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Is more information always better? Experimental financial markets with cumulative 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 information about an asset's intrinsic value is cumulatively distributed among traders. 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 above average information levels) where additional information does not yield higher returns. The latter result implies that the value of additional information need not be strictly positive.

JEL classification: C91; D82; D83; G1

Keywords: Cumulative 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 such as 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. Traders will 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 a little 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; 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 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 of 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, just *different* information. This led Figlewski (1982, p. 99) to claim that "independent information is not likely to be an adequate description of the information structure of a real-world speculative market". Rather, we think it is more realistic to assume that information is cumulatively distributed, meaning that some traders know more than others by having the same plus some extra information. For instance, 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 such as their public financial statements or revenue outlook. Finally, there may be some very well-informed traders (insiders) having all the previously mentioned information, but

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

also knowing some important details (such as a planned merger or a product innovation) that are not publicly known.

Given that there is no empirical evidence on the value of additional information when information is cumulatively distributed, we have opted for an experimental approach. In the laboratory we are able to control carefully 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 amount. By implementing such a 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. Section 3 presents our experimental study. Section 4 offers a concluding synopsis.

2. Markets and the marginal value of additional information

The question of 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 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 fully reveal the information of traders. As a consequence, there is no reason to expect better informed traders to perform better than worse informed traders, but there is also no incentive to gather any information. According to this line of reasoning 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 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, 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. They develop a market model with a large number of heterogeneously informed traders who

[2] Recently, Allen et al. (in press) 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.

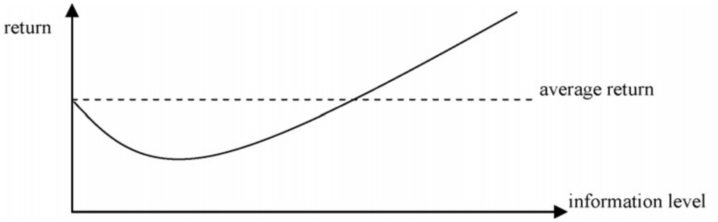

Fig. 1. Rate of return per information level as assumed by Schredelseker (1984, p. 51).

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 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 leads to higher 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 the best informed market participants (i.e., insiders) can gain above average returns,[4] while on the other hand 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] If uninformed traders earn the average market return and insiders above average returns, it follows that some traders with an intermediate information level need to earn below average returns, as is shown in Fig. 1. As a consequence, there will be at least some information levels where more information is associated with lower, instead of higher, returns. The intuition for that claim is that medium informed traders sometimes receive skewed signals on which they

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

[4] There is quite some evidence supporting this claim (see Jeng et al., 2003; Lin and Howe, 1990; Lakonishok and Lee, 2001; Krahnen et al., 1999). Jeng et al., for instance, show that insider purchases yield excess returns of about 6 percent per year. Lakonishok and Lee show that insiders are better able to predict market movements, in particular with respect to the returns of relatively smaller firms, which makes insider trading so profitable.

[5] One might argue that the least informed traders should not trade at all, as in a zero-sum game they should recognize that they will lose for sure when betting against better informed traders (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.

put too much weight and to which they ascribe too much precision when taking positions on the market.[6]

3. Experiment

We study the marginal value of additional information in three separate treatments that differ either with respect to the mechanism used to determine the market price (either a call market or a continuous double auction market[7] 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, claiming 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, which seems a reasonable approximation of real-world financial markets. For the sake of clarity, we will present each treatment, its design and its results separately and offer a concluding synthesis of all experimental results in Section 4 (see Appendix A for supplementary material).

3.1. Treatment T1—call market with binomial process

3.1.1. Experimental design

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 that 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.[8] 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

[6] In Section 3.1.2, we will come back to this issue of skewed signals in the context of our experimental market. Schredelseker (2001) provides a simulation on the effects of skewed signals for trading profits in a market with cumulative information. Schredelseker claims that at least one equilibrium of strategies should exist where each trader chooses his best response to other trader's actions. In this equilibrium most traders (except insiders) do *not* condition their bids on their available information, but make random bids and, consequently, earn profits slightly below the average. Only insiders are able to outperform the market.

[7] Many major stock exchanges in the world (like Eurex in Frankfurt, Euronext in Paris, Brussels and Amsterdam, or SETS in London) have an opening call auction when trading starts and later on a continuous double auction market.

[8] 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.

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 9 out of 10 random draws. It is common knowledge in the market that a trader with information level I_y knows precisely what all traders with level I_x know, if $y > x$, yet a trader with level I_y has only a subset of the information available to a trader with level I_z, if $y < z$.

Given their information level, traders can make bids for the asset.[9] 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.[10] 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 (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 denotes trader i's bid,

$$R_i = \frac{B_i - P}{|B_i - P|} \times [V - P], \quad \text{with } R_i = 0 \text{ if } B_i = P. \tag{1}$$

There are 20 trading periods in the experiment. For each period, the sequence of the 10 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 0 to 10) both for the experimental sessions as well as for the whole distribution.

At the beginning of sessions, 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 10 traders. Therefore, we have a group of 10 traders as independent unit of observation. In total, we have seven of these groups in T1.[11] The experimental sessions were fully computerized (using z-Tree of Fischbacher, 1999) and were run in June 2002 at the University of Innsbruck. Sessions lasted on average 75 min, with subjects earning on average €14.[12]

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[9] 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 an 'bid' is an offer to buy and an 'ask' is an offer to sell.

[10] 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 such as 0–2–3–3–4–4–4–5–6–7 that yields 4 as the market price. There are four sellers and three buyers. Assume that the intrinsic value of the asset were 6; then each of the three buyers would make a profit of 2 units of money, whereas each of the four sellers would have a loss of 1.5 units of money.

[11] Note that the trader with information level I0 was computerized (bidding randomly either 0 or 10). Given that one of the referees cast doubt about this practice, we abstained from this practice in treatments T2 and T3.

[12] At the beginning of the experiment, subjects received an initial endowment that 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*.

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 (percent)											
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

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 “1” the expected value of the *unknown* draws, then trader *i*’s bid B_i can be calculated as follows:

$$B_i = \sum_{k=0}^{i} b_k + [(n - i) \cdot 0.5] \tag{2}$$

with $n = 10$ denoting the total number of random draws, i 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 “0” and value one if draw k yielded a “1”. 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. Bids calculated as in Eq. (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 Fig. 2 represent the average profit of a single trader with a given information level in one of our seven independent groups. The bold line shows the average profit across the seven 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 Fig. 2 does not support the stylized argument of Schredelseker (1984) (see Fig. 1). Only from an intermediate information level onwards do 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, $N = 7$).

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 Eq. (2).[13] The correlation is significantly increasing

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

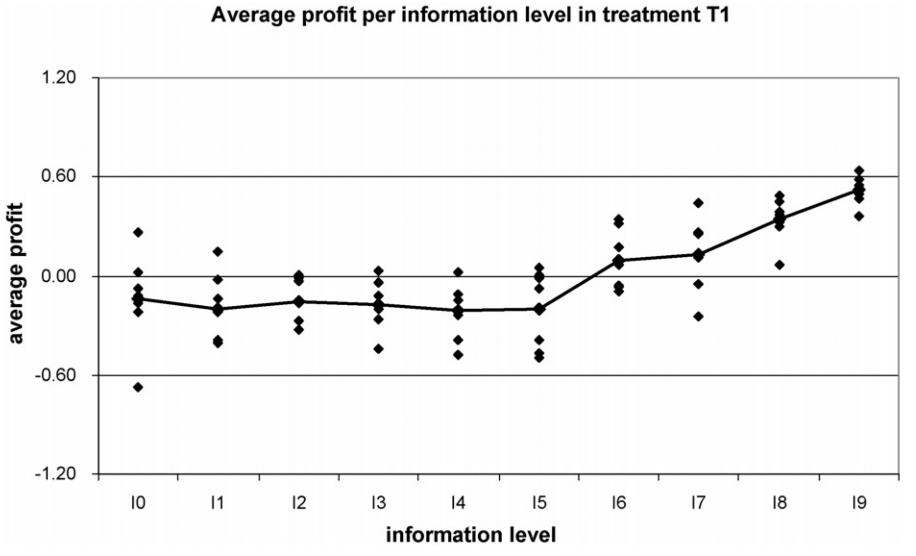

Fig. 2. Average profit per information level in treatment T1.

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

(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.

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 Fig. 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 Eq. (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 knows 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 is skewed such that it contains many identical outcomes in a row. An extreme example for such a *consecutive* sequence would be 0000111111.[14] In such cases active information processing according to Eq. (2) leads to

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

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
Periods 1–10 (1)	−0.15	−0.22	−0.19	−0.22	−0.47	−0.19	0.19	0.16	0.44	0.65
Periods 11–20 (2)	−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

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 Eq. (2). Table 2 has indicated that this is less the case for worse informed traders. The latter seem to be able to discard misleading information in consecutive sequences, at least to a certain extent, which actually helps them prevent losses.

As a final aspect to be considered in this treatment we look at the average profits across the seven markets in both halves of the experiment.[15] As we can see from Table 3, average profits are on average higher in 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. 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.

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, 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.

[15] 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.

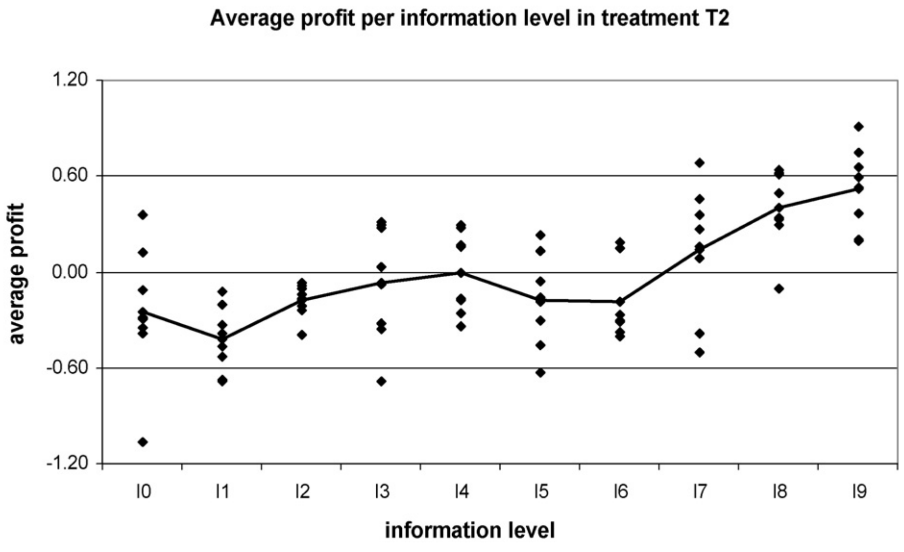

Fig. 3. Average profit per information level in treatment T2.

Each of the 20 periods in the experiment lasted 150 s in which traders could make and accept bids and asks. Each trader could realize at most three 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.[16]

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, that is 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 min and yielded average payoffs of €14 per participant.

3.2.2. Experimental results in T2

Fig. 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.

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

[16] 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.

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

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.

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

When we look at intertemporal developments we find that the number of trades per period is decreasing from 9.04 in periods 1–10 to 8.48 in periods 11–20. The decrease is not significant ($p = 0.12$, Wilcoxon signed ranks test; $N = 8$), nor is the increase in the average number of bids and asks per period from the first to the second half of the experiment (36.6 versus 41.2; $p = 0.16$). However, the ratio of bids and asks to the actual number of trades is, in fact, significantly increasing from periods 1–10 to periods 11–20 (4.0–4.9; $p < 0.05$). This indicates that subjects are less willing to accept offers in the latter part of the experiment. In particular, they hesitate to accept the very first offers placed in a trading period. As a consequence, the variance of prices decreases significantly from periods 1–10 to periods 11–20 ($p < 0.01$, Wilcoxon signed ranks test), as is shown in Fig. 4, where the bold line indicates the overall average. Whereas the variance of prices decreases, profits do not change significantly from periods 1–10 to periods 11–20.

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

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

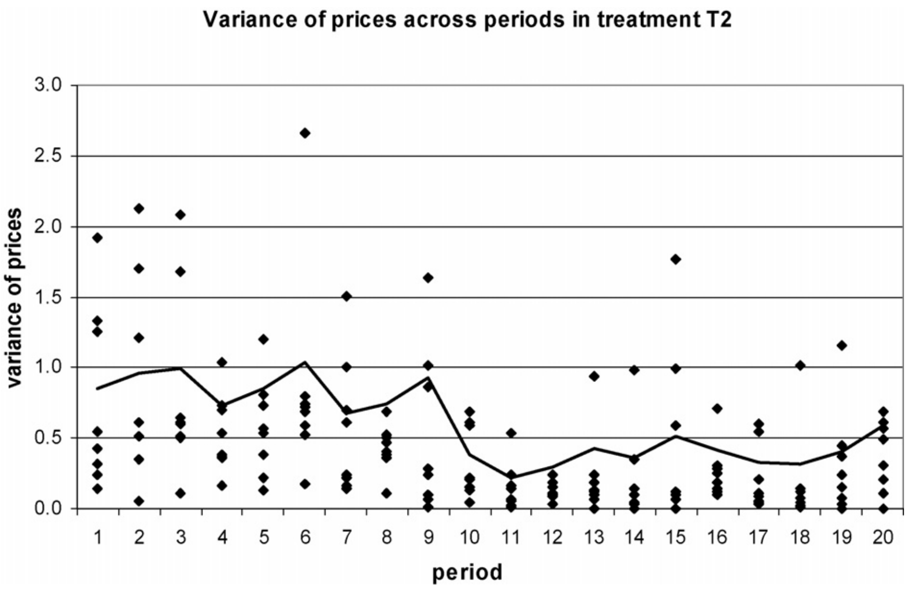

Fig. 4. Development of the variance of prices across periods in treatment T2.

the traders' knowledge about future dividends.[17] In general, trader I_x 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 eight 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 is a normally distributed random term with a mean of zero and a variance of $\sigma^2 = 0.0004$.

As 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). Trading time was 100 s per period. In total, we had 30 periods,[18] after which subjects' accounts were exchanged into money at the rate of 200 Taler = €1.

At the start of each period subjects received information on the future dividends according to their information level. In addition we displayed to each trader the net present value of the stock

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

[18] The results to be reported below would remain qualitatively identical if we considered only 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.

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 that was also discounted,[19]

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

$E(V|I_{j,t})$ denotes the conditional expected value of the asset in period t, j the index for the information level of trader I_j and r_e is the risk adjusted interest rate that was fixed at 0.5 percent. 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 were accepted the subjects' accounts were adapted accordingly. Contrary to the previous treatments we let cash holdings earn a small interest of 0.1 percent per period.[20] 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 closest to the conditions in real markets. Therefore, we think that treatment T3 is the hardest test of whether more information is always better for traders.

The experimental sessions for treatment T3 were implemented in July 2004 with a total of seven independent groups of nine subjects. Each of the nine subjects had a different information level ranging from I1 to I9.[21] The average duration of the sessions was 90 min, with average earnings of €18.

3.3.2. Experimental results in T3

Fig. 5 shows the individual and average returns (bold line) for different information levels.[22] 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 $W_{T,j}$);

$$R_{T,T-X,j} = \frac{W_{T,j} - W_{T-X,j}}{W_{T-X,j}} \tag{5}$$

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 percent for traders I5 to 22.2 percent for traders I9. Due to a relatively high variance in single traders' returns[23] a Fried-

[19] 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.

[20] 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.

[21] We economized on subjects (9 instead of 10), because 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).

[22] Two outliers with information level I2 (with average returns of +52 percent, respectively, −31 percent) are not included in Fig. 2.

[23] Overall, 22 out of 63 traders exceeded the expected return of the stock of 16.1 percent. Traders with all 9 different information levels are among those 22 traders. Nine out of 63 traders ended up with a return that was lower than the risk-free rate (of 3.0 percent in 30 periods). Seven of these nine traders actually suffered losses from trading.

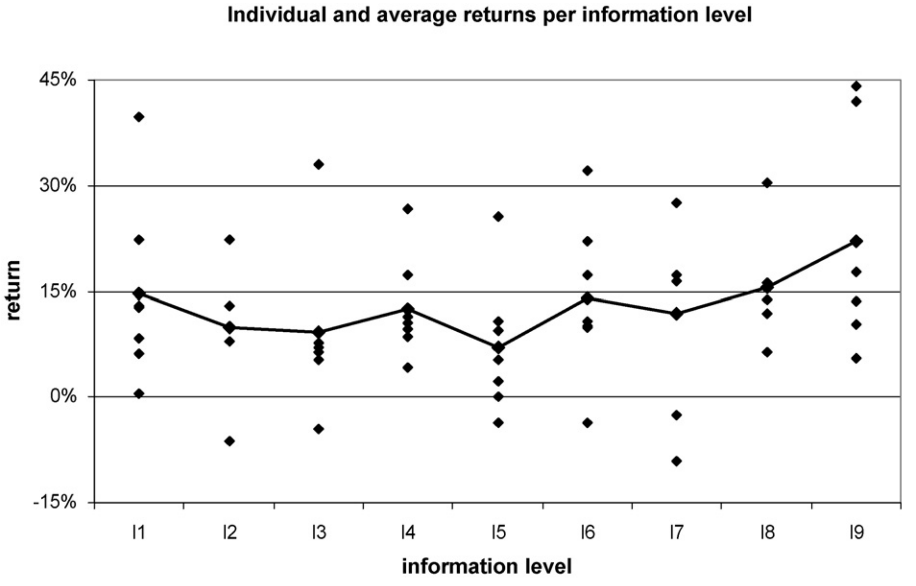

Fig. 5. Individual and average returns per information level in treatment T3.

man 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 do 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. 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 Eq. (5). The results are displayed in Fig. 6.

Two features of Fig. 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 from the beginning to 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 Fig. 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 Fig. 5) is therefore not due to a few periods, but it is the result of different performance throughout the experiment.

Second, Fig. 6 also shows an important feature of the dividend stream. While the zero-sum property of treatments T1 and T2 necessarily implied some traders win and others lose in

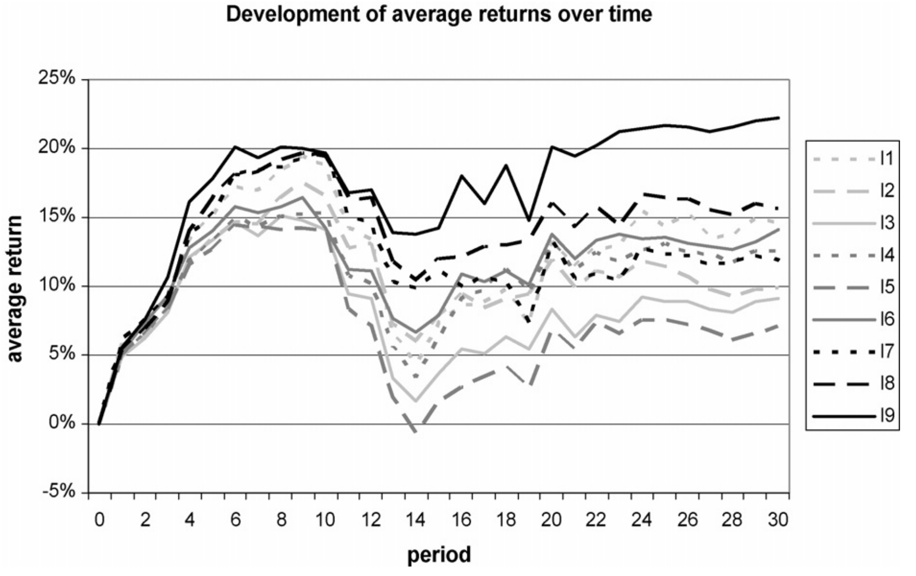

Fig. 6. Development of average returns $R_{T,0,j}$ over time in treatment T3.

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 1–9) or all get poorer (see, e.g., periods 10–14), depending upon the prospects for the asset's dividends.

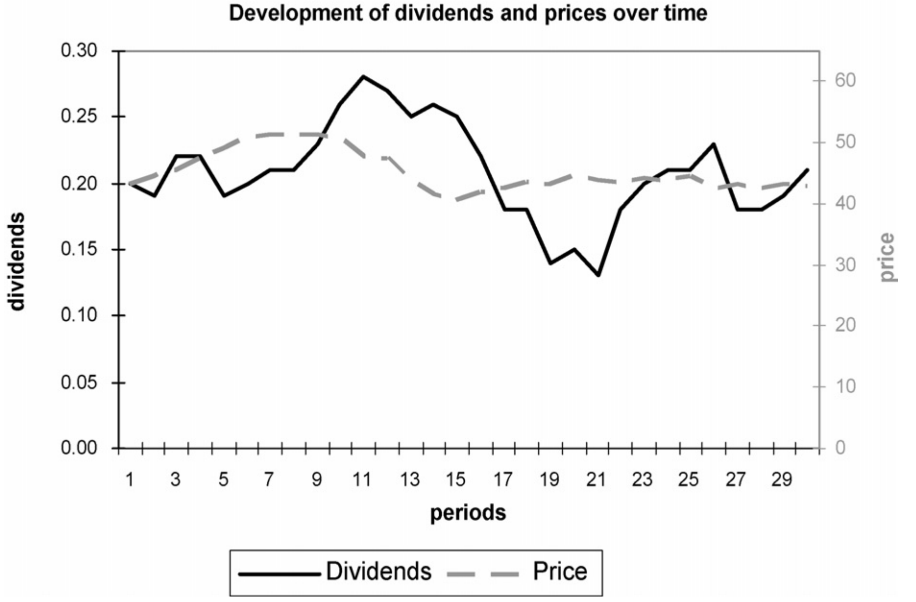

Fig. 7. Development of dividends and average prices over time.

Table 6
Frequency of trading in treatment T3

	Information level								
	I1	I2	I3	I4	I5	I6	I7	I8	I9
Average number of transactions per period	6.60	8.23	3.80	3.17	5.53	5.27	7.00	4.97	5.63
Relative frequency of buying (selling) if net present value > (<) current price	0.61	0.63	0.65	0.64	0.60	0.70	0.77	0.61	0.72

In Fig. 7, we plot the asset's dividends in each period (see left-hand scale and solid line)[24] 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 five periods,[25] which is exactly the information level of the median informed trader I5.[26] However, prices show a smoother path with smaller variance than dividends do. This is a result of all but one trader in the market knowing more than just the current dividend.

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 percent. 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 stronger to the 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 percent of cases where the net present value is higher (lower) than the current price, whereas the corresponding figure is 63 percent for traders with information level I1 to I5 (see bottom line of Table 6).

Finally, we would like to address how trading activity is related to the information level. Overall, there are about 20 transactions per period. Table 6 provides the average number of transactions per period, contingent on the information level. Obviously trading activity is not correlated with a trader's information level, but the information level has an influence on when traders buy or sell shares. Fig. 8 shows the average number of stock holdings in the course of the experiment.[27] The best informed trader I9 is the first one to start buying actively (and at relatively low prices), because he is the first one to realize that dividends are steadily increasing from period 5 to period 12 (see the solid line in Fig. 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 his conditional expected 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

24 Recall that the dividends were identical across all seven groups of traders.

25 Spearman–Rho coefficients of average prices per period and dividends of five periods later are significantly positively correlated in all but one session. Correlation coefficients range from 0.56 to 0.83.

26 This finding is somewhat related to Kyle's (1985) finding. 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.

27 For the sake of clarity we have selected only the uneven information levels in Fig. 8. A separate figure with the stock holdings of traders with an even information level shows a very similar pattern and is available upon request.

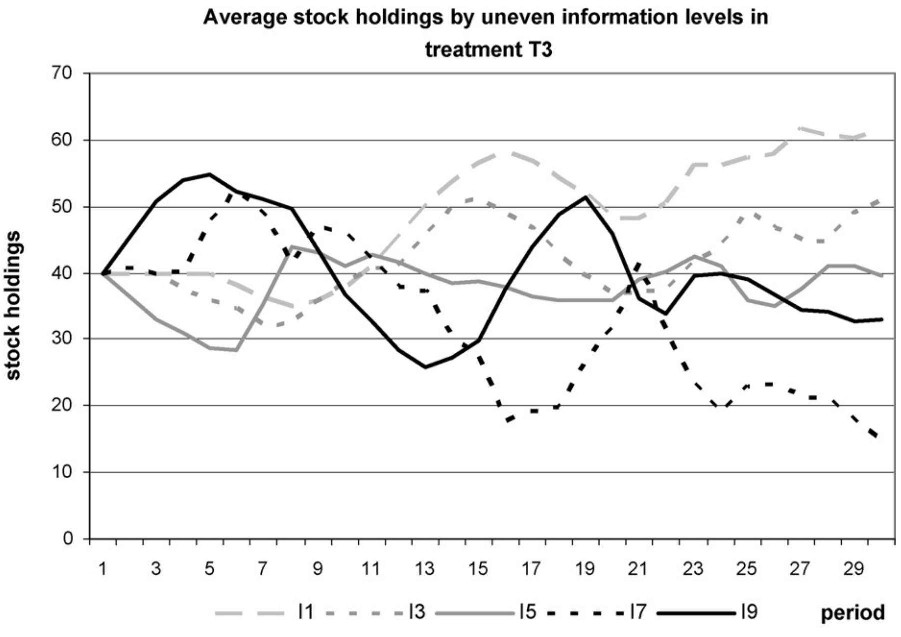

Fig. 8. Average stock holdings of selected traders by uneven information levels in treatment T3.

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 Fig. 7).

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 of financial markets quite reasonably. It is particularly the second feature that 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 remarkably 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 not found that having more information leads to significantly *lower* returns or profits. This latter finding is clearly inconsistent with the model of Schredelseker (1984) that would predict that additional information can, in fact, be harmful. Given that our findings have proved robust in three different experimental markets,[28] the difference between Schredelseker's model and our results does not seem to depend on the type of market. Rather, it might be that the number of participants is critical. In markets with a large number of traders in which the price and an unbiased estimate of the value of an asset are known, Schredelseker's theory may hold because the uninformed traders can always buy or sell at the market price and make zero expected profits. In all of our markets, however, we have found that uninformed traders actually suffer losses. This could have been due to the fact that in our markets with relatively few participants any bid introduces some noise in the price, which is then no longer an unbiased estimate of the asset's value.

Nevertheless, we deem it an important finding that *more* information does *not* lead to *higher* returns or profits in a wide range of information levels. 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 such as profits or revenue). Medium informed traders may have some information, but they often take bets against even better informed traders, thereby losing money quite frequently. The information that medium informed traders get may also be rather skewed, causing a bias in the conditional expectation of the asset's value. Completely uninformed traders cannot suffer from such a bias, given that they have no information. Seen from this perspective, it even might seem surprising that medium informed traders did not perform significantly worse than uninformed traders. This might be due to medium informed traders knowing the possible distribution of values (in treatments T1 and T2) and becoming aware of the fact that their partial information might be misleading. The latter conjecture can be supported by the observation that trading becomes less active in the latter part of the experiment.

More generally, our key result on the (often zero) value of additional information seems 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). However, we leave it open for future research to corroborate this conjecture.

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[28] The robustness across three different kinds of markets should also remove doubts that our results depend on the sample sizes used in our three treatments.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jebo.2005.05.012.

References

Ackert, L., Church, B., Zhang, P., 2002. Market behaviour in the presence of divergent and imperfect private information. Experimental evidence from Canada, China and the United States. Journal of Economic Behavior and Organization 47, 435–450.

Allen, F., Morris, S., Shin, H.S. Beauty contests and iterated expectations. Review of Financial Studies, in press.

Bassan, B., Scarsini, M., Zamir, S., 1997. I don't want to know! Can it be rational? Discussion Paper No. 158. Hebrew University Jerusalem. Center for Rationality and Interactive Decision Theory.

Blackwell, D., 1951. Comparison of experiments. In: Neyman, J. (Ed.), Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability. University of California Press, Berkeley, pp. 93–102.

Copeland, T., Friedman, D., 1992. The market value of information: experimental results. Journal of Business 65, 241–265.

Cowles, A., 1933. Can stock market forecasters forecast? Econometrica 1, 309–324.

Cowles, A., 1944. Stock market forecasting. Econometrica 12, 206–214.

Diamond, D., Verrecchia, R., 1981. Information aggregation in a noisy rational expectations economy. Journal of Financial Economics 9, 221–235.

Fama, E., 1970. Efficient capital markets: a review of theory and empirical work. Journal of Finance 25, 383–417.

Figlewski, S., 1982. Information diversity and market behaviour. Journal of Finance 37, 87–102.

Fischbacher, U., 1999. Z-tree: Zürich toolbox for readymade economic experiments. Working Paper No. 21. Institute for Empirical Research in Economics, University of Zurich.

Gibbons, R., 1992. A Primer in Game Theory. Prentice Hall, Gosport.

Grossman, S.J., 1976. On the efficiency of competitive stock markets where traders have diverse information. Journal of Finance 31, 573–585.

Grossman, S.J., Stiglitz, J.E., 1980. On the impossibility of informationally efficient prices. American Economic Review 70, 393–408.

Hellwig, M., 1982. Rational expectation equilibrium with conditioning on past prices: a mean-variance example. Journal of Economic Theory 26, 279–312.

Hirshleifer, D., 2001. Investor psychology and asset pricing. Journal of Finance 56, 1533–1597.

Jeng, L.A., Metrick, A., Zeckhauser, R., 2003. Estimating the returns to insider trading: a performance-evaluation perspective. Review of Economics and Statistics 85, 453–471.

Kamien, M.I., Tauman, Y., Zamir, S., 1990. On the value of information in a strategic conflict. Games and Economic Behavior 2, 129–153.

Krahnen, J.P., Rieck, C., Theissen, E., 1999. Insider trading and portfolio structure in experimental asset markets with a long-lived asset. European Journal of Finance 5, 29–50.

Kyle, A.S., 1985. Continuous auctions and insider trading. Econometrica 53, 1315–1335.

Lakonishok, J., Lee, I., 2001. Are insider trades informative? Review of Financial Studies 14, 79–111.

Lin, J., Howe, J., 1990. Insider trading in the OTC market. Journal of Finance 45, 1273–1284.

Malkiel, B.G., 2003a. Passive investment strategies and efficient markets. European Financial Management 9, 1–10.

Malkiel, B.G., 2003b. The efficient market hypothesis and its critics. Journal of Economic Perspectives 17, 59–82.

Mehra, R., Prescott, E., 1985. The equity premium: a puzzle. Journal of Monetary Economics 15, 145–161.

Radner, R., 1979. Rational expectations equilibrium: generic existence and the information revealed by prices. Econometrica 47, 655–678.

Schredelseker, K., 1984. Anlagestrategie und Informationsnutzen am Aktienmarkt. zfbf—Schmalenbachs Zeitschrift für Betriebswirtschaftliche Forschung 36, 44–59.

Schredelseker, K., 2001. Is the usefulness approach useful? Some reflections on the utility of public information. In: McLeay, S., Riccaboni, A. (Eds.), Contemporary Issues in Accounting Regulation. Kluwer, Norwell, pp. 135–153.

Shiller, R.J., 2003. From efficient markets theory to behavioral finance. Journal of Economic Perspectives 17, 83–104.