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Bubbles and information: An experiment*

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Abstract

We study whether information about imminent future dividends can abate bubbles in experimental asset markets. Using the seminal design of Smith et al. (1988) we find that markets where traders are asymmetrically informed about future dividends have smaller, and shorter, bubbles than markets with symmetrically informed or uninformed traders. Hence, fundamental values are better reflected in market prices – implying higher market efficiency – when some traders know more than others about the future prospects of an asset. We also find that asymmetric information has a similar abating impact on bubbles as when uninformed traders accumulate experience, though for different reasons.

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1 Introduction

Since the seminal paper by Vernon L. Smith, Gerry L. Suchanek and Arlington W. Williams (henceforth SSW, 1988) economists have been intrigued by the persistence of bubbles in experimental asset markets. Bubbles are characterized by large deviations of prices from the fundamental values of traded assets. Whereas fundamental values are hard, if not impossible, to determine in real markets, experimental asset markets can control both for an asset's fundamental value by letting the experimenter define it exogenously and for the information of market participants by instructing them about the process generating the fundamental value. Despite the fact that the development of an asset's fundamental value over time is common information in such experimental asset markets, the literature that followed SSW (1988) has documented that bubbles are robust to a plethora of modifications of the original SSW-design.[1]

To date, trader experience has been identified as the main factor that moderates bubbles.[2] Exposing traders repeatedly to a stationary market environment reduces bubbles to the extent that prices track fundamentals very closely when traders are twice-experienced with a given market setting. Martin Dufwenberg, Tobias Lindqvist and Evan Moore (henceforth DLM, 2005) have shown that even a small fraction of experienced traders in relation to

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[1] None of the following factors has been found to prevent bubbles: short selling (Ronald R. King et al., 1993; Ernan Haruvy and Charles N. Noussair, 2006); buying on margin (King et al., 1993); using call markets instead of continuous double auctions (Mark van Boening, Williams and Shawn LaMaster, 1993); adding a parallel market with a short-term asset that exists only for one period (Vivian Lei, Noussair and Charles R. Plott, 2001); keeping the fundamental value constant over time (Noussair, Stephane Robin and Bernard Ruffieux, 2001) instead of letting it decline as in SSW; precluding speculation by prohibiting buyers to resell the asset and sellers to buy it (Lei et al., 2001); asking participants for expectations about future prices (Haruvy, Yaron Lahav and Noussair, 2007); or running the experimental markets with professional business persons (SSW, 1988; King et al., 1993).

[2] Introducing a futures market alongside the spot market has also been found to influence the size of bubbles, though the evidence is less clear than with respect to experience. David Porter and Smith (1995) have

inexperienced ones suffices to reduce bubbles considerably, such that prices in markets with a mixture of experienced and inexperienced traders are not different from markets with twice-experienced traders only.[3]

In this paper we examine whether information of traders about imminent dividends – rather than experience from previous markets – helps to reduce or eliminate bubbles. Similar to the claim of DLM (2005) that real financial markets are characterized by a mixture of experienced and inexperienced traders, we argue that there is heterogeneity across traders on real markets with respect to their knowledge about the future development of an asset's fundamental value. However, although it seems obvious that analysts and investors on real financial markets spend a lot of money and time to gain knowledge about future cash flows as an indicator of a company's fundamental value, it is hardly possible to control for traders' knowledge (and the accuracy of this knowledge) about future events since traders would have no incentive to reveal their information. Therefore, we exploit one of the key methodological advantages of experimental economics, i.e., that it offers perfect control over subjects' information.

More specifically, we study the development of prices in experimental asset markets where traders may have knowledge about the future realization of an asset's dividend one or two periods ahead. In addition to a control treatment, where no trader has advance knowledge of future dividends, we have one treatment in which we inform each trader at the beginning of a trading period about the asset's dividend realization at the end of the period. We find that

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reported futures markets (for one particular period) to reduce, but not eliminate, bubbles. Noussair and Steven Tucker (2006) have found that futures markets (for each trading period) eliminate bubbles.

[3] A very recent paper by Reshmaan N. Hussam, Porter and Smith (2008) has shown that bubbles can be rekindled, though. Hussam et al. (2008) also stress that experience in the same environment is the only condition that has reliably eliminated price bubbles, but they show that markets with experienced subjects still produce bubbles if there are major changes in the environment, like when market liquidity or dividend uncertainty are strongly increased.

bubbles are not significantly reduced in the latter treatment. In a third treatment we implement an asymmetric information distribution, such that one third of traders knows the next two dividends for sure, one third of traders knows the next dividend, and one third of traders does not know any future dividend in advance. Our results show that this treatment reduces bubbles significantly, meaning that prices track fundamental values much closer than in the control treatment or the treatment with symmetric advance information. Hence, markets with heterogeneously informed traders about the future development of asset dividends are less prone to bubbles than when information about the imminent future is symmetrically distributed or not available at all. Interestingly, we find that the deviation of prices from fundamentals in markets with completely inexperienced, but asymmetrically informed traders is not different from the deviation that prevails in markets with twice-experienced traders who have no information about future dividends. This means that asymmetric information about (near) future dividends has the same moderating effects on bubbles as has been found consistently for experience.

Though no previous study has addressed the effects of information on bubbles in the way we do it, two papers are somewhat related since both manipulate the information of traders in a specific way. King et al. (1993) have studied a treatment where a subset of traders were familiarized with the SSW (1988)-paper and the characteristic patterns of price paths in such markets. If (and only if) those traders were given the chance of short-selling assets, then bubbles effectively disappeared. Note that this particular treatment of King et al. (1993) differs from our approach in two key aspects. First, insider information in their treatment does not mean advance knowledge of future dividends, but knowledge about typical price paths that were observed in past experiments. Second, they combined insider information with short-selling, whereas we will not allow short-selling. Also note that bubbles were robust to insider information in the setting of King et al. (1993) when short-selling was not possible.

Porter and Smith (1995) have designed a treatment where the uncertainty about future dividends was completely removed by having each asset pay a fixed amount for sure after each period. Hence, in their setting all traders knew *all* future dividends with certainty. Nevertheless, bubbles still occurred, lending strong support to the interpretation that behavioral and strategic uncertainty about other traders' behavior are the driving forces for bubbles. This finding implies that the common information on fundamental values is not sufficient to induce common knowledge as long as traders are uncertain whether other traders will act on this information. Note that Porter and Smith's (1995) treatment with known dividends constitutes an extreme case of perfect information about all future dividends of an asset. We have a much more limited, and probably more realistic, case in mind, where traders know at best the short-term future cash flows of a longer-lived asset. In addition, we focus on the effects of asymmetrically distributed information, since this seems to reflect the conditions on real markets better than if all traders share the same information.

In section 2 we introduce the experimental design in more detail. Section 3 presents the experimental results, and section 4 concludes the paper.

2 Experimental design

2.1 Basic market structure

Our experimental design is based on DLM (2005). Like them, we consider an experimental asset market in which assets of a virtual company can be traded. Holding an asset generates a stochastic dividend stream. In each period the asset pays a dividend of either 0 or 20 experimental currency units (ECU) with equal probability. The actual dividend in a particular period is the same for all assets that can be traded. Each *market* consists of three rounds, and each *round* in turn consists of ten trading *periods*. A trading period lasts 120 seconds. Trading is organized as a continuous double auction with open order book. Subjects can buy and sell any quantity of assets, given the limitations of their asset inventory and cash endowment, i.e., neither loans are provided nor is short selling allowed. Cash and stock holdings are carried over from one period to the next within a given round. At the beginning of a new round of ten periods the inventories are reset to the initial starting levels. This means that an asset's life-span is ten periods. Since no "buy-out" is provided for holding an asset at the end of period 10, assets are worthless at the end of a round. This feature of the experimental design implies a declining fundamental value within each round. The expected dividend is 10 ECU per period. Assuming risk neutrality, the fundamental value is given by $k \times 10$ ECU, where k indicates the number of periods remaining. An asset's fundamental value is, therefore, declining from 100 ECU in period 1 to 10 ECU in period 10.

Each experimental market consists of six traders. Three of these traders are endowed with 3,000 ECU and 10 units of the asset at the beginning of each of the three rounds. The other three traders receive 1,000 ECU and 30 stocks at the start of each round. All traders are accurately informed about the dividend generating process of the asset (see the experimental instructions in Supplement A), in particular about the expected value (in terms of dividends) of holding the asset for a given number of periods.

2.2 Experimental treatments

Our three treatments differ with respect to the traders' knowledge about future dividends:

1) Treatment *CONTROL*. None of the six traders in a market knows any future dividend. Hence, when trading in period t starts, the realization of the asset's dividend for period t is unknown. Only when trading stops after 120 seconds the dividend becomes known to all traders and traders receive the dividend for each asset they hold at the end of period t. In the following, we speak of information level *I0* for traders in *CONTROL*.

2) Treatment *INFO*. When trading in period t starts, all traders already know the dividend that the asset will pay at the end of period t. Yet, traders have no information about the actual dividend in periods $z > t$. The information about period t's dividend is symmetrically distributed in this treatment, and we refer to information level *I1* for all traders in *INFO*, because they know the next dividend realization in advance.

3) Treatment *INSIDER*. Here we introduce three different types of traders with respect to their information about the asset's future dividends. Two traders get to know the dividends in periods t and t+1 before trading in period t begins. We call this information level *I2*. Two other traders have information level *I1*, hence they know period t's dividend realization before trading begins. The remaining two traders have information level *I0*, knowing only that the asset will pay with equal probability 0 ECU or 20 ECU in period t. Note that the information levels are randomly assigned to traders at the beginning of the experiment and remain fixed for the entire 30 trading periods. Traders know their own information level and the distribution of information levels, but they do not know the information level of a particular trader who has posted a bid or ask.

Table 1 summarizes the distribution of information levels in the three treatments.[4] Comparing the relation of prices to fundamental values in *CONTROL* and *INFO* will allow examining whether bubbles can be abated if traders know an asset's dividend already when they are still buying and selling it in a given period. In both *CONTROL* and *INFO* traders are symmetrically informed, though. Keeping the median information level (*I1*) constant, a

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[4] In the *INSIDER*-treatment it is ensured that the two traders with a given information level have a different initial endowment at the beginning of each round, i.e. one of them has 3,000 ECU and 10 stocks, and the other one 1,000 ECU and 30 stocks. Hence, the endowment is balanced within and across information levels in *INSIDER*.

comparison of *INFO* and *INSIDER* will reveal whether the asymmetric information distribution implemented in *INSIDER* has an effect on bubbles.

[Table 1 about here]

2.3 Experimental procedure

Before conducting the experiments, we drew randomly a sequence of 30 realizations of the dividend (of either 0 ECU or 20 ECU). We then created a second sequence by “mirroring” the randomly drawn sequence, such that in each period the dividends in both sequences were different.[5] Finally, we fixed these two sequences of dividends and used them in six markets each in each treatment (see supplement B). This procedure of pre-determining dividends in single markets was chosen in order not to confound possible differences across treatments by different realizations of the dividends in the three treatments. Traders’ computer screens were also identical across treatments. During a trading period traders were informed about their endowment in cash and stocks, the future dividends (if applicable), the current period’s trades, and the open order books for bids and asks. The prices of trades were also shown in a graphical chart (see the trading screen in the instructions, given in Supplement A). At the end of each period, traders saw a history screen with details on their endowment, this period’s closing prices and the actual dividend, a trader’s total dividend earnings from this period and the mean prices of all previous periods in a particular round.

We ran 12 markets in each treatment, yielding a total of 36 markets, in which 216 undergraduate students at the University of Innsbruck participated. None of the students had any prior experience in market experiments and none had been introduced to the literature initiated by SSW (1988). The recruitment of participants was done with ORSEE (Ben

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[5] If the dividend in period t is 0 ECU (20 ECU) in sequence 1, it is 20 ECU (0 ECU) in period t of sequence 2.

Greiner, 2004), and the experiment was computerized with zTree (Urs Fischbacher, 2007). Each experimental session was run with 18 participants (yielding three independent markets per session), and the average duration of a session was approximately 90 minutes. Average earnings were 24 Euro (about 36 Dollars at the time of the experiment).

3 Results

Figure 1 presents the development of average prices in the three treatments. Recall that each market consists of three rounds with 10 periods each. The dotted line indicates the declining fundamental value. The line with the empty circles represents the average price across the 12 markets in treatment *CONTROL*. As is typical for such markets, there is a marked difference between the average trading price and the fundamental value, and the difference is typically growing within a given round of 10 periods. Also note that with repetition, i.e. across the three rounds, the gap between the average price and the fundamental value decreases. This is the well-documented effect of experience. Hence, our *CONTROL*-treatment produces a price path that resembles closely what is known from previous findings.

[Figure 1 about here]

The crucial feature of Figure 1 is that providing traders with information about imminent dividends decreases the difference between the average prices and the fundamental value, even though traders know at best the next two dividends. Hence, information about future dividends seems to reduce the size of bubbles. In particular, the price path in *INSIDER* is always closest to the fundamental value, except for the first two periods.

It is noteworthy from Figure 1 that repetition leads to a convergence of prices to the fundamental value also in treatments *INFO* and *INSIDER*, since the gap between prices and the fundamental value decreases in the second and third round of the experiment. This confirms the robustness of experience in moderating bubbles even in situations where traders know imminent dividends.

[Figure 2 about here]

In Figure 2 we provide a comparative assessment of the effects of information about future dividends and experience about previous trading phases. To do so, we plot the average prices in *round 3* of *CONTROL*, i.e., for twice-experienced traders, versus the average prices in *round 1* of *INSIDER*, i.e., when traders are still inexperienced. It is striking how close the two price paths are, and they are not significantly different from each other according to a panel regression. We regard this as a very important finding as it shows that experience (in *CONTROL*) and information (in *INSIDER*) can have the same effects on the magnitude of bubbles.

[Table 2 about here]

Table 2 reports an OLS panel regression in order to examine the effects of information more rigorously. The dependent variable is the difference between the average trading price in period t and the fundamental value. A positive coefficient indicates overvaluation. The *CONTROL*-treatment serves as the benchmark. We see that the overvaluation is smaller in the *INFO*-treatment, but not significantly so. Yet, asymmetric information about the dividend realization in the current and the next period leads to a significantly smaller amount of overvaluation in *INSIDER* than in *CONTROL*. A Wald-test also shows that the overvaluation is significantly smaller in *INSIDER* than in *INFO* (p = 0.06). In sum, bubbles are abated significantly in the *INSIDER*-treatment with its asymmetric distribution of knowledge about imminent dividends.[6]

The other independent variables included in Table 2 show qualitative results that are fully consistent with previous findings (e.g., DLM, 2005). The overvaluation increases with the number of periods in a given round, but decreases across rounds, i.e., with an increase in experience. There is also strong path dependence, as overvaluation in the previous period has a positive effect on overvaluation in the current period.

[Table 3 about here]

In line with previous research we present in Table 3 some frequently used indicators to measure bubbles and overall market activity.[7] *Haessel's R^2* (Walter W. Haessel, 1978) measures the goodness-of-fit between the mean price per period and the fundamental value. The Haessel R^2 approaches 1 if trading prices converge to fundamental values. The *duration* of a bubble is measured as the number of periods (within rounds) in which there is an observed increase in the market price relative to the fundamental value. This means that duration $D = \max\{m : P_t - F_t < P_{t+1} - F_{t+1} < ... < P_{t+m} - F_{t+m}\}$. Finally, we measure the market

[6] The regression in Table 2 is based on the average trading price within a given period. Note that using the weighted average price (weighted by the number of stocks traded for a particular price) yields qualitatively identical results. We also ran regressions where we considered only the price of the first trade in a period (in order to examine whether the treatment differences can be systematically detected already at the beginning of a period or whether the treatment differences evolve within a period). We find that the very first trading price is significantly closer to the fundamental value in both treatments with information than in *CONTROL*, and closest in *INSIDER*. Given this finding we then checked whether there is also a treatment difference between the posted bids and posted asks before the first trade takes place within a given period. Again we find that these bids and asks are closer to the fundamental value in the treatments with information than in *CONTROL*.

[7] We dispense with further measures, like the normalized absolute price deviation, the normalized average price deviation, or the price amplitude (see DLM 2005, or Hussam et al., 2008), since the relation of prices to the fundamental value has been analyzed already in the discussion of Table 2.

turnover as $T = \sum_t V_t / S$, where *V* is the volume of trade in period *t* and *S* is the total number of assets in the market.

The Haessel R² is highest in *INSIDER*, supporting our previous finding that fundamental values are most closely tracked in this treatment. Though it fails significance in pairwise comparisons, the Haessel R² is larger in *INSIDER* than in the other two treatments combined ($p = 0.06$; Mann-Whitney U-test).

The duration of bubbles is longer in *CONTROL* than in either of the treatments where traders know imminent dividends ($p = 0.07$ for *CONTROL* vs. *INFO*, and $p = 0.01$ for *CONTROL* vs. *INSIDER*; Mann-Whitney U-tests). Since there is no difference in the duration of bubbles between *INFO* and *INSIDER* (in contrast to the differences found with respect to overvaluation), it seems that information about future dividends is sufficient to keep bubbles short, but that the distribution of information does not matter for the duration.[8]

Market turnover is clearly highest in *CONTROL* ($p = 0.07$ for *CONTROL* vs. *INFO*, and $p = 0.03$ for *CONTROL* vs. *INSIDER*; Mann-Whitney U-test). If traders in the market have information about the current (or next) period's dividend, then trading is substantially reduced by about 30% to 40%.

In sum, the bubble measures support the existence of treatment differences, though they point partly in different directions. The measures duration and turnover imply that there is a divide between treatments where traders are completely uninformed (as in *CONTROL*) and treatments where (at least some) traders know imminent dividends (as in *INFO* and *INSIDER*). Haessel's R² as well as the regression in Table 2 imply a divide between

[8] Of course, the shorter duration of bubbles in *INFO* and *INSIDER*, compared to *CONTROL*, may be caused by the reaction of traders to bad news on period *t*'s dividend (i.e. when it is zero). If traders decrease their valuation of the asset by more than 10 ECU when they see a zero dividend, then it becomes very likely that duration of the bubble does not increase beyond period *t*. In Table 4 below it will become clear that traders

treatments where all traders have the same information level (as in *CONTROL* and *INFO*) and the treatment with asymmetric information of traders (*INSIDER*). Since we focus on the determinants of bubbles, the latter divide is the important one for us.

In Table 4 we approach the determinants of bubbles from another angle by examining how the information about period *t*'s dividend affects the overvaluation in the treatments *INFO* and *INSIDER* where all traders (except the two traders with information level *I0* in *INSIDER*) know the current period's dividend before trading starts. The benchmark in Table 4 is the *INFO*-treatment and a dividend realization of 20 ECU in period *t*. If the actual dividend is zero ECU, the overvaluation decreases by 12.3 ECU.[9] Hence, prices react strongly to bad news about the current period's dividend. In another model specification (not shown here) we have also checked how the overvaluation in period *t* is affected by the knowledge of traders with information level *I2* (in *INSIDER*) about the actual dividend in period *t*+1. It turns out that the dividend in period *t*+1 has no significant effect at all on the overvaluation in period *t*. Hence, future dividends beyond period *t* are not yet revealed in prices.

[Table 4 about here]

Note from Table 4 also the negative effect of the dummy for the *INSIDER*-treatment on the amount of overvaluation ($p = 0.065$). Hence, even when controlling for the current period's dividend, there is a treatment effect of the asymmetric distribution of information in *INSIDER*. Since the current period's overvaluation does not depend on the knowledge of

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on average overreact on bad news, which explains largely the shorter duration of bubbles in *INFO* and *INSIDER* than in *CONTROL*.

[9] This coefficient is significantly larger than 10, meaning that the price drops by more than the decline in expected value if traders know that period *t*'s dividend is zero. As argued in the previous footnote, this finding contributes to the shorter duration of bubbles in *INFO* and *INSIDER* in comparison to *CONTROL*.

traders with information level *I2* about the dividend in period *t*+1, it seems that the interaction of traders with different information levels yields the smaller overvaluation in *INSIDER*.

Therefore, we provide some further details on trading in *INSIDER*. We start by noting that trading activity is slowest in *INSIDER*. The average trading time (averaged over the timing of all trades within a given period) is 69 seconds in *INSIDER*, which is significantly larger than the 64 seconds in *CONTROL* and the 65 seconds in *INFO* ($p < 0.05$ for each comparison; panel regression). It seems particularly noteworthy that the first trade occurs considerably later in *INSIDER* than in the other treatments. The average time of the first trade within a period is after 28 seconds in *INSIDER*, but already after 18 seconds in *CONTROL* and after 23 seconds in *INFO* ($p < 0.05$ for each comparison; panel regression). Hence, the asymmetric information – and the common knowledge of it – makes traders more cautious in striking deals.

Looking at the trading patterns of traders with a different information level we find no difference with respect to the number of posted bids and asks, yet a significant difference with respect to market orders. The better informed traders make more market orders, meaning that they accept standing bids or asks more often than the less informed traders ($p < 0.05$; Friedman test). Traders with information level *I2* place on average 1.89 market orders per period, traders with level *I1* only 1.60, and uninformed traders with level *I0* only 1.21 market orders. By accepting open orders of others, rather than posting orders themselves, traders with information level *I2* try to avoid revealing their private information. The volume of trades is also higher for better informed traders. The two traders with level *I2* trade 6.28 assets per period on average, traders with level *I1* (*I0*) only 5.74 (5.35) assets ($p < 0.05$; Friedman test). These findings suggest that the better informed traders are the most active ones, trying to exploit their informational advantage. In fact, when traders with information level *I1* or *I2* know that period *t*'s dividend is 20 ECU, they increase their stock holdings significantly, but decrease it when the dividend is known to be zero. The informed traders, thus, act on their information. Knowing that there are better informed traders in the market, the uninformed traders may try to protect themselves against the informational advantage of the better informed ones. One obvious way to do so is to post bids and asks – or to accept standing bids and asks – that are relatively close to the fundamental value of an asset. As noted earlier (see footnote 6) the initial bids and asks are in fact closer to the fundamental value in *INSIDER* than in *CONTROL*. This leaves less room for trading prices that are far away from fundamental values, and it leads ultimately to the price pattern observed in Figure 1.

4 Conclusion

This paper has focused on the question whether information about imminent dividends can abate bubbles in experimental asset markets. We have found that experimental markets with asymmetrically informed traders about imminent dividends have significantly smaller bubbles than markets where all traders have the same information. Hence, fundamental values are better reflected in market prices – implying higher market efficiency – when some traders know more than others about the future prospects of an asset.

Our finding contributes to the lively literature on the determinants of bubbles in experimental asset markets. Whereas so far experience has been found to be a main factor for reducing the size of bubbles (see, e.g., SSW, 1988; DLM, 2005), we have shown that bubbles are also less likely in markets with some knowledge about future dividends, in particular when this knowledge is distributed asymmetrically, as is typically the case in real markets.

One striking feature of our data has been the very similar effects of asymmetric information in *INSIDER* and of repetition (i.e., experience) in *CONTROL*. Twice-experienced subjects in *CONTROL* are as close with their prices to the fundamental value as inexperienced subjects in *INSIDER*, but we think this happens for different reasons. The reason why experience abates bubbles in experiments comparable to our *CONTROL*–treatment has been ascribed to a learning process about the behavior of other market participants, which decreases the degree of strategic uncertainty with repetition (SSW, 1988; Haruvy and Noussair, 2006). In contrast, in our *INSIDER*-treatment the smaller bubbles can be attributed mainly to the consequences of traders with different information levels interacting with each other. Traders with no information are less willing to trade – and trade less – than better informed ones. This may be seen as an attempt to avoid exploitation by better informed traders, and as a strategy trying to infer information about the asset's fundamental value from observing the other traders' activities. Since the better informed traders are actually the more active ones, some of their information may be revealed and reflected in prices that track the fundamentals closer than in the other treatments.

Future research may reveal whether asymmetric information can be regarded as equally robust as trader experience as a means to moderate bubbles in conditions where there are no major changes in the environment. One straightforward future research project would be to check whether asymmetric information can prevent bubbles from reoccurring even when the market environment changes. Such an examination would provide a robustness check both for the recent findings of Hussam et al. (2008), and for the findings reported in this paper.

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Tables and Figures

Table 1: Summary of treatment conditions

	# traders with information level		
Treatment	*I0*	*I1*	*I2*
CONTROL (*N* = 12)	6	-	-
INFO (*N* = 12)	-	6	-
INSIDER (*N* = 12)	2	2	2

Table 2. The determinants of overvaluation

Dependent variable: Average price – fundamental value	
Constant	5.02***
INFO (dummy)	–1.39
INSIDER (dummy)	–3.89***
Period	0.66***
Round 2 (dummy)	–2.44
Round 3 (dummy)	–4.38***
Lagged period * Round 1-dummy	0.86***
Lagged period * Round 2-dummy	0.71***
Lagged period * Round 3-dummy	0.68***
R^2	0.66
N	1023

*, **, ***: significant at 10%-, 5%-, 1% level

Table 3. Various measures, by treatment and market

	Haessel R^2			Duration			Turnover		
Market	*CONTROL*	*INFO*	*INSIDER*	*CONTROL*	*INFO*	*INSIDER*	*CONTROL*	*INFO*	*INSIDER*
1	0.29	0.02	0.81	7.33	7.33	2.00	1.87	1.91	0.38
2	0.35	0.94	0.12	9.00	1.33	2.67	1.21	1.10	1.55
3	0.54	0.70	0.81	6.33	2.67	1.67	2.34	1.11	0.87
4	0.77	0.19	0.28	4.33	4.67	2.00	1.15	1.03	1.21
5	0.23	0.76	0.36	8.33	3.33	7.67	2.40	1.30	1.88
6	0.15	0.30	0.78	7.00	4.33	7.00	3.97	1.12	2.50
7	0.02	0.25	0.82	7.67	5.33	2.67	6.42	1.66	1.33
8	0.27	0.44	0.94	8.00	5.33	1.33	1.76	2.04	1.22
9	0.97	0.74	0.94	2.00	2.00	2.67	1.65	2.28	1.65
10	0.79	0.91	0.83	3.67	2.33	4.00	2.27	1.57	1.54
11	0.59	0.53	0.90	3.33	5.00	2.67	2.14	1.80	1.08
12	0.96	0.80	0.80	2.33	3.33	3.33	1.59	2.34	2.18
Average	*0.49*	*0.55*	*0.70*	*5.78*	*3.92*	*3.31*	*2.40*	*1.61*	*1.45*

Table 4. Information about dividend and overvaluation

Dependent variable: Average price – fundamental value	
Constant	12.88***
INSIDER (dummy)	–2.38*
Period	0.05
Round 2 (dummy)	–2.97*
Round 3 (dummy)	–3.89**
Lagged period * Round 1-dummy	0.86***
Lagged period * Round 2-dummy	0.75***
Lagged period * Round 3-dummy	0.72***
Dividend = 0 ECU in period *t* (dummy)	–12.30***
R^2	0.69
N	675

*, **, ***: significant at 10%-, 5%-, 1% level

Includes data from *INFO* and *INSIDER*

Figure 1. Average prices per period and fundamental value

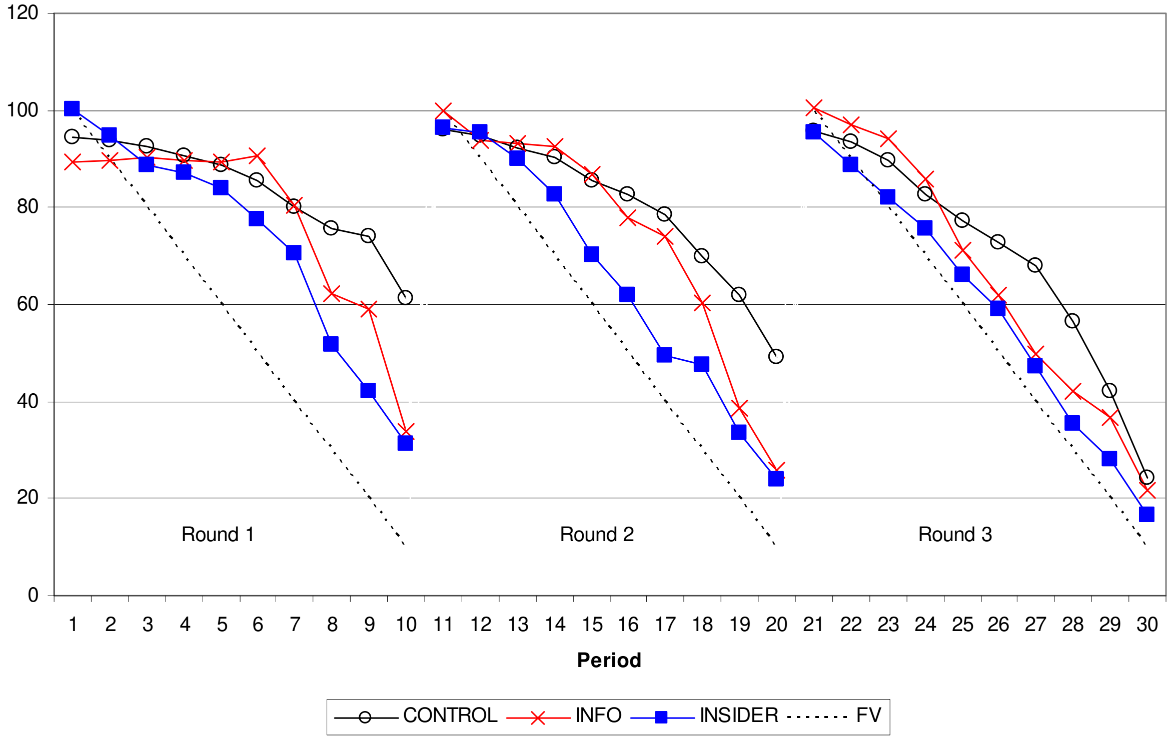
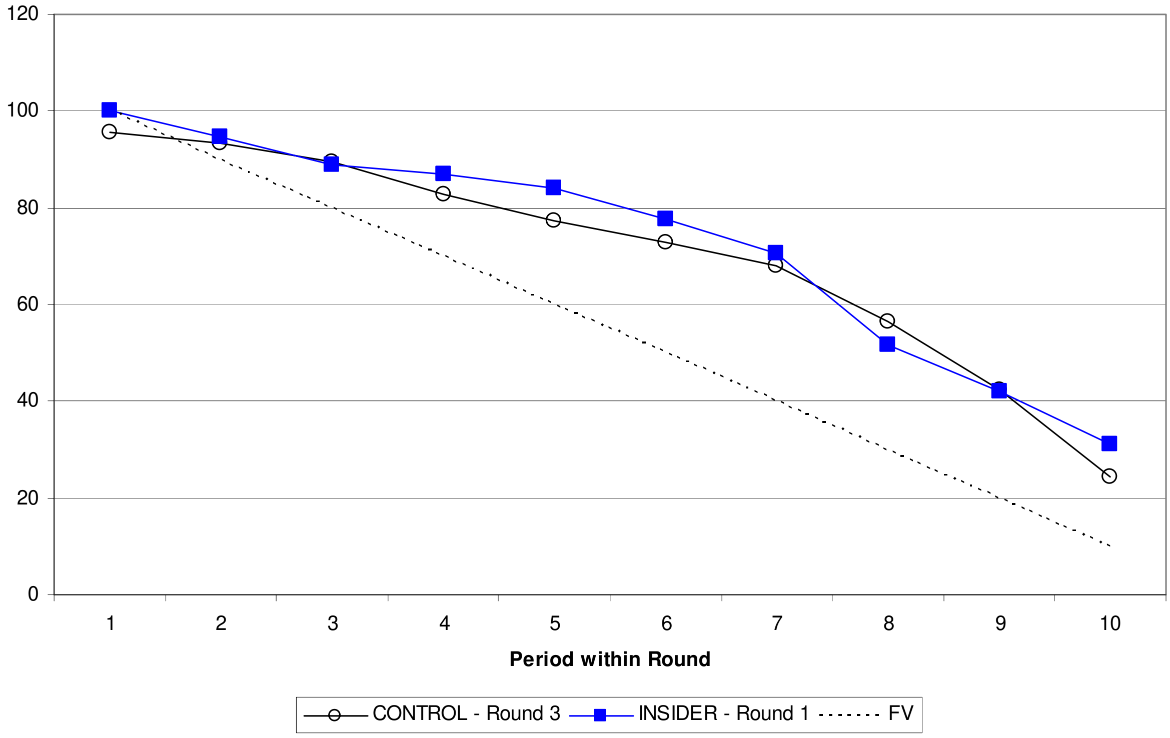


Figure 2. Twice-experienced traders in CONTROL vs. inexperienced traders in INSIDER



Supplement A. Experimental instructions for treatment *INSIDER*

For treatments CONTROL and INFO, the section "Information Levels" was omitted or shortened and screenshots were adapted accordingly. (Supplements are not for publication.)

Dear participant, welcome to this experiment. Please do not speak with any other participant from now on. If you face any difficulties, contact one of the supervisors.

General Information

The present experiment represents the simulation of a stock market. The experimental session comprises three successive markets, each consisting of ten consecutive trading periods. In the process you can sell and buy assets (of a virtual enterprise).

Market Description

The market consists of six participants. Three of the six traders get an initial endowment of 10 assets and a working capital of 3000 monetary units (MU), another three are endowed with 30 assets and 1000 MU at the outset. In every period you can sell and/or buy assets, and you take along your (asset and money) inventories to the next trading period, respectively. Each trading period automatically terminates after two minutes.

Trade is accomplished in form of a double auction, *i.e.*, each trader can appear as buyer and seller at the same time. Therefore you can submit any quote of assets with prices ranging from 0 to a maximum of 300 MU (with at most one decimal place). For every bid you make, you have to enter the amount of assets you intend to trade as well. Note that your cash and asset inventory cannot drop below zero.

At the end of each trading period, every asset pays a dividend which gets summed up to your cash holding. The dividend (for one asset) amounts either 0 or 20 MU with equal probability. Thus, an asset's average dividend amounts 10 MU for every period. After a trading period is completed, dividends (for assets hold in your inventory) add on to your cash holding. Assets feature a life-span of 10 trading periods, *i.e.*, after dividends are paid out at the end of period 10, assets are worthless.

After the market's completion (*i.e.*, after 10 trading periods), the same market gets replicated two more times. Note that - again - dividend realizations will be randomly chosen by the computer (with equal probability). Regardless of your profit earned in the first market, you will again be endowed with an inventory of 10 (or 30) assets and 3000 (or 1000) MU at the beginning of market two and three. Your total profit will be calculated by adding up earnings from all three (independent) markets at the end of the experiment.

Information Levels

The present market is characterized by different information levels (*I0, I1, I2*) of traders. At the beginning of the experiment you get randomly assigned to one of these levels. Two of the six participants (*I0*) posses no information about the actual dividend realization, *i.e.*, they have no information about the actual dividend payment in the current, nor the subsequent periods. They just know that the dividend in every period will amount either 0 or 20 MU. *At the end of a period*, all participants (including *I0*-type) get knowledge about the actual dividend payment of the terminated trading period.

Another two participants in the market get classified as *I1*-type of traders. They have a prediction horizon of one period in advance, *i.e.*, they posses information about the actual dividend payment (0 or 20 MU) for the current period *t* even before trading in period *t* starts.

Finally, another two participants will be chosen as *I2*-type who have a prediction horizon of two periods in advance. They know the actual dividend realization for the current period *t* as well as the subsequent period *t*+1.

Average Holding Value

You can use the subsequent table to help you make decisions. The first column, labelled "Ending Period", indicates the last trading period of the market. The second column, labelled "Current Period", indicates the period during which the average holding value is being calculated. The third column gives the number of holding periods from the period in the second column until the end of the market. The fourth column, labelled "Average Dividend

Value Per Period", gives the average amount that the dividend will be in each period for each unit held in your inventory. The fifth column, labelled "Average Holding Value Per Unit of Inventory", gives the expected total dividend earnings (per asset) for the remainder of the experiment. That is, for each unit you hold in your inventory for the remainder of the market, you receive in expectation the amount listed in column 5. The number in column 5 is calculated by multiplying the numbers in columns 3 and 4.

Suppose for example that there are 4 periods remaining in a market. Since the dividend on a unit of asset has a 50% chance of being 0 and a 50% chance of being 20, the dividend is in expectation 10 MU per period for each asset. If you hold one asset for 4 periods, the total dividend paid on the unit over 4 periods is in expectation $4 \times 10 = 40$.

Average Holding Value Table

Ending Period	Current Period	Number of Holding Periods	×	Average Dividend Value Per Period	=	Average Holding Value Per Unit of Inventory
10	1	10		10		100
10	2	9		10		90
10	3	8		10		80
10	4	7		10		70
10	5	6		10		60
10	6	5		10		50
10	7	4		10		40
10	8	3		10		30
10	9	2		10		20
10	10	1		10		10

Calculate Your Earnings

Your earnings for a period are given by the actual dividends received at the end of a period, plus revenues for assets sold, minus expenditures for purchases.

YOUR EARNINGS FOR A PERIOD =

DIVIDEND PER UNIT × NUMBER OF UNITS IN INVENTORY (AT THE END OF THE PERIOD) + REVENUES – EXPENDITURES (ACCRUING IN THE COURSE OF TRADING).

If you *buy* assets, your cash holding is diminished by the respective expenditures (price × volume). Inversely, if you *sell* assets, your cash holding will be increased by the respective revenues (price × volume). Your total profit in the market results from the initial cash endowment (1000 or 3000 MU), plus the sum of earnings acquired in all 10 trading periods.

YOUR TOTAL EARNINGS IN THE MARKET =

INITIAL CASH ENDOWMENT +

EARNINGS FOR PERIOD 1 + EARNINGS FOR PERIOD 2 +

EARNINGS FOR PERIOD 3 + EARNINGS FOR PERIOD 4 +

EARNINGS FOR PERIOD 5 + EARNINGS FOR PERIOD 6 +

EARNINGS FOR PERIOD 7 + EARNINGS FOR PERIOD 8 +

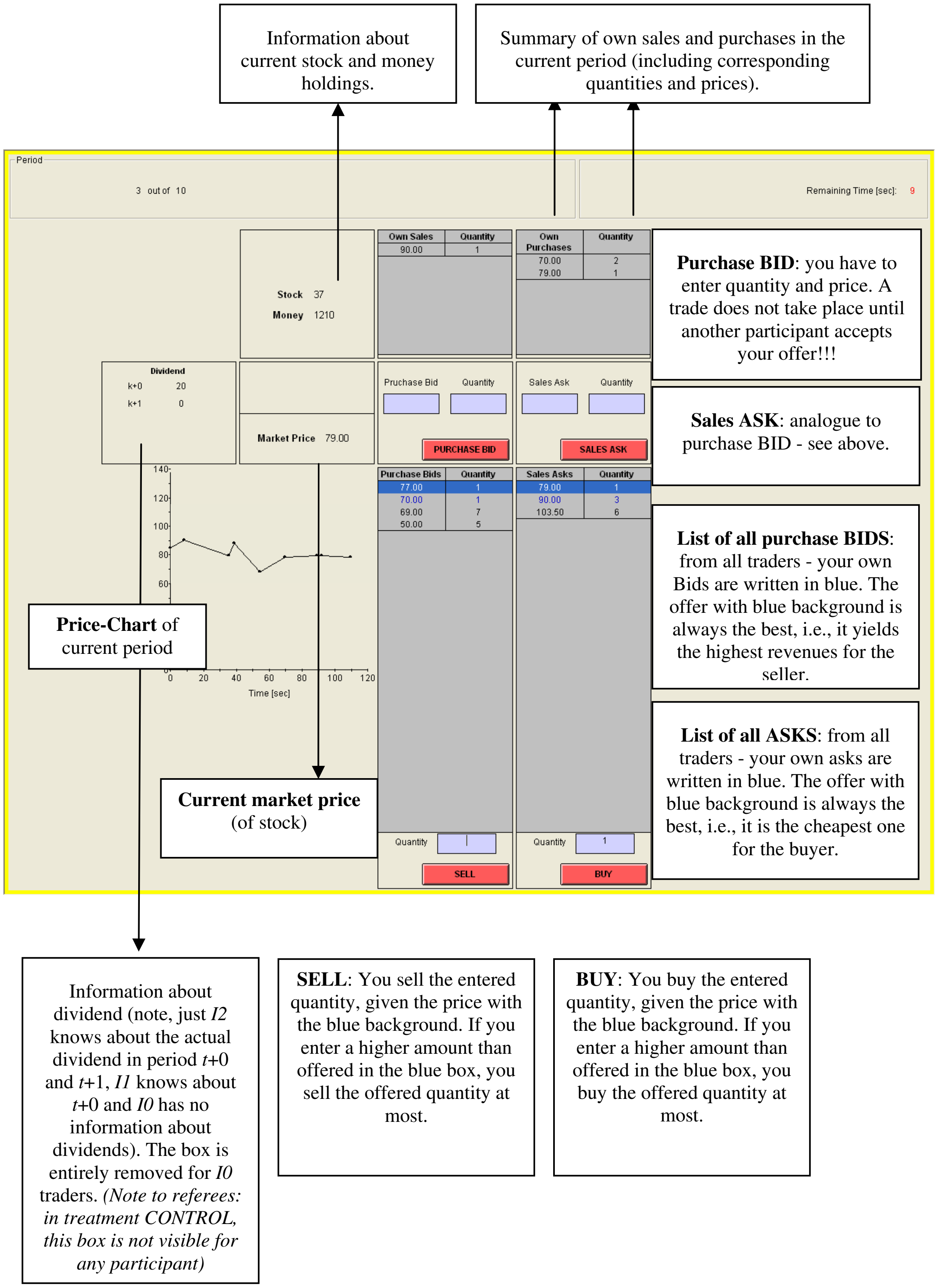
EARNINGS FOR PERIOD 9 + EARNINGS FOR PERIOD 10

At the end of the market (after 10 periods), assets have a value of zero. Only your cash holdings contribute to your total earnings. Your total profit for the experiment is determined by summing up profits from all three (independent) markets. Based on your total profit acquired in the experimental currency unit MU, you will receive the according amount in Euro. Your total earnings for the experiment (sum of all three markets) is converted by

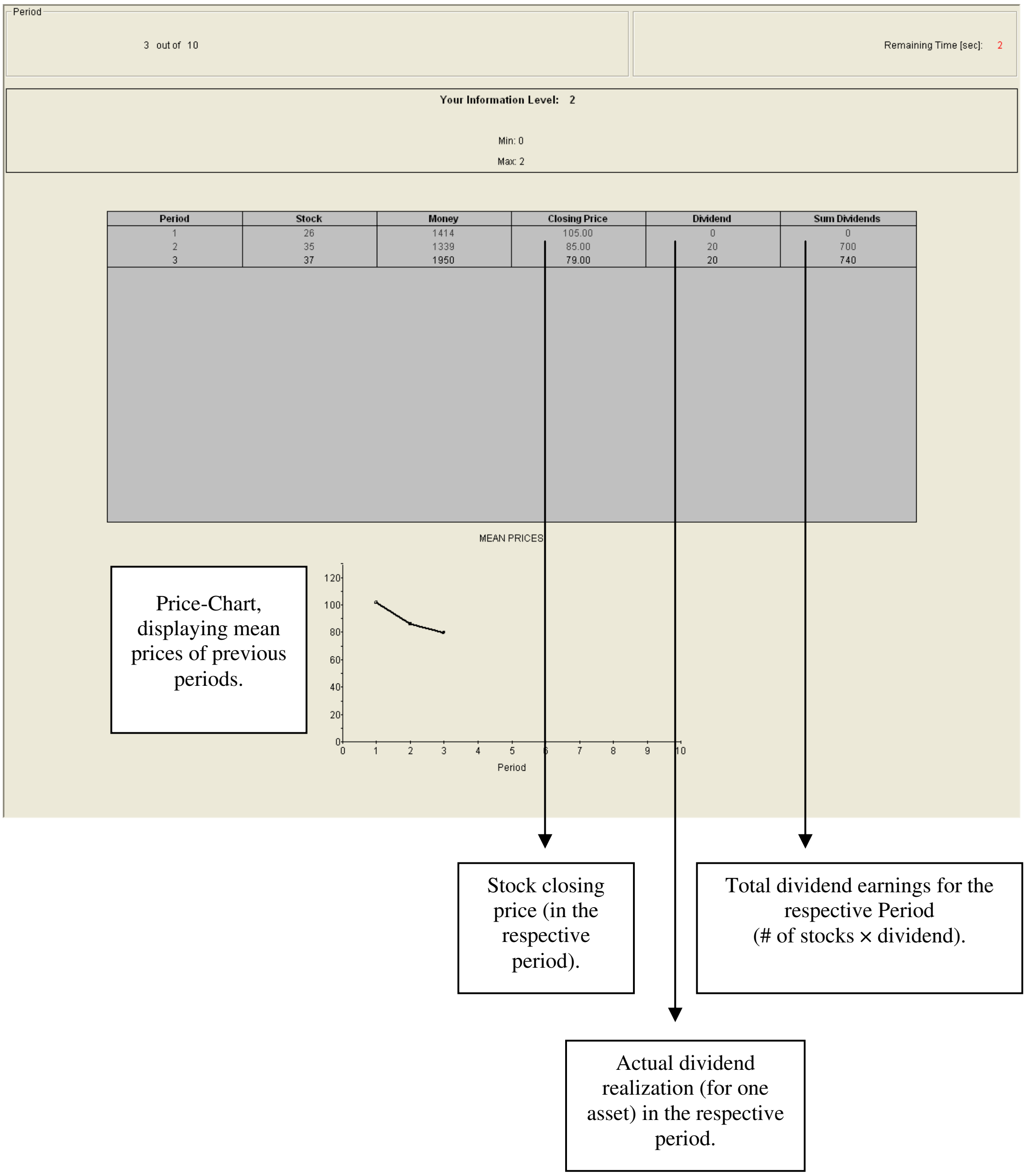
100 MU = 0.2 Euro

into the according cash amount in Euro.

Trading Screen: By means of the following graphics, the procedure of trading (buying and selling) will be illustrated.



History Screen: appears after every trading period, providing you with vital information:



Supplement B: Dividend realizations used in the experiments

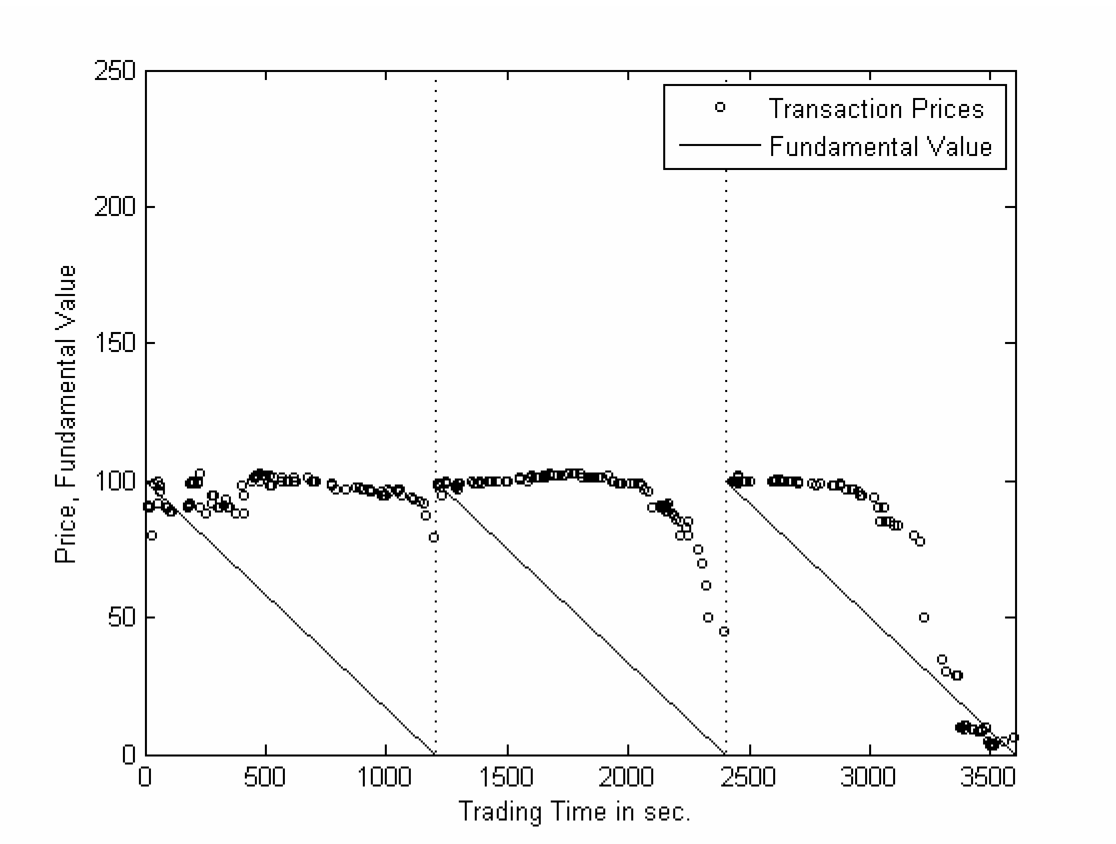
Note that the dividends in markets M1 to M3 and M7 to M9 are identical. The sequence of dividend realizations in these markets has been randomly pre-determined and then fixed for the experiment. Markets M4 to M6 and M10 to M12 are also identical and show a "mirror" sequence of dividends, such that in each period the dividends in both sequences were different (e.g., 0 ECU in sequence 1, and 20 ECU in sequence 2).

Table B1. Actual dividends across 30 periods in the 12 markets of each treatment

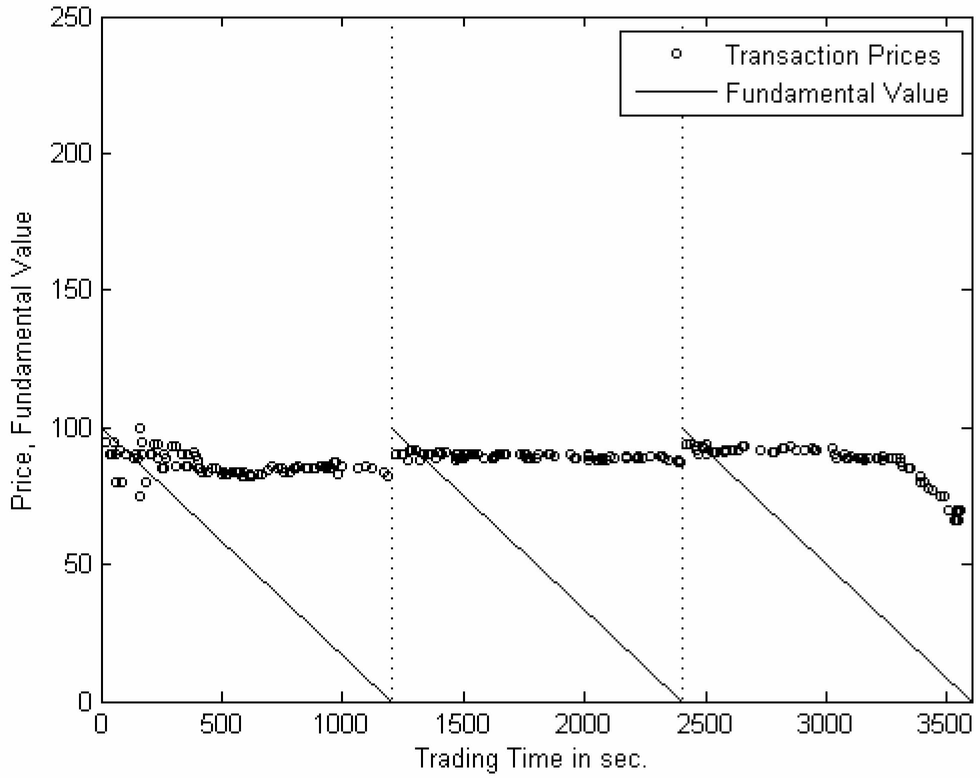
Period	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
1	0	0	0	20	20	20	0	0	0	20	20	20
2	0	0	0	20	20	20	0	0	0	20	20	20
3	20	20	20	0	0	0	20	20	20	0	0	0
4	0	0	0	20	20	20	0	0	0	20	20	20
5	20	20	20	0	0	0	20	20	20	0	0	0
6	20	20	20	0	0	0	20	20	20	0	0	0
7	0	0	0	20	20	20	0	0	0	20	20	20
8	20	20	20	0	0	0	20	20	20	0	0	0
9	20	20	20	0	0	0	20	20	20	0	0	0
10	0	0	0	20	20	20	0	0	0	20	20	20
11	0	0	0	20	20	20	0	0	0	20	20	20
12	20	20	20	0	0	0	20	20	20	0	0	0
13	0	0	0	20	20	20	0	0	0	20	20	20
14	0	0	0	20	20	20	0	0	0	20	20	20
15	20	20	20	0	0	0	20	20	20	0	0	0
16	0	0	0	20	20	20	0	0	0	20	20	20
17	20	20	20	0	0	0	20	20	20	0	0	0
18	20	20	20	0	0	0	20	20	20	0	0	0
19	0	0	0	20	20	20	0	0	0	20	20	20
20	20	20	20	0	0	0	20	20	20	0	0	0
21	20	20	20	0	0	0	20	20	20	0	0	0
22	20	20	20	0	0	0	20	20	20	0	0	0
23	0	0	0	20	20	20	0	0	0	20	20	20
24	0	0	0	20	20	20	0	0	0	20	20	20
25	0	0	0	20	20	20	0	0	0	20	20	20
26	20	20	20	0	0	0	20	20	20	0	0	0
27	0	0	0	20	20	20	0	0	0	20	20	20
28	20	20	20	0	0	0	20	20	20	0	0	0
29	0	0	0	20	20	20	0	0	0	20	20	20
30	20	20	20	0	0	0	20	20	20	0	0	0

Supplement C: Prices and trades in individual markets

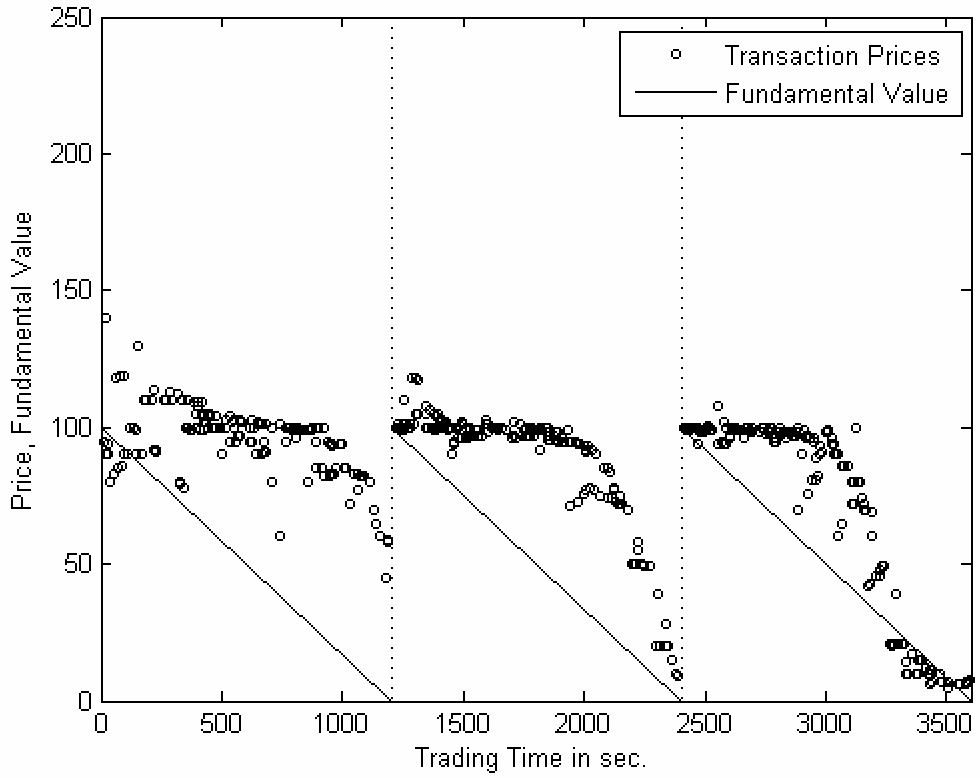
Market M1 in *CONTROL*



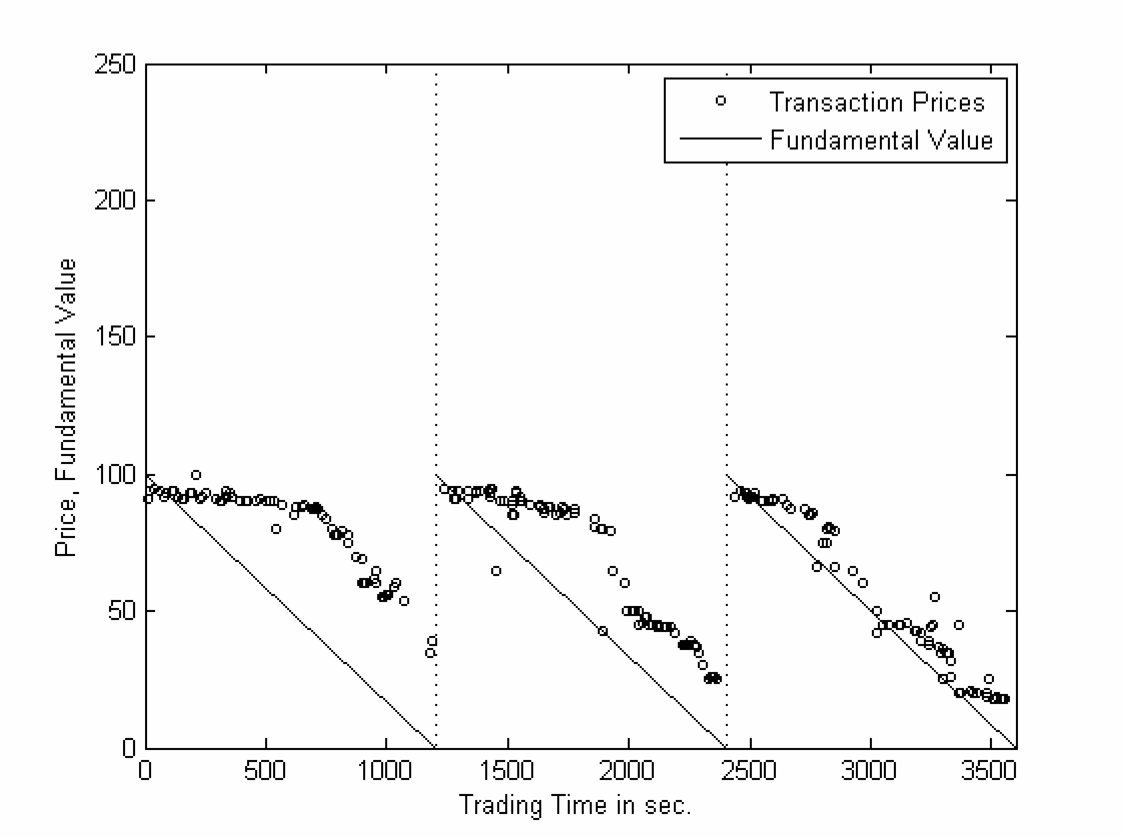
Market M2 in *CONTROL*



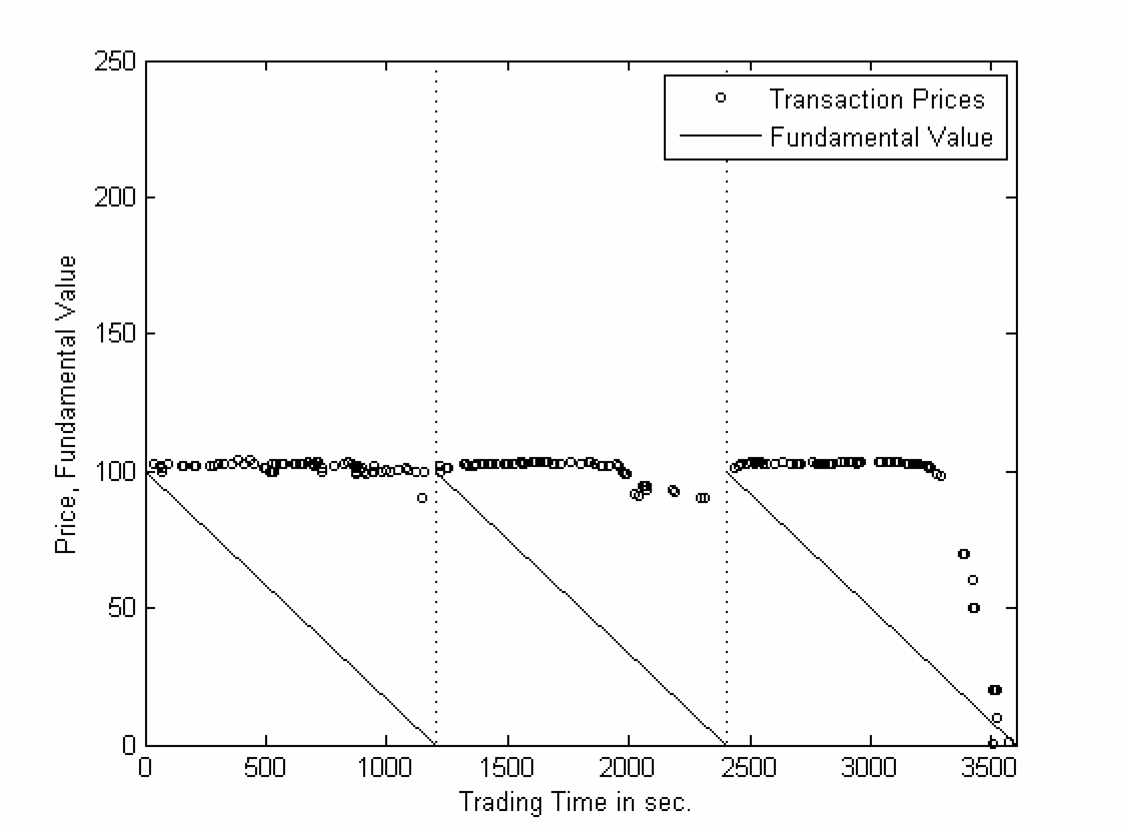
Market M3 in *CONTROL*



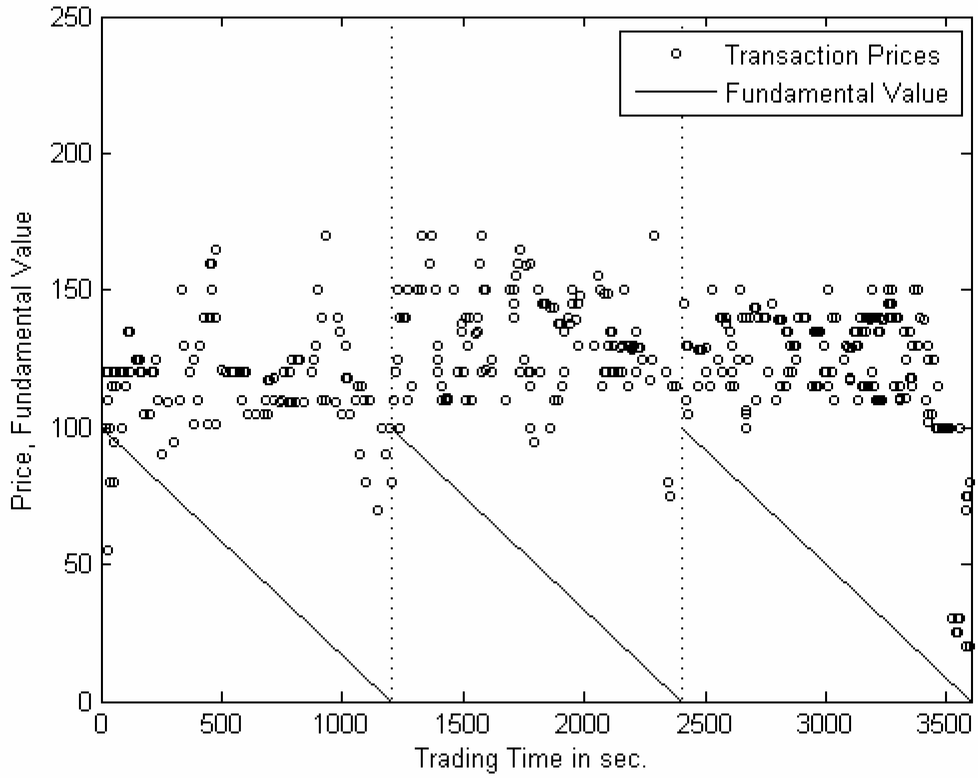
Market M4 in *CONTROL*



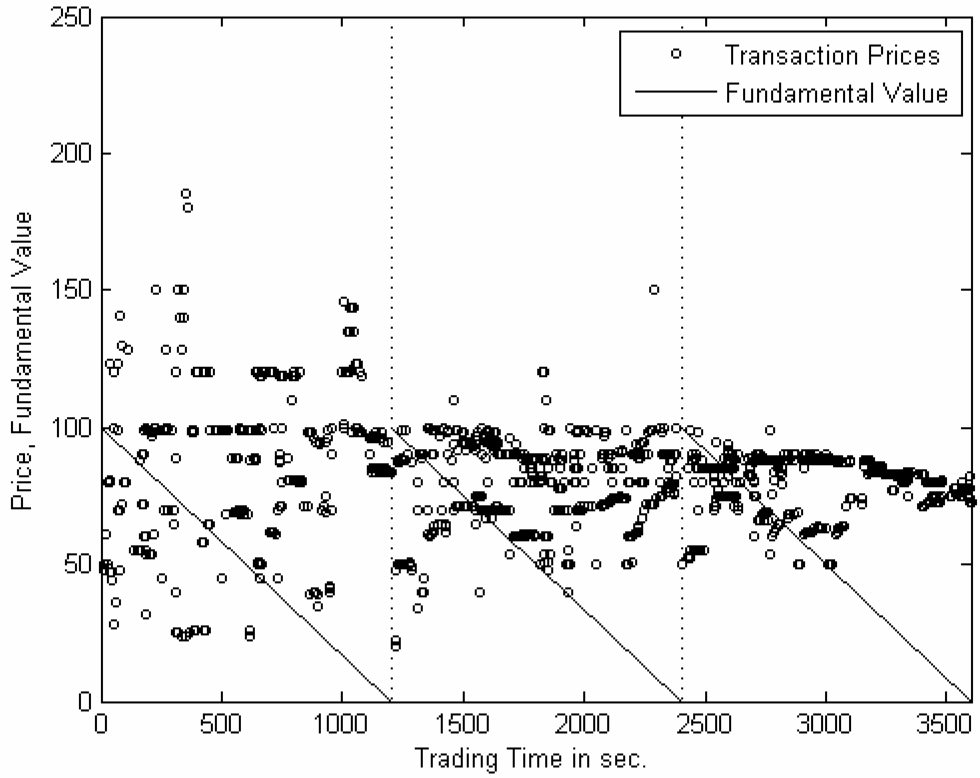
Market M5 in *CONTROL*



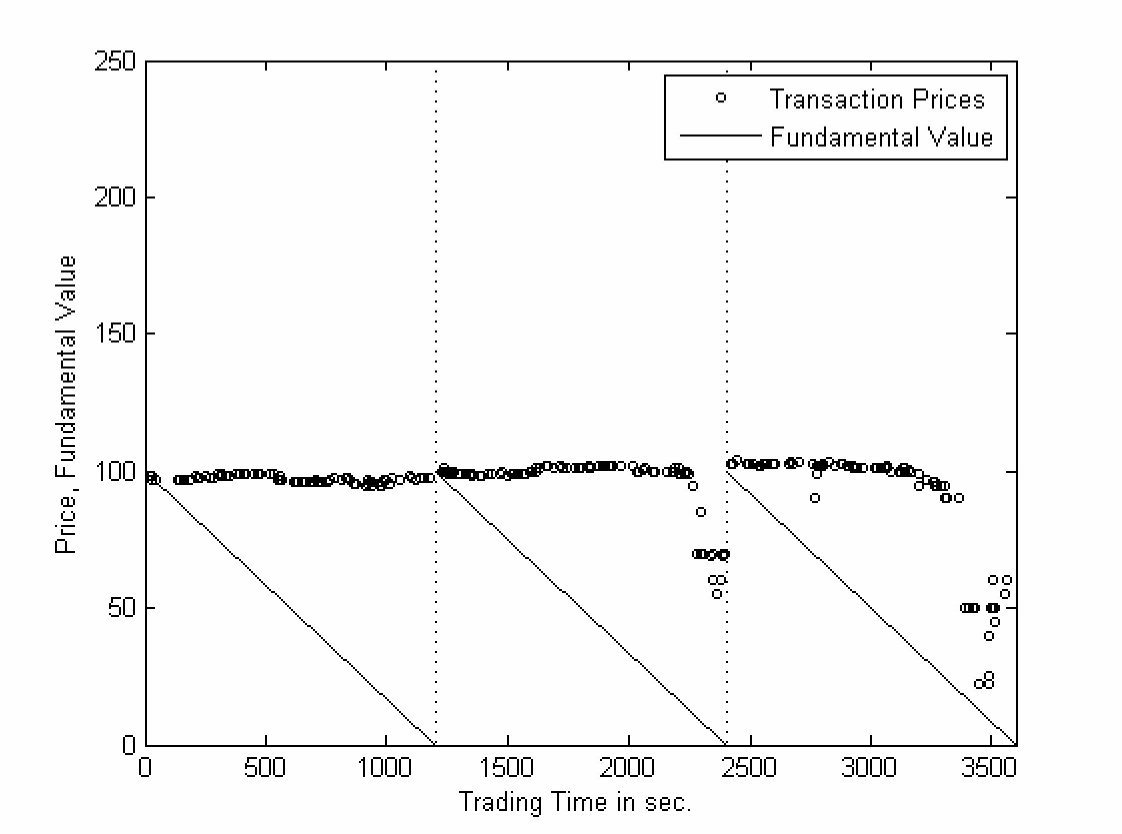
Market M6 in *CONTROL*



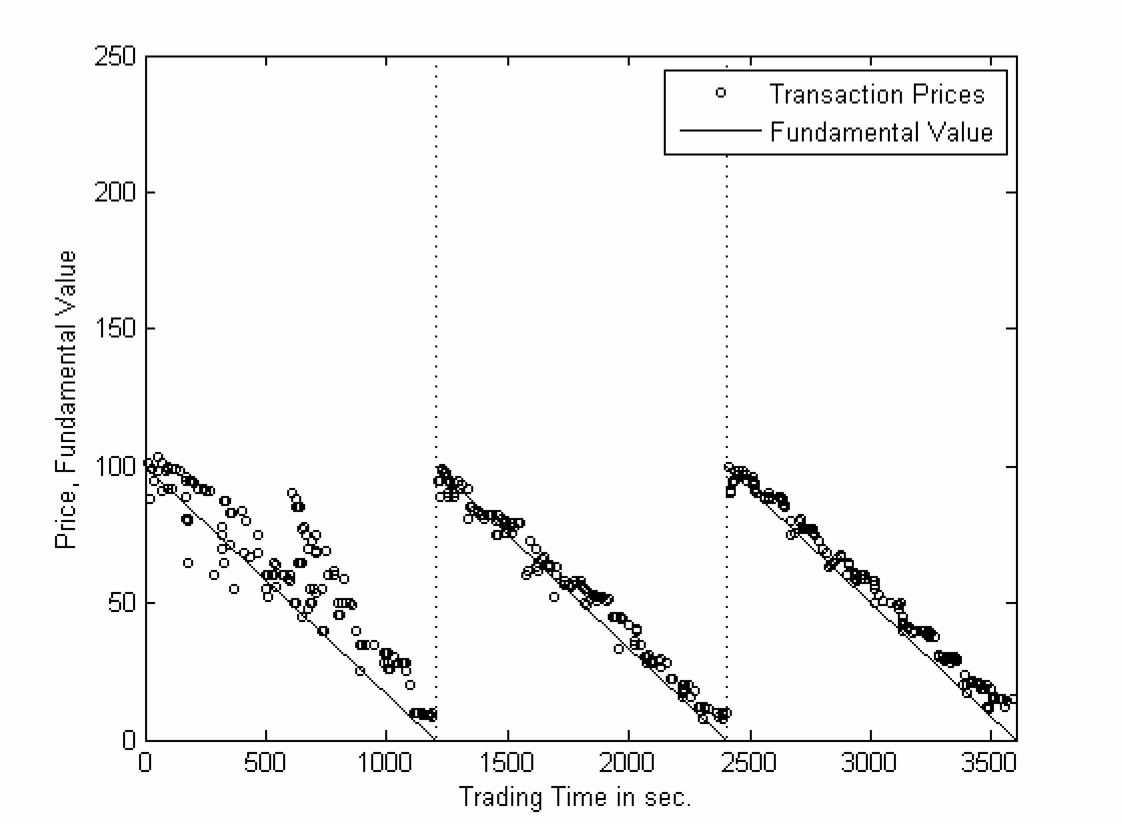
Market M7 in *CONTROL*



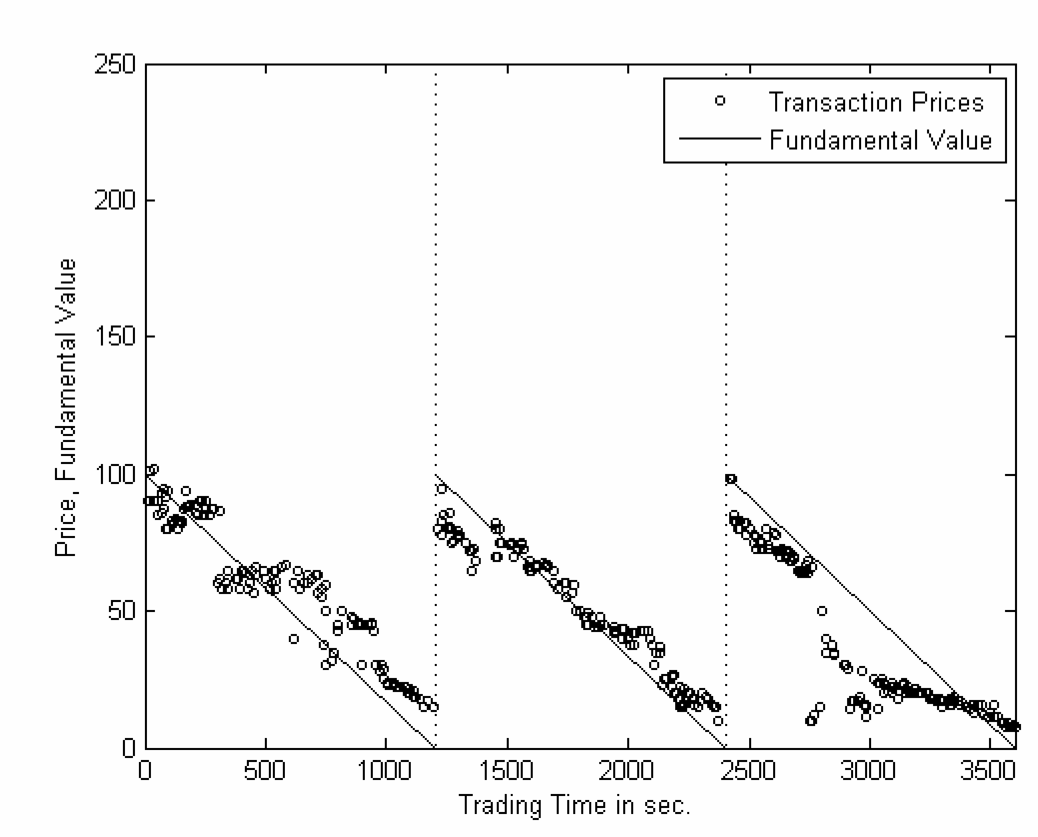
Market M8 in *CONTROL*



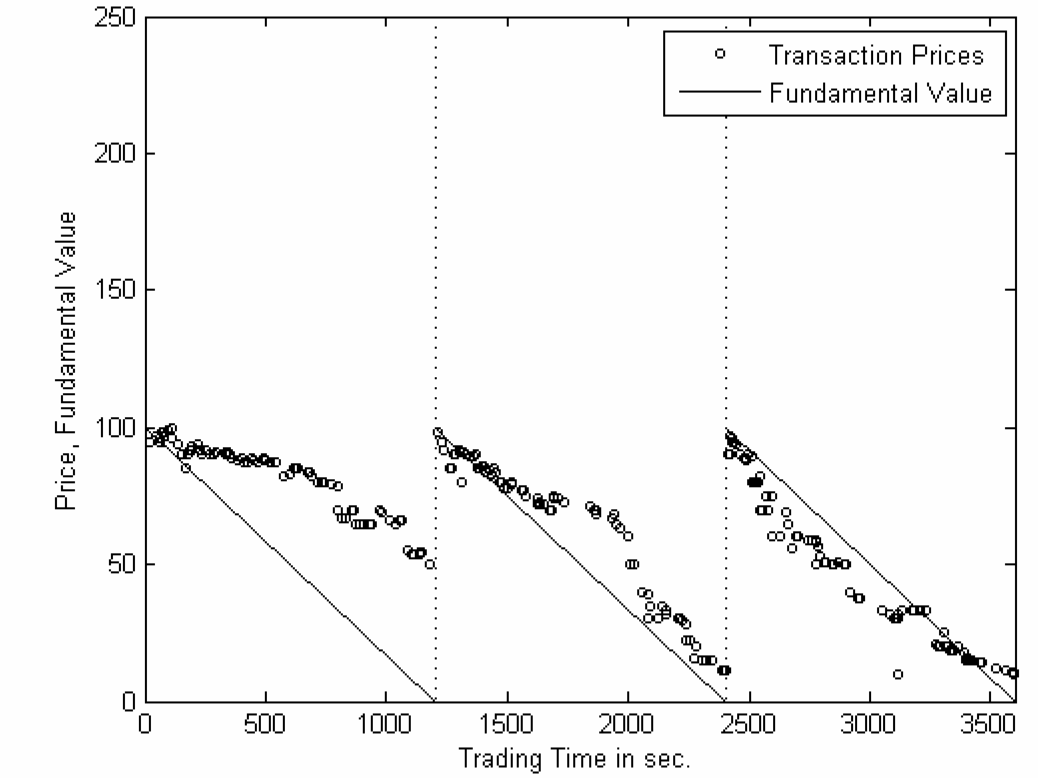
Market M9 in *CONTROL*



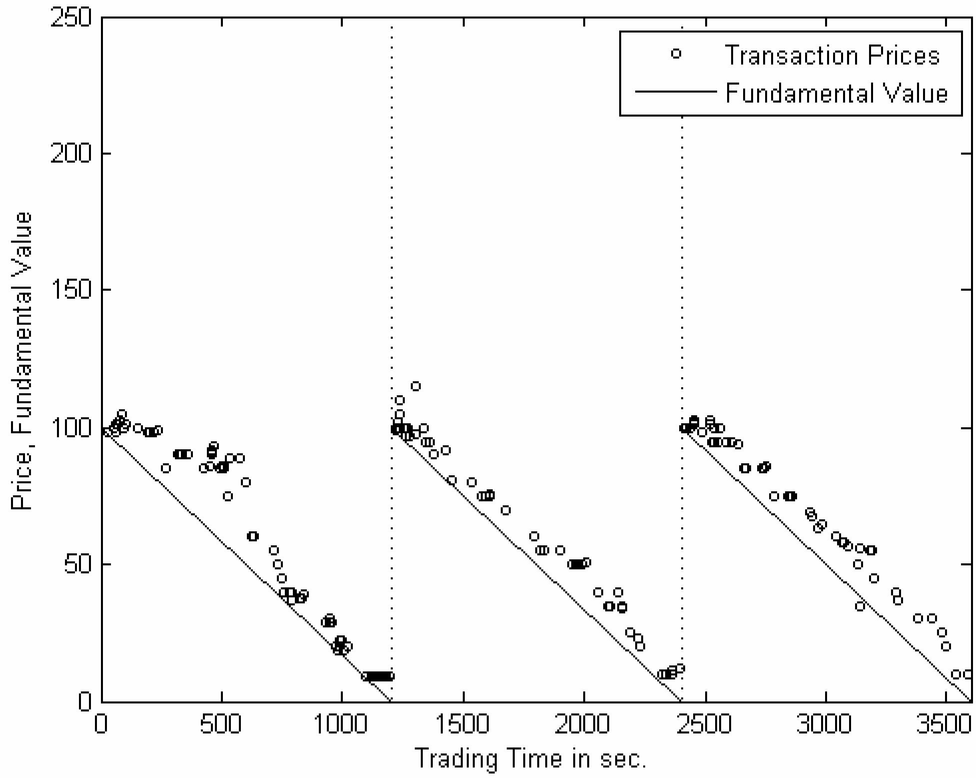
Market M10 in *CONTROL*



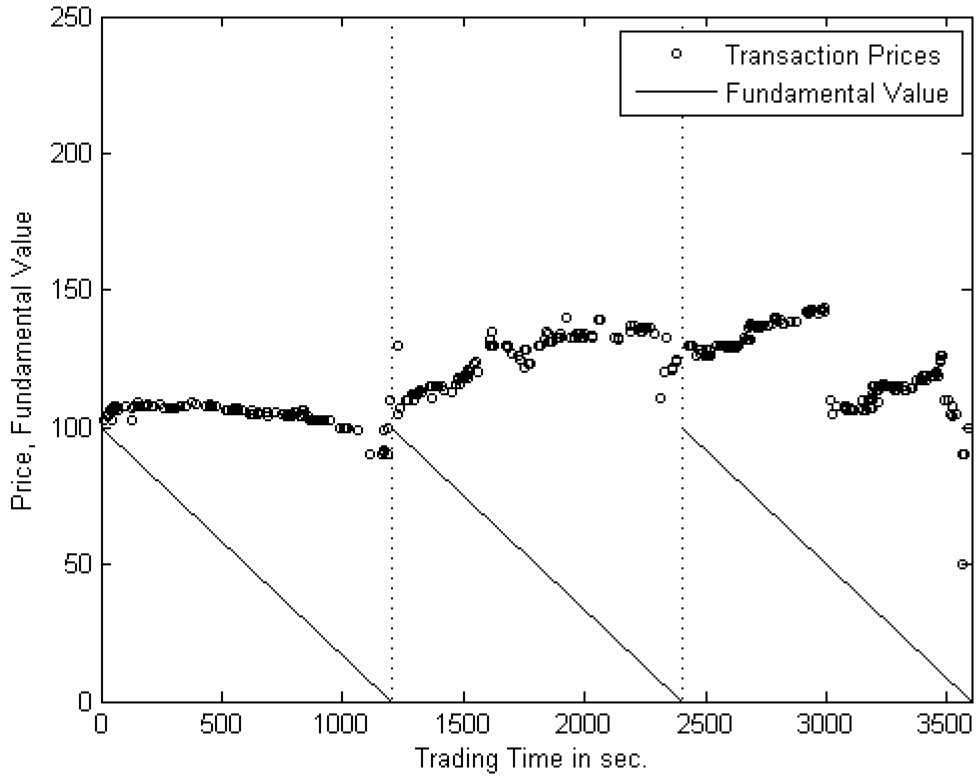
Market M11 in *CONTROL*



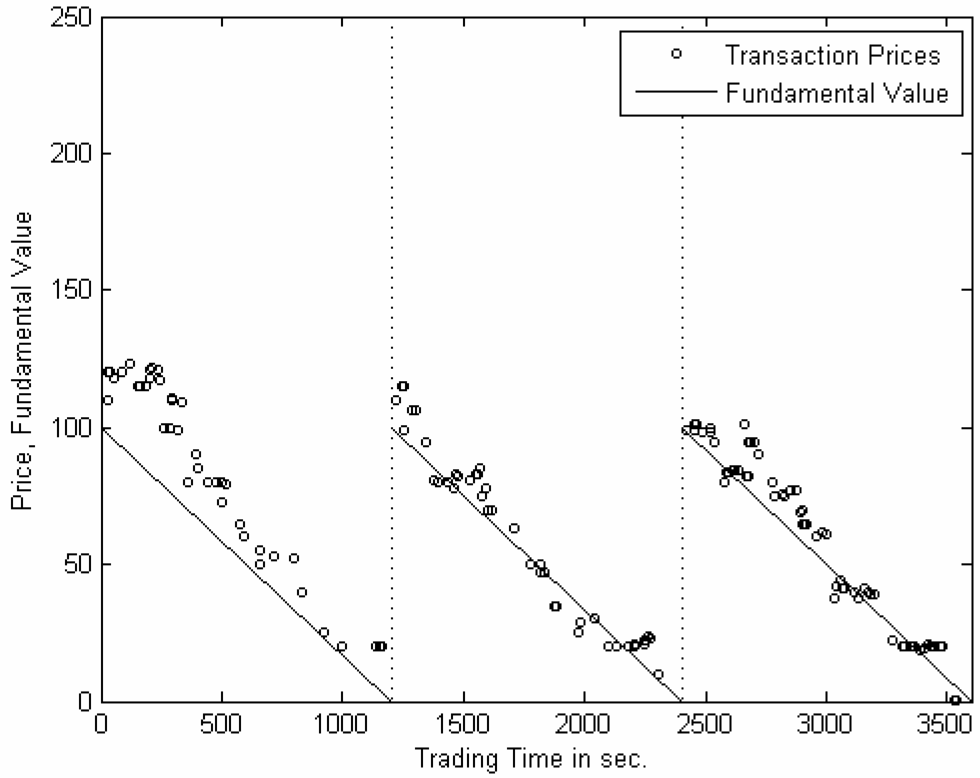
Market M12 in *CONTROL*



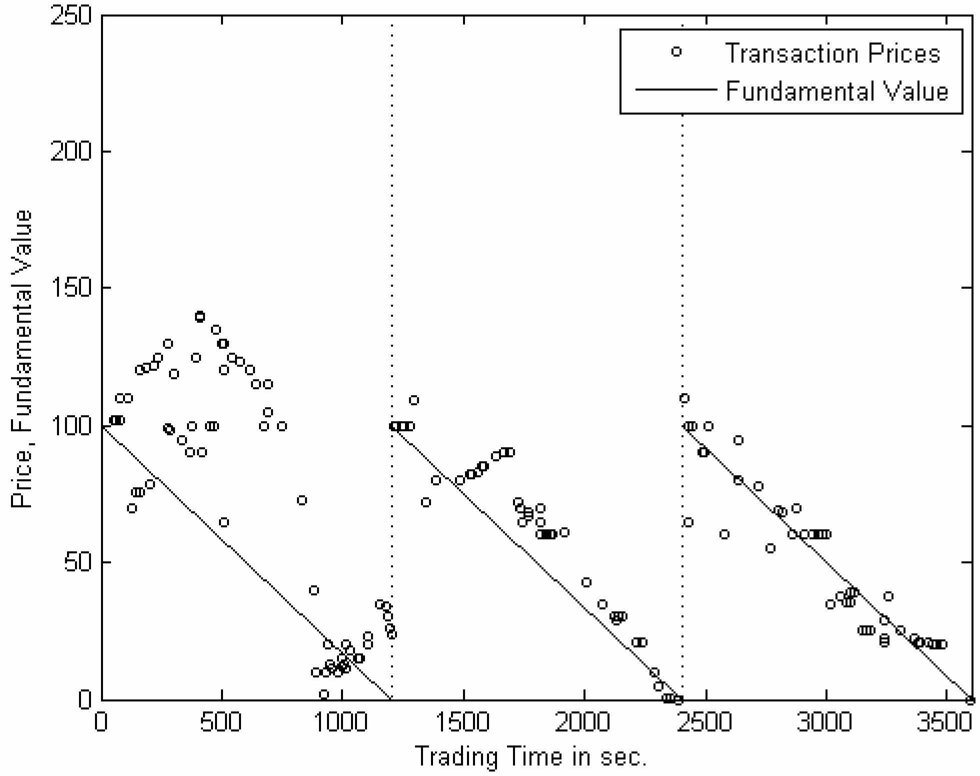
Market M1 in *INFO*



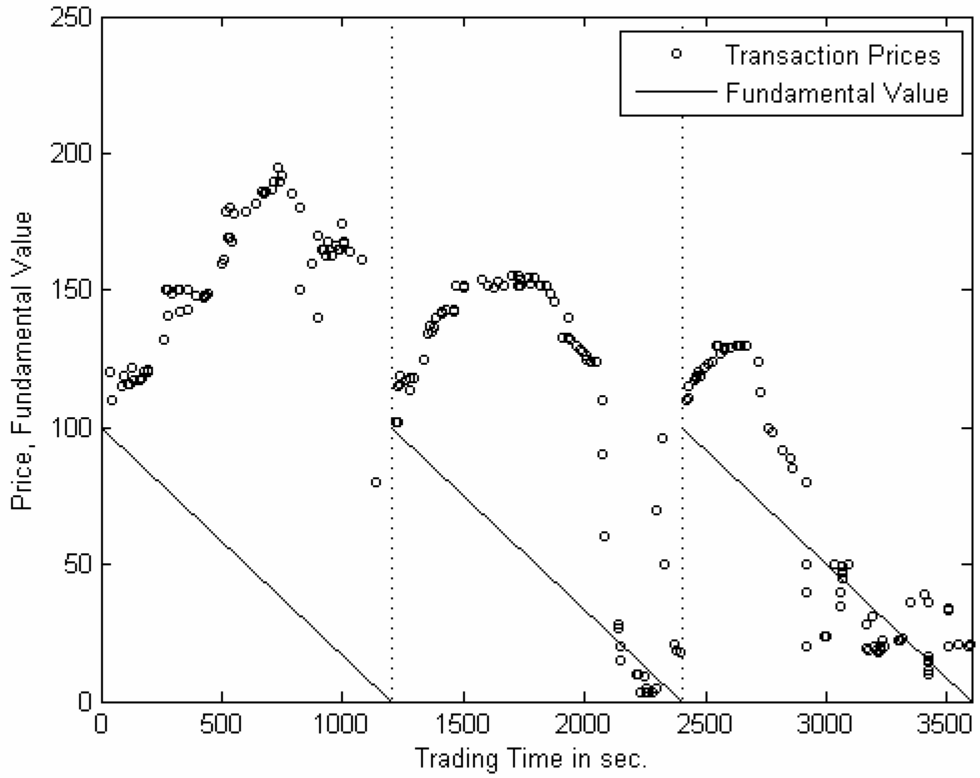
Market M2 in *INFO*



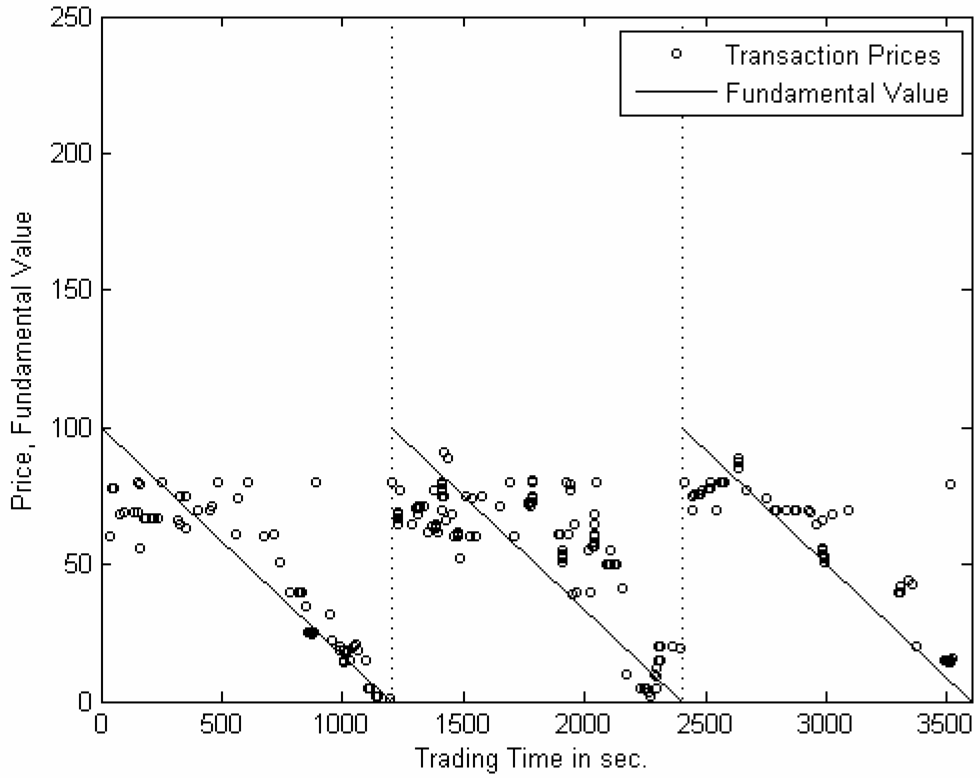
Market M3 in *INFO*



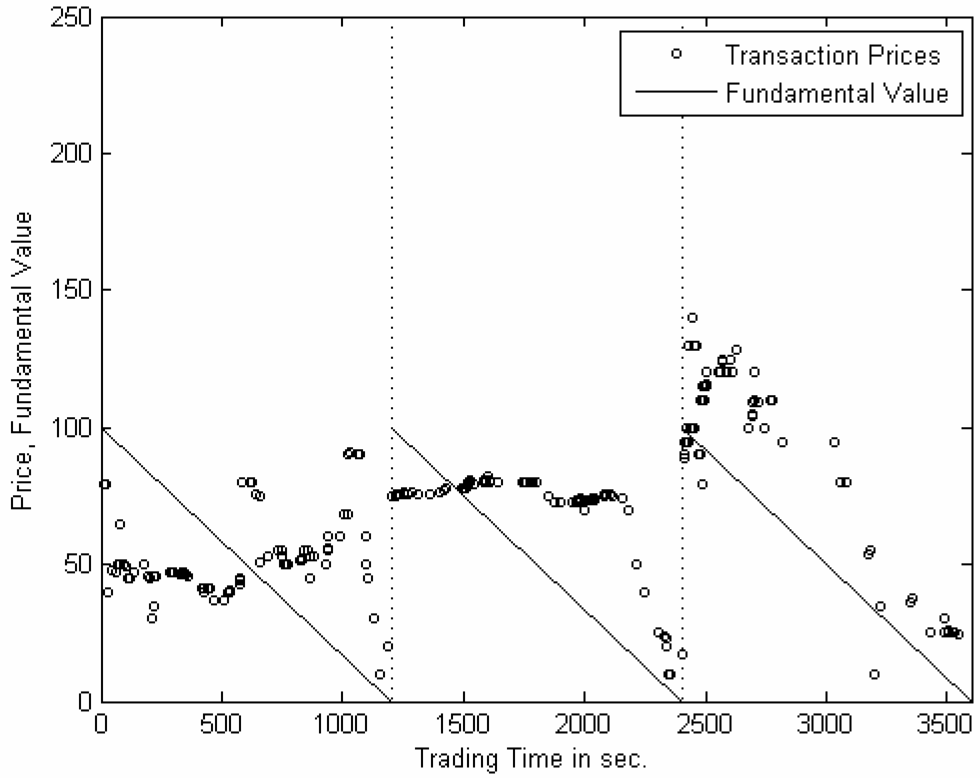
Market M4 in *INFO*



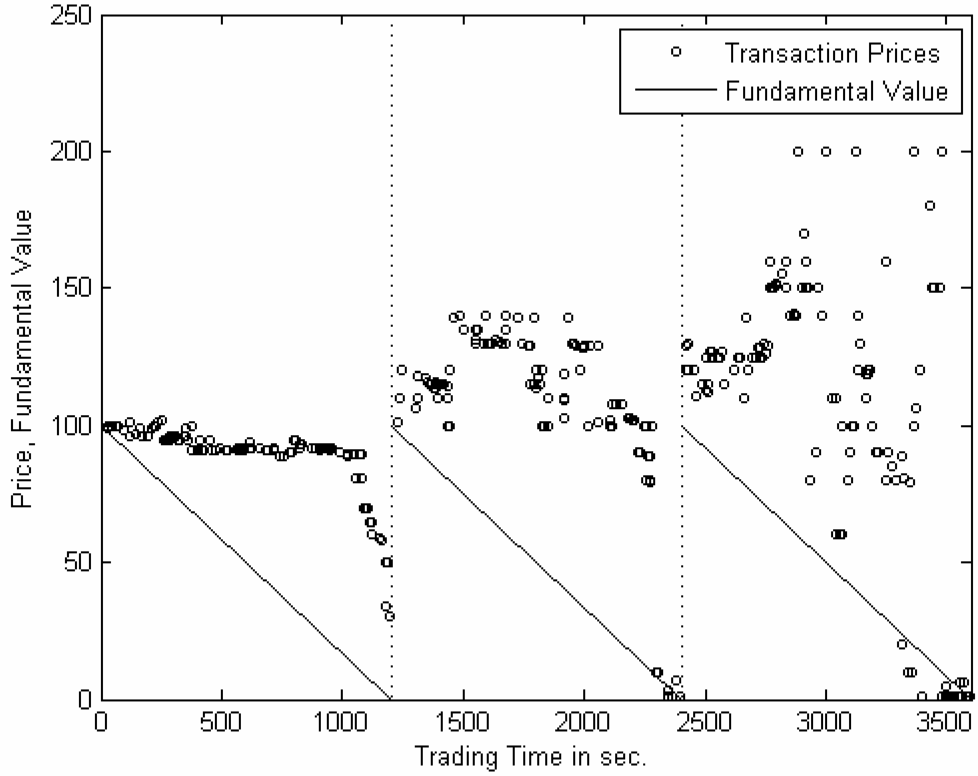
Market M5 in *INFO*



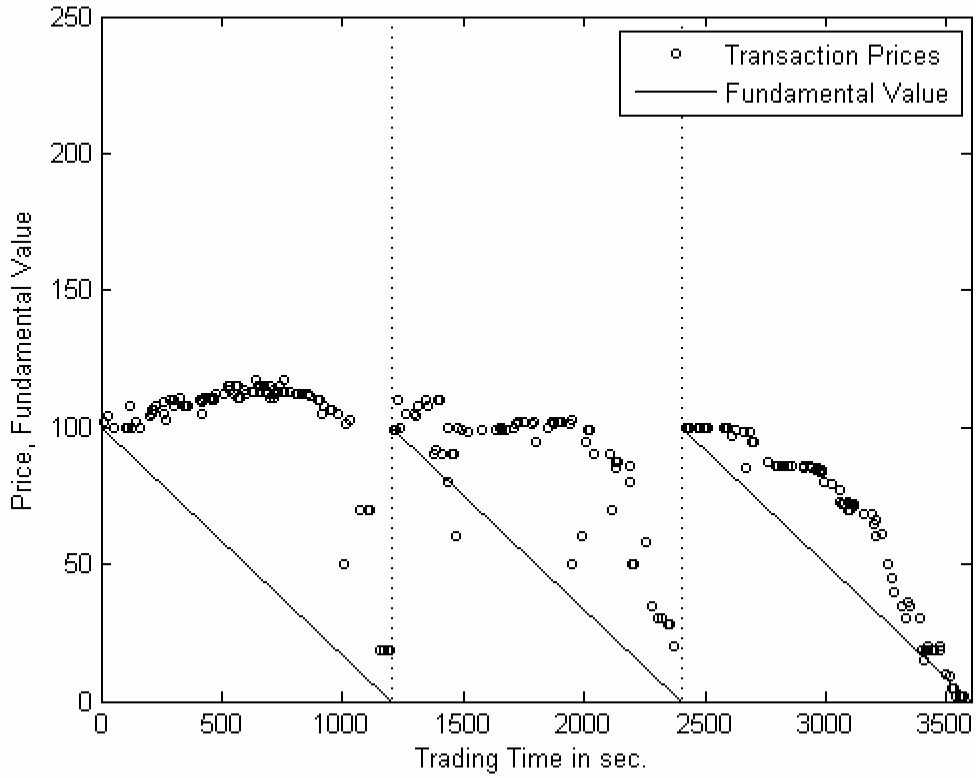
Market M6 in *INFO*



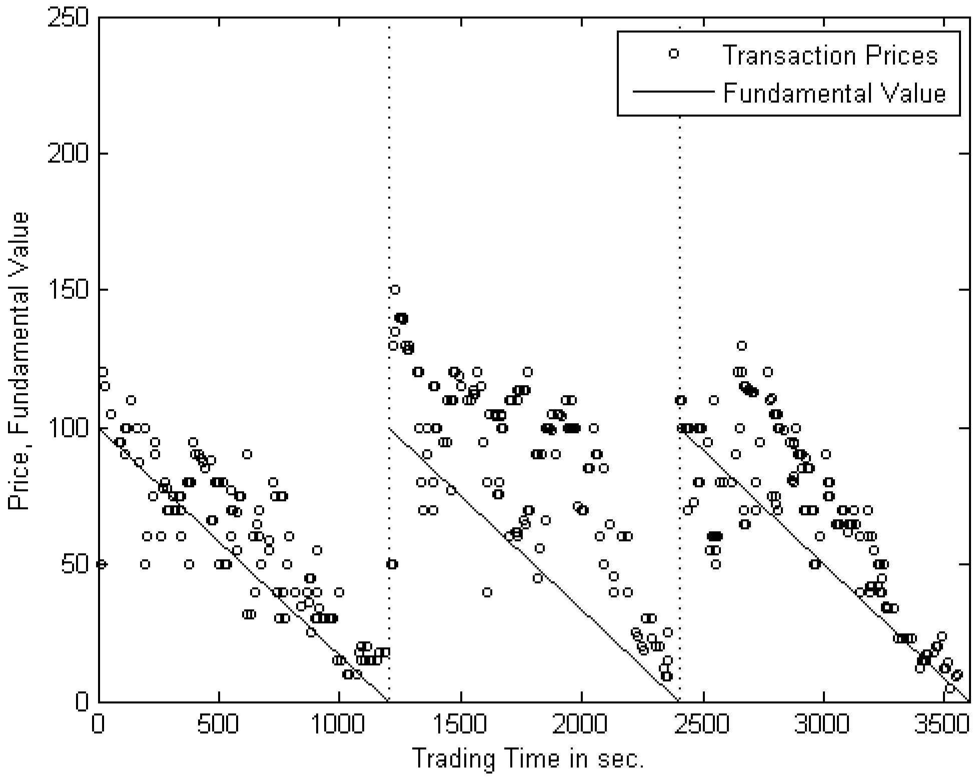
Market M7 in *INFO*



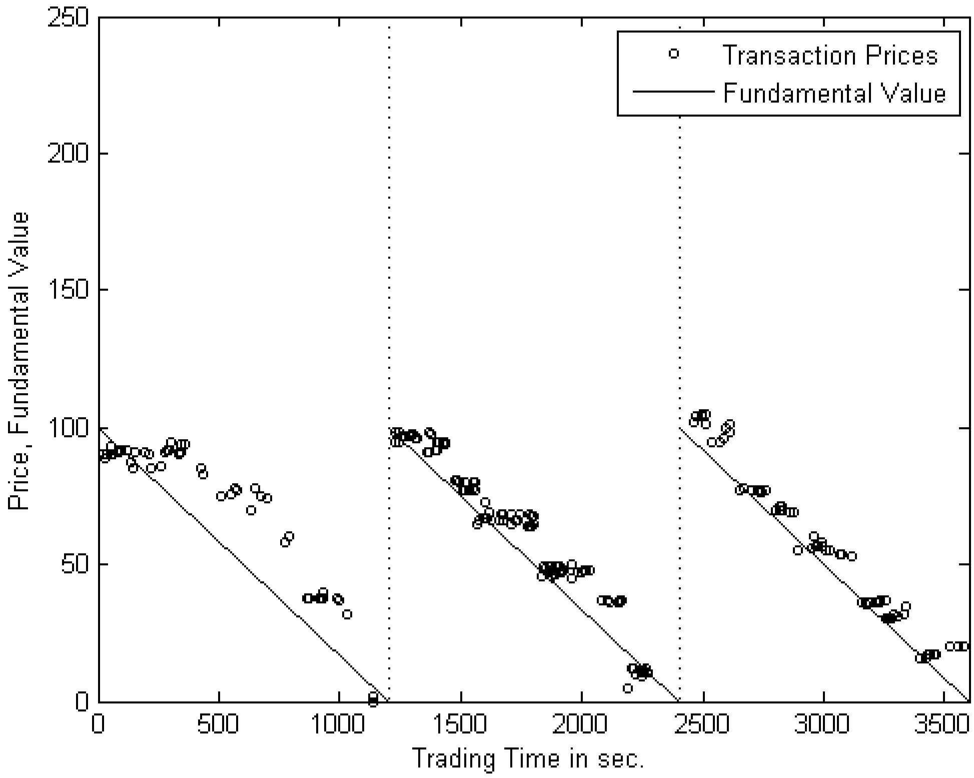
Market M8 in *INFO*



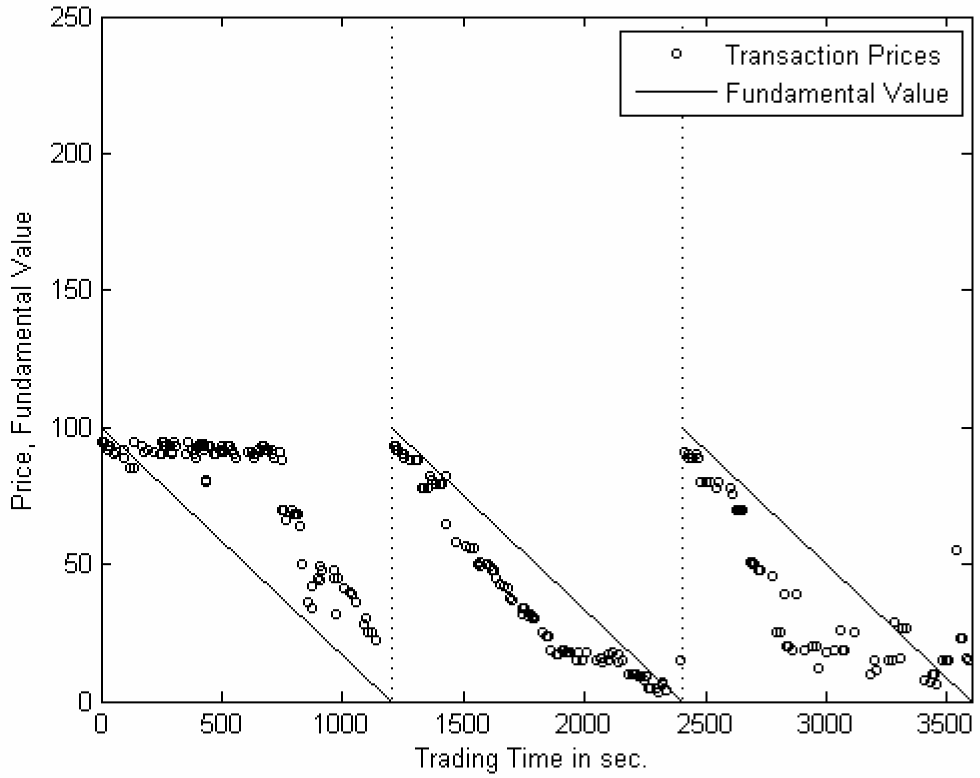
Market M9 in *INFO*



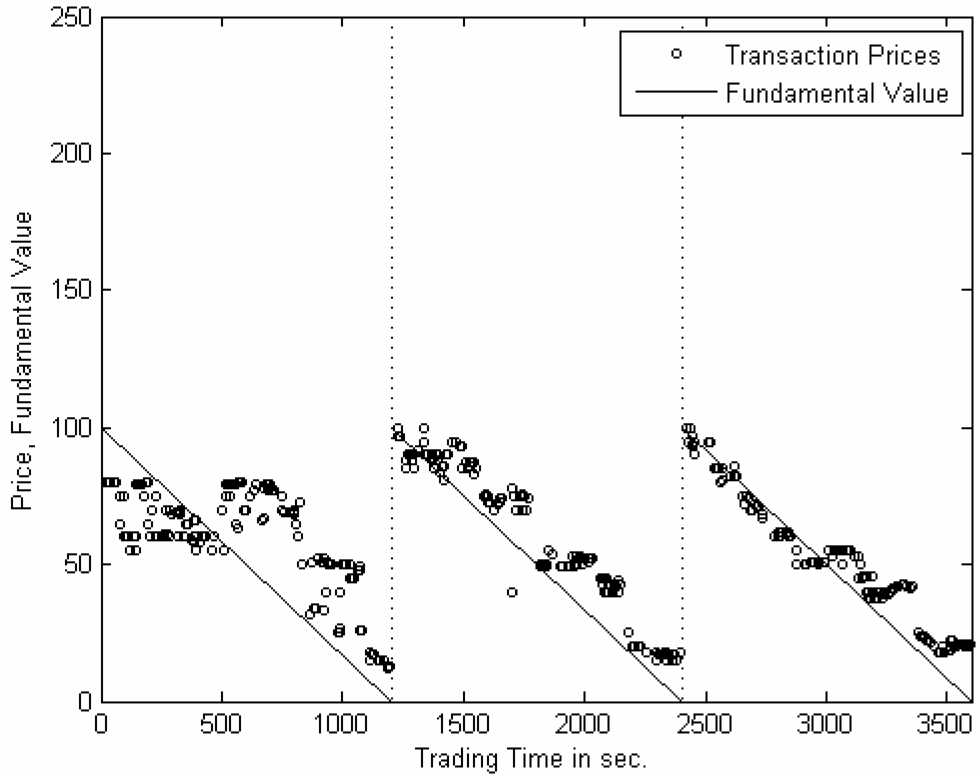
Market M10 in *INFO*



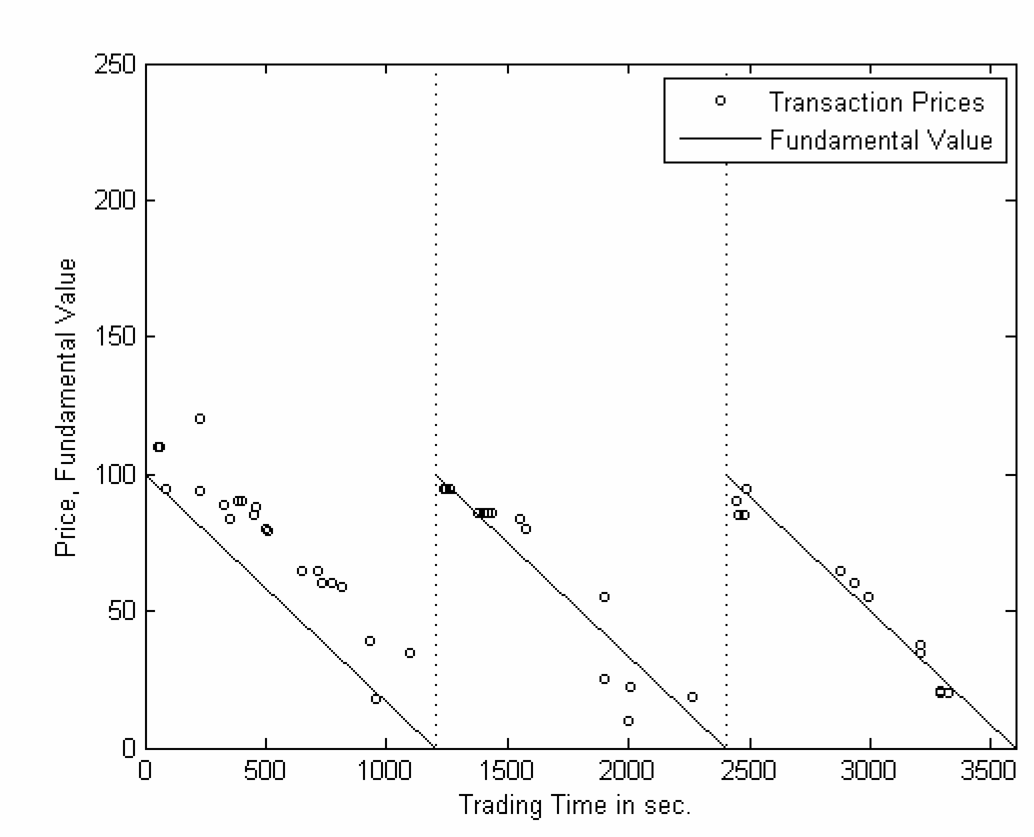
Market M11 in *INFO*



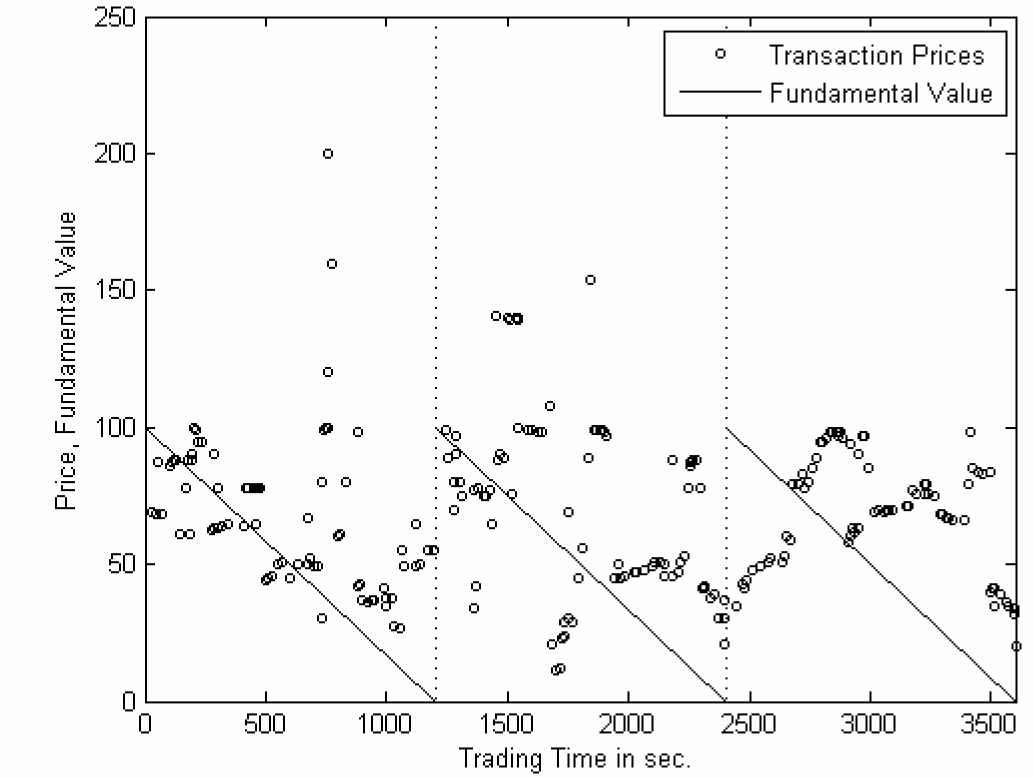
Market M12 in *INFO*



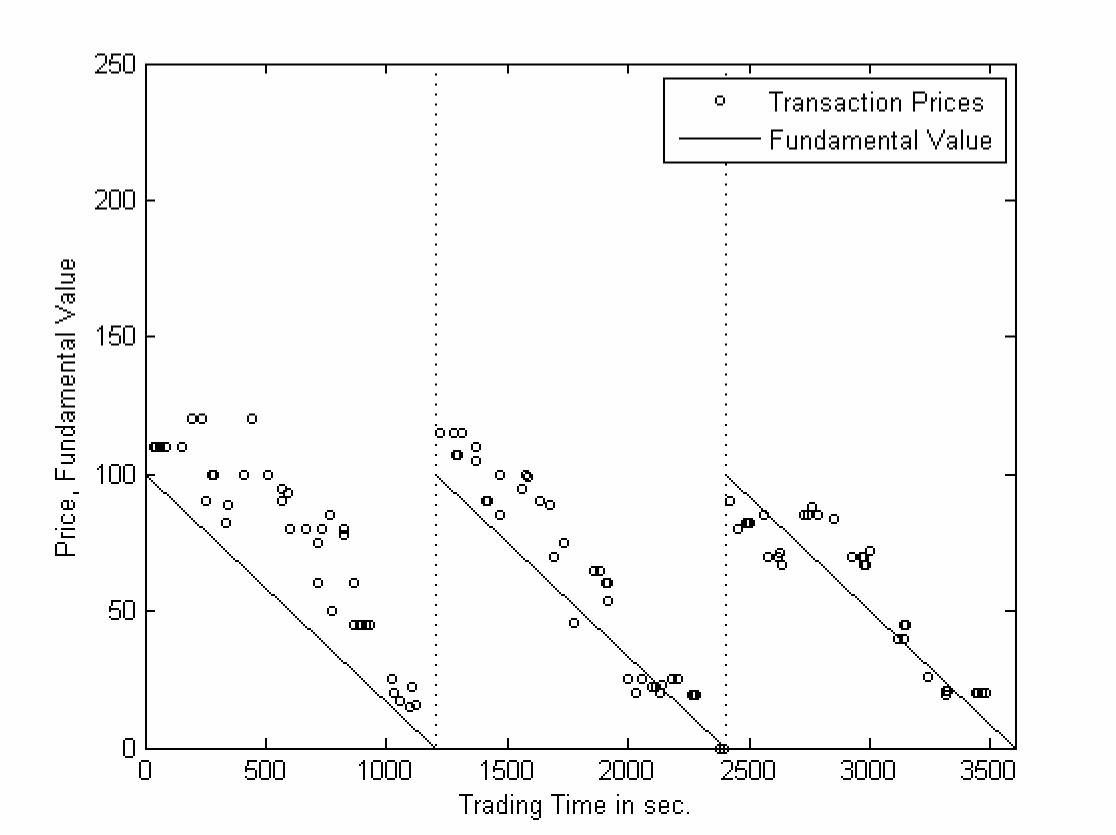
Market M1 in *INSIDER*



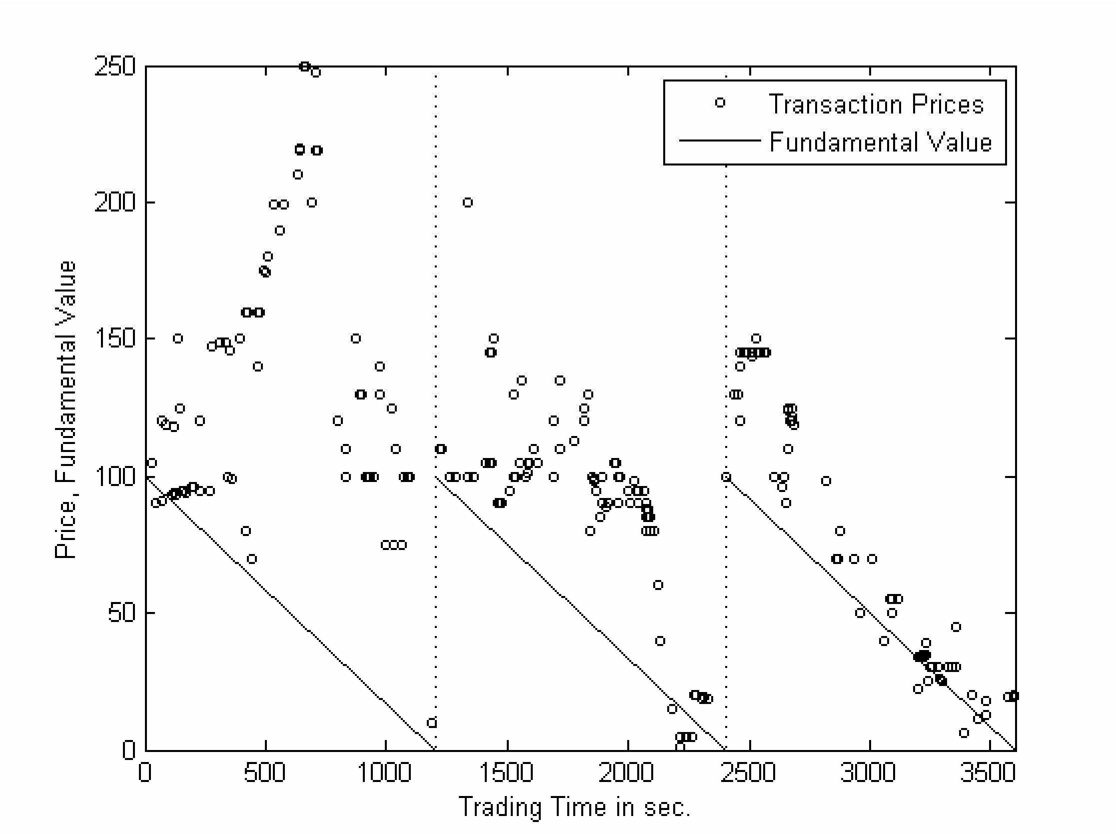
Market M2 in *INSIDER*



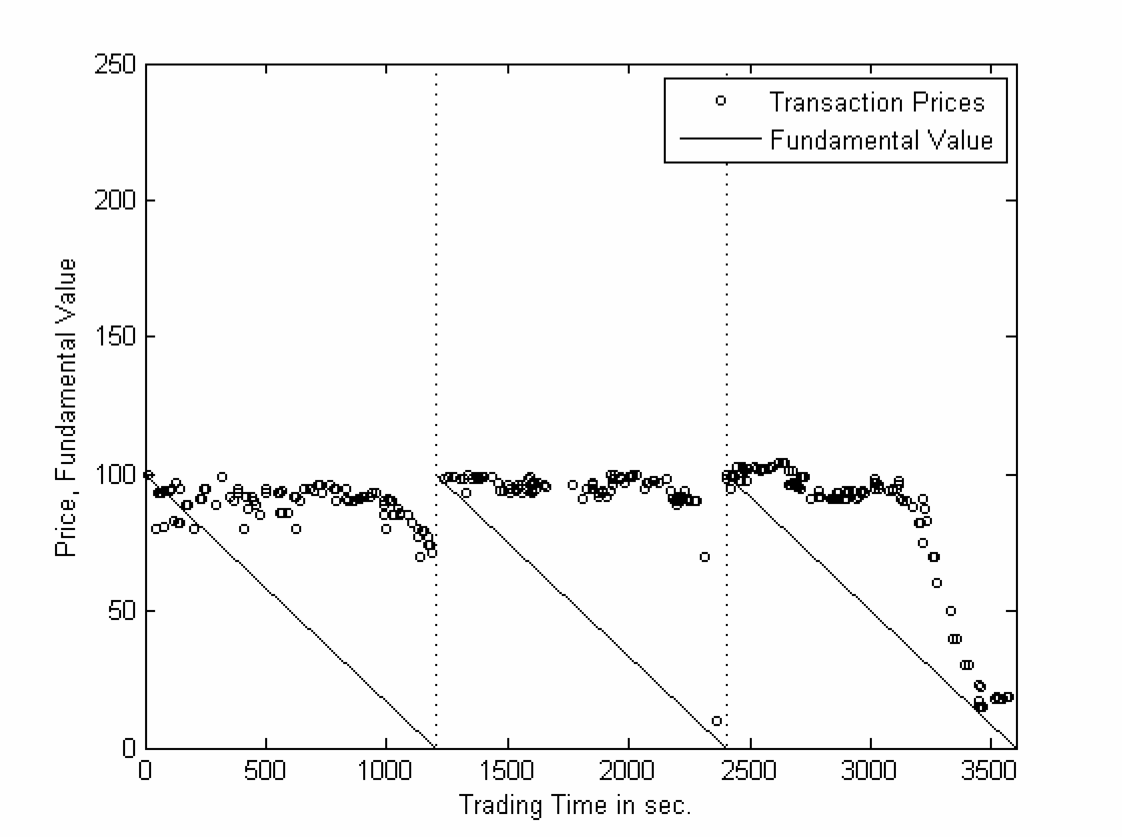
Market M3 in *INSIDER*



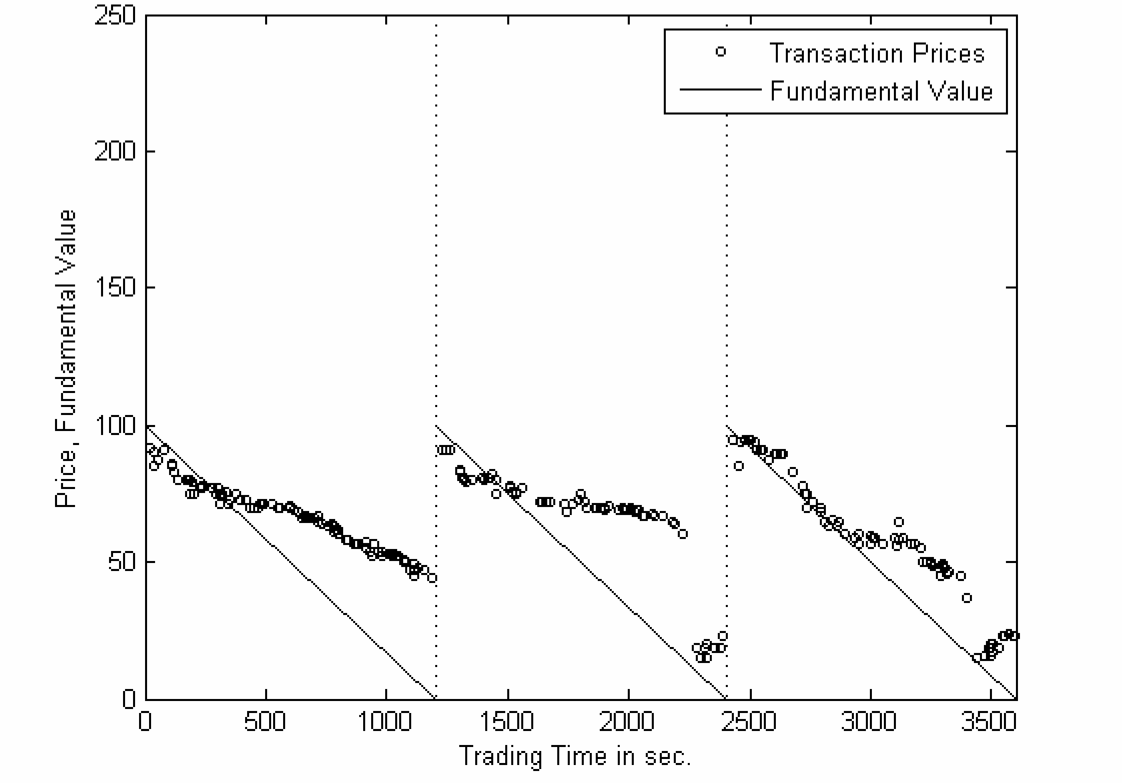
Market M4 in *INSIDER*



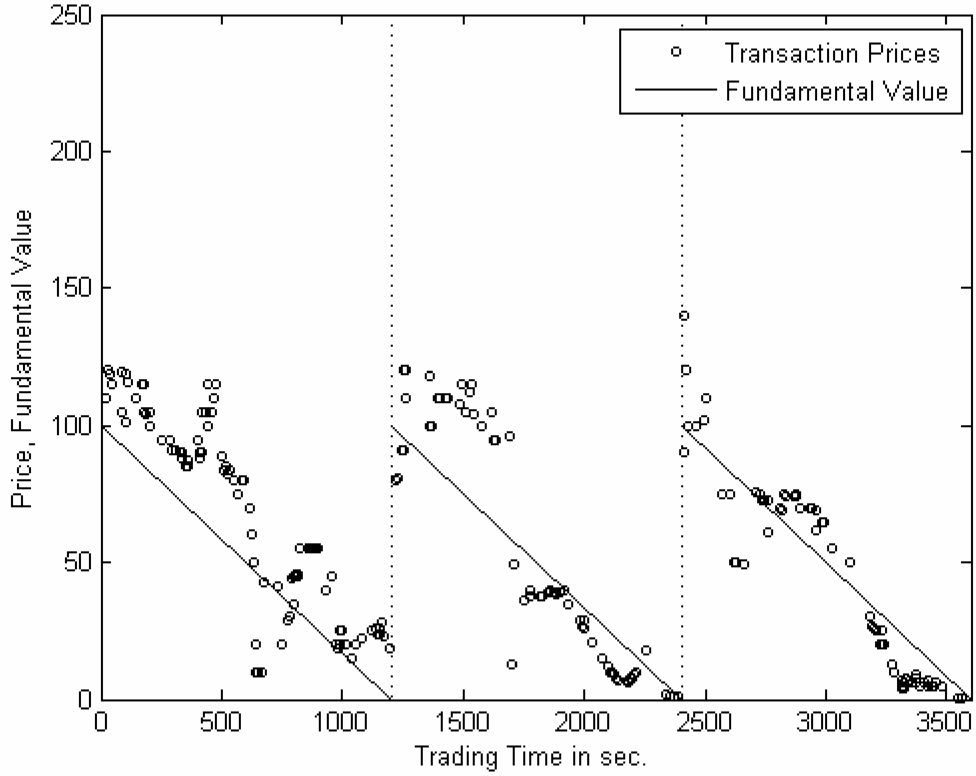
Market M5 in *INSIDER*



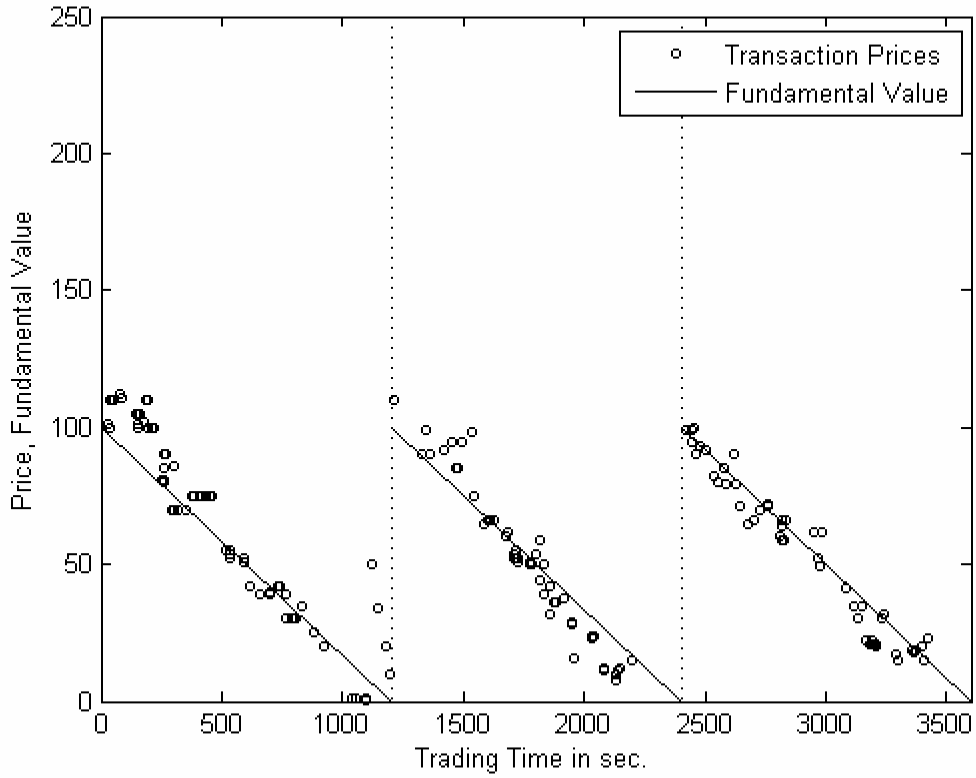
Market M6 in *INSIDER*



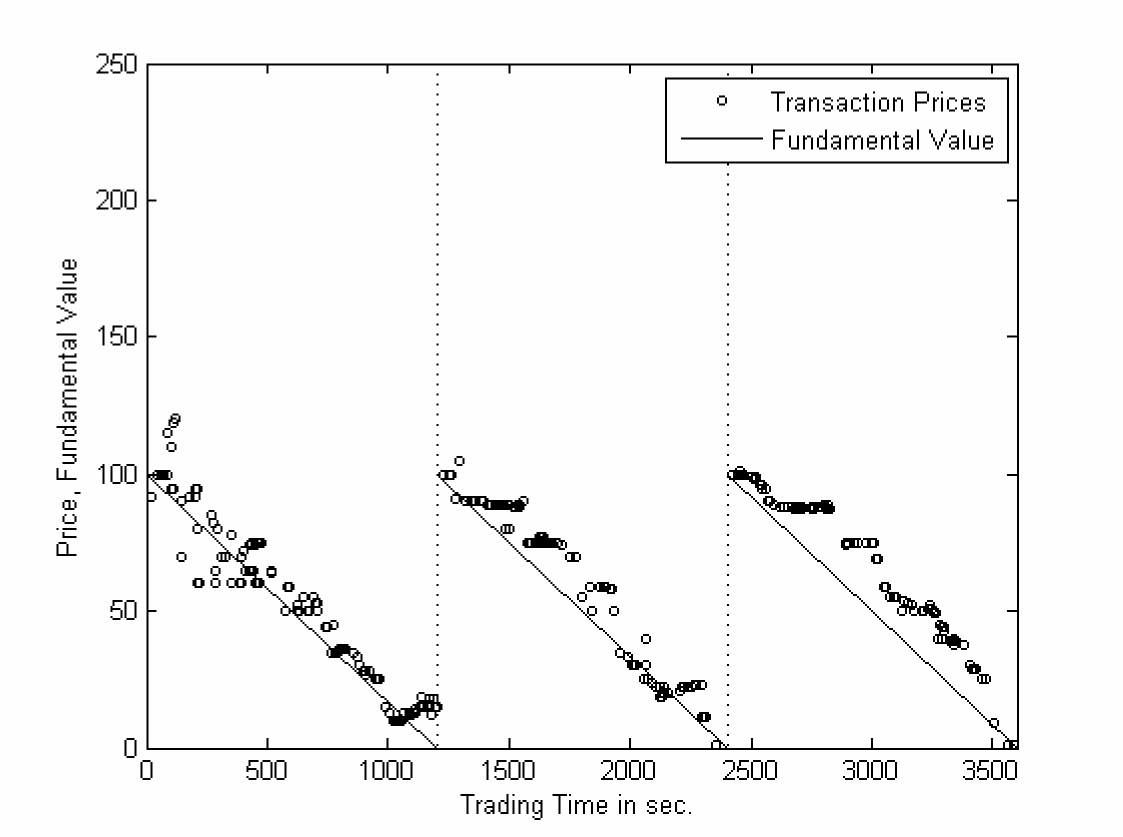
Market M7 in *INSIDER*



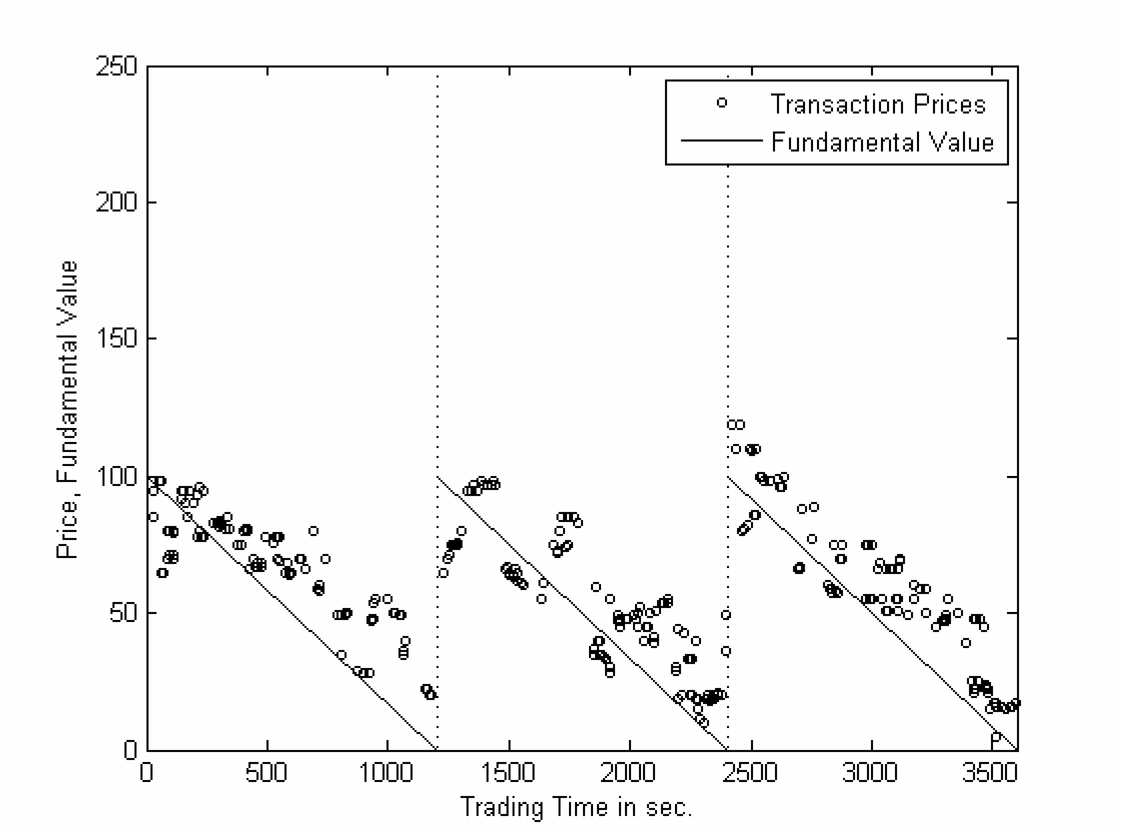
Market M8 in *INSIDER*



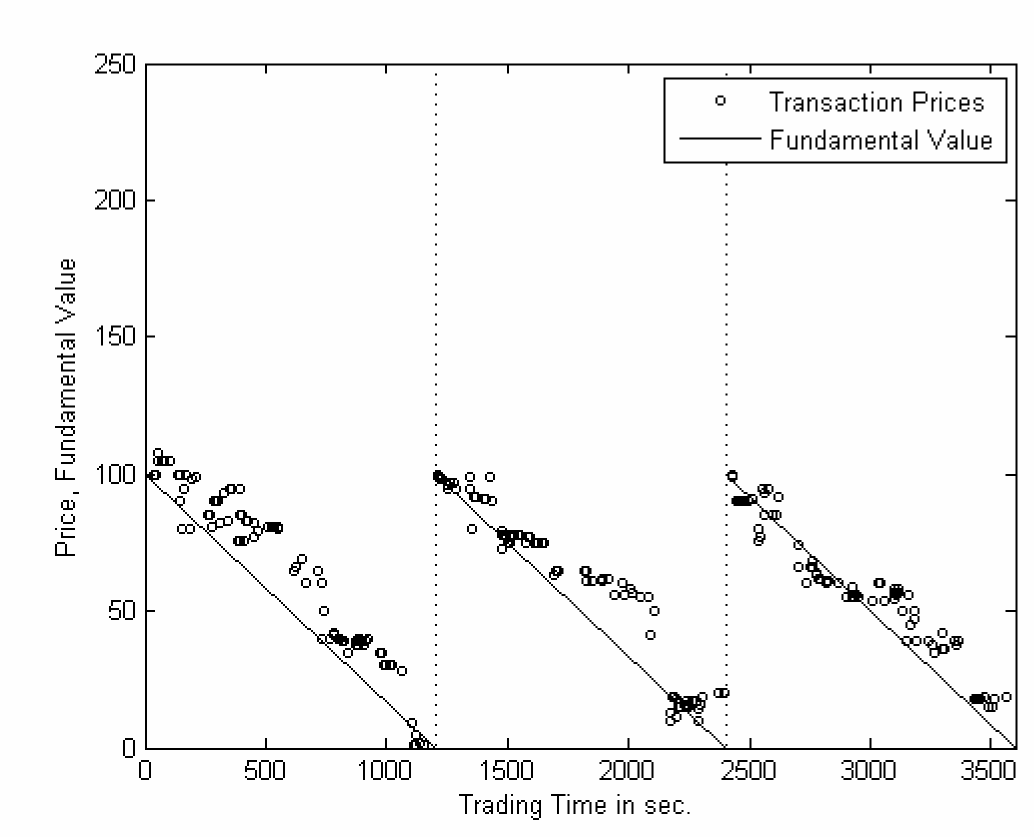
Market M9 in *INSIDER*



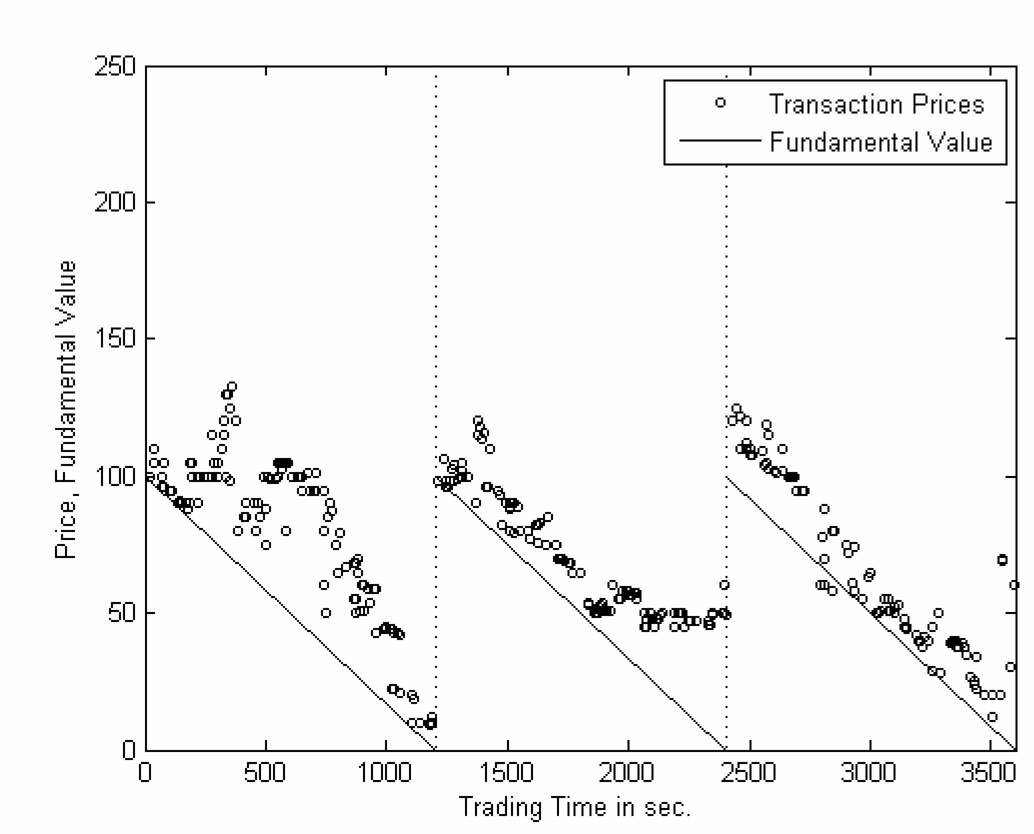
Market M10 in *INSIDER*



Market M11 in *INSIDER*



Market M12 in *INSIDER*



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Bubbles and information: An experiment

Abstract

We study whether information about imminent future dividends can abate bubbles in experimental asset markets. Using the seminal design of Smith et al. (1988) we find that markets where traders are asymmetrically informed about future dividends have smaller, and shorter, bubbles than markets with symmetrically informed or uninformed traders. Hence, fundamental values are better reflected in market prices – implying higher market efficiency – when some traders know more than others about the future prospects of an asset. We also find that asymmetric information has a similar abating impact on bubbles as when uninformed traders accumulate experience, though for different reasons.

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