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**Insider Trading and Portfolio Structure  
in Experimental Asset Markets  
with a Long Lived Asset**

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## Foreword

Given that the Johann Wolfgang Goethe University is located in Frankfurt, it is not surprising that finance has always been one of the focal points of teaching and research at its Department of Economics and Business Administration. The new Working Paper Series is intended to document the continuing prominence of this field in the work of the department. But most of all, it shall foster the exchange of ideas both within the academic world and between academics and practitioners. We would be pleased if these papers were to contribute to this dialogue.

The timely dissemination of research results is now even more critical than it was in the past. Unfortunately, the time-span between the completion of a paper and its submission to the editor of an academic journal or book and its formal publication has increased considerably in recent years. It is an important objective of the Working Paper Series to reduce this time-lag. However, in some cases papers that have already been published will also be included in the Series if they have appeared in books or journals which interested readers would find it difficult to obtain.

As a rule, the papers published in this Working Paper Series will be written by teachers and researchers at the Institute of Business Administration of the Goethe University or by persons closely associated with this institute. Thus, the editors of the Series are the professors who are members of the business finance faculty, which is currently composed of Ralf Ewert, Günter Gebhardt, Jan-Pieter Krahn, Helmut Laux, Martin Nell and myself, acting as managing editor.

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Reinhard H. Schmidt

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**Insider Trading and Portfolio Structure in  
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**Abstract**

We report results of a series of nine market experiments with asymmetric information and a fundamental value process that is more "realistic" than those in previous experiments. Both a call market institution and a continuous double auction mechanism are employed. We find considerable pricing inefficiencies that are only partially exploited by insiders. The magnitude of insider gains is analyzed separately for each experiment. We find support for the hypothesis that the continuous double auction leads to more efficient outcomes. Finally, we present evidence of an endowment effect: the initial portfolio structure influences the final asset holdings of experimental subjects.

JEL classification: C91, G14

Key words: experimental asset markets, market efficiency, market institutions, endowment effect

## 1 Introduction

The most important economic function of asset markets is the allocation of capital. In an informationally efficient market in the sense of Fama 1970, asset prices reflect all available information and can, therefore, serve their allocational function. There is, however, a considerable debate over the degree of market efficiency. First, markets are not generally considered to be strong-form efficient. Therefore, market participants with superior information may earn excess returns and cause prices to deviate from fundamental values. Theoretical work suggests that the existence of multiple insiders, as opposed to a monopolist insider, greatly enhances the efficiency of the price discovery process (Holden/Subrahmanyam 1992). Second, the detection of an increasing number of “anomalies”, systematic patterns in asset prices that cannot be explained by standard theories (e.g., day of the week effects, the January effect and return reversals) has cast doubt on the long held view that markets are semi-strong form efficient.

It is unclear, however, how far prices actually differ from fundamental values. The work of Shiller, summarized in Shiller 1989, suggests that price volatility is too large to be explained by changes in fundamental values. Black 1986 argues that a market is reasonably efficient if the price is more than half and less than twice the fundamental value. The question how far prices may deviate from fundamental values is of obvious importance, as is the analysis of the causes of these deviations. Both the existence of noise trading (cf Black 1986 and the models of De Long et al. 1990, 1991) and the microstructure of the market are potential determinants of the degree of market efficiency.

The latter point deserves attention in the light of recent proposals to change the organization of asset trading on major European markets. The London Stock Exchange plans to introduce elements of an order driven system into their quote-driven system. The Frankfurt Stock Exchange, on the other hand, is about to integrate designated market makers (*Betreuer*) into an

electronic open limit order market. In addition, call market trading (which at present is exclusively used to trade small capitalization stocks) is to be supplemented with continuous trading. Finally, there is a trend, most strongly evidenced by the recent structural changes on the Paris Stock Exchange, towards **automation** of the trading process.

Liquidity and transaction cost considerations are the driving force behind these proposals. Growing international competition forces stock exchanges to react to (institutional) customer needs and to offer a market structure that provides high liquidity and low execution costs. It is not clear, however, whether the proposed structural changes will also increase market efficiency. Black 1986, p. 532, makes the point that “(w)hat’s needed for a liquid market causes prices to be less efficient.”

The unobservability of the fundamental value makes it difficult to address these questions with field data. In this paper we therefore provide evidence from laboratory markets. The experimental method has two advantages. First, the fundamental value and the information structure are known to the experimenter, and second, the organization of the market can be varied holding everything else constant. This allows us to address three questions related to the informational efficiency of asset markets. We investigate the relation between prices and fundamental values, compare the efficiency of batched and continuous auction markets and investigate the profitability of access to superior information.

Our experimental design is developed to make the decision situation resemble the situation encountered in real markets. In particular, contrary to most previous experiments, we use a design with a long-lived asset. The subjects’ portfolios are therefore determined by previous transactions and are not, as has been the case in many previous experiments, re-initialized after each period. This allows us to investigate portfolio choice in a dynamic context.

Our main result is that prices deviate significantly from the fundamental value. Despite having a considerable informational advantage, however, the average payout to insiders is only 6% higher than the payout to uninformed investors. Equally surprising, the insiders' expectations about the fundamental value are not significantly more accurate than those of the outsiders. Consequently, the main factor to explain the individual wealth levels at the end of the experiments is not access to information, but rather initial endowment. Concerning the influence of the market institution, we observe a slight advantage of the continuous auction market as compared to the call market institution.

The paper is organized as follows: In section 2 we describe the experimental design in detail and discuss how it differs from previously employed designs. Section 3 develops the hypotheses and describes the results, section 4 concludes.

## **2 Experimental Design**

### **2.1 Relation to previous work**

Experimental investigation of asset markets started with Plott/Sunder 1982. The design introduced in this pioneering study has been used in a large percentage of subsequent experimental research. There are four main characteristics:

- **Double auction:** The trading institution employed is the (computerized) continuous double auction (among the exceptions are Friedman 1993a, Krahen/Weber 1997 a, b, Schnitzlein 1996 and Theissen 1997 who compare differently organized markets).
- **Stochastic dividends:** Uncertainty is modeled by differing dividend values, the dividend depending upon the state of nature occurring. Informational asymmetry is introduced by informing some of the subjects about the actual state of nature.

- Private values: There are two or more groups of traders holding different valuations for the asset in the *same* state of nature. For example, in state A the asset may be worth 50 for participants in group 1 and 100 for those in group 2. We term this a private value design. This feature allows clear predictions of the optimal allocation since the traders with the highest valuation in the given state of nature should end up holding all assets.
- Short-lived assets: Trading periods are stationary replications of the same situation, i.e. endowments are re-initialized at the beginning of a new period, while the state of nature is determined by a new draw from a constant distribution.

These design features allow the investigation of many important questions. It is usually possible to make clear predictions about equilibrium prices and allocations under different hypotheses (e.g. rational expectations equilibrium). This type of design does, however, possess some features that run counter to the usual intuition about the nature of asset trading. First, the stationary replication facilitates learning but makes decisions in different periods independent of each other. Second, the informational advantage of insiders is very large in that they know the dividend, and thus the asset value, with certainty. Third, although different valuations by different traders might be justified by different tax brackets or different expectations, an asset with a value common to all traders may better describe the situation encountered in real world asset markets. Fourth, the value of the asset is determined entirely by the dividend it pays; since there is a finite horizon, the asset value declines to zero in the course of an experiment. Although this is in line with theory (stock prices are usually assumed to reflect the discounted value of future dividends and *are* thus determined entirely by the dividends the stock pays), subjects have a completely different everyday experience because they are accustomed to infinite dividend horizons and, hence, do not observe asset values declining over time.

Smith/Suchanek/Williams 1988 were the first to use a long-lived asset with finite horizon, zero liquidation value. The asset pays a stochastic dividend (drawn from a stationary distribution) over 15 or 30 trading periods, implying that the fundamental value of the asset declines from period to period. It is possible that the pronounced price bubbles observed in these experiments (and confirmed in subsequent work using a similar fundamental value process, e.g. King et al. 1993, Van Boening 1991, Van Boening et al. 1993) are an artefact of this specific asset feature.

Our design confronts subjects with a situation that is more in line with their everyday experience of asset trading. The security has a fundamental value following a binomial process with an upward drift. It is traded over 14 periods with no re-initialization of the endowments. Informed subjects can calculate the mathematical expectation of the final value of the asset (which is the value relevant for their payoff), but do not know this value with certainty (except for the last trading period). Of course, the realism of this experimental design is not without cost. First, learning is more difficult here because the situation encountered by the subjects is not stationary. Second, a well grounded prediction of the equilibrium price is only possible under the assumption of risk neutrality. It is, however, possible to predict a certain shape of the time series of prices under the alternative assumption of risk aversion. Finally, predictions about the allocation of assets are not possible, since this would require knowledge of each participant's degree of risk aversion (see Krahen/Rieck/Theissen 1997 for an attempt to construct a simple measure of risk aversion for experimental purposes). We believe, however, that these problems are more than offset by the additional insights our experimental design may yield.



## 2.2 Description

In the experiments, participants trade a risky security against money. We conducted 9 experimental sessions, each consisting of 14 trading periods. Each session lasted for approximately three hours, including the time for reading the instructions.

### Subjects and payoff

All subjects were undergraduate students of Economics and Business Administration at the University of Giessen. To guarantee that participants had the same level of experience in all experimental sessions, each subject was only allowed to participate in one of the experiments. The participants were motivated by monetary payoffs approximately equivalent to the going hourly rates normally earned by students for paid work. The payoffs were proportional to the success in the experiments, that is, the values of the final portfolios were converted to real money according to a preannounced factor. Each portfolio consisted of the two assets “money” and “security”. The security’s value was determined by the following stochastic process.

### Asset value

The basic value of the security follows a binomial process with an upward drift. It starts with a value predetermined by the experimenter. After each round of trading a ball is drawn from a box containing six red and four white balls. If a red ball is drawn, the basic value rises by 7%; if a white ball is drawn, it decreases by 7%, so that the expected upward drift is 1.4% per period. This process for the basic value is common knowledge. To assure that subjects did not question the randomness of the chance value movements, each ball was drawn by one of the (informed) traders. The expectation in period  $t$  of the asset’s payoff-relevant final value (in round 14) is given by

$$E_t(V_{14}) = V_t * 1.014^{(14-t)}$$

where  $V$  denotes the basic value and  $E(\cdot)$  is the expectations operator. This expected value can be interpreted as the *fundamental value* of the asset for a risk neutral investor.

The starting value and the actual realizations of the value process are revealed to only half of the participants, termed the “*informed traders*” or “*insiders*”. Both the existence and the number of informed traders are common knowledge. Using their information, insiders can easily calculate the fundamental value using the above formula. As the number of remaining chance movements is reduced from trading period to trading period, the variance of the fundamental value declines in the course of the experiment,<sup>2</sup> and the informed traders’ information becomes more and more precise. In trading period 14, they know the final fundamental value with certainty.

The uninformed traders, on the other hand, have no information about the current basic value, not even in period 1. We chose different starting values for the nine experiments. Hence, uninformed subjects have to infer all information about the fundamental value from market prices and transaction volumes.

The stochastic value process is a characteristic of our design. As argued earlier, this procedure guarantees fundamental values which do not cause artificial bubbles. On the other hand, it adds considerable noise to the experimental results because each experimental session has its own realizations of fundamental values. At first sight, a solution could be to create one path of fundamental values (either deliberately chosen values or one realization of a random process) and to conduct all experimental sessions with this value path. However, the problem with this approach is that there is no way of assuring that the participants believe the process to be ran-

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<sup>2</sup> This decline in the volatility of the expected asset value can be justified by assuming a fixed horizon.

dom. They might well perceive the experiment as a strategic game against the experimenter. Note that the asset value in period 14 is used to value the portfolios and pay the subjects. Subjects might thus expect the experimenter to choose declining values, particularly near the end of the experiment. In our experiments this problem is overcome by having subjects publicly draw the realizations of the fundamental value process.

### *The market institution*

In six of the experiments a call market trading institution (batched auction) was employed (see table 1 for details of the experiments). Each participant is allowed to submit at most one buy and one sell order in each period with no restrictions on order size beyond the prohibition of short sales. Only limit orders are allowed.<sup>3</sup> Individual orders are private knowledge (i.e. there is no open orderbook). After submission of all orders, the auctioneer calculates the market price at which all transactions take place. This price is determined such that the trading volume is maximized. If several prices lead to the same transaction volume, i.e. there is no unique equilibrium price, the lower bound of the interval of volume maximizing prices is chosen.<sup>4</sup>

If demand and supply are not equal at the market price, priority rules for order execution are as follows: (i) the limit price (higher buy and lower sell orders get priority), (ii) order size (larger orders get priority). If this is not sufficient to clear the market, a random mechanism is employed to decide which orders are executed. The first four call market experiments were conducted as classroom experiments. The two remaining experiments were conducted using the

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<sup>3</sup> Note that a market order can be mimicked by setting the limit price arbitrarily high (in the case of a buy order) or low (in the case of a sell order).

<sup>4</sup> This price setting rule creates problems when the interval of volume maximizing prices is large. In the last period of experiment 15, one subject (probably erroneously because the lowest price so far had been 400) entered a large sell order at a price limit of 10. This single order caused the market price to be 10. Otherwise there would have been no transaction, the market spread being 360/363. We replaced the market price of 10 by the midpoint of the spread, 361,5, in the analysis. As no decisions were made after period 14, the price announcement of 10 in the experiment cannot have influenced any of the results. Another experiment where a similar problem occurred in an early period was completely discarded from the data set.

MAX computerized trading system (cf. Krahnert / Rieck / Theissen 1995). This is a Windows-based computer program where subjects can submit their orders via computers; they also receive all information via the trading screen. Of course, only the informed subjects have access to the information about the basic value. The trading rules are completely identical to those used in the classroom experiments. Computerizing the trading process thus shortens the time needed for an experiment without, in our opinion, affecting the results.<sup>5</sup>

Three of the nine experiments were conducted as computerized continuous double auctions, also using the MAX software system. These auctions were organized as follows: each subject can submit an order at any point in time if this order narrows the market spread. The buy order with the highest and the sell order with the lowest price limit are displayed to all traders. In order to avoid the identification of informed orders, the subject that has entered the order is not identified to others, i.e., trading is anonymous. Transactions occur whenever a trader (completely or partially) accepts a standing quote.<sup>6</sup>

### Initial endowments

At the beginning of each session, subjects start with asymmetric endowments. Half of the participants possess only cash, the others possess only securities. Thus, the experimental design is 2x2 factorial: Subjects are assigned randomly to one of the four groups (informed / uninformed, cash only / assets only).

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<sup>5</sup> Note that most of the arguments brought forward in favor of, or against, screen trading do not apply here. Most importantly, since no transaction costs exist, screen trading does not lead to cost reduction. On the other hand, in the classroom experiments no communication between subjects was allowed. There is thus no "floor information" that can be used for decision making. The information sets of the subjects are, therefore, not altered by switching to screen trading.

<sup>6</sup> In some cases a subject, due to a typing error, entered a very unfavorable order (e.g. a sell order at a price of 1) which, in turn, was immediately accepted by another trader. We have discarded the corresponding transactions from the data set. This resulted in the elimination of a total of 6 transactions. In all cases the transaction price was less than 12% of the previous transaction price. It therefore seems safe to attribute these transactions to typing errors.

There are basically four reasons for the asymmetry of the endowments. First, a trading motive is induced because risk averse subjects will want to hold diversified portfolios rather than only cash or only assets. Second, symmetric endowments would have enabled uninformed traders to use the ratio of cash and asset holdings to estimate the initial fundamental value. We wanted to avoid this in order to have better control over the expectations of uninformed traders. Third, the asymmetry removes the incentive of informed traders to collude in order to collectively exploit uninformed traders by means of price manipulation. Finally, the asymmetry allows us to analyze whether the initial portfolio structure affects individual behavior. In particular, we can test whether an endowment effect (Kahneman/Knetsch/Thaler 1990) exists.

#### Subjects' expectations

Prior to each trading round subjects have to write down their expectations of the next period's market price and the asset value at the end of the experiment (i.e. after round 14). Subjects are informed that the variables they have to forecast are the determinants of their payoff. There is, however, no additional reward for the quality of the forecasts.<sup>7</sup>

#### Instructions

The details of the experiment are explained to the subjects in a set of written instructions (available from the authors on request). After having read the instructions, participants have to pass a self-test. The experiment does not start until every subject has correctly answered the questions in the self-test. Subjects who were not able to answer these questions correctly were excluded from the experiments. This happened to one subject in two experiments.

Details of the nine market experiments are given in table 1.

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<sup>7</sup> Rewarding the quality of the forecasts would give subjects an incentive to “diversify” between their trading decisions in the experiments and the forecast they make. They could, for example, buy assets expecting a high value and “hedge” against a low value by reporting an appropriately biased forecast.

[insert table 1 here]

### 3 Hypotheses and Results

The central issue in a market with asymmetric information is its informational efficiency. We address this problem by answering the following questions:

1. To what extent are informed participants able to exploit their informational advantage?
2. If insiders do earn excess returns, do these accrue in early or late trading periods? Is there a relation between the price path and the accumulation of insider gains?
3. Are there differences in the degree of informational efficiency between the continuous double auction and the call market?
4. Does the initial portfolio structure allow predictions about the final portfolio structure, i.e. is there evidence of an endowment effect? If so, are there differences between informed and uninformed subjects with respect to portfolio composition?

#### 3.1 Efficiency of Prices and Insider Advantages

The question of informational efficiency is split into two parts. First, we ask if prices equal the fundamental value. If they do, insiders cannot exploit their informational advantage since their information is immediately revealed through prices. If they are not, then insiders may earn excess returns. In that case, the second question concerns the magnitude of the difference in earnings between insiders and outsiders.

If all traders were risk neutral, prices should equal the fundamental value, i.e., the mathematical expectation of the basic value of period 14. If traders were risk averse, prices should be below that fundamental value. However, the difference  $E_t(V_{14}) - P_t$  should decrease over time,

reaching zero in period 14, since the risk associated with the fundamental value process decreases over time (in period 14 insiders know the fundamental value with certainty). Figures 1 and 2 depict the price paths realized in the nine experiments. The figures show the relative difference between the fundamental value and the market price  $\frac{E_t(V_{14}) - P_t}{E_t(V_{14})}$  in the call market experiments (figure 1) and the double auction experiments (figure 2), respectively. The difference between price and value has been normalized by the respective fundamental value in order to make the experiments comparable.

[insert figure 1 here]

[insert figure 2 here]

These figures show that prices tend to converge to their equilibrium level in period 14. During the course of the experiment, however, prices deviate considerably from their equilibrium levels, while the directions and magnitudes of these deviations do not exhibit any clear pattern and differ considerably between experiments.

Given the observed deviations of prices from the fundamental value we can conclude that there is a potential for insider gains. This finding is confirmed by table 2 which shows results for two measures of informational efficiency. The first is the mean absolute difference (MAD) between prices and the fundamental value:

$$\text{MAD} = \frac{1}{14} \sum_{i=1}^{14} |P_t - E_t(V_{14})|$$

The second measure is the mean relative difference (MRD), defined as

$$\text{MRD} = \frac{1}{14} \sum_{t=1}^{14} \frac{|P_t - E_t(V_{14})|}{E_t(V_{14})}.$$

It expresses the average absolute deviation between price and fundamental value as a fraction of the latter. It thus corrects the MAD measure for differences in the initial value and the subsequent realizations of the fundamental value process and is therefore better suited for comparisons between the experiments.

[insert table 2 here]

The MRD measure in table 2 reveals that the price is, on average, between 6% and 26% away from the fundamental value. Are these deviations high or low? If we share the view of Black 1986 cited in the introduction, then the experimental markets are efficient. On the other hand, the decision problem is much easier than the one encountered in real world markets. We therefore have to leave unanswered the question of whether the results reported in table 2 are “good” or “bad”. In any case, however, they suggest that there is a potential for insider gains. The question that we now turn to is whether informed participants are able to exploit that potential for excess returns.

Table 3 provides evidence relating to this question. It shows the ratio of the insiders’ average payoff to the outsiders’ average payoff for each experiment. The second and third row give the figures for traders with cash-only and assets-only endowments separately. This is done because the initial portfolio structure, together with the realizations of the fundamental value process, may influence portfolio values.

[insert table 3 here]

Table 3 shows that the insider position is, on average over all experiments, advantageous: the informed participants’ payoff is 6.1% higher than the uninformed participants’ income. This advantage seems to be more pronounced for those insiders with an initial portfolio consisting of cash only. The difference to the assets-only group is, however, partly due to the result of



experiment 15 where the excess gain to insiders amounts to 27.4%. If this observation is eliminated the figures read 1.052 for the cash-only group and 1.024 for the assets-only group.

The differences between the experiments are considerable. In some experiments insiders are not able to earn any excess profits at all (e.g. experiments 8 and 9) whereas in others insider advantages are substantial. It is natural to relate these differences to the pricing efficiency of the experiments. We find that the rank correlation between the profitability of the insider position as measured in table 3 and the MAD of table 2 is 0.5833. This is (marginally) significant at the 5% level (one-tailed test). It therefore appears that insiders can take more advantage of their superior information when the market is less efficient.

This result is not surprising. The crucial question is: *why* is the market inefficient, and what determines the degree of inefficiency? Before we turn to this question in the following section, some remarks are in order. First, the experimental results of Smith/Suchanek/Williams 1988 have shown that a systematic tendency toward overvaluation may exist even in an environment without asymmetric information. Second, our results cannot be explained by assuming that informed subjects collectively “exploit” the uninformed in some experiments but fail to do so in others. The reason is that informed participants as a group do not have a common incentive to drive prices up or down. At the beginning of the experiment half of the informed subjects are endowed with cash (and thus have an incentive to drive prices down) while the other half is endowed with assets (and thus have an incentive to drive prices up). One might, therefore, expect that competition between informed participants leads to efficient prices, as models like Holden/Subrahmanyam 1992 would predict in the case of multiple insiders. As table 2 has shown, this did not happen. This may be partly due to the budget restriction imposed by the experimental design. As neither credit nor short sales were allowed, participants had to optimize their orders over time in order to be able to buy and sell in later periods. This may have

led to a reluctance to submit large buy or sell orders. The order volume of informed traders was thus insufficient to bring prices quickly back to their equilibrium level. Loosening the budget constraint might help to improve the efficiency of prices, although King et al. (1993) report that allowing short sales did not reduce the occurrence of bubbles in their experiments.

### **3.2 The Dynamics of Insider Gains**

It is evident from the above analysis that there is, in most experiments, a potential for insider gains and that insiders are able to exploit their informational advantage when market prices are inefficient. On the other hand we have seen that insider activities are not usually sufficient to bring prices back to their fundamental level. This raises the question of when insider gains are actually realized and how they relate to market activities.

Since the 14 trading periods of an experiment are not independent from one another we have to treat each experiment as one observation. This leaves us with nine observations. We therefore do not intend to offer a statistical analysis of the data but instead restrict ourselves to a closer inspection of entire experimental sessions. For this purpose we chose the following four experiments:

- Experiment 6, which is characterized by persistent overpricing without any significant insider gains,
- Experiment 7, which exhibits very large price deviations,
- Experiment 12, a continuous double auction experiment whose price pattern exhibits underpricing as well as overpricing,
- Experiment 15, which is extreme in that insider gains are larger than in any other experiment although price deviations are not very pronounced.

In order to evaluate the (average) portfolio value of informed and uninformed traders after each trading period, we value the securities with their fundamental value given by

$$E_t(V_{14}) = V_t \times 1.014^{(14-t)}.$$

### Experiment 6

In experiment 6 informed participants failed to earn higher profits although the persistent overpricing demonstrated in figure 1 offered some opportunity for exploiting the informational advantage. Figure 3 provides a partial explanation of this finding. The dotted line represents the efficiency of prices as measured by the MRD measure. The solid line shows the net change in securities holdings of the informed traders in the respective trading period. It can be seen that in trading periods 4 and 5 they bought on balance a substantial number of securities from uninformed traders although they observed the overpricing. This is, in itself, not rational unless the overpricing persists.<sup>8</sup> Apart from this, in the case of experiment 6 the fundamental value reached its maximum in period 4. Thus, insiders bought shares that were overpriced *and* that eventually turned out to be worth less than could be expected at the time of buying.

[insert figure 3 here]

### Experiment 7

This experiment is characterized by large and persistent overpricing. As figure 4 reveals, insiders consistently sold shares. Furthermore, the fundamental value declined in the course of the experiment. In period 1 the fundamental value was 480, the actual period 14 value was 361. This reinforced the disadvantage of the uninformed traders and resulted in high excess gains for the insiders.

[insert figure 4 here]

### Experiment 12

Experiment 12 is a continuous double auction experiment. Prices were very efficient as evidenced by a mean average deviation of only 6%. Nevertheless, insider gains were larger than in the other two double auction experiments. Figure 5 reveals that insiders as a group sold assets in period 5 (when assets were slightly overpriced) and bought assets in periods 9, 10 and 11 (when assets were slightly underpriced). It is, however, not price efficiency that drove insider gains in this experiment but the subsequent realizations of the fundamental value process. In periods 9, 10 and 11, insiders bought, on balance, more than 100 (out of a total of 288) assets from the uninformed subjects. From period 8 onwards only red balls were drawn and thus the value of the assets rose considerably.

[insert figure 5 here]

### Experiment 15

In experiment 15 insiders realized very high excess returns even though prices were much more efficient than in some of the other experiments. Figure 6 helps to explain this finding. Informed participants consistently sold assets when they were overvalued. This drove prices back to their fundamental level several times. That is, insiders engaged in (profitable) arbitrage. In addition, from period 7 onwards, the fundamental value declined steadily (six white balls were drawn in seven consecutive drawings). This further devalued the portfolios of the uninformed subjects, who were, on average, buying assets.

[insert figure 6 here]

The description of the four experiments has demonstrated that the relative performance of informed traders as a group is explained by a variety of factors, some of which (e.g. the realiza-

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<sup>8</sup> It is, however, consistent with the results of Smith/Suchanek/Williams (1988) and others.

tion of the fundamental value process) are specific to a certain experiment. As a general result, one would expect to find that insider gains are at least partially due to informed participants as a group buying shares when they are underpriced and selling shares when they are overpriced. We test this hypothesis using data from all nine experiments. The hypothesis implies a systematic relationship between the direction and magnitude of the pricing error and the allocation of shares between informed and uninformed participants. Specifically, informed traders as a group should end up holding a low [high] fraction of the assets at the end of an experiment when the asset is overvalued [undervalued] on average. This conjecture is supported by the data. The rank correlation between the pricing error, averaged over the 14 periods of an experiment, and the fraction of shares held by insiders at the end of the experiment is  $-0.78$  which is significant at the 5% level.

To summarize, the observed insider profits can be explained *ex post*. The efficiency of the transaction prices and the realization of the fundamental value process are the main determinants. However, the behavior of the informed participants, e.g. the question of whether they act aggressively enough to bring prices back to their equilibrium level as in experiment 15, is somewhat exogenous to the explanation. Possible explanations for the differences in individual behavior may be revealed by a detailed analysis of the relation between past price (and basic value) patterns and specific decisions. This is an interesting field for future research.

### **3.3 Double Auction Versus Call Markets**

Six of the nine experiments used a call market institution while in the remaining three a continuous double auction was employed. In a comparison of market institutions each experiment is one observation. Therefore, we do not intend a formal statistical analysis but rather describe our findings and relate them to what has been found in the literature.

The continuous double auction institution is renowned for the fast convergence of prices and the high allocative efficiency it attains (see Friedman 1993b for a recent survey and Smith et al. 1982). Therefore most experiments involving capital markets with asymmetric information have used the continuous double auction mechanism. Among the few exceptions is Friedman 1993a. He found that there were no significant differences between the informational efficiency of the call market and the double auction. Allocational efficiency and trading volume were higher in the double auction whereas the call market provides greater market depth.<sup>9</sup> Schnitzlein 1996 compares the performance of the call market and the double auction in the presence of a monopolist insider (as in Kyle 1985). In his experiments the call market provides higher liquidity and lower adverse selection costs to uninformed noise traders at the expense of slightly less efficient prices.

The findings for our experiments are summarized in table 4. Consistent with the findings of Friedman 1993a, the trading volume is higher in the double auction markets. The results concerning informational efficiency are not in line with those of Friedman but rather support the findings of Schnitzlein 1996. It appears that the efficiency of the double auction market as measured by the MAD and MRD measure is higher than the efficiency of the call markets. This is remarkable since the number of participants was considerably higher in the call market experiments (29, on average, as compared to 11 in the double auction markets). These different findings might be attributable to the different experimental design. For example, Friedman 1993b suggests that a common value design, i.e. a design where the value of the asset is the same for all traders (as is the case in our experiments), might lead to different conclusions than the traditional private value design used in most previous experiments.

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<sup>9</sup> Depth is measured by the bid-ask spread. In the call market the spread is defined as the difference between the lowest rejected ask and the highest rejected bid.

To conclude, our experiments suggest that the double auction institution depicts higher trading volume and more efficient prices. We cannot present results on allocational efficiency since our design does not allow well grounded predictions as to the allocation of shares. However, the very high allocational efficiency of the continuous double auction institution has repeatedly been demonstrated and does not even seem to depend on trader rationality (Gode/Sunder 1993 a, b).

[insert table 4 here]

### **3.4 Portfolio Structure**

Subjects are assigned randomly to one of two endowment groups. They either have an initial portfolio consisting entirely of cash or entirely of assets. In equilibrium, risk preferences should determine the number of shares held by each participant. Due to the random group assignment, we do not expect any systematic difference between the (average) risk preferences of the two groups. Therefore, after some trading periods in which portfolios are being balanced, there should be no significant difference in the portfolio structures. Any test of this hypothesis should treat informed and uninformed subjects separately since, as we have seen, there are systematic differences between the fractions of shares held by insiders and outsiders.

The data show that portfolio balancing is a time-consuming process, accounting on average for half the time needed for the experiment. We measure this as follows: initially, those subjects who started with a portfolio of cash can only buy shares while the other group can only sell shares. Hence, in the subsequent periods, the traders of the cash-only group remain, on average, on the buying side whereas the members of the assets-only group remains, on average, on the selling side. We consider portfolio balancing as terminated in the first period in which the

subjects of the cash-only group *sell* assets on average. This happens between period 4 (in experiments 11 and 12) and period 9 (in experiment 7). Figure 7 shows a typical pattern.

[insert figure 7 here]

There is some evidence that portfolio balancing takes less time in the continuous double auction experiments (average 4.7 periods as compared to 7 periods for the call market experiments). This can be explained by the characteristics of the two trading institutions. In a call market a trader who wants to transact submits a limit buy or sell order. If the limit price of a buy order is too low or the limit of a sell order too high, the trader has to delay his transaction for at least one period. The double auction market, on the other hand, makes it possible to adjust limit prices *within* a trading period. Therefore, participants are able to adjust their orders to the terms of trade of the market, and to thus accomplish their transactions faster.

Table 5 compares the final portfolios of the cash-only and the assets-only groups. The figures reveal that there is some evidence of an endowment effect. Subjects who are endowed with a portfolio consisting entirely of assets tend to hold more shares, on average, than subjects in the cash-only group. This tendency seems to be more pronounced for the uninformed participants. One possible explanation for this finding is that subjects who possess less information are more inclined to “stick to what they have”. The status quo serves as a reference point and subjects try to “insure” against the uncertainty caused by their information status by not moving too far away from their initial portfolio. This hypothesis is supported by the fact that the transaction volume of the informed participants is higher than that of the uninformed in 6 out of the 9 experiments.

[insert table 5 here]



The endowment effect just described is not a consequence of subjects not having enough time to balance their portfolios since, as was already demonstrated, portfolio balancing is terminated after about half of the experiment.

#### **4 Summary and Conclusion**

In this paper we have described the results of nine market experiments designed to examine the effect of asymmetric information and differing endowments in a multiperiod setting with a long-lived asset. Two alternative market institutions, a call market and a continuous double auction, were employed. The fundamental value process, a binomial process with an upward drift, was designed to conform to the “real life” experience of asset trading (because the fundamental value converges to an uncertain finite value and not to zero as is the case in dividend models).

Prices in these experimental markets did not fully reveal the information of informed traders, thus creating a potential for insider gains. The profitability of the insider position varied considerably between experiments. Insider gains could be explained, with the efficiency of the prices and the realizations of the fundamental value process being their main determinants.

The behavior of the experimental subjects, e.g. the question of whether insiders act aggressively on their information and thus bring prices back to the fundamental value, is exogenous to the explanation of the market outcomes. That subjects do not, however, behave entirely rationally is evidenced by an endowment effect: subjects whose initial portfolio consisted of assets only tend to hold more shares at the end of the experiment than do subjects whose initial endowment consisted entirely of cash. It therefore seems safe to conclude that quasi-rational, behavioral theories of asset trading play a role in explaining the experimental results.

The continuous double auction tends to produce better results than the call market institution: prices are closer to the fundamental value, insider gains are smaller, and trading volume is higher. It thus appears that the organization of the trading process influences the market outcome. This suggests that the recent proposals to change the organization of trading on some major European exchanges will have economic consequences beyond the liquidity and transaction cost considerations usually brought forward to advance the proposals.

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Table 1

## Details of the nine market experiments

Columns 1, 2 and 3 show the number of the experiment<sup>\*</sup>, the trading mechanism employed and the number of participants, respectively. Column 4 contains the specific realization of the fundamental value process. The initial value was chosen by the experimenter and, before each of the rounds 2-14, a ball was drawn from a box determining whether the fundamental value goes up by 7% (probability 0.6) or moves down by 7% (probability 0.4). The figures in column 4 give the starting value and the terminal value after 13 drawings. The last column shows the average monetary payoff to the participants.

<b>Experiment</b>	<b>Trading institution</b>	<b>No. of participants</b>	<b>Starting and final value of the asset</b>	<b>Average earnings</b>
6	call market	36	500 - 519	DM 25.86
7	call market	44	400 - 361	DM 25.26
8	call market	25	250 - 226	DM 24.88
9	call market	34	300 - 413	DM 30.60
10	computerized cont. double auction	9	400 - 550	DM 29.00
11	computerized cont. double auction	11	300 - 413	DM 28.91
12	computerized cont. double auction	12	500 - 598	DM 26.35
15	computerized call market	18	350 - 364	DM 35.67
16	computerized call market	17	400 - 416	DM 42.02

\* The first number is 6 because five previous experiments were conducted with a different design.

Table 2

## Mean absolute difference between price and fundamental value

Table 2 shows the mean absolute difference (MAD) and the mean relative difference (MRD) for each of the nine experiments. The MAD measure is defined as

$$\text{MAD} = \frac{1}{14} \sum_{t=1}^{14} |P_t - E_t(V_{14})|$$

It is thus the average (over the 14 trading periods) of the absolute value of the deviation between price and fundamental value (“mispricing”). The MRD measure is defined as

$$\text{MRD} = \frac{1}{14} \sum_{t=1}^{14} \frac{|P_t - E_t(V_{14})|}{E_t(V_{14})}$$

It thus corrects the MAD measure for different fundamental value levels in the experiments. A value of 0.15 indicates that the average absolute deviation between price and fundamental value is 15% of the fundamental value.

Exp.	6	7	8	9	10	11	12	15	16
MAD	82.45	95.97	18.84	27.52	47.56	32.75	30.38	36.31	94.05
MRD	0.15	0.26	0.07	0.07	0.09	0.08	0.06	0.08	0.20

Table 3

## Ratio of average earnings of informed and uninformed participants

Figures in table 3 show the ratio of the average earnings of the informed and the uninformed participants for each experiment. In columns 3 and 4 this is done separately for participants with a cash-only and an assets-only initial endowment. The last row contains the (unweighted) average over the nine experiments.

Experiment	all traders	cash-only	assets-only
6	1.029	0.979	1.057
7	1.141	1.100	1.153
8	0.996	0.987	1.007
9	0.972	0.996	0.961
10	1.032	1.027	1.066
11	1.008	1.041	1.001
12	1.060	1.110	1.015
15	1.274	1.427	1.175
16	1.037	1.179	0.935
average over all exp.	1.061	1.094	1.041



Table 4

## Comparison of Call Market and Double Auction

The table contains averages for the six call market experiments and the three double auction market experiments. MAD is the mean absolute difference between price  $P_t$  and the expectation in period  $t$  of the round 14 fundamental value,  $E_t(V_{14}) = V_t * 1.014^{(14-t)}$ . MRD is the mean of the normalized absolute difference between price  $P_t$  and the expectation in period  $t$  of the round 14 fundamental value. Normalization is obtained by dividing by  $E_t(V_{14})$ , which makes experiments with different starting values and subsequent realizations of the fundamental value process comparable. Insider advantage is the ratio of the average payoff to the informed participants and the average payoff to the uninformed.<sup>10</sup> Normalized trading volume is the average trading volume divided by the total number of shares outstanding.

	MAD	MRD	Insider Advantage	Normalized Volume
Call Market	59.19	0.138	1.056	0.07
Double Auction	36.90	0.077	1.033	0.22

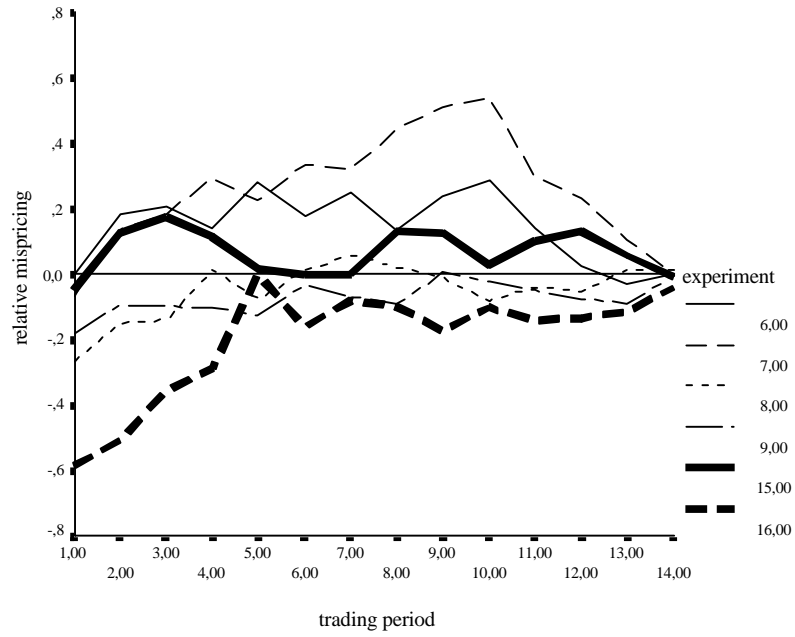
<sup>10</sup> The values in table 4 are different from an average across experiments calculated from table 3 because the number of participants differs across experiments.

Table 5

## Comparison of initial and terminal portfolio structures

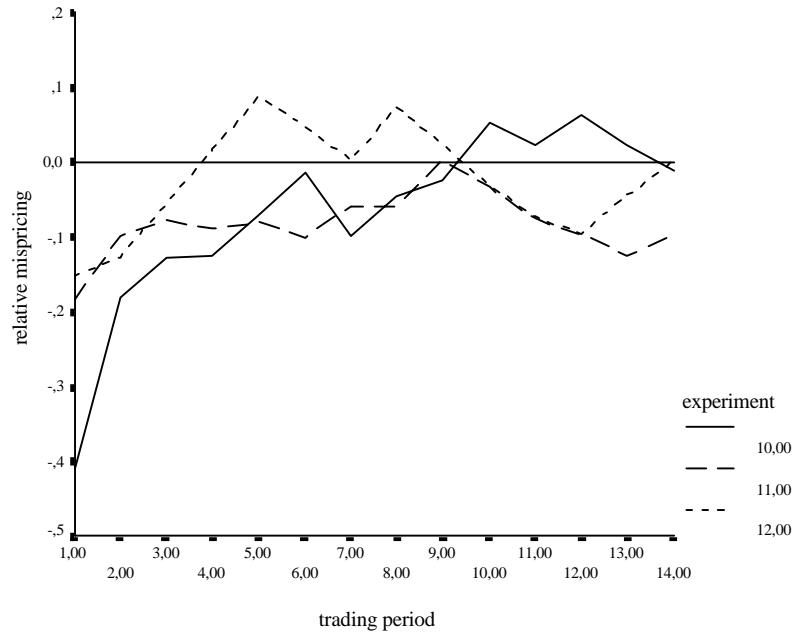
The table shows the ratios of the final asset holdings (i.e. after termination of period 14) of those participants whose initial portfolio consisted of assets only and those whose initial portfolio consisted of cash only (termed assets-only group and cash-only group, respectively, in the text). A value of 1.80 is to be interpreted as follows: final asset holdings of the assets-only group exceed those of the cash-only group by a factor of 1.8; e.g. subjects in the former group hold 18 shares on average while those in the latter group hold 10. Column 2 shows this ratio for all subjects, while columns 3 and 4 contain this ratio for the informed and the uninformed subjects separately.

Experiment	all	uninformed	informed
6	1.80	2.29	1.34
7	1.29	1.30	1.26
8	0.94	1.08	0.80
9	1.37	2.67	1.00
10	2.49	2.82	2.27
11	1.64	16.0	1.23
12	1.25	0.81	1.74
15	1.41	1.42	1.33
16	1.73	1.89	1.57



**Figure 1: Relative mispricing in the call market experiments:** The lines plot the relative mispricing for each of the six call market experiments. “Mispricing” is defined as the difference between the price in period  $t$  and the mathematical expected value in period  $t$  of the final (i.e. period 14) fundamental value. To obtain the relative mispricing, this variable is divided by the mathematical expected value in period  $t$  of the final fundamental value.

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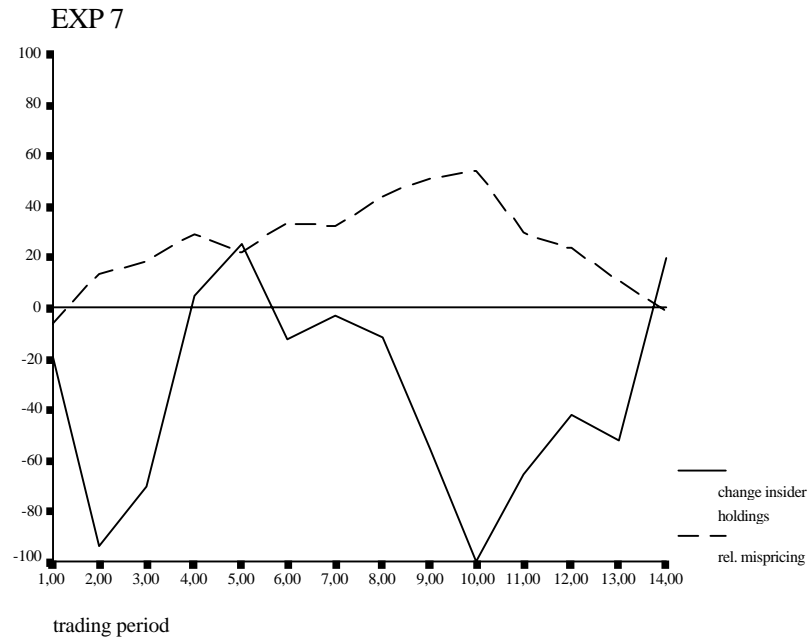
**Figure 2: Relative mispricing in the double auction experiments:** The lines plot the relative mispricing for each of the three double auction experiments. “Mispricing” is defined as the difference between the price in period  $t$  and the mathematical expected value in period  $t$  of the final (i.e. period 14) fundamental value. To obtain the relative mispricing, this variable is divided by the mathematical expected value in period  $t$  of the final fundamental value.

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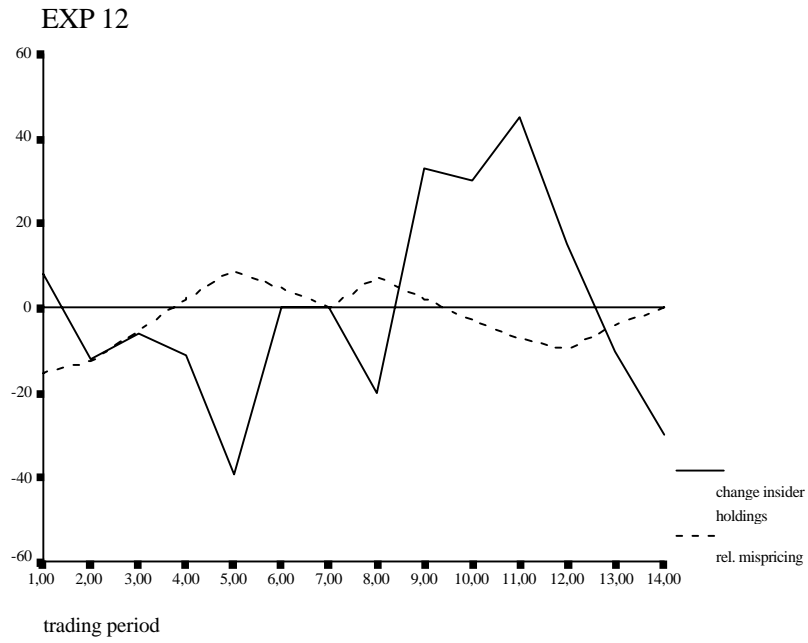


**Figure 3: Net change in asset holdings and efficiency of prices, experiment 6:** The broken line plots the relative mispricing, expressed in percent, for each trading period of experiment 6, the solid line plots the net change in asset holdings of the informed traders in the respective period. The relative mispricing is defined as the difference between the price in period  $t$  and the fundamental value, divided by the latter. The net changes in asset holdings are obtained by summing the numbers of assets bought and sold by insiders in the respective period.

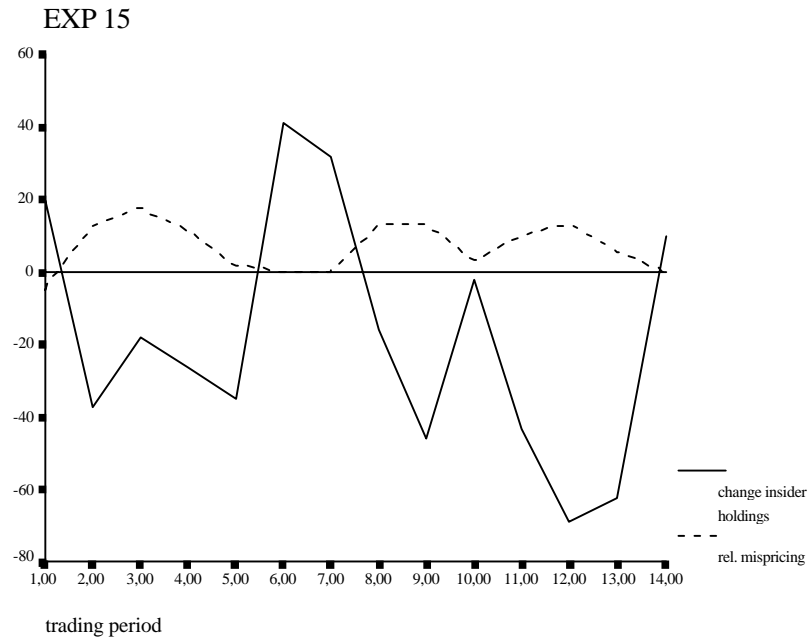
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**Figure 4: Net change in asset holdings and efficiency of prices, experiment 7. For legend see figure 3.**

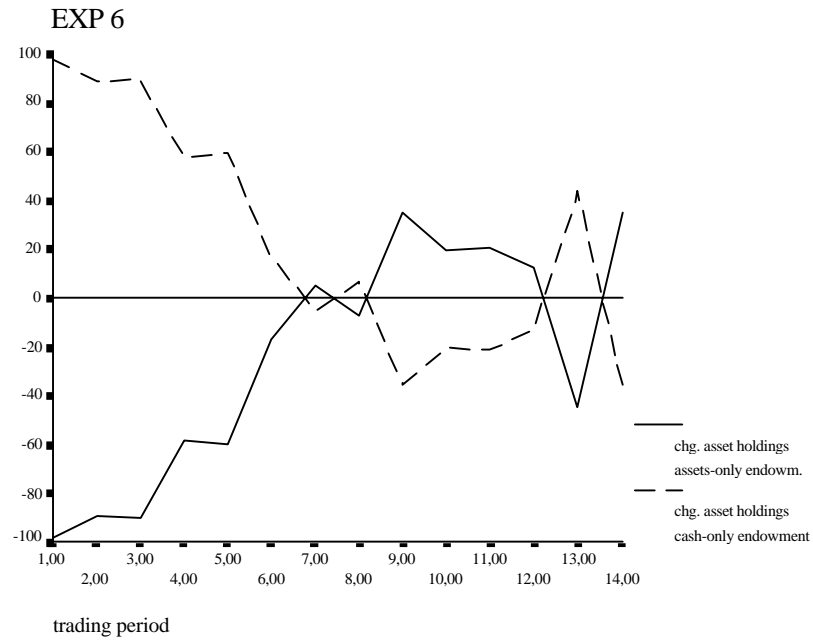


**Figure 5: Net change in asset holdings and efficiency of prices, experiment 12. For legend see figure 3.**



**Figure 6: Net change in asset holdings and efficiency of prices, experiment 15. For legend see figure 3.**





**Figure 7: Net change in asset holdings and efficiency of prices, experiment 6:** The lines plot the net change in asset holdings against periods. The solid line applies to the group of traders with an initial portfolio consisting of only assets, the broken line applies to the cash-only group. The net changes in asset holdings are obtained by summing the numbers of assets bought or sold by the traders of the respective group.

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