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Abstract

We investigate traders' behaviour in an experimental asset market where uninformed agents cannot be sure about the presence of insiders. In this framework we compare two trading institutions: the *continuous double auction* and the *call market*. The purpose of this comparison is to test which of the two trading mechanisms performs better in disseminating the information and in promoting a convergence towards the efficient equilibrium price. Furthermore, we aim to determine which of the two trading institutions is more likely to promote a higher level of informational market efficiency. In a framework where the presence of insiders is neither certain nor common knowledge, inspired by Plott and Sunder (1982) and Camerer and Weigelt (1991), we first test whether a discrete time mechanism of trading, like the call market, might be able to prevent the occurrence of *information mirages* and promote a greater level of efficiency when no inside information is in the market. Second, we also compare the efficiency of the two trading institutions during periods when insiders are present in the market.

Key Words: Experimental Markets, Market Efficiency, Information Mirages, Trading Institutions

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1. Introduction

As pointed out by Sunder (1995), asset markets are significantly different from other markets for at least two reasons: the informational role of prices and the duality of traders' behaviour. The first feature suggests that prices contain information. This is generally true for any other kind of market, but there is a specific issue characterizing asset market prices. While in other markets, prices are informative in the sense that they make customers aware of their budget constraints, asset market prices reflect the information available to each trader at any instance in time. Strictly speaking, asset markets are informative in the sense that they convey information from informed to uninformed traders. As Plott (2000) points out, asset markets could be compared to a statistician who collects and aggregates the information dispersed across the market, and the asset price is the form in which the findings are published. The second feature refers to the fact that each trader could be a buyer as well as a seller in the same market, i.e. traders can, both, buy and sell assets in exchange for money.

We investigate traders' behaviour in an experimental asset market where uninformed agents cannot be sure about the presence of insiders. In this framework we attempt to compare two trading institutions: the continuous double auction and the call market. The purpose of this comparison is to test which of the two trading mechanisms performs better in disseminating the information and in promoting a convergence towards the efficient equilibrium price. In other words, we test which of the two trading institutions is more likely to promote a higher level of informational market efficiency.

Several previous studies (see Sunder, 1995) show that the continuous double auction trading mechanism succeeds in the complicated task of disseminating the information from informed to non-informed traders within contexts where enough traders hold the information and the presence of insiders into the market is common knowledge. In this sense, Plott and Sunder (1982) show that, for a one period life asset with a common and uncertain value, the double auction mechanism was able to drive the price convergence towards the fundamental value of the asset. Differently stated, non-informed traders were able to infer information held by informed traders and no relevant differences between informed and non-informed traders' profits were found. According to the authors, the continuous type of trading involved in the double auction institution may be the main factor responsible for the information dissemination.

Some years later, Camerer and Weigelt (1991) investigated traders' behaviour in an experimental environment where subjects were not sure about the presence of informed traders in a given trading period. While in experiments where the presence of insiders is common knowledge, the only challenge for non-informed traders is to interpret the information from the insiders' activity, in Camerer and Weigelt's (1991) framework, traders were not sure whether insiders were or were not present during a certain trading period. As a consequence, traders could mistakenly infer information even in cases where no insiders were in the market and prices did not convey any information. When one trader incorrectly interprets information during periods with no inside information, he may negotiate as if he was an insider. At this point, other traders may wrongly conclude that he is an insider and so on. The price path consequently generated is known as the "information mirage". Camerer and Weigelt (1991) show that information mirages cause prices to depart from the efficient equilibrium price and undermine the overall market efficiency. Inspired by the previous two studies, in a framework where the eventual presence of insiders in not common knowledge, we first test whether a discrete time form of trading, like the call market, might be able to prevent the occurrence of information mirages and promote a greater level of efficiency when no inside information has entered the market. Second, we also compare the efficiency of the two trading institutions during periods when insiders are within the market.

The remainder of this work is organized as follows. In the next section we present a review of the literature and in the third section the experimental design. In section 4 we discuss the theoretical background, then in sections 5 and 6 we present the hypothesis tested and the results obtained, respectively. Finally, section 7 concludes.

2. Literature review

As is apparent, the informational role of prices is directly connected with the informational efficiency of asset markets. The latter is a key theme in modern finance. Many authors like Fama (1965, 1970, 1991, 1998), Samuelson (1965) and Bachelier (1900) have produced several papers describing empirical evidence on the statistical properties of prices. According to Fama (1965), a market is efficient whenever prices are able to "fully reveal" the available information. In other words, informed traders move to take advantage of their information, causing a price change that reveals their private information. At the same moment, uninformed traders observing the price change can deduce that some informed traders have favourable information about the asset. In a real life context, it is really difficult to identify and analytically represent the information set and it is also hard to compute the correct theoretical price of a generic asset, which would serve as a benchmark for the analysis. Probably the best way to test this theory is in a controlled environment, i.e. in an economic laboratory.

Experimental studies about market efficiency are subdivided into three strands of literature. The first is the dissemination of information from informed to uninformed traders. The second strand involves studies about the aggregation of information among market participants. The third focuses on determining simultaneous equilibrium in asset and information markets. These three strands of literature are strongly linked and, when investigating market efficiency, none of these strands should be omitted.

General details about how to design asset markets can be found in Sunder (1991) and Friedman and Sunder (1994). Most experimental designs present a double-auction mechanism in which traders are, at any moment, free to post their bid and ask prices and/or accept existing bids and asks. This mechanism has the attribute of being symmetric and several studies show its appropriateness in reaching the efficient equilibrium (Smith, 1962, 1964, 1976; Plott and Smith, 1978; Ketcham, Smith and Williams 1984; Holt, Langan and Villamil, 1986; Davis and Williams, 1986; Smith and Williams, 1989; Gode and Sunder, 1989, 1991; Davids, Harrison and Williams, 1993; Mestelman and Welland, 1992; Holt, 1995).

Dissemination of information studies show how information switches from informed to uninformed traders. One of the first key papers shedding light on the information dissemination topic is by Plott and Sunder (1982). They study the conditions under which information is disseminated from informed to uninformed traders. They show that the rational expectations (RE) model performs better than the prior information (PI) model in disseminating the pooled information in the market. Furthermore, the convergence process accelerates with subjects' experience. Two years later, Forsythe et al. (1984), in a similar framework, confirmed Plott and Sunder's (1982) main results.

Some years later, Camerer and Weigelt (1991), in an effort to explain the huge amount of volatility that sometimes affects asset prices, designed a double auction mechanism where, in each period, no traders or half of the traders were insiders. This particular experimental design caused uninformed traders to face an additional challenge. If in standard contexts (see Plott and Sunder, 1982) the only concern for non-informed traders was to try to infer the available information, in this new framework traders could not be sure about the presence of insiders within the market. As a consequence it might be that, even in periods with no insiders, some agents could mistakenly think that there were insiders in the market. Then, these agents could start trading as if they were informed, inducing other traders to believe that some information was in the market and so on. This mechanism could lead to the creation of a price pattern named "information mirage". The latter occurs when traders see information even when no information is within the market. They find that mirages are more likely to happen during early periods, because during late periods traders were able to infer the presence of insiders by looking at non-price information like the speed of trading. Therefore, information mirages in late trading periods were more sporadic.

Brandouy, Barneto and Leger (2000) provide further evidence about price formation, asymmetric information and insider trading influence. They investigate, experimentally, the effects of asymmetric and misleading information in a (double-auction) stock market. They find that asymmetric information releases its effect into the market only when it has been revealed to all market participants. When the presence of informed traders was unknown to the other agents, the inside information allowed insiders to make greater profits, but did not produce any effects in terms of informational efficiency.

Maciejovsky (2001) provides further evidence about information dissemination: with respect to the previously presented papers, he also considers the presence of a public signal, accounting for the interaction between private and public information. In particular, the paper investigates the interaction between differently informed traders within an experimental market. Market participants could obtain either a precise public signal, a vague public signal or no public signal. In support of the market efficiency theory, the author points out that the initial heterogeneity of information among traders tended to disappear over the trading sessions. Public information soon became common knowledge as traders submitted their bids and asks and as contracts were concluded. The trading profit analysis also confirms this result, evidencing that informed traders were not able to make profits higher than average.

As we have seen, the level of information and the way in which it is disseminated are the main responsible factors driving price patterns. Further evidence about dissemination was provided by Schnitzlein (2002), who studied order-driven dealer markets where there is uncertainty about the number of insiders in the market. Schnitzlein (2002) found that insiders were more likely to compete aggressively when the number of insiders was common knowledge with respect to the treatment in which there was no disclosure. Moreover, the uncertainty about the actual number of insiders causes a convergence towards the fundamental value of the asset to be slower. So, the price efficiency is higher when the number of insiders is publicly known. This occurred because, in the disclosure treatment, the aggressive competition tended to reveal a lot of information and this allowed non-insider subjects to adjust their behaviour. However, in the no disclosure treatment, non-informed agents had difficulty making such an inference from insiders. Therefore, the presence of insiders and non-informed traders closely affected market participants' behaviour. In regard to this, Grossman (1976) argued that uninformed agents were likely to show imitative behaviours. Hey and Morone (2004) provide additional evidence related to imitative behaviour. In their framework, traders could buy partially informative signals about the true value of the asset. The authors found greater volatility when the reliability of the signal was lower and the cost of the signal was higher. Both conditions were responsible for less information and more noise entering the market. In most periods, the prices exhibited converged to the real dividend value. Herd behaviour was detected in two trading periods.

Two years later, Koessler, Noussair and Ziegelmeyer (2006) produced extensions of rational herd behaviour models, with negative payoff externalities included. In particular, the authors theoretically investigated betting behaviour in pari-mutuel markets under the hypothesis of asymmetric information. The study demonstrated that the equilibrium properties of simultaneous and sequential markets were significantly different, pointing out that, in equilibrium, the odds reflect the private information in the simultaneous case but not necessarily in the sequential case. The main factors responsible for causing information inefficiency in sequential markets were determined to be herd behaviour, which was associated with high quality information, and contrarian behaviour, which was associated with low quality information.

Huber, Kirchler and Sutter (2008) provide additional experimental evidence about the role of privileged information. In an experimental market with agents trading a general security with an uncertain value, the paper investigates whether having more information than others is always an advantage in terms of final profits. The authors found that there is a wide range of levels of information in which having additional information does not provide benefits in terms of higher returns. A positive relationship between information and higher profits was detected only for very high levels of information.

Finally, more recent experimental studies about fundamental value trajectories were provided by Noussair and Powell (2010), Giusti et al. (2012), Huber et al. (2012), Breaban and Noussair (2014), and Noussair and Yilong Xu (2014). As described above, asset markets have a tendency to price at levels that are not always consistent with the intrinsic value of the asset. Over time, many works focussing on this regularity have been performed (Smith et al. (1988), Caginalp et al. (1998, 2000), Lei and Vesely (2009), Lahav and Meer (2010), Lugovskyy et al. (2012), Andrade et al. (2012)). One commonly mentioned observation was the suspicion that the declining path of the fundamental value could be a source of mispricing. Since securities are finite with a maturity date, and pay a dividend at the end of the period, the expected value of future dividends decreases as the dividend is paid. Authors such as Noussair (2001) and Kirchler (2012) argue that agents trading in a laboratory are not as confident with the declining time patterns of fundamental values, because they usually deal with assets in the real world. Consequently, the confusion generated by decreasing fundamental patterns could lead to a mispricing phenomenon. The topic has been treated differently across the authors. Noussair and Powell (2010) designed an experiment with peak and valley phases. Peak phases were characterized by fundamentals increasing in the first half of the total periods and decreasing in the second half. Valley sessions occurred in the complementing pattern. The authors demonstrate that prices tracked the fundamental value closer during a peak than a valley. Giusti et al. (2012) compared experiments in which fundamental values either increased or decreased, finding that fundamental value trajectories with an increasing trend were more conducive to pricing closer to fundamentals than those that were decreasing. Huber (2012) found overpricing and underpricing associated to decreasing and increasing fundamental trajectories, respectively. Generally, previous studies showed such a relationship between the fundamental value patterns and the price discovery process.

Finally, Noussair and Yilong Xu (2014) studied the occurrence of a financial contagion and its relationship with information mirages in an experimental asset market. The authors showed that, during periods when insiders were present, the private information was rapidly revealed by prices, however during periods with no privileged information, information mirages occurred frequently. The latter can be easily interpreted as a form of financial contagion, which leads traders to mistakenly believe that some information is in the market even during periods without insider presence. As a consequence, a market specific shock can be transmitted from one asset to another without a justifiable underlying reason.

Unfortunately, literature is lacking concerning the relationship between trading institutions and financial market performance. The continuous double auction and the call auction have been the main trading institutions on which most empirical and experimental investigations have been performed so far.

Most of the theoretical research focuses on modelling trading institutions. In regard to call auction modelling, the main theoretical contributions can be found in Mendelson (1982), Ho et al. (1985), Satterthwaite and Williams (1993), and Rustichini et al. (1994). As far as double auction modelling is concerned, the main contributions can be found in Friedman (1984, 1991), Wilson (1987), Easley and Ledyard (1993), and Glosten (1994).

In any case, very few experimental studies have been produced on the relationship between trading institutions and market efficiency. Smith et al. (1982) compared the continuous double auction with a call market institution. The authors found the price convergence process to be more rapid and reliable in the continuous double auction than in the call market. The double auction was also found to perform better in terms of allocational efficiency.

Friedman (1993a) provides another relevant contribution. He studied the impact of both a continuous double auction and a clearing house (with multiple orders) trading mechanism on market efficiency. He found that the informational efficiency was very similar for the two trading institutions compared, however the continuous double auction exhibited greater allocational efficiency in respect to the clearing house treatment.

Theissen (2000) compared continuous double auctions, call markets and dealer markets. The author focuses on informational efficiency within a sequentially arriving information framework. He found that, in the call market institution, opening prices were closer to the fundamental value of the asset than opening prices in the continuous auction and in the dealer markets. Concurrently, the call market showed a significant tendency to underreact to the arrival of new information, exhibiting a poor ability to relay the new information to prices. The continuous auction and the dealer markets were found to be more efficient at the average period price level, in the sense that, on average, these institutions exhibited fewer deviations from the true value of the asset. Nevertheless, the dealer market presented the highest transaction costs.

Van Boening, Williams and LaMaster (1993) showed that the price bubbles and crashes observed in the double auction institution were also found with regularity in a 15-round closed-book call market treatment. Trading prices were more likely to track the fundamental value of the asset only when the same group of experienced traders participated in three consecutive 15-round markets.

In our experiment we move from the classical framework in which the presence of insiders, if there are any, is common knowledge and we investigate the relationship between market efficiency and trading institutions in a framework where uninformed traders are unsure about the possible presence of insiders. In this new experimental setting, we test which of the two main competing trading institutions (the continuous double auction or the call market) performs better in promoting a convergence towards the efficient equilibrium price. Our study does not allow testing for allocational efficiency, since in our experimental design the security has the same value for each holder. Further details about our experimental design are provided in the next paragraph.

3. The experimental design

We consider six markets where a total of 51 agents trade a generic asset. Each agent is provided with 200 units of experimental money and 10 units of a generic asset. At the end of each trading period the asset pays out a risky dividend. The value of the dividend could be either 20 or 10, depending on two equally likely world states. At the beginning of each trading period, the experimenter sets the dividend value that the asset will pay at the end of that trading period by flipping a coin.

The experiment consists of two treatments: In the first treatment trading takes place through a continuous double auction trading mechanism (DA), in the second treatment trading is conducted through a call market mechanism (CM). The double auction treatment is composed of 4 sessions and the call market treatment is composed of 2 sessions. In both treatments, each session consists of 13[1] trading periods. In each session, 9[2] traders are involved. The first trading period of each session is a practice period, in which traders are not paid and become aware of the trading mechanism functioning. In the double auction treatment, each trading period lasts 5 minutes. In the call market treatment, each trading period consists of 4 calls (sub-periods) of 1 minute each.

[1] Session 2 (DA treatment) was run over 11 trading periods.
[2] Session 2 (DA treatment) and session 1 (CM treatment) were run with 7 and 8 participants respectively.

In each period, traders know that there is only a 50% chance that no traders have information about the fundamental value of the asset and a 50% chance that only 5[3] traders out of 9 are informed about the asset value previously randomly determined by the experimenter. In other words, in some periods there will be no information within the market and, in the remaining periods, only five traders out of nine will be informed about the value of the dividend.

The experiment was programmed in zTree (Fischbacher, 2007) and was run at the University of Tilburg (CentER). The detailed instructions of the experiment and the zTree screen shots can be found in appendixes A and B.

2.1. Earnings

Earnings were expressed in terms of Experimental Currency Units (ECU), which were converted to Euro at the end of the session at a conversion rate of 1 ECU to €0.005 for the double auction sessions and 1 ECU to €0.003 for the call market sessions. At the end of each period, both the dividend of the period and the profit were announced to traders. At the end of the session, the total profit, expressed as the sum of the profits in the 12 real periods, was communicated and paid out to each trader. Traders could not sell more units of asset than they owned and could buy shares only if they had enough money in their portfolio. In our experiment traders earned, on average, 10 Euros per hour.

2.2. State of Information

At the beginning of each trading period, the software randomly chooses the state and the dividend value. The state could be either "Insiders" (I) or "No Insiders" (NI) with a 50% chance. The dividend value could be either 10 ECU (Bad State) or 20 ECU (Good State) with a 50% chance. Only at the end of each trading period were traders informed about the dividend of the period. Before trading started, traders were provided with a signal regarding the information on the fundamental value of the asset. The signal could be either "no information on the dividend" or "the dividend is 10" or "the dividend is 20". Traders who received the informative signal (10 or 20) were insiders. Traders receiving the non-informative signal did not have any information about the true dividend and could not be sure that the randomly chosen state was NI. In fact, in each trading period, there existed a 50% chance that all traders received the non-informative signal and a 50% chance that only 5 traders out of 9 received the informative signal. The identity of insiders, if there were any, was randomly chosen at the beginning of each period and not revealed to the market participants. Subjects met in the laboratory and were read the instructions (reported in appendixes A

[3] Session 2 (DA treatment) and session 1 (CM treatment) were run with 4 insiders, because of the lower number of participants with respect to the other sessions.

and B). The probabilities of the state, the dividend distribution and the number of insiders (if there were any), were common knowledge.

2.4. Trading Institutions

In a continuous double auction mechanism, each trader, at any moment during the trading period, was free to enter a bid (an offer to buy one unit of the asset for a specific amount of cash) or a request (an offer to sell one unit of the asset for a specific amount of cash). When a trade proposal is submitted, it appears on the book and it becomes public information. Traders can accept outstanding bids and asks. When an existing bid or ask is accepted by another trader, then a transaction is completed and the price at which the contract has been closed also appears on the book and becomes public information. Traders can buy/sell one unit at a time and as often as they wanted in each trading period. Plott and Sunder (1982) showed that a double auction trading mechanism performs particularly well in disseminating the information, because it involves a continuous type of trading. In particular, each subject, while trading, can observe the other traders' behaviours in the market. This feature allows uninformed traders to infer the information held by informed traders just by observing their trading activity. If the inference process is complete and immediate, actual prices should reveal at any moment all the aggregate information in the market. However, in a call market (call auction) mechanism, each trader privately submits his purchase or sale order. For a single unit of the asset, the purchase order consists of the highest acceptable purchase price and the sale order represents the lowest acceptable sale price. When the trading (sub) period closes, all the orders previously submitted are collected and processed. In particular, purchase orders are ordered from the highest to the lowest and the demand function is derived. Sale orders are ordered from the lowest to the highest and the supply function is derived. The intersection point of the demand and supply function determines the *clearing price* at which the orders will be executed. Nevertheless, there is no guarantee that all the submitted orders will be executed. In particular, only the purchase orders at a price equal to or above the clearing value and only the sale orders at a price equal to or below the equilibrium value will be executed. Then, the clearing system provides the market with a uniform price for each call. Typically, there could be more than one call per period. In our experiment there are four calls in each trading period. In this kind of trading mechanism, each trader, when submitting his proposal, cannot observe whether the other market participants are operating as sellers or buyers and at which price they would like to sell or buy the asset. Only at the end of each trading (sub) period does each trader observe the demand and supply functions and the clearing price, realizing whether or not his proposal was executed. Therefore, in a call auction system, a discrete type of time trading takes place.

In our particular framework, in the call market sessions, traders had the chance to choose among three options: buying, selling or no-trading. If traders decided to be buyers (sellers) they were asked to submit the price at which they would like to buy (sell) the asset and how many units they would like to buy (sell) at that price. The state and the signal remained the same in the 4 sub-periods of each period. Only at the end of each period was the dividend revealed to the market participants.

In the determination of the equilibrium price (clearing price), some particular cases can arise in the call market mechanism. In fact, traders' orders can lead to situations in which there is an overlap of either suitable quantities or prices. In other words, it may be that a horizontal segment of the aggregate demand curve intersects with a horizontal segment of the aggregate supply curve. In this case, there is an overlapping of quantities. Similarly, it may be that a vertical segment of the aggregate demand curve intersects with a vertical segment of the aggregate supply curve. In this case, there is an overlapping of prices. To explain how, in equilibrium, price and quantity are determined in these special cases, first we report an example of quantities overlapping. Suppose that 6 subjects are trading in the market and that three of them are buyers and the other three are sellers. Among the buyers, the first subject (subject 1) would like to buy 2 units at 17 ECU, the second subject (subject 2) desires to buy 3 units at 15 ECU and the third subject (subject 3) wants to buy 2 units at 13 ECU. Among sellers, the first subject (subject 4) would like to sell 2 units at 11 ECU, the second subject (subject 5) desires to sell 2 units at 15 ECU and the third subject (subject 6) wants to buy 3 units at 16 ECU. The buyer and seller orders are summarized in table 1; the demand and supply functions are drawn as in figure 1.

Demand side			Supply side		
Buyer	Price	Quantity	Seller	Price	Quantity
Subject 1	17	2	Subject 4	11	2
Subject 2	15	3	Subject 5	15	2
Subject 3	13	2	Subject 6	16	3

Table 1

As we can see in figure 1, quantities overlap in the range from 2 to 4 units. The equilibrium price is 15 ECU, where the demand and supply functions intersect. In this case, quantities are split in the following way: the first buyer (subject 1) who offered to buy 2 units at 17 ECU will buy 2 units at 15 ECU, the second buyer (subject 2) who offered to buy 3 units at 15 ECU will buy only 2 units at 15 ECU. Subject 2 was not able to additionally buy the third unit because there were only two units left at a price equal or below 15 ECU. The third buyer (subject 3) who offered to buy 2 units at 13 ECU bought no units because there were no units left at a price equal to or below 13 ECU. Similarly, the first seller (subject 4) who asked to sell 2 units at 11 ECU, sold 2 units at 15

ECU. The second seller (subject 5) who asked to sell 2 units at 15 ECU, sold 2 units at 15 ECU. The third seller (subject 6) who asked to sell 3 units at 16 ECU did not buy anything because there were no units left at a price equal to or above 16 ECU.

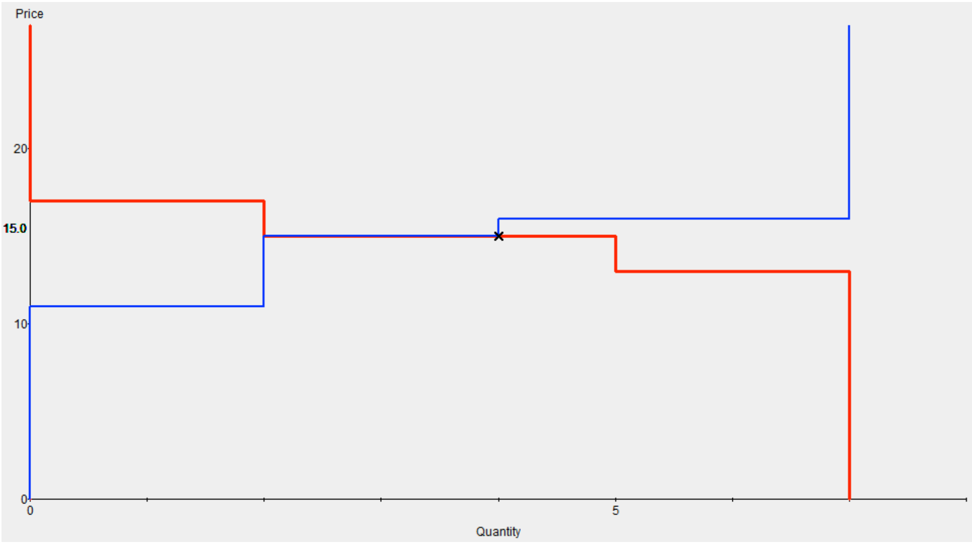

Figure 1

Second, we report an example where prices overlap. Suppose that 4 subjects are trading in the market and that two of them are buyers and the other two are sellers. Among buyers, the first subject (subject 1) would like to buy 2 units at 15 ECU and the second subject (subject 2) desires to buy 2 units at 14 ECU. Among sellers, the first subject (subject 3) would like to sell 2 units at 10 ECU and the second subject (subject 4) desires to sell 2 units at 17 ECU.

Demand side			Supply side		
Buyer	Price	Quantity	Seller	Price	Quantity
Subject 1	15	2	Subject 3	10	2
Subject 2	14	2	Subject 4	17	2

Table 2

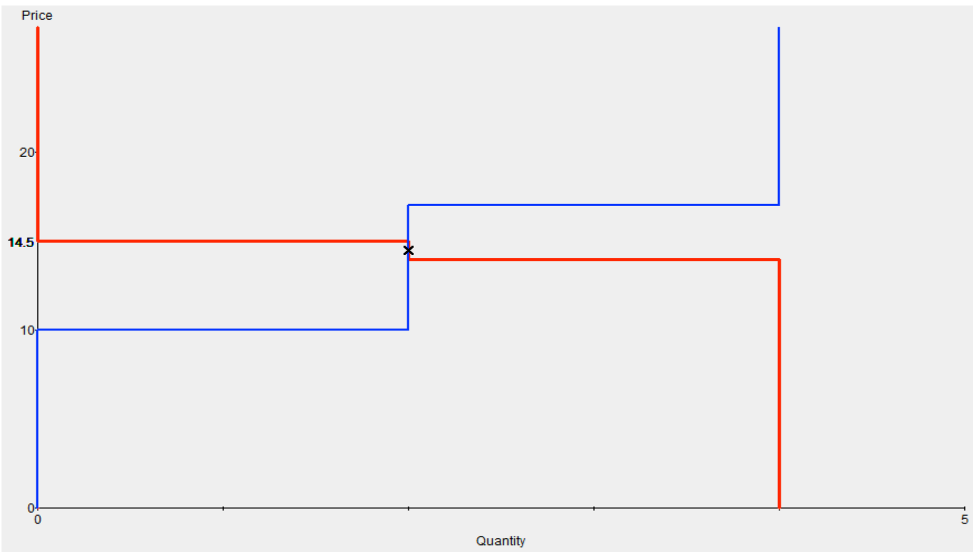

Figure 2

The buyer and seller orders are summarized in table 2; the demand and supply functions are illustrated in figure 2. As we can see in figure 2, suitable prices overlap the range 14 to 15 ECU. The equilibrium quantity is unique and equal to 2 units. By definition, a competitive equilibrium occurs at any price that equates the offered and demanded quantities. In this special case, the demand and supply functions intersect along the vertical segment between 14 and 15. As a consequence, any point on this vertical line is potentially a competitive price, which leads to the same welfare. For concreteness, in cases with no-unique price solution, we compute the equilibrium price as the mid-point of all the possible competitive prices. So, in this particular case, the competitive price is assumed to be 14.5, which is the midpoint between 14 and 15. In particular, the first buyer (subject 1), who offered to buy 2 units at 15 ECU, bought 2 units at 14.5 ECU and the first seller (subject 3), who asked to sell 2 units at 10 ECU, sold 2 units at 14.5 ECU. Both the second buyer (subject 2) and the second seller (subject 4) did not buy anything because their proposals were respectively below and above the equilibrium price.

3. Theoretical Background

There are two main competing models that can be applied to our data. The first is the prior information (Walrasian) model and the second is the rational expectations model.

The prior information model has been the traditional way to study how information is incorporated into actual prices. It states that, under expected utility and risk neutrality assumptions, traders' expectations on future prices are exogenous to the price formation mechanism. Strictly speaking, traders form their price expectations relying only on prior information (i.e. the dividend distribution), and they never update their *a priori* information during the trading period.

The rational expectations model states that traders' expectations on future prices are endogenous to the price formation process. Differently stated, traders continuously condition their private *a priori* information on actual prices. According to this model, uninformed traders are able to infer the realized state from market prices. In this sense, prices always fully reveal the aggregate information available in the market. As a consequence, there are no under-valued or over-valued securities in the market and the information is promptly revealed from informed to non-informed traders. Since the inside information can at any moment be fully revealed, there is no longer any advantage in being an informed trader and, at the end of the trading period, we should expect informed and non-informed traders' profits to be indistinguishable.

These two models will be applied to our data to see which of them is the best predictor of price patterns. The methodology of our analysis will be explained in detail in the next paragraph.

In terms of price predictions, the crucial difference between the two models can occur when the expected value of the asset is higher than the dividend associated to the realized state. In terms of security holdings, the two models' predictions are different independent of the realized state. When the good state is the realized one, according to the prior information model, informed traders are expected to be willing to bid more than uninformed traders who only evaluate the asset at its expected value (which is lower than the good state dividend). Then, only informed traders will manage to buy the asset and the price is expected to converge, at most, to the high dividend. Note the high dividend price is only the highest value in the possible equilibrium price range consistent with the model. The high dividend price will be attained only if informed traders have enough cash to bid up the prices. If not enough liquidity reaches buyers' hands and if sellers aggressively compete to sell out the asset, then insiders will be able to buy at prices even below the high dividend value (20). Then, the price range consistent with the model depends on the market liquidity and on the demand and supply conditions. For sure, the high dividend will be the upper bound of this range.

According to the rational expectations model, as prices are fully revealing, uninformed traders will behave as if they were insiders. Then, the price will converge to the high dividend but, in contrast to the prior information prediction, both informed and uninformed traders will hold the asset. Now suppose that the bad state is the realized one. In this case, the expected dividend is higher than the dividend associated with the realized state. If the prior information model holds, uninformed traders evaluate the asset more than informed traders and, as a consequence, only uninformed traders will manage to buy the asset and the price is expected to converge at most to the expected dividend. Also in this case, the expected dividend is only the upper bound of the possible equilibrium price range. Then, if not enough cash has reached buyers' hands and if sellers aggressively compete to sell the security, it is likely that uninformed traders will manage to buy at prices even below the expected dividend, having never attained the upper bound. However, if the rational expectations model holds, uninformed traders infer the realized state and will no longer be willing to pay as much as the expected dividend. Then the price will converge to the bad state dividend and both uninformed and informed traders will hold the asset at the end of the trading period.

4. The Methodology of the Analysis

The crucial issue of our research is that insider presence in the market is not common knowledge. Strictly speaking, uninformed traders cannot be sure whether or not there are informed agents in the market. Then, in our analysis we need to distinguish between periods with and without inside information. Taking into account the two competing models introduced in the previous paragraph (i.e. the prior information model, and the rational expectations model), we now perform a closer investigation on what to expect in our specific framework. In particular, we analyse the models' predictions in terms of equilibrium price and security holdings. Starting from periods with inside information, a summary of the models' predictions is reported in table 3:

	Good state, p=0.5	Bad state, p=0.5
	20	10
RE eq. price	20	10
RE asset holder	Type 1 Type 2	Type 1 Type 2
PI eq. Price	20 (at most)	15 (at most)
PI asset holder	Type 1	Type 2

Table 3: RE and PI predictions in periods with inside information

Both, good and bad states could occur with equal probability. The dividends associated with the good and bad state are 20 and 10 respectively; thus the expected dividend is 15 (also called the *uninformed price*). Let us denote informed traders as "type 1" and uninformed traders as "type 2". In particular, type 1 traders are those who knew the dividend value at the beginning of the period and type 2 traders are those who did not have any information on the fundamental value of the asset when trading started.

Suppose the good state is the realized one. If the prior information equilibrium holds, informed traders (type 1) will evaluate the asset at 20 at most, while uninformed traders (type 2) will evaluate the asset at 15. Then, only type 1 traders are expected to manage to buy and hold the asset at the end of the period and the price is predicted to converge at most to 20. Note that 20 is only the upper bound of the equilibrium price range consistent with the model. However, it is not certain that the high dividend equilibrium price will be attained. For instance, if insiders do not have enough cash to bid up the prices or if sellers compete aggressively to sell the security, it may occur that insiders will be able to buy even at prices below the high dividend value. If the rational expectations equilibrium holds, uninformed traders (type 2) are expected to infer the realized state and to start trading as if they were fully informed. Then the price should converge to 20 and both type 1 and type 2 traders will hold the asset at the end of the period.

Now suppose that the bad state is the realized one. If the prior information model holds, uninformed traders (type 2) will evaluate the security more than informed traders (type 1). Then the price is expected to converge at most to 15 and type 2 traders are supposed to hold the security at the end of the period. Also in this case, 15 is only the highest value in the equilibrium price range consistent with the model. Then, there is no guarantee that the expected dividend value will be attained. If non-informed agents do not have enough liquidity to bid up the prices or if insiders strongly compete to sell out the asset, then uninformed agents might be able to buy the security even at prices below the expected dividend value. However, if the rational expectations model holds, uninformed traders (type 2) will be able to learn that the asset will only pay out 10 at the end of the period. Then, the price is expected to converge to 10 and both types 1 and 2 traders are supposed to hold the security at the end of the period.

As far as periods without insiders having information are concerned, the rational expectations and the prior information models lead to the same equilibrium prediction. The equilibrium price is expected to be 15, without any distinction about the type of traders holding the asset. The reason for this is straightforward: there is just no information to be disseminated and traders are expected to rely only on their prior probabilities (assuming risk neutrality and expected utility).

Taking into consideration these model predictions in our particular framework, we build up our set of hypotheses. In the first step of our analysis, we investigate whether information mirages are more likely to occur in the double auction rather than in the call market treatment. An information mirage can potentially occur in periods without insiders if non-informed traders mistakenly believe that there is some information in the market. In periods with no insiders, the rational expectations and the prior information predictions coincide and both of them state that the actual prices should converge to the uninformed price, which is equal to the expected value of the dividend distribution. Then, if the market is efficient, during periods without insiders we should observe prices fluctuating around 15, which is the uninformed price. But if an information mirage occurs, we can observe prices converging to the wrong value, which can be either 10 (bad state dividend), or 20 (good state dividend) or, more generally, any other value different from the expected dividend.

We now formulate our first hypothesis and its alternative hypotheses:

> ***Hypothesis 1****: Information mirages are equally likely to occur independent of the trading institution through which trading is conducted.*
>
> ***Alternative Hypothesis 1a****: Information mirages are more likely to occur when trading takes place through a double auction institution.*
>
> ***Alternative Hypothesis 1b****: Information mirages are more likely to occur when trading takes place through a call market institution.*

In order to detect an information mirage we use a very stringent methodology, which requires three conditions. First, we look at periods without insiders. Second, we require the median actual price to be closer to the mirage price (10 or 20) than to the RE/PI prediction price. Third, the mean squared error (*MSE*) between the actual prices and the mirage price has to be lower than the *MSE* between the actual prices and the RE/PI prediction price. The *MSE* is used as a measure of deviation of actual prices from the RE/PI predictions. The formulation is reported below:

$$MSE = \frac{1}{n}\sum\nolimits_{i=1}^{n}\left(P_E - P_i\right)^2$$

where:

P_E represents the theoretical equilibrium value according to the RE/PI predictions,

P_i represents the actual prices.

Generally speaking, the *MSE* measures the average squared deviation of trade prices over the theoretical equilibrium value. The lower the *MSE* is, the more the market is trading in proximity of the RE/PI prediction. Then, the third condition requires that actual prices exhibit less deviation from the mirage price than from the uninformed price.

In the second step of our analysis, we test the informational market efficiency. Strictly speaking, we test how much closer the actual prices time series is with respect to the RE/PI predictions. In this step, we distinguish between periods with no inside information in the market and periods with informed insiders. As stated above, the reason for this distinction is that the RE/PI predictions are different depending on the presence of insiders in the market.

Then, we formulate our second hypothesis and its alternative hypotheses. Our second hypothesis is divided into hypothesis 2a and 2b.

Hypothesis 2a: *During periods with no inside information, prices exhibit the same deviation from the rational expectations predictions when trading takes place through the call market and the double auction mechanism.*

Alternative Hypothesis 2a(i)*: During periods with no inside information, prices exhibit closer convergence to the rational expectations predictions when trading takes place through the call market mechanism.*

Alternative Hypothesis 2a(ii)*: During periods with no inside information, prices exhibit closer convergence to the rational expectations predictions when trading takes place through the double auction mechanism.*

Hypothesis 2a is strictly linked with hypothesis 1. In fact, if we find that information mirages are more likely to occur in the double auction treatment, we should also expect alternative hypothesis 2a(i) to be accepted. Indeed, information mirages undermine the overall efficiency of the market, causing prices to depart from the efficient equilibrium price. So, if we find that the call market institution is more likely to prevent the occurrence of information mirages, then we should also expect the call market mechanism to perform better when no inside information is within the market.

Hypothesis 2b*: During periods when insiders have information, prices exhibit the same deviation from the rational expectations predictions when trading takes place through the call market and the double auction mechanism.*

Alternative Hypothesis 2b(i)*: During periods when insiders have information, prices exhibit closer convergence to the rational expectations predictions when trading takes place through the double auction mechanism.*

Alternative Hypothesis 2b(ii)*: During periods when insiders have information, prices exhibit closer convergence to the rational expectations predictions when trading takes place through the call market mechanism.*

In order to test hypothesis 2, we compute the mean squared error (*MSE*) of actual prices versus the RE/PI price predictions. In a given trading period, if the actual prices' *MSE* tendency toward the RE prediction is lower than the *MSE* computed tendency toward the PI prediction, then this indicates that prices more closely track the RE prediction price than the PI one. It has to be pointed out that, when the good state occurred, the RE and the PI price forecasts are not so different from each other. In fact, the RE model predicts a convergence toward 20 and the PI model predicts that prices can converge at most to 20, depending on the market liquidity and on the demand/supply conditions. So, if the good state occurs and we detect a price convergence toward 20, we cannot definitely state which of the two equilibria is being achieved. In this case, to state whether the RE or the PI model is holding, we investigate the RE and PI security holdings predictions. More details on this procedure will be reported in the next paragraph.

In the third step of our analysis we investigate how profits are distributed between informed and uninformed traders. This step is useful for further investigation of information dissemination during the insider state. In fact, when there are insiders within the market, if the information is promptly disseminated, one should expect insiders' and non-insiders' profits to be indistinguishable at the end of the period. In other words, if uninformed traders soon discover the realized state, they are expected to trade as they were informed, eliminating the informational advantage of informed traders. The sooner the information is disseminated, the sooner the insiders informational advantage diminishes. If the information dissemination occurs only in late periods, then informed traders have the possibility to exploit their informational advantage in the early moments of the trading period, making higher profits than uninformed traders. So, not only does it matter whether or not the information is disseminated but also the timing of the dissemination process is significant for profits accountability.

To test how profits are distributed between insiders and non-informed agents, we compute, within each period with inside information, the percentage ratio of the average realized profit per informed trader to the average realized profit per uninformed trader. We call this measure "insider premium". In a given period, if the insider premium approximates 100%, it would mean that, on average, informed and non-informed traders realized the same profit. Differently stated, it would mean that the dissemination was sufficiently rapid to allow uninformed traders to recover their informational disadvantage and to perform, on average, as well as the informed agents. Then we formulate our third hypothesis and its alternative hypotheses.

***Hypothesis 3**: During periods when inside information, there are no significant differences between the double auction and the call market insider premium.*

***Alternative Hypothesis 3a**: During periods when insiders have information, the double auction insider premium is higher than the call market insider premium.*

***Alternative Hypothesis 3b**: During periods when insiders have information, the call market insider premium is higher than the double auction insider premium.*

In the next paragraph we report our experimental results for each of the three previously stated hypotheses.

5. Experimental Results

Looking for **informational mirage** we can report our first result: we reject hypothesis 1 and we accept alternative hypothesis 1a, i.e. information mirages are more likely to occur when trading takes place through a double auction mechanism. As mentioned in the last paragraph, first we look for information mirages during the no insider periods. Then, we require the median actual price to be closer to the mirage price (10 or 20) than to the RE/PI price, and the mean squared error (*MSE*) between the actual prices and the mirage price to be lower than the *MSE* between the actual prices and the RE/PI price. Figure 3 illustrates situations where we detect information mirages in the double auction treatment.

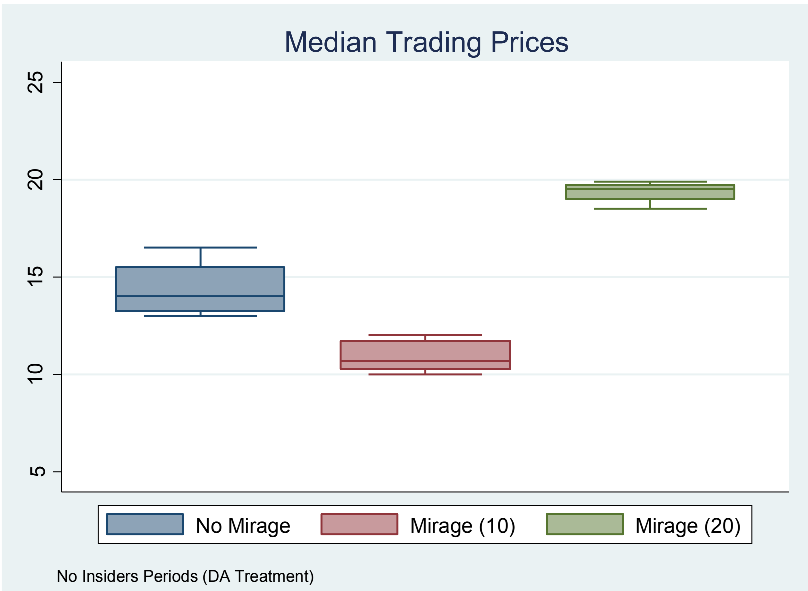

Figure 3: Distribution of Median Actual Prices during periods with no inside information (DA), grouped by type of mirage

In the double auction treatment, we detect 9 mirages out of 20 periods without inside information[4]. Out of the 9 mirages detected, 3 reflected the good state price and 6 reflected the bad state price.

In the call market treatment, we detect 2 mirages out of 9 periods with no inside information (see figure 4). Both mirages reflected the good state price (20).

Then, considering both treatments, out of the 11 mirages detected, 6 reflected the bad state price (10) and 5 reflected the good state price (20). So, mirages did not exhibit a remarkable tendency to reflect the good state price rather than the bad state price[5].

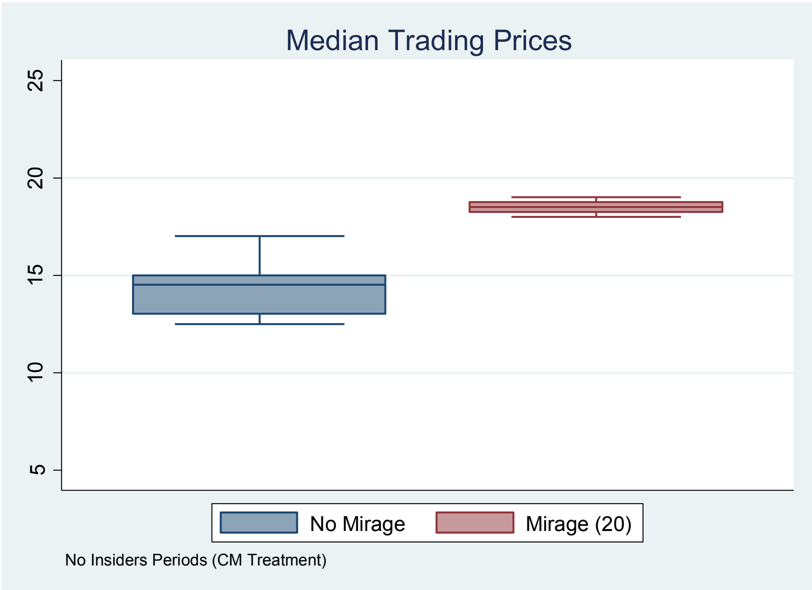

Figure 4: Distribution of Median Actual Prices in periods with no inside information (CM), grouped by type of mirage

We now concentrate on **informational efficiency**. We reject hypothesis 2a and we accept alternative hypothesis 2a(i). During periods with no insider information in the market, prices exhibited a closer convergence to the RE equilibrium when trading took place through a call market mechanism. Since information mirages are more likely to occur in the double auction treatment, our result about hypothesis 2a is not surprising. Since, the call market mechanism is more likely to prevent information mirages from occurring, we should also expect the call market to promote a greater level of informational efficiency when no insiders are present in the market. Remembering

[4] We exclude 4 periods that, even satisfying our three conditions, exhibited a trading activity, which did not resemble the typical activity during insider periods. In particular, we exclude period 12 of session 1 and periods 4, 5 and 7 of session 4. The trading activity in these periods is illustrated in appendix C. Looking at the activity in periods 12, 4 and 5, we see that for the most of the period prices are closer to a potential mirage price and that the convergence towards the expected dividend only occurs in the late moments of the period. In period 7, even in the final part of the period, prices fluctuated over a range between 10 and 15. In this case, we think that a great level of risk aversion may be responsible for this price pattern.

[5] Trading activity in all the periods in which we detect information mirages is reported in appendix D.

that the market is efficient if prices fluctuate around the expected dividend (uninformed price), but not during insider periods. Then, to classify the market as efficient, we require trading prices to exhibit a lower *MSE* when compared with the uninformed price than when compared with both the good (20) and bad (10) state prices. The clearest way to show this kind of result is to count, period by period (only when no insiders are in the market), how many times the *MSE* to the expected dividend (15) is lower than both the *MSE* to the low dividend (10) and the *MSE* to the high dividend (20). Performing this analysis, we find that, in the double auction treatment, in 7 out of 20 (35% of the cases) periods with no insiders, the *MSE* to the uninformed price is lowest when it is compared to, both, the low and the high dividend. Note that it is not obvious when a non-mirage situation coincides with a situation where the market is efficient in the sense described above. For example, period 12 of session 3 has not been classified as a mirage, even though the *MSE* to the low dividend was the lowest, since the median price was 16 and it was closer to the uninformed price than to any other possible dividend. Therefore, one of our three conditions was missing. In any case, even if no mirage occurred during this period, the market cannot be said to be efficient because the *MSE* value to the expected dividend was higher than the *MSE* to the low dividend. Apart from period 12 of session 3, in all other non-insider periods, a non-mirage always coincides with a situation in which the efficient price was attained. Similarly, in the call market treatment, in 7 periods out of 9 (77% of the cases) with no insiders in the market, the *MSE* value to the uninformed price was lower than both the *MSE* to the low and the high dividend. So, we find the call market mechanism to be more efficient than the double auction one when there is no information in the market. As a further step, during all non-insider periods in which the uninformed price is the best approached benchmark, we compare the double auction *MSE* distribution with the call market one. This further test is useful to identify in which of the two treatments the rational expectations price was approached with a lesser margin of error. Figure 5 shows the box plot analysis of the *MSE* distribution in the two treatments.

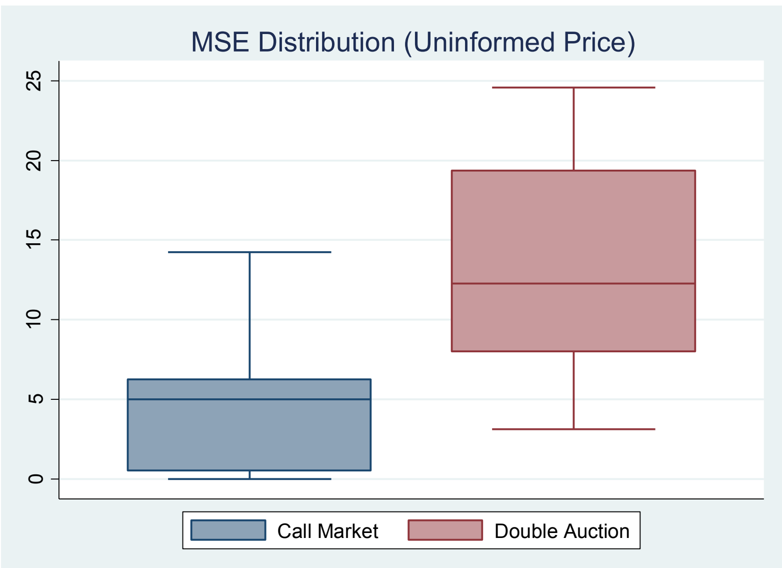

Figure 5: *MSE* Distribution

As we can see, there is a remarkable shift between the two distributions. In particular, there is no overlap between the boxes, with the call market *MSE* distribution lower than the double auction *MSE* distribution. This suggests that, when no information was in the market, actual prices tracked the efficient equilibrium price more accurately in the call market treatment than in the double auction one[6].

Therefore, it is possible to state that, when trading takes place through the call market mechanism and there are no insiders in the market, actual prices track the rational expectations price prediction much better than when trading occurs through a double auction institution. We can conclude that, from testing hypothesis 2a, without information in the market, in the clearing mechanism prices converge to the RE prediction in 77% of the periods contrasted against 35% of the cases of the double auction treatment. We also conclude that, when the convergence towards the RE prediction occurred, actual prices exhibited, on average, smaller deviations from the equilibrium value when trading was conducted through the call market mechanism. Differently stated, in the call market treatment, the benchmark tracking was closer than in the double auction one.

Furthermore, in periods with no inside information, we find that prices exhibited lower volatility when trading took place by means of a clearing mechanism. Excluding insider periods, the average price volatility over the four double auction sessions was 1.86, against an average volatility of 0.44 computed over the two call market sessions. This suggests that, excluding insider periods, the call market also performed very well in reducing noise and in stabilizing trading prices. This feature will be relevant for our policy implications.

As far as hypothesis 2b is concerned, we test which of the two market institutions performs better in disseminating information when insiders are present in the market. Recalling that, when the realized state is the bad one (dividend 10), the RE prediction price is 10 and the PI predicts a convergence of 15 maximum. However, when the realized state is good (dividend 20) the RE prediction is 20 and the PI predicts a convergence of 20 maximum. So, when the bad state occurs, testing for informational efficiency is straightforward, but when the good state occurs it is not obvious. Since, when the good state occurs and prices converge to 20, we cannot be sure which model prediction has been achieved. Then, when the good state occurs, we also look at security holdings to assess whether the convergence occurs toward the RE or the PI prediction. In particular, the PI model predicts that uninformed traders should be willing to pay, at most, as much as the expected value of the asset (15). Otherwise, informed traders, since they know in advance the realized state, should be willing to pay, at most, 20 to buy the asset. In so doing, and in accordance with the PI model, only informed traders are supposed to hold the security at the end of the trading

[6] This result is quantitatively confirmed by the two-sample Kolmogrov-Smirov test, see Box 1 in Appendix F.

period. In contrast, the RE model predicts that uninformed traders should be able to infer the realized state and so they should be willing to pay, at most, 20 to buy the security as well. As a consequence, if we detect convergence toward the good state price with only informed traders holding the asset at the end of the period, then we can be sure that the PI model was attained. Similarly, if we detect convergence toward the good state price with both informed and uninformed traders holding the asset at the end of the period, then it suggests that the RE prediction was reached.

In the double auction treatment, out of 16 periods where the bad state (10) occurred, in 12 of those periods prices converged toward the RE prediction price, which is 10. In the call market treatment, out of 5 periods where the bad state (10) was realized, in 2 of those periods prices converged toward the RE prediction price (10). So, in the double auction treatment, the convergence to the RE prediction occurred in 75% of the cases, in contrast to 40% of the cases in which the RE prediction was attained in the call market treatment.

In the double auction treatment, out of 10 periods where the good state value (20) occurred, in 7 of those periods trading prices exhibited convergence toward the RE/PI equilibrium price. In the call market treatment, convergence toward the RE/PI equilibrium took place in 5 out of 10 periods where the good state occurred. In both treatments, none of the periods ended with only informed traders holding the security. Then, we cannot conclude that the PI equilibrium was attained in both treatments. Nevertheless, we find significant differences in holding securities between the double auction and the call market treatment[7]. We can now state that, on average, uninformed traders held 19.36% of the total shares in the call market and 35.82% in the double auction treatment. Then, on average, in the double auction treatment, uninformed traders held 16.46% more of the total shares with respect to the call market treatment[8].

This result suggests that uninformed traders in the call market were less able to infer the inside information. However, when trading took place through a double auction mechanism, the inside information was more promptly disseminated and uninformed traders were better able to learn the realized state. This result is corroborated by the observation that, in the double auction treatment, uninformed traders never ended up with no shares. Additionally, in the call market treatment, in all periods where prices converged to 20 (good state), at least one uninformed trader ended up with no shares. This may be due to the fact that, in the double auction institution, the continuous type of trading and the real time updating of bids and asks promoted a more qualitative information dissemination.

[7] See Box 2 in appendix F.

[8] This difference is also statistically significant. We can accept the hypothesis that, in the call market, the mean of the distribution of the non-insiders' percentage of shares is lower than in the double auction with a p-value of 0.29.

In conclusion, we reject hypothesis 2b and we accept alternative hypothesis 2b(i). In both the bad and good states, the double auction mechanism performed quantitatively and qualitatively better in disseminating the inside information. The trading activity during the insider periods is reported in appendix E.

Now we move on to the **profit analysis**. As said above, when the information is promptly disseminated into the market, we should expect uninformed and informed traders' profits to be indistinguishable. That is because, as the information is disseminated, it soon becomes common knowledge and not only insiders but also uninformed agents can act on it, since they knew in advance the realized state. It has also been said that the measure in which insiders and non-insiders' profits are indistinguishable crucially depends on the timing through which the information dissemination occurs. On one hand, if complete dissemination occurs only when the market is about to close, then informed agents have enough time to exploit their informational advantage and, consequently, to realize higher profits than uninformed agents. On the other hand, if the information dissemination occurs just after the market opens, then uninformed traders have a lot of time to behave *as if* they were fully informed. As a consequence, insiders' informative advantage soon disappears and, at the end of the trading period, insiders' and non-insiders' profits should only differ insignificantly.

In our specific framework, focusing on all the inside periods in which prices exhibited convergence toward the rational prediction price expectations, we investigate which trading institution is more likely to promote a sufficiently rapid dissemination so as to cause uninformed and informed agents' profits to be indistinguishable. In order to address this point, we compute the percentage ratio of the average realized profit 'per insider' to the average realize profit 'per uninformed' trader. We call this measure "insider premium". The more this premium approaches 100%, the more uninformed and informed traders' profits are indistinguishable and the more the information has been promptly and quickly disseminated.

Based on the insiders' premium, we find that the median premium in the double auction treatment was 104.23% against a call market treatment median premium of 106.17%. Therefore, the median premium in the double auction treatment is almost 2 percentage points lower than the median premium in the call market treatment.

This result suggests that, when some inside information was present in the market, it more rapidly disseminated in the double auction treatment, and this caused uninformed and informed traders' profits to be more similar with respect to the call market treatment. This result is not statistically significant[9], i.e. the two distributions cannot be said to come from populations with different medians. Then, we accept hypothesis 3.

6. Conclusion, discussion and policy implications

There is an ongoing debate over the relationship between market efficiency and trading institutions. Our study focuses on comparing two trading institutions, the continuous double auction and the call market, in a framework in which uninformed traders are unsure about the presence of insiders in the market. Strictly speaking, the presence of informed agents in the market was not common knowledge. In this environment, even when no inside information is in the market, for some reason, uninformed agents may mistakenly believe that some insiders are trading in the market. This mistake could generate an "information mirage", that is, a price pattern in which actual prices depart from the efficient equilibrium price.

Our results show that information mirages are more likely to occur when trading takes place through a double auction mechanism.

Furthermore, in periods with no inside information, the call market mechanism performed significantly better in causing trading prices to converge to the efficient equilibrium price than the double auction one. Moreover, when considering all non-insider periods in which the convergence toward the RE prediction occurred, actual prices exhibited, on average, smaller deviations from the efficient equilibrium price when trading was conducted through the call market mechanism. Then, the call market promoted a more qualitative benchmark tracking with respect to the double auction mechanism.

However, when inside information was present in the market, the double auction mechanism performed better in disseminating the available information than the call market mechanism. It is probable that the prominent characteristics of the double auction mechanism (such as the continuous type of trading, the absence of limits to the number of traders' proposals, the public sharing of the agents' proposals as they are submitted and the continuous update of the book) are responsible for promoting the information dissemination when insiders are in the market. However, when they are not present, and traders mistakenly believe the opposite, the double auction mechanism is more likely to disseminate information that does not exist, causing information mirages. Similarly, the main distinctive features of the call market mechanism (i.e. the "discrete time" type of trading; the limited number of proposals per trader; the revelation of the agents' proposals only at the end of each call) hinder the convergence process when some inside information is in the market. Anyway, according to our results, these characteristics also limit the

[9] See Box 3 in appendix F.

occurrence of information mirages and then promote a greater level of efficiency during periods with no insider presence in the market.

As far as traders' profits are concerned, during periods where inside information was disseminated, we find that, in the double auction treatment, uninformed and informed traders' profits were more similar with respect to the call market mechanism. This suggests that, in the double auction treatment, the speed and the quality of the dissemination process was greater than in the call market mechanism. As a consequence, most of the informational advantage of informed agents tended to disappear in the double auction, allowing uninformed traders to make profits that were not statistically lower than those realized by the insiders. This efficiency advantage of the double auction was found to be not statistically significant.

In conclusion, our results show that the double auction mechanism performs better in the presence of insiders, and the call market institution should be preferred when no inside information is in the market. However, in real world financial markets, it is not easy to establish *ex-ante* if some inside information is fluctuating in the market.

Nevertheless, some general guidelines could be derived from our research. First of all, in real world financial markets, there is a pre-opening phase in which the official opening price is determined. Typically, in the pre-opening sessions, information is still more heterogeneous and uncertain and there is no well-defined inside information fluctuating in the market. Then, during these phases, the probability of having agents engaging in insider trading behaviour is expected to be limited. However, in the remainder of the day's trading session there might be agents who are more likely than others to access inside information and, consequently, to act as insiders. Therefore, according to our results, a call auction mechanism could be more appropriate in the pre-opening sessions because the probabilities of insider trading behaviour are limited and, as demonstrated, the call auction is likely to perform better in that context. The double auction institution could instead be adopted during the remainder of the trading day. Another factor that supports this implication, as we have seen, is that during periods with no inside information, the call market mechanism prices exhibited less variance with respect to the double auction mechanism. In the pre-opening sessions, because of the typical great level of information heterogeneity and uncertainty, negotiations are affected by immense volatility. For this reason, we think that a clearing mechanism in the pre-opening sessions could also reduce the amount of volatility and act as a price stabilizer. This effect is supposed to be particularly prominent when it comes to setting an opening price. In the real world, some financial markets, like the New Stock Exchange, the Tokyo Stock Exchange and the London Stock Exchange, already rely on our suggested policy to use a call auction to determine the opening price and the double auction for the rest of the trading session. However, there are also some markets, like the Nasdaq, Hong Kong and Jakarta and Singapore's markets, that adopt a continuous double auction throughout the entire trading session. Still, there are some markets, like in Malaysia and Taiwan that use a call auction for the whole trading session. In this sense, our policy implication consists of suggesting a call auction in the pre-opening phase and then a continuous double auction in the remainder of the trading session. For the same reasons, in times of market stress, a temporary switch to a call market mechanism rather than a trading halt could also be a powerful solution to achieve stabilizing prices and reduce trading noise.

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APPENDIX A

Instructions: double auction treatment

Welcome to the experiment

This is an experiment on decision making in financial markets. The experiment is straightforward and the instructions are easy to understand. If you follow them carefully and make good decisions, you could earn a considerable amount of money, which will be paid to you in cash at the end of the experiment.

Experiment Overview

In this experiment you participate in a simple market. The market will take place over a sequence of 13 trading periods. You may think of each trading period as a "business or trading day". In this market a generic asset ("financial good") is being traded and, at any moment during each trading period, you are free to buy or sell the asset. The money used in this experiment is "Experimental Currency Units" (ECU). Your cash payment at the end of the experiment will be in Euro. The conversion rate will be 200 ECU to 1 Euro.

In this experiment you make money either by trading the asset or from the dividend on the asset.

General Instructions

The market consists of 9 participants and 13 trading periods. Each trading period will last 300 seconds, during which you can trade the asset in exchange for experimental money. The first period is a trial period, useful to understand the trading mechanism. In the trial period no money will be paid for your earnings. The remaining 12 trading periods are "real" periods and they will count for your earnings. At the beginning of each trading period, you will be endowed with 200 ECU and 10 units of the asset. At the end of each trading period, the asset will pay a dividend of either 10 or 20. At the beginning of each period, the dividend value will be randomly chosen by the experimenter and not revealed to the market participants. Then, with 50% chance the dividend will be 10 and with 50% chance the dividend will be 20. At the start of each trading period, with 50% chance, none of you will have information about the value of the dividend in that trading period and, with 50% chance, only 5 of you out of 9 will be informed about the true dividend that the asset will pay at the end of that trading period.

Buying and selling the asset

At the beginning of each trading period, the screen will show you your initial amount of money, the number of units of asset in portfolio and a signal about your information on the dividend.

You could receive one of the following two signals:

1. "You have no information on the value of the dividend"

2. “The value of the dividend is “x” (with “x” = “10” or “20”)

If you receive the signal “you have no information", it means that you do not have any information about the dividend the asset will pay at the end of that trading period. If this is the case, it may be either that you are in a trading period where nobody is informed about the dividend or that you are in a trading period where only 5 of you have information on the dividend and you are not among these five people. If you receive the signal “10” or “20”, it means that the true dividend is 10 or 20 respectively. In this case, for sure you are in a trading period where only 5 of you have information on the dividend and you are among these five people. The identity of informed people will be randomly chosen by the computer in each trading period.

How to use a computerized market

As reported in Figure 1, on the top left of the screen you will see the trading period in which you are trading. On the top right of the screen you will see how much time is left in the current trading period. In the center of the screen you will see your amount of money, the number of assets you own and your signal.

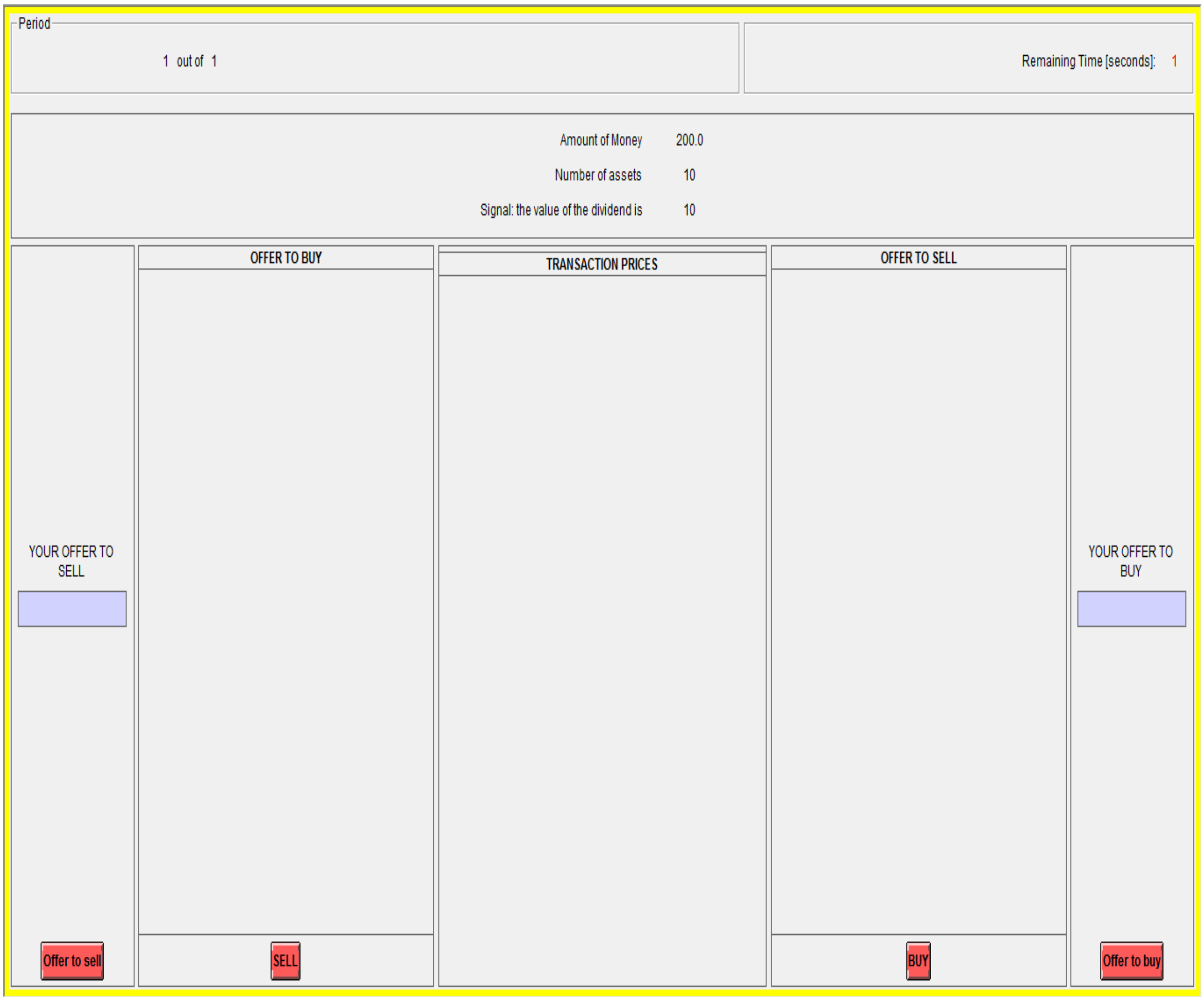


Figure 1: Buying and selling the asset

You can participate to the market in the following four ways:

1. Making an offer to sell the asset, by entering the price at which you are willing to sell.

To offer to sell a unit of the asset, enter the price at which you would like to sell in the box labeled "Your offer to sell" in the first column from the left of the screen, then click on the button "Offer to sell" on the bottom of the same column.

The second column from right will show a list of offers to sell, each submitted by a different participant. The lowest offer to sell will be always placed on the bottom of the list. Your own offer will appear in blue.

2. Making an offer to buy the asset, by entering the price at which you are willing to buy.

To offer to buy a unit of the asset, enter the price at which you would like to buy in the box labeled "Your offer to buy" in the first column from the right of the screen, then click on the button "Offer to buy" on the bottom of the same column. The second column from left will show a list of offers to buy, each submitted by a different participant. The highest offer to buy will be always placed on the bottom of the list. Your own offer will appear in blue.

3. Selling an asset by accepting an offer to buy.

You can select an offer to buy from the second column from the left by clicking on it. If you click the "sell" button at the bottom of this column, you will sell one unit of the asset at the selected price. You are not allowed to sell a unit of the asset to yourself. When you accept an offer to buy, it will disappear from the list. If you also previously submitted an offer to sell, it will disappear from the offers to sell because you have just sold a unit of your asset.

4. Buying an asset by accepting an offer to sell.

You can select an offer to sell from the second column from the right by clicking on it. If you click the "buy" button at the bottom of this column, you will purchase one unit of the asset at the selected price. You are not allowed to buy a unit of the asset from yourself. When you accept an offer to sell, it will disappear from the list. If you also previously submitted an offer to buy, it will disappear from the offers to buy because you have just bought a unit of your asset.

You can only buy/sell one unit of the asset at a time. You can buy/sell several times in each trading period. When you buy an asset, the amount of your money will decrease by the price of purchase. You can only buy an asset if you have enough money to pay for it. When you sell an asset, the amount of your money will increase by the price of the sale. You can sell units of asset as long as you own them in portfolio. In the middle column of the screen, labeled "Transaction Prices", you will see the prices at which the units of the asset have been traded in the current trading period. Any time you accept an offer to sell or buy, a new contract has been closed and the selected price will appear in the column "Transactions Prices".

Your Earnings

As reported in figure 2, at the end of each trading period your profit will be equal to your "Money before payment of dividends" minus "Initial Money" plus "Your total dividend".

At the end of the experiment, your final earnings will be equal to the sum of your profits in each of the twelve "real" trading periods (the trial period does not count).

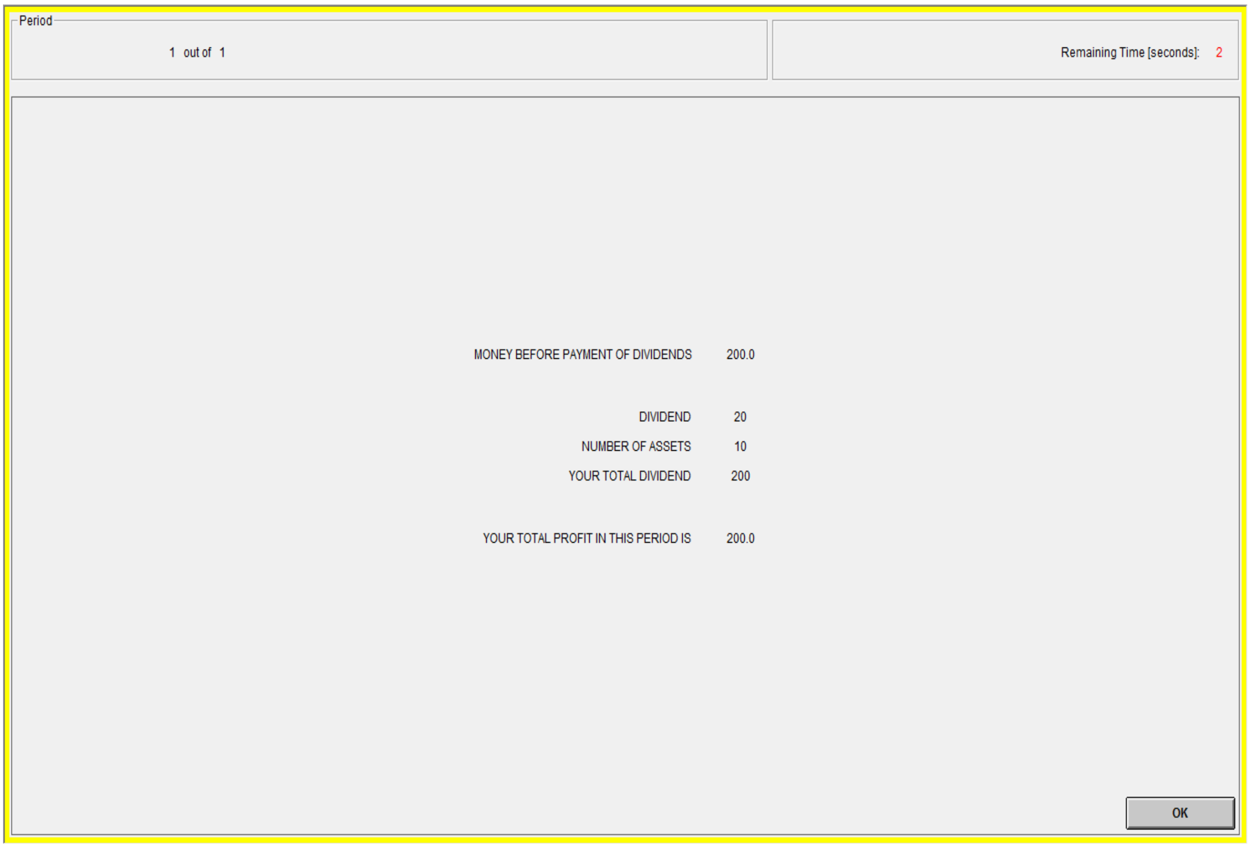


Figure 2: Your earnings

The following scheme shows the composition of your earnings for each period:

Initial Money (200 ECU) –
(Nr. of assets you bought x market price) +
(Nr. of assets you sold x market price)
= Money before payment of dividends

\-

Initial Money (200 ECU)

\+

Dividend of the period x
Nr. of assets at the end of the period
= Your total dividend

=

Your earnings at the end of the period

APPENDIX B

Instructions: call market treatment

Welcome to the experiment

This is an experiment on decision making in financial markets. The experiment is straightforward and the instructions are easy to understand. If you follow them carefully and make good decisions, you could earn a considerable amount of money, which will be paid to you in cash at the end of the experiment.

Experiment Overview

In this experiment you participate in a simple market. The market will take place over a sequence of 13 trading periods. You may think of each trading period as a "business or trading day". In this market a generic asset ("financial good") is being traded and you are free to buy or sell the asset. The money used in this experiment is "Experimental Currency Units" (ECU). Your cash payment at the end of the experiment will be in Euro. The conversion rate will be 300 ECU to 1€

In this experiment you make money either by trading the asset or from the dividend on the asset.

General Instructions

The market consists of 9 participants and 13 trading periods, of which 1 trial period (period 0) and 12 real periods. In the trial period (period 0) you will not be paid for your earnings. Only the real periods will account for your earnings. At the beginning of each period you will be endowed with 200 ECU and 10 units of asset. At the end of each trading period, the asset will pay a dividend of either 10 or 20. At the beginning of each period, the dividend value will be randomly chosen by the experimenter and not revealed to the market participants. Then, with 50% chance the dividend will be 10 and with 50% chance the dividend will be 20. At the start of each trading period, with 50% chance, none of you will have information about the value of the dividend in that trading period and, with 50% chance, only 5 of you out of 9 will be informed about the true dividend that the asset will pay at the end of that trading period. Each trading period is divided in 4 sub-periods. Each sub-period will last 60 seconds, during which you can trade the asset in exchange for experimental money. The value of the dividend drawn at the beginning of each period will remain the same for all the 4 sub-periods of each period.

Buying and selling the asset

At the beginning of each trading period, the screen will show you your initial amount of money, the number of assets in portfolio and a signal about your information on the dividend.

You could receive one of the following two signals:

1. "You have no information on the value of the dividend"
2. "The value of the dividend is "x" (with "x" = "10" or "20")

The signal you receive will not change in the 4 sub-periods of each trading period.

If you receive the signal "you have no information", it means that you do not have any information about the dividend the asset will pay at the end of that trading period. If this is the case, it may be either that you are in a trading period where nobody is informed about the dividend or that you are in a trading period where only 5 of you have information on the dividend and you are not among these five people. If you receive the signal "10" or "20", it means that the true dividend is 10 or 20 respectively. In this case, for sure you are in a trading period where only 5 of you have information on the dividend and you are among these five people. The identity of informed people will be randomly chosen by the computer in each trading period.

How to use a computerized market

As reported in Figure 1, on the top left of the screen you will see the trading period and the sub-period in which you are trading. On the top right of the screen you will see how much time is left in the current trading period. In the left part of the screen you will see your amount of money, the number of assets you own and your signal. In the right part of the screen you will be showed the set of possible actions you can perform.

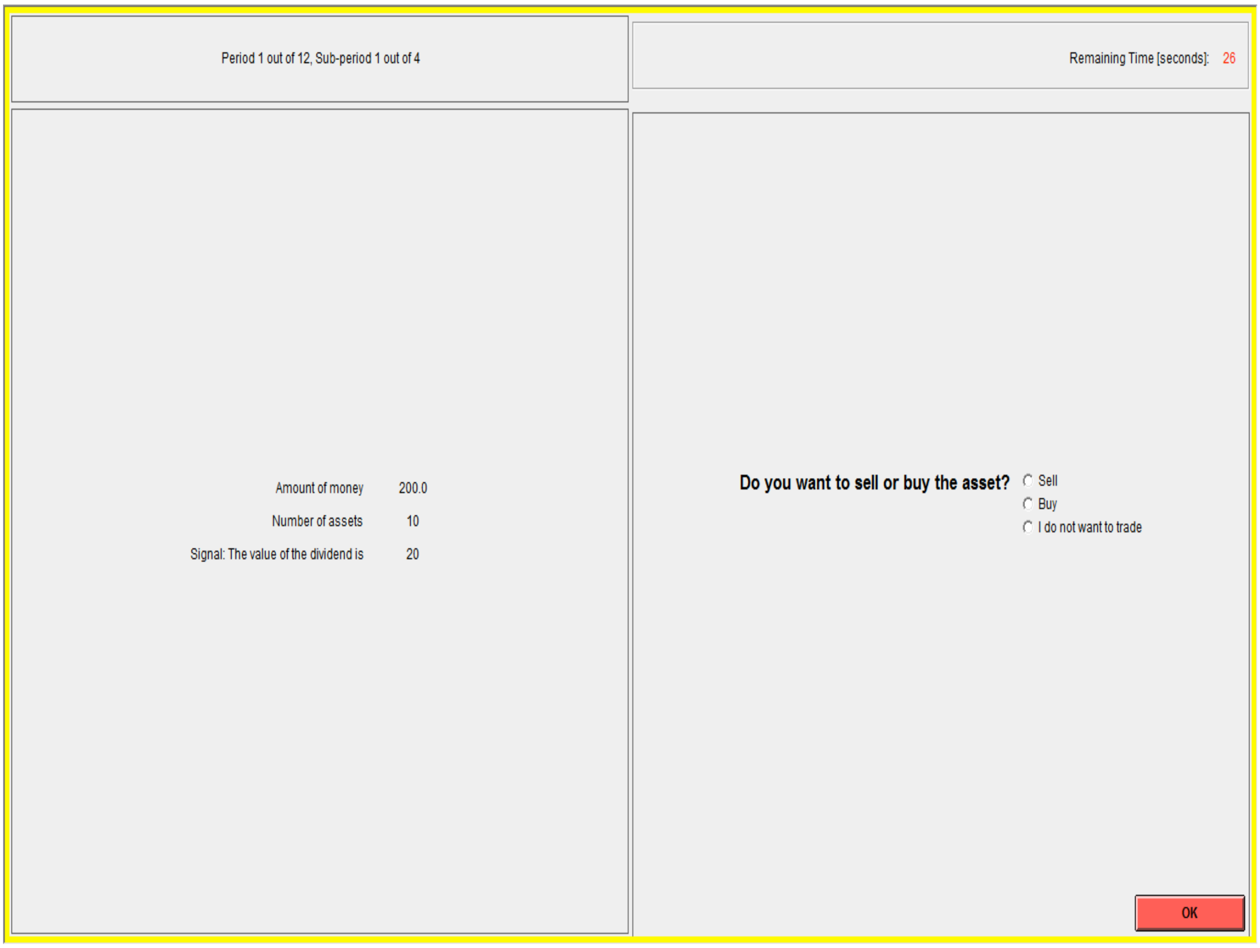


Figure 1: Buying and selling the asset

In particular, in each sub-period of any trading period, you can make the following three decisions:

i. Selling the asset
ii. Buying the asset
iii. I do not want to trade

If you decide to sell or buy the asset, the next screen you will be asked for the price at which you <u>would like</u> to sell or buy the asset and for the number of units of asset you <u>would like</u> to sell or buy. For example, if you decide to sell shares, you will move to the following screen (Figure 2):

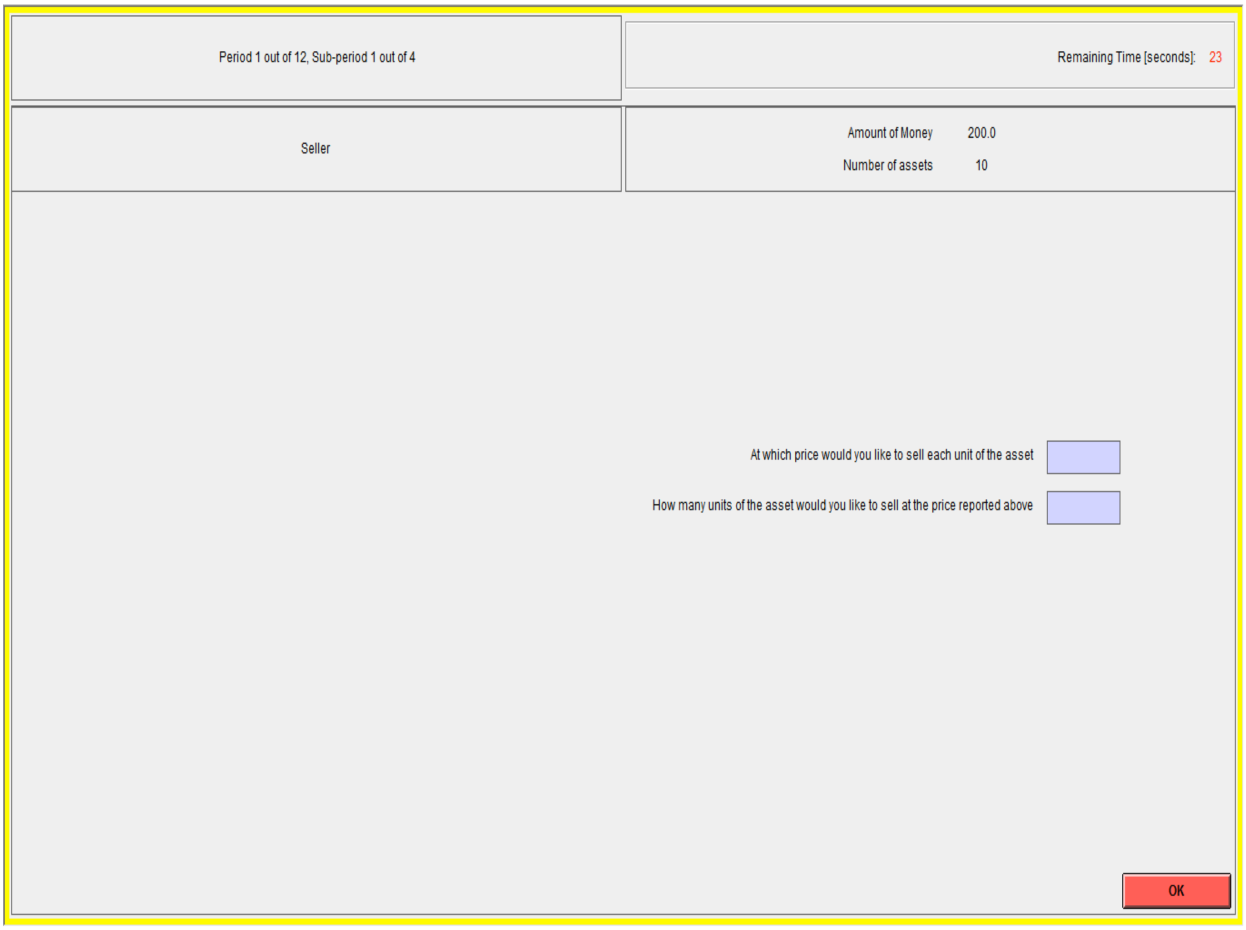


Figure 2: I would like to be a seller

In addition to the general parameters described above (period, money, number of units of asset and time left), this screen will show, in the second line up on the left of the screen, your position of "Seller". In the central part of the screen, you are asked to enter the selling price and the number of units of asset you would like to sell at that price. The same procedure will be followed if you decide to buy. In this case, the screen will show, in the second line up on the left of the screen, your position of "Buyer". In the main part of the screen, you are asked to enter the purchase price and the number of units of asset you would like to buy at that price. Finally, if you decide for the option "I do not want to trade", you will not take part in trading. Therefore your amount of money and the number of shares you own will not change.

In this market, your sale and purchase orders only represent a proposal and there is no guarantee that your order will be executed. The execution of orders depends on the following.

At the end of each sub-period, purchase prices will be ordered from the highest to the lowest, thus the demand function will be drawn. Sale prices will instead be ordered from the lowest to the highest, thus the supply function will be drawn. In each sub-period, the intersection point of the supply and demand functions will represent the equilibrium price.

The equilibrium price is the price at which the purchase and sale orders previously submitted by you and the other participants will be executed. However, only purchase orders at a price equal or higher than the equilibrium price will be executed and only the sale orders at a price equal or lower than the equilibrium price will be executed. Following the determination of the equilibrium price, only if your sale order will be executed (that is, if you had proposed a sale price equal or lower than the equilibrium price), the number of units of asset held by you will decrease by the number of units that you had offered to sell and the money at your disposal will increase by an amount equal to the number of units sold multiplied by the sales price (i.e the equilibrium price) of each unit. Following the determination of the equilibrium price, only if your purchase order will be executed (that is, if you had offered a purchase price equal or higher than the equilibrium price), the number of shares held by you will increase by the number of shares that you had proposed to buy and the money at your disposal will decrease by an amount equal to the number of units purchased multiplied by the purchase price (i.e the equilibrium price) of each unit.

Your Earnings

At the end of each sub-period you will receive an update on your activity in the sub-period. The update will include the number of shares and cash at the beginning of the sub-period, your order to buy or sell with its price (if you decided to submit an order), the number of units you purchased or sold with its execution price (if your order was executed), the residual number of units of asset and the remaining money. In addition to such information, as shown in Figure 3, only in the last sub-period of each period (i.e at the end of each period), you will be revealed the value of the dividend, your earnings from dividend (Total Dividend) and the total profit of the period.

Your profit at the end of the experiment will be equal to the sum of the profits made in the 12 real periods (the trial period does not count for your earnings).

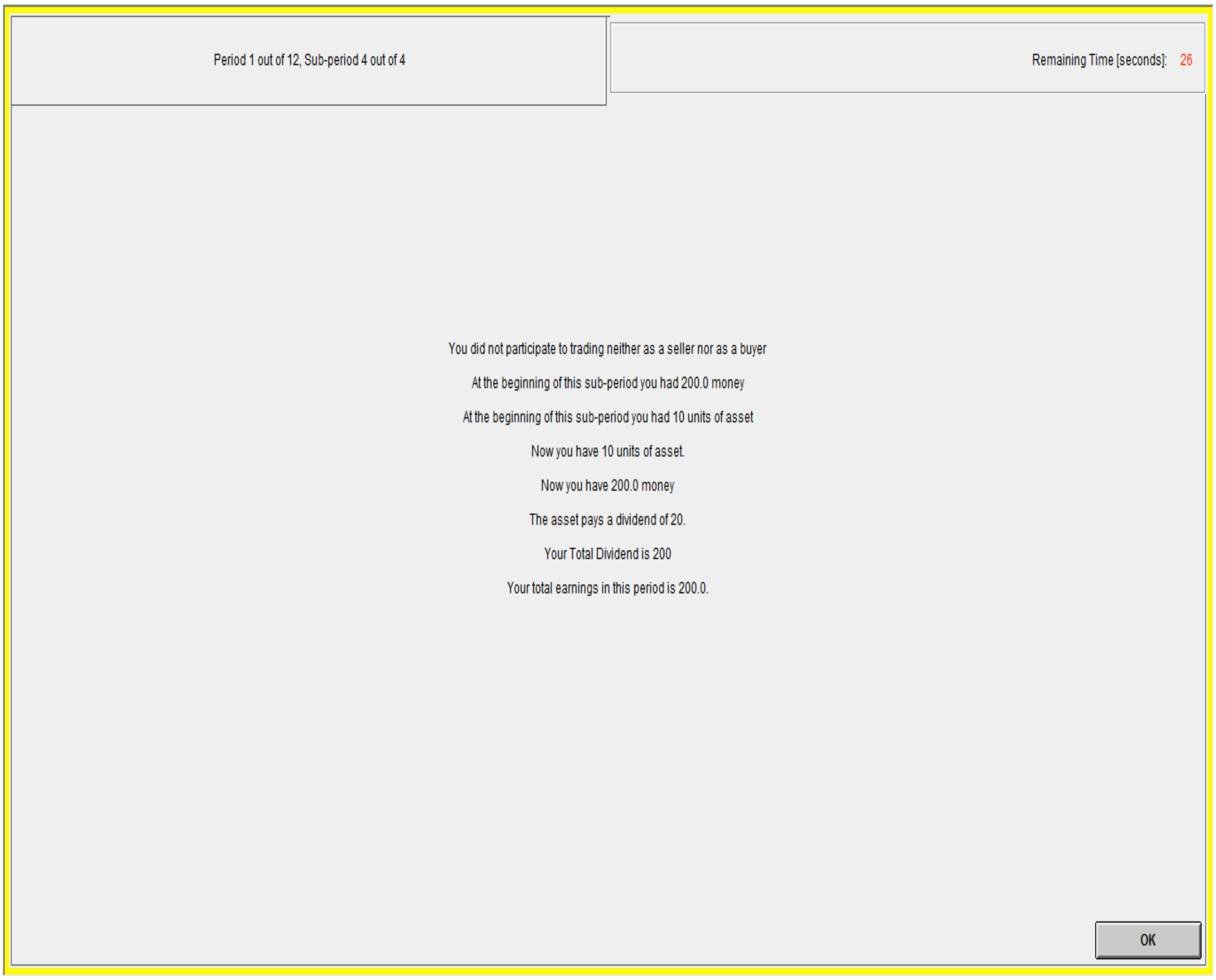
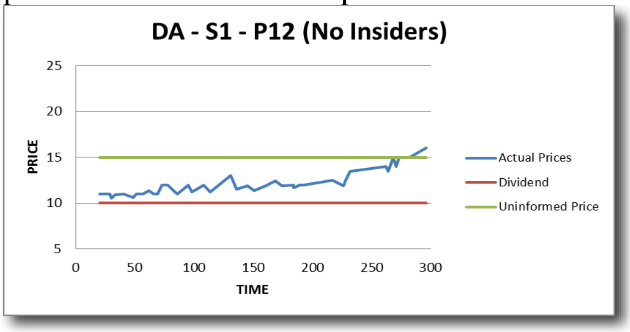
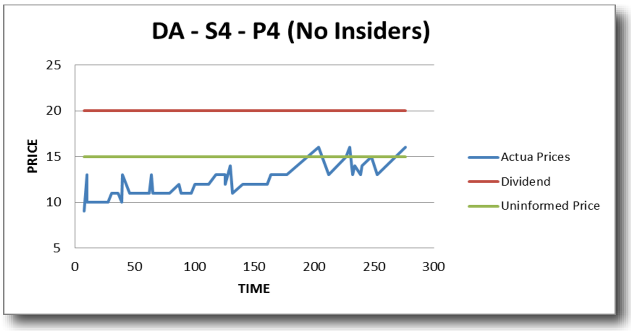


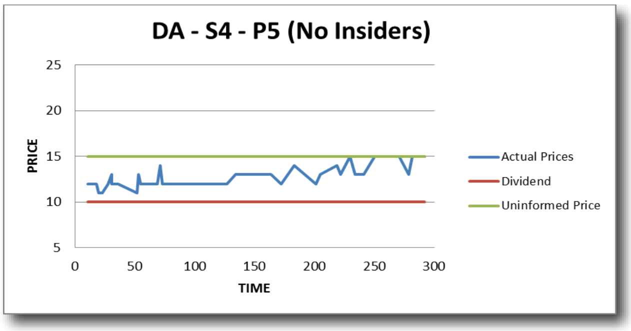
Figure 3: Your earnings

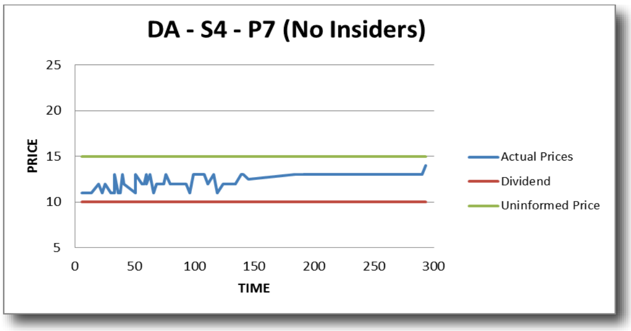
APPENDIX C

No insider periods that, even satisfying our information mirage conditions, have not been considered as a mirage because the trading activity does not resemble the typical convergence pattern observed in inside periods.



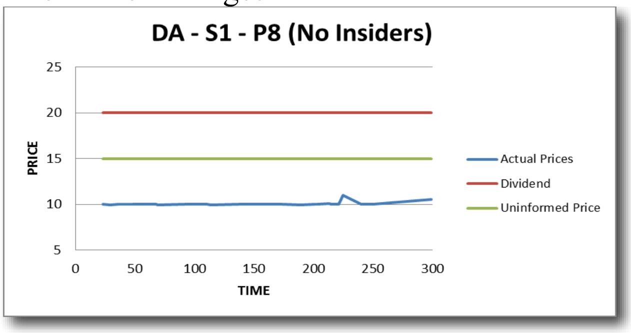


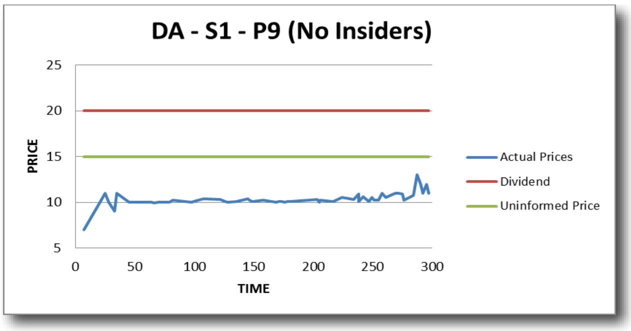


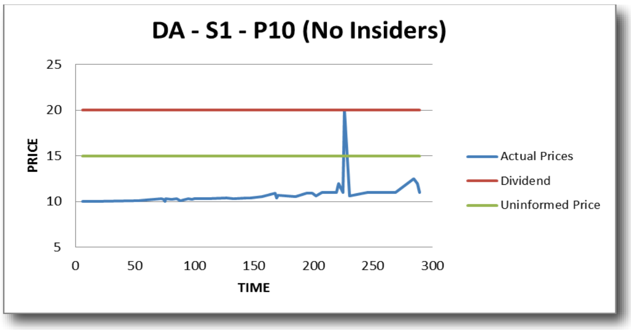


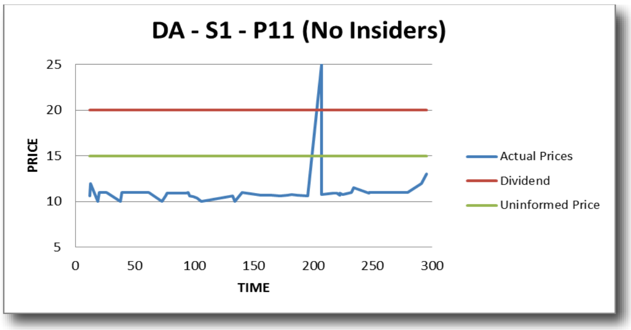
APPENDIX D

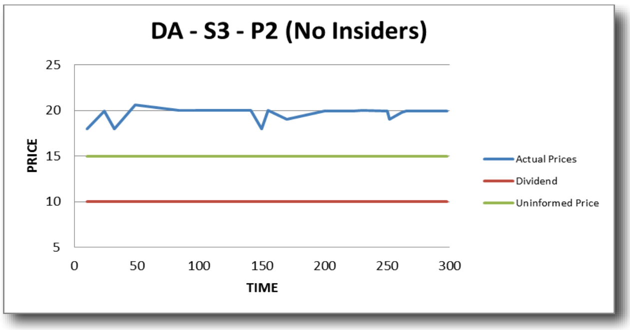
Information mirages










DA - S3 - P2 (No Insiders)
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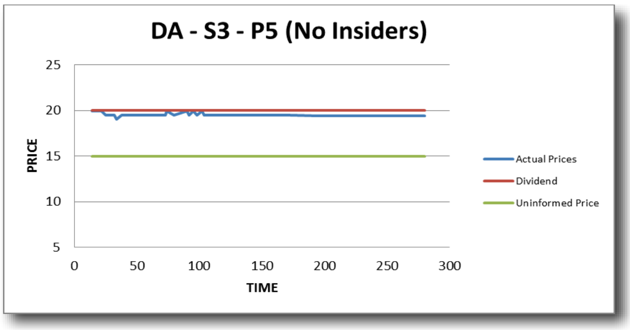
Actual Prices
Dividend
Uninformed Price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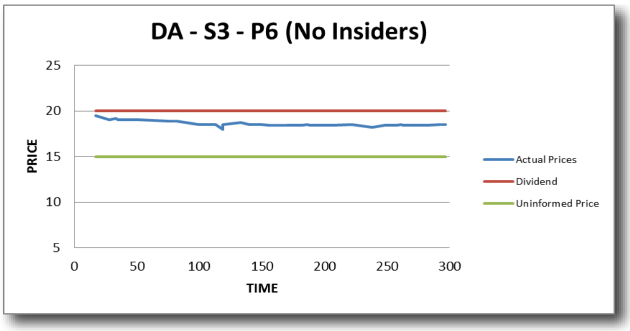
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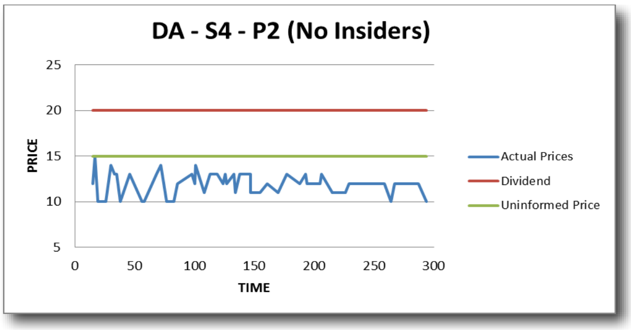
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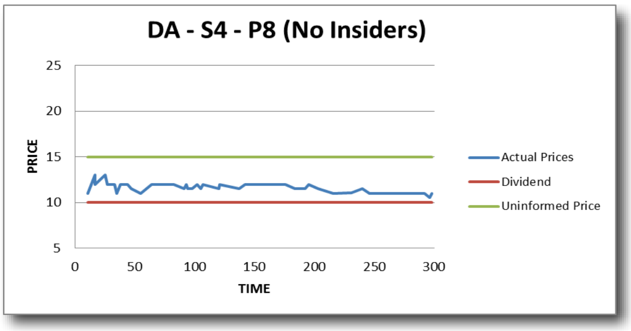
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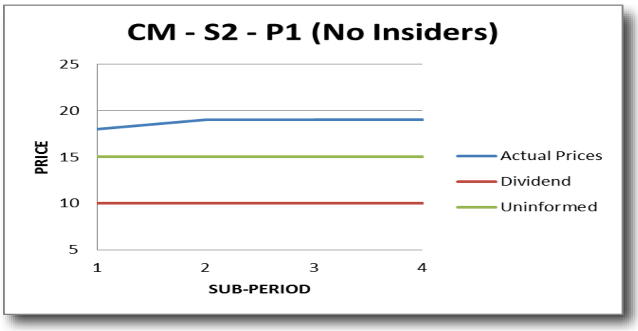
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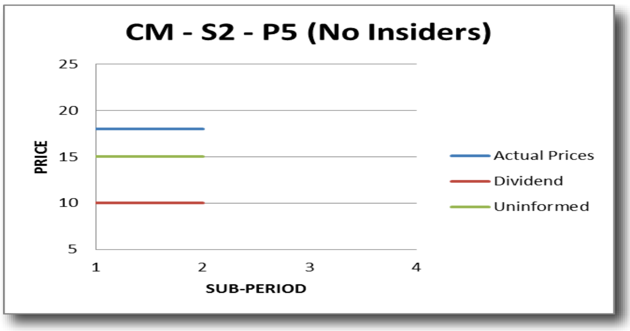
CM - S2 - P5 (No Insiders)
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Actual Prices
Dividend
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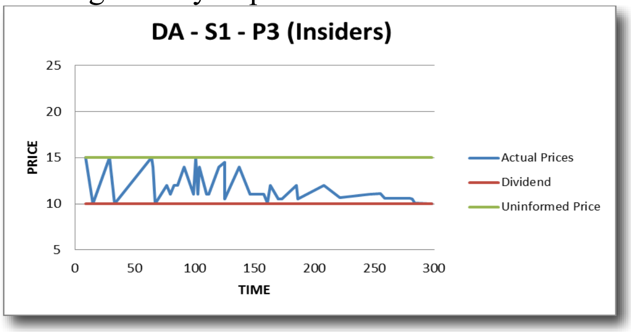
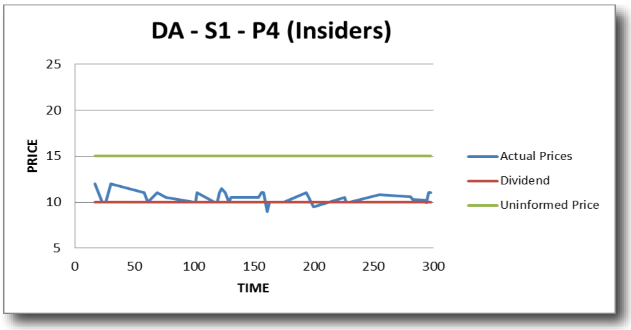
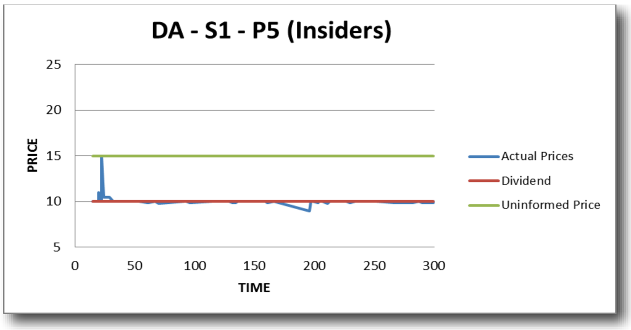
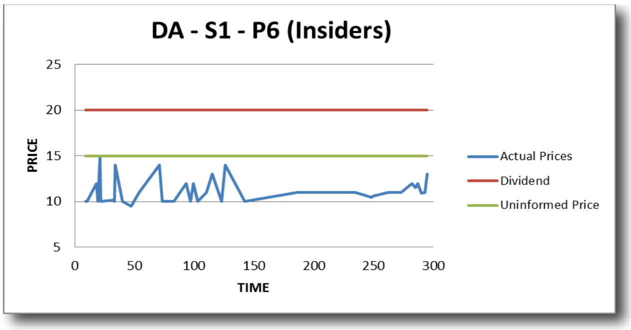
APPENDIX E

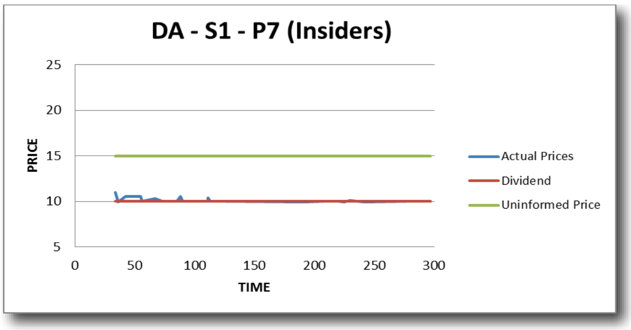
Trading activity in periods with inside information

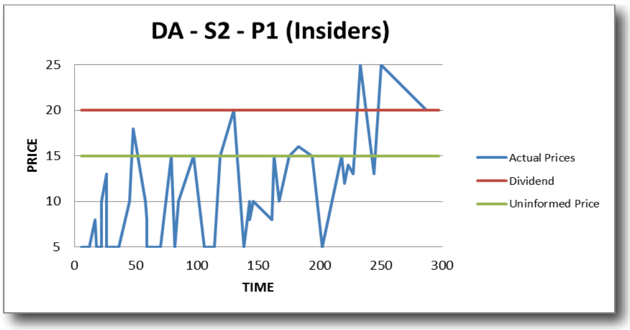


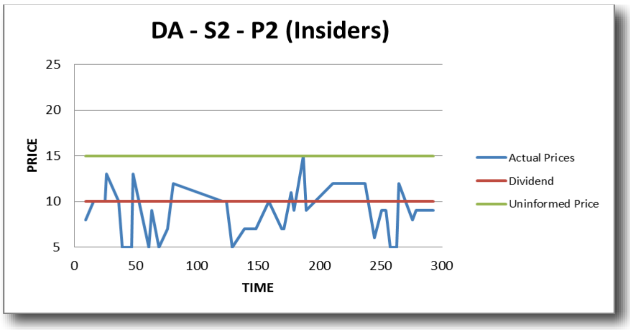


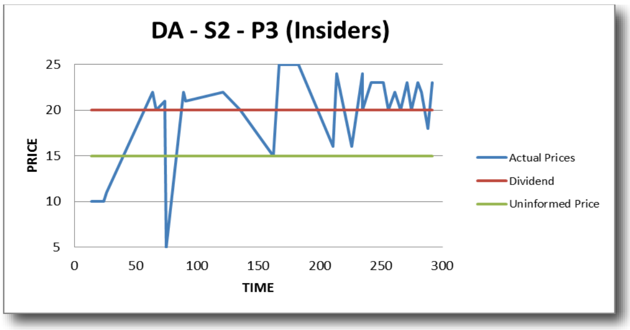


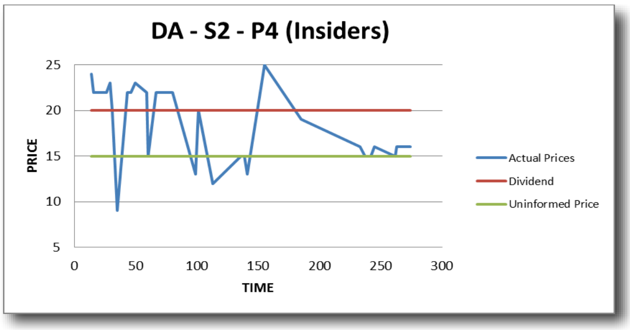








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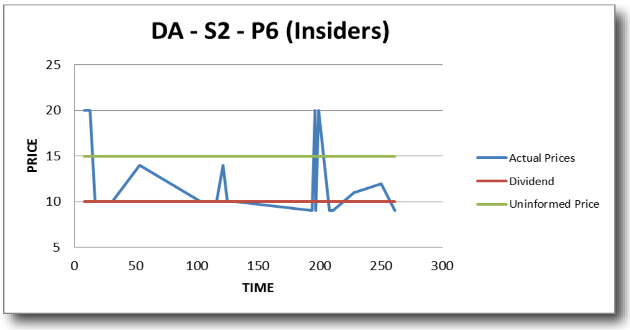
Dividend
Uninformed Price


DA - S2 - P6 (Insiders)
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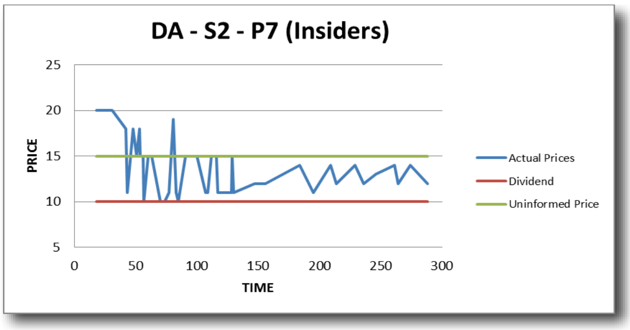
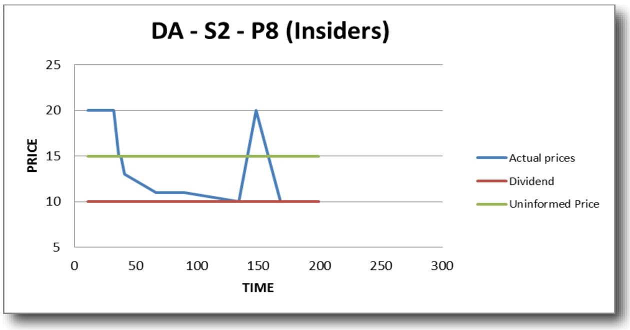
Dividend
Uninformed Price


DA - S2 - P7 (Insiders)
PRICE
TIME
Actual Prices
Dividend
Uninformed Price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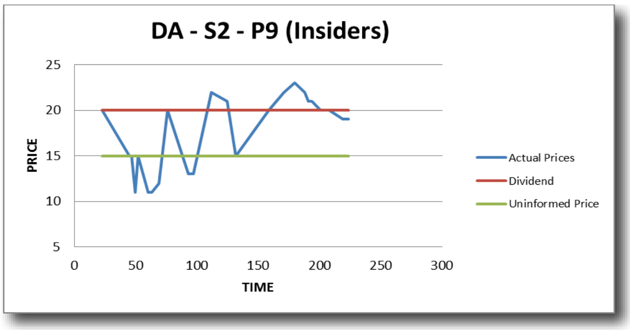
PRICE
TIME
Actual prices
Dividend
Uninformed Price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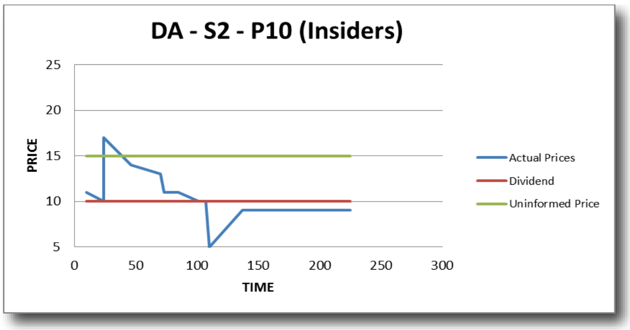
PRICE
TIME
Actual Prices
Dividend
Uninformed Price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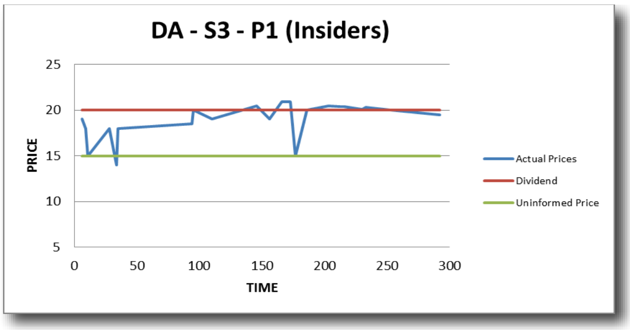
PRICE
TIME
Actual Prices
Dividend
Uninformed Price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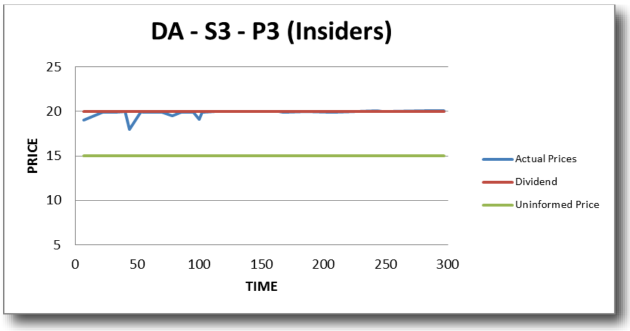
PRICE
TIME
Actual Prices
Dividend
Uninformed Price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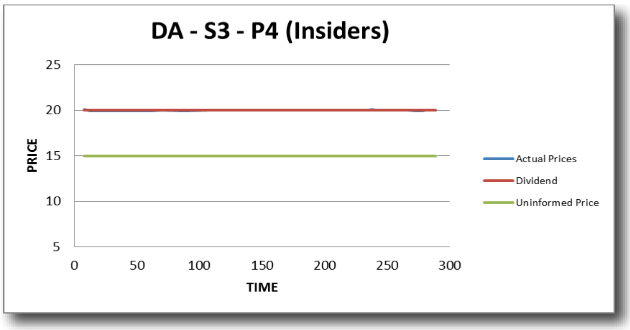
PRICE
TIME
Actual Prices
Dividend
Uninformed Price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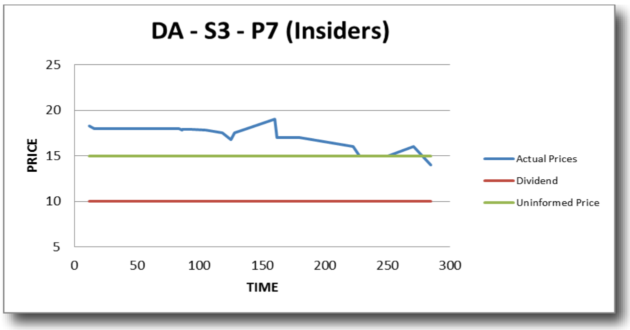
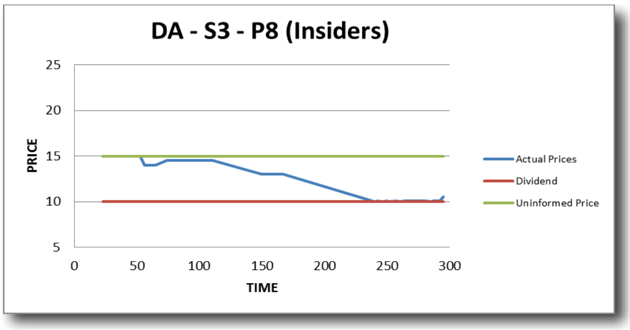
PRICE
TIME
Actual Prices
Dividend
Uninformed Price


DA - S3 - P7 (Insiders)
PRICE
TIME
Actual Prices
Dividend
Uninformed Price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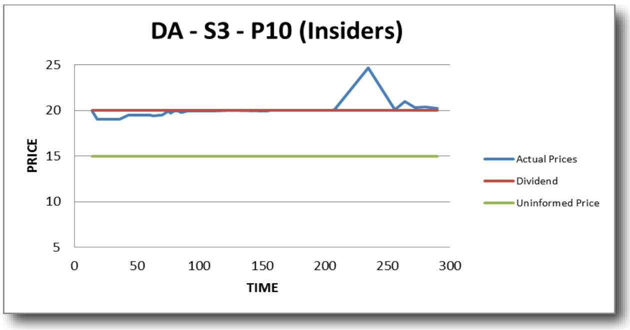
PRICE
TIME
Actual Prices
Dividend
Uninformed Price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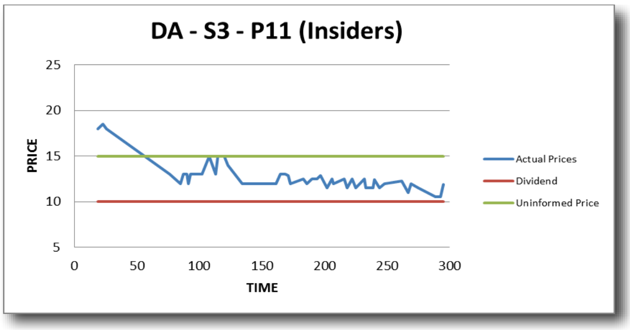
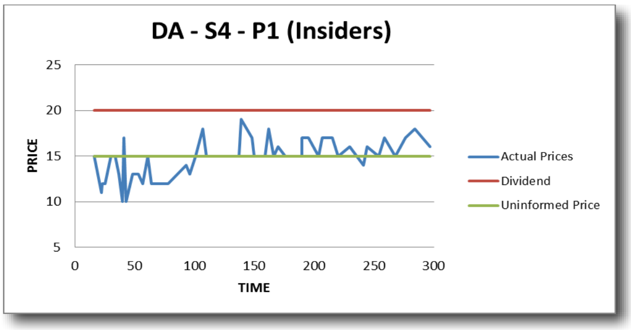
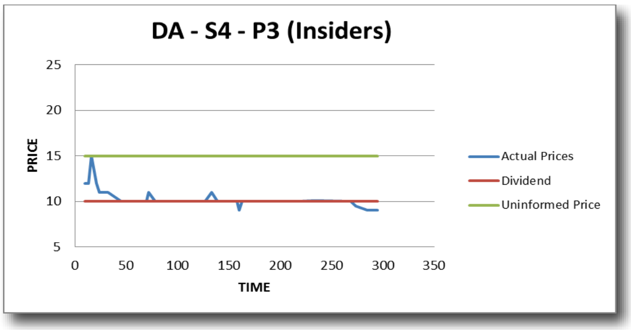
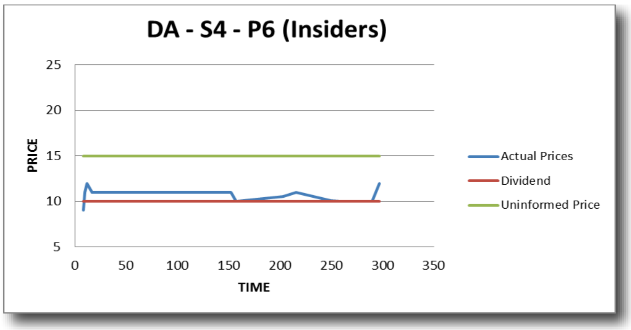
PRICE
TIME
Actual Prices
Dividend
Uninformed Price


DA - S3 - P11 (Insiders)
PRICE
TIME
Actual Prices
Dividend
Uninformed Price


DA - S4 - P1 (Insiders)
PRICE
TIME
Actual Prices
Dividend
Uninformed Price


DA - S4 - P3 (Insiders)
PRICE
TIME
Actual Prices
Dividend
Uninformed Price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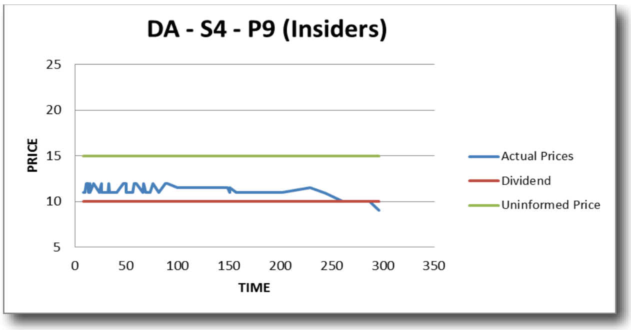
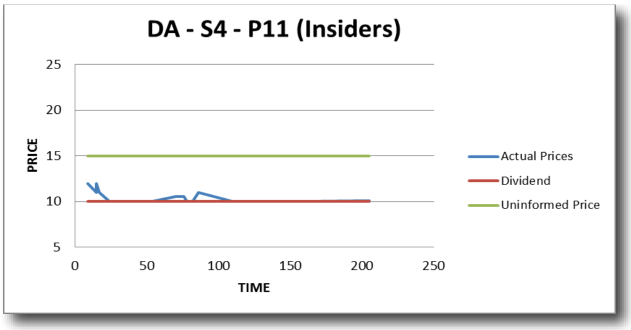
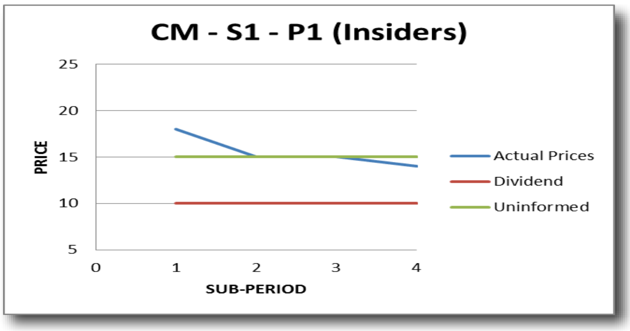
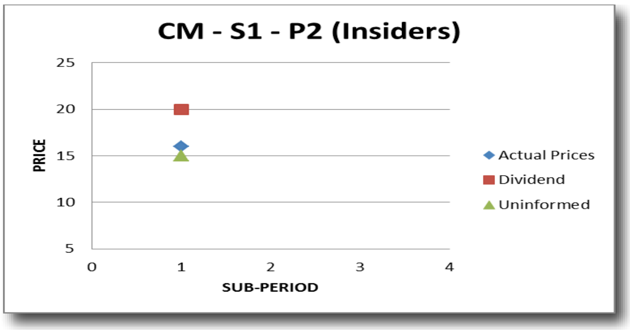
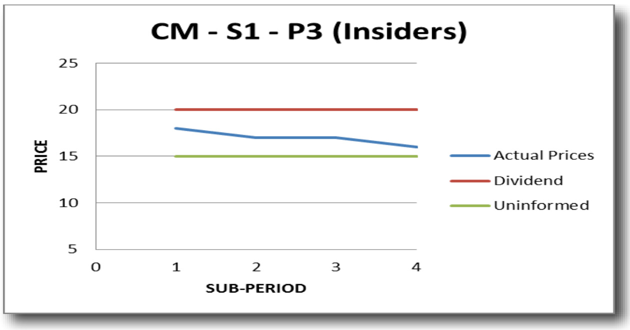
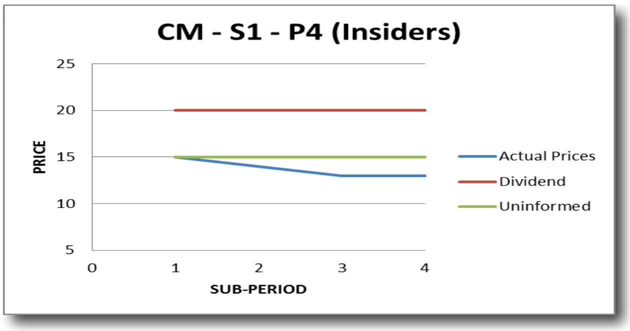
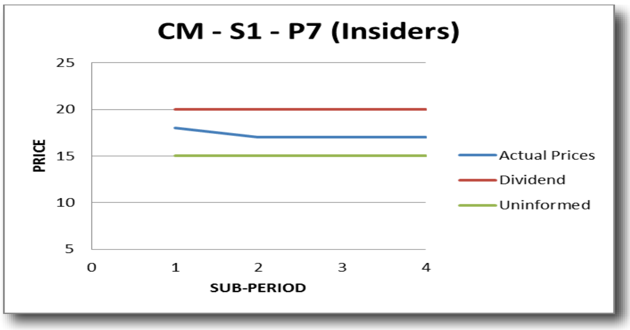
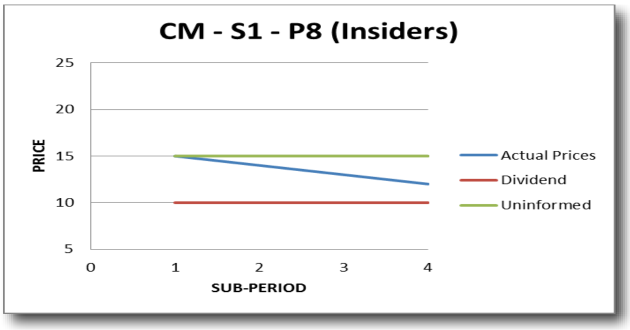
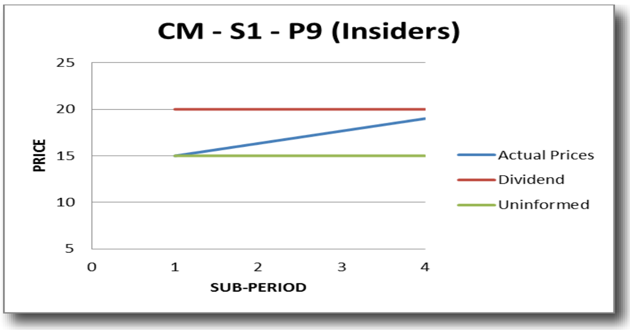
PRICE
TIME
Actual Prices
Dividend
Uninformed Price


DA - S4 - P9 (Insiders)
PRICE
TIME
Actual Prices
Dividend
Uninformed Price


DA - S4 - P11 (Insiders)
PRICE
TIME
Actual Prices
Dividend
Uninformed Price


CM - S1 - P1 (Insiders)
PRICE
SUB-PERIOD
Actual Prices
Dividend
Uninformed


CM - S1 - P2 (Insiders)
PRICE
SUB-PERIOD
Actual Prices
Dividend
Uninformed


CM - S1 - P3 (Insiders)
PRICE
SUB-PERIOD
Actual Prices
Dividend
Uninformed

CM - S1 - P4 (Insiders)
PRICE
SUB-PERIOD
Actual Prices
Dividend
Uninformed

CM - S1 - P7 (Insiders)
PRICE
SUB-PERIOD
Actual Prices
Dividend
Uninformed

CM - S1 - P8 (Insiders)
PRICE
SUB-PERIOD
Actual Prices
Dividend
Uninformed

CM - S1 - P9 (Insiders)
PRICE
SUB-PERIOD
Actual Prices
Dividend
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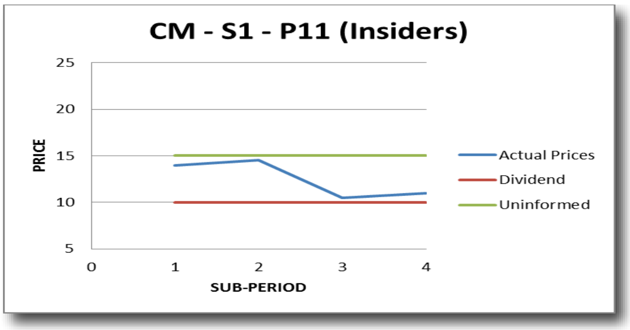
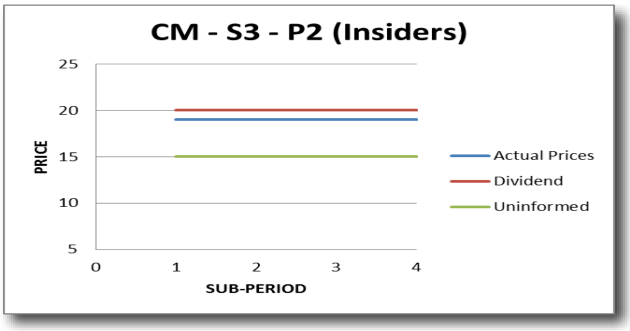

CM - S1 - P11 (Insiders)
PRICE
SUB-PERIOD
Actual Prices
Dividend
Uninformed

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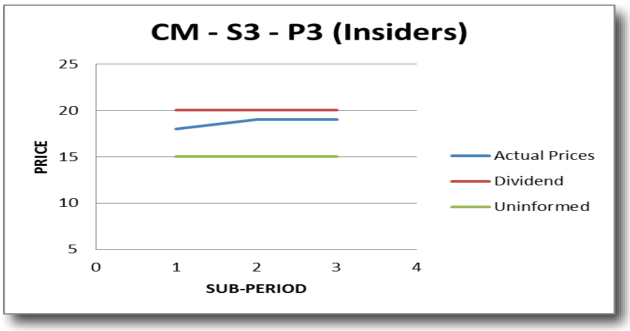
PRICE
SUB-PERIOD
Actual Prices
Dividend
Uninformed

CM - S3 - P3 (Insiders)
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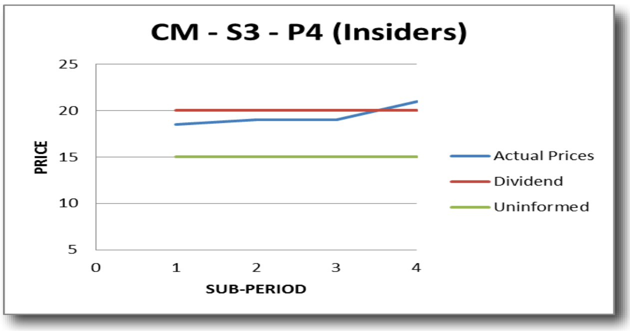
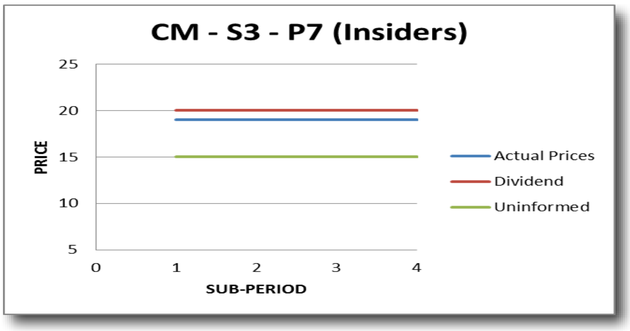
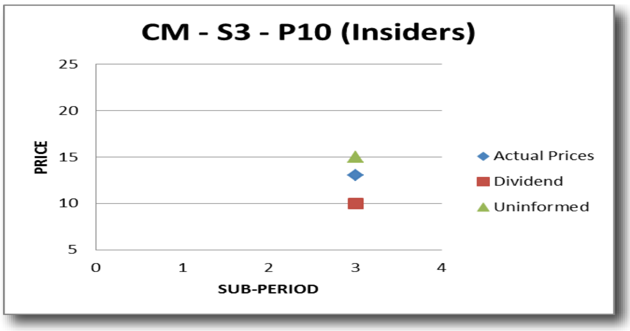
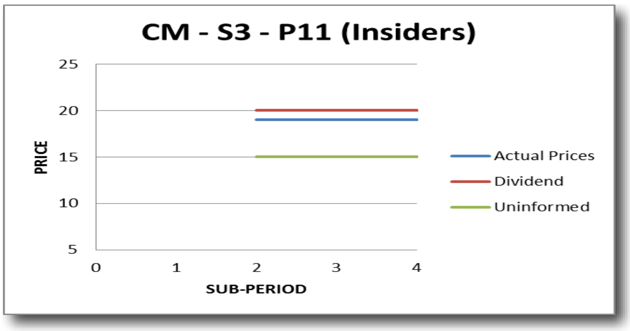
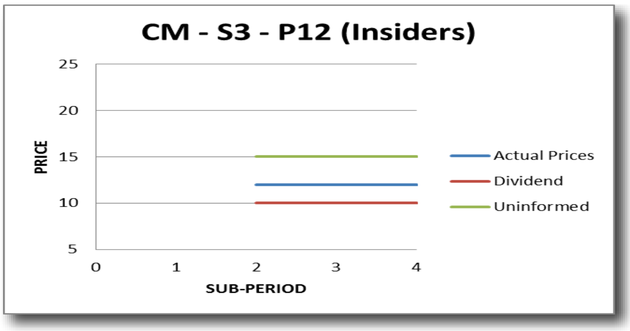
SUB-PERIOD
Actual Prices
Dividend
Uninformed

CM - S3 - P4 (Insiders)
PRICE
SUB-PERIOD
Actual Prices
Dividend
Uninformed

CM - S3 - P7 (Insiders)
PRICE
SUB-PERIOD
Actual Prices
Dividend
Uninformed


CM - S3 - P10 (Insiders)
PRICE
SUB-PERIOD
Actual Prices
Dividend
Uninformed


CM - S3 - P11 (Insiders)
PRICE
SUB-PERIOD
Actual Prices
Dividend
Uninformed


CM - S3 - P12 (Insiders)
PRICE
SUB-PERIOD
Actual Prices
Dividend
Uninformed

Appendix F

Box 1

Generally speaking, the two samples Kolmogrov-Smirov test is used to state whether or not two sample distributions are likely to come from the same population. In particular, in the first line, we test the null hypothesis that the double auction *MSE* distribution is lower than the call market *MSE* distribution. In the second line we test the null hypothesis that the call market *MSE* distribution is lower than the double auction *MSE* distribution. From the test we reject the hypothesis that the two distributions come from the same population and we accept the hypothesis that the call market *MSE* distribution contains smaller values than the double auction *MSE* distribution. The latter hypothesis is accepted with a p-value of 0.4.

Two-sample Kolmogorov-Smirnov test for equality of distribution functions

Smaller group	D	P-value	Corrected
1:	0.0000	1.000	
2:	-0.6725	0.004	
Combined K-S:	0.6725	0.008	0.003

Table 1: two-sample kolmogrov-Smirov test for the DA and CM MSE distribution in no insider periods

Box 2

In each period of both the DA and CM treatment, we measure the percentage of shares held by uninformed traders. Using these data, we perform a two-sample mean comparison test to assess in which treatment the security holding was more equally split between uninformed and informed traders. If in a given period insiders were able to buy as much they liked, it means that the information was not well disseminated and that someone of the uninformed traders did not understand that it would have been very profitable acting as net buyer. Results from the two-sample comparison test are reported in Table 2.

Two-sample t test with unequal variances

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
A	5	19.36	3.310529	7.402567	10.1685	28.5515
B	7	35.82857	3.277391	8.671162	27.80908	43.84806
combined	12	28.96667	3.327305	11.52612	21.64332	36.29002
diff		-16.46857	4.658422		-26.91321	-6.023928

diff = mean(A) - mean(B) t = -3.5352
Ho: diff = 0 Satterthwaite's degrees of freedom = 9.56056

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0
Pr(T < t) = 0.0029 Pr(|T| > |t|) = 0.0058 Pr(T > t) = 0.9971

Table 2: two-sample mean comparison test for security holdings in the DA and CM treatment. Only insider periods with the good state (20) are taken into consideration.

Variable A represents the distribution of the percentage of shares held by uninformed traders in the call market treatment. Variable B stands for the distribution of the percentage of shares held by uninformed traders in the double auction treatment. We only consider the insider periods in which the good state occurred and in which prices exhibited convergence toward the realized state price. In other words, we consider those insider periods where the information was disseminated.

Box 3

To test whether this result is significant, we performed the K-sample equality of median test, reported in figure 10.

Median test

Greater than the median	K 1	2	Total
no	10	2	12
yes	8	4	12
Total	18	6	24

Pearson chi2(1) =   0.8889   Pr = 0.346

Table 3: k-sample median comparison test for the percentage ratio of the average realized profit per insider to theaverage realized profit per uninformed trader in the DA and CM treatment

This test is typically useful to state whether k sample distributions come from populations with the same median. In our case, k is equal to 2. The first distribution of the test contains the double auction insider premium, while the second distribution contains the call market insider premium. As we can see from the test, in the double auction treatment, 10 observations out of 18 are lower than the overall median (i.e. the median computed by merging the two distributions), while in the call market 2 observations out of 6 are below the overall median. Nevertheless, the test does not lead to a statistically significant result.