Is more information always better? Experimental financial markets with asymmetric information[#]

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Abstract

We study the value of information in financial markets by asking whether having more information always leads to higher returns. We address this question in an experiment where single traders have different information levels about an asset's intrinsic value. In our treatments we vary the nature of the information and the trading mechanism. We find that only the very best informed traders (i.e. insiders) significantly outperform less informed traders. However, there is a wide range of information levels (from zero information to an average information level) where additional information does not yield higher returns. The latter result implies that the value of information is not strictly monotone.

JEL-classification: C91; D82; D83; G1

Keywords: Asymmetric information, Experimental economics, Value of information

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1 Introduction

This paper addresses the question whether having more information than others is always advantageous when trading on financial markets. More precisely, we study whether traders who are better informed about the intrinsic value of an asset can expect to earn higher returns than traders with less information. If the answer to that question were positive, then we might conclude that having more information has generally a positive marginal benefit. In individual decision-making tasks this is typically the case, as has already been pointed out by Blackwell (1951). However, in an interactive context – like trading on financial markets – the answer to our question is less obvious and might not necessarily be positive for all information levels. Game theory, for instance, shows that "having more information (or, more precisely, having it known to other players that one has more information) can make the player worse off" (Gibbons, 1992, p. 63).[1]

We will present an experimental study to examine the marginal value of additional information for traders in financial markets. In the experimental market, there will be several traders which all have different levels of information about the intrinsic value of a tradable asset. The distribution of information is cumulative, meaning that a better informed trader knows everything that a less informed trader knows, plus an additional extra. By implementing such a cumulative information system and holding all other conditions constant, it is possible to analyze the marginal value of additional information. The two features of (i) considering more than two different information levels and (ii) having a cumulative information system distinguish our paper from almost all previous studies. Most experimental papers on the value of information have considered two distinct information levels only, showing that informed traders outperform uninformed ones (see, e.g., Copeland and Friedman, 1992; Güth et al., 1997; Ackert et al., 2002). Yet, two information levels (in particular in the binary context of informed versus uninformed traders) are not enough to conclude that more information is always better. There are several theoretical papers on the value of information when more than two traders have different information. These models – which will be related

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[1] Bassan et al. (1997) provide some nice examples for situations in which having more information is actually detrimental to a player's payoffs in a two-person game (see also the related paper of Kamien et al., 1990). In the context of financial markets one might refer to Cowles (1933, 1944) who was the first to show that financial advisors and professionals are almost without exception not able to outperform the market. Hence, the (presumably) better information of financial experts need

more specifically to our paper in section 2 – are typically characterized by a combination of public information about an asset and private information, with the latter being idiosyncratic for each trader. Although these models provide very useful insights into asset pricing, they are not suitable for answering the question whether more information leads to better results (in terms of trading profits) than less information, because no trader has *more* information than another trader in these models, but just *different* information. However, we think it is realistic to assume that some traders know more than others by having the same plus some additional information. There may be some investors relying exclusively on information from newspapers or TV. Such information is, of course, also available to better informed investors who also take into account companies' fundamentals, like their public financial statements or revenue outlook. Finally, there may be some very well informed traders (insiders) having all the previously mentioned information, but also knowing some important details (like a planned merger or a product innovation) which are not publicly known. In sum, we think that the cumulative information system that will be considered in this paper is similar to what can be observed in reality (Figlewski, 1982).

Of course, it would be most desirable to study the value of additional information in a field setting. Yet, using field data entails two major problems to address our question. First, it is hard to quantify traders' information level exactly, *provided* that traders were willing to reveal their information level. Yet, the latter is very unlikely, because traders have no incentive to reveal their information when trading. Second, even if the information level of single traders could be revealed and exactly measured, it would be next to impossible to satisfy the *ceteris paribus* condition, which requires that market conditions were identical for all traders – except for their information level about the traded assets – such that different profits from trading were exclusively due to different information levels. Given the limitations of field data for our purpose, we think that an experiment is a more appropriate tool to study whether more information is always better. In the laboratory we are able to control carefully for a trader's information about the value of an asset. In particular, we can easily assign to single traders different levels of information in a cumulative way, such that better informed traders know everything that less informed traders know, plus an additional extra. By implementing such a

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not yield higher returns. A related argument is made by Malkiel (2003a, 2003b) who shows that 80 percent of professionally managed funds do worse than the market average.

cumulative information system and holding all other conditions constant, we can track down the marginal value of additional information.

The rest of the paper is organized as follows. In section 2 we will relate our research question to the literature on the value and on the processing of information in markets. Then we will study the marginal value of information in an experiment which will be presented in section 3. We have implemented three different treatments where we have varied the price mechanism prevailing in the market (either a call market or a double auction market with open order book) and the type of information about an asset's intrinsic value (being determined either by a sequence of random binary variables or by a series of dividend streams to be paid out in the future). We will present each treatment, its design and its results separately, and we will offer a concluding synopsis of our results in the conclusion in section 4.

2   Markets and the marginal value of additional information

The question whether better informed traders can earn higher returns than worse informed traders is intimately related to the issue of how markets process information. Fama's (1970) efficient market hypothesis (EMH) has become one of the milestones in the finance literature. In a nutshell, the EMH claims that prices "fully reflect all available information at all times" (Fama 1970, p. 385). As a consequence of this claim, gathering information seems superfluous, as all information is already incorporated in the market prices. A related finding is the fact that market prices may reveal to traders all available information. Radner (1979) shows that when traders have different information about the assets to be traded then the market price may reveal to some traders information that was originally only available to other traders. A rational expectations equilibrium is possible when traders have a certain 'model' of how equilibrium prices are related to initial information[2] and when the alternative states of initial information are finite. Both conditions together imply that market prices are fully revealing the information of traders. As a consequence, there is no reason to expect better informed traders to perform better than worse informed traders. Moreover, when prices reflect all available information at all times, investors have no incentive at all to

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[2] Recently, Allen et al. (2003) have shown, however, that when asset prices depend on higher order expectations of others' information, then there is a bias in the prices such that they are overly sensitive to public information, whereas traders underweight their private information.

gather information. But then it remains a puzzle how prices could reflect all available information, as Grossman (1976) formulated in his information paradox. Grossman and Stiglitz (1980) as well as Diamond and Verrecchia (1981) have suggested models to solve the information paradox. Grossman and Stiglitz (1980) assume asymmetric information of traders and costs of gathering information. Due to some noise in the market, gathering additional information can increase the returns from trading. Yet, when players play their equilibrium strategy, the extra return from additional information matches exactly the costs of gathering the additional information. As a result, the net return after accounting for information costs is the same for all traders. Although it is not explicitly addressed in the paper by Grossman and Stiglitz (1980), their model also implies a strictly positive value of additional information if one assumes that gathering additional information has strictly positive marginal costs at any information level.

Another way to tackle the information paradox is the approach by Diamond and Verrecchia (1981) who develop a market model with a large number of heterogeneously informed traders. They observe public as well as (differential) private information. In the noisy rational expectations equilibrium of the model prices do not fully reflect a trader's *own* information. Due to this only partially revealing nature of the market price traders have a private incentive to collect information and the information affects the price through supply and demand. Note that the information system in the model of Diamond and Verrecchia (1981) is not cumulative, but stochastically independent, as each trader receives different private information. The precision of information is identical across traders, since each trader has the same prior beliefs and is endowed with private information of the same precision. Under such conditions, it is not possible (and it was not the intention of Diamond and Verrecchia, as we should stress) to analyze whether more information is better by leading to higher returns or whether it is possible that more information may not increase returns.

Schredelseker (1984) addresses the possible relationship between a trader's level of information and his profit by assuming a continuum of information levels, ranging from complete ignorance to insider knowledge. Traders with a higher information level have complete knowledge of what traders with a lower information level know, but not vice versa. Schredelseker does not consider information costs, though their inclusion would not change his main argument, which runs along the following lines: If one accepts that

markets are not fully efficient in processing information[3] then it seems very reasonable to acknowledge that on the one hand side the best informed market participants, i.e. insiders, can gain above average returns.[4] On the other hand side, the least informed traders who do not gather any information, but trade purely randomly, can be expected to earn the market return on average, if their portfolio is as diversified and as risky as the index of the market.[5] Given that one can expect the uninformed traders to earn the average market return and insiders to get above-average returns, it follows that some traders with an intermediate information level need to earn below average returns, because it is not possible that all traders in a market earn average or above average returns. If one accepts this reasoning, it must be the case that there are at least some information levels where more information is associated with lower, instead of higher, returns. A schematic figure of Schredelseker's argument is drawn in Figure 1.
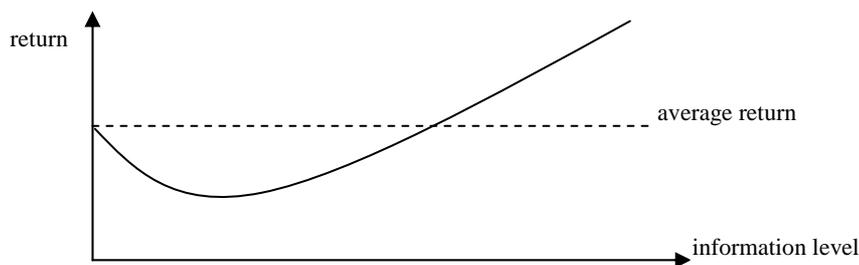
Fig. 1. Rate of return per information level as assumed by Schredelseker (1984, p.51)

Yet, if additional information yielded permanently lower returns then the little to medium informed traders should be able to learn that using their information is inferior to a pure random trading strategy (which those traders with zero information apply). Consequently, these traders should switch from using their information (which we call active information processing) to random trading. In fact, using a simulation approach it can be shown in case of a cumulative information distribution only the best informed

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[3] A series of anomaly effects (like calendar effects) suggest that markets are less than fully efficient (see Hirshleifer, 2001; Shiller, 2003).

[4] There is quite some evidence supporting this claim, see, e.g., Jeng et.al. (2003), Lin and Howe (1990), Lakonishok and Lee (2001), Krahnen et.al. (1999).

[5] One might argue that underperforming traders should not trade at all (no trade theorem). Yet, since the well-established equity premium puzzle (Mehra and Prescott, 1985) rests on the fact that there is a systematic and significantly positive margin between the returns of risky assets and those of risk-free ones, even an underperforming trader may have an incentive to trade, as long as he is willing to accept the risk associated with the expected positive margin between risky and risk-free assets.

insiders have a positive marginal value of additional information, whereas the return of traders with little to medium information does not depend on their information level when they trade randomly.[6] However, since the results of simulation studies typically depend crucially on the simulator's algorithm (for the price mechanism and the bidding strategies in our case), we would like to leave the address our question whether more information is always better in an economic experiment where human subjects with different information levels trade on an experimental market.

3 Experiment

We study the marginal value of additional information in three separate treatments, which differ either with respect to the mechanism used to determine the market price (either a call market or a double auction market with open order book) or with respect to the type of information about an asset's intrinsic value (being determined either by a sequence of random binary variables or by a series of dividend streams to be paid out in the future). Treatment *T1* is motivated by the argument of Schredelseker (1984) and based on the model developed in Schredelseker (2001). Since prices are only ex-post observable in *T1*, the results in *T1* might be affected by this feature of the market. As the literature discussed in section 2 has shown, it is important that the market price is observable in order to be able to make some inference about other traders' information. As a control for the possibility that results in *T1* depend crucially on the price mechanism, we have designed treatment *T2* where everything is kept constant with the exception of using a continuous double auction where all bids and asks are public information and observable for all market participants in real time (i.e., also before they make bids). Treatments *T1* and *T2* use a binomial process to determine the tradable asset's intrinsic value. One might object to using such a process that the intrinsic value of an asset is, basically, the net present value of its future dividends and redemption value. Treatment *T3* is intended to come closer to this concept of intrinsic value by letting traders know the future dividends of the asset, with better informed traders knowing the dividends of a longer time horizon than worse informed traders do. By using such a stream of dividends, *T3* moves from the rather static settings of *T1* and *T2* to a dynamic setting of the asset price mechanism. For the sake of clarity, we will

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[6] A stylized simulation of this sort can be found in Schredelseker (2001), for instance.

present each treatment, its design and its results separately and offer a concluding synthesis of all experimental results in section 4.

3.1   Treatment *T1* – Call-market with binomial process

3.1.1   *Experimental design*

Treatment *T1* is motivated by the simulation of Schredelseker (2001). We have set up a market with 10 traders who can buy or sell an asset. The asset's intrinsic value is determined by the sequential random draw of 10 binary variables, which can either take the values "0" or "1" with equal probability. The sum of the 10 random variables is the intrinsic value of the asset.[7] Each trader knows how the intrinsic value is determined, but has a different information level about the actually realized outcomes of the 10 random draws. The trader with information level zero (denoted as *I0*) knows none of the realized outcomes. The trader with level *I1* knows the realization of the first random draw, the trader with level *I2* the realizations of the first two random draws, and so on. Finally, the trader with level *I9* knows the realized values of the first nine out of ten random draws. It is common knowledge in the market that a trader with information level *Iy* knows precisely what all traders with level *Ix* know, if $y > x$. Yet, a trader with level *Iy* has only a subset of the information available to a trader with level *Iz*, if $y < z$.

Given their information level, traders can make bids for the asset.[8] As usual in a call-market one price per period is clearing the market. In our market bids are collected and arranged in ascending order and the median of bids becomes the market price. For instance, if the bids are 0-3-4-4-5-6-7-7-7-8, the market price is 5.5. All traders whose bid is lower than the market price are sellers, while the other traders are buyers.[9] Traders' payoffs depend upon the relation of the market price to the intrinsic value of the asset. A buyer makes a profit if the intrinsic value is higher than the market price and a loss otherwise. A seller gains (loses) from trading if the intrinsic value is below

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[7] Of course, the expected value is 5. If one considers all $2^{10} = 1024$ possible realizations of the 10 binary variables, the standard deviation of the expected value is 1.58.

[8] The 'bids' in treatment *T1* represent separation prices. This implies that if the market price is below this bid traders would buy; else they would sell the asset. In treatments T2 and T3 prices are no longer separating and a 'bid' is an offer to buy and a 'ask' is an offer to sell, as is common in financial markets.

[9] Traders having bid the median are neither sellers nor buyers. As a consequence, it is possible that the number of sellers is not equal to the number of buyers. In such cases scale selling applies in order to satisfy the zero-sum property of the market. Consider a set of bids like 0-2-3-3-4-4-4-5-6-7, which yields 4 as the market price. There are 4 sellers and 3 buyers. Assume that the intrinsic value of the asset was 6, then each of the 3 buyers would make a profit of 2 units of money, whereas each of the 4 sellers would make a loss of 1.5 units of money.

(above) the market price. The profit R_i for trader i from trading can then be calculated as follows, where V denotes the intrinsic value, P the market price, and B_i trader i's bid.

$$R_i = \frac{B_i - P}{|B_i - P|} \cdot [V - P],\tag{1}$$

There are 20 trading periods in the experiment. For each period, the sequence of the ten random draws (and, thus, the asset's intrinsic value) has been determined randomly in advance of the experimental sessions. Then they have been randomly ordered from period 1 to period 20. Finally, this order has been fixed for each group (of 10 traders) in order to make the experimental conditions perfectly comparable between the different groups. The distribution of the intrinsic value of the asset in the experiment has been chosen such that it matches the whole distribution of the $2^{10} = 1024$ possibilities as closely as possible. Table 1 indicates the absolute and relative frequencies of a given intrinsic value (in the possible range from zero to ten) both for the experimental sessions as well as for the whole distribution.

Table 1. Absolute and relative frequencies of intrinsic values in the experiment

Intrinsic value	0	1	2	3	4	5	6	7	8	9	10
Absolute frequency											
Experiment	0	1	0	2	4	5	4	3	1	0	0
Set of 2^{10} possibilities	1	10	45	120	210	252	210	120	45	10	1
Relative frequency (%)											
Experiment	0.0	5.0	0.0	10.0	20.0	25.0	20.0	15.0	5.0	0.0	0.0
Set of 2^{10} possibilities	0.1	1.0	4.4	11.7	20.5	24.6	20.5	11.7	4.4	1.0	0.1

At the beginning of the treatment, participants have been randomly assigned to an information level from *I0* to *I9*. This assignment has been kept fixed for the whole session, as has been the group composition of ten traders. Therefore, we have a group of ten traders as independent unit of observation. In total, we have 7 of these groups in *T1*.[10] The experimental sessions were fully computerized (using z-Tree of Fischbacher,

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[10] Note that the trader with information level *I0* was computerized (bidding randomly either zero or ten). Given that one of the referees cast doubt about this practice, we abstained from this practice in treatment *T2* and *T3*.

1999) and were run in June 2002 at the University of Innsbruck. Sessions lasted on average 75 minutes, with subjects earning on average €14.[11]

Before we present our experiment results, we would like to introduce one possibly prominent trading strategy that we call *active information processing strategy*. If we assume that a trader forms his bid by adding to the number of *known* random draws with "one" the expected value of the *unknown* draws then trader i's bid B_i can be calculated as follows

$$B_i = \sum_{k=1}^{i} b_k + \left[(n-i) \cdot 0.5 \right] \qquad (2)$$

with $n = 10$ denoting the total number of random draws, i denoting the number of draws of which trader i knows the outcome and b_k denoting an indicator variable with value zero if draw k yielded a zero and value one if draw k yielded a one. Consider the example where trader *I6* knows the following realizations of the binomial process: 110101. The expected value of the four unknown random draws is 2, so trader *I6*'s bid is assumed to be 6 (i.e. 4 from the known draws plus 2 from the unknown draws). Bids calculated as in equation (2) will serve as useful benchmark for our analysis, even though we do not suggest that such bids are optimal.

3.1.2   Experimental results in T1

The diamonds in Figure 2 represent the average profit of a single trader with a given information level in one of our 7 independent groups. The bold line shows the average profit across the 7 markets for a given information level. The overall average returns of traders with levels *I0* to *I5* all lie in the narrow range from -0.14 to -0.21 and are not significantly different from each other. Hence, in this range of information levels additional information has no significantly positive value. Rather, additional information seems to be irrelevant for returns. Yet, we probably should stress that additional information is not detrimental, i.e. it never leads to significantly lower profits. Hence, our Figure 2 does not support the stylized argument of Schredelseker (1984; see Figure 1 above). Only from an intermediate information level onwards we find a clearly positive relation between information and profits. More precisely, average profits are significantly increasing from *I5* to *I9* ($p < 0.05$, Friedman-test, $N = 7$).

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[11] At the beginning of the experiment, subjects received an initial endowment which was not specified in the instructions and was only private knowledge. Trader *I0* received the highest initial endowment of 19€. For each additional information we subtracted 1€, yielding 10€ for *I9*.
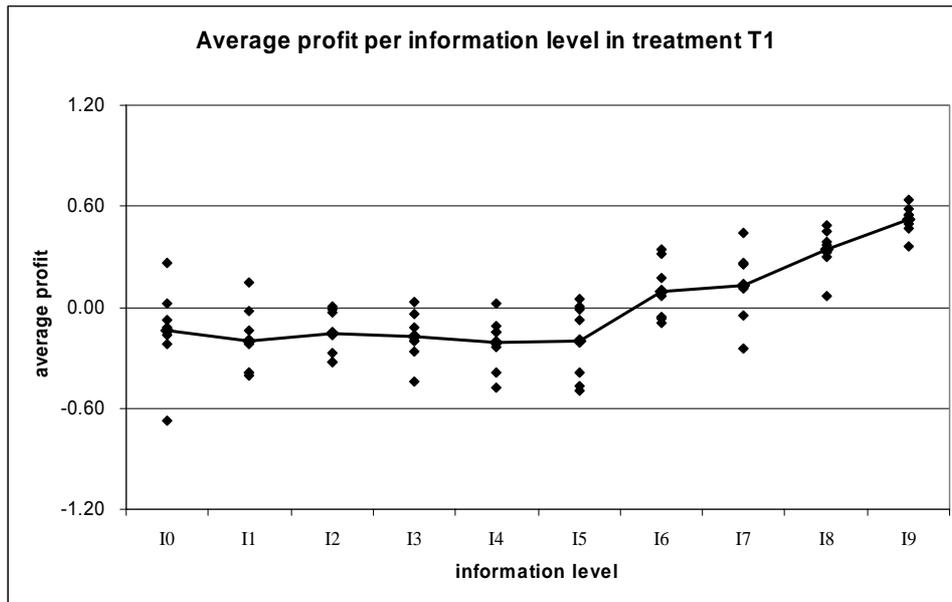
Fig. 2. Average profit per information level in treatment T1

Table 2 yields more insights into the actual use of available information in the experiment. It reports the Pearson correlation between a trader's actual bid and the bid we would expect with active information processing according to equation (2).[12] The correlation is significantly increasing (with $p < 0.05$, Page test for ordered alternatives, $N = 7$), showing that better informed traders use their information more actively in the sense that they condition their actual bid more systematically on the available information about the realizations of the binary random draws. Less informed traders, though, more often ignore their available information.

Table 2. Correlation coefficients between actual and expected bid
under active information processing in treatment T1

Information level	I1	I2	I3	I4	I5	I6	I7	I8	I9
Correlation	-0.03	0.38	0.40	0.40	0.58	0.81	0.78	0.74	0.85

Even though traders *I2* to *I5* condition their bids more on their available information (see Table 2) than traders with *I0* or *I1* they do not earn systematically higher profits on average (see Figure 2). Hence, using their information must have

drawbacks for traders *I2* to *I5*, at least sometimes. A thorough analysis of our data reveals that this hinges on how the sequence of the random draws looks like. Let us call a sequence *alternating* when the sum of two consecutive draws is always one. The following sequence is an example for an alternating one: 0101011010. In the case of alternating sequences, it is noteworthy that traders' bids (according to equation (2)) are more or less insensitive to their information level, because smaller bits of the whole sequence yield almost the same bid as when a trader knew the whole sequence. In such cases, most traders post the same bid, which will become the market price. At this price most traders will neither win nor lose much, and, hence, their profits are basically independent of their information level.

The situation is different when the sequence of random draws contains many identical outcomes in a row. An extreme example for such a *consecutive* sequence would be 0000111111.[13] In such cases active information processing according to equation (2) leads to unfavorably low bids of medium informed traders (e.g. trader *I4* would bid 3), which drives the market price (4.25) below the intrinsic value (6), causing losses for traders with information levels *I2* to *I6* as they sell the asset too cheap. Hence, only the very well informed traders (*I7* to *I9*) and the uninformed or poorly informed traders (*I0* and *I1*) would gain from trading in such situations, provided every trader would actively use his information and bid according to equation (2). Table 2 has indicated that this is less the case for worse informed traders, which actually saves the latter type of traders from incurring losses in case of a consecutive sequence of random draws.

As a final aspect to be considered in this treatment we take a look at the average profits across the 7 markets in both halves of the experiment.[14] As we can see from Table 3, average profits are on average higher in the periods 11-20 than in periods 1-10 for the less informed traders. Even though the increase in profits is only significant for traders with information level *I4*, we can take this as tentative evidence that less informed traders can slightly increase their performance in the course of the experiment.

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[12] Note that the correlation for I0 can not be calculated, as the variance of the expected bid (according to equation (2) which always gives a result of 5) is zero. Therefore the correlation coefficient is not defined (division by zero).

[13] Of course, the probability for any specific sequence is always the same, i.e. 0.5^{10}.

[14] It seems noteworthy that the average absolute deviation of the market price from the intrinsic value decreases from an average of 1.36 in the first ten periods to 0.84 in the second half of the experiment. If we take this measure as an indicator for the market's efficiency, we might conclude that market efficiency is higher in periods 11-20 than in periods 1-10.

This is mainly due to a shift in their information processing strategy, since the correlation between their actual bid and the one in case of active information processing is decreasing from periods 1-10 to periods 11-20. Since trading in our market satisfies a zero-sum property, the increase of profits of less informed traders comes at the cost of a decrease of profits for better than average informed traders.

Table 3: Average profits in periods 1-10 and periods 11-20 in treatment T1

Information level	I0	I1	I2	I3	I4	I5	I6	I7	I8	I9
1) Periods 1 – 10	-0.15	-0.22	-0.19	-0.22	-0.47	-0.19	0.19	0.16	0.44	0.65
2) Periods 11 – 20	-0.13	-0.18	-0.13	-0.13	0.05	-0.21	0.00	0.10	0.24	0.39
Difference 2) – 1)	0.02	0.04	0.05	0.09	0.52	-0.02	-0.19	-0.06	-0.20	-0.26

3.2 Treatment *T2* – Double-auction market with binomial process

3.2.1 Experimental design

Treatment *T2* differs from treatment *T1* only in a single aspect, i.e. the price mechanism. In *T2* we used a continuous double auction where all traders could post as many bids and asks for buying or selling the asset as they wished. All bids and asks were public information. A trade was realized as soon as another trader accepted an offer to buy or sell at a given price. The market prices of all trades within one period were also observable for all other traders. At the end of each period participants saw a "history screen" displaying information on past prices, values, and own profits.

This sort of price mechanism yields two important differences in comparison to treatment *T1*. First of all, prices become observable (whereas they are only set ex post in *T1*). The observability of prices, though, is one of the key elements of the theoretical models discussed in the previous section, such that traders can infer something about the other traders' information only when they can observe the market price. Second, traders are no longer forced to trade, but rather they can deliberately abstain from trading by not making any asks or bids.

Each of the 20 periods in the experiment lasted 150 seconds in which traders could make and accept bids and asks. Each trader could realize at most 3 trades per period, whereas there was no restriction on the number of bids and asks. In order to induce

trading, we provided an incentive to trade by paying a small premium for each realized trade.[15]

We used exactly the same random draws in *T2* as in *T1* in order to keep all other conditions as comparable as possible. In total, we had 80 participants in *T2*, i.e. 8 independent groups of 10 traders each. None of the participants had taken part in a session of treatment *T1*. The computerized sessions were run in April 2004, lasted about 70 minutes and yielded average payoffs of 14 € per participant.

3.2.2 Experimental results in T2

Figure 3 shows the average profits per period, contingent on traders' information levels. A Friedman-test reveals that the profits per trade are not significantly different for traders with information levels *I0* to *I7*. Only traders with information levels *I8* and *I9* have significantly higher profits than all other traders ($p < 0.05$). Hence, even when market prices are fully observable and determined in a double auction, there is a wide range of information levels where additional information does not lead to higher profits. Note that the average profits of traders with information level *I0* are only marginally lower than those with information level *I6*, for instance.
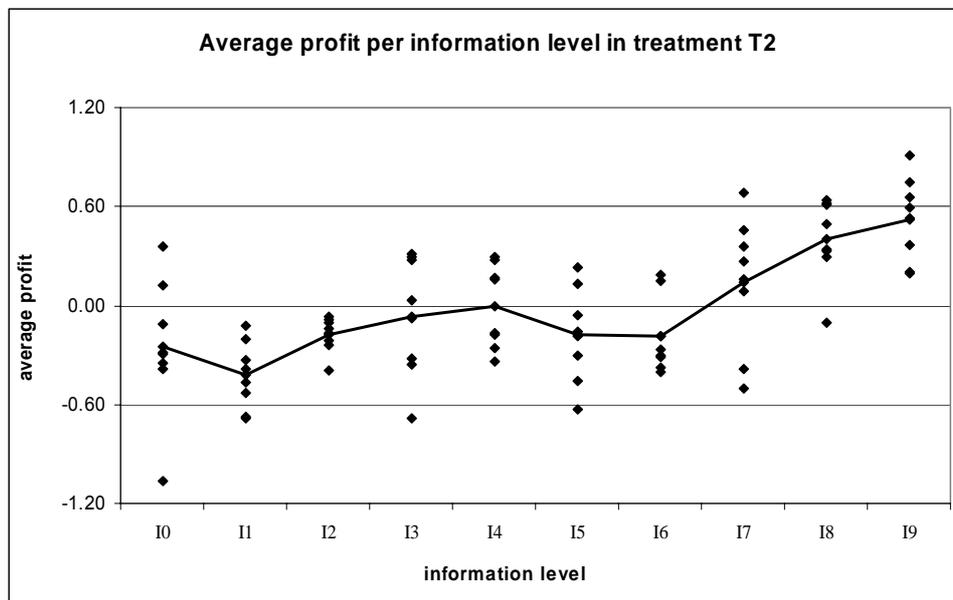

Fig. 3. Average profit per information level in treatment T2

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[15] The premium was 1 Taler per trade (see the instructions in Appendix A2), reflecting the risk premium in real markets. Note that the premium was much lower than the potential losses from trading.

Since traders could strike more than one deal per period, we are interested in the relation of trading activity and information level. Table 4 reports the average number of trades, respectively bids and asks per period, contingent on a trader's information level. Traders with information levels *I0* to *I7* make on average between 1.53 and 1.78 trades per period, with no significant differences between these traders. Only traders with *I8* and *I9* make significantly more trades than the other traders ($p < 0.05$, Friedman test, $N = 8$). Hence, they actually use their superior information to make more trades. The best informed traders also make the most bids and asks per period. However, due to a large variance in the number of bids and asks there is no significant difference between any information levels.

Table 4. Number of trades and bids and asks per period in treatment T2

Information level	I0	I1	I2	I3	I4	I5	I6	I7	I8	I9
Trades per period (Average)	1.64	1.58	1.72	1.61	1.78	1.56	1.53	1.66	2.06	2.38
Bids and asks per period (Average)	4.56	4.93	4.19	3.85	4.83	3.43	4.48	4.69	6.14	6.51

Like in treatment *T1* we find that the better informed traders make more use of their information when making bids and asks. To confirm this finding we correlate the average price of a trader's transactions per period with his fictitious bid that would arise from active information processing (see equation (2)). This correlation is significantly increasing in the information level ($p < 0.05$, Page test for ordered alternatives, $N = 8$), as can be seen from Table 5.

Table 5. Correlation coefficient between average price of a trader's transactions per period and expected bid under active information processing in treatment T2

Information level	I1	I2	I3	I4	I5	I6	I7	I8	I9
Correlation	0.45	0.53	0.60	0.65	0.79	0.76	0.78	0.79	0.84

As regards the development of profits per trade in the course of the experiment, we do not find any significant changes from periods 1-10 to periods 11-20. However, when we look at the variance of prices in each period (see Figure 4, where the bold line indicates the overall average) we see a significant decrease from the first to the second half ($p < 0.01$, Wilcoxon signed ranks test). Hence, prices converge due to the public information on bids, asks, and realized trades.
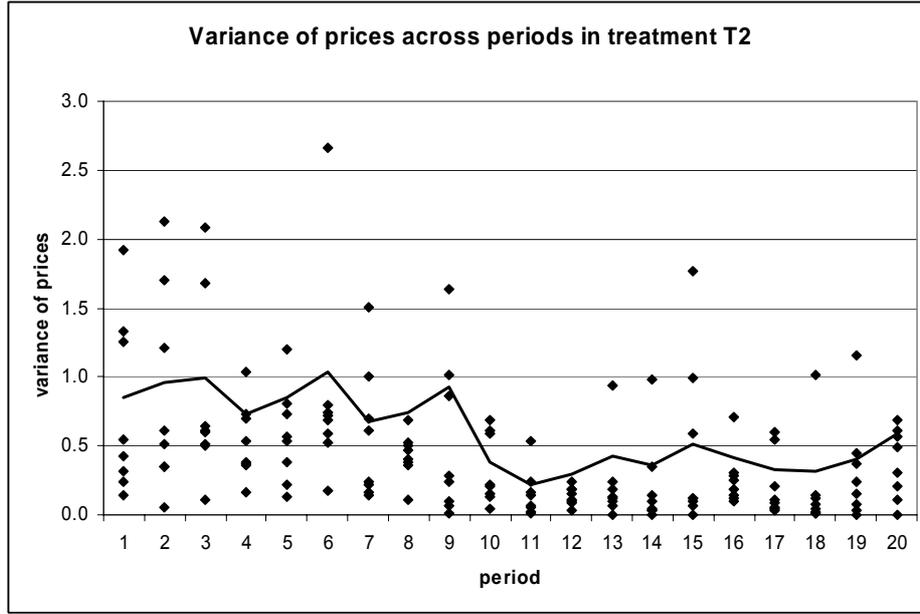
Fig. 4. Development of the variance of prices across periods in treatment T2

3.3 Treatment T3 – Double-auction market and dividend process

3.3.1 Experimental design

Treatment *T3* also relies on a double auction with open order book for setting the prices of the tradable asset. However, contrary to the previous treatments, the asset's value in *T3* is determined by a dividend stream. The different information levels of traders are implemented by varying the traders' knowledge about future dividends.[16] In general, trader *Ix* knows the dividend of this and the next (*x*-1) periods. For instance, a trader with information level *I1* knows this period's dividend only, whereas a trader with level *I9* knows the dividends of this and the next 8 periods. For the sake of simplicity we assume that traders know the exact value of the future dividends.

At the end of each period the current dividend is paid out for each stock owned. In the next period the information on dividends is updated, such that the former dividend for period *t*+1 is now the dividend of period *t*. The dividend stream follows a random walk and is determined as follows:

$$D_t = D_{t-1} + \varepsilon \tag{3}$$

D_t denotes the dividend in period *t*, D_0 was set to 0.2, and ε a normally distributed random term with a mean of zero and a variance of $\sigma^2 = 0.0004$.

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[16] Such a situation, though with only two information levels, was first studied by Hellwig (1982).

Like in the previous treatments, the sequence of dividends was randomly determined before running the experimental sessions and was, then, kept constant in order to guarantee identical conditions in all sessions. All subjects started with an endowment of 1600 units of money (Taler) and 40 stocks with an initial price of 40 Taler each (see the instructions in Appendix A3). Then they were informed about the future dividends according to their information level, and trading started. Trading time was 100 seconds per period. In total, we had 30 periods[17], after which subjects' accounts were exchanged into money at the rate of 200 Taler = 1 €

At the start of each period subjects got information on the future dividends according to their information level. In addition we displayed to each trader the net present value of the stock given this information. The net present value was derived using Gordon's well-known formula, discounting the known dividends and assuming the last one to be a continuous, infinite stream which was also discounted.[18]

$$E(V \mid I_{j,t}) = \frac{D_{t+j-1}}{(1+r_e)^{j-1} \cdot r_e} + \sum_{i=t}^{t+j-2} \frac{D_i}{(1+r_e)^{i-t}} \tag{4}$$

$E(V \mid I_{j,t})$ denotes the conditional expected value of the asset in period t, j is representing the index for the information level of trader Ij and r_e is the risk adjusted interest rate which was fixed at 0.5%.[19] The expected growth rate of the dividend was set as zero and is therefore not shown in the formula.

In each round, traders could make as many bids and asks as they wished. If any of them was accepted the subjects' accounts were adapted accordingly. Contrary to the previous treatments we let cash holdings earn a small interest of 0.1% per period. Trader j's wealth in period t, $W_{t,j}$, is then calculated as the sum of cash and wealth in stocks, with the latter being calculated by multiplying the number of stocks with the current price, i.e. the price of the last transaction.

By using a dividend stream to determine an asset's intrinsic value and by allowing for cash holdings that earn a fixed interest rate we regard our treatment *T3* as the one

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[17] The results to be reported below would remain qualitatively identical if we only considered 20 periods, which is the length of treatments *T1* and *T2*. We opted for 30 periods because the dividend stream process implies that trader *I9* already knows the dividends for the first 9 rounds at the beginning of the experiment. In order to have also the best informed trader getting about 20 times new information (as in *T1* and *T2*) we extended the duration to 30 periods in *T3*.

[18] Subjects were informed in the instructions how the net present value was calculated and that it depended on the information level, particularly on their last known dividend.

[19] The periods were assumed to be roughly a month in the real world. The respective annual interest rates would be approximately 1.2 percent for the risk-free and 6.2 percent for the risky asset.

closest to the conditions in real markets. Therefore, we think that treatment *T3* is the hardest test whether more information is always better for traders.

The experimental sessions for treatment *T3* were implemented in July 2004 with a total of 7 independent groups á 9 subjects. Each of the 9 subjects had a different information level ranging from *I1* to *I9*.[20] The average duration of the sessions was 90 minutes, with average earnings of 18 €

3.3.2 Experimental results in T3

Figure 5 shows the individual and average returns (bold line) for different information levels. The returns are calculated according to the following formula, where $R_{T,T-X,j}$ denotes trader *j*'s return from period *T-X* (with wealth $W_{T-X,j}$) to period *T* (with wealth $W_{T,j}$).

$$R_{T,T-X,j} = \frac{W_{T,j} - W_{T-X,j}}{W_{T-X,j}} \tag{5}$$
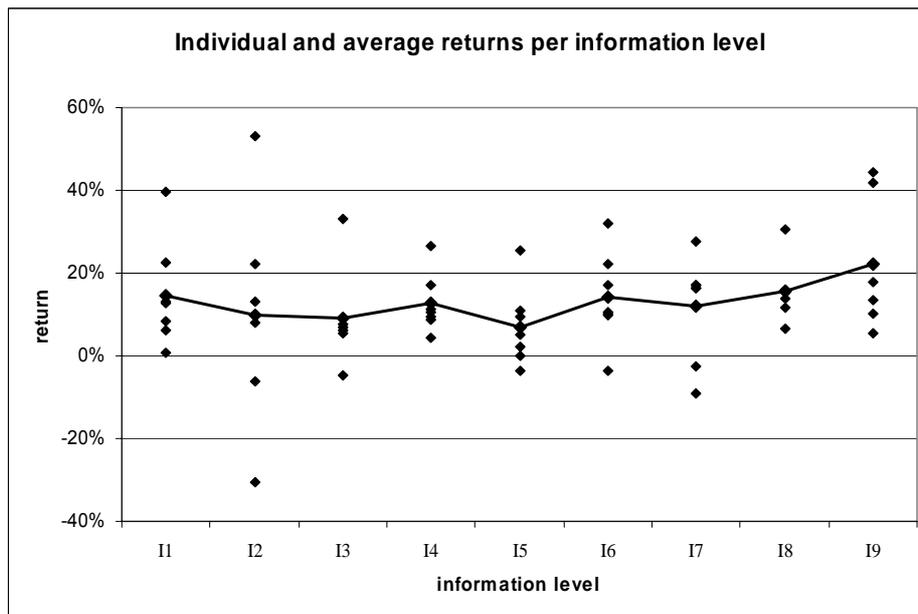
Fig. 5. Individual and average returns per information level in treatment T3

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[20] We economized on subjects (9 instead of 10) for two different reasons. First, one referee argued that one should expect that all traders in a market have at least some minimal level of information, which implies that there should be no traders with zero information (I0). Second, the sessions were run in the final (examination) week of the summer term when it is quite difficult to get participants.

As in the other two treatments we find that the best informed agents earn on average the highest returns, but that there is no generally positive relationship between a trader's information level and his return. Average returns range from 7.1% for traders $I5$ to 22.2% for traders $I9$. Due to a relatively high variance in single traders' returns[21] a Friedman test shows that there is no significant difference in the returns of traders with different information levels ($p = 0.11$; two-sided Friedman test including all information levels, $N = 7$). Only when we look for pairwise differences, we find that the average returns are significantly higher for traders with level $I9$ than for traders with either level $I3$, $I4$ or $I5$ ($p < 0.05$ in each pair wise test, Wilcoxon signed ranks test, $N = 7$). Hence, our results in treatment $T3$ confirm our findings from the previous treatments, indicating that there is a broad range of information levels where additional information has no significantly positive influence on returns, and that only the very best informed traders can actually outperform (some of) the less informed ones.

So far, we have only considered the final wealth of subjects and their returns from trading over all 30 periods. Yet, it might be interesting to check whether information levels and returns are somewhat differently (or even positively) related in earlier periods of the experiment. To do so, we compare the average wealth per information level with the initial wealth $W_{0,j}$ of information level j. From that we can calculate the average return $R_{T,0,j}$ according to equation (5). The results are displayed in Figure 6.

Two features of Figure 6 are particularly noteworthy: First, we see that the performance of traders across time is remarkably stable. The insiders $I8$ and $I9$ have the best performance at the beginning, in the middle and at the end of the experiment. Similarly, the finally worst performing traders $I5$ and $I3$ are already lagging behind after the first few periods. In general, there are very few intersections in Figure 6. Rather the differences increase over time – $I9$ wins more and more, while $I5$ falls back relatively more and more. The distribution of final average returns (see Figure 5) is therefore not due to a few periods, but it is the result of different performance throughout the experiment.

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[21] Overall, 22 out of 63 traders exceeded the expected return of the stock of 16.1%. Traders with all nine different information levels are among those 22 traders. 9 out of 63 traders ended up with a return which was lower than the risk free rate (of 3.0% in 30 periods). 7 of these 9 traders actually made losses from trading.
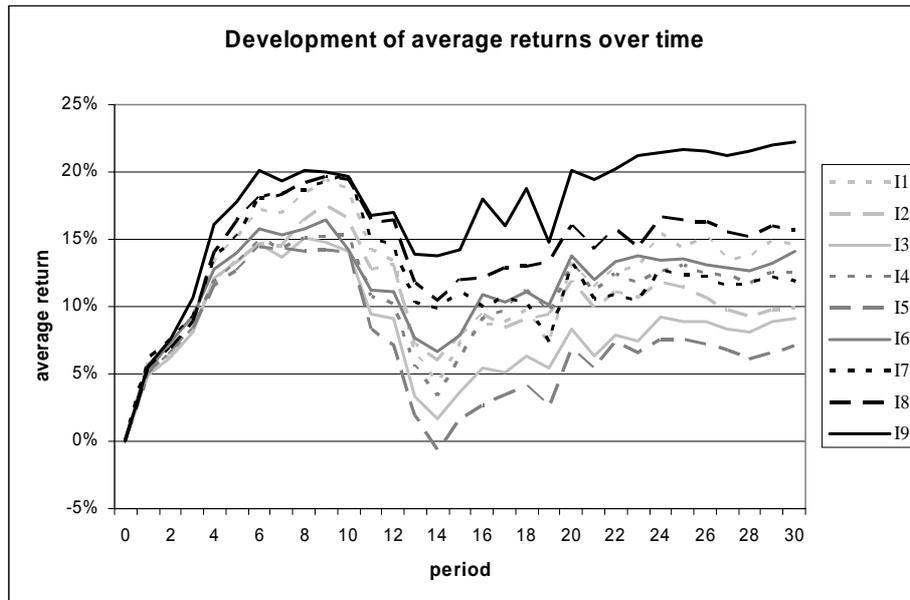
Development of average returns over time

Fig. 6. Development of average returns $R_{T,0,j}$ over time in treatment T3

Second, Figure 6 also shows an important feature of the dividend stream: While the zero-sum property of treatments *T1* and *T2* necessarily implied some traders to win and others to lose in the same period, the dividend stream process makes it possible that the wealth of all traders can be positively aligned in a given period such that they all get richer (see, e.g., periods 1 to 9) or all get poorer (see, e.g., periods 10 to 14), depending upon the prospects for the asset's dividends.

In Figure 7 we plot the asset's dividends in each period (see left-hand scale and solid line[22]) and the average price of the asset across all seven groups of traders (see right-hand scale and broken line). It seems that during the most part of the experiment average prices are leading dividends by about 5 periods[23] which is exactly the information level of the median informed trader *I5*.[24] However, prices show a smoother path with smaller variance than dividends do. This is a result of all but one traders in the market knowing more than just the current dividend.

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[22] Recall that the dividends were identical across all seven groups of traders.

[23] Spearman-Rho coefficients of average prices per period and dividends of 5 periods later are significantly positively correlated in all but one session. Correlation coefficients range from 0.56 to 0.83.

[24] This finding is somewhat related to Kyle's (1985). Although his model is constructed in a very different way, he also finds that market prices reflect exactly half of the best informed traders' (insider) information.
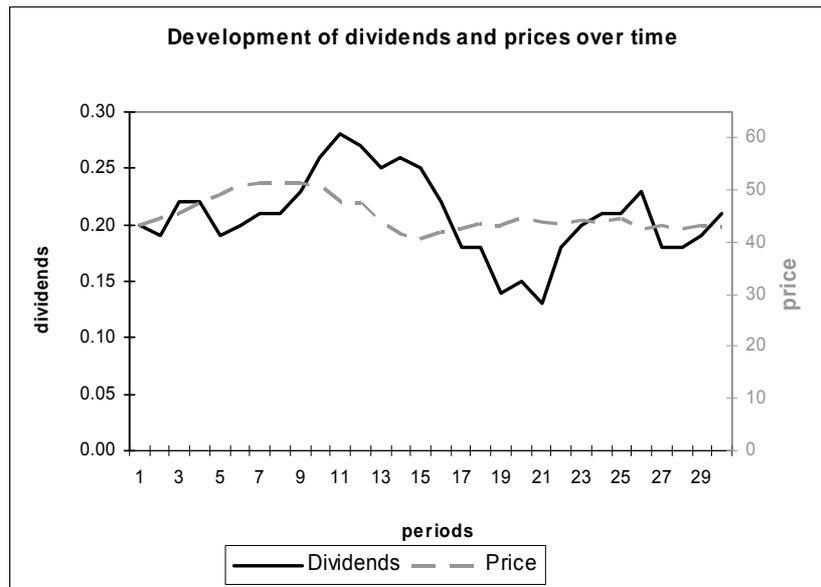
Fig. 7. Development of dividends and average prices over time

Next we are interested in how traders reacted in buying and selling stocks on the information about the asset's dividends. In particular, we have checked the relative frequency with which traders with a given information level bought (or sold) stocks when the present value they saw was higher (or lower) than the current transaction price. If trading did not depend on the relation between present value and current price, one would expect roughly a rate of 50%. Yet, on average we find a relative frequency of about two thirds, indicating that traders react significantly to their available information ($p < 0.01$; Binomial test). Better informed traders typically react a stronger to relation between the net present value and the current price, because traders with information levels *I6* to *I9* buy (respectively sell) on average in 70% of cases where the net present value is higher (lower) than the current price, whereas the corresponding figure is 63% for traders with information level *I1* to *I5* (see Table 6).

Table 6. Relative frequency of trading contingent the relation between

net present value and current price

Information level	I1	I2	I3	I4	I5	I6	I7	I8	I9
Relative frequency*	0.61	0.63	0.65	0.64	0.60	0.70	0.77	0.61	0.72

*Relative frequency of buying (and selling) when the net present value is higher (lower) than the current price.

20

Finally, we would like to address how trading activity is related to the information level. Overall, there are about 20 transactions per period. However, trading activity is in no way correlated with a trader's information level. To support this statement, we show in Figure 8 the average number of stock holdings for traders with different information levels.[25] The best informed trader $I9$ is the first one to start buying actively (and at relatively low prices), because he is the first one realizing that dividends are steadily increasing from period 5 to period 12 (see the solid line in Figure 7). Alternatively, when prices are high and prospects for dividends deteriorating, trader $I9$ is the first to sell. Overall, the correlation of trader $I9$'s stock holdings and the estimated present value of the asset is 0.92. Traders $I5$ who have the lowest average returns are the most eager ones to sell stocks at the beginning of the experiment, as they have the lowest estimates of the present value. These stocks are quite frequently bought by traders $I9$. When traders $I5$ realize around period 6 that dividends increase in the future they start buying stocks actively (and at a relatively high price) – supposedly in the hope that the price will maintain its upward trend. Yet, this is not the case, leading in sum to the relatively bad performance of traders with information level $I5$. The worst informed traders with level $I1$ begin to buy actively when prices are relatively low (around period 15; compare Figure 7 above).
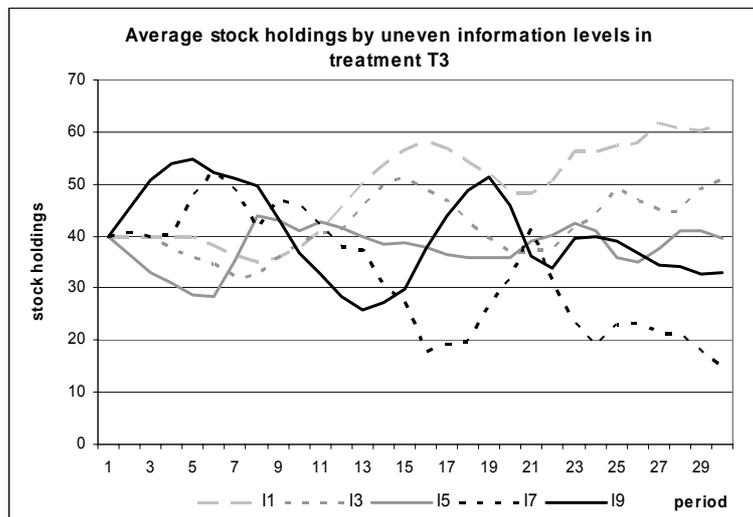

Fig. 8. Average stock holdings of selected traders

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4 Conclusion

We have studied in an experiment the value of additional information in financial markets. The combination of two specific features of our experiment distinguishes our paper from previous ones. First, we consider more than two information levels. Second, we use a cumulative information system. Both features seem to mirror the conditions on financial markets quite reasonably. It is particularly the second feature which we deem important, because very well informed traders can be expected to have at least a good guess of what less informed traders know (from newspapers, TV, corporate reports, etc.).

Though our three experimental treatments *T1*, *T2*, and *T3* differ in some notable ways, their main results are surprisingly similar, indicating that the results are not driven by some peculiarities of a particular treatment. The most important result is the fact that more information is not always better for traders on financial markets, even though it pays to have insider (i.e. far above average) information. Whereas the benefit of insider information has been documented before, our design and analysis provides the first evidence that there is a broad range of information levels – ranging from basically uninformed traders to traders with an average information level – where additional information does not lead to higher returns or profits from trading. Of course, we should stress that we have never found that having more information leads to significantly *lower* returns or profits. However, more information does *not* lead to *higher* returns or profits in this range of information levels, which is an important enough finding.

Why is it then possible that almost uninformed traders perform basically equally well as traders with an average information level – as has been found in all three different treatments? This result seems to be related to the market as an institution where traders take bets with other traders on the future development of a stock price (besides taking into account the current fundamentals like profits or revenue). Medium informed traders may know some information, but they often take bets against still better informed traders, thereby loosing quite frequently. Uninformed traders and those having almost no information have very little information to process, making their trades almost random and very hard to predict.

Our key results on the (often zero) value of additional information seem to question the widespread assumption that having more information is always a good thing, even in a world where information is costless – as we have assumed throughout the paper.

Actually, the introduction of positive marginal costs for additional information can be expected to strengthen our results that having more information need not be positive for a trader's overall profits (including information costs). Franzelin and Wimmer (2004) provide preliminary evidence on the willingness to pay for costly information. They have run a pilot experimental study using the same setup as in our treatment *T1*, with the notable exception that subjects in groups of 10 traders could bid for the different information levels (from *I0* to *I9*) in an auction. Basically, the information levels were auctioned off in descending order with a first-price design. The trader with the highest bid for *I9*, for instance, got this information level and dropped out of the auction for level *I8* and all lower ones. The trader who didn't win any auction from *I9* to *I1* was assigned to information level *I0*. The auction was repeated every 4 rounds (with a total of 24 rounds in order to allow for learning). The results of Franzelin and Wimmer (2004) show that subjects are willing to pay higher prices for higher information levels. Thus, there is in general a monotonic relationship between the information level and the willingness to pay. However, the profits from trading are almost exactly like those that we have presented in Figure 2 (see section 3.1). Adding information costs to the profits from trading then yields total profits which are decreasing from zero informed traders to medium informed ones, and only thereafter they increase again. Of course, this result is at odds with the predictions from Grossman and Stiglitz (1980), and it clearly deserves further experimental studies whether acquiring costly information in financial markets may make subjects worse off. It seems to be particularly interesting to study this question in other settings than the very stylized one of our treatment *T1*. However, we leave that open for future research.

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Appendix (The following instructions are translated from German.)

A1. Experimental instructions for treatment *T1*

We welcome you to the experiment and ask you
not to talk to other participants during the whole experiment

Experiment background

The experiment is a replication of a stock market, where 10 participants trade a virtual asset. The experiment consists of 20 independent periods. Each participant has a different information level about the intrinsic value of the asset.

Individual goal

Your personal goal is to maximize your personal profit. The higher your profit in the experiment, the higher your final monetary payment at the end of the 20 periods will be.

Composition of ONE period

Information levels and the intrinsic value of the asset

To derive the intrinsic value of the asset each period ten coin flips are made, showing either "1" or "0" each with probability 0.5. The intrinsic value is the sum of these ten coins.

Example:

Information level	0	1	2	3	4	5	6	7	8	9	10	value
Coin set 1		1	1	0	1	0	0	1	0	1	1	6
Coin set 2		0	1	0	0	0	1	1	0	0	0	3
…												

Each trader has a different information level: some know many of the ten coins, others know just a few. Specifically trader I1 knows the first coin, I2 knows the first and the second coin, etc. until trader I9 who knows the first nine of the ten coins. In addition, there is a computer-simulated trader I0 knowing nothing. This trader chooses a bid of 0 or 10 randomly.

Trader I6 knows in coin set 1 that the first six coins show 1, 1, 0, 1, 0, 0 and he also knows that he does not know the other four coins. In addition he knows that e.g. trader I4 knows only the first four of these coins.

Entering a separation price

> Each period you estimate the intrinsic value, which is the
> sum of the ten coin flips. How you get this estimate, is up to you!

Some **important information** on the intrinsic value:
❍ The maximal value is 10
❍ The minimal value is 0
❍ If you enter a separation price of **0** you are a sure **seller** in this period
❍ If you enter a separation price of **10** you are a sure **buyer** in this period

Deriving a price and market positions

The ten separation prices entered by the ten traders are ordered from the lowest to the highest and the median (between 5th and 6th separation price) is the market price for this period. All traders who have posted a separation price below the market price are sellers in this period, those who have posted a higher separation price are buyers. Those who have posted exactly the market price are neutral in this period.

> Example: the arranged separation prices of the traders are 0-3-4-4-6-7-7-7-7-8. The market price is therefore 6.5 (median of 5th and 6th price). The traders with separation prices 0, 3, 4, 4, 6 are sellers, while the other five are buyers.

Individual payment per period

The difference (**market price minus intrinsic value**) gives the profit/loss per period:
❍ If the **separation price > market price** you are **buyer**
❍ If the **separation price < market price** you are **seller**
❍ If the **separation price = market price** you are **neutral**

❍ If you are **buyer** you make a **profit** of (**intrinsic value minus market price**) if the **intrinsic value > market price**, else you loose this amount
❍ If you are **seller** you make a **profit** of (**market price minus intrinsic value**) if the **intrinsic value < market price**, else you loose this amount
❍ Neutral traders have neither profits nor losses

> Example: If the intrinsic value is 7 and the separation prices are 4-4-5-5-5-6-7-7-8-10, then the market price is 5.5 and the five traders having posted lower separation prices are sellers. The other five traders are buyers. As the intrinsic value is higher than the market price each buyer earns a profit of 1.5 (the difference of 7-5.5), while each seller looses this amount.

> Example: The separation prices are 0-3-4-5-6-6-6-6.5-7-7.12. The 5th, 6th and 7th separation prices are all "6", which therefore is the market price. The three traders with these separation prices are neutral in this period and have neither profits nor losses. We therefore have 4 sellers and 3 buyers. As the sum of profits and losses has to be equal (zero-sum-game) we use scale selling: If the value is 7, then each buyer gets his profit (=1), while the four sellers loose only 0.75 (= 1*3/4) instead of 1.

Time

Each period you have 45 seconds to enter your separation price. After each trading period you have 30 seconds to write a short description how you came up with the separation price (protocol).

Final Payment

Your payment at the end of the experiment is derived as follows:

> Sum of profits/losses per period
> + Starting money (depends on your information level; see first screen)
> = Final payment

A2. Experimental instructions for treatment *T2*

**We welcome you to the experiment and ask you
not to talk to other participants during the whole experiment**

Experiment background

The experiment is a replication of a **stock market** where 10 participants trade a virtual asset. In order to be able to trade you get an initial endowment with money depending on your information level. Each money unit represents one Euro and at the end of the session you get paid your total earnings in cash. The experiment consists of 20 independent periods.

The intrinsic value of the asset

To derive the intrinsic value of the asset each period ten coin flips are made (representing relevant information for the asset value: inflation, economic growth, etc.), showing either "1" (good) or "0" (bad) each with probability 0.5. The intrinsic value is the sum of these ten coins.

Example:

Information level	0	1	2	3	4	5	6	7	8	9	10	value
Coin set 1		1	1	0	1	0	0	1	0	1	1	6
Coin set 2		0	1	0	0	0	1	1	0	0	0	3
…												

Each trader has a different information level: One trader (I0) knows none of the coins. Trader I1 knows the first coin, I2 knows the first and the second coin, etc. until trader I9 who knows the first nine of the ten coins.

Trader I6 knows in coin set 1 (see example above) that the first six coins show 1, 1, 0, 1, 0, 0 and he also knows that he does not know the other four coins. In addition he knows that e.g. trader I4 knows only the first four of these coins.

Trading

Trading takes place in a double auction. This means that each trader can be buyer and seller. Each trader can post as man bids and asks between 0 and 10 as he wants. The trading screen has several sectors. On the very left you find your information. Next you have the possibility to post your asks and to accept offers by other traders. In the middle you see the prices of this period and on the right you can accept or post bids.

Your information in this period

Open asks, arranged from the highest to the lowest. The last offer is the best

Open bids, arranged from the lowest to the highest. The last offer is the best

Period

1 out of 2

Remaining time [sec]:   40

Minimum bid/ask: 0

Maximum bid/ask: 10

Note that at maximum 2 decimal places are allowed!

Asks of all traders	Prices of current period	Bids of all traders
6.20	5.20	4.00
6.10	5.30	4.50
6.00		5.00
6.00		5.10
5.95		5.15
5.90		
5.50		
5.40		

Information

1
0
-
-
-
-
-
-
-
-
-
-
-

Ask
5.3

Bid

OK   BUY   SELL   OK

Here you post the price at which you would sell and confirm below

Prices of all transactions in this period. The last price is always last in the list

Here you post the price at which you would buy and confirm below

If you push this button you buy the marked offer

If you push this button you sell the marked offer

Profit and loss

At the end of each period the intrinsic value is revealed and profits and losses are calculated. You make a profit, if you sold the asset at a higher price than the intrinsic value or if you bought it cheaper than the intrinsic value.

Profit buyer = intrinsic value – price (negative, when price > intrinsic value)

Profit seller = price – intrinsic value (negative, when price < intrinsic value)

Important details

- Each round you may make up to three transactions. You may, however, post as many bids and asks as you want.
- Each trading period lasts for 150 seconds (2.5 minutes)
- In each period when you make at least one transaction you get a risk premium of 1 Taler.

History Box:

At the end of each period you get an overview in the history box. Each period you see the most relevant data (intrinsic value, trading, profit, etc.). The history box will be shown for 30 seconds after each period.

Period

2 out of 2   Remaining time [sec]: 21

Period	Intrinisic Value	Trading profit	Risk premium	Total profit	Current pay out	Avg total profit
1	6	-3.00	1.00	-2.00	28.00	-2.00
2	4	-6.60	1.00	-5.60	22.40	-3.80

A3. Experimental instructions for treatment *T3*

**We welcome you to the experiment and ask you
not to talk to other participants during the whole experiment**

Background of the experiment

This experiment is concerned with replicating asset markets where 9 participants in a group can trade the stocks of a fictive company for 30 consecutive periods (months). With trading you can increase your wealth and at the end you will receive a cash payment depending on your wealth.

Characteristics of the market

Each trader is endowed with 1600 Taler (experimental currency) and with 40 stocks worth 40 at the beginning of the experiment. The only fundamental information you receive is the dividend of the stock (monthly dividend equals monthly profit). Changes of the dividend per period have an expected value of zero and will fluctuate randomly at maximum +/- 50%. The market is characterized by an asymmetric information distribution. Worst informed traders are informed only about the dividend of the current period, while better informed ones know the dividend of the company a few months in the future. The best informed trader knows this periods dividend and the dividends of the coming 8 periods.

At the end of each period (which lasts 100 seconds) you will receive the current dividend for each stock you own. A risk free interest rate of 0.1% is paid for the cash holdings in each period. The risk adjusted interest rate for evaluation of the stock equals 0.5%.

Trading

The trading mechanism is implemented by a double auction. This means that each trader can buy or sell stocks freely. Therefore you can enter as many bids/asks as you wish within the range of 0 and 200 (with at maximum one decimal place).

Overview of stock and cash holdings; Wealth = money + [stock*current price]

Overview of own transactions in the current period.

Calculator

History Box: „Average price" denotes the average price of the past periods.

Period

2 out of 2

Remaining time [sec]: 7

Sales
40.1
40.4
40.9

Purchases
39.4

Period	Average price
1	39.0
2	-1.0

Stock 38
Money 1691.6
Wealth 3192.6

Ask

ASK

Bid

BID

Bids of all traders
38.4
38.6
39.0
39.1
39.2

Asks of all traders
44.5
44.0
43.0
42.6
42.3
42.0
41.3

Prices of current period
40.1
40.4
40.9
39.4
40.2
39.7
39.5

DIVIDENDS

t	0.195
t+1	0.224
t+2	0.216
t+3	0.194
t+4	0.200
t+5	-1.000
t+6	-1.000
t+7	-1.000
t+8	-1.000

PRESENT VALUE STOCK
40.03

SELL

BUY

Your dividend information for this period with „t" denoting the current period and "-1.000" standing for no information.

Conditional expected value of the stock.

SELLIING AREA
You can either insert your own asks and confirm them with clicking on the „ASK" button or accept an open bid of another trader with clicking on the "SELL" button. All bids are sorted from the lowest to the highest.

BUYING AREA
You can either insert your own bids and confirm them with clicking on the „BID" button or accept an open ask of another trader with clicking on the "BUY" button. All asks are sorted from the highest to the lowest.

Chronological history of prices of the current period.

Calculation of the conditional expected value (present value, PV)

Generally it is up to you on what kind of information you will trade and how you will evaluate the stock. If you use your fundamental information you can see the present value (PV) of all future dividends (of course only those you can estimate on the basis of your information level) on the bottom left side of the trading screen. Your PV is derived using Gordon's well-known formula, discounting the known dividends and using the last one as a continuous, infinite stream which was also discounted as a company is basically designed for infinity.

$$PV_0 = {}_{i=0}\Sigma^{n-1} D_i/(1.005)^i + D_n/0.005/(1.005)^n \text{ with n denoting the last period}$$

Example: The dividends of this and the next 2 periods are 0.191; 0.214; 0.202. So, the PV on basis of this information level is calculated as follows: $0.191 + 0.214/1.005 + 0.202/0.005/1.005^2$ = 40.40. This PV is shown on the bottom left side of the trading screen.

Wealth

Your wealth is the sum of your cash holding and the product of your stock holdings multiplied with the current price. If you are buying a stock your cash holdings are reduced by the price you paid and at the same time your stock holdings are enlarged by one stock. Generally, for evaluation of your wealth the current price on the market is being used, so your wealth will change even if you have not participated in the last transaction. After expiration of each trading period (month) an interest rate of 0.1% per month is paid for the current cash holdings, and the dividends for your stocks are being added to your cash.

Example: If you own 1600 in cash and 40 stocks with a price of 40 and the dividend equals 0.215 at the end of a period, so your wealth is increasing from 3200 to 3210.2 (Hence, the increase is wealth consists of +1.6 for interest earnings (= 1600*0.001) +8.6 for dividend earnings (= 40*0.215)).

Important details

- Per period you can trade as much as you wish (of course, only within the boundaries of your cash and stock holdings). Negative cash holdings are not possible.
- Trading time per period is 100 seconds, which is being displayed at the top right side of the trading screen.
- Your payment at the end of the experiment depends on your wealth in the last period.