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Experimental asset markets with endogenous choice of costly asymmetric information

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Abstract Asymmetric distribution of information, while omnipresent in real markets, is rarely considered in experimental financial markets. We present results from experiments where subjects endogenously choose between five information levels (four of them costly). We find that (i) uninformed traders earn the highest net returns, while average informed traders always perform worst even when information costs are not considered; (ii) over time traders learn to pick the most advantageous information levels (full information or no information); and (iii) market efficiency decreases with higher information costs. These results are mostly in line with the theoretical predictions of Grossman and Stiglitz (Am. Econ. Rev. 70:393–408, 1980) and provide additional insights that studies with only two information levels cannot deliver.

Keywords Information costs · Asset markets · Experiment · Value of information · Asymmetric information

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1 Introduction

Asymmetric distribution of information, while omnipresent and highly relevant in real markets, is rarely considered in experimental financial markets. In this paper we build on theoretical research of Grossman and Stiglitz (1980) and implement asset market experiments with subjects endogenously choosing from five information levels (four of them costly). We find that (i) uninformed traders earn higher net returns than all other information levels. Even when information costs are not considered, the uninformed outperform the average informed, while insiders earn the highest gross returns. Thus, the relationship between information levels and gross returns is J-shaped. (ii) We further observe that traders learn to pick the most advantageous information levels (full information and no information) over time, and (iii) market efficiency decreases with higher information cost. Our results are mostly in line with Grossman and Stiglitz (1980) and provide additional insights that studies with only two information levels cannot deliver—e.g. gross and net returns of average informed traders are lowest in each treatment, and subjects learn to ignore outdated fundamental information over time by choosing either insider information or no information.

While Grossman and Stiglitz (1980) consider only two levels of information—informed and uninformed[1]—real markets are populated by subjects with a broad range of different information levels. Therefore, building on Hellwig (1982), Huber (2007), and Kirchler (2010), we implement an information structure with five information levels ranging from uninformed (I0) to insiders (I4), where the better informed traders always receive relevant information earlier than worse informed. Going from two to five information levels is not only a quantitative, but also a qualitative change. With more information levels strategic behavior becomes more important, since insiders trade against several groups of average informed (I1–I3), who receive outdated fundamental information, and against uninformed traders (I0), who do not receive any information about the fundamental value. The latter is important, since being uninformed may prevent subjects from jointly trading on outdated information that average informed traders sometimes do.[2] Furthermore, with several information levels, which are allocated endogenously, one's own relative position becomes less clear: having information level I3 could mean a subject is the best informed trader in the market (if all others bought information levels I0 to I2), but it could also mean the subject is the least informed (if all others chose information level I4). An insider (I4) will act differently, depending on whether he is the only insider, or whether there are several others. In our experiments traders can switch between information levels, allowing subjects to learn over time.

From a theoretical point of view our study builds on the "efficient market hypothesis" (EMH, formulated by Fama 1970). The EMH in its strong form states that

[1] The same holds for the only experimental exploration of this question we are aware of, conducted by Sunder (1992).

[2] See Schredelseker (2001), Huber (2007), and Kirchler (2010) for further elaborations.

prices fully reflect all relevant information at all times. By formulating the "information paradox", Sanford Grossman showed that the strongest form of the EMH cannot hold: If all available information were immediately reflected in prices, no excess profits could be earned even with insider information (Grossman 1976). When gathering information costs time and/or money no rational trader would collect it, as it would lower his net return. As a consequence, prices cannot reflect all available information. To solve this paradox, Grossman and Stiglitz (1980) show that there has to be an "*equilibrium degree of disequilibrium*" in the market, where prices reflect the information of informed individuals only partially. This allows informed traders to earn above-average gross returns to cover their information costs with net returns being indistinguishable between information levels. Additionally, Grossman and Stiglitz (1980) show that in equilibrium the number of insiders as well as market efficiency decrease with higher information costs. This is also evident in our results.

The paper is structured as follows: In Sect. 2 we present the model design and the experimental implementation. In Sect. 3 we formulate hypotheses which are tested in Sect. 4. Section 5 concludes the paper.

2 Model

Sunder (1992) argues that there are essentially two ways to sell information in a market: either the quantity offered is fixed while the price is adjusted, or the price is fixed while the quantity is adjusted. We cover both possibilities with a total of four treatments, three with prices fixed at different levels (T_high, T_mid and T_low), and one in which information levels were auctioned to the highest bidders (T_auc). For each treatment six markets were conducted with different cohorts of students. In particular, ten subjects constituted one market, in which subjects traded stocks of a virtual company for experimental currency in a continuous double auction for six blocks of five periods each.[3] At the beginning of each block subjects chose their information level on the fundamental value (FV) of the stock on an information market which was followed by five periods of trading (with the information level unchanged). At the end of each block all stocks were bought back at the FV of the last period of the respective block. In the following, we demonstrate the functioning of the market by explaining one block, as this is the relevant building unit of the markets.

2.1 Information system

The dynamics of the underlying FV of the stock are governed by a stochastic process:

$$FV_k = FV_{k-1} \cdot (1 + \varepsilon_k) \tag{1}$$

[3] In a continuous double auction traders have two alternatives to place buy and sell orders. Limit orders provide the possibility to fix both number of stocks and price. However, a transaction is only executed if another trader accepts the offer with a market order. A market order is executed by accepting a limit order that already exists and the trader posting the market order only specifies how many stocks he wants to buy/sell. The trading time of one period is 100 seconds.

Table 1 Information costs per period in percent of initial wealth for each information level in the different treatments (in Taler)

IL	T_high	T_mid	T_low	T_auc
I0	0	0	0	0
I1	0.13	0.06	0.03	3rd highest bid for I1
I2	0.25	0.13	0.06	3rd highest bid for I2
I3	0.50	0.25	0.13	3rd highest bid for I3
I4	1.00	0.50	0.25	3rd highest bid for I4

Here, FV_k denotes the fundamental value in period k and ε_k is a normally distributed random variable with a mean of 0.5% and a standard deviation of 7.2%. We use the same six randomly generated FV-paths in each treatment of the experiment.[4]

Asymmetric information is implemented by providing better informed traders with a timing advantage in receiving information about the fundamental value of the stock. Only insiders (labelled I4) know the fundamental value of the current period k. Fundamental information given to I4 in period k becomes available to I3 one period later, to I2 in period $k+2$, and to I1 in period $k+3$. The initial FV in period $k=-3$ equals 40 Taler (experimental currency).[5] The spectrum of possible information levels is completed by uninformed subjects (I0) who receive no information about the FV.

2.2 Market for information

We implement four treatments differing in the way information is allocated and in the level of information costs. For treatments T_high, T_mid, and T_low an information market with fixed prices is set up, with T_high (T_low) being the treatment with the highest (lowest) costs for each information level. At the beginning of each block, subjects choose their information level for the entire block of five periods.[6] Theoretically all subjects could choose the same information level. Table 1 summarizes the differences in information costs between the treatments.

In treatment T_auc we fix the maximum number of traders for each information level (except for I0) at two by using a Vickrey-auction in which the two highest bidders for information level j receive the information at the price of the third-highest bid.[7] Traders bid secretly and simultaneously for each information level at the same time. Once all bids are submitted, distribution of IL starts from I4 downwards. The

[4] Each of the six markets within a treatment consists of six blocks, each with its own path of the fundamental value (path A to F). The six paths are randomly ordered for the first market conducted. The next market has the same order of paths but a different starting path to reduce the influence of the path structure on results. E.g. Market 1 has the path order BEFDAC, Market 2 EFDACB, Market 3 FDACBE, etc.

[5] The FV starts in period $k=-3$ because we need to provide information to all traders already in the first period of the block.

[6] The information costs per period are deducted from subject's Taler holdings each period.

[7] This auction mechanism is widely considered to be one of the most efficient mechanisms to ensure that subjects reveal their true valuations (see Vickrey 1961, Rothkopf et al. 1990, and Copeland and Friedman 1992).

two highest bidders for I4 receive I4 for the price of the third highest bid and their bids for all other information levels are deleted. Then the two highest bidders (of the remaining eight traders) for I3 receive information level I3, and so on.[8]

2.3 Architecture of the asset market

Subjects trade on a continuous double auction market, i.e. each subject can buy and sell stocks by submitting limit orders (bid/ask) and market orders (buy/sell). Limit orders are sorted according to price and then time priority, while market orders are executed instantaneously. Holdings of cash and stocks are carried over from one period to the next, but they are re-initialized at the start of each block. Traders can submit as many bids and asks as they want, provided they have enough money to buy or enough stocks to sell. There are no transaction costs, and negative holdings of stocks or money are not allowed. The trading screen provides subjects with current information about their stock and money holdings, a realtime chart of past transaction prices, their estimate of the FV, their trades of the current period and their current wealth. After each period a history screen informs subjects about their stock and cash holdings, wealth, the closing price of the market, their trading volume and the total trading volume on the market. A chart of average market prices for the past periods completes the history screen.[9]

2.4 Experimental implementation

At the beginning of each experimental session all subjects were briefed with written instructions that were read out aloud. Afterwards we ran three trial periods to give subjects the possibility to become familiar with the trading mechanism. Each trader was endowed with 1600 Taler and 40 units of the stock at the beginning of each block.

Right after the information market and before trading started subjects were able to buy a newsletter for 5 Taler per block, providing them with the distribution of information levels among traders.[10]

At the end of each block, all stocks were bought back at the fundamental value FV_{end} (information of the insider, I4) of the last period. Final wealth (units of the stock multiplied by FV_{end} plus money holdings) was converted into EUR at the exchange rate of 1 EUR = 1000 Taler in T_low, T_mid and T_high and 1 EUR = 800 Taler in T_auc.

We conducted all treatments between October 2007 and May 2008 at the University of Innsbruck with a total of 240 business students. Most subjects already took part in other experiments in economics, but none of them participated in more than

[8] If a trader does not bid on any IL or does not receive any IL in the auction because her bids are never among the two highest, she receives information level I0. If there are only two or fewer bids for a given IL, the bidders receive information for free, as there is no third-highest bid. If there are no bids for an information level, the information level is not assigned to anybody.

[9] See Appendix for detailed instructions and screenshots.

[10] The newsletter contained information on how many traders have chosen and received each information level. In T_auc, additional information about the prices of each IL (the third-highest bid) was revealed. The actual bids for information levels were not published.

one of the markets. Each session lasted about 100 minutes and the average payment was 24 Euros. All treatments were programmed and conducted with zTree 3.0.6 (Fischbacher 2007). The recruitment of students was carried out using ORSEE (Greiner 2004).

3 Hypotheses

According to Grossman and Stiglitz (1980), information aggregation in markets can only work properly when better informed traders can recover their information costs through higher gross abnormal returns. As Schredelseker (2001), Huber (2007) and Kirchler (2010) show a nonlinear relationship between information level and gross return, we adapt the conjectures of Grossman and Stiglitz (1980) and formulate the following nondirectional hypotheses:

Hypothesis 1a Gross abnormal returns (GAR) differ between information levels.

H0: Gross abnormal returns (GAR) do not differ between information levels.

Hypothesis 1b Net abnormal returns (NAR) differ between information levels.

H0: Net abnormal returns (NAR) do not differ between information levels.

For the above hypotheses to hold the costs of information have to be taken into account by traders when making their decisions. Therefore, we formulate the following directional hypotheses which are inspired by Grossman and Stiglitz (1980):[11]

Hypothesis 2 The costs of insider information have a negative impact on the percentage of subjects choosing insider information.

H0: The costs of insider information have no impact on the percentage of subjects choosing insider information.

Hypothesis 3a The percentage of insiders in the market has a positive impact on market efficiency.

H0: The percentage of insiders in the market has no impact on market efficiency.

Hypothesis 3b The percentage of uninformed traders in the market has a negative impact on market efficiency.

H0: The percentage of uninformed traders in the market has no impact on market efficiency.

[11] To be consistent with the above formulated Hypothesis 1a and 1b we test the following directional hypothesis two-sided as well.

4 Method and results

4.1 Hypothesis 1

In Fig. 1 we plot average gross returns (GRET_j) and average net returns (NRET_j) for each information level j. To arrive at these measures we calculate each trader i's gross return in block b of market m according to (2) and average across traders for each information level ((3) for net returns).

$$\text{GRET}_{m,b,i} = \frac{\text{GWEALTH}_{m,b,i,K}}{\text{GWEALTH}_{m,b,i,0}} - 1 \tag{2}$$

$$\text{NRET}_{m,b,i} = \frac{\text{NWEALTH}_{m,b,i,K}}{\text{NWEALTH}_{m,b,i,0}} - 1 \tag{3}$$

Here, $\text{GWEALTH}_{m,b,i,K}$ ($\text{NWEALTH}_{m,b,i,K}$) denotes gross (net) wealth—number of stocks multiplied by FV plus money holdings—at the end of block b with K indicating the last period of the respective block.

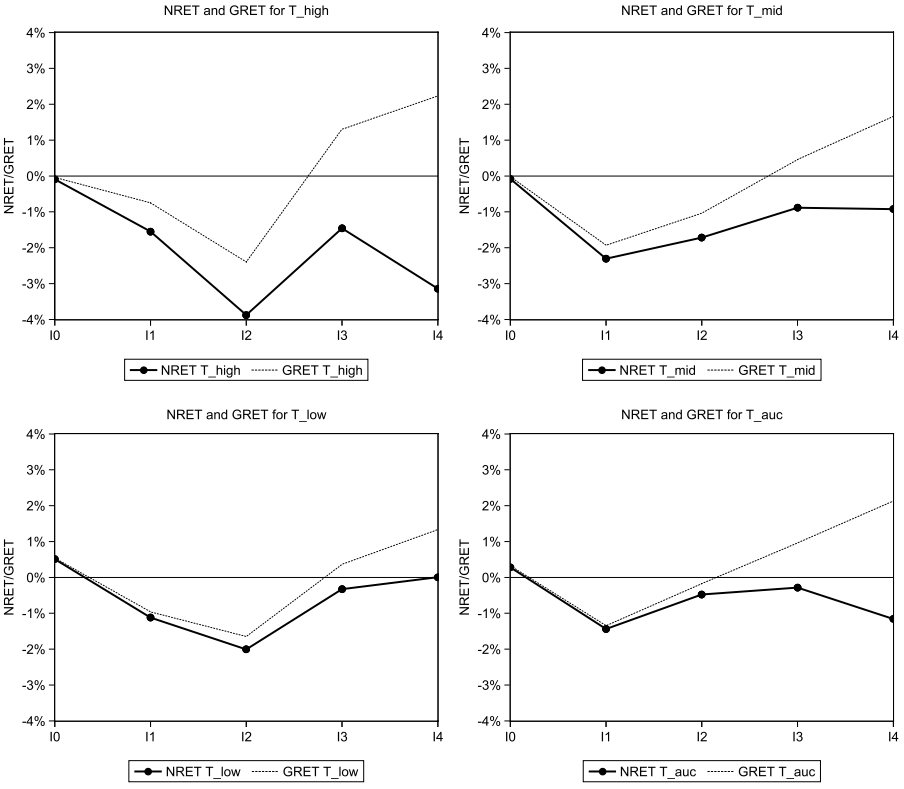

Fig. 1 Average gross returns per block (*thin line*) and average net returns per block (*bold line with dots*) as a function of information level. Each plot represents one treatment: T_high (*top left panel*), T_mid (*top right panel*), T_low (*bottom left panel*) and T_auc (*bottom right panel*)

When focussing on gross returns in Fig. 1 (thin line), one can find a J-shaped pattern in each treatment, as either I1 or I2 perform worst. Insiders always outperform all other traders, while uninformed earn approximately the market return.[12] Elaborating on the reasons for this J-shaped return pattern, Huber (2007) argues that during trends in prices and in the FV a higher level of fundamental information is generally useful, while during trend reversals the average informed will perform worst, as they buy high and sell low. In a similar model Stöckl and Kirchler (2010) observe a J-shaped return distribution as well. They find that insiders benefit strongly in periods in which the change in the fundamental value is large. The insiders' trading partners are mostly average informed traders who systematically lose, whereas uninformed traders are independent from fundamental information and hence do not make systematic mistakes.

Turning to net returns (NRET, bold line with dots in Fig. 1), the huge impact of information costs in treatments T_high, T_mid, and T_auc becomes evident, as on average all informed and insider traders (I1 to I4) earn negative net returns.

To test the null hypotheses of Hypotheses 1a and 1b we run panel regressions for each treatment separately with 60 cross-sections i (subjects) and 6 observations b (blocks) over time according to (4). As the relationship of information level and gross returns seems to be J-shaped we do not consider a linear model to explain this relationship. Instead, binary dummy variables for each information level I1 to I4 (I0 serves as intercept α) are used as independent variables.[13] As dependent variable we introduce y which either stands for gross abnormal returns (GAR) in Hypothesis 1a or net abnormal returns (NAR) in Hypothesis 1b. We derive gross abnormal returns (GAR, (5)) by subtracting the market return ($\overline{\text{GRET}_{m,b}}$) from each trader's return ($\text{GRET}_{m,b,i}$). The net abnormal returns (NAR) are calculated analogously.

$$y_{i,b} = \alpha + \beta_1 \text{I1}_{i,b} + \beta_2 \text{I2}_{i,b} + \beta_3 \text{I3}_{i,b} + \beta_4 \text{I4}_{i,b} + \epsilon_{i,b} \tag{4}$$

$$\text{GAR}_{m,b,i} = \text{GRET}_{m,b,i} - \overline{\text{GRET}_{m,b}} \tag{5}$$

Focussing on GAR (top panel of Table 2) one can see that most of the average informed traders with I1 and I2 perform significantly worse than uninformed traders. Insiders (I4) outperform the market and most other information levels significantly (pairwise Wald-coefficient tests), while uninformed traders I0 underperform the market slightly. Hence, we reject the null hypothesis of Hypothesis 1a that gross abnormal returns do not differ between information levels. Rather, by finding a J-shaped pattern of gross abnormal returns we accept the alternative hypothesis that there are differences across information levels. This finding is in line with earlier studies by Schredelseker (2001) and Huber (2007) and only partly confirms theoretical predictions of Grossman and Stiglitz (1980), since the latter analyse only two information levels.

[12] The J-shaped pattern cannot be explained by differences in trading volumes, as these are comparable across information levels with averages of 12.5 to 15.5 units of the stock traded per period and trader. In total, we observe between 640 and 750 trades per market in the four treatments.

[13] Additionally, the White cross-section coefficient covariance method is applied to correct for heteroskedasticity between cross-sections. This is done in each panel regression throughout the paper.

Table 2 Panel regression model to test Hypotheses 1a and 1b on gross and net abnormal returns per information level. The independent variables I1 to I4 are binary dummies and their coefficients are presented in percentage points

Dependent variable: GAR (gross abnormal returns)

Factor	T_high	T_mid	T_low	T_auc
α	−0.60***	−0.79	−0.32	−0.38**
	(0.000)	(0.138)	(0.462)	(0.034)
I1	−0.79*	−0.87	−2.64***	−1.47***
	(0.087)	(0.257)	(0.005)	(0.000)
I2	−1.32**	−0.96	−1.31**	−0.17
	(0.041)	(0.425)	(0.077)	(0.740)
I3	0.85	0.60	0.13	0.75*
	(0.217)	(0.531)	(0.833)	(0.051)
I4	1.88***	1.88***	1.14**	1.92***
	(0.000)	(0.008)	(0.025)	(0.000)
R^2	8.81	6.09	5.62	7.15
n	360	360	360	360

Dependent variable: NAR (net abnormal returns)

Factor	T_high	T_mid	T_low	T_auc
α	1.24***	0.55	0.30	0.51**
	(0.000)	(0.345)	(0.483)	(0.037)
I1	−1.21**	−1.28*	−2.78***	−1.41***
	(0.040)	(0.091)	(0.004)	(0.000)
I2	−2.27***	−1.60	−1.59**	−0.32
	(0.002)	(0.166)	(0.033)	(0.543)
I3	−1.33**	−0.68	−0.42	−0.41
	(0.054)	(0.492)	(0.476)	(0.417)
I4	−2.60***	−0.39	0.04	−1.28*
	(0.000)	(0.625)	(0.933)	(0.074)
R^2	10.87	12.68	2.85	2.30
n	360	360	360	360

*, ** and *** represent the 10%, 5% and the 1% significance levels. p-values of a double-sided test are provided in parenthesis

Turning to net abnormal returns (bottom panel of Table 2), the pattern changes: only the uninformed traders outperform the market in all treatments (two of them significantly), while most of the coefficients of the other information levels are significantly negative. We thus reject the null hypothesis of Hypothesis 1b as the uninformed traders (I0) earn significantly higher returns than most other information

levels (pairwise Wald-coefficient tests). Again, this finding is only partly in line with Grossman and Stiglitz (1980) who predict indistinguishable net returns across information levels.

4.2 Hypothesis 2

For Hypotheses 2, 3a and 3b we examine treatments with fixed information costs as in each hypothesis the percentage of I4 is either the dependent or the independent variable. The number of insiders in T_auc is always two (as there were always enough bids) and hence these analyses are not possible for this treatment.

The three panels in Fig. 2 provide an overview of the percentage of traders choosing each information level. One can see that information levels I0 and I4 are the two most frequently chosen ones in each treatment, especially in the last few blocks. The fraction of traders selecting I1 to I3 is much smaller and decreasing over time. We interpret this as learning of the subjects: intermediate information levels frequently earn negative returns, and quite rationally most subjects chose either I0 or I4. Among these two information levels costs (and the associated net returns) clearly influence subjects' choices: e.g., in T_high the share of I4 falls from 38% in block 2 to 28% in the last block whereas in T_low the share of I4 increases from 34% in block 2 to 56% in the last block.

Overall, we observe an increasing concentration of traders in the "extreme" information levels I0 and I4 in each treatment. Obviously, over the course of the experiment traders learn that it is best to have insider information or to trade without any costly information. Therefore, the number of traders with information level I1 to I3 decreases from approximately 50% in the first block to below 25% in the last block in all treatments.

To test the null hypothesis of Hypothesis 2 (whether the percentage of insiders is independent of information costs) we run panel regressions according to (6).[14] The percentage of insiders among all traders (Perc_I4) serves as dependent variable, whereas the related information costs of I4 (IC_I4) is the independent variable.

$$\text{Perc\_I4}_{m,b} = \alpha + \beta_1 \text{IC\_I4}_{m,b} + \epsilon_{m,b} \tag{6}$$

On aggregate we find that the coefficient of IC_I4 is negative on the 1%-level, thus rejecting the null hypothesis of Hypothesis 2 and confirming the predictions of Grossman and Stiglitz (1980). In particular, for every 100 Taler of information costs (app. 3.1% of traders' initial wealth) the fraction of insiders among all traders decreases by 10 percentage points.

4.3 Hypothesis 3

With Hypotheses 3a and 3b we explore whether market efficiency is affected by the numbers of insiders and uninformed traders. To measure market efficiency we rely

[14] The panel is set up with 18 cross-sections (six markets of three treatments each) and 6 observations (blocks) over time.

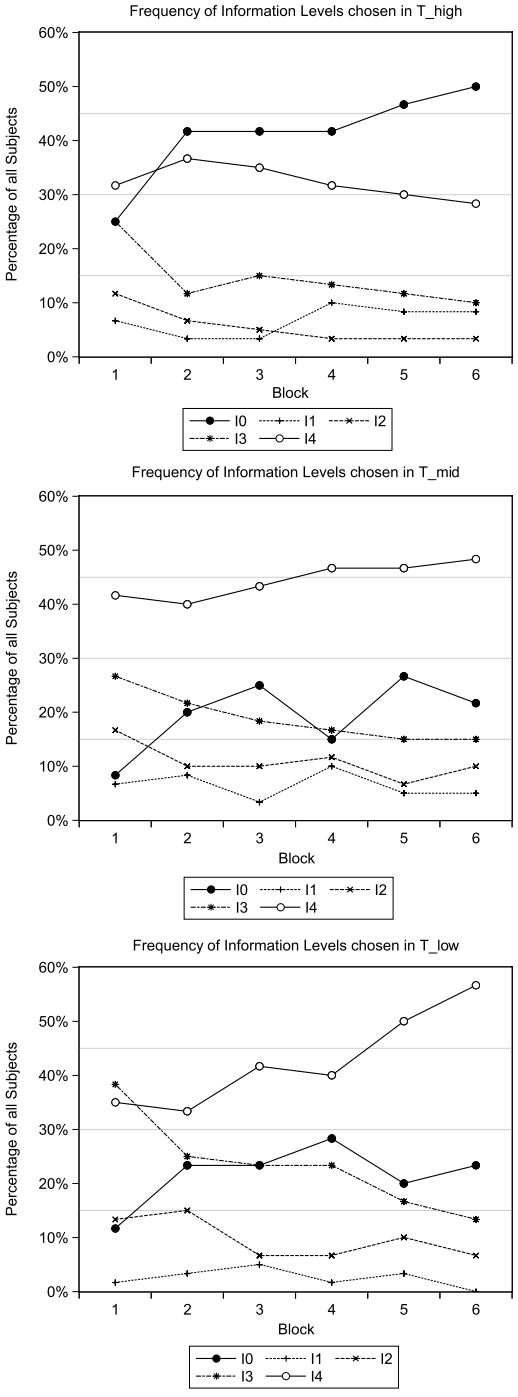

Fig. 2 Percentage of traders with each information level as a function of block in treatments T_high (*top panel*), T_mid (*middle panel*), and T_low (*bottom panel*)

Table 3 Panel regression testing Hypotheses 3a and 3b. RAD defines the dependent variable and is provided in percentage points. Perc_I4 and Perc_I0 represent the percentage of traders with information levels I4 and I0, respectively

Dep. variable: RAD	
Factor	Agg: T1–T3
α	8.053***
	(0.000)
Perc_I4	−0.093***
	(0.000)
Perc_I0	0.012
	(0.564)
R^2	22.37
n	108

*, ** and *** represent the 10%, 5% and the 1% significance levels. p-values of a double-sided test are provided in parenthesis

on Stöckl et al. (2010), who propose a robust measure for mispricing: RAD (relative absolute deviation) is the average absolute difference of volume-weighted prices and fundamental values, normalized by the average fundamental value. Thus, RAD measures mispricing in percent of the average FV, with lower values indicating more efficient markets. The average RAD with 5.4% is highest in T_high while it is lower in T_mid (4.8%) and T_low (3.9%).

To test Hypotheses 3a and 3b we run the following panel regression:

$$\text{RAD}_{m,b} = \alpha + \beta_1 \text{Perc\_I4}_{m,b} + \beta_2 \text{Perc\_I0}_{m,b} + \epsilon_{m,b} \tag{7}$$

Perc_I4 and Perc_I0 denote the fractions of traders (in percent) with information levels I4 and I0, respectively. One can infer from Table 3 that market efficiency increases with each additional insider (reduction of RAD by 0.93 percentage points), whereas market efficiency remains unaffected by the number of uninformed traders I0.[15] Hence, we reject the null hypothesis of Hypothesis 3a for insiders but we cannot reject the null hypothesis of Hypothesis 3b for uninformed traders. Hence, insiders have a positive impact on market efficiency which is in line with the theoretical predictions of Grossman and Stiglitz (1980) but uninformed traders do not influence mispricing in our markets.

5 Conclusion

In this paper we presented results from laboratory asset markets where subjects endogenously chose from five information levels (four of them costly) before they traded on an asset market. With this setting we built on and tested theoretical predictions of Grossman and Stiglitz (1980) and extended their ideas from two to five information levels.

[15] Note that with 10 traders in each market one additional trader selecting information level I4 represents an increase in the fraction of insiders by 10 percentage points.

We found that (i) uninformed traders typically earned higher net returns than all other information levels. Even when information costs were not considered, uninformed traders outperformed the average informed, while insiders earned the highest returns. Thus, the relationship between information level and gross returns was J-shaped. (ii) Furthermore, traders learned to pick the most advantageous information levels over time (full information and no information), and (iii) market efficiency decreased with higher information cost, since fewer traders chose the highest information level. Our results are mostly in line with Grossman and Stiglitz (1980) and provide additional insights that studies with only two information levels cannot deliver, e.g. gross and net returns of average informed traders were lowest and subjects learned to avoid outdated fundamental information over time by choosing either insider information or no information.

Appendix

Instruction for T_high. (The instructions for T_mid and T_low were identical but for the costs of information. The differences in T_auc are printed in bold.)

We welcome you to this experimental session and ask you to refrain from talking to each other for the duration of the experiment.

Background of the experiment

In this experiment you will trade on a stock market preceded by an information market. Trade takes place in six blocks. Each block consists of an information market and five periods of trading on the stock market. On the information market each of the ten traders has the possibility to buy information about the fundamental value of the stock traded. On the stock market the ten market participants trade stocks of a virtual company. Each participant is endowed with 1600 Taler cash and 40 stocks with an initial fundamental value of 40 Taler each at the beginning of each block. All your holdings (stocks and money) are carried over from one period to the next. At the end of a block all stocks are bought back at the FV of the final period. The value of your stock holdings and your money holdings are summed up to your final wealth of the block. The earnings of all six blocks are added up to calculate the Euro payment you receive at the end of the experiment.

At the start of the next block all endowments are reinitialized. Your goal is to maximize your payment at the end of the experiment which depends on the sum of all final profits of the blocks.

The fundamental value of the stock

On the information market you can buy information about the fundamental value (FV) of the stock, which stands for the fundamentally justified valuation of the company in a period. The fundamental value starts at 40 and changes randomly each period. The FV does not change within a period but changes from period to period. The random change each period is $+0.5\%$ with a standard deviation of 7.2%. At the end of each block all stocks are bought back at their FV.

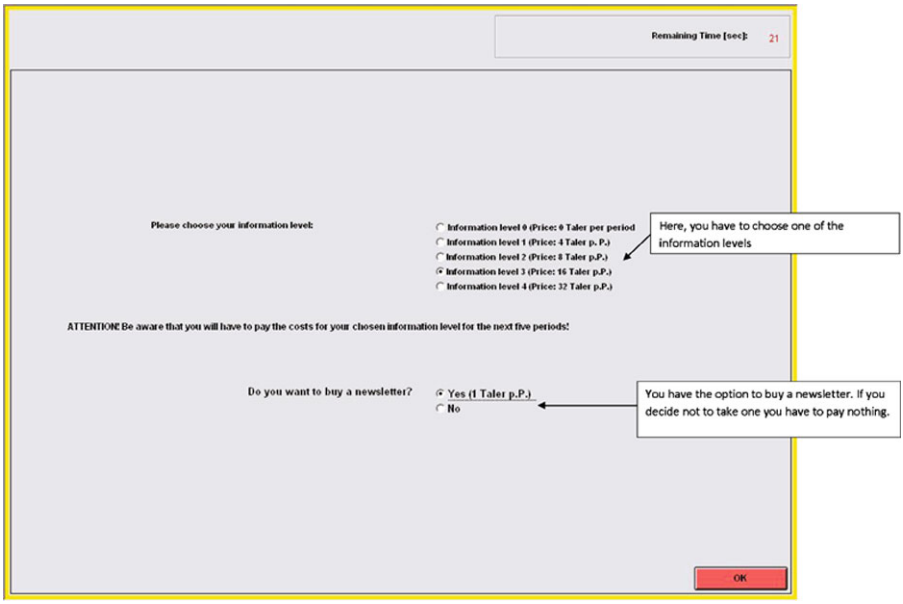

Fig. A1 The information market

Table A1 Information cost per period for each information level (in Taler)

IL	Costs per period
I0	0
I1	4
I2	8
I3	16
I4	32

The information market

Each trader has the possibility to buy information about the FV of the stock. A trader receives his information chosen for the five periods of one block and therefore has to pay the respective costs in each period. It is possible to buy one of five information levels (IL0, IL1, IL2, IL3, IL4). IL4 provides the current FV, while IL3 has the FV of the last period as an estimation for the current FV. The information provided to IL2 is even older and shows the FV of two periods before the current period and IL1 receives the FV of three periods before the current. IL0 has no information about the FV at all and is therefore for free.

Each IL can be bought by any number of traders and has a specific price that has to be paid in each period (see Table A1).

In T_auc the distribution of information levels is executed by a Vickrey-auction. All traders have the possibility to submit a sealed bid for each of the information levels. The two highest bids for IL4 receive IL4 for this block. The price per period is the third highest bid for IL4. Afterwards the bids of the two

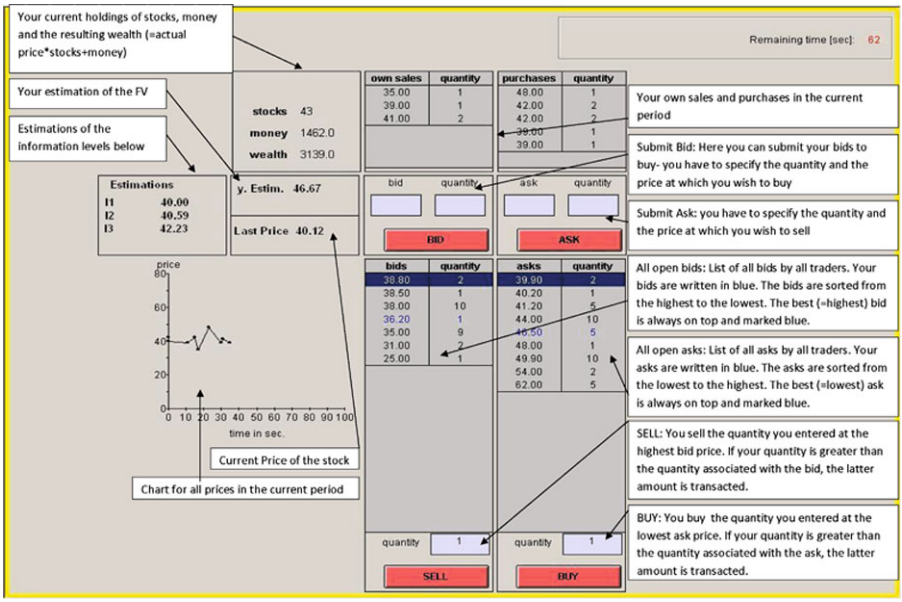

Fig. A2 The trading screen

winners for all other ILs are deleted. Next, the two highest remaining bidders for IL3 receive IL3 and have to pay the third highest bid for IL3, etc. All traders who do not receive an IL by winning one of the auctions and those who do not bid on any IL receive IL0 and do not have to pay any costs.

The newsletter

Additionally to the information about the FV each trader has the option to buy a newsletter, which tells how many traders have chosen each IL.

In T_auc the newsletter also informs about the prices which had to be paid for each IL, but not about the bids itself.

The stock market

You trade in a continuous double auction market with open order books. Market orders are always executed instantaneously. You can submit as many bids and asks as you want, provided you have enough money to buy or enough stocks to sell. Shorting stocks or borrowing money is not allowed. Any order size and the partial execution of limit orders are possible and there are no transaction costs.

Your current wealth is calculated by the multiplication of the number of stocks you own with the current market price and adding your current money holdings (Wealth = Stocks $*$ Market Price + Money). In the field "y.Estim" (your estimation) you receive an estimation of the FV of the stock according to your information level. Furthermore, you are informed about the estimates of the less informed information levels. IL0 receives no estimation about the FV.

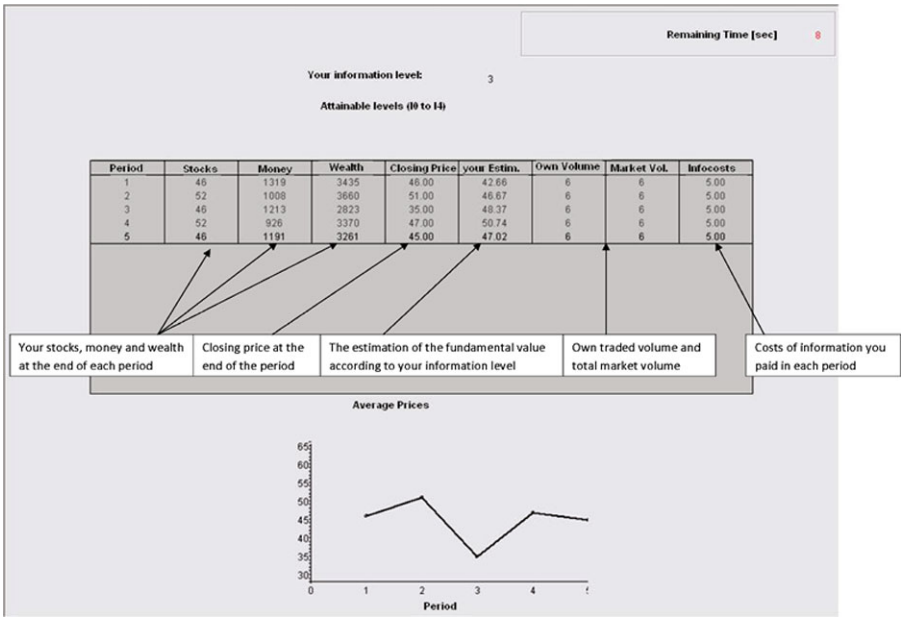

Fig. A3 The history screen appearing after each period

Each period of trading lasts exactly 100 seconds and time is displayed as a countdown from 99 to zero on the top right of the screen.

Summary screen of the period

After each period you see a screen which provides you with the summary of the period. Each line in the table stands for one period. It displays your information costs and the development of your wealth. You can also see the final market price and the estimation of the FV you received according to your information level. Additionally a graph shows the development of the market prices over the periods of the current block.

Summary screen of the block

After the 5 periods of one block are completed a summary of the block is displayed. This gives you the opportunity to compare your own performance to the market performance. Another important number on this screen is your performance compared to the market. It is possible that there are blocks in which no trader is able to achieve an absolute profit. If you are able to beat the market you may have done a good job even when your own absolute return is negative in that block. With those numbers and the general development of your wealth you can judge the success of your strategy with a specific information level.

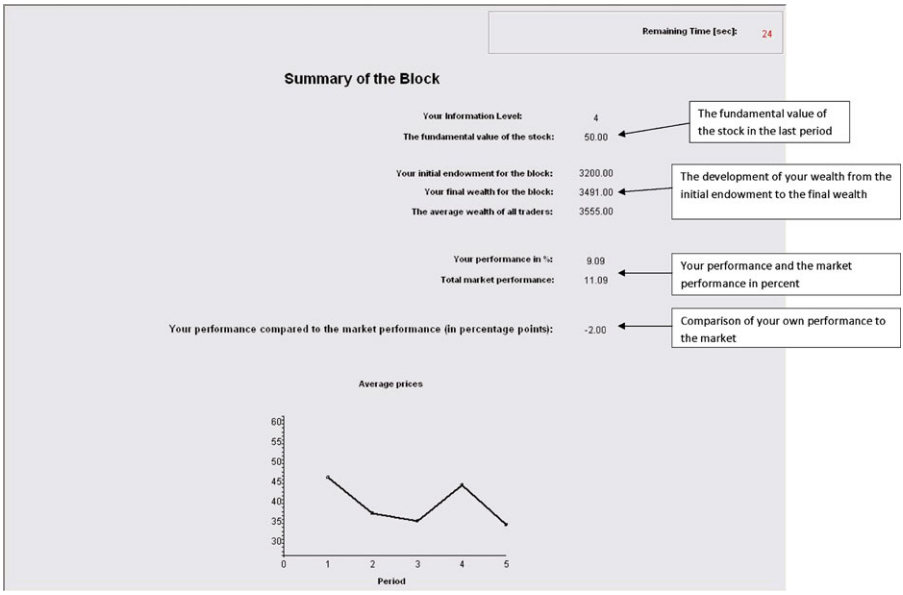

Fig. A4 The block history screen appearing after each block

Payment to participants

The earnings of all six blocks are added up. At the end of the last block your payment is calculated as:

Payment in Euro = (Sum of **Final Wealth** of all blocks in Taler)/1000
Final Wealth in block b = (Stocks $*$ FV) + Money

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