7.33	-25.61	-6.31
PA0	-10.76	-5.67	-10.80	-5.75
PA60	12.90	3.43	12.80	3.30
PA80	-7.39	-1.49	-7.78	-1.45
PA60E	7.29	1.60	7.10	1.53
PA80E	-5.41	-0.54	-5.90	-0.54
Value200	-1.21	-0.76	-1.32	-0.88
AP60*Value200	4.42	1.07	4.54	1.11
AP80*Value200	43.12	5.79	43.29	5.80
AP60E*Value200	7.42	1.07	7.47	1.07
AP80E*Value200	50.43	8.53	50.58	8.71
PA0*Value200	-3.83	-1.42	-3.76	-1.41
PA60*Value200	8.62	1.85	8.73	1.90
PA80*Value200	54.54	9.76	54.58	9.81
PA60E*Value200	9.18	1.31	9.50	1.37
PA80E*Value200	52.23	3.76	52.46	3.75
no short sales	4.51	2.28	4.14	3.03
no short sales*div60			0.07	0.03
no short sales*div80			0.75	0.19
adj. R^2	0.50		0.50	