Thar She Bursts revisited:

Children, Adolescents and Bubble Experiments

Carles Aulés
Anna Baiget
Rut Balada
Eduard Cruset
Gerard Martín

Abstract In 1988 Smith, Suchanek, and Williams illustrated that large bubbles were formed in experimental asset markets, a result that appeared to be robust to treatment changes. Subsequently, Huber, Kirchler, and Stöckl concluded that slight modifications in the framing of the experiment aiming at reducing the confusion among subjects had decisive impacts in order to reduce mispricing. All previous research had been conducted with adults.

Our objective is thus, to compare bubble formation between children and teenagers given different experimental treatments. We confronted the Smith, Suchanek, and Williams market model against the Huber, Kirchler, and Stöckl one, both having been adapted to children and teenagers.

We observe that both children and adolescents create price bubbles regardless of the treatment, despite children never bursting them. In addition, we statistically prove that bubbles in children are larger both in intensity and duration. Finally, we show that Huber, Kirchler and Stöckl market model only attenuates bubbles in children experiments.

Keywords Experimental economics · Bubbles · Asset Markets · Adolescents · Children

1. Introduction

In a pivotal paper published in 1988, Smith, Suchanek and Williams showed that not only trade was observed in experimental asset markets, but also that bubbles were created in their market model. From then on, many social scientists have further worked on similar setups to test whether bubbles were robust under different experimental treatments and found that, indeed, bubbles persisted unless twice-experienced subjects played the experiment. In 2010, however, Vernon Smith admitted that subjects might have been experiencing "home-grown expectations of prices rising" to illustrate that subjects may be confused when performing the experiment. In fact, Huber, Kircher and Stökl have concluded that, indeed, little changes in framing attempting to reduce the level of confusion of subjects can radically change bubble patterns.

All previous research, however, exclusively used adults to run experiments. For this reason, we focus on experimental economics on children and adolescents. In this paper, we specifically want to find which is the behaviour of these younger populations when performing experiments of bubbles under two different treatments, SSW -which replicates the Smith, Suchanek and Williams market model- and Gold Mine -which replicates the Huber, Kircher and Stöckl market model-. This yields four different research questions: (i) Are there differences between children and adolescents in the Gold Mine treatment? (ii) Are there differences between children and adolescents in the classical SSW market model? (iii) Are there differences between both treatments on children? (iv) Are there differences between both treatments on adolescents?

In order to answer these research questions we structure this paper as follows: in section 2 we start by explaining the previous research on bubbles and children; subsequently, in section 3 we describe the experiments run; in section 4, we analyse the results obtained, results that will be summarized in section 5. In section 6, we finally expose our conclusions.

2. Previous research on bubble experiments

A) Previous research on bubble experiments

One of the most cited papers in experimental economics involving financial bubbles is the study carried out by Smith, Suchanek and Williams (1988) **[20]** (henceforth, SSW) that reproduced an experimental asset market with such characteristics that generated robust bubbles. Nonetheless, many other authors had already built the theoretical basis of financial markets under which SSW stands.

John Muth was the first to establish the concept of rational expectations on financial markets. As stated in Muth (1961, p. 361) **[15]**: "*Expectations of firms* [...] *tend to be distributed, for the same information set, about the predictions of the theory*". His main argument is that agents cannot have permanent mistaken price expectations and, thus, they will eventually tend to have expectations consistent with the rational economic theory. Agents' expectations may possibly be wrong, but are correct on average over time: agents cannot have systematically biased expectations. The rational expectations theory has indeed been the foundation of the modern understanding of economics: financial markets were also studied from the scope of rational expectations.

SSW also takes into account Fama's (1970) **[5]** approach on capital markets efficiency, which affirms arbitrage cannot yield positive net profits, given that efficient capital markets tend to be similar to a *fair game*.

Tirole's (1982) **[22]** research on the possibility of speculation under rational expectations is also considered in SSW. According to Tirole (1982, p. 1163) **[22]**: *Unless traders have different priors or are able to obtain insurance in the market, speculation relies on inconsistent plans, and thus is ruled out by rational expectations*. If traders have rational expectations, following Fama's (1970) **[5]** view on the issue, market does not give rise to gains from trade. Furthermore, Tirole (1982, p. 1165) **[22]** introduces the idea of a *myopic* rational expectations equilibrium: "*in markets with heterogenous information, traders base their behaviour on the comparison between current price and (the probability distribution of) next period's price*".

From Muth (1961) **[15]**, Fama (1970) **[5]** and Tirole (1982) **[22]** we can induce bubbles are irrational and, therefore, rational expectations disregard the possibility of the creation of bubbles. However, some authors argue that bubbles can in fact be rational. Blanchard (1979) **[2]** affirms that: "*Self ending bubbles, i.e., speculative bubbles followed by market crashes, are consistent with the assumption of rational expectations*". If agents are in a situation in which a financial bubble has already formed, it is rational to take part in it before the market crashes. In addition, there have been more recent treatments on rational bubbles, namely the *Bubble Game* by Moinas and Pouget (2012) **[14]**. They propose a sequential trading of an asset commonly known to be valueless. If traders ignore their position in the market sequence and there is no cap on the maximum price, bubbles can rationally be formed.

Provided this previous research, mainly Muth (1961) **[15]**, Fama (1970) **[5]** and Tirole (1982) **[22]**, SSW starts posing different questions to be addressed. First, SSW tackles

whether agents actively trade an asset if all investors face identical dividend structures, alternatively, if different dividend structures are a necessary condition for observing trade. A straightforward plain analysis would conclude that, if Tirole (1982) **[22]** applies, the immediate answer is negative. However, a more careful analysis can have some more complex conclusions, which we will further discuss later on. The second problem SSW arises is to determine price patterns given that the agents effectively trade. Basically, SSW seeks to clarify whether prices follow adaptive expectations on previous trades, vis-à-vis the Cobweb Theorem presented by Ezekiel (1938) **[4]**; or whether price expectations follow rational expectations in the sense of Muth (1961) **[15]**, henceforth REM.

We will first focus on the initial objective of SSW which is to determine whether trade would occur when all traders faced identical uncertain dividend payments. It appears that different private dividend values are not a necessary condition for the observance of trade and consequently there is sufficient diversity in agent price expectations and risk attitudes to induce gains from trade.

In regards to the second objective, SSW conjectured that, due to a lack of trade, bubbles might not be formed; but they obtained results pointing to the exact opposite direction: in most treatments we see a clear tendency towards bubble creation that attend to the following patterns. In the first period the mean price is below the fundamental value and suggests that risk aversion might play a role in bubble markets by reducing prices at first. Immediately after, we find a recovery of the price that creates a expectation of capital gains through speculative trade. The average price is preserved during the central periods and gradually differs more from the decreasing intrinsic price of the asset. Somehow, the collapse of prices is augured by a lesser amount of bids compared to the volume of offers and ends with a crash in market prices where the volume of trade is significantly smaller than the trading volume in the *boom* phase.

The number of transactions differs between the experiments with inexperienced subjects and those with experienced ones. The latter type is characterised by a lesser amount of trade; and although the disparity between agent price expectations and intrinsic price tends to persist, it is attenuated and consequently, bubble formation is significantly reduced. As agents are more experienced, bubble formation disappears.

The conclusions to which SSW reaches might seem, to some extent, contradictory to the previous research on financial markets, namely Muth (1961) **[15]**, Fama (1970) **[5]** and Tirole (1982) **[22]**. However, SSW (1988, p. 1148) claims that "*None of the above*

conclusions are inconsistent with Fama (1970) criterion for REM (no arbitrage profits) or with the Tirole (1982) model (agents have common priors)". According to SSW, common dividend structure and knowledge is insufficient to induce common expectations, i.e. common priors in the sense of Tirole (1982) **[22]**. Therefore, as SSW concludes that agents do not have common priors at the beginning, price bubbles are indeed possible because of subjective uncertainty about the behaviour of others; these conclusions also stated in Smith and Van Boening (1993, p. 183) **[19]**. Moreover, we can infer that bubbles are a form of myopia (Tirole, 1982) **[22]**, although agents eventually understand that gains from trade cannot be indefinitely sustained. Hence, both Fama (1970) **[5]** and Tirole (1982) **[22]** apply in SSW: agents manage to aggregate common priors whenever they get enough experience, despite not having started in such situation. Once it occurs, rational expectations rules out speculation and no gains from trade can be attained. In this situation, prices tend to move towards REM: expectations are adaptive and such adaptation is to a REM.

Since the SSW experiment, many variations of the experimental asset market have been run to study under which conditions bubbles did create. In Smith and Van Boening (1993) **[19]** some of these variations are exposed and include: allowing for short-selling, allowing for margin buying, equal endowments for the participants, a fee for each exchange that recreates transaction costs, the intrusion of previously informed "insiders" or traders, a limit price change rule and the use of corporate executives and market dealers as subjects. Smith and Van Boening (1993, p. 199) **[19]** finally concludes that the only way to completely abate bubbles is by running the experiment with twice-experienced subjects: "*These bubbles are robust with respect to all of the above treatments; only experience is ultimately reliable in eliminating bubbles. This reinforces the basic findings in SSW: common information is not sufficient to yield common expectations, but enough experienced subjects come to have common expectations*".

Similarly, Porter and Smith (1995) **[17]** reject the possibility of risk aversion being the source of bubbles and show that the same price pattern arises when the dividend is known -i.e. not random.

In Caginalp, Porter and Smith (2001) **[3]** it is showed that bubbles persist, though dampened, when the following factors are taken together: 1) low initial liquidity, 2) deferred dividend and 3) a bid-ask book that is open to all traders.

Finally, Noussair, Robin, and Ruffieux (2001) **[16]** report that with a constant face value there are only moderated bubbles and name frequent dividend payments as the main

driver of bubble formation.

Already in 2010, Smith (2010, p. 6) **[18]** himself opened the Pandora's box when talking about subjects having "*home-grown expectations of prices rising*" that collided with the assumption that "*subjects reason like economists*". In this sense, Smith admits that subjects might be "confused" and that researchers had "*erred in believing that they* [subjects] *should think as we* [researchers] *expected*".

The possibility of being confusion the factor that explained robust bubbles in experimental asset markets has recently been further explored by many researchers. Current research on experimental asset markets focus on how the framing of the experiment can affect the final outcome.

In a pivotal paper which studies the effect of framing on SSW markets, Kirchler, Huber and Stöckl (2012) **[12]** (henceforth, KHS) study the effect of slightly changing the name of the asset traded from "stock" to a "stock of a depletable Gold Mine". Here is an extract of the instructions they gave to the participants: "*The stocks are of a depletable gold mine, in which gold is mined for 10 periods. In each period the probability of finding (not finding) gold is 50 percent. If gold is found in period p, a dividend (profit) of 10 Taler* [the fictitious currency] *for each unit of the stock will be paid. If no gold is found, the dividend will be zero. After 10 periods the gold mine is depleted and the value of the stock is zero".* This study concluded that "*results from [...] the different context 'stocks of a depletable gold mine' showed significantly mispricing and overvaluation than the comparable treatment with the term 'stock'*". They further argue that these results should be regarded as evidence showing that SSW market participants are confused and this leads to bubbles.

Having preluded the conclusions of KHS, Huber and Kirchler (2012) **[11]** states that: "*In particular, we show that mispricing is significantly reduced and overvaluation is eliminated completely (i) when the fundamental value process is displayed in a graph instead of a table or (ii) when subjects are asked about the current fundamental value at the beginning of each period*". It thus includes a questionnaire at the beginning of each period to ensure agents realise the intrinsic value of the asset.

Finally, the view of KHS has been challenged by Baghestanian and Walker (2014) **[1]**, which argues that *"the particular features of the KHS-design generate asset prices which equal the fundamental value through increased focalism or anchoring, and not because agents are less 'confused.'"*

The history of bubbles in experimental asset markets is thus summarised as follows: in

the late eighties, nineties and in the beginning of the 21st Century, economists found that bubbles formed in many variations of experimental asset markets. Currently, economists explore the validity of these past claims by arguing that perhaps the artificiality of the laboratory explains a bigger part of the picture than what was actually thought.

B) Previous research on children experiments

Adults make economic decisions in society. But they have been children. As stated in Krause and Harbaugh (1999, p. 1) **[13]**: "*In every science one of the first steps towards understanding something is understanding its development*". This is the reason why our paper is based on children.

From Harbaugh, Krause and Vesterlund (2007) **[8]** it can be concluded that, at the age of 8, children are able to understand the market, so trade in order to maximise its monetary payoffs.

Harbaugh, Krause and Vesterlund (2002) **[7]** emphasises that it is important to use real payoffs and make crystal clear that these payoffs will be determined by current choices, this is because (p. 56): "*real and readily apparent payoffs are essential for ensuring that children pay attention to the instructions and maintaining their interest during the experiment"* . Similarly, in two different papers, Harbaugh, Krause and Vesterlund (2007) **[8]** and Krause and Harbaugh (1999) **[13]** use tokens instead of cash because children seem to perform better with them. When the experiment ends, they can exchange these tokens for toys.

According to Harbaugh, Krause and Vesterlund (2007) **[8]** most learning models consist in different periods: exploration (information is accumulated) and exploitation (when agents get benefit of what they had learned). Children are unable to achieve the second period with few periods, so it is important to have more than five periods.

Regarding the incentive schemes to properly motivate our children, Hogarth and Camerer (1999, p. 1) **[10]** add that: "*Economists presume that experimental subjects do not work for free and work harder, more persistently, and more effectively, if they earn more money for better performance. Psychologists believe that intrinsic motivation is high enough to produce steady effort even in the absence of financial rewards".* Children might see experiments as a game they have to win, being this fact enough to generate intrinsic motivation.

As it is said in the experiment of Harbaugh, Krause and Berry (2001, p. 1545) **[6]**: "*at*

age 7 children's choices about consumption goods show clear evidence of rationality, though also many inconsistencies, when choosing consumption goods. By age 11, choices by children with below-average mathematical ability are as rational as choices by adults with above-average intelligence, although even these adults' choices show many inconsistencies". Since there is little rationality in adults' behaviour, an obvious place to start looking for the source of failure is the behaviour of children. Despite the fact that it has not been proved yet, Kraus and Harbaugh (1999) **[13]** believe that it is important to develop experiments to test whether the violations of rational behaviour that have been found in adult subjects can be found in children too. In our core SSW treatment, we observe that adults start performing irrationally when price bubbles arise: we want to further analyse whether children perform in a similar way.

Finally, as Harbaugh, Krause and Vesterlund (2002) **[7]** conclude: "*Most experimental work on adults finds that they tend to overweight low-probability outcomes and underweight high-probability ones, a pattern of behavior that can be explained by a regressive probability weighting function. In children, we find the opposite regressive weighting. [...] Children and youths significantly underweight low probability events and overweight high-probability ones. This means that in situations with a small probability of a large loss they will be more likely to take the risky than the safe option*". Therefore, we can conclude that children appear to be less risk-averse than adults.

3. Description of the experiment and methodology

A) Basic elements

In each fictional market, nine individuals trade an asset for fictitious currency in a sequence of twelve periods, each one lasting for 180 seconds. Most elements of the experiments are analogue (assets, dividends and currencies) and computers are only used to record the transactions.

At the beginning of each experiment individuals are separated into buyers and sellers. The former are endowed with 36 coins while the latter are endowed with an asset with an intrinsic value of 12 coins and a liquid endowment of 24 coins. Therefore, the initial wealth is the same for both buyers and sellers. Dividends are constant and equal to one coin, and they are paid out at the end of each period.

The basic methodology is extracted from SSW, with some simplifications in order to adapt it to our peculiar sample, on which we will proceed to comment. We have reduced the number of periods from fifteen to twelve. The initial endowments are different, but

the proportion between sellers and buyers is kept constant. The dividends in SSW are distributed probabilistically, but we use fixed known dividends, following Porter and Smith (1995) **[17]**. Furthermore, we do not allow subjects to hold more than one asset.
As we run analogue experiments, our currency is poker tokens with an adhesive on their respective numbers so as to avoid confusion on the value of those tokens. Subjects are reminded that every coin has the same value and that the objective of the game is to accumulate as much coins as possible. Finally, subjects are told that they will be able to exchange their currency for candy at the end of the experiment.

Endowment		**Dividend per**	**Intrinsic (Dividend) Value per Asset in**
Class I	Class II	**Period**	**Period 1**
($36, 0; 5)[a]	($24, 1; 4)	1	12

[a] (Initial number of coins, number of assets; number of traders assigned to this class)

Table 1: Distribution of the initial endowment and characteristics over the intrinsic value.

The fundamental value is computed using:

$$FV = E(dividend) \cdot remaining\ periods + terminal\ value$$

Being exactly 0 the terminal value.

B) Experimental treatments

In order to test our hypothesis that results will change as the framing conditions change, we run two identical treatments framed in a substantially different way:

I. Treatment *SSW*

The asset traded is a piece of paper with the word "bonus" written on both sides that emulates a share. Nine-year-old children are told that they will trade a "bonus" which pays them one coin to the holder of that piece of paper at the end of each period; whereas sixteen-year-old adolescents are told that they will trade a "share" that pays a "dividend" to the holder at the end of each period, as the big majority already knows the meanings of these terms.

The decreasing fundamental value is orally explained in detail at the beginning of the experiment as follows:

"*Recall that the value of your bonus/share decreases as the experiment goes by. The reason why it decreases is that, if you never sell your bonus/share during the experiment at the beginning of the experiment, you will earn 12 coins, each one at the*

end of each period. If you are at period 6 and there still are 6 more periods left, that bonus/share will yield 6 more coins to the holder if he or she decides to never sell it again. Obviously, at the last period, the holders of that bonus/share will only earn 1 more coin. The bonus/asset will [metaphorically] *directly be dropped to the bean once the experiment ends, so in the end of the experiment the holders of bonuses/shares will have a worthless piece of paper*".

At the end of each period, asset-holders sit in front of non-holders and the former are given a coin that emulates the dividend.

Before starting the next period, subjects are orally reminded of the value of the bonus/share that they are to trade. If the subjects still happen to express any misunderstanding on how to compute the value of the bonus/share traded, they are explained once again the link between periods left and dividends left and how that piece of paper will directly be dropped to the bean at the end of the experiment.

II. Treatment *Gold Mine*

The asset traded is transparent plastic box with twelve coins inside. Subjects are told that they will trade such boxes during the experiment and that they have to regard each one of those boxes as a piggy bank that allows the holder to extract one coin at the end of each period.

Although the explanation is more straightforward, the decreasing fundamental value is also orally explained in detail at the beginning of the experiment as subjects are told that, as periods go by, the box empties.

At the end of each period, asset-holders sit in front of non-holders and they are allowed to open the transparent box and pick one coin each.

Before starting the next period, all subjects are orally asked one by one how many coins the transparent box or piggy bank still contains. This is the application of the questionnaire originally implemented in KHS.

C) Market architecture

The market architecture is the same for both experiments.

In each of our laboratory markets, subjects trade in a continuous public double auction with all orders executed according to price and then time priority. Neither borrowing money nor shorting assets are allowed. While the minimum price allowed to exchange the asset was zero, the maximum was the total amount of coins each buyer owned.

Each market simulation consists of 12 trading periods of 180 seconds each. Money and

asset holdings are carried over from one period to the next and there is neither interest paid nor any transaction cost. As assets are worthless at the end of the experiment, only money is relevant for final payments.

Two other important features of the market are an increasing Capital/Asset ratio and a decreasing fundamental value of the assets traded. Both are kept equal from the classic SSW market model.

D) Methodology and data collection

Six simulations were conducted for each experiment and group of age (i.e. six *Gold Mine treatment* experiments for children and six for adolescents, six *SSW treatment* experiments more for children and six for adolescents; 24 in total).

All 24 experiments were conducted between May and June 2017 at different schools and high schools in the province of Barcelona with a total of 216 students participating. The institutions where the experiments were carried out are the following: *Escola Avenç, Escolàpies Sant Martí, Escolàpies Llúria Barcelona, Escola Pia Nostra Senyora, Institut Verdaguer, Escola Voramar* and *Escola Frederic Mistral-Tècnic Eulàlia.*

Before each experiment, supervisors assign a number to each subject in order to anonymously identify them. Subjects are then told to sit down in nine chairs so that subjects with the numbers 1-4 (initial potential sellers) sit in front of subjects with numbers 5-9 (initial potential buyers). This same distribution is kept throughout the experiment: asset-holders (potential sellers) always sit in front of non-holders (potential buyers). Once the subjects are sat, the instructions are carefully explained in 15 minutes. We obviously avoid explaining what the subject of our study is in order to prevent subjects from being biased. After delivering the instructions, an example of a double auction is showed by the supervisors using mobile phones as assets to ensure the understanding of the procedures. Extraorbital prices are told to avoid anchoring.

The experiment starts with two supervisors ensuring the proper functioning of the market: one supervisor asks for the highest bids and communicates them out loud whereas the other supervisor asks for the lowest asks and communicates them out loud in order to avoid direct communication between the subjects. Once a bid and an ask coincide, the first subject to bid/ask at that price is told to stand up and tell the registrar "me, number x sold to number y at a price z". Subjects then exchange their money and asset and go back to their chairs: number x is a new buyer and number y is a new seller.

4. Interpretation of the results

A) Overview

Let us recall the research questions outlined in the introduction:

- RQ1: Are there differences between children and adolescents with the treatment Gold Mine?
- RQ2: Are there differences between children and adolescents with the treatment SSW?
- RQ3: Are there differences between treatment Gold Mine and SSW on children?
- RQ4: Are there differences between treatment Gold Mine and SSW on adolescents?

Therefore, we will focus on contrasting the differences between treatments and the differences between age groups: we will encounter four different types of experiments (combinations of two age groups and two treatments), which we will compare. Henceforth, to facilitate further understanding of this section, we will name each of the four possible types of experiments, which we executed as follows:

- E1: Treatment SSW with children,
- E2: Treatment SSW with adolescents,
- E3: Treatment Gold Mine with children,
- E4: Treatment Gold Mine with adolescents.

We have executed six experiments of each type.

Tests and research questions	Goldmine_adolescents (E4)	SSW_children (E1)
Goldmine_children (E3)	RQ1	RQ3
SSW_adolescents (E2)	RQ4	RQ2

Table 2: outline of the research question regarding the experiments.

Provided our research questions tackle the differences between age groups given an experimental treatment (RQ1 and RQ2) and the differences between experimental treatments given an age group (RQ3 and RQ4), we should now aim attention at how to measure said differences. Thus, we will conduct statistical tests regarding four evaluation criteria. In section C, we will contrast our research questions using Relative Absolute Deviation (henceforth, RAD) and Relative Deviation (henceforth, RD). Similarly, in section D we will study the differences in bubble duration. In section E, we

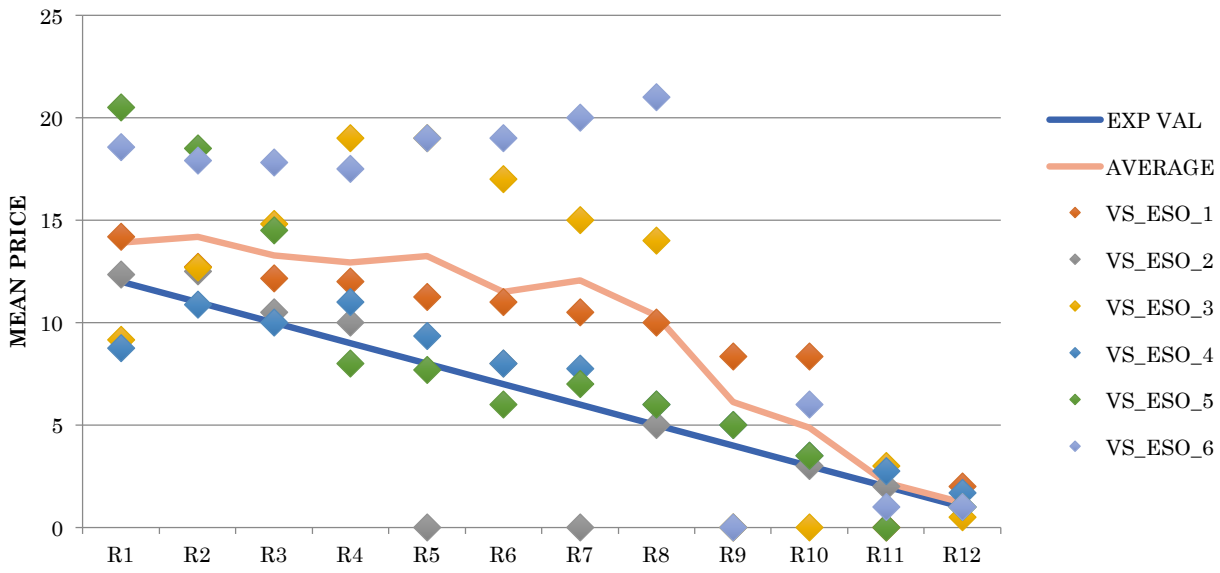
will test how trade activity changes depending on treatments and age groups. Finally, we will point out some experimental observations vis-à-vis rationality.

We would also like to point out that we will be using the Mann-Whitney U test to contrast our hypotheses. Unlike the t-test, it does not require the assumption of normal distributions. However, it requires: (a) the sample drawn from the population is random, (b) independence within the sample and mutual independence, (c) ordinal measurement scale. All three assumptions are respected in our sample and, as such, we will centre our statistical study on the Mann-Whitney U test. It contrasts the null hypothesis that it is equally likely that a randomly selected value from one sample will be different from a randomly selected value from a second sample.

B) Graphical analysis of the treatments

In this section we present the graphical results from our experiments. Figure 1 provides an overview of the results from secondary school of both treatments, SSW and Gold Mine.

Figure 1 shows that both treatments generate price bubbles, although in treatment SSW the bubble is shorter on quantity and duration. Moreover, the crash happens, on average, in different periods: in treatment SSW the bubble crashes at period 8 on average whereas in treatment Gold Mine the bubble crashes, on average, in period 6. However, based on statistical tests these appreciations are not significant: we will further discuss this issue in section C.



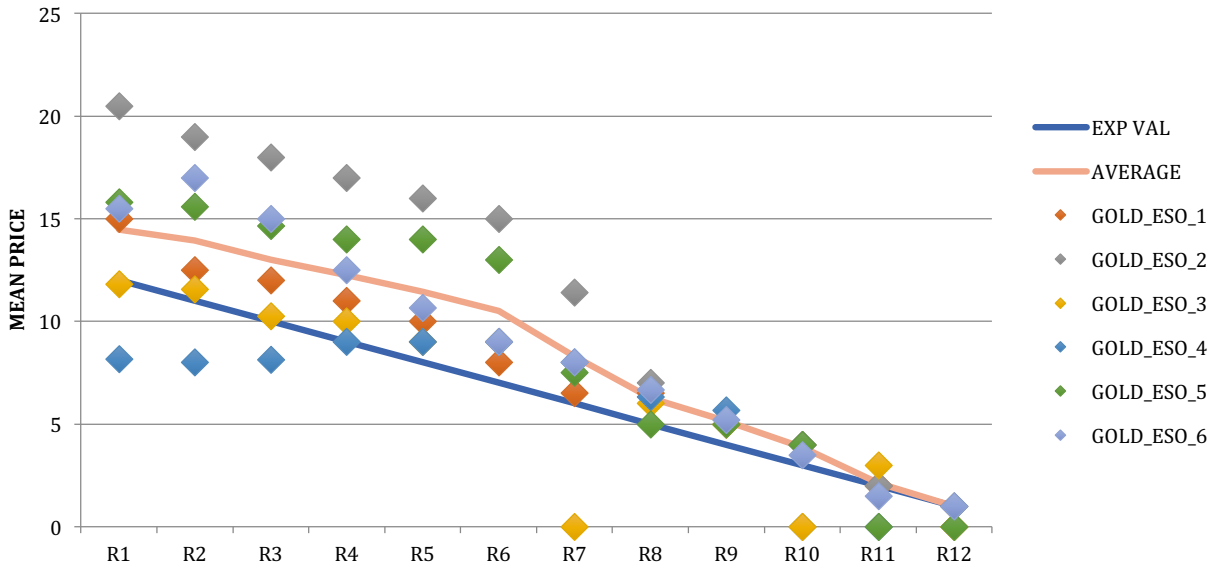


Figure 1: Graphical representation of experimental results in secondary schools.

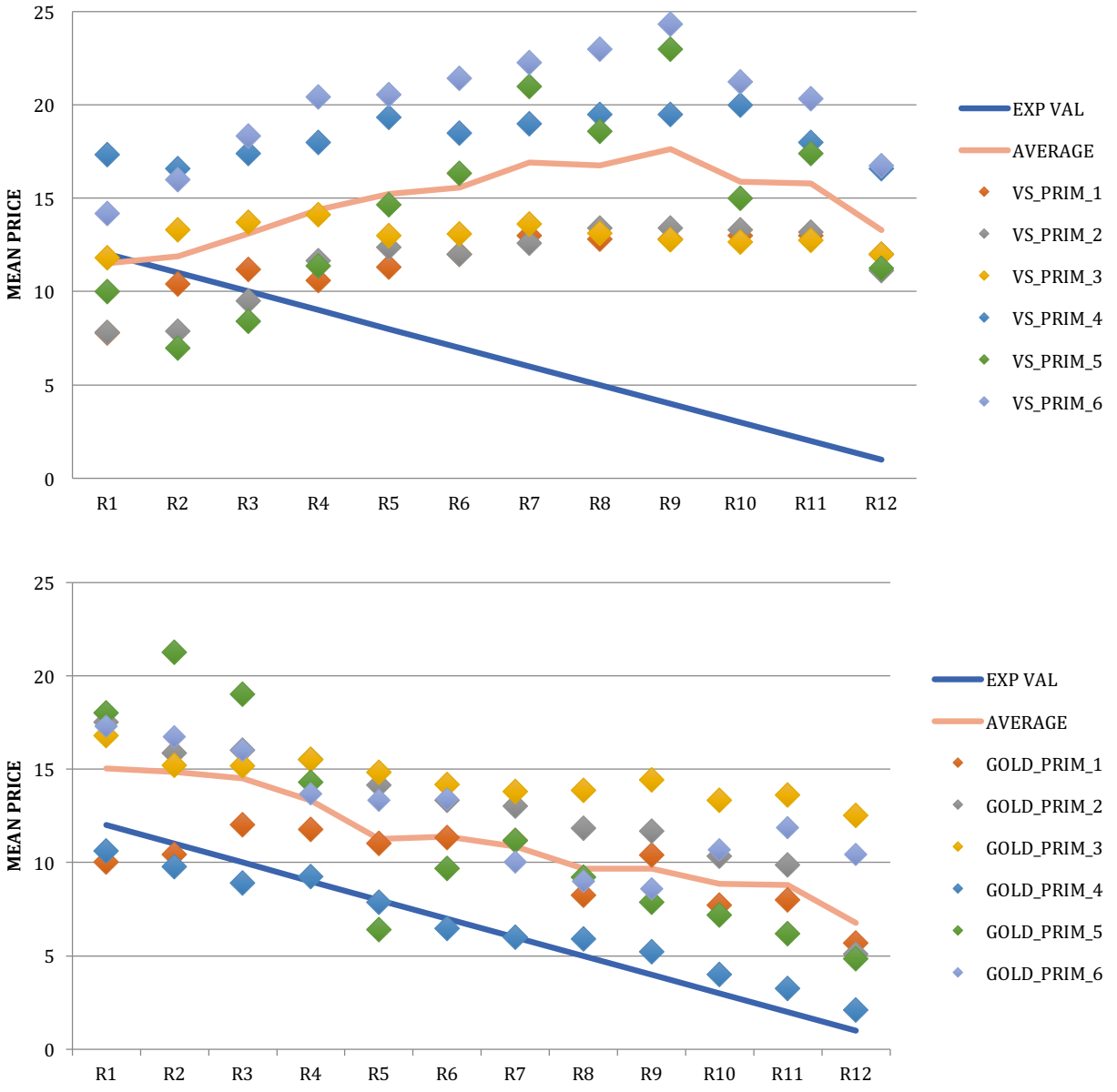


Figure 2: Graphical representation of experimental results in primary schools.

Figure 2 represents the results from students of primary school. As it is evident in Figure 2, both treatments present a different behaviour. In the treatment SSW, the mean price is, on average, increasing along the twelve periods, whereas in treatment Gold Mine it is decreasing. However, both treatments generate bubbles and mispricing.

C) Analysis of bubble activity using RAD and RD

In order to reliably contrast bubble activity, we will base our statistical study on RAD and RD, which measure the average level of mispricing. Although the canonical bubble measures in literature might be other, we are convinced to use both RAD and RD as our main testing measures, based on Stöckl *et al* (2010) **[21]**. According to this research, bubble measures should (a) relate fundamental value and prince; (b) monotone in the difference between fundamental values and prices and (c) is invariant to nominal changes in experimental setting. As stated in Stöckl *et al* (2010) **[21]**, *none of the currently used bubble measures fulfils the three criteria and thus could be considered a reliable measure robust to nominal changes in the experimental setting*. RAD and RD overcome said drawbacks and, hence, we will use them as our principal measure for bubble activity.

RAD, as considered in Stöckl *et al* (2010) **[21]**, *measures the average of the absolute differences between the (volume-weighted) mean price and the FV across all periods p and normalising it with the absolute value of FV of the market*.

$$RAD = \frac{1}{N} \Sigma \, |P - FVt| / |FVt|$$

RD is similarly calculated, but instead of considering absolute price deviations, it works with raw price deviations:

$$RD = \frac{1}{N} \Sigma (Pt - FVt) / |FVt|$$

Following the table 3, we consider the RD/RAD of Gold Mine with children and test them against the RD/RAD of Gold Mine with adolescents (to test our RQ1) using the previously mentioned Mann-Whitney U test and continue the same procedure for each of the four research questions.

Even though tests for both RD and RAD have been computed, only those with results that have substantial differences between relative deviation and relative absolute deviation will be commented separately; otherwise it is assumed that the result is the same or very similar. Moreover, all the tests in this subsection will be one-sided unless

stated otherwise.

After computing the test for RQ1 (with H_0: *There are no differences in the RD/RAD with children and adolescents for the treatment Gold Mine*; and H_1: *RD/RAD is greater for children than for adolescents for the treatment Gold Mine*) we find that we can reject the null hypothesis (H_0) at a confidence level of the 95%; therefore, we find that the overvaluation of the asset is greater for those experiments were children participated when the treatment Gold Mine was implemented.

For the test corresponding to RQ2 (with H_0: *There are no differences in the RD/RAD with children and adolescents for the treatment SSW*; and H_1: *RD/RAD is greater for children than for adolescents for the treatment SSW*) we obtain that we can reject the null hypothesis (H_0) with 99% confidence so we can assert that both RD and RAD are greater for children than for adolescents (i.e. children tend to overvalue the asset while adolescents keep closer to the fundamental value for the treatment SSW).

When testing RQ3 (with H_0: *There are no differences in the RD/RAD with children for treatments Gold Mine and SSW*; and H_1: *RD/RAD is greater with children for treatment SSW than for treatment SSW)* we can again reject the null hypothesis; therefore, we can state at a confidence level of 95% that overpricing is greater in the treatment Gold Mine than in the treatment SSW when carrying out the experiment with children.

Vis-à-vis the test implemented to study RQ4 (with H_0: *There are no differences in the RD/RAD with adolescents for treatments Gold Mine and SSW*; and H_1: *RD/RAD is greater with adolescents for treatment SSW than for treatment SSW*) this is the only case where we cannot reject the null hypothesis so given the results we cannot assure that the mispricing is distinct for the different treatments.

	P-value (one-sided test) RD	P-value (one-sided test) RAD	W-RD	W-RAD	95% CI RD	95% CI RAD
RQ1	0.03247(**)	0.03247 (**)	30	30	[0.0123, ∞)	[0.0424, ∞)
RQ2	0.007576(***)	0.007576 (***)	33	33	[0.32, ∞)	[0.45, ∞)
RQ3	0.04654 (**)	0.03247 (**)	29	30	[0.0118, ∞)	[0.0389,∞)
RQ4	0.3496	0.3496	21	21	[-0.2625, ∞)	[-0.1941, ∞)

(***) Shows that the null hypothesis can be rejected at a confidence level of 99%
(**) Shows that the null hypothesis can be rejected at a confidence level of 95%
(*)Shows that the null hypothesis can be rejected at a confidence level of 90%

Table 3: Statistical results on RAD and RD.

Summarising, after running all four tests we find that we can reject the null hypothesis of the three first Research Questions. Hence, we conclude that there are differences when implementing the treatments with different age groups for both Gold Mine and SSW, meaning that children always tend to overvalue the asset much more than adolescents who are much more aware of the intrinsic value of the asset; so children, regardless of the treatment, tend to create more intense bubbles than adolescents. On the other hand, we find that children act differently for each treatment while adolescents do not. That shows us that confusion is reduced for children when implementing the treatment Gold Mine in contrast to SSW; however, we cannot assert that for adolescents.

D) Analysis of bubble activity using duration

In this section we will analyse the bubble activity using the duration. The duration measures the length of the bubble, regardless of its intensity (which we have already studied using RAD and RD). As defined by Porter and Smith (1995) **[17]**, it is the maximum number of consecutive periods within an experimental market which the price deviations from fundamental value increase. It is calculated as:

$$Duration = max\{m: P_t - f_t < P_{t-1} - f_{t-1} < \ldots < P_{t+m} - f_{t+m}\}$$

The boom duration also examines the length of the bubble. As it is described in Haruvy and Noussair (2006) **[9]**, the boom duration is the greatest number of consecutive periods that median transaction prices are above fundamental. However, we have disregarded the statistical study of boom duration because, since our experiment was based on certain dividends, there were almost no transactions with lower values as the fundamental value. Differently, if dividends are randomised, boom duration are indeed more descriptive.

We have used the Mann-Whitney U test to statistically answer our research questions. For our RQ1 (differences between children and adolescents given the Gold Mine treatment) we execute a one-sided contrast between the null hypothesis H_0 (there are no differences in duration between children and adolescents given the Gold Mine treatment) against the alternative hypothesis H_1 (duration in children experiments is higher than in adolescents experiments). We can reject the null hypothesis (at a confidence level of 95%) that bubble duration is the same between children and adolescents given the Gold Mine treatment: bubble durations are longer in children than in adolescents if we frame the experiment as a Gold Mine.

To answer RQ2, we consider another one-sided Mann-Whitney U test between the H_0 (there are no differences in duration between children and adolescents given the SSW treatment) and against the H_1 (durations in children are higher). Our statistical analysis shows we can reject the null hypothesis at a 99% confidence level: we can statistically affirm that bubble durations in children experiments are higher than bubble durations in experiments with adolescents.

Regarding RQ3, we will contrast the null hypothesis H_0 that there are no differences in bubble durations between treatments Gold Mine and SSW in children experiments against the alternative hypothesis H_1 that bubble durations in the SSW treatment are higher than durations in Gold Mine. We can reject the null hypothesis at a 95% confidence level, so bubble durations in the SSW are higher than bubble durations in Gold Mine.

Vis-à-vis RQ4, our null hypothesis is H_0: there are no differences in bubble durations between treatments Gold Mine and SSW in experiments in adolescents; while our $H_1$is: bubble duration is higher in SSW than in Gold Mine in experiments with adolescents. After executing the Mann-Whitney U test, we can conclude that we cannot reject the null hypothesis. The differences in both treatments in adolescents are not statistically significant.

	P-value (one-sided test)	W	95% Confidence interval
RQ1	0.04292 (**)	28.5	[7.806899e-05, ∞)
RQ2	0.007876 (***)	33.5	[2.000057, ∞)
RQ3	0.02173 (**)	31	[0.9999928, ∞)
RQ4	0.1521	24.5	[-3.622306e-05, ∞)
(***) Shows that the null hypothesis can be rejected at a confidence level of 99% (**) Shows that the null hypothesis can be rejected at a confidence level of 95% (*)Shows that the null hypothesis can be rejected at a confidence level of 90%			

Table 4: Statistical results on duration.

To sum up, statistical analysis has answered our four research questions. Firstly, we can affirm that children have lengthier bubbles than adolescents given both the SSW treatment and the Gold Mine. Secondly, there is a difference in the duration of the bubbles in children. In the SSW, the bubbles tend to be longer than in Gold Mine. Thirdly, there is no statistical evidence to affirm that treatments generate different

results in adolescents.

Thus, children, independently of the treatment, tend to form longer bubbles than adolescents. This reinforces the notion that children have a lower understanding of the market procedures. In relation to the effect that the treatment has on the formation of bubbles, our tests have shown SSW generates longer bubbles than Gold Mine in children: treatments have a statistical significative effect. Differently, there is no statistical evidence to prove that, in adolescents, SSW generates a longer bubble than Gold Mine: both bubble durations are statistically similar.

E) Analysis of trade activity

In this section we analyse the trading activity, measured by the turnover, of children and adolescents in SSW and Gold Mine treatments. The following figure provides the number of transactions per period for the different experiments.

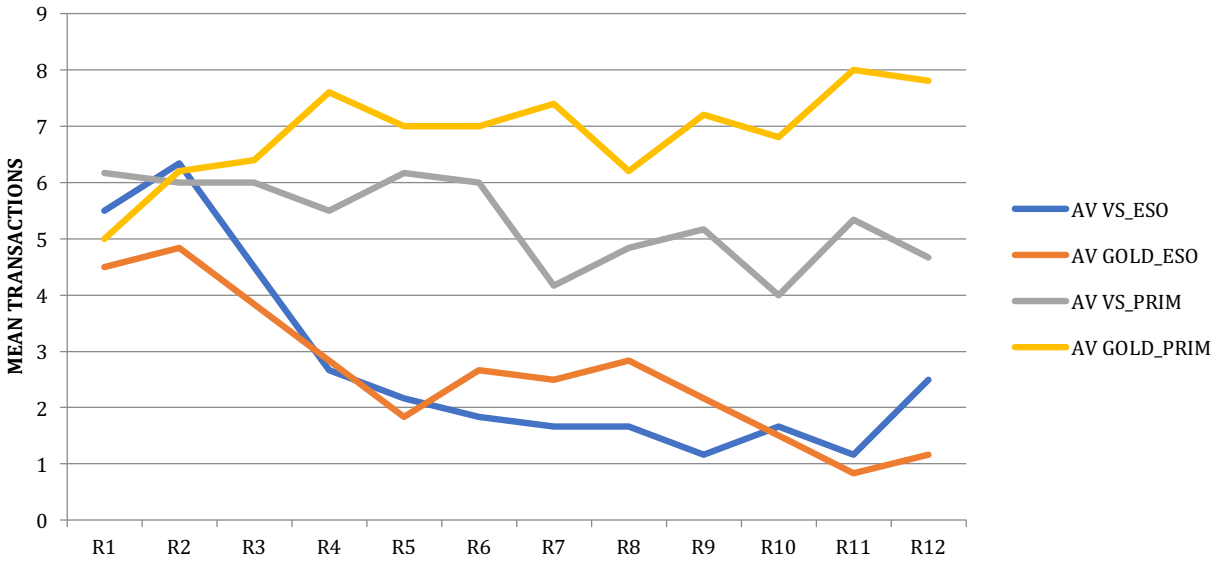


Figure 3: Graphical representation of the number of transactions in the different experiment types.

Figure 3 shows that students of primary school did more transactions than students of secondary school. Moreover, students of secondary school have decreasing transactions.

As stated above, we have chosen the turnover as a measure of trade activity. Turnover, as exposed in Porter and Smith (1995) **[17]**, is a normalised index of the trading activity and it is calculated as the total volume of trade divided by the total shares outstanding across all trading period. Formally:

$$Turnover = (\Sigma_t\, g_t)/(TSU)$$

Being g_t the quantity of units of the asset exchanged in period t and TSU the total stock

of units that the agents hold, namely 4 in our paper.

In order to know whether there is a significant difference in the number of transactions, we consider one-sided Mann-Whitney U tests, answering the four research questions.

Firstly, we compare E3 and E4 in order to answer RQ1 (with H_0: *There are no differences between children and adolescents in the treatment Gold Mine*; and H_1: *Average turnover is greater in children than in adolescents with the treatment Gold Mine).* After doing the statistical test we can reject the null hypothesis at a confidence level of 99%, what leads us to assert that children made more transactions than adolescents.

Regarding RQ2 (with H_0: *There are no differences between children and adolescents;* and H_1: *Average turnover is greater in children than in adolescents with the treatment SSW)* we find that we can reject the null hypothesis at a confidence level of 99%; therefore, also for the SSW treatment, we can state that children made more transactions than adolescents.

In addition, we compare the two treatments on children (RQ3). We state the following hypotheses: H_0: *There are no differences on turnover between treatment Gold Mine and SSW on children* and H_1: *Average turnover is greater in SSW than in Gold Mine on children.* The results of the statistic test show that we cannot reject the null hypothesis; rather, given such a high p-value, it suggests that children tended to make the same amount of transactions no matter the framing.

After computing the test so as to answer RQ4 (H_0: *There are no differences on turnover between treatment Gold Mine and SSW on adolescents*; and H_1: *Average turnover is greater in SSW than in Gold Mine on adolescents)* the result of the test shows that we cannot reject the null hypothesis; therefore, we have not enough data to statistically conclude that the number of transactions is different for adolescents given the framing.

	p-value (one-sided test)	W	95% Confidence interval
RQ1	0.001082(***)	36	[0.6875, ∞)
RQ2	0.007576(***)	33	[0.25, ∞)
RQ3	0.9457	8.5	[-0.8541444, ∞)
RQ4	0.4048	20	[-0.1875545, ∞)
(***) Shows that the null hypothesis can be rejected at a confidence level of 99% (**) Shows that the null hypothesis can be rejected at a confidence level of 95% (*)Shows that the null hypothesis can be rejected at a confidence level of 90%			

Table 5: Statistical results on turnover.

In summary, we reject the null hypothesis for RQ1 and RQ2. For this reason, we can say that, in both treatments, children have a greater turnover than adolescents. Hence, children do, in average, a higher number of transactions than adolescents. This could be explained because, in some sense, children want to play. On the other side, with children, both treatments yield the same number of transactions. The same happens with adolescents.

Finally, before exposing some observations on the rationality of our subjects, we add table 6, which summarises all the results for the bubble measures used.

	RAD	RD	Duration	Boom Duration	Turnover
SSW_Prim_1	0.9176	0.7952	10	10	1.2708
SSW_Prim_2	0.9735	0.7737	10	9	1.5625
SSW_Prim_3	1.0052	1.0009	7	11	1.8750
SSW_Prim_4	1.8175	1.8175	11	12	0.7500
SSW_Prim_5	1.4259	1.2318	5	9	1.0625
SSW_Prim_6	2.0630	2.0630	8	12	1.4792
GoldMine_Prim_1	0.5745	0.5086	6	10	1.9375
GoldMine_Prim_2	0.9757	0.9757	2	12	1.7292
GoldMine_Prim_3	1.2200	1.2200	10	12	1.2708
GoldMine_Prim_4	0.1297	0.0160	3	6	2.3333
GoldMine_Prim_5	0.7719	0.7309	2	7	1.3333
GoldMine_Prim_6	0.9346	0.9346	4	12	1.6458
SSW_ESO_1	0.4670	0.4670	6	10	1.0417
SSW_ESO_2	0.0556	0.0556	1	4	0.3542
SSW_ESO_3	0.7670	0.6809	4	7	0.5417
SSW_ESO_4	0.1717	0.0847	3	9	0.8125
SSW_ESO_5	0.3376	0.2778	1	3	0.5833
SSW_ESO_6	1.1121	1.0865	7	8	0.7708
GoldMine_ESO_1	0.1987	0.0166	1	9	0.4792
GoldMine_ESO_2	0.7295	0.0608	1	9	0.7083
GoldMine_ESO_3	0.1024	0.0085	1	5	0.6458
GoldMine_ESO_4	0.2270	0.0189	5	6	0.8125
GoldMine_ESO_5	0.4303	0.0359	4	7	0.5417
GoldMine_ESO_6	0.3658	0.0305	1	10	0.7500

Table 6: Summary of relevant bubble characteristics in each experiment.

F) Observations on rationality

The results described above can be better understood if we expose some further observations that we extracted from the experiments.

Table 7 shows the recorded transactions in period 5 for a nine-year-old child in a SSW experiment. In less than 180 seconds, this child buys the asset for 14 coins, sells back for 8 coins and buys again for 13 coins. Although the majority of children understood the functioning of the double auction and that the goal of the experiment was to sell expensive and buy cheap, we always observed at least one irrational child per experiment as that described by table 7. Obviously, these types of subjects never realised the existence of bubbles.

		START	TRADE			DIVIDEND	END
PLAYER 1	ASSET	0	1	-1	1		1
	CASH	42	-14	8	-13	1	24

Table 7: Experimental behaviour of one subject in one period.

On the other hand, on some occasions some nine-year-old subjects expressed concerns regarding the prices that their fellow participants bid and asked. One subject even asked the supervisors, at the beginning of the last period: "How can it be that a thing that has a value of 1 coin has a price of 12?". These types of subjects, though a minority among nine-year-old children, understood the experiment.

The majority of children, however, lie between these two extremes. They understood the speculative mechanism according to which they had to sell expensive and buy cheap, but they seemed to never realize that it was nonsense (or, at least, dangerous) to buy an asset worth 1 coin for 12 coins even if there were 60 seconds of the experiment left. In the Gold Mine treatment, however, the bubble sometimes burst when there were 10 seconds left, with asks falling from, say, 10 coins to 5, 3 and 2 in a desperate try to sell during the last seconds. In SSW subjects still bought for 10 even though there were 5 seconds left, so they kept dancing even if the music had already stopped.

The conclusion we extract from these observations is that children generally didn't seem to understand the relation between price and value.

Regarding adolescents, we did not observe irrational behaviours as that described by table 7. Furthermore, as our results already suggest, everyone finally understood the logic behind the experiment as every single bubble burst in some period. We observed, however, that at the beginning of some experiments adolescents ignored the declining

fundamental value of the assets and that they solely engaged in speculative behaviours to earn coins, without predicting that asset prices would necessarily (assuming rationality) have to burst in some point of the future. That is why we observed so low trade compared to children: adolescents initially followed the speculative strategy to earn coins, and, if the price had already climbed to a high level, sellers categorically refused to lower their prices, even if they had been reminded that their asset was losing value. In this situation, buyers bid not-sufficiently high prices as they found that the asset was too expensive and sellers asked too high prices as they felt they would be committing a mistake by buying for, say, 17 coins and selling for 16 coins.

From this observation we claim that perhaps an important driver of mispricing in experimental asset markets is the *status quo* bias.

In these experiments, however, when 3 or 4 subjects realised that selling or buying above the fundamental value could not be persistently sustainable, the behaviour of these individuals was sufficient to induce common rational expectations regarding future asset prices and the bubble burst. This usually happened in an earlier period in the treatment Gold Mine than in the treatment SSW.

We conclude from this observation that when a significant fraction of the subjects in any *adolescent* experiment realised that prices could not persistently stay above the fundamental value, the bubble burst.

5. Summary of experimental outcomes

After the statistical study of the results, in this section we will commence with a global analysis and subsequently we will proceed to answer -based on our results- each of the research questions presented in the introduction.

1. Our first experimental result is an expected one: both age groups generate price bubbles in the SSW treatment. These outcomes are similar to the ones outlined by most of the literature done so far: adults, as stated in SSW **[20]**, in Smith and Van Boening (1993) **[19]** and in Porter and Smith (1995) **[17]**, tend to generate robust bubbles if inexperienced with the market. We can conclude that adolescents and children also generate bubbles given no previous experience in the experimental market we conducted.
2. However, we have found important differences given the Gold Mine experimental treatment. The experimental results in Huber and Kirchler (2012) **[11]** and in Kirchler, Huber and Stöckl (2012) **[12]** conclude that, if confusion among subjects is

reduced, mispricing and bubbles tend to completely disappear. Our conclusions confirm otherwise: both in adolescents and in children, bubbles are still formed even if we induce a less confused context, using a Gold Mine treatment. As stated in section B of our results, it is clear that both treatments generate mispricing, a conclusions that differs from behaviour in adults. Cognitive immaturity might prevent the Gold Mine treatment to eradicate bubble formation.

3. Both adolescents and children form bubbles, but their characteristics are very different. Adolescents form bubbles right at the first period, where mean price is already higher than the fundamental value in said period. Yet, adolescents, regardless of the treatment used, end up bursting the bubble at some point. At the last period, mean prices are equal to the fundamental value. Bubbles in adolescents follow a similar patron to bubbles in adults, despite little differences: namely, in every experiment with adults in SSW **[20]**, mean prices in the first period are below their fundamental value.
4. Nonetheless, children generate very distinct bubbles, their main characteristic being the fact that bubbles never burst. Children do not understand that they are overvaluing the asset and, even if its residual value is null and periods are finite, mispricing in the final period is still very substantive. We can infer that children, in general, are not able to effectively assess the value of an asset and, thus, totally misprice them in market transactions.
5. Our conclusions in adolescents are not inconsistent either with Fama (1970) **[5]** (no arbitrage profits) or with Tirole (1982) **[22]**. Adolescents tend to converge to near the rational expectations' equilibrium in the sense of Muth (1961) **[15]** in the last trading periods: expectations of adolescents are adaptive and such adaptation is to the rational expectations outcome. These results are consistent with SSW's **[20]** findings in adults. Similarly, as SSW **[20]** also concludes, common knowledge on the experiment and on the dividends is not sufficient to induce initial common priors. At the end, adolescents achieve such common priors, yielding to results consistent with Tirole (1982) **[22]**.
6. Children's results are definitely inconsistent with rational expectations equilibria, the theory of no arbitrage profits and the model of common priors. Children behave irrationally and the fact that bubbles are never burst makes it clear that their evaluation mechanisms of the market are not yet efficient. Although some subjects truly understand the experiment and the market characteristics, most of the

subjects are not able to do so.

7. Regarding the first research question (i) we can conclude that there are indeed differences in whether the Gold Mine treatment is implemented in children or in adolescents. Overvaluation of the asset is higher in children what seemingly leads to more lasting bubbles, and finally, average turnover is also greater in children, what seems reasonable given that SSW **[20]** determines that average number of transactions is higher when participants are more inexperienced and we believe there is a link between inexperience and lack cognitive maturity.
8. Concerning the second research question (ii) we find similar results to those in the previous research question. All statistical tests lead us to determine again that children overvalue the asset, create more lasting bubbles and that the average number of transactions is higher, thus, there certainly are differences in children and adolescents for the treatment SSW.
9. Proceeding to comment research question number three (iii) we see that children respond different depending on the framing; bubbles are both larger and last longer with the treatment SSW the only exception being that the turnover keeps put. Finally, vis-à-vis research question four (iv) we do not have enough evidence to statistically state there are differences: data suggests that adolescents act the same regardless of the treatment.

6. Conclusions

In this paper we observed both the difference between children and teenagers when they face a bubble and whether the framing of the experiment could affect the results observed. After designing two experimental treatments in order to control for the level of confusion affecting our subjects' behaviour, we hypothesised that (i) results would differ when comparing confused/less confused children with confused/less confused adolescents and (ii) results would differ when comparing confused children/adolescents with less confused children/adolescents. Our results conclude that (i) children always create larger bubbles than adolescents, (ii) children never burst the price bubble, while adolescents always do, and (ii) changing the level of confusion is insufficient to statistically change the bubble in adolescents, whereas it changes the bubble (without making it disappear) in children.

Our results are also consistent with the previous research on experimental asset markets. Past studies had shown that (i) agents engage on trading (even though the

initial allocation is itself efficient) because there is "sufficient home-grown diversity in agent price expectations to induce subjective gains from trade" (SSW, 1988, p. 1158) **[20]**, (ii) distinct bubble patrons appear when different experimental treatments are run and (iii) the level of confusion affecting the subjects has a big impact on the results observed and can even abate bubbles.

Our results specifically show that (i) cognitive immaturity, a source of "home-grown diversity in agent price expectations", explains the level of trade observed, (ii) the bubbles created by children are significantly different from those created by teenagers and (iii) the level of confusion affecting the subjects does also have an impact on results. In the light of past results, our paper reinforces the idea that confusion, via different framing or via different cognitive maturity, is a main driver of bubble formation in experimental asset markets. Basically, the less subjects understand the experiment, the more bubbles we observe.

However, we also conclude that, contrary to the predictions of the theory, the Gold Mine treatment does not completely abate bubbles neither in children nor in adolescents.

Finally, further developing our findings in adolescents and children by running different experimental treatments, namely more/less liquidity, short-selling allowed, experienced insiders, etc., merits careful investigation.

References

1. Baghestanian, Sascha, and Walker, Todd B. (2014): "Anchoring in Experimental Asset Markets", *SAFE Working Paper*, 54.
2. Blanchard, Olivier J. (1979): "Speculative Bubbles, Crashes and Rational Expectations", *Economics Letters,* 3, 387-389.
3. Caginalp, Gunduz, Porter, David P., and Smith, Vernon L. (2001): "Financial Bubbles: Excess Cash, Momentum, and Incomplete Information", *The Journal of Psychology and Financial Markets*, 2, 80-99.
4. Ezekiel, Mordecai (1938): "The Cobweb Model", *The Quarterly Journal of Economics*, 52, 255-280.
5. Fama, Eugene F. (1970): "Efficient Capital Markets: A Review of Theory and Empirical Work", *Journal of Finance*, 25, 383-417.
6. Harbaugh, William T., Krause, Kate, and Berry, Timothy R. (2001): "GARP for Kids: On the Development of Rational Choice Behavior", *The American Economic Review*, 91, 1539-1545.

7. Harbaugh, William T., Krause, Kate, and Vesterlund, Lise (2002): "Risk Attitudes of Children and Adults: Choices Over Small and Large Probability Gains and Losses", *Experimental Economics*, 5, 53-84.
8. Harbaugh, William T., Krause, Kate, and Vesterlund, Lise (2007): "Learning to Bargain", *Journal of Economic Psychology*, 28, 127-142.
9. Haruvy, Ernan, and Noussair, Charles N. (2006): "The Effect of Short Selling on Bubbles and Crashes in Experimental Spot Asset Markets", *The Journal of Finance*, 61, 1119-1157.
10. Hogarth, Robin M., and Camerer, Colin F. (1999): "The Effects of Financial Incentives in Experiments: A Review and Capital-Labour-Production Framework", *Journal of Risk and Uncertainty*, 19, 7-42.
11. Huber, Jürgen, and Kirchler, Michael (2012): "The impact of instructions and procedure on reducing confusion and bubbles in experimental asset markets", *Experimental Economics*, 15, 89-105.
12. Kirchler, Michael, Huber, Jürgen, and Stöckl, Thomas (2012): "Thar She Bursts: Reducing Confusion Reduces Bubbles", *American Economic Review*, 102, 865-883.
13. Krause, Kate, and Harbaugh, William T. (1999): "*Economic Experiments That You Can Perform at Home on Your Children", University of Oregon Department of Economics Working Paper*, 1.
14. Moinas, Sophie, and Pouget, Sebastien (2012): "The Bubble Game: An Experimental Study of Speculation", *Southern Economic Journal*, 82.
15. Muth, John F. (1961): "Rational expectations and the theory of price movements", *Econometrica*, 29, 315-335.
16. Noussair, Charles N., Robin, Stephane, and Ruffieux, Bernard (2001): "Price Bubbles in Laboratory Asset Markets with Constant Fundamental Values", *Experimental Economics*, 4, 87-105.
17. Porter, David P., and Smith, Vernon L. (1995): "Futures Contracting and Dividend Uncertainty in Experimental Asset Markets", *The Journal of Business, The University of Chicago Press*, 68, 509-541.
18. Smith, Vernon L. (2010): "Theory and Experiment: What are the Questions?", *Journal of Economic Behaviour & Organization*, 73, 3-15.
19. Smith, Vernon L., Van Boening, Mark (1993): "The Robustness of Bubbles and Crashes in Experimental Stock Market", *Oxford University Press,* 183-200.
20. Smith, Vernon L., Suchanek, Gerry L., and Williams, Arlington W. (1988):

"Bubbles, Crashes, and Endogenous Expectations in Experimental Spot Asset Markets" *Econometrica*, 56, 1119-115.

21. Stöckl, Thomas, Huber, Jürgen, and Kirchler, Michael (2010): "Bubble Measures in Experimental Asset Markets", *Experimental Economics*, 13, 284-298.
22. Tirole, Jean (1982): "On the Possibility of Speculation under Rational Expectations", *Econometrica*, 50, 1163-1182.

Acknowledgements

Had it not been for the invaluable contribution of many people around us, this paper would not have been a reality.

We are sincerely grateful to *Escola Avenç, Escolàpies Sant Martí, Escolàpies Llúria Barcelona, Escola Pia Nostra Senyora, Institut Verdaguer, Escola Voramar* and *Escola Frederic Mistral-Tècnic Eulàlia*, which kindly collaborated to our experiments. Without their help, our sample would never have been possible.

We would also like to thank Dr. Rosemarie Nagel for her insightful and wise comments. They were more useful than she might think.

Finally, our most heartfelt thanks to Dr. Marta Reynal-Querol for her guidance and help in the achievement of this work. We hope she keeps giving support to her students with such enthusiasm.