An Experimental Study of Bubble Formation in Asset Markets Using the Tâtonnement Pricing Mechanism

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Abstract

We report the results of an experiment designed to study the role of institutional structure in the formation of bubbles and crashes in laboratory asset markets. In a setting employing double auctions and call markets as trading institutions, bubbles and crashes are a quite robust phenomenon. The only factor appearing to reduce bubbles is experience across markets. In this study, we replace the double auction with a tâtonnement pricing mechanism. The results show that bubbles are significantly mitigated, suggesting that the trading institution plays a crucial role in the formation of bubbles.

Keywords: Bubbles, Trading Institutions, Pricing Mechanisms, Tâtonnement

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1. **Introduction**

Price bubbles are not a rare phenomenon. Indeed, there are many examples of economics bubbles occurring between the first recorded, Tulipmania (Holland, 1637), until the more recent real estate bubble (US, 2007). Economic bubbles are generally considered to have a negative impact on the economy because they tend to cause misallocation of resources into non-optimal uses. In addition, the crash that usually follows an economic bubble can destroy a large amount of wealth and cause continuing economic malaise. A protracted period of low risk premiums can simply prolong the downturn in asset price deflation as was the case of the Great Depression in the 1930s for much of the world and the 1990s for Japan. Not only can the aftermath of a crash devastate the economy of a nation, but its effects can also reverberate beyond its borders, as is happening with the current recession.

Another important negative aspect of economic bubbles is their impact on spending habits. Market participants with overvalued assets tend to spend more because they "feel" richer (there is a wealth effect). Many observers quote the real estate/housing market in the United Kingdom, Australia, Spain and parts of the United States in recent times, as an example of this effect. When the bubble inevitably bursts, those who hold on to these overvalued assets usually experience a feeling of poorness and tend to cut discretionary spending at the same time, hindering economic growth or, worse, exacerbating the economic slowdown.

As bubbles represent a phenomenon with substantive economic implications, they are widely studied in finance and economics. In this paper, we study bubbles by means of experimental methods. As pointed out in other studies (e.g., Dufwenberg, Lindqvist and Moore, 2005), there are several advantages in doing so.

A bubble as defined by King, Smith, Williams, and Van Boening (1993) is "trade at high volumes at prices that are considerably at variance from intrinsic values." While in actual markets it is difficult to isolate factors of various nature (e.g., some instances it is impossible to pin down intrinsic values), that is not the case in experimental markets, where the experimenter can exercise more control. Thus, one hopes to gain some insights about the real world by studying simplified environments.

The existence of price bubbles is one of the most interesting and robust results from the multi-period asset market studies in the experimental literature. Smith, Suchanek, and Williams (1988) were the first to observe price bubbles in long-lived finite horizon asset markets. Their design implements a continuous double auction market mechanism with a finite time horizon of 15 to 30 trading periods. It is common knowledge that (1) each unit of the asset pays a dividend to its holder at the end of each period, (2) the dividend value is drawn each period from an independent equi-probable 4-point distribution, and (3) assets are worthless after the final dividend draw in the terminal period. Therefore, subjects are able to calculate the fundamental value of the asset at any time during the experiment. The time series of the fundamental value declines over time, i.e., the fundamental value decreases each period by the value of the expected dividend payment. Smith et al. find that with inexperienced subjects the typical time series of prices in these markets exhibits a bubble and crash pattern. That is, prices initially start below the fundamental value and then climb over time to prices that are significantly greater than the fundamental accompanied by excess market activity, and ending with a crash in the last periods of the experiment to the fundamental value.

Many studies have followed the pioneering work of Smith et al. in order to test the robustness of the price bubble phenomenon (King, Smith, Williams, and Van Boening 1993; Fisher and Kelly 2000; Lei, Noussair, and Plott 2000; Noussair, Robin, and Ruffieux 2001; Porter and Smith 1995; Van Boening, Williams, and LaMaster 1993). Specifically relating to trading institutions, bubbles have been shown to be robust to the double auction (Smith et al. 1988) and uniform-price sealed-bid-offer call markets (e.g., Van Boening, Williams and LaMaster 1993; Caginalp, Porter and Smith 2000; Haruvy, Lahav and Noussair 2007; Hussam, Porter and Smith 2008).

To date, the only treatment variable that appears to consistently eliminate the existence of the price bubble is experience of all or some of markets participants via participation in previous asset market sessions of the same (Van Boening, Williams and LaMaster 1993; Dufwenberg, Lindqvist and Moore, 2005).[1]

In this paper we ask: Is there a trading institution that may facilitate experience *within* a market session as opposed to *across* markets? We think tâtonnement may be an answer to this question. Specifically, in this study, we test the conjecture that the price bubble phenomenon in multi-period lived asset markets will be significantly reduced or eliminated by the implementation of a tâtonnement market mechanism instead of the standard double auction or call market used in all the previous studies. Note also that the

[1] Hussam, Porter and Smith (2008) show that if the environment is subject to changes in liquidity and uncertainty, then even experience is not sufficient to eliminate bubbles.

tâtonnement mechanism is not just an abstract theoretical construct as it is employed in some of the actual markets, e.g., the Tokyo grain exchange (Eaves and Williams, 2007).

A characteristic of the double auction market mechanism is that buyers and sellers tender bids/asks publicly. Typically the highest bid to buy and the lowest ask to sell are displayed and open to acceptance, and price quotes progress to reduce the bid\ask spread. Trading is open for a limited period of time and occurs bilaterally and sequentially at different prices within a period. In the call market, on the other hand, bids and asks are accumulated and the maximum possible number of transactions are simultaneously cleared at a single price per period.

How does the tâtonnement differ from these institutions and why do we think it may facilitate learning? In our implementation of tâtonnement, in every period, the initial price is selected randomly. Subjects submit their bids/asks at the given price. If aggregate demand is equal to aggregate supply, the market clears. Otherwise, the market proceeds with iterations. In particular, the price moves upward if there is excess demand or moves downward if there is excess supply (the actual workings of the price adjustment mechanism are explained in Section 2), and a new provisional price is called. Subjects submit their bids and asks at the new provisional price, and the process continues until the market clears. Thus, there are several non-binding iterations *within* each period which are publicly observable and which reflect the formation of aggregate demand and supply, and equilibrium price.

Note that this may allow subjects to learn demand, supply, and equilibrium price without actual trading. In particular, this is in contrast with the double auction mechanism where trades occur in continuous time, and extreme behavior and confusion may be reflected more easily in transactions. In other words, in order for trade to occur under tâtonnement, subjects need to find some sort of collective agreement (as market clears only if excess demand is equal to zero) while in double auction or call markets that is not the case.[2] In other words, under tâtonnement, the sequence within a period itself reveals information allowing subjects to have a more accurate belief about equilibrium and gain experience within a period rather than across periods as in other studies. Thus, there is a strong learning tool for inexperienced subjects embodied in the mechanism.

We find that under tâtonnement bubbles are indeed mitigated according to all bubble measures employed in the literature. Furthermore, we develop a measure that accounts also for volumes of trade. Under this measure, bubbles are eliminated under tâtonnement.

Section 2 describes the experimental design and procedures. We discuss the results in Section 3 and conclude with Section 4.

2. The Experiment

The experiment consisted of four sessions conducted between September and October 2004 at the University of Canterbury in Christchurch, New Zealand. Twelve traders for each session were recruited from undergraduate courses throughout the university. Some of the subjects had participated in previous experiments, but none had experience with asset markets. Each subject only took part in a single session of the

[2] An additional benefit of tâtonnement: the magnitude of excess supply/excess demand signals to participants about the general consensus regarding the equilibrium price. For example, if excess supply is only 5 shares, I should not be that concerned as a buyer about doing something wrong. However, if excess supply is 100 (with 120 shares in total), and I am trying to buy, I might start thinking about why the vast majority of participants has very different belief about the equilibrium price than me.

study. The experiment was computerized and used the z-Tree software package.[3] Trade was denominated in "francs" which were converted to New Zealand dollars at the end of the experiment at the predetermined publicly known conversion rate of 600 francs to 1 NZD. On average, sessions lasted approximately 2.5 hours including initial instructional period and payment of subjects. Subjects earned 26.80 NZD on average.[4]

At the beginning of the experiment, subjects were endowed with 10 units of the asset and a cash balance of 10,000 francs. The asset had a finite life of 15 periods. At the end of each trading period, each unit of the asset in a subject's inventory paid an uncertain dividend that was equally likely to be 0, 8, 28, or 60 francs (e.g., Smith et al.1988; King et al., 1993; Lei et al. 2001; Noussair and Tucker, 2006). Therefore, the average dividend paid per unit of the asset held in each period equaled 24 francs. The dividend was independently drawn each period. After the final dividend payment in period 15, the asset was worthless. Therefore, the fundamental value of the asset at any given time during the market equaled 24 francs times the number of periods remaining. Subjects were provided an "Average Holding Value Sheet" within their instructions packet that illustrated the value of the stream of dividend payments from a given period to the end of the experiment.[5] Although the dividend process was explained in detail within the instructions, there was no suggestion of a relationship between the dividend process and prices at which one should be willing to make transactions.

The trading institution employed in all markets was the tatonnement auction. In each period, subjects were allowed to buy or sell units of X as long as they had sufficient

[3] See Fischbacher (1999) for a discussion of the z-Tree software package.
[4] At the time of the experiment, the adult minimum wage in New Zealand was 9.00 NZD per hour (1 NZD = 0.6708 USD).
[5] A copy of the instructions is provided in the Appendix.

cash on hand to cover the purchase or sufficient inventory of assets to make the sale. The specifics of the tatonnement auction used within our experiment are as follows. At the beginning of each period, the computer announced a randomly drawn initial price from a uniform distribution on the interval [0, 500]. Each subject decided how many units of X that they wanted to buy or sell at this given price by placing bids or asks respectively. The computer aggregated individual decisions and compared the market quantity demanded (Q_D) to the market quantity supplied (Q_S). If the market cleared ($Q_D = Q_S$), then the process stopped and transactions were completed. If the market did not clear at the initial random price, then the price would adjust in the appropriate direction.[6] Specifically, we employed "proportional" adjustment rule, which can be thought of as proceeding in two stages (see also Joyce (1984, 1998)).

In the first stage, the price adjusts proportionally according to the following rule: $P_t = P_{t-1} + \gamma_t(Q_{D,t-1} - Q_{S,t-1})$, where $\gamma \in \{10, 5, 2.5, 1, 0.5, 0.25, 0.05\}$ is the adjustment factor and subscript *t* is the iteration of adjustment. The initial adjustment factor is 10 and decreases to the next lower value unless we observe either an excess supply or an excess demand twice in a row, i.e., unless $(Q_{D,t} - Q_{S,t})$ is of the same sign as $(Q_{D,t-1} - Q_{S,t-1})$.[7] For small levels of excess supply/demand (or in the second stage), whenever $0 < |\gamma_t(Q_{D,t-1} - Q_{S,t-1})| < 1$, the price adjustment rule is replaced by $P_t = P_{t-1} + \frac{(Q_{D,t-1} - Q_{S,t-1})}{|Q_{D,t-1} - Q_{S,t-1}|}$. That is, if $0 < \gamma_t(Q_{D,t-1} - Q_{S,t-1}) < 1$, the pricing rule is $P_t = P_{t-1} + 1$, and if $-1 < \gamma_t(Q_{D,t-1} - Q_{S,t-1}) < 0$, the pricing rule is $P_t = P_{t-1} - 1$.

[6] The price is adjusted upward in case of excess demand and downward in case of excess supply.
[7] In general, as the number of iterations increases, it takes a larger gap between aggregate quantity demanded and supplied to significantly adjust the price.

Figure 1 illustrates how the price adjustment rule works via the data collected in period 1 of session 1. At the initial price of P_1=188, aggregate demand is $Q_{D,1}$=53 and aggregate supply is $Q_{D,1}$=9. In the next iteration, the price is P_2=188+10(53-9)=628. At P_2=628, aggregate demand is 6 and aggregate supply is 55, which implies that the adjustment factor used in the iteration will be 5, so that P_3=383. Similarly for all other prices in the iteration sequence of the period.

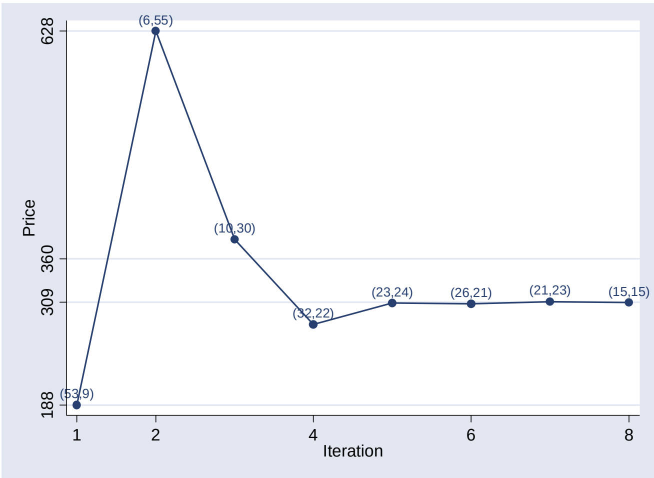

Figure 1. Pricing rule iterations in period 1 of Session 1

Subjects had access to flow information so they could see the aggregate demand and supply of stocks in every iteration of every period.

Since we did not implement an "improvement rule" analogous to those typically used in previous double-auction asset markets, it is possible that the above price adjustment process may result in an infinite number of oscillations around a narrow region of prices. That is, current bids/asks are not constrained by bids/asks made in previous iterations. For any given announced price, participants could choose any amount to buy or sell irrespective of their decisions in the previous adjustment iteration (there is no improvement rule). In order to avoid the oscillating prices, we employed a manual closing rule if $Q_D \neq Q_S$ within several iterations. More specifically, if according to the price adjustment mechanism the price changed by only one franc and remained in a region of three francs for four periods in a row, then the period was concluded manually.[8] The process for manual conclusion of a period was as follows. An announcement was made by the experimenter that a manual conclusion was to be conducted and the subjects were not to enter an amount to buy or sell into the computer for the current iteration announced price. On Bidding Sheets provided to them within the instructions, subjects had to write the announced price given by the computer for this iteration and the amount of X that they wanted to buy or sell at this price. The experimenter then collected these sheets and totaled the amount of X that people wanted to buy and sell. If $Q_D = Q_S$, then the transactions were made according to the bids/asks made. If $Q_D > Q_S$, then the units sold were randomly allocated to the buyers. If $Q_D < Q_S$, then the units bought were randomly divided among the sellers. Once the allocation was determined for the period, the experimenter redistributed the Bidding Sheets back to the subjects who then entered the amount assigned to them to buy/sell into the computer, which concluded the period.

3. Results

The time series of market clearing prices are shown in Figure 2. Each period of the experiment is provided on the horizontal axis and market clearing prices are indicated on the vertical axis. According to Figure 2 the prices in Sessions 1 and 2 remain close to the fundamental value, while the prices in Sessions 3 and 4 display typical departures associated with price bubbles.

[8] Examples of the criteria for implementing the manual closing rule is if the price went from 100, to 101, back to 100, then back to 101, or if the price went from 100, to 101, to 102, then back to 101.

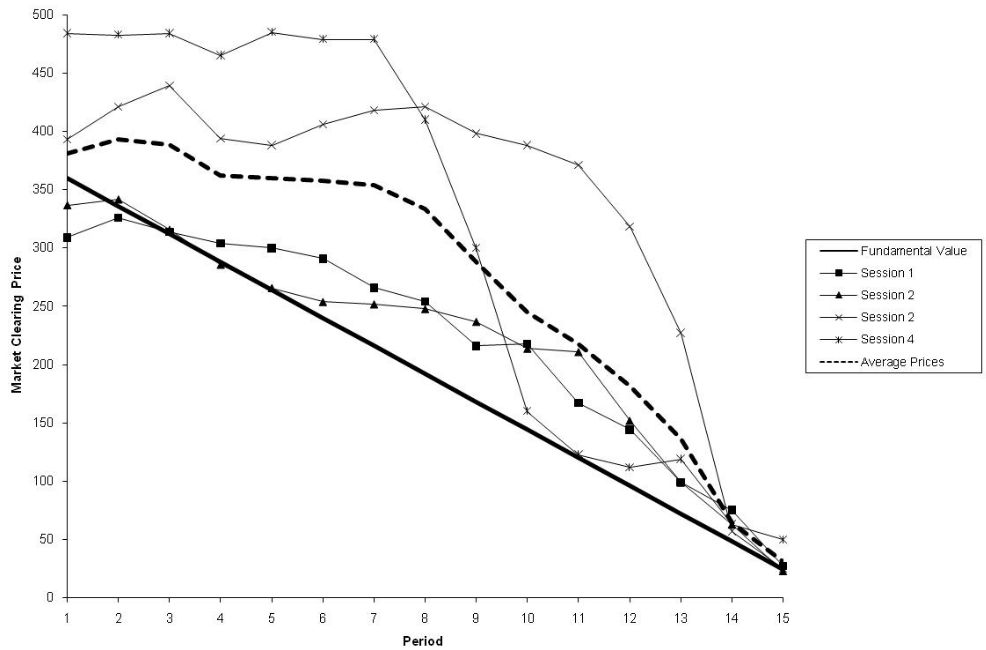

Figure 2: Market Clearing Prices across Sessions

If judged only by Figure 2, it appears the tâtonnement process only partially succeeds in eliminating a bubble, since in two out of four sessions we observe price deviations from the fundamental value similar to previous experiments. However, a careful evaluation of bubble size, as pointed out by the definition of bubble itself, should involve two dimensions, transaction price and quantity.[9] Indeed, once both factors are taken into account, the tâtonnement process appears to have quite a strong dampening effect on the bubble phenomenon. In particular, the trade volumes in each of our sessions are much lower than the corresponding quantities in the previous experiments.

To confirm the impression that the tâtonnement mechanism has an attenuating effect on asset price bubbles, we employ the measures of the magnitude of bubbles in laboratory markets developed by King et al. (1993), Van Boening et al. (1993); and

[9] A bubble is "trade in *high volumes* at prices that are considerably at variance with intrinsic values (italics ours)" (see King et al., 1993).

Porter and Smith (1995). The measures allow comparisons between different treatment conditions and different studies with regard to the extent of bubble formation. Three of these measures are *Price Amplitude*, *Normalized Absolute Price Deviation*, and *Turnover*.

- The *Price Amplitude* is defined as the difference between the peak and the trough of the period price relative to the fundamental value,[10] normalized by the initial fundamental value, f_1 (in our markets f_1 = 360). In other words, price amplitude equals
- $A = \max_t \{(P_t - f_t)/f_1\} - \min_t \{(P_t - f_t)/f_1\}$, where P_t is market clearing price[11] and f_t is the fundamental value in period *t*.
- The *Normalized Absolute Price Deviation*: Is the sum, over all transactions, of the absolute deviations of prices from the fundamental value, divided by the Total Number of Shares outstanding: $D = \sum_t n_t |P_t - f_t| / (100 * TSU)$, [12] where n_t is the number of units traded in period *t*, and *TSU* is the total stock of units.[13]
- The *Turnover* is defined as the total number of transactions over the life of the asset divided by the total stock of units: $T = \left(\sum_t n_t\right) / TSU$.

A high Price Amplitude indicates large price swings relative to fundamental value, evidence that prices have departed from fundamental values. A high Normalized Absolute Deviation corresponds to a large amount of trading activity at prices removed from fundamental value. A high Turnover means that there is a high volume of trade,

[10] In the double auction case, mean period prices are used as trades occur at different prices within a period.
[11] In the double all pay auction P_t denotes the average transaction price.
[12] We divide by 100*TSU rather than just TSU to render our measure comparable to previous studies where the expected dividend is 24 cents and the normalized deviation was calculated in terms of dollars, i.e., units of 100 cents.
[13] Note, that the corresponding measure under the double auction pricing mechanism is $D = \sum_i \sum_t |P_{it} - f_t| / (100 * TSU)$, where P_{it} is the individual price in transaction *i* of period *t*.

suggesting either heterogeneous expectations or errors in decision making prompting trade.

We report the value of each measure in Table 1. The table also includes data previous studies in which the asset traded had a life of 15 periods and a declining fundamental value over time as in our experiment.

Table 1. Traditional Measures of Bubble Size

Session	Turnover	Amplitude	Normalized Deviation
Session 1	1.56	0.347	0.491
Session 2	0.98	0.317	0.291
Session 3	1.63	0.694	2.048
Session 4	1.37	0.722	1.472
Overall	1.38	0.366	1.075
NRR (2001)	4.19	0.515	2.24
SVW (2000)	4.35	1.39	5.5
PS(1995) Baseline	5.49	1.53	N/A
VWL (1993)	5.05	4.19	5.12
SSW (1988)	4.55	1.24	5.68
NT (2006) 41503	1.16	0.161	0.165
NT (2006) 40903	0.59	0.537	0.254
NT (2006) 40403	0.9	0.452	0.296
NT (2006) 100802	1.29	0.175	0.241

As illustrated in the table, each of our four sessions have bubble measures comparable with Noussair and Tucker (2006) and smaller than the average obtained in any of the other previous studies of markets where the asset has a declining fundamental value.

Noussair and Tucker (2006) have provided additional futures market and demonstrated that its presence impedes bubble formation. Our study demonstrates that an alternative way to impede bubble formation is to use tâtonnement mechanism instead of double auction. In this case we do not need an additional market.[14] That is, we have significantly reduced the bubble within the single market itself. Even though we have price deviations from the fundamental in session 3 and 4, the quantity traded was very low.

The measure of market volume, turnover, ranges from 0.98 to 1.63 in our data, while in previous studies it typically averages between 4 and 6; 0.59 to 1.29 in NT (2006). The normalized deviation ranges from 0.291 to 2.048 in the current study, while in the other studies it takes on values between 2 and 6; NT 0.165 to 0.296. The drastically lower value reflects lower transaction volume as well as smaller deviations from fundamental value. Amplitude shows a similar pattern, ranging from 0.317 to 0.722 in our data, while reaching values between 0.515 and 4.19 in the previous studies; NT: 0.161 to 0.537. All previous studies where the asset has a declining fundamental value, and that are therefore the most comparable to our markets, show amplitude greater than 1.24, more than three times the average in our data. Thus, the evidence is clear that spot market bubbles are much smaller in our markets than in previous studies.

In order to assess the importance of trade volumes in measuring bubbles sizes, in addition to comparing observed price deviations from fundamental value across

[14] It is also worth pointing out that even though in Noussair and Tucker (2006), the bubble is eliminated from the spot market, it still persists in the futures market.

experiments, we also compare price deviations from fundamental weighted by period turnovers. In particular, we compare our data with Smith et al. (1988) and King et al. (1993).

We start by comparing the observed price deviations from fundamental values across experiments. For this purpose, we normalize the fundamental values across studies so that the maximum fundamental is normalized to 100. That is, in period *i*, the normalized fundamental value is $F^i_{norm} = {}^{100}\!/_{F^{\max}} F^i$. For example, in our experiment, the maximum fundamental value is 360 (at the beginning of period 1) and the fundamental value in period 6 is 240. Thus, the normalized fundamental values in period 6 is 240*100/360=67. The prices are also normalized as follows: $P^i_{norm} = {}^{100}\!/_{F^{\max}} P^i$.

Figure 3 depicts the time series of normalized prices and fundamentals across experiments (the middle graphs denoted as lpts1-4 are from our experiment).

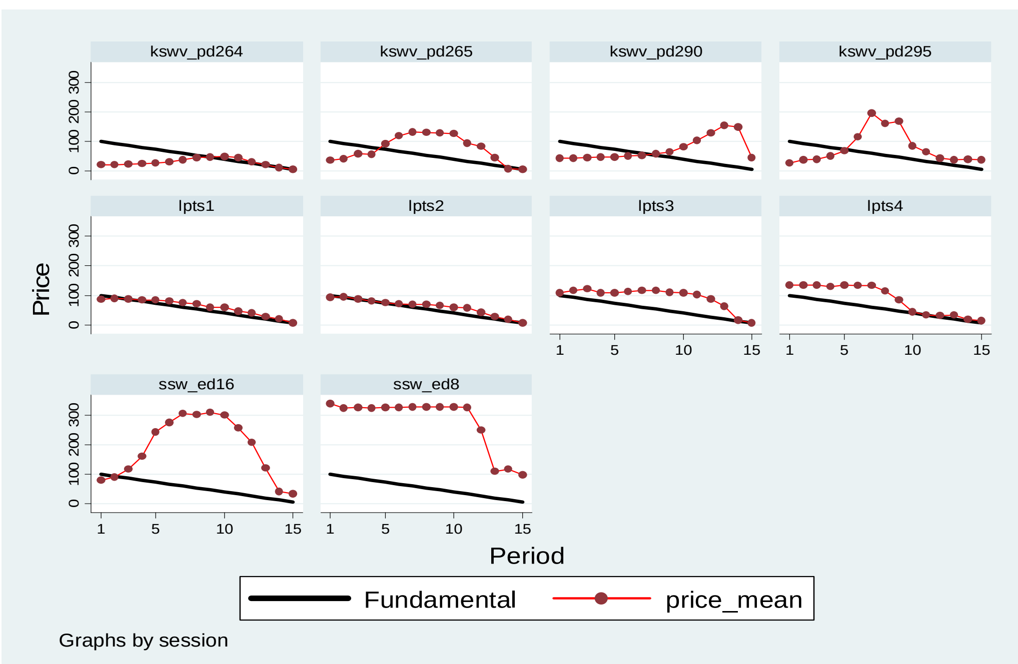

Figure 3. Normalized Prices and Fundamental across Studies

As shown in the figure, if we just look at trading prices, two of our sessions display prices above fundamental value. On the other hand, if we adjust for trade volumes, this is no longer the case (see Figure 4). Specifically, in order to account for trade volumes, we introduce the weighted price (weighted by trade volume) to analyze the extent of the bubble. When looking at the deviation from fundamental, we now weight the price by the volume of trade to take into account the thickness of the market. The expression for the weighted price is $P^i_{weighted} = {}^{100}\!/_{F^{\max}} \left[F^i + \left(P^i + F^i\right) {}^{Q\_traded^i}\!/_{Q\_total} \right]$. The time series data of adjusted prices across experiments is plotted in Figure 4.

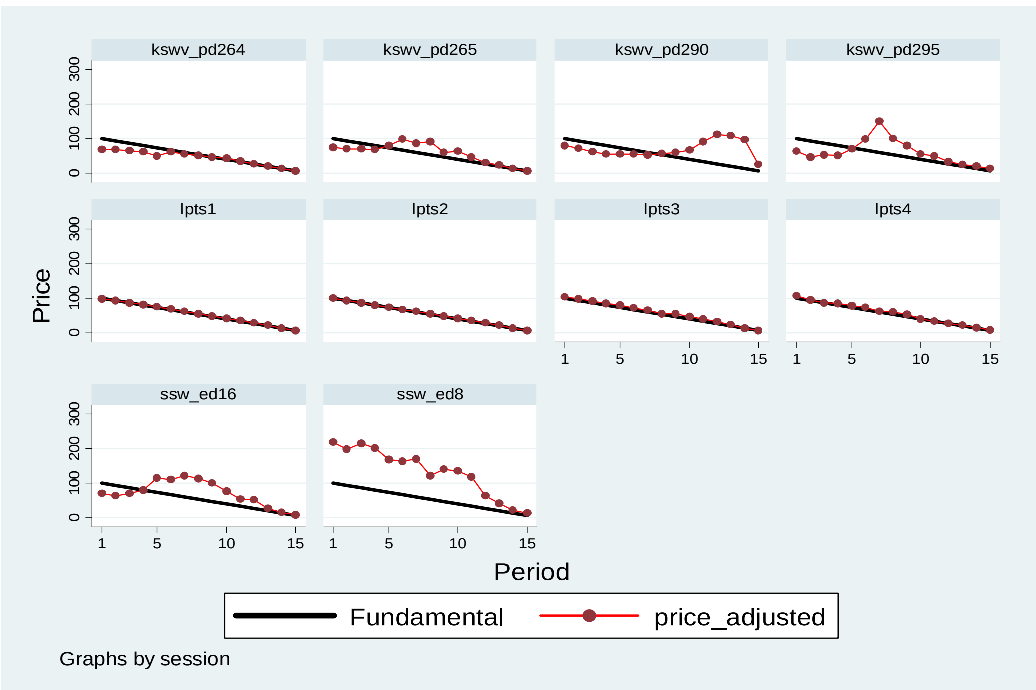

Figure 4. Weighted Prices and Fundamental across Studies

To see how this formula works, we continue our previous example. Suppose the observed normalized price in period 6 is 83 and consider the following two scenarios. In the first scenario, the quantity traded is 12 units, while in the second it is 108. In the first case the adjusted price is 68.6 (not that far from fundamental value) while in the other case, it is 81.4.

As shown in figure 4, if we account for trade volumes, the bubble is completely eliminated in our study, while it still persists in other studies.

4. Conclusions

In this paper we have studied the impact of tâtonnement on bubble formation in asset markets. As suggested by several studies, bubbles appear to be extremely robust to changes in the experimental environment. The only factor that appears to reduce bubbles is across markets experience. We find that tâtonnement, as opposed to double auctions and call markets, appears to facilitate learning about the equilibrium price or fundamental values of an asset. In particular, tâtonnement plays a key role in the elimination of bubbles in experimental settings.

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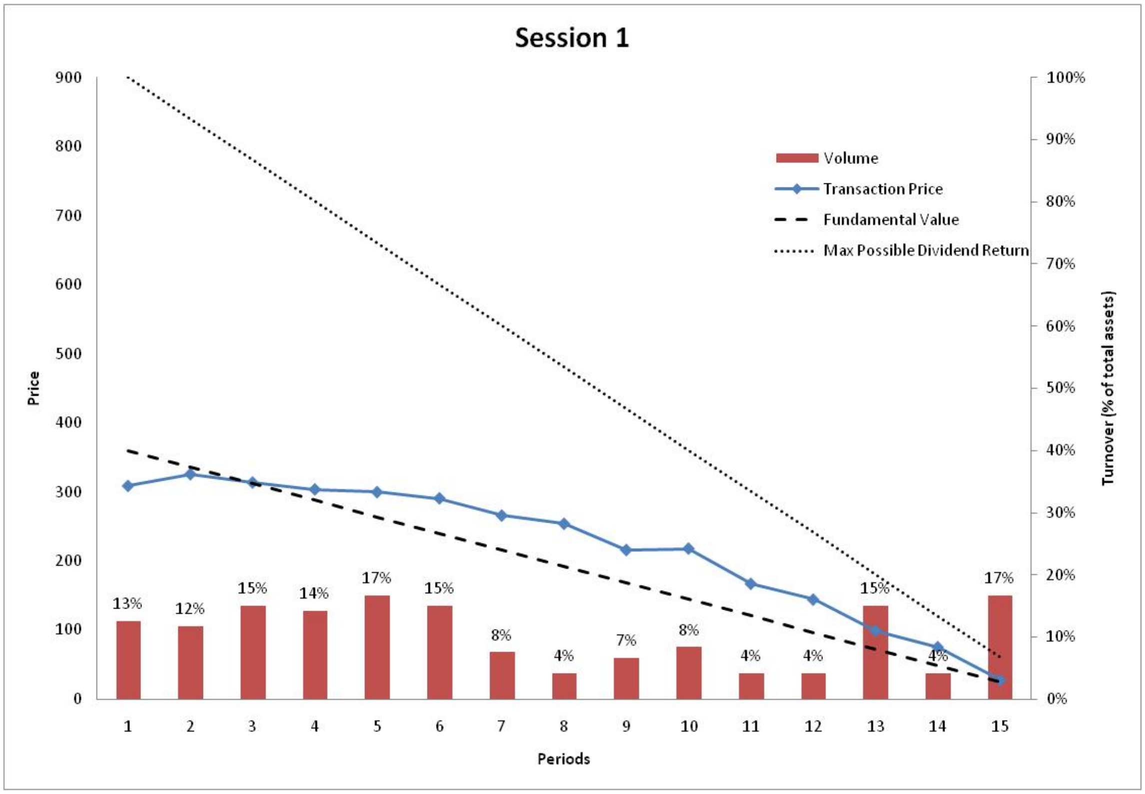
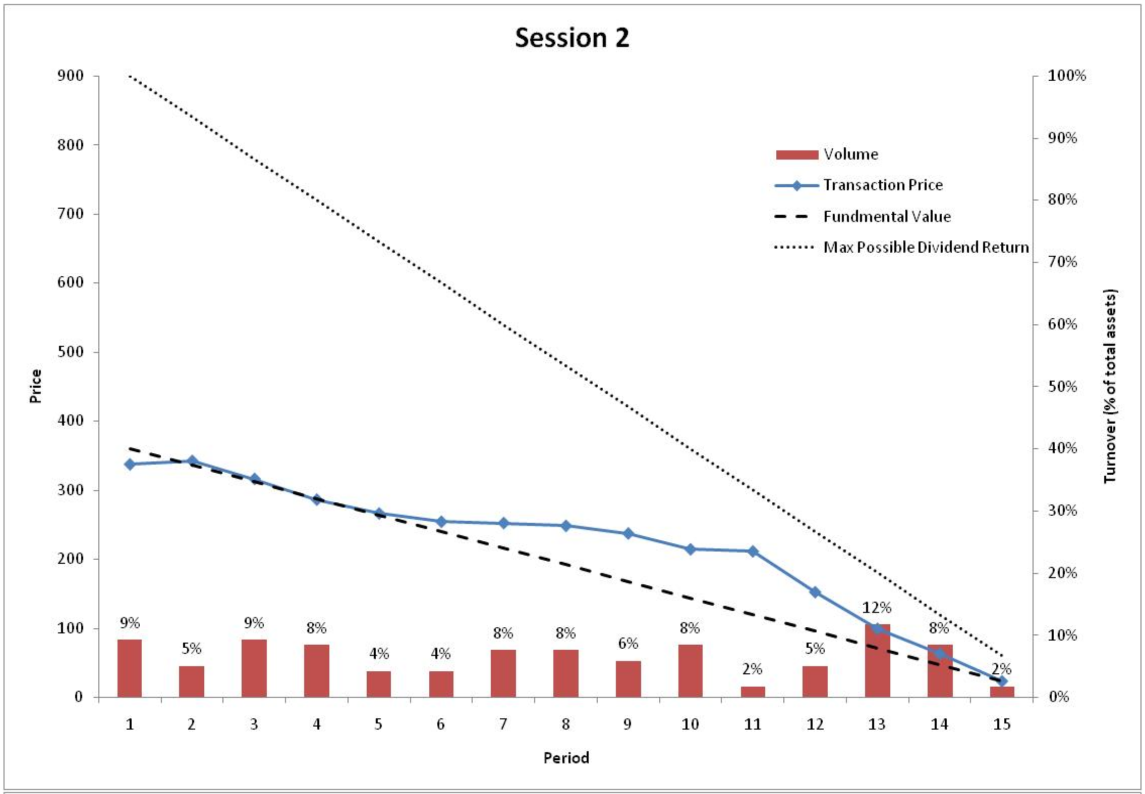
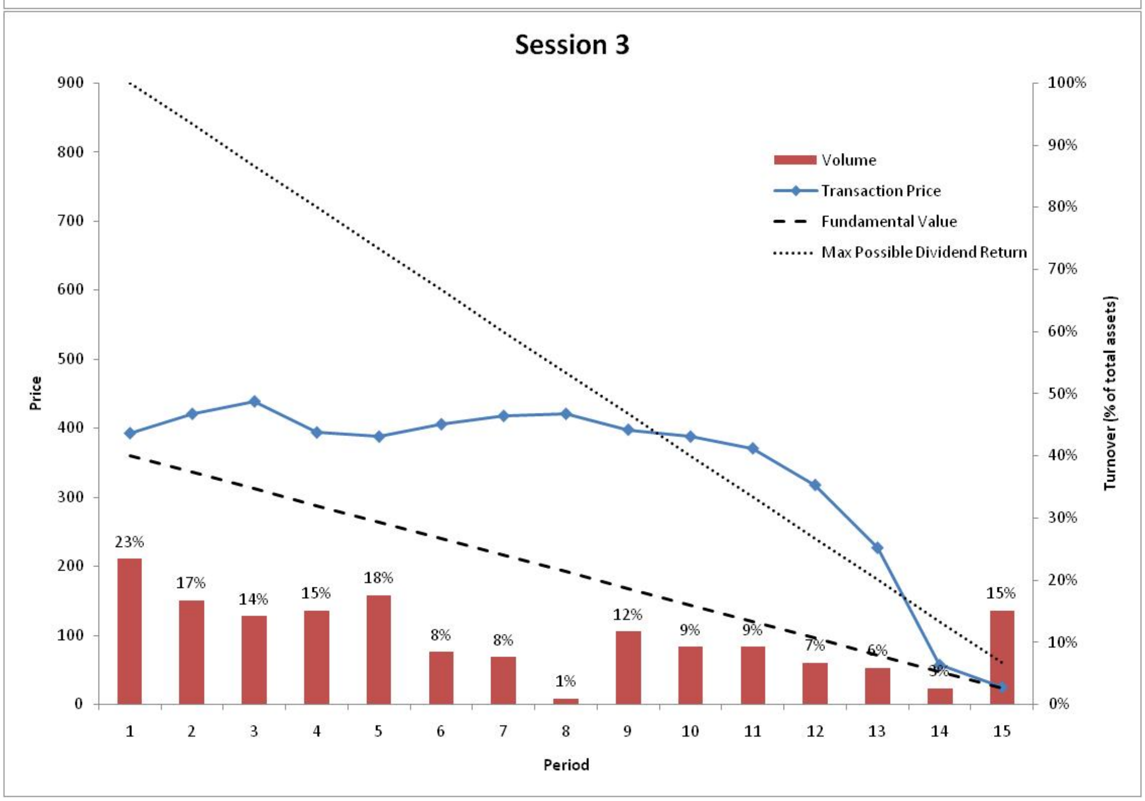
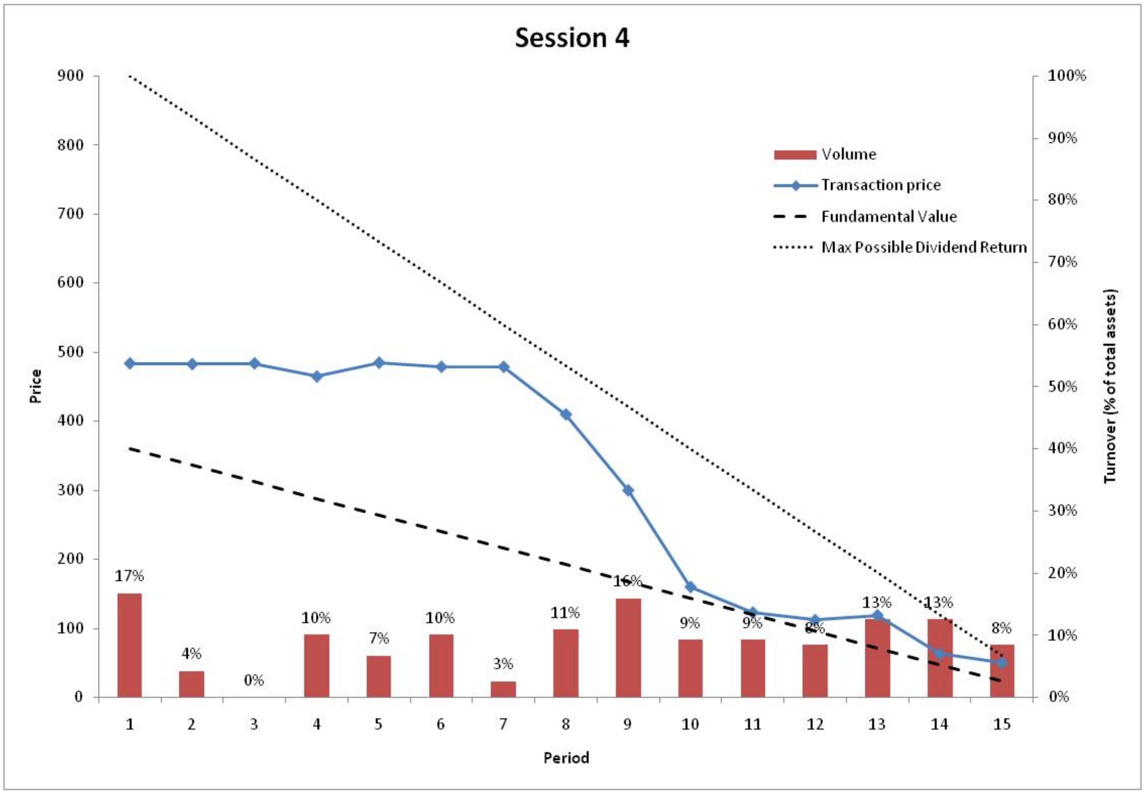
Appendix A: Time Series Data




Session 2
Volume
Transaction Price
Fundmental Value
Max Possible Dividend Return
Price
Turnover (% of total assets)
Period


Session 3
Volume
Transaction Price
Fundamental Value
Max Possible Dividend Return
Price
Turnover (% of total assets)
Period



Session 4
Volume
Transaction price
Fundamental Value
Max Possible Dividend Return
Price
Turnover (% of total assets)
Period
0
100
200
300
400
500
600
700
800
900
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
1
2
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4
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17%
4%
0%
10%
7%
10%
3%
11%
16%
9%
9%
8%
13%
13%
8%

Appendix B: Instructions

General Instructions

This is an experiment in the economics of market decision-making. The instructions are simple and if you follow them carefully and make good decisions, you might earn a considerable amount of money, which will be paid to you in cash at the end of the experiment. The experiment will consist of *fifteen* trading periods in which you will have the opportunity to buy and sell in a market. The currency used in the market is francs. All trading and earnings will be in terms of francs.

600 francs = 1 NZ dollar

At the end of the experiment, your francs will be converted to dollars at this rate, and you will be paid in dollars. The more francs you earn, the more dollars you earn.

In each period, you may buy and sell units of a good called X in a market. X can be considered an asset with a life of 15 periods, and your inventory of X carries over from one trading period to the next. Each unit of X in your inventory at the end of *each* trading period pays a dividend to you. The dividend paid on each unit is the same for every participant.

You will not know the exact value of the dividend per unit until the end of each trading period. The dividend is determined by chance at the end of each period by a random number generator. The dividend in each period has an equally likely chance of being 0, 8, 28, or 60. The information is provided in the table below.

Dividend	→	0	8	28	60
Likelihood	→	25%	25%	25%	25%

The average dividend per period for each unit of X is 24 francs.

The dividend draws in each period are independent. That means that the likelihood of a particular dividend in a period is not affected by the dividend in previous periods.

2. Your Earnings

At the beginning of the experiment, you will be given 10,000 francs in your Cash inventory. Your earnings for the entire experiment are equal to your Cash inventory at the end of period 15.

All dividends you receive are added to your Cash inventory.

All money spent on purchases is subtracted from your Cash inventory.

All money received from sales is added to your Cash inventory.

Example of earnings from dividends: if you have 6 units of X at the end of period 3 and the dividend draw is 8 francs (which has a 25% chance of occurring), then your dividend earnings for period 3 are equal to 6 units x 8 francs = 48 francs.

3. Average Value Holding Table

You can use your **AVERAGE HOLDING VALUE TABLE** to help you make decisions. There are 5 columns in the table. The first column, labeled **Ending Period**, indicates the last trading period of the experiment. The second column, labeled **Current Period**, indicates the period during which the average holding value is being calculated. The third column gives the number of holding periods from the period in the second column until the end of the experiment. The fourth column, labeled **Average Dividend per Period**, gives the average amount that the dividend will be in each period for each unit held in your Actual Asset inventory for the rest of the experiment. The fifth column, labeled **Average Holding Value Per Unit of Inventory**, gives the average total dividend for the remainder of the experiment for each unit held in your Actual Asset inventory for the rest of the experiment. That is, for each unit you hold in your Actual Asset inventory for the remainder of the experiment, you receive on average the amount listed in column 5. The number in column 5 is calculated by multiplying the numbers in columns 3 and 4.

Suppose for example that there are 7 periods remaining. Since the dividend paid on a unit of X has a 25% chance of being 0, a 25% chance of being 8, a 25% chance of being 28, and a 25% chance of being 60 in any period, the dividend is on average 24 per period for each unit of X. If you hold a unit of X for 7 periods, the total dividend paid on the unit over the 7 periods is on average 7*24 = 168.

4. Market and Trading Rules

At the beginning of the experiment, you will have an initial inventory of 10 units of X and 10,000 francs. The experiment will consist of 15 periods. In each period, each participant will have an opportunity to place offers to sell or buy units of X. At the beginning of the period, the computer will announce a randomly drawn initial price. To place an offer to buy (sell) units of X at this announced price level, enter how many units of X you would like to buy (sell) at this announced price level and select the buy (sell) button on your screen. The computer totals all the offers to buy and all the offers to sell.

If the total number of units that participants offer to buy is greater than the total number of units that participants offer to sell, then the program increases the announced price level and each participant may then make offers to buy or sell at this higher price level.

If the total number of units that participants offer to buy is less than the total number of units that participants offer to sell, then the program decreases the announced price level and each participant may then make offers to buy or sell at this lower price level.

If the total number of units that participants offer to buy equals the total number of units that participants offer to sell, then the period is over and the offers placed by each participant at this price level are transacted. Each participant records the number of units that they bought (sold) and their earnings for the period.

Manual Conclusion of Period: If the price changes by one franc and remains in a region of three francs for four periods in a row (for example, if the price went from 100, to 101, back to 100, then back to 101, OR if the price went from 100, to 101, to 102, then back to 101), then we will conclude the period manually. The manual period conclusion process is as follows: an announcement will be made by the experimenter that a manual conclusion is to be made and not to type anything into the computer at this stage. On your BIDDING SHEET provided, write the price given by the computer for this iteration and the amount of X that you want to buy or sell. Note that if you want to sell, the amount written on the BIDDING SHEET cannot be more than your available inventory of X. The experimenter will then collect these sheets and total the amount of X that people want to buy and sell. If these amounts are equal, then the transactions will be made according to the bids made. If the amount wanted to buy is greater than the amount wanted to sell, then the units sold will be randomly allocated to the buyers. If the amount wanted to sell is greater than the amount wanted to buy, then the units bought will be randomly divided among the sellers. Once the allocation is determined for the period, enter the amount assigned to you to buy/sell into the computer.

5. Recording your earnings

At the end of each period, record our earnings on your **PERIOD EARNINGS SHEET**. At the end of period 1, record your cash on hand at the end of the period in column 2 in the row marked period 1. In column 3, record your cash on hand at the beginning of the period. Record your inventory of units at the end of the period in column 4 in the row marked period 1. Fill in the divided of each unit in column 5. Record your earnings for the period in column 6. Your earnings in each period equal the difference in your cash on hand from the beginning to the end of the period plus the value of the dividends you receive at the end of the period for the units of X in your inventory at the end of the period. That is:

YOUR EARNINGS = END OF PERIOD CASH – BEGINNING OF PERIOD CASH + DIVIDEND PER UNIT * NUMBER OF UNITS IN INVERNTORY AT THE END OF PERIOD

Subsequent periods should be recorded similarly. Your earnings for the entire experiment are the total of your earnings for periods 1-15, plus the initial cash endowment.

6. Quiz

Question 1: Suppose that you purchase a unit of X in period 1.

- **a.** What is the average dividend payment on the unit of X for period 1? _____
- **b.** If you hold that unit of X till the end of the experiment (15 periods including the current period), what is the average total dividend paid on the unit of X? _____
- **c.** What is the maximum possible dividend paid on the unit of X till the end of the experiment (15 periods including the current period)? _____
- **d.** What is the minimum possible dividend paid on the unit of X till the end of the experiment (15 periods including the current period)? _____

Question 2: Suppose that you purchase a unit of X in period 5.

- a. What is the average dividend payment on the unit of X for period 5? _____
- b. If you hold that unit of X till the end of the experiment (11 periods including the current period), what is the average total dividend paid on the unit of X? _____
- c. What is the maximum possible dividend paid on the unit of X till the end of the experiment (11 periods including the current period)? _____
- d. What is the minimum possible dividend paid on the unit of X till the end of the experiment (11 periods including the current period)? _____

Question 3: Suppose that you purchase a unit of X in period 15.

- a. What is the average dividend payment on the unit of X for period 15? _____
- b. If you hold that unit of X till the end of the experiment (1 period including the current period), what is the average total dividend paid on the unit of X? _____
- c. What is the maximum possible dividend paid on the unit of X till the end of the experiment (1 period including the current period)? _____
- d. What is the minimum possible dividend paid on the unit of X till the end of the experiment (1 period including the current period)? _____

AVERAGE HOLDING VALUE TABLE

Ending Period	Current period	Number of Holding Periods	*	Average Dividend Value Per Period	=	Average Holding Value Per Unit of Inventory
15	1	15	*	24	=	360
15	2	14	*	24	=	336
15	3	13	*	24	=	312
15	4	12	*	24	=	288
15	5	11	*	24	=	264
15	6	10	*	24	=	240
15	7	9	*	24	=	216
15	8	8	*	24	=	192
15	9	7	*	24	=	168
15	10	6	*	24	=	144
15	11	5	*	24	=	120
15	12	4	*	24	=	96
15	13	3	*	24	=	72
15	14	2	*	24	=	48
15	15	1	*	24	=	24

BIDDING SHEET

(1) ENTER THE PERIOD OF MANUAL CONCLUSION	(2) ENTER THE PRICE GIVEN BY COMPUTER	(2) CIRCLE WHETHER YOU WANT TO BUY OR SELL	(3) ENTER NUMBER OF UNITS WANTED TO BUY OR SELL	(4) NUMBER OF UNITS ALLOCATED
		BUY / SELL		
		BUY / SELL		
		BUY / SELL		
		BUY / SELL		
		BUY / SELL		
		BUY / SELL		
		BUY / SELL		
		BUY / SELL		
		BUY / SELL		
		BUY / SELL		
		BUY / SELL		
		BUY / SELL		
		BUY / SELL		
		BUY / SELL		
		BUY / SELL		
		BUY / SELL		

PERIOD EARNINGS SHEET

(1)			(2)		(3)		(4)		(5)		(6)
PERIOD	PRICE	NET SUPPLY OF X	END CASH		BEGINNING CASH		CLOSING X ON HAND		DIVIDEND PER-UNIT		PERIOD EARNINGS
0				-	10000	+		*		=	
1				-		+		*		=	
2				-		+		*		=	
3				-		+		*		=	
4				-		+		*		=	
5				-		+		*		=	
6				-		+		*		=	
7				-		+		*		=	
8				-		+		*		=	
9				-		+		*		=	
10				-		+		*		=	
11				-		+		*		=	
12				-		+		*		=	
13				-		+		*		=	
14				-		+		*		=	
15				-		+		*		=	

Total Earnings in terms of Francs = _______

Total Earnings in terms of Dollars = _________