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An Investigation of the Tatonnement Mechanism on Bubbles in Experimental Asset Markets

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Abstract: The existence of price bubbles is one of the most interesting 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. The typical bubble price pattern is for prices to 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. To date, the only treatment variable that consistently eliminates the existence of the price bubble is experience via participation in two previous asset market sessions of the same.

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 Tatonnement market mechanism (TM hereafter) instead of the standard double auction used in all the previous studies. The reason being is that the TM overcomes the two main conjectures from the extensive asset market literature: (1) confusion/mistakes and (2) lack of common knowledge of rationality. The TM overcomes these two issues by virtue of the repetition of the price adjustment process typically required in each period to obtain a market clearing price. This repetition protects the confused/inexperienced from "mistakes" that they may make early in the market, which have the potential of not only being very costly the confused individual, but to the market as a whole. That is, this mistake may reinforce the belief that there is a lack of rationality in the market, and thus fuels speculative behavior for capital gains, which propels the bubble. The fact that TM prohibits purchases that are outside the preferences of the group as a whole not only protects the individual from costly mistakes, but also protects the market as a whole (society) from the potential consequences of these mistakes. The nature of the price adjustment process embodied in TM promotes experience, learning, and common knowledge of rationality from the very first period of the asset market. That is, the knowledge that typically requires participation two to three complete asset markets by all participants is now accomplished in the first period. We find that TM does significantly reduce the decoupling of prices from the fundamental value and produces bubble measures lower than previous studies.

Keywords: *Asset Market Bubbles, Trading Institutions, Pricing Mechanisms, Tâtonnement*

1. INTRODUCTION

Bubbles are not an uncommon phenomenon. Indeed, it is not difficult to find examples of economics bubbles occurring between the first recorded bubble, 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 which 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 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 hard 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). For instance, bubbles are robust to trading institutions such as double auction (Smith et al. 1988), or 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 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).

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 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. Else, the market proceeds with iterations. In particular, the price moves upward is 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 if excess demand is equal to zero) while in double auction or call markets that is not the case. 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.

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 study. The experiment was computerized and used the z-Tree software package. 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.

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. 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 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. 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: $P_t = P_{t-1} + \gamma_t \left(Q_{D,t-1} - Q_{S,t-1}\right)$, 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 $\left(Q_{D,t} - Q_{S,t}\right)$ is of the same sign as $\left(Q_{D,t-1} - Q_{S,t-1}\right)$. For small levels of excess supply/demand (or in the second stage), whenever $0 < \left|\gamma_t \left(Q_{D,t-1} - Q_{S,t-1}\right)\right| < 1$, the price adjustment rule is replaced by $P_t = P_{t-1} + \left(Q_{D,t-1} - Q_{S,t-1}\right) / \left|\left(Q_{D,t-1} - Q_{S,t-1}\right)\right|$. That is, if $0 < \gamma_t \left(Q_{D,t-1} - Q_{S,t-1}\right) < 1$, the pricing rule is $P_t = P_{t-1} + 1$, and if $-1 < \gamma_t \left(Q_{D,t-1} - Q_{S,t-1}\right) < 0$, the pricing rule is $P_t = P_{t-1} - 1$.

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. 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 1. Each period of the experiment is provided on the horizontal axis and market clearing prices are indicated on the vertical axis. According to Figure 1 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.

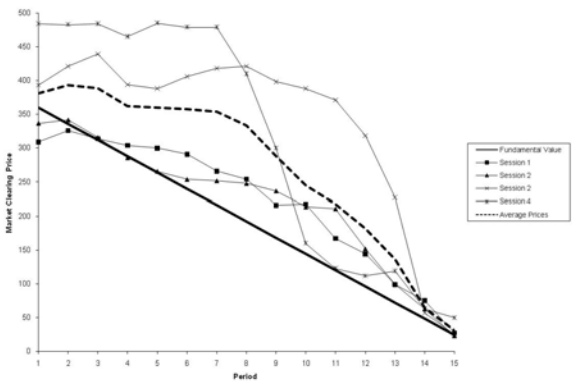

Figure 1: Market Clearing Prices across Sessions

If judged only by Figure 1, 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. 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 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, normalized by the initial fundamental value, f1 (in our markets f1 = 360). In other words, price amplitude equals $A = \max_t\{(P_t - f_t)/f_t\} - \min_t\{(P_t - f_t)/f_t\}$, where P_t is market clearing price 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: $D = \sum_t n_t |P_t - f_t| / (100 * TSU)$ where n_t is the number of units traded in period t, and TSU is the total stock of units.
- 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, 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.

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.

Table 1: Traditional Measures of Bubble Size across Studies

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

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. That is, we have significantly reduced the bubble. Even though we have price deviations from the fundamental in session 3 and 4, the quantity traded was very low.

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

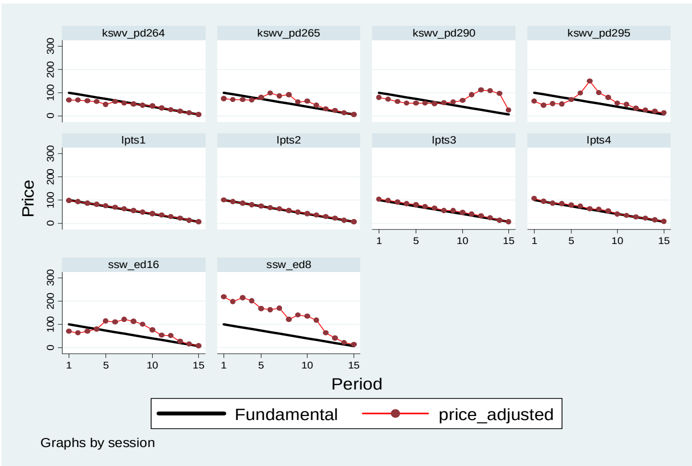

Figure 2: Normalized Prices and Fundamental across Studies

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 2 depicts the time series of normalized prices and fundamentals across experiments (the middle graphs denoted as pts1-4 are from our experiment). 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 $P^i_{weighted} = {100}/{F^{\max}} \left[F^i + (P^i + F^i) Q\_traded^i / Q\_total \right]$.

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.

The time series data of adjusted prices across experiments is plotted in Figure 3, which illustrates that if we account for trade volumes, the bubble is completely eliminated in our study, while it still persists in other studies.

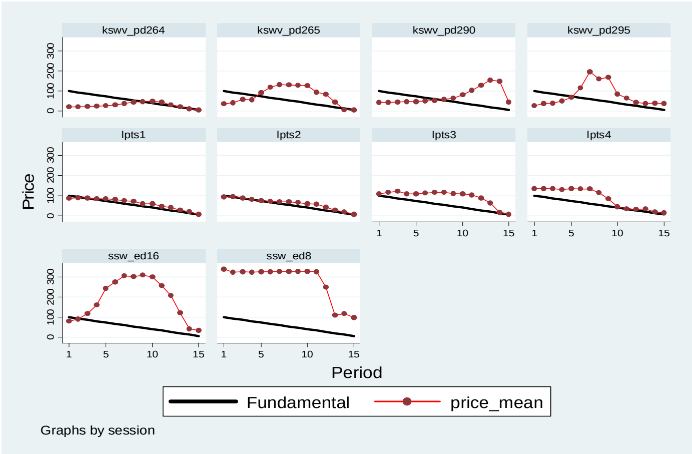

Figure 3: Weighted Prices and Fundamental across Studies

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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