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Market Efficiency, Trading Institutions and Information Mirages: evidence from an experimental asset market

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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 promoting a convergence towards the efficient equilibrium price. 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. Motivational Framework

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. In this sense, several previous studies (see Sunder, 1995) show that, under certain circumstances, asset markets manage to gather and spread the dispersed information through the price adjustment mechanism. 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.

Our contribution is framed in the literature strand which investigates the relationship between market performance and trading institutions. The latter commonly refers to the set of exchange rules that determines how purchase and sale proposals are matched and, consequently, how prices are derived. Trading institutions differ from one another in several variants, i.e. the richness of within period information feedback, the continuous *vs.* discrete time through which information is processed and the number of trading opportunities allowed in each period. It has been showed that all these variables play a prominent role in establishing different incentives and coordination strategies associated with price formation and exchange. Indeed, several studies (see Plott,1982; Holt, 1995; Cason and Friedman 1999; Ockenfels and Roth, 2002) have found, in a more general framework, that trading institutions crucially matter for market performance and convergence to the clearing outcome.

In line with most of both theoretical and experimental works on trading institutions (see the related literature section) this study compares the performance of a continuous double auction and a call market (with multiple orders per period). The market environment in which this comparison is performed constitutes the main novelty of our contribution. Indeed, while in related works whether or not there were insiders in the market was commonly known, in our framework uninformed agents cannot be sure about the presence of insiders in the market. This variation has two major implications. As a first point, it contributes to frame the relationship between market performance and trading institutions in a more realistic context, since in real world financial markets there is no certainty about the presence of informed traders. Second, it sheds light on the potential impact of trading institutions on information mirages[1]. Information mirages were first detected in a leading contribution by Camerer and Weigelt (1991). The authors showed that, in a continuous double auction experimental market where subjects could not be sure about the presence of informed traders, the incorrect information inference during periods with no inside information led to a price path, i.e. an "information mirage", in which prices departed from the efficient equilibrium price, undermining the overall market efficiency.

In a framework that resembles that of Camerer and Weigelt (1991), we ask whether a call market institution might prevent, with respect to a continuous double auction mechanism, 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. Related Literature

As it 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.

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. Past experimental studies on double auction markets have shown that these markets

[1] Similar phenomenon are herd behaviour (Banerjee, 1992; Morone, 2012; Morone and Samanidou, 2008) and informational cascades (Bikhchandani *et al.* 1992; Fiore and Morone, 2008; Morone *et al.* 2009)

exhibit a rapid price convergence to the competitive equilibrium price as well as efficient allocations (see Smith, 1976; Smith and Williams, 1983; Smith *et al.,* 1982). For this reason, double auction markets have also been widely used as a benchmark for testing the performance of other institutions (see, for example, Ketcham *et al.,* 1984).

In a seminar paper, Plott and Sunder (1982) showed that, for a one period life asset traded through a continuous double auction mechanism, price convergence towards the fundamental value of the asset does occur in an environment where half of the traders are insiders and their presence is commonly known among market participants. Some years later, Camerer and Weigelt (1991), showed that the informational market efficiency was strongly challenged in a double auction market where the common knowledge on the insiders presence was removed. Indeed, in this case, uninformed traders did 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 led 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. As a consequence, actual prices depart from the competitive equilibrium level (since they reflect some non-existent information), undermining the overall market efficiency.

A powerful implication of the information mirage issue has been investigated by, Noussair and Yilong (2015). The experimental design involves a market where two assets are traded and the value of one of them is, at some point, reduced by an exogenous shock. The correlation between the two assets may be known or unknown with 50% chance. In the former case, only half of the traders know the correlation. While during periods when insiders were present the private information was rapidly revealed by prices, during periods with no privileged information, information mirages occurred, reflecting misleading information on the non-shocked asset value. The latter can be then interpreted as a form of financial contagion, implying that a market specific shock can be transmitted from one asset to another without a justifiable underlying reason.

With specific regard to the literature on trading institutions, the continuous double auction (CDA) and the single call market (SCM) have been the two most employed trading institutions in both theoretical and experimental works.

As far as theoretical research is concerned, in regard to call auction modelling, the main contributions can be found in Mendelson (1982), Ho *et al.* (1985), Satterthwaite and Williams (1993), and Rustichini *et al.* (1994). About double auction modelling, the main contributions can be found in Friedman (1984, 1991), Wilson (1985, 1987), Easley and Ledyard (1993), Glosten (1994). Finally, a powerful theoretical and empirical contribution on continuous and discrete trading has been provided by Budish *et al.* (2015). The authors show that the predominant continuous limit order book market design fails to properly work at high-frequency time horizons, since correlations break down leading to mechanical arbitrage opportunities. Then, Budish *et al.* (2015) show that continuous markets should then be replaced by frequent batch auctions, which manage to eliminate arbitrage opportunities and enhance liquidity.

With regard to the experimental literature, Smith *et al.* (1982) compared the continuous double auction with several variants of the single call market institution. The authors found the price convergence process to be more rapid in the continuous double auction. The latter institution also outperformed in terms of allocational efficiency except when a multiple unit recontracting variation of the single call market mechanism was introduced. In the latter case, the single call market showed the same allocational efficiency as the continuous double auction.

Friedman (1993) studied the impact of both a continuous double auction and a call market trading mechanism (with multiple orders per period) on market performance. Treatments differed in the pay-out contingent states across traders (homogeneous *vs.* heterogeneous) and in the sequential rather than simultaneous arrival of information. While the two employed trading institutions exhibited similar performance in terms of informational efficiency, the continuous double auction showed slightly greater allocational efficiency with respect to the call market. Market depth, meant as the difference between the best rejected bids and asks, was higher in the call market. Contrarily, market volume, i.e. the number of shares sold or bought, was higher in double auction markets.

Cason and Friedman (1996, 1997, 1999) compare the performance of four market institutions: the continuous double auction (CDA), the uniform price double auction (UPDA), the single call market (SCM) and the multiple call market (MCM). The authors find that trading efficiency, expressed as the realized percentage of the maximum gains from exchange, is remarkably higher in CDA and MCM sessions, suggesting that multiple trading opportunities within a period (like those allowed in the CDA and MCM mechanisms) bring about higher trading efficiency. On the opposite, the UPDA and the SCM institutions generate the highest informational efficiency, since they exhibit fewer deviations of transaction prices from the competitive equilibrium prediction levels. Then, the presence of multiple trading opportunities on one hand improves trading efficiency – since it induces traders not to under-reveal their true values and costs – but, on the other hand, it generates greater mispricing with respect to the case in which only one trading opportunity is permitted.

Shnitzlein (1996), in an experimental framework based on Kyle (1985), compares continuous and call auctions under asymmetric information. He finds that, in addition to not be less efficient than continuous auctions, call auctions also enhance market liquidity and imply less adverse selection costs for noise traders.

Theissen (2000) compared continuous double auctions, call markets and dealer markets. The author focused on informational efficiency within a sequential 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 incorporate the new information into 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.

Hinterleitner *et al.* (2015) investigate whether the market opening structure does impact on subsequent trading. In particular, they find that implementing a call auction in the market pre-opening phase improves market efficiency and liquidity with respect to the stand-alone continuous double auction.

Van Boening *et al.* (1993) showed that the price bubbles and crashes typically 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 was involved in three consecutive 15-round markets.

Our experiment crucially differs from the previous ones in the same strand in the fact that the continuous double auction and the call market (with multiple orders per period) institutions performance are compared in a framework in which the presence of insiders, if there are any, is not common knowledge. This new environment is worthy to be investigated for at least two reasons. First, Camerer and Weigelt (1991) have shown, in a resembling context, that market efficiency is seriously undermined because of the occurrence of information mirages. In this sense, it is interesting to test whether the continuous *vs.* trading type adopted might affect market efficiency. For this reason, a continuous double auction control treatment is opposed to a call auction design to test the ability of the latter, by preventing information mirages, to enhance market efficiency when no insiders are in the market. Second, our contribution frames the trading institutions research strand in a much more realistic context. It occurs because real world financial markets are far away from the classical experimental setting in which the presence of insiders is known to all traders. Contrarily, as in our framework, asset markets are affected by uncertainty about the influence of informed traders.

3. The experimental design

We consider eight markets where a total of 69 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[2] trading periods. In each session, 9[3] 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.

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[4] traders out of 9 are informed about the asset value previously randomly determined by the experimenter[5]. 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 z-Tree (Fischbacher, 2007) and was run at the University of Tilburg (CentER). The detailed instructions of the experiment and the z-Tree screen shots can be found in appendixes A and B.

3.1. 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

[2] Session 2 (DA treatment) was run over 11 trading periods.
[3] Session 2 (DA treatment) and session 1 (CM treatment) were run with 7 and 8 participants respectively.
[4] 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.
[5] In line with Plott and Sunder (1982), we ensure that, in periods with inside information, at least half of the traders are fully informed about the realized state.

they had enough money in their portfolio. In our experiment traders earned, on average, 10 Euros per hour.

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

3.3. 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. For these reasons, this trading institution is the richest one in terms of within period information and trading opportunities. On the opposite side, 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[6]

4. Theoretical Background

Theoretically speaking, assuming that traders have rational expectations, if the initial allocation is Pareto optimal, receiving some private information does not incentive any trade in the market. It occurs because any attempt to initialize a trade reveals the implicit private information owned by the proposer, removing any chance to gain from trade. As a consequence, no activity in the market is expected[7]. Nevertheless, there is abundant empirical evidence in contrast with the no trade equilibrium hypothesis, in which excess trade is observed even in a market where there is no gain from trade (see for example Lei *et al.*, 2001; Hey and Morone, 2004; Morone, 2008; Ferri and Morone, 2014; Alfarano *et al.*, 2011).

It remains open the question why, in these experimental markets, there is so much activity. One possibility is that hinted at by Hung and Plott (2001): subjects are bored and preferred to do

[6] These particular cases are discussed in detail in Appendix D.
[7] Reference to this branch of literature can be found in Milgrom and Stockey (1982) and Tirole (1982).

something than to do nothing. Angrisani *et al.* (2011) tested the no-trade theorem in a laboratory financial market where subjects can trade an asset whose value is unknown. They found that market feedback matters: trading losses encourage more conservative strategies, thereby reducing trade. Subjects lose money more frequently when there are no gains from trade, so feedback tends to drive these markets in the direction of no-trade. Overall, they concluded that their results "offer some vindication to both detractors and defenders of the no-trade theorems empirical validity. For the latter, the fact that trade is virtually wiped out in a setting where traders must learn a noisy information structure on the fly demonstrates that the no-trade logic is not as fragile as sometimes supposed. The former can counter that when the level of noise rises, informational trade is driven out much more gradually, and we cannot conclude that it will ever cease entirely". Our experiment adds more empirical evidence against the no trading hypothesis. As we will see in section 6, this theoretical equilibrium is never realized, since we observe a sustained level activity in the asset markets. Then, the "do nothing" equilibrium turns out not to be empirically relevant in our study.

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

5. 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. According to the discussion reported in the theoretical background section, table 1 reports the models' predictions in terms of equilibrium price and security holdings in periods where there are insiders in the market.

	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 1: RE and PI predictions in periods with inside information

Where:
Type 1 traders: informed traders
Type 2 traders: non-informed traders

As far as periods without insiders 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 methodology requiring two conditions. First, we look at periods without insiders. Second, 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:

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

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 second 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 traders. 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. In both the cases we test for the informational market efficiency by computing the mean squared error (*MSE*) of actual prices versus the RE/PI price predictions.

With regard to the cases in which no insiders are in the market, informational efficiency is someway related with information mirages. Indeed, if we should find that information mirages occur more frequently in the double auction treatment, it would also imply that we detect a greater number of cases in which the efficient price was attained in the call market. This is due to the fact that the set of conditions used to test for information mirages and informational efficiency in no-insiders periods is exactly the same.

Differently, as far as informational efficiency in insider periods is concerned, we formulate hypothesis 2 and its alternatives:

> ***Hypothesis 2****: During periods when insiders are in the market, 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****: During periods when insiders are in the market, prices exhibit closer convergence to the rational expectations predictions when trading takes place through the double auction mechanism.*

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

It has to be pointed out that, when the good state occurred in insider periods, 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 order to compare the market institutions performance, in a first step we aggregate all periods of the four sessions per treatment. In this case, each period is considered as an independent observation. Although this method does have the advantage of preserving a lot of information, it still presents a theoretical counter-indication. Indeed, since observations of subjects who participated in the same session might exhibit some correlations, counting each period as an independent observation is not theoretically appealing. While a clear articulation to address the session effect has not been developed yet, a widely accepted way[8] to overcome the issue is that of using session averages or medians of the variable of interest. This way, each session is taken into account as an independent observation. Unfortunately, the latter practice is not free from counter-indications. Indeed, as Friedman (1993) states, taking a single observation from each experimental session "…drastically reduces the information content of the data but still doesn't completely cure the problem since experimenter and subject pool effects may still be present". In the light of this open issue, in the next paragraph, we report our findings by showing the results derived from using both each period (following Friedman's (1993) practice) and each session (following Frechette (2012) an the reference therein) as an independent observation.

6. Experimental Results

Looking for information mirages, following the approach *à la* Camerer and Weigelt (1991) and Noussair and Xu (2015), we count the number of mirages that occur in each of the possible instances, i.e. in each of the periods without inside information in the market. As mentioned in the last paragraph, first we look for information mirages during the no insider periods. Then, we require 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[9].

In the double auction treatment, we detect 12 mirages out of 20 periods (60% occurrence) without inside information. Out of the 12 mirages detected, 3 reflected the good state price and 9 reflected the bad state price.

[8] See Fréchette (2012).
[9] In the limit case where, in a given trading period, the *MSE* of actual prices toward the efficient price coincides with that toward one of the two possible mirage prices, we look at the median price. In particular, if the mirage price is closer to the uninformed price (or midway between the uninformed price and one of the two possible mirage prices, the corresponding period is strictly not considered as a mirage case. On the opposite, if the median price is closer to the mirage price, the period is included in the mirage cases. Two limit cases (period 6 of session 2 and period 1 of session 3) occurred in the call market treatment. According with the previous discussion, one period (period 1 of session 3) has been considered as a mirage and the other one (period 6 of session 2) as a non-mirage case.

In the call market treatment, we detect 9 mirages out of 18 periods (50% occurrence) with no inside information. Out of 9 mirages, 3 reflected the good state price (20) and 6 reflected the bad state price.

Result 1: *Information mirages occurrence is 10% lower in the call market treatment.*

We now focus on informational efficiency. As far as periods without inside information are concerned, our first rough result directly derives from hypothesis 1, since the set of conditions used to test for information mirages is the same as that used to test for informational efficiency. Recalling that, in no insider periods, the market is efficient if prices fluctuate around the expected dividend (uninformed price), since information mirages occur more frequently in the double auction treatment, we can conclude that the call market does present a greater number of cases in which the efficient price has been attained. In particular, while in the double auction treatment, in 8 out of 20 (40% 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), in the call market treatment the efficient price has been attained in 50% of the possible instances. As a more rigorous practice, in periods without insiders, we compare the double auction and the call market *MSE* distributions by performing a non-parametric two-sided Mann-Whitney U test. When the latter is run using each period as an independent observation (see Table 1C, Appendix C), we find that the call market *MSE* distribution is significantly ($z = -1.95$, $p = 5\%$) lower than the double auction one.

Result 2: *When no insiders are in the market the call market mechanism is more efficient than the double auction.*

Anyway, a great reduction in the significance is detected when the test is performed by using both session averages (see Table 2C, Appendix C) and session medians (see Table 3C, Appendix C) as independent observations (in both the cases $z = -0.86$, $p = 38.65\%$). This led us to carry out a further step where, during all non-insider periods in which the uninformed price is the best approached benchmark (i.e. in no insider periods where the market is efficient), 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 smaller margin of error. A Mann-Whitney U test, where each period serves as an independent observation (see Table 4C, Appendix C) shows that the call market *MSE* distribution is significantly ($z = -2.69$, $p < 1\%$) lower than the double auction one. This implies 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. This evidence turns out to be particularly robust since even when the Mann-Whitney U test is performed on both session averages and medians (see Table 5C and 6C respectively, Appendix C) significance is still preserved ($z = -2.02$, $p < 5\%$ in both the cases).

Result 3: *In the no insiders periods where the market is efficient, when trading takes place through the call market mechanism actual prices track the rational expectations price prediction with smaller errors than when trading occurs through a double auction institution.*

Excluding insider periods, the average price volatility over the four double auction sessions was 1.86, against an average volatility of 0.59 computed over the four call market sessions. This advantage of the call market in reducing noise and stabilizing trading prices is also statistically significant in all the cases (Mann-Whitney U test: $z = -2.98$, $p < 1\%$ when periods are accounted as independent observations; Mann-Whitney U test: $z = -2.02$, $p < 5\%$ when session averages are considered as independent observations; Mann-Whitney U test: $z = -1.73$, $p < 10\%$ when session medians are counted as independent observations; see Tables 7C, 8C and 9C respectively, Appendix C).

Result 4: *trading prices, in periods with no inside information, exhibited lower volatility when trading took place by means of a clearing mechanism.*

This latter finding will be relevant for our policy implications. As far as hypothesis 2 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 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.

As a descriptive analysis, in the double auction treatment, out of 16 periods where the bad state (10) occurred, in 12 of those periods (75% of the cases) prices converged toward the RE prediction price, which is 10. In the call market treatment, out of 12 periods where the bad state (10) was realized, in 7[10] of those periods (58.33% of the cases) prices converged toward the RE prediction price (10).

In the double auction treatment, out of 10 periods where the good state value (20) occurred, in 7 of those periods (70% of the cases) trading prices exhibited convergence toward the RE/PI equilibrium price. In the call market treatment, convergence toward the RE/PI equilibrium took place in 7[11] out of 18 periods (38.88% of the cases) 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. Anyway, comparing the call market and the double auction *MSE* distributions in periods with insiders, a Mann-Whitney U test cannot reject hypothesis 2, i.e. that the two distributions come from the same population (periods as independent observations: $z = 0.57$, $p > 10\%$; session averages as independent observations: $z = -0.28$, $p > 10\%$; session medians as independent observations: $z = 0.57$, $p > 10\%$; see Tables 10C, 11C and 12C, Appendix C).

Result 5: *none of the two employed trading institutions does present an advantage in disseminating the inside information with respect to the other one.*

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

[10] We detected two limit cases where the *MSE* of actual prices toward the dividend price was equal to that toward the uninformed price. Like with information mirages, only if the median price is closer to the dividend price, the corresponding period was included in those in which the information was disseminated.

[11] We detected one limit case where the *MSE* of actual prices toward the dividend price was equal to that toward the uninformed price. Since the median price was not closer to the dividend price, that period has not been included among those in which information was disseminated.

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 the median premium in the double auction treatment was 104.23% against a call market treatment median premium of 104.62%. Therefore, the two ratios are pretty indistinguishable and statistically not different from each other (Mann-Whitney U test: periods as independent observations $z = -0.14$, $p > 10\%$; session averages as independent observations $z = -0.28$, $p > 10\%$; session medians as independent observations $z = 0.57$, $p > 10\%$; see Tables 13C, 14C and 15C, Appendix C). This leads us to accept hypothesis 3.

Result 6: *none of the two institutions does present an advantage in the sense of allowing a more equal profit split between insiders and non-informed traders..*

7. 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, i.e. 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 descriptive results show that information mirages do exhibit a greater occurrence rate when trading takes place through a double auction mechanism.

Furthermore, especially considering the periods with no inside information as independent entities, the call market mechanism performed better than the double auction in causing trading prices to converge to the efficient equilibrium prediction. This call market advantage is also qualitatively appealing since, when considering the subset of all the 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. In addition, when no information has entered the market, the clearing house institution does significantly outperform the double auction in reducing noise and stabilizing trading prices.

However, when inside information was present in the market, none of the two trading mechanisms was outperforming in terms of informational efficiency. This result is also confirmed by the fact that the insider premium distributions were not statistically different from each other.

Although in real world financial markets, it is not easy to establish *ex-ante* if inside information is fluctuating in the market, 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, for this reason, negotiations are affected by immense volatility. Then, since we find that in the CM prices exhibited less variance with respect to the DA, we think that adopting the former in the pre-opening sessions could reduce 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 <u>not</u> 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.

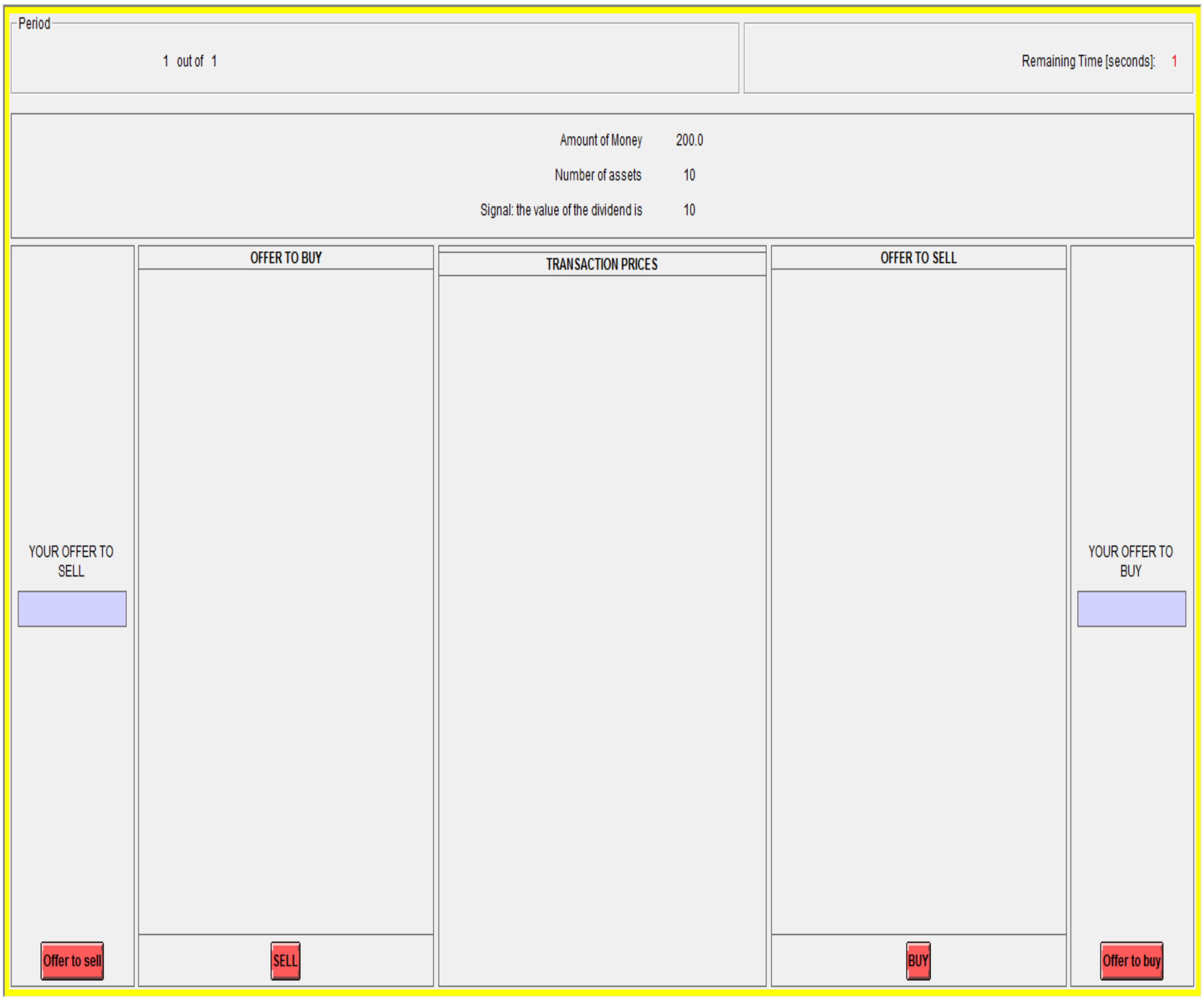

Figure 1: Buying and selling the asset

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).

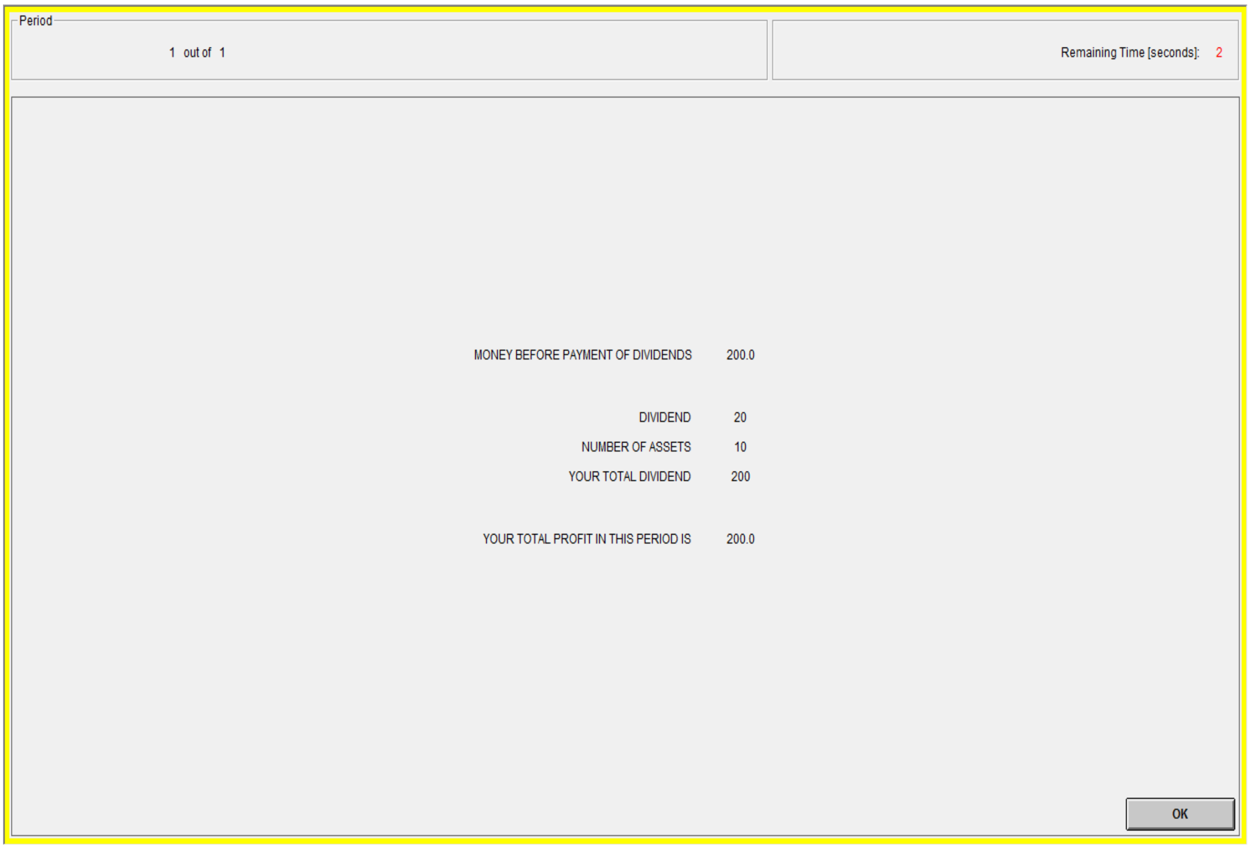

Figure 2: Your earnings

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.

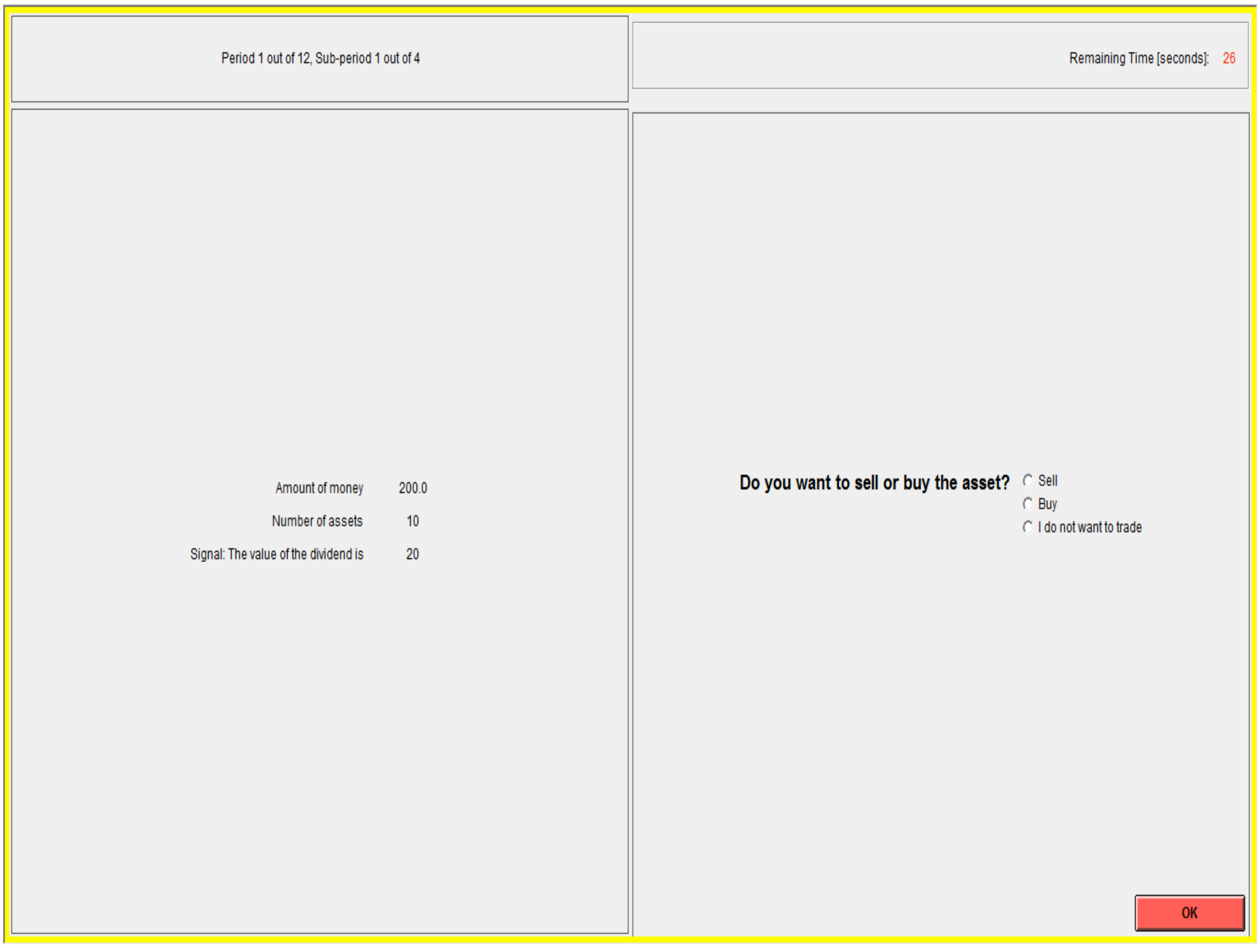

Figure 1: Buying and selling the asset

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 would like to sell or buy the asset and for the number of units of asset you would like to sell or buy. For example, if you decide to sell shares, you will move to the following screen (Figure 2):

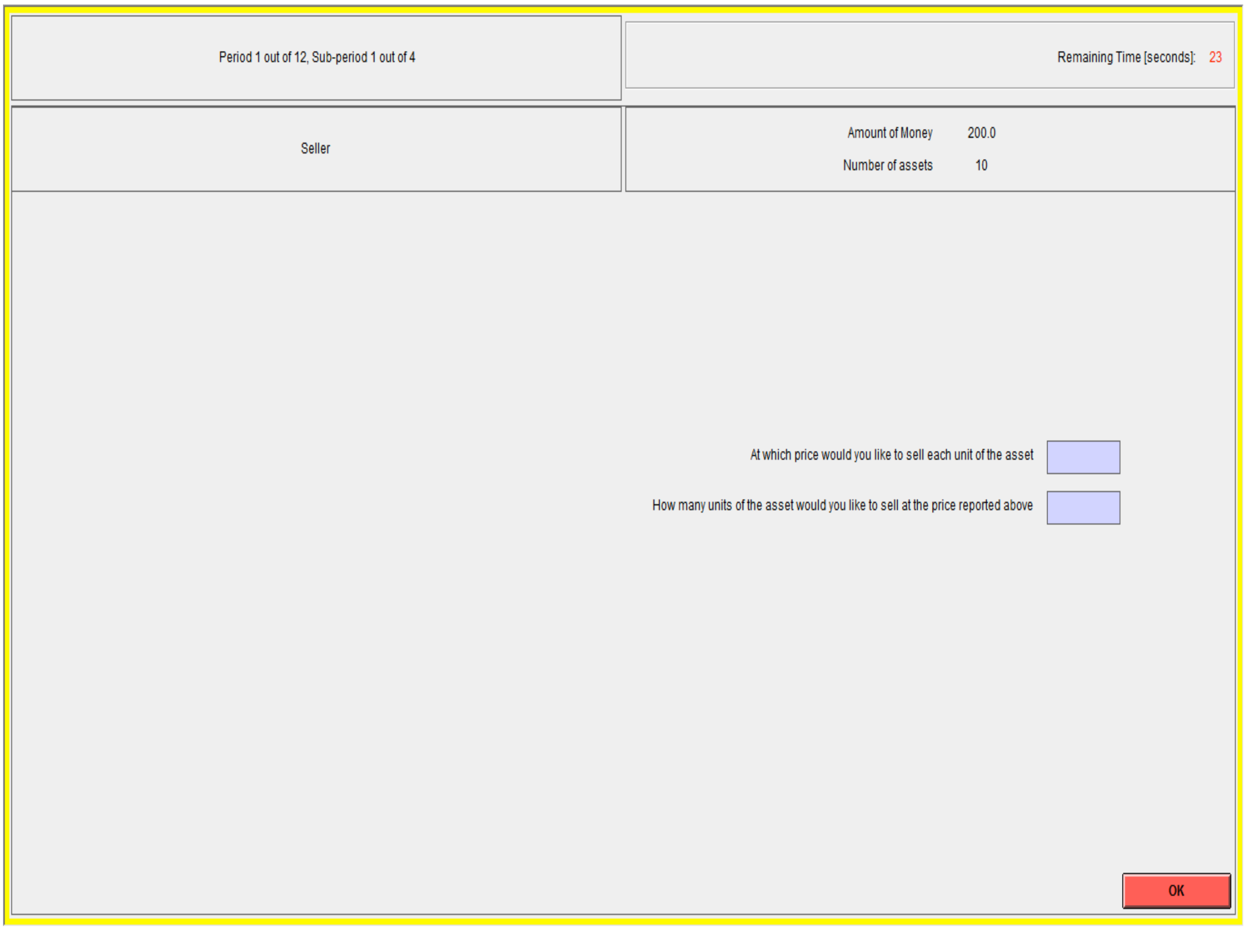

Figure 2: I would like to be a seller

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).

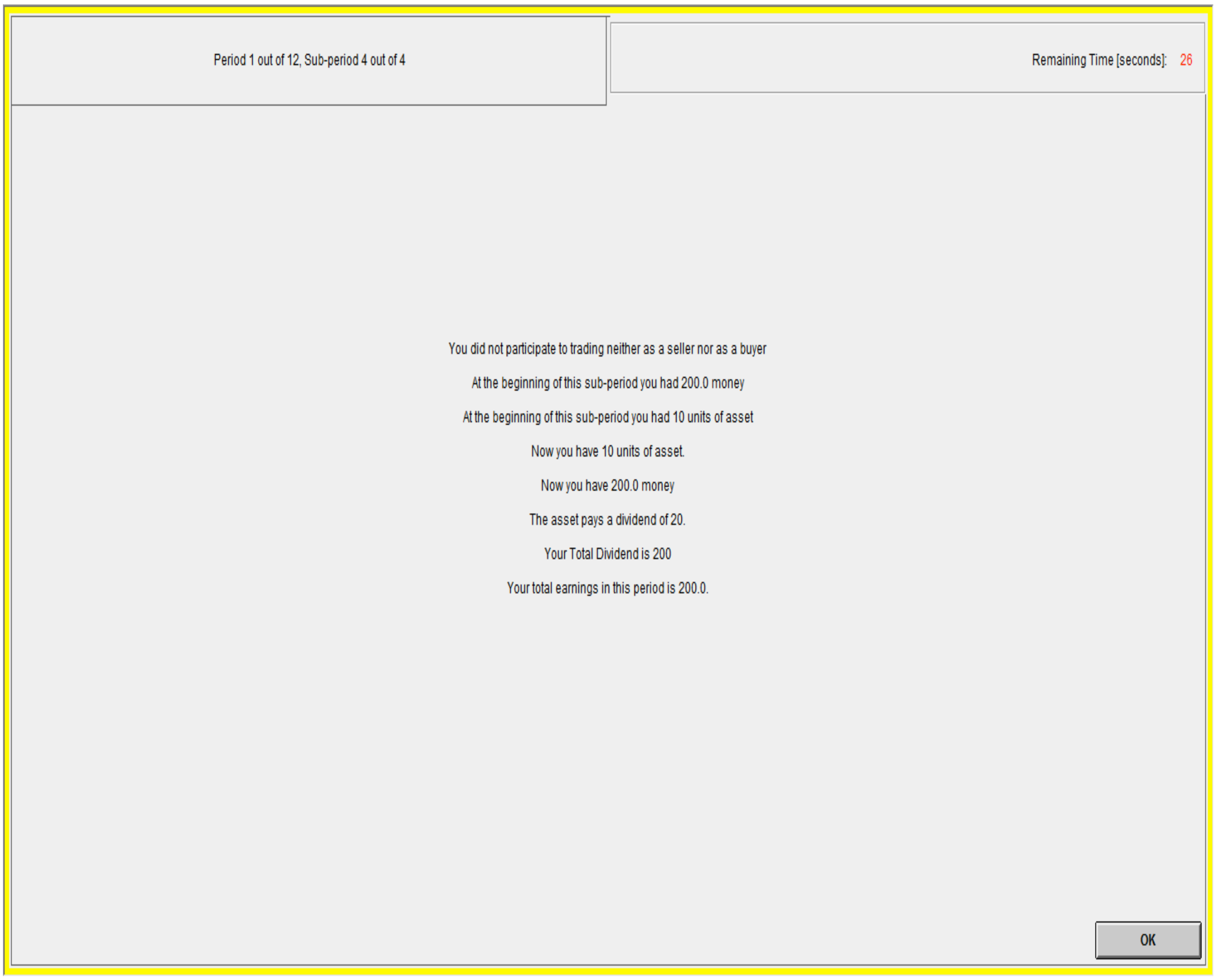

Figure 3: Your earnings

Appendix C

```
Two-sample Wilcoxon rank-sum (Mann-Whitney) test

           B |      obs    rank sum    expected
-------------+---------------------------------
          CM |       18         284         351
          DA |       20         457         390
-------------+---------------------------------
    combined |       38         741         741

unadjusted variance     1170.00
adjustment for ties       -0.26
                      ----------
adjusted variance       1169.74

Ho: A(B==CM) = A(B==DA)
             z =  -1.959
    Prob > |z| =   0.0501
```

Table 1C

```
Two-sample Wilcoxon rank-sum (Mann-Whitney) test

           D |      obs    rank sum    expected
-------------+---------------------------------
          CM |        4          15          18
          DA |        4          21          18
-------------+---------------------------------
    combined |        8          36          36

unadjusted variance       12.00
adjustment for ties        0.00
                      ----------
adjusted variance         12.00

Ho: C(D==CM) = C(D==DA)
             z =  -0.866
    Prob > |z| =   0.3865
```

Table 2C

```
Two-sample Wilcoxon rank-sum (Mann-Whitney) test

           F |      obs    rank sum    expected
-------------+---------------------------------
          CM |        4          15          18
          DA |        4          21          18
-------------+---------------------------------
    combined |        8          36          36

unadjusted variance       12.00
adjustment for ties        0.00
                      ----------
adjusted variance         12.00

Ho: E(F==CM) = E(F==DA)
             z =  -0.866
    Prob > |z| =   0.3865
```

Table 3C

```
Two-sample Wilcoxon rank-sum (Mann-Whitney) test

           B |      obs    rank sum    expected
-------------+---------------------------------
          CM |        9          53          81
          DA |        8         100          72
-------------+---------------------------------
    combined |       17         153         153

unadjusted variance      108.00
adjustment for ties       -0.13
                      ----------
adjusted variance        107.87

Ho: A(B==CM) = A(B==DA)
             z =  -2.696
    Prob > |z| =   0.0070
```

Table 4C

```
Two-sample Wilcoxon rank-sum (Mann-Whitney) test

           F |      obs    rank sum    expected
-------------+---------------------------------
          CM |        4          11          18
          DA |        4          25          18
-------------+---------------------------------
    combined |        8          36          36

unadjusted variance       12.00
adjustment for ties        0.00
                      ----------
adjusted variance         12.00

Ho: E(F==CM) = E(F==DA)
             z =  -2.021
    Prob > |z| =   0.0433
```

Table 5C

```
Two-sample Wilcoxon rank-sum (Mann-Whitney) test

           F |      obs    rank sum    expected
-------------+---------------------------------
          CM |        4          11          18
          DA |        4          25          18
-------------+---------------------------------
    combined |        8          36          36

unadjusted variance       12.00
adjustment for ties        0.00
                      ----------
adjusted variance         12.00

Ho: E(F==CM) = E(F==DA)
             z =  -2.021
    Prob > |z| =   0.0433
```

Table 6C

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

C	obs	rank sum	expected
CM	18	249	351
DA	20	492	390
combined	38	741	741

unadjusted variance 1170.00
adjustment for ties -3.33

adjusted variance 1166.67

Ho: B(C==CM) = B(C==DA)
z = -2.986
Prob > |z| = 0.0028

Table 7C

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

D	obs	rank sum	expected
CM	4	11	18
DA	4	25	18
combined	8	36	36

unadjusted variance 12.00
adjustment for ties 0.00

adjusted variance 12.00

Ho: C(D==CM) = C(D==DA)
z = -2.021
Prob > |z| = 0.0433

Table 8C

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

N	obs	rank sum	expected
CM	4	12	18
DA	4	24	18
combined	8	36	36

unadjusted variance 12.00
adjustment for ties 0.00

adjusted variance 12.00

Ho: M(N==CM) = M(N==DA)
z = -1.732
Prob > |z| = 0.0833

Table 9C

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

B	obs	rank sum	expected
CM	30	890	855
DA	26	706	741
combined	56	1596	1596

unadjusted variance 3705.00
adjustment for ties -0.63

adjusted variance 3704.37

Ho: A(B==CM) = A(B==DA)
z = 0.575
Prob > |z| = 0.5653

Table 10C

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

D	obs	rank sum	expected
CM	4	17	18
DA	4	19	18
combined	8	36	36

unadjusted variance 12.00
adjustment for ties 0.00

adjusted variance 12.00

Ho: C(D==CM) = C(D==DA)
z = -0.289
Prob > |z| = 0.7728

Table 11C

Two-sample Wilcoxon rank-sum (Mann-Whitney) test

F	obs	rank sum	expected
CM	4	20	18
DA	4	16	18
combined	8	36	36

unadjusted variance 12.00
adjustment for ties 0.00

adjusted variance 12.00

Ho: E(F==CM) = E(F==DA)
z = 0.577
Prob > |z| = 0.5637

Table 12C

```
Two-sample Wilcoxon rank-sum (Mann-Whitney) test

           B |      obs    rank sum    expected
-------------+---------------------------------
          CM |       14         234         238
          DA |       19         327         323
-------------+---------------------------------
    combined |       33         561         561

unadjusted variance      753.67
adjustment for ties       -0.13
                     ----------
adjusted variance        753.54

Ho: A(B==CM) = A(B==DA)
             z =  -0.146
    Prob > |z| =   0.8841
```

Table 13C

```
Two-sample Wilcoxon rank-sum (Mann-Whitney) test

           D |      obs    rank sum    expected
-------------+---------------------------------
          CM |        4          17          18
          DA |        4          19          18
-------------+---------------------------------
    combined |        8          36          36

unadjusted variance       12.00
adjustment for ties        0.00
                     ----------
adjusted variance         12.00

Ho: C(D==CM) = C(D==DA)
             z =  -0.289
    Prob > |z| =   0.7728
```

Table 14C

```
Two-sample Wilcoxon rank-sum (Mann-Whitney) test

           F |      obs    rank sum    expected
-------------+---------------------------------
          CM |        4          20          18
          DA |        4          16          18
-------------+---------------------------------
    combined |        8          36          36

unadjusted variance       12.00
adjustment for ties        0.00
                     ----------
adjusted variance         12.00

Ho: E(F==CM) = E(F==DA)
             z =   0.577
    Prob > |z| =   0.5637
```

Table 15C

Appendix D

In the determination of the equilibrium price (in CM institution), 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.

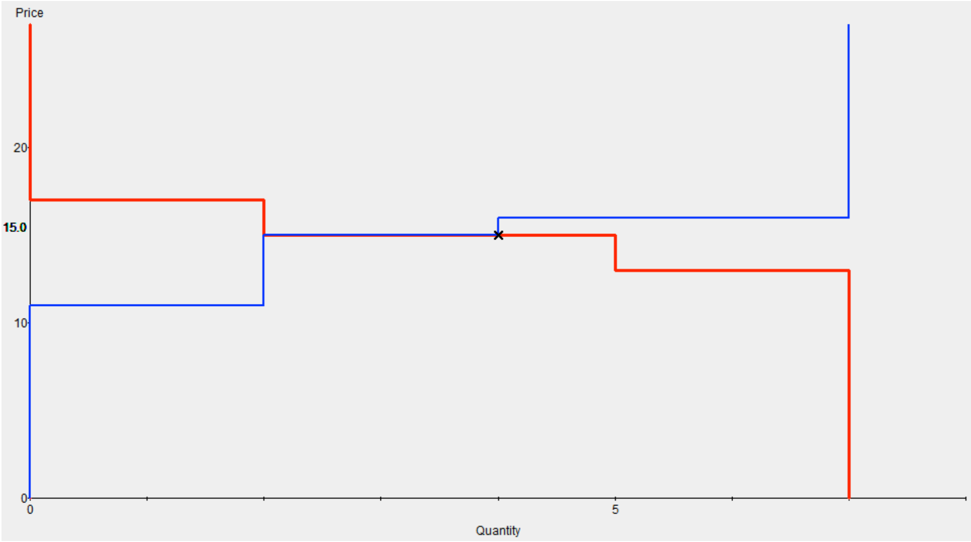

Figure 1

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

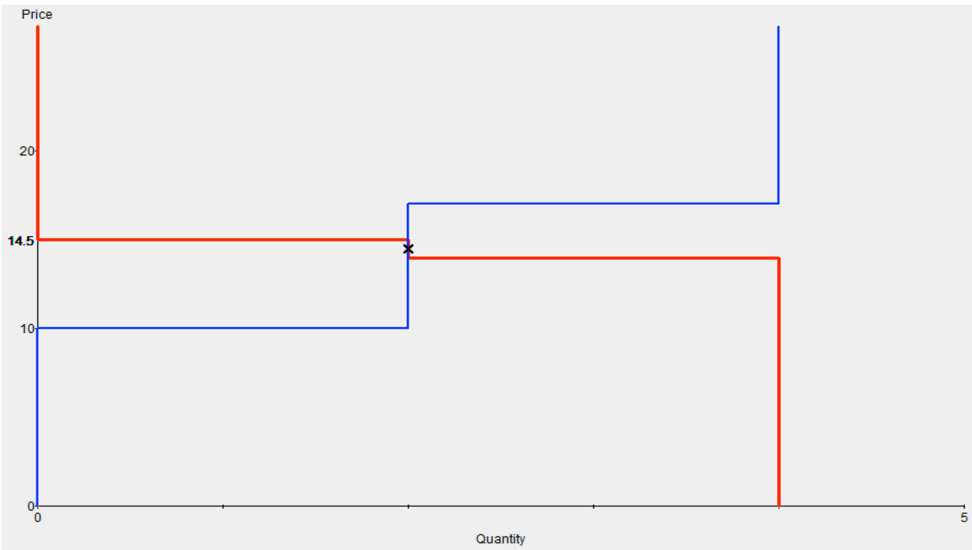

Figure 2

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.