Bubbles in Experimental Asset Markets[1]

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Introduction

One can define a bubble as a persistent increase in the price of an asset over and above its fundamental value with an abrupt fall in prices when no buyers are available to make purchases. The occurrence of market bubbles has a long history, starting with the Dutch Tulip Mania (1624-1637) to the South Sea and Mississippi Bubble (1716-1720), the British Railway Mania (1840´s) to the crash of 1929. Recent events have been the crash of 1987, the dot-com bubble (1990s) to the most recent housing crisis in early 2000. Even though bubbles, and a subsequent crash, may reallocate resources to more efficient activities, the economic costs of bubbles are large and sometimes felt for long periods of time.

It is important to emphasize that markets perform an important role in that they aggregate information (Hayek, 1945) for its participants. The aggregation of information occurs through the price discovery process. In the real world markets are seldom efficient and mis-pricing is common. Due to this, information aggregation seldom happens and consequently one observes deviations of prices from their fundamentals on a regular basis.

Market bubbles are an elusive phenomenon and it is due to this that the prior knowledge of the occurrence of a bubble is difficult. In most cases we only know of their occurrence when we observe a crash, but by then it's too late. Simply stated, bubbles reflect mis-pricing of an asset from its fundamental value. Clearly, knowing the fundamental value in the real world is a challenge.

The use of economic experiments is important to study the nature of bubbles for this very reason. Bubbles are hard to detect. The institutional environment is easily controlled in a laboratory setting and one can study the reasons behind the deviation of prices from their fundamental value by carefully varying the experimental parameters. Information that is not easily available in real world settings, such as the fundamental value, is observed and can be controlled in a laboratory setting (declining, constant, ambiguous etc.). Typically, experimental studies on asset market bubbles utilize the continuous Double Auction institution where a participant can be on either side of the market acting as a buyer or seller. This may depend upon the underlying market conditions or their choice of the role based upon their expectations. The good in a typical asset market is durable and lasts till the end of the experiment. For our purpose we will limit ourselves to studies that use perfectly durable goods in asset markets. A good purchased in any period earns a dividend at the end of that period and can be resold at any point of time till the last period and is not perishable. The knowledge of the last period is common to all subjects.

[1] This is not an exhaustive review of the literature. For a detailed review of the literature and references see Palan (2013), Powell and Shestakova (2016).

The experiments

Experimental research on asset market bubbles started with the seminal paper of Smith Suchanek and Williams (1988) (henceforth SSW) when they "accidently" discovered bubbles in experimental asset markets. SSW asked whether the common knowledge of a (common) dividend payout is sufficient to induce common expectations. In their experiments subjects had complete information regarding the asset they were trading. Each participant was assigned a given amount of assets and a cash endowment. The assets could be sold, meanwhile the cash endowment could be used to purchase the asset from other traders. If the asset is not sold than it earns a per period dividend. The asset produces a dividend stream, drawn from a fixed and known distribution, that lasts the duration of the experiment.

Clearly rational agents, acting on the information they possess, would not trade in such an environment. If any trade did occur, it would be at the (expected) fundamental value. Surprisingly, they discovered that while prices started below fundamental value at the beginning, they soon overshot the fundamental value until a crash occurred in later periods. The early periods were characterized by a trading frenzy which died in the later periods resulting in the crash of the overpriced asset. This result has since been replicated in a large number of studies with varying geography and other experimental variations (see Table 1). It is important to note that they control expectations by providing each bidder complete information on the bidding behavior of their rivals. That is, the order book in any period is visible to all participants.

In SSW markets are created for assets with a life of 15 periods. The asset pays a dividend in each period, which is drawn from the distribution {0, 8, 28, 60}. At the end of each period the dividend is drawn randomly from the distribution and is identical for all the traders. Importantly there are no transaction costs to trade. This information is common knowledge. Final compensation in these experiments is the final cash position additional to the show up fees, net of the costs for the units purchased. Also, note that first time participants are called as being inexperienced, while second and third time participants are called once and twice experienced.

Table 1: Various factors and their effects on bubbles and crashes

Number of traders	No effect (Williams, 2008).
Short selling	Lower prices (Haruvy and Noussair, 2006; Ackert et al., 2006).
Margin buying	Moderates bubbles when used in conjunction with short-selling (Ackert et al., 2006).
Transaction fees	Price efficiency is not affected (Kirchler et al., 2011).

Circuit breakers	Price deviations are generally larger (King et al., 1993).
Futures markets	Does not eliminate bubbles (Porter and Smith, 1995); full set of futures markets reduces mispricing (Noussair and Tucker, 2006); single futures market reduces prices but not mispricing, increases price volatility (Noussair et al., 2016).
Dividend uncertainty	Does not eliminate bubbles (Porter and Smith, 1995).
Trading institution	Sealed bid auctions also generate bubbles (Van Boening, 1993). Tattonement reduces mispricing relative to a double auction (Lugovskyy et al., 2014).
Experience	Subjects who have previous experience with the given market environment produce fewer bubbles (King et al., 1993; Peterson, 1991; Dufwenberg et al., 2005; Haruvy et al., 2007). Experience in markets with different parameters is not sufficient to reduce mispricing (Hussam et al., 2008).
Subject characteristics	Business professionals are just as likely to produce bubbles as students (King et al., 1991). Ethnic diversity reduces bubbles (Levine et al., 2016).

Individual characteristics

As mentioned earlier, prices typically start below the fundamental value and rise beyond it from around the third period onwards, crashing to zero in later periods. Most experiments with inexperienced subjects share this typical pattern across heterogeneity in subjects. Part of the explanation may lie in a lack of common knowledge of rationality among the subjects. Under this scenario even rational agents, who may buy low to sell high, and so on, would result in mis-pricing. This suggests that speculation may be one of the major motives behind asset market bubbles, suggesting that if the motives for speculation, i.e. resales, is eliminated one would expect bubbles in experimental asset markets to be at least mitigated.

Following this line of research, Cheung *et al*. (2014) show that inducing common knowledge of rationality leads to markets exhibiting fewer and smaller bubbles. Interestingly, similarly

informed and trained subjects produce substantial bubbles and subsequent crashes in the absence of common knowledge of rationality. Using the standard Double Auction institution Lei et al (2001), meanwhile, eliminate the motives for speculation by not allowing resale of the asset. Further, they allowed for a second market selling a non-durable good lasting for one period. They show that at least some subjects *do* act irrationally in SSW markets and observe price mis-pricing due to subject mistakes. In their experiments, bubbles are observed in a setting where resale (due to speculative motives) is not possible. One way to reconcile these results is that subjects make mistakes or do not understand the underlying experimental environment. They find evidence of systematic errors in decision making accompanying bubbles. Traders engage in unprofitable transactions at prices above the maximum possible or below the minimum possible dividend stream.

Subject experience has been found to be important in explaining experimental bubbles. It seems that providing dividend probabilistic structure as common information is not sufficient to ensure (common) expectations among participants. Subjects tend to develop common expectations with experience. In their seminal paper SSW stress that the lack of common expectations could be an explanation for bubble formation. They "control" expectations by giving each bidder complete information on the bidding behavior of her rivals. How expectations adapt is related with experience. They find that experience diminishes bubbles in some cases (SSW, figure-5 and 6, page 1130). The role of experience has since been well documented in that in a static environment experience diminishes to eliminates bubbles. Early work on this is attributed to King (1991)[2]. Later on, Dufwenberg et al. (2005) show that if even a proportion of traders are experienced then a bubble is substantially diminished. They find that the effect of one or two-thirds of all subjects are thrice experienced is comparable to markets with twice experienced subjects. Haruvy et al. (2007) clarify the mechanism through which the elimination of bubbles (via experience) occurs by relating it to adaptive updating of expectations. They show that the effect of experience stems from a process of myopic adaptation of expectations.

However, experience on its own is not sufficient to ameliorate bubbles. Bubbles can be re-kindled if the market parameters are modified by increasing liquidity and dividend uncertainty (Hussam et al., 2008). Clearly, the elimination of bubbles through experience is sensitive to change in parameter values that can then dominate the effect of experience. Finally, it has been shown that there are cases when experience may not ameliorate bubbles. Noussair and Powell (2010) use a non-monotonic fundamental value structure where they show experience may not be sufficient to eliminate bubbles. Besides experience other subject characteristics that impact bubble formation could be trading teams (Cheung and Palan, 2012), the number of traders (Williams and Walker (1993), Williams (2008)), overconfidence (Kirchler and Maciejovsky, 2002) and emotional state (Heap and Zizzo, 2012; Breaban and Noussair, 2013). Generally, a higher emotional state, i.e. being excited, or increased confidence results in increased bubbles size. Clearly the result of an enhanced emotional state is transitory while that of overconfidence is more durable if it is a stable subject characteristic.

[2] See Palan (2013).

An empirical regularity in these experiments is the buying frenzy observed in the early periods. The buying frenzy then moderates and then disappears in the last periods resulting in the crash. This reduction in volume coincides with the substantial reduction in the number of bids/offers in the periods prior to the cash. Some recent papers have linked trading with cognition. Baghestanian et al. (2015) classify subjects into momentum-noise traders and adaptive fundamental traders. They show that the bubble decreases in the proportion of the adaptive fundamental traders who also score higher on the cognitive reflection test (CRT) (Frederick, 2005). Corgnet et al. (2015) relate house money to trading volumes. They find that trading is significantly lower when subjects make decisions with "earned" as compared to "house money." Further, being a net buyer or seller is related to the cognition type. That is, subjects with a score of 1 or above on the CRT are net buyers when the price is below the fundamental value and are net sellers when the price lies above it. Bosch-Rosa et al. (2015) explicitly test the role of cognition in determining mispricing. They run a two-part experiment in which they first identify low and high cognitive individuals using the CRT. Then, each type of individual is invited to participate in a separate market experiment. Thus each market consists of traders of either low or high cognitive ability. The results show that bubbles and crashes only occur in markets populated with traders of low cognitive ability.

Another issue is how subjects evaluate the probability of the draw. It is well known that individuals have subjective probability judgements of draws over a distribution. It has been shown that rational speculators (Ackert et al, 2012) earn more than individuals that are prone to these probability judgement errors.

Kirchler et al. (2012) study whether confusion may play any role in the formation of asset market bubbles. Using a questionnaire they found that the declining fundamental value process confuses subjects, it seems that subjects expect the fundamental value to stay constant. This is surprising as experiments with a constant fundamental value, in the past, have resulted in experimental asset market bubbles. They run the asset market experiment with a different context ("stocks of a depletable gold mine" instead of "stocks") and find that this significantly reduces mispricing and overvaluation as it reduces confusion.

An interesting recent line of research concerns how different cognitive abilities impact bubbles in experimental asset markets. As mentioned earlier it has been claimed that confusion may play a role in the robustness of bubbles. Consequently, cognitive ability should play an important role. That is, higher level of cognitive ability must imply a better understanding of the market mechanism. As mentioned earlier, Corgnet et al (2015) study the role of cognitive ability in accounting for the differences in earnings distribution across treatments by using the cognitive reflection test (Frederick, 2005) (CRT). They find that low CRT (score >0) subjects earned less than high CRT subjects. Interestingly, low CRT subjects were net purchasers (sellers) of shares when the price was above (below) fundamental value. The opposite was true for high CRT subjects. This suggests that high cognition subjects play an important role both in the formal and subsequent crash of an asset market bubble. Further, note that higher cognition subjects earn more than those scoring a zero on the CRT. The role of cognition in experimental asset markets has also been studied by Noussair et al. (2016), who find that CRT scores correlate posivitely with earnings. They also consider an extended measure of CRT scores that accounts for mistakes that display some

level of sophistication, but find that this measure generates results similar to those found with the classic CRT measure.
Gender is another characteristic that plays an important role in the formation of bubbles in experimental asset markets. Eckel and Füllbrunn (2015) run a meta-analysis of 35 markets from different studies and show an inverse relationship between the magnitude of price bubbles and the proportion of female traders in the experimental asset market. Further, female prices forecasts are significantly lower, even in the first period. Meanwhile, Holt et al. (2015) check for price bubbles in experimental asset with gender effects and risk aversion. They have an interesting experimental design that is longer than the typical fifteen period experiment (SSW). In their experiments participants trade an asset with a "flat" fundamental value with interest payment on cash. They find that bubbles are present, with bubbles for females starting later and peaking at higher levels than those observed for males. As in earlier studies females predict lower prices in the initial periods, however, this difference is smaller than that reported in Eckel and Füllburn (2015). They find no relationship between market level risk aversion averages and bubble amplitudes. Also, males submitted about 50 percent more bids and asks than females. However, Cueva and Rustichini (2015) also conduct markets populated with subjects of a particular gender. They find all-female and all-male markets to be equally prone to bubbles and crashes. They observe an interesting asymmetry among heterogeneous and homogeneous gender markets. Markets populated by both genders are significantly more efficient and less variable than those with only one gender.

This type of non-monotonic effect also extends to other subject characteristics. For example, Levine et al. (2014) find that mispricing increases with the degree of ethnic homogeneity among market participants. Gladyrev et al. (2014) study a more directly measurable characteristic of subjects: namely, their performance in previous markets. Subjects are first ranked in terms of performance (low, medium or high) based on three repeated markets. Then a fourth market, identical in setup to the first three markets, is conducted in which these experienced subjects are matched with new inexperienced traders. They find that bubbles are most likely when the experienced traders are those with the highest or lowest earnings in previous markets. This suggests that it is not only lack of sophistication that leads to bubbles, but rather that bubbles are the result of an asymmetry in (perceived) ability or some other trait among traders.

Market characteristics

Several studies show that different market environments have different efficiency properties. For example, the SSW paper used a Double Sided Oral Auction to facilitate trading. Results have subsequently shown that sealed bid auctions (Van Boening et al., 1993) produce similar bubble levels, whereas tatonnement trading (Lugovsky et al., 2014) reduces bubbles.

Corgnet et al. (2015) study the role of Earned over House Money in bubble formation. The evidence of the "house money effect" was found by Thaler and Johnson (1995) in a lottery choice experiment. They found that subjects showed more risk seeking behavior in the presence of a prior gain. In their experiment Corgnet et al (2015) first allowed their subject to take part in a real-world task, all participants were paid the same amount for the effort. The amount earned was then credited towards a following asset market experiment. They

found that bubbles were robust to the “house money effect”, however, house money did impact trading volumes and earnings dispersion which were both lower.

Another important determinant of bubbles in experimental asset markets is the cash-to-asset ratio. It is well known that increasing the amount of liquidity in the system results in increased bubble size (King et al., 1993). Haruvy and Noussair (2006) increase the cash endowment ten times and find that this leads to higher prices and greater mispricing. Deck et al. (2014) study the role of liquidity in an overlapping generation experiments. They observe price bubbles forming when new generations enter the market with additional liquidity and bursting as old generations exit the market and withdrawing cash. They also ask subjects to forecast prices in the next period. They find that trading experience results in price expectations closer to the fundamental value. Kirchler et al. (2012) use a 2x2 design that varies 1) the path of the fundamental value (declining or constant), and 2) whether the cash-to-asset ratio is constant or increasing. Their results show that the increasing cash-to-asset ratio generally increases overvaluation of the asset.

The role of dividend structure is important as it (indirectly) affects earnings expectations of traders. Many variations of this setup have been studied to test the robustness of SSW bubbles. Smith et al. (2000) study three treatments where the dividend is paid at the end of the market, the standard every-period dividend setup, and a combination of the two. They find that the bubble is mitigated in the delayed dividend setup and highest in the standard per-period dividend. It seems that paying the market dividend at the end of the last period mitigates bubbles (Lei et al., 2001; Caginalp, 2001)). This finding is explained by the “dividend hypothesis” that states that increasing the frequency of dividends make traders myopic and hence distracts from the long term intrinsic value of the asset. Palan (2010), meanwhile, offers an alternative interpretation of these findings. He argues that this behavior is a form of myopia over time-weighted payments. Subjects overweight the value of cash flows occurring relatively earlier. He argues that the evidence is in agreement with bubbles increasing the more dividend mass is shifted forward in time, as opposed to the number of dividend payments alone. Interestingly dividend certainty (Porter and Smith, 1995), or the use of a two, or five, dividend structure (Boening et al., 1993; Lei et al., 2001) do little in softening the bubbles in the classic SSW structure. Finally, Hussam et al. (2008) also show that changing dividend structure (amongst other parameters) re-ignites bubbles.

Related to the dividend distribution is the structure of the fundamental value. In the classic SSW paper the fundamental value takes a linearly decreasing path. Various studies have looked at constant, increasing or non-monotonic fundamental value paths. Different patterns are typically achieved through a combination of dividends, taxes on asset holdings, and final buyouts. Smith et al. (2000) find that constant fundamental values produce significantly more efficient prices than the classic decreasing fundamental value case.

This is reproduced by Stöckl et al. (2015), who additionally consider the cases of increasing and randomly fluctuating fundamentals. This study is particularly important since it controls the complexity of the fundamental value across settings. In previous studies, different time paths are constructed using different ingredients (dividends, taxes or buyouts), making it difficult to isolate the effect of changes in the fundamental value. Stöckl et al. (2015) find that the increasing case produces mispricing of a similar magnitude as that in the decreasing case. Across all non-constant treatments, prices tend to be sticky and lag behind changes to

the fundamental value. They do however observe that the decreasing case has significantly larger bid-ask spreads and trading volume than the other treatments.

The fluctuating nature of economic activity places particular significance on non-monotonic time paths for the fundamental value. Noussair and Powell (2010) design experiments to measure how well asset market prices track fundamentals when the fundamental value has a trough (V) or a peak (>).They observe greater price efficiency, i.e. less mispricing, in markets with the "peaks" than in markets with the "trough". Remarkably, this difference persists even after 3 repetitions of the market environment. This suggests that markets require more monitoring during economic upswings than downturns. Further work along these lines by Breaban and Noussair (2015) study markets for an asset whose value is constant for half of the duration of the market, followed by either a duration of increasing or decreasing value. These patterns correspond roughly to so-called Bull (increasing) and Bear (decreasing) markets. They find that Bull markets are less efficient than Bear markets, and relate this to various characteristics of individual traders.

An interesting, and important, extension to the classic SSW dividend structure is the incorporation of futures markets. Porter and Smith (1995) were the first one to introduce futures trading. Palan (2010), with a small variation, replicates Porter and Smith (1995) replacing the futures contract with a digital option one. He finds no evidence of smaller bubbles. Noussair and Tucker (2006) publicly reveal subject´s future price expectations that allows them to understand the assets dividend holding value. They create a single futures market for every period and open them in reverse order starting with the last period. Spot trading commences only when all futures markets are open. This is a clever implementation that allows subjects to obtain the full stream of prices for all futures periods. They find that price efficiency increases resulting in prices being closer to fundamental value. This result tells us that making subjects "think" about the dividend stream and holding value in time is important in generating efficient pricing. This idea is tested further in Noussair et al. (2016), in which only a single futures market for the last period is open. This is to test whether the single futures market is sufficient to induce the backwards induction process that reduces mispricing in the spot market. The results show that the futures market reduces prices, but not necessarily mispricing. Additionally, the futures market appears to increase the volatility of prices. Therefore it is not clear to what extent futures market help in stabilizing market performance.

The role of communication is another interesting avenue of research in experimental markets. Financial markets are overwhelmed by daily announcements from novices, experts and policy makers. With the increased use of social media this has become increasingly important. Measurement of communication in the real world is especially problematical. There is some research on this topic. Oechssler et al. (2011) allow subjects to trade via public electronic chat messages before trading in each period. Subjects can receive insider information on which asset will pay a higher dividend. They find that this type of communication can attenuate bubbles.

Another aspect of messages are the ones we receive from experts or policy makers. Corgnet et al. (2010), meanwhile, study the effect of releasing public messages with varying levels of reliability on asset prices. In their structure subjects know that they will receive a preset message at the beginning of periods 3, 7 and 12. The message is either one of the two, "The

price is too high" or "The price is too low." They find that the source of the message, i.e. preset (the experimenter), contingent or random matters. Messages can play a significant role in dampening bubbles, or rekindling them. The preset message, "The price is too high," decreases the amplitude and duration of bubbles for inexperienced subjects. Announcements that depend on the actual level of mispricing reduce bubble magnitude. A preset or random message, "The price is too low," prevents experienced subjects from abating bubbles. They also find that public messages are especially effective when they confirm to subject beliefs. Stoian (2014) has a similar setup, except the message simply consists of a reminder about the fundamental value of the asset. In this case, the message has no significant impact on price efficiency.

Corgnet et al. (2014) have also looked at the ambiguity premium in experimental asset markets. Ambiguity aversion has been shown to be relevant in explaining financial anomalies such as the equity premium puzzle and the home equity bias. Additionally, ambiguity aversion has been employed to show that price over and under-reactions may depend on whether the news is positive or negative. Their results indicate that the role of ambiguity aversion in explaining financial anomalies is limited. Price changes are consistent with news revelation regarding the dividend, independent of subject experience and the degree of ambiguity. Additionally, there is no under or overprice reactions to news. Regardless of experience, market reaction to news moves in line with fundamentals. Importantly, they find no significant differences in the control versus ambiguity treatments regarding prices, price volatility and trading volume for experienced subjects. It seems that subjects internalize ambiguity in dividends efficiently in this experimental setup.

This line of research is interesting as it tells us that messages, either about the market or impacting subject beliefs, can in certain (but not all) cases play an important role in determining experimental asset prices. Clearly more research is needed to understand the interaction between communication/information in experimental asset markets.

Communication can be interpreted as a form of (non-intrusive) intervention in the market. More explicit forms of intervention that directly impact trading in the market have also been studied. Noussair et al. (2012) consider whether nominal shocks have an effect on the market. Specifically, at a pre-specified point in the market, fundamentals and cash holdings are either increased or decreased by a certain amount. They find that prices respond much more rapidly to inflationary shocks. Deflationary shocks lead to substantial mispricing. Ackert et al. (2014) show that abnormal offers (offers at prices far away from the current market equilibrium) have a tendency to stabilize the market and eliminate bubbles. This suggests that these types of events may act as coordination mechanisms that provoke action on the part of traders. Finally, Havury et al. (2014) study the role of stock repurchases and the floating of new shares in the market. In period six of the market, the experimenter enters the market and attempts to either repurchase half of the assets in the market, or sell a similar number of units of the asset to the market. The experimenter uses a simple offer mechanism to slowly make improving offers to the market until its trading goal is achieved. These types of operations mimic common firm actions in real markets, and have a direct impact on the supply of the asset available for trade. Compared to a benchmark of no intervention, both types of interventions have a significant impact on prices, with share floats reducing and repurchase programs increasing share prices. This is consistent with a

downward-sloping demand for the asset that depends monotonically on the supply of the asset in the market.

Bubble measures

The literature on experimental asset market bubbles now covers a wide array of topics. This proliferation of research has also lead to the usage of a wide array of measures to capture the size of a bubble. Therefore it is not clear to which extent reported results are robust to changes in the type of mispricing measure used. The literature has sought to address this issue in two ways. First, the theoretical properties of different measurement methods have been discussed. Stöckl et al. (2010) review many of the measures in use and show that none control for the average level of the fundamental value. This implies that measured mispricing would be sensitive to the nominal base of the market (for example, whether values were expressed in terms of “Euros” or “Euro cents”). On this basis, they propose two measures that are normalized by the average level of the fundamental value.

Unfortunately, there are still many measures that can be normalized in this way. Powell (2016) uses the condition of numeraire independence to argue that mispricing measures should be based on a geometric, rather than arithmetic, mean. This effectively reduces the set of available measures, so that under certain conditions the measure of mispricing is unique. Powell and Shestakova (2017) evaluate the robustness of mispricing results to several properties of the mispricing measure, including the choice of mean. They show that roughly 30% of results change significance when calculated under an alternative specification. This implies that further work is necessary to establish the significance of certain treatment effects, and in particular care should be taken when choosing how mispricing in a particular study is measured.

Conclusion:

What we have learned about bubbles in experimental asset markets is that bubbles, as in the real world, are impacted by a multitude of factors ranging from the role of experience, to mistakes, futures markets, emotional states, etc. The one robust findings is that bubbles re-emerge and are robust to a large number of experimental variations, both in terms of characteristics of the market institution and the traders themselves

It seems that generating common expectations and understanding through experience or training is a way to soften bubbles. However, it is not clear whether this will survive shocks to the system a la Hussam et al. (2008). Neither is experience robust to change in experimental parameters (Hussam et al, 2008) and the robustness of the effect of forward markets to variations in experimental parameters is yet to be studied. The issue of confusion relates to generating common expectations, this seems like an interesting exercise. However, how robust this is to shocks or alterations in experimental parameters is not clear.

Other ways of increasing understanding and reducing confusion have been studied. Inducing common knowledge about the understanding of the other traders in the market has a dampening effect on bubbles (Cheung et al., 2014). Direct communication in the form of

price reminders can have an impact when the reminders explicitly compare prices to the fundamental value (Corgnet et al., 2010). On the other hand, when reminders simply repeat information that is already known to subjects, this has no effect (Stoain, 2014). This tells us that messages, either about the market or impacting subject beliefs, can in certain (but not all) cases play an important role in determining experimental asset prices.

Various types of explicit interventions are commonplace in modern markets. In particular, stocks of traded assets are regularly increased or decreased via share repurchases and share floats (Haruvy et al., 2014). The evidence so far shows that these programs have an effect on prices that is consistent with a downward-sloping demand for the assets. More generally, market liquidity has been shown to play an important role, with excess cash leading to higher prices (Kirchler et al., 2012).

The analysis by Eckel and Füllbrunn (2015) suggests that there may be gender differences in the propensity to generate bubbles. More research needs to be done to this regard as recent research has shown that females bubble later, and bubbles are as large as observed under males (Cueva and Rustichini (2015); Holt et al. (2015)). They further find no evidence on market level risk aversion averages and bubble amplitudes. These experiments point towards an interesting time dimension to female decision making, that is, females bubble later in a longer run asset market experiment.

One of the more interesting lines of research relates to cognition and bubble formation. It seems that “high cognition” traders play a role both in the formation and crash of bubbles. These traders are net buyers when the price of the asset is below the fundamental value and net sellers otherwise. Importantly, it appears that not only cognition level, but differences in cognition levels across traders are a cause of mispricing. This extends to other traits such as trading performance and ethnicity. Since real world markets are characterized by the interactions of heterogeneous individuals, this suggests that mispricing may occur more readily than was previously believed.

In terms of asset structure, both the timing of dividend payments and the temporal properties of the fundamental value have been shown to influence mispricing. During recoveries and periods of volatility, market prices may find it substantially more difficult to track fundamentals than during calm times and downturns. These results also extend to repeated market settings.

Central to studying all of these effects is the question of how to appropriately capture bubbles, or mispricing in general. Currently, different studies report different measures, thus calling into question the robustness of the results. Ideally, a unique measure of mispricing would be identified based on a certain set of criteria. Powell (2016) identifies one such measure based on the idea of numeraire independence and other auxiliary assumptions.

Markets play an important role in allocating resources and organizing economic activity, and it has long been acknowledged volatility in market prices can burden the economy with substantial costs. Recent events suggest that large fluctuations in market prices are still as relevant an area of research today as they were when the experimental literature on the topic became established almost 30 years ago. As trading platforms and participants

become more sophisticated and inter-related, further work is needed to provide market designers and policy makers with an understanding of how different factors may influence the price efficiency of our markets.

References:

Ackert, L. F., Jiang, L., & Qi, L. (2014). Liquidity Shocks in Experimental Asset Markets.

Ackert, L. F., Kluger, B. D., & Qi, L. (2012). Irrationality and beliefs in a laboratory asset market: Is it me or is it you?. *Journal of Economic Behavior & Organization*, *84*(1), 278-291.

Baghestanian, S., Lugovskyy, V., & Puzzello, D. (2015). Traders' heterogeneity and bubble-crash patterns in experimental asset markets. *Journal of Economic Behavior & Organization*, *117*, 82-101.

Breaban, A., & Noussair, C. N. (2013). Emotional state and market behavior.

Breaban, A., & Noussair, C. N. (2014). Fundamental value trajectories and trader characteristics in an asset market experiment.

Caginalp, G., Porter, D., & Smith, V. (2001). Financial bubbles: Excess cash, momentum, and incomplete information. *The Journal of Psychology and Financial Markets*, *2*(2), 80-99.

Cheung, S. L., & Palan, S. (2012). Two heads are less bubbly than one: team decision-making in an experimental asset market. *Experimental Economics*, *15*(3), 373-397.

Corgnet, B., Kujal, P., & Porter, D. (2010). The effect of reliability, content and timing of public announcements on asset trading behavior. *Journal of Economic Behavior & Organization*, *76*(2), 254-266.

Corgnet, B., Hernán-González, R., Kujal, P., & Porter, D. (2015). The effect of earned versus house money on price bubble formation in experimental asset markets. *Review of Finance*, *19*(4), 1455-1488.

Corgnet, B., Kujal, P., & Porter, D., "Reaction to Public Information in Asset Markets: Does Ambiguity Matter?" *vol. 123 (569), pages 699-737, 06, The Economic Journal, 2013.*

Deck, C., Porter, D., & Smith, V. (2014). Double bubbles in assets markets with multiple generations. *Journal of Behavioral Finance*, *15*(2), 79-88.

Dufwenberg, M., T. Lindqvist, E. Moore. 2005. Bubbles and Experience: An Experiment on Speculation. *American Economic Review*, 95(5), 1732-1737.

Gladyrev, D., Powell, O., & Shestakova, N. (2014). The Effect of Financial Selection in Experimental Asset Markets.

Haruvy, E., C. N. Noussair. 2006. The Effect of Short Selling on Bubbles and Crashes in Experimental Spot Asset Markets. *Journal of Finance*, 61(3), 1119-1157.

Hayek, F. A. 1945. The Use of Knowledge in Society. *The American Economic Review*, *35*(4), 519-530.

Heap, S. P., & Zizzo, D. J. (2011). Emotions and chat in a financial markets experiment. *Available at SSRN 1783462*.

Holt, C. A., Porzio, M., & Song, M. Y. (2015). *Price Bubbles, Expectations, and Gender in Asset Markets: An Experiment*. University of Virginia working paper.

Hussam, R. N., Porter, D., & Smith, V. L. (2008). Thar she blows: Can bubbles be rekindled with experienced subjects?. *The American Economic Review*, *98*(3), 924-937.

Kindelberger, C., R. Aliber. 2011. Manias, Panics and Crashes: A History of Financial Crises, Sixth Edition, Palgrave Macmilan.

King, R. R., V. L. Smith, A. W. Williams, M. Van Boening. 1993. The Robustness of Bubbles and Crashes in Experimental Stock Markets. In *Nonlinear Dynamics and Evolutionary Economic*, ed. Richard Day and Ping Chen, 183–200. Oxford: Oxford University Press.

Kirchler, E., & Maciejovsky, B. (2002). Simultaneous over-and underconfidence: Evidence from experimental asset markets. *Journal of Risk and Uncertainty*, *25*(1), 65-85.

Kirchler, M., Huber, J., & Kleinlercher, D. (2011). Market microstructure matters when imposing a Tobin tax—Evidence from the lab. Journal of economic behavior & organization, 80(3), 586-602.

Kirchler, Michael, Jürgen Huber, and Thomas Stöckl. "Thar she bursts: Reducing confusion reduces bubbles." *The American Economic Review* 102.2 (2012): 865-883.

Lei, V., C. N. Noussair, C. R. Plott. 2001. Nonspeculative Bubbles in Experimental Asset Markets: Lack of Common Knowledge of Rationality vs. Actual Irrationality. *Econometrica*, 69(4), 831-859.

Levine, S. S., Apfelbaum, E. P., Bernard, M., Bartelt, V. L., Zajac, E. J., & Stark, D. (2014). Ethnic diversity deflates price bubbles. *Proceedings of the National Academy of Sciences*, *111*(52), 18524-18529.

Noussair, C. N., S. Tucker. 2006. Futures Markets and Bubble Formation in Experimental Asset Markets. *Pacific Economic Review*, 11(2), 167-184.

Oechssler, J., Schmidt, C., & Schnedler, W. (2011). On the ingredients for bubble formation: informed traders and communication. *Journal of Economic Dynamics and Control*, *35*(11), 1831-1851.

Palan, S. (2010). Digital options and efficiency in experimental asset markets. *Journal of Economic Behavior & Organization*, *75*(3), 506-522.

Porter, D. P., V. L. Smith (1994) Stock Market Bubbles in the Laboratory. *Applied Mathematical Finance* 1(2), 111-128.

Porter, D. P., V. L. Smith (1995) Futures Contracting and Dividend Uncertainty in Experimental Asset Markets. *The Journal of Business*, 68(4), 509-41.

Powell, O. (2016). Numeraire independence and the measurement of mispricing in experimental asset markets. *Journal of Behavioral and Experimental Finance*, *9*, 56-62.

Powell, O. and N. Shestakova (2017). The robustness of mispricing results in experimental asset markets.

Smith, V. L., G. L. Suchanek, A. W. Williams. 1988. Bubbles, Crashes, and Endogenous Expectations In Experimental Spot Asset Markets. *Econometrica,* 56(5), 1119-1151.

Smith, V. L., Van Boening, M., & Wellford, C. P. (2000). Dividend timing and behavior in laboratory asset markets. *Economic Theory*, *16*(3), 567-583.

Stöckl, T., Huber, J., & Kirchler, M. (2015). Multi-period experimental asset markets with distinct fundamental value regimes. *Experimental Economics*, *18*(2), 314-334.

Stoian, A. (2014). Public messages and asset prices. *Atlantic Economic Journal*, *42*(4), 441-454.

Van Boening, M. V., Williams, A. W., & LaMaster, S. (1993). Price bubbles and crashes in experimental call markets. *Economics Letters*, *41*(2), 179-185.

Williams, A. W. (2008). Price bubbles in large financial asset markets. *Handbook of Experimental Economics Results*, *1*, 242-246.

Williams, A. W., & Walker, J. M. (1993). Computerized laboratory exercises for microeconomics education: Three applications motivated by experimental economics. *The Journal of Economic Education*, *24*(4), 291-315.