How Do Markets React to (Un)expected Fundamental Shocks? An Experimental Analysis

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ABSTRACT

We rely on experimental asset markets to study the impact of expected and unexpected fundamental value shocks on prices and turnover. We collected data for a total of 36 markets, 21 markets with constant fundamental value and 15 markets with stochastic fundamental value (8 with upward shocks and 7 with downward shocks). Price bubbles appear in almost all markets, with and without FV shocks. FV shocks affect negatively transaction prices, deflating the price bubble, and negatively trading volumes. These results suggest that FV shocks tend to reduce information asymmetry. Specifically, lower spread between median/mean prices and fundamental value (lower price deviation) and lower turnover have been observed. The depression effect on the volume of transactions after a shock is observed whatever the direction (upwards or downwards) and the type (expected or unexpected) of the shock. Transactions prices tend to underreact following a negative shock and no reaction following positive shock. Finally, shocks increase sharply the difference of opinions, but this effect does not affect the volume of transactions.

Keywords: Experimental asset market, underreaction, over-reaction, price bubble.

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I. Introduction

The experimental literature on financial markets has provided ample evidence about the relevance of price bubbles in laboratory asset markets. The seminal findings of Smith, Suchanek, and Williams (1988) (SSW hereafter) have been replicated and extended by a growing literature (e.g., King et al. (1993), Van Boening, Williams, and LaMaster (1993), Lei, Noussair, and Plott (2001), Noussair, Robin, and Ruffieux (2001), Haruvy and Noussair (2006), Gunduz, Porter, and Hao (2010), Noussair and Richter (2012), Noussair and Tucker (2014), Noussair, Tucker, and Xu (2014) and Stöckl, Huber, and Kirchler (2015)[1].

So far, most experiments relied on a deterministic process of fundamental value (FV thereafter). While such an assumption is useful for identifying and isolating the characteristics of speculative behavior in the lab, it may lead to particular behavioral insights that are valid only for rather unrealistic contexts. For instance, a deterministic FV may encourage speculation by traders who are over-confident in their ability to buy low and sell high. Introducing randomness in the FV process may therefore temper experimental traders' speculative expectations and, as a consequence, prevent the formation of price bubbles. Compared to a situation where the FV is deterministic, and therefore perfectly anticipated, when traders are exposed to a stochastic FV process, they face both strategic uncertainty and background uncertainty, providing therefore a more important role for expectations.

The purpose of this paper is to study experimentally the formation of asset price bubbles in experimental markets. Generally speaking, empirical studies suffer from the impossibility of observing the FV. In experiments fundamentals become clearly observable as they are controlled by the experimenter. This advantage however, comes at a cost of external validity and subject pool effects (Hanke et al. (2010)). In our experiment we control for shocks: the FV process may be affected by random shocks, which can either be expected or unexpected by the traders.

More specifically, we compare markets in which traders are perfectly aware that a shock will occur and in which period, but they ignore the direction of the shock, to markets in which traders are perfectly aware that a shock may occur and they ignore the period and the direction of the shock.

In our framework a shock consists is an upwards or downwards shift of the FV path. We consider binary symmetric shocks, i.e. the upwards shift is of the same magnitude than the downwards shift with uniform probability. We compare markets with shocks to markets without shocks by considering mean-zero shocks, keeping thereby constant the expected FV before the outcome of the shock applies. In markets without shocks we implement a constant FV path as in Noussair, Robin, and Ruffieux (2001).

Introducing a mean zero perturbation of the FV path is similar to adding an *unfavorable background risk,* i.e. a zero or negative mean risk, to a preexisting risk. Such increase in risk affects negatively risk-taking for decreasingly risk-averse agents as shown in Gollier and Pratt (1996), a conjecture which is experimentally supported (Beaud and Willinger, 2015). We therefore expect that the introduction of a binary symmetric shock in an experimental asset

[1] For detailed reviews on experimental asset markets we refer to Palan (2013) and Powell and Shestakova (2016). In addition, the review of Morone and Nuzzo (2016) is of particular interest as it is focused on diffusion of information.

market is likely to increase the demand for the risk-free asset and thereby mitigates the formation of a price bubble.

We implemented a within-subject design for which each subject was first involved in a market without a shock and later in a market with shock. Subjects were endowed with different types of portfolios and their main task was to submit bids and asks for trading units of a financial asset. We elicited individual price expectations at the opening of each market round in order to measure the traders' difference of opinions (DO).

Our main findings are the following. First, we observe price bubbles in markets without shocks as well is in markets with (expected or unexpected) shocks. However, on average the price deviation of the median prices from the FV is lower after a shock, suggesting a reduction in the variability of price expectations among traders. Second, after a downward shock we observe that the median price underreacts in contrast to an upwards shock where neither underreaction nor overreaction is observed. Third, after a shock the difference of opinions (DO hereafter) increases, whatever the type of the shock (expected or unexpected) and whatever its direction (upward or downward), except with upward unexpected shock. Unexpectedly the larger DO induced by shocks is not accompanied by larger transaction volumes, but instead by a sharp drop in them.

Our findings contribute to the understanding of the formation of asset price bubbles in a richer context where the FV is affected by random shocks. They also contribute to the understanding of traders' behavior who are both exposed to strategic uncertainty as well as background uncertainty.

The rest of the paper is organized as follows. In section 2 we review the main findings of the experimental literature on asset markets with deterministic FV. Section 3 describes our experimental design. In section 4 we discuss the theoretical predictions of FV shocks on prices, transactions and DO. Section 5 presents our results and Section 6 discusses our findings.

II. Literature review

Most of the literature on experimental financial markets has focused on a single asset with a deterministic FV, i.e. subjects can know in advance the time path of the FV. Moreover, until recently this literature also assumed a monotonic (non-stochastic) FV process. Recent exceptions are Noussair and Powell (2010), Kirchler, Huber, and Stockl (2012), Breaban and Noussair (2013) and Stöckl, Huber, and Kirchler (2015). A few papers also introduced a stochastic FV "random-walk FV-processes" (Weber and Welfens (2007), Nosic and Weber (2009), Kirchler (2009), Nosic, Weber, and Glaser (2011), Kirchler, Huber, and Kleinlercher (2011), Stöckl, Huber, and Kirchler (2015). There is therefore scarcity of knowledge with respect to one of the key components of real financial markets, stochasticity. Furthermore in real asset markets, the FV process is not only stochastic, it is also unobservable. Traders are therefore unable to predict exactly the time path of the FV. The advantage of relying on experimental asset markets is that the experimenter is able to observe the FV process and the traders' behaviors and expectations with respect to stochastic FV shocks. Identifying the reactions of market prices and transaction volumes to such shocks, which is a challenging issue with real market data, becomes easy with experimental data.

In what follows, we briefly review the key findings of the literature that relied on a deterministic FV before discussing the attempts to take into account randomness in the FV process. Most of the literature that relied on a deterministic FV assumed also monotonicity of the FV process. The first experiment (SSW)[2] was based on a monotonically decreasing FV. The implementation of such a process is straightforward. Subjects are informed that each unit of stock entails a random dividend payment $\tilde{x}_t$ at the end of each period which is i.i.d. for each t. Let us therefore note $\bar{x} = E[\tilde{x}]$ the per period constant expected value of the dividend payment. The stock market opens for a limited number of trading periods T which is common knowledge. Therefore for t > T the FV is equal to 0 and for t < T the FV is equal to $(T - t)\bar{x}$.

Many of the later papers adopted this design (e.g., Noussair, Robin, and Ruffieux (2001), Noussair and Richter (2012) Smith, Boening, and Wellford (2000), Haruvy, Noussair, and Powell (2013), Huber and Kirchler (2012), Kirchler, Huber, and Stockl (2012)[3], Ikromov and Yavas (2011), Giusti, Jiang, and Xu (2012) and Strážnická and Weber (2011)). The main finding of this literature is that price bubbles are frequent and robust to various market mechanisms, e.g. short-selling (Haruvy and Noussair (2006) and King et al. (1993)) lack of common knowledge (Lei, Noussair, and Plott (2001)), availability of non-speculative markets (Lei, Noussair, and Plott (2001)) and constant FV process (Noussair, Robin, and Ruffieux (2001)). However experimental papers which implemented an increasing FV over time (e.g., Giusti, Jiang, and Xu (2012), Johnson and Joyce (2012) and Stöckl, Huber, and Kirchler (2015)) did not find significant evidence for bubbles, confirming the conjecture of Smith (2010) and Oechssler (2010) that bubbles are less likely under increasing FV patterns, which correspond to the market experience of most individual traders.

A few papers examined the case where the FV is non-monotonic (Noussair and Powell (2010), Breaban and Noussair (2013) and Kirchler (2009)). Noussair and Powell (2010) investigated how the trajectory of FVs affects price discovery in an experimental asset market and transaction prices behavior facing downward and upward variation of FV. They used two treatments *Peak* and *Valley*. In the *Peak* treatment, fundamentals first rise and then fall, while in the *Valley* treatment fundamentals first fall and then recover. They found that both *Peak* and *Valley* treatments generate bubbles when traders are inexperienced. However, price discovery is faster and complete in the peak treatment for which the prices track the FV, the direction of the trend, and changes in the trend, more closely than in the valley treatment. Breaban & Noussair (2014) studied how the time path of the FV trajectory affects the level of adherence to fundamentals, by comparing the level of mispricing for decreasing and increasing FV trajectories. They observed closer adherence to FVs when the trajectory follows a decreasing rather than an increasing trend.

In experiments where the FV fluctuates randomly, as in Gillette et al. (1999) or Kirchler (2009), market prices tend to underreact to changes in FV leading to lower prices when the

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[2] Research in multi-period experimental asset markets has started with Smith (1962), Smith (1982) and Plott and Sunder (1982), but is now dominated by SSW.

[3] The authors show that adding a "gold mine" context to the standard declining FV process considerably abates bubbles.

FV is predominantly increasing and to higher prices when the FV is predominantly decreasing. In other words there seems to be a tempering effect of random shocks on the price deviation from the FV. The latter issue was more clearly investigated by Weber and Welfens (2007) who studied how prices react to the arrival of new information about the final value of the asset with a non-deterministic FV. In the first half of the rounds, subjects knew that four equally likely values were possible. In the beginning of the second half of the rounds they were told either that only the two higher values were discarded (negative FV shock) or the two lower values were discarded (positive FV shock), the remaining values being equally likely. After a positive shock, prices underreact strongly while after a negative shock underreaction is much less pronounced. However, in both cases after the shock the average price slowly converges towards the new postshock FV. The authors appeal to the disposition effect (Statman and Shefrin (1985)) to explain the underreaction asymmetry and momentum[4]. Introducing a Tobin tax is comparable to providing new information about the FV as in Weber and Welfens (2007). Hanke et al. (2010) and Kirchler, Huber, and Kleinlercher (2011) compared the impact of an unexpected Tobin tax under various market settings. For instance, in Kirchler, Huber, and Kleinlercher (2011) different market microstructures (with and without market makers) are compared. The authors observed that in markets without market makers an unilaterally imposed Tobin tax (i.e. a tax haven exists) increases volatility. In contrast, in markets with market makers they observe a decrease in volatility in unilaterally taxed markets. Stöckl, Huber, and Kirchler (2015) compared different FV regimes, in particular deterministic and non-deterministic FVs. They found efficient pricing with constant FVs, overvaluation with decreasing FVs, undervaluation with increasing FVs and overvaluation (undervaluation) when FVs predominantly decline (when FVs are mostly upward- sloping) with randomly fluctuating FVs.

Our experimental setting is close to Weber and Welfens's (2009). The main difference is that we rely on a standard asset market consisting in successive periods (days). In our markets traders participate to 15 two minutes trading periods. The shock always happens in period 8. This allows to have sufficient periods before and after the shock to observe eventual price bubbles and to detect changes in prices, volumes and expectations. In contrast, Weber and Welfens (2007) consider a single trading period with an interruption in the middle to announce new information about the possible states of the world. The new information "shifted" the FV upwards or downwards, and subjects had only 120 seconds for trading before and after the shock. Our design allowed for 8 periods of 120 seconds each before the shock and 7 periods of 120 seconds after the shock, which provides more feedback information (e.g. closing prices after each round) and more time to observe the formations of prices bubbles.

[4] In a preliminary stage of the experiment the authors relied on subjects' decisions in an individual choice task to classify them either as high or low "disposition-prone". Subjects are matched by type in high or low "disposition-prone" markets. The authors observe higher underreaction and higher momentum in high disposition markets.

III. Experimental Design

A total of 270 subjects participated in the experiment. They were recruited from a large subject-pool (with over 7000 volunteers) with ORSEE (Greiner (2004)). Subjects were students[5] from different disciplines at the University of Montpellier (France). They were inexperienced with experimental asset markets and could participate only in one session (table 1). The experiment was programmed with the z-Tree software (Fischbacher (2007)). In each session, two independent groups[6] of nine subjects traded in a sequence of two markets: market 1 and market 2. Each market consisted of 15 periods, during which individuals could trade units of an asset. It was common knowledge that the asset's lifetime was equal to the 15 periods. The numéraire in the experiment consisted of "Experimental Currency Units" (ecus), which were converted into euros at the end of a session at a predetermined, publicly known, conversion rate *(1 euro = 337.5 ECUs).* Each session lasted approximately 3 hours, including instructions and payment of subjects. Subjects earned on average 28 euros.

The experiment is broken into three treatments: **T1** *"Expected fundamental shock"*, **T2** *"Unexpected fundamental shock"* and **T0** *"No-shock"*. Market 1 is the same in all three treatments and similar to the market studied by Noussair, Robin, and Ruffieux (2001) in which the FV of the asset is constant over the entire life of the asset. By contrast, in treatment T1 and T2, market 2 (inspired by Weber & Welfens's (2007) design), involves a shock in period 8 on the FV which becomes either larger or lower compared to the pre-shock value. In T1 subjects are informed that a random shock will arise at the end of period 8. In treatment T2 the shock is the same as in T1 but subjects ignore that a random shock will arise in the end of period 8[7]. Treatment T0 represents a control treatment in which subjects participate in two consecutive identical markets with constant FV (two markets without shock). Table 2 summarizes our experimental design and the parametric setting. The instructions provided to subjects are available in appendix 1.

Each session was divided into three parts: part one (real effort task), part two (experimental markets) and part three (risk aversion questionnaire).

IV.1 - Part one: real effort task

In part 1 subjects had to perform a real effort task in order to accumulate *private money*. The task consisted to count the number of "1's" in a grid containing a sequence of "0's" and "1's"

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[5] Most of our subjects are graduate student from scientific, economic and business administration disciplines (see table 1). Haigh and List (2005) showed that professional traders do not better (and partly worse) than university students in an investment task that examines myopic loss aversion.

[6] In one of the sessions we had only one group due to the absence of several subjects.

[7] T2 is the closest to the real stock market, where traders have often good or bad unexpected news about the value of their stock. To avoid the deception effect we used a design characterized by an unexpected news, knowing that the news in our design are related to the terminal value of stocks (buyout).
Two experimental market studies used a design characterized by an unexpected Tobin tax news (Kirchler, Huber, and Kleinlercher (2011) and Hanke et al. (2010)). In both studies subjects do not get any information about the potential implementation of transaction taxes before the main experiment starts and they are not informed whether and when the tax regime is changed again. Furthermore, the tax rate is also placed on the trading screen once a tax has been introduced. By contrast in the following studies (Bloomfield et al. (2009) and Cipriani and Guarino (2008)) subjects know in advance that Tobin tax will be levied.

(appendix). The reason of part 1 was to avoid the house-money effect (DeBondt and Thaler (1990), (Thaler and Johnson (1990), Ackert et al. (2006)) that is likely to favor speculative behavior in the experimental asset markets. The private amount accumulated in part 1 will then be used for making bids in the second part of the experiment. In order to avoid another source of variability due to possible differences in task performance, subjects received a flat rate for task completion. All subjects who had succeeded in achieving the task received 6,750 ecus (which corresponds to 20 euros) to participate in the second part of the experiment. The part one condition was: "*Those who do not complete the task will not be able to participate in the second part and their pay was equal only to participation fee*". It is important that these facts are common knowledge. Subjects were aware that all market participants have been successful in performing the task and furthermore have the same earning.

Table 2: Experimental design

Mar kets	***Type***	***Direc-tion***	***Groups***	***Portfolio type: endowments (ecus, shares)- number – portfolio value (ecus)***	***Dividend Distribution (ecus), probability, expected value and variance***	***FV from period 1 to 8***	***FV from period 9 to 15***
Markets 1			*G1-G19*	*P1: (5850, 3) – 3 – 6,750* *P2: (4950, 6) – 3 – 6,750* *P3: (4050, 9) – 3 – 6,750*	*D= (-45, -15, 15, 45)* *P(D)= (1/4, 1/4, 1/4, 1/4)* *E(D) = 0* $\sigma^2(D)$*= 1125*	*FV = 300*	*FV = 300*
Markets 2	***T0: No-shock***		*G17, G18, G19*	*P1: (5850, 3) – 3 – 6,750* *P2: (4950, 6) – 3 – 6,750* *P3: (4050, 9) – 3 – 6,750*	*D= (-45, -15, 15, 45)* *P(D)= (1/4, 1/4, 1/4, 1/4)* *E(D) = 0* $\sigma^2(D)$*= 1125*	*FV = 300*	*FV = 300*
	T1: Expected	***Up***	*G1, G3, G5, G7*				*FV = 200* *Or* *FV = 400*
		Down	*G2, G6, G8*				
	T2: Unexpected	***Up***	*G20, G21, G24, G25*				
		Down	*G23, G24, G26, G27*				

Note: Each market had 15 transactions periods and each period lasted two minutes. Each subject participated in market 1 (without shock) followed by market 2 (with shock in T1 and T2 and without shock in T0).

IV.2 - Part two: Experimental markets

In this part, subjects participated in a sequence of two consecutive markets. Before market 1 began subjects were randomly assigned to a group of nine traders. The groups remained identical for the two markets. In each group subjects were randomly assigned to one of three types: P1 trader, P2 trader or P3 trader. Each group consisted of 3 traders of each type. Each trader type was defined according to the composition of its portfolio. However the expected portfolio value is equal to 6,750 ecus for all types (P1, P2 and P3). Table 2 describes the portfolio composition of each type.

Before starting the first market, subjects were involved in a training phase for two minutes to allow them to become comfortable with the interface. Gains and losses of the training phase were not counted as accumulated wealth for cash payment.

a) Market One

After the training phase, subjects participated in the fifteen market periods of market 1. Each trading period lasted 2 minutes, during which subjects could buy and/or sell units of a single stock. Prices were quoted in terms of experimental currency units (ecus), and gains were converted into euros at the end of the session. The traded asset had a fifteen period lifetime.

At the end of each period, the asset paid a dividend of either 45 or 15 ecus, or incurred a holding cost of either -15 or -45 ecus. A random draw determined at the end of each period the dividend or the holding cost for that period, with uniform probability (according to the roll of a four-sided die). The expected value of the dividend/holding cost equals therefore zero in each period. Dividends and holding costs were accumulated in a separate account and were added and subtracted from the final market gain (accumulated and distributed at the end of the last period). The separate account was introduced in order to keep constant the liquidity and the number of stock constant over time. However, subjects were informed after each period about the dividend/cost level of that period.

Each unit of the asset paid a terminal value (buyout) of 300 ecus to its owner at the end of market 1. Thus the FV for each unit of the asset is equal to 300 ecus at any period[8] of market 1. The dividend process, the number of periods and the terminal value were common knowledge.

At the beginning of each period, subjects were required to make a price forecast about the current period contract prices. We asked them to provide a forecast in interval form, by setting a lower bound and an upper bound in the beginning of each period. The forecasting task was incentivized as follows: the forecast profit of subject $\mathrm{i} = 1,..,9$ $in\, period\, t$ was defined by $\pi_{i,t} = Max(G_{i,t}; 0)$, where $G_{i,t}$ equals :

$$G_{i,t} = \quad 10\,\frac{h}{h^*{}_t} \quad - \quad 5 \quad \frac{(a_i - a^*{}_t)}{a^*{}_t} \quad for\ \ a_i - a^*{}_t > 0$$

$$G_{i,t} = \quad 10\,\frac{h}{h^*{}_t} \qquad\qquad\qquad for\ \ a_i - a^*{}_t \leq 0$$

[8] The FV of a unit of asset in period t equals $f_t = Buyout + (T - t) \times E(d_t),\ t = 1, 2, \ldots, T$, where f_t correspond to the FV in period t, T the total number of periods, t the current period and $E(d_t)$ the expected value of the dividend payment in period t. In our markets $E(d_t) = 0$ for all t, so $f_t = Buyout$ for all t.

$a^*{}_t$ is the size of the realized price interval $a^*{}_t$ ={$max_t\ (P_t) - min_t(P_t) + 1$}, a_i is the size of the predicted interval, i.e. a_i ={upper bound – lower bound + 1} for subject i, $h^*{}_t$ is the total number of transactions in period t, h is the number of transaction prices which felt into the forecasted interval. Note that the forecast payoff is at most equal to 10 ecus and at minimum 0 ecus.

b) *Market 2*

The only difference between market 1 and market 2 (in treatments T1 and T2) is that the latter involved a FV shock for most groups. We therefore only describe the characteristics of the shock for market 2. The shock always affects the FV at the end of period 8 (an extract of this section of the instructions is provided in Appendix 1.A).

T1: *Expected fundamental value shock*:
Two final buyout values are possible after the shock: 200 or 400 ecus with equal probability. Hence, the expected value of the buyout in the pre-shock periods was equal to 300 ecus as in market 1. All subjects knew that at the end of period 8, one of the two possible buyout values would be randomly selected and publicly announced to all members of their group. The shock could be upward if the selected value was equal to 400 ecus or downward if the selected value was equal to 200 ecus. After the shock, the final buyout was displayed on the subject's screens and the FV was equal to the selected buyout.

T2: *Unexpected fundamental value shock:*
In this treatment, subjects were aware that the FV may change. At the beginning of market 2, we told them that the initial FV was equal to 300 ecus as in market 1 but it is possible that a new information regarding the terminal value will be provided to them during the market. More precisely, they don't know neither the type of news (good or bad) nor the period of news announcing.
At the end of the period 8, a warning message was displayed on their screens, in which they could read that the final buyout was no longer equal to 300 ecus but to 400 ecus in the upward case or to 200 ecus in the downward case. In addition to the displayed message, the experimenter announced aloud that a new redemption value was set.

T0: *No fundamental value shock:*
This treatment represents a control treatment in which subjects participate to two similar markets with constant FV (two markets without shock).

At the end of the session one of the two markets was randomly selected to be paid out. Subjects were aware of this rule before starting market 1. The final gain/loss in ecus for the selected market was determined as follows:

$$Final\ gain = Final\ cash\ balance + (Final\ buyout \times Inventory\ of\ asset) + Savings\ account\ balance$$

Note that the savings account consisted of the accumulated net dividends and forecasts profits. The cash balance could evolve with successive transactions, in particular by capital gains (losses) due to difference between selling and buying prices of units of stock.

Subjects final earning was equal to their final gain for the selected market plus their participation fee.

IV.3 - Part three: Risk aversion and demographic questionnaires

Subjects were asked a series of questions on their self-declared risk attitudes. More precisely, they were asked about their willingness to take risks in general and in specific contexts, e.g. driving, financial matters, health domain, occupational risks, sports, and social risks. Subjects had to indicate their answer on a scale ranging from 0 to 10*: 0 if extremely risk averse and 10 if fully prepared to take risks* (see Appendix 1.B). This questionnaire follows closely Vieider et al. (2014). A final short questionnaire allowed to collect demographic data (age, gender, ... etc.).
The next section exposes the theoretical predictions of FV shock effects.

IV. Predictions

In this section we state our key predictions about the impact of a FV shock. Our statements rely both on theoretical arguments as well as on empirical regularities. We break the predictions into two categories: predictions about changes in asset prices and predictions about changes in trading volumes.

IV.1 Price predictions

According to the Efficient Market Hypothesis (EMH) competition among investors clears all positive net present value trading opportunities (Fama, 1970), implying that securities are fairly priced, based on their FV and the information that is available to investors. Therefore after an exogenous shock stock prices should convergence quickly to their FV. There are many cases against EMH (Haugen 1999). Market can overreact to news (Thaler and De Bondt (1985)) and deviations from the FVs can last several weeks creating momentum and favorable conditions for the appearance of bubbles (Jegadeesh and Titman (1993)). Barberis, Shleifer, and Vishny (1998) and Daniel, Hirshleifer, and Subrahmanyam (1998) have identified several cognitive biases that are likely to lead to such outcomes: conservatism, herding, overconfidence, the confirmation bias and the disposition effect. It is unclear how bubbles which are driven by cognitive biases, i.e. “behavioral bubbles” (DeGrauwe and Grimaldi, 2004), might be affected by FV shocks? We conjecture however, that traders who are aware of a future shock may be discouraged to trade. Consequently, we expect a price reduction after a shock and therefore a tempering effect on the formation of bubbles. In accordance with previous experimental data we conjecture that price bubbles will also occur in our experimental setting, but to a lesser extent when shocks are present.

Prediction 1: *(attenuation effect): Price bubbles emerge in markets with and without shocks, but are attenuated in markets with shocks.*

Possible reactions to a shock are: underreaction, overreaction or no-reaction. In this section we mainly focus on underreaction and overreaction. Underreaction corresponds to insufficient adjustment after a shock: prices adjust in the right direction but insufficiently to compensate the FV gap[10]. Overreaction means that prices jump above (below) the FV in case of an upwards (downwards) shock. A few experimental studies report underreaction (Gillette et al., 1999) or mis-reaction (Nelson et al., 2001) after new information becomes available.

Stevens and Williams (2004) report that forecast data reveal systematic underreaction to both positive and negative information and that underreaction is generally greater for positive information than for negative information. This conjecture is supported by Weber and Welfens (2007), who found that prices underreact both to positive and to negative shocks. However, their results suggest that the underreaction following a positive shock is stronger than the underreaction following a negative shock. Analogous evidence was provided by Caginalp, Porter, and Hao (2010) who investigated experimentally the effect of news about the underlying value of an asset on its trading price. According to their findings, investors tend to underreact to news on asset valuation. They also documented that traders "anchor" their price expectations on preexisting prices and/or valuations. Following the above findings, we suggest the following prediction:

Predictions 2-5 concern overreaction and underreaction.

Prediction 2: *(underraction): Subjects tend to underreact to news on asset valuation.*

A few studies reported market overreaction. Thaler and De Bondt (1985) and DeBondt and Thaler (1987) interpret the fact that past winners tend to be future losers (and vice versa) as evidence for overreaction. Following the literature in the vein of Morris and Shin (2002), overreaction consists in the fact that the equilibrium weight assigned to the public signal in the beauty contest (w) is larger than in the first-order expectation of the fundamental (f). In an experiment, overreaction can be assessed either against the theoretical weight or against the observed weight assigned to the public signal in the first-order expectation.

Prediction 3: *Markets overreact to new information.*

Based on field data, DeBondt and Thaler (1990) rejected the hypothesis that forecasts are unbiased expectations. Their results are consistent with overreaction, more precisely they show that forecasts are too extreme and then tend to be corrected. Odean (1998) shows that

[10] Frazzini (2006) provides in his study a test of underreaction hypothesis. He describes the main of underreaction hypothesis as follow: under the conjecture of the presence of disposition-prone investors, stock prices underreact to a specific set of news, and thereby generate post-event drift. More precisely when most of the current holders are facing a capital loss (capital gain), stock prices underreact to negative news (positive news) and in turn generate a negative (positive) post-announcement price drift. Moreover, holding the news constant, the capital gains overhang forecasts post-event returns.

investors who think that their signal is more accurate than it really is, tend to overreact to their signal which generates overreaction of market prices.
Several studies have identified the occurrence of overreaction in laboratory experiments. For instance: Kahneman and Tversky (1973) showed experimentally that subjects tend to put too much weight on meaningless and practically irrelevant information. In the same vein Massey and Wu's (2005) experimental study indicates that individual overreaction is present if subjects receive information with relatively high strength and low weight. Hommes et al. (2005) reported individual and aggregate overreaction in experimental prediction markets. In their setting market prices are generated by an asset pricing model with heterogeneous beliefs. More precisely in their design a computer determines market prices by taking the average beliefs of all market participants and adding some extra noise term.
Griffin and Tversky (1992) provide evidence that overreaction at the individual level affects aggregate market prices and overall demand and is present in situations that are characterized by high strength and low weight. In their experiment, subjects are aware that the coin that is flipped is biased with a prior probability of 0.5 in favor for head or for tail. After having observed a sequence of outcomes, subjects are asked to report an updated probability conditional on the observed sequence. The findings of Griffin and Tversky (1992) were supported by other papers, e.g. Barberis, Shleifer, and Vishny (1998) and Sorescu and Subrahmanyam (2006).
Sorescu and Subrahmanyam (2006) analyzed the price reaction to analysts' forecast revisions and find evidence for the strength and weight hypothesis by Griffin and Tversky (1992). Using an analyst' ability and experience as a proxy for the weight of a signal and the dramatic nature of an event, i.e. the level of a down- or upgrade, as a proxy for the strength of a signal they test the hypotheses in Griffin and Tversky (1992). Consistent with their hypothesis, they show that for signals with relatively high strength and low weight market prices tend to overreact. Their results imply aggregate overreaction for large down- or upgrades (high strength) by inexperienced analysts from investment banks with a relatively bad reputation (low weight).
Thomas and Zhang (2008) provided probably the most convincing evidence for overreaction at a market level. Analyzing subsequent earnings announcements by different firms from the same industry they document that both the price of an announcing firm and the price of a non-announcing firm from the same industry move in the same direction. However, this price response of the non-announcing firm is negatively related to its price response when it subsequently announces earnings. This result indicates that prices for subsequent announcers overreact to an early announcer's earnings and are corrected later on. With the same experimental design, Biais, Nosic, and Weber (2009) found overreaction to new information both in stock price forecasts and transaction prices. They observe strong and persistent overreaction for individual estimates as well as for market prices following both-good and bad news. They also found that subjects are not able to learn from their previous failures and thus do not correct their erroneous beliefs. The trading structure of their market closely resembles to structure of Gillette et al. (1999).
Biais, Nosic, and Weber (2009) offer experimental evidence on the relationship between information signals, beliefs, and financial decisions. They use a novel experimental design, it consists to ask subjects to estimate the future asset price, incorporating as information signal

the stock price development of a related asset. Their results show (in first experimental environment) that a substantial level of overreaction seems to exist. This finding is in agreement with Griffin and Tversky (1992) findings on an individual level and on Thomas and Zhang (2008) findings on an aggregate level. Biais, Nosic, and Weber (2009) show also that more overconfident subjects tend to overreact more heavily. Finally they give evidence that more overreaction has an impact on financial variables such as portfolio risk and portfolio efficiency.

To summarize the above literature, agents tend to overreact to news both at the individual and the aggregate levels. In our experiment we focus on the aggregate level only. Furthermore, some papers also found overreaction in expectations. For instance, Bloomfield, Libby, and Nelson (2000) and Nelson et al. (2001) found that overreaction is significantly larger in stock forecasts than in prices. We conjecture therefore the following :

Prediction 4: *Overreaction is larger in stock forecasts than in prices***.**

Another interesting track gets our attention: the effects of shocks on the trading volume and on the difference of opinions/beliefs. Standard models predict that the difference of opinion of traders and the trading volume are positively related, as quoted by Nosi and Weber (2009): *"the straightforward implication that trading volume is higher the more heterogeneous the traders' beliefs are".*

IV.2 Trading volumes predictions

The standard view of the EMH is best expressed in the no trade theorem. Some authors (e.g., Milgrom and Stokey (1982)) argue that if agents have rational expectations no trade should occur even in the wake of new private information. This view was challenged by several authors, such as Harrison and Kreps (1987), Tirole (1982) and Varian (1989) among others. Their key argument is that if traders have different priors they will have different expectations about market prices even if all information is common knowledge. In other words, heterogeneity of beliefs can generate trade. Besides the possibility theorem for trade, the more relevant conjecture for our experiment is that larger heterogeneity may generate more trade, i.e. we expect to observe a positive correlation between belief heterogeneity and volume of trade. There are two possible sources of heterogeneity of beliefs in our framework: (i) differing prior beliefs and (ii) differences in subjects' interpretation of new public information. We hypothesize that in markets with expected shocks there will be higher heterogeneity before the shock because of the uncertainty about the direction of the shock, and there will also be higher heterogeneity after the shock because of differences in reactions to the shock. Therefore, in accordance with models predicting a positive relation between heterogeneity and transaction volumes (Varian (1989), Harris and Raviv (1993), Kandel and Pearson (1995), Cao and Ou-Yang (2009)) we expect to observe higher trading volumes before the shock in markets with expected shocks and after the shock in markets with expected and unexpected shocks. Empirical support for a positive relation between difference of opinion and trading volume was provided by Antweiler and Frank (2004) and Bamber, Barron, and Stober (1997)[11]. There also exists some experimental support in favor of a positive correlation between trading volume and difference of opinion. Hales (2009) shows that subjects in a 2-person economy trade more aggressively if they receive more diverging signals. Nosi and Weber (2009) investigate two competing hypotheses about higher trading volumes: differences in risk attitudes and differences of opinion. They find that only differences of opinions are significantly and positively related to trading volume.

Prediction 5: *(difference of opinion): The volume of transactions increases in the trader's difference of opinions.*

Two interesting experimental studies provide evidence about a possible link between trading volume and shocks. Nosi and Weber (2009) observed a larger number of transactions before subjects received a signal, than after receiving it. Similarly, Weber and Welfens (2007) found substantially lower levels of trading following a fundamental shock. Moreover Nosic and Weber (2009) find that the number of shares held by subjects at the end of a period varies substantially from a low of 0 to a high of 23.

Hanke et al. (2010) and Kirchler, Huber, and Kleinlercher (2011) also observed that trading volume drops after the introduction of a "surprise" Tobin tax[12]. Introducing suddenly such a tax is similar to an unexpected negative FV shock The findings of the papers mentioned above support the finding of Mannaro, Marchesi, and Setzu (2008) who include a group of random traders and contrarians in addition to fundamentalists and chartists and find a negative impact of a Tobin tax on trading volatility and a positive impact on volatility. Theses findings allow us to refine prediction 7 as follows:

Prediction 5.1: *Shocks affect negatively the trading volume.*

Finally, if shocks affect negatively the trading volume, and if the trading volume and the difference of opinion of traders are positive related, then shocks should also reduce the difference of opinion.

Prediction 5.2: *Shocks reduce the difference of opinion of traders.*

The next section describes the procedures of the experiment.

V. Results

V-1 Descriptive results

[11] Antweiler and Frank (2004) compare the level of disagreement in internet stock messages boards with trading volume in stock markets. They find evidence for the positive relation between difference of opinion and trading volume. Bamber, Barron, and Stober (1997) show in their study (accounting literature) that trading volume around earnings announcements is related to different aspects of disagreement among agents.

[12] In both experiments, the introduction of the Tobin tax was unexpected by the participants.

In this subsection we provide an overview of our data. We observed 7 groups for treatment T1, 8 groups for treatment T2 and 3 groups of treatment T0 (see table 1). Each group participated in two consecutive markets. We therefore have 36 markets in all (7 with expected shock, 8 with unexpected shock and 21 without shock).

Figure 1 shows the time series (for all groups and all treatments) of the median[13] transaction price for markets without shock and markets with shock. It can be seen that for almost all markets, median prices are substantially higher than FVs in most periods. Clear bubble patterns are therefore visible in our experimental markets with and without shocks whatever the direction (upward or downward) and the type (expected or unexpected) of the shock.

(Please insert Figure 1 **about here)**

Result 1. *Bubbles arise in all markets, with and without shocks.*
With respect to market 1, result 1 is in line with the findings of Noussair, Robin, and Ruffieux (2001) that *"A constant FV is not sufficient to remove the tendency for bubbles and crashes to form in experimental markets".*
In markets 2 we can observe clearly that bubbles are attenuated probably due to an experience effect (figure 1, treatment T0), when subjects replicate the same market without shock. By contrast bubbles are not attenuated by the shock whatever the direction and the type of the shock. We can therefore consider that shocks contribute to the persistence of bubbles.

Visual inspection of figure 1 provides further insights about the effects of a shock on prices. On average, prices remain above the FV before and after the shock in both treatments. On average, median prices do not seem to react after an upwards shock in both treatments. However, underreaction seems to prevail following a downward shocks.

V-2 Bubbles

In this subsection we provide detailed evidence about bubbles, based on standard empirical measures that were introduced in previous papers (e.g.: Porter and Smith (1995), Noussair, Robin, and Ruffieux (2001), Corgnet et al. (2014)): *(i) price amplitude (PA), (ii) normalized absolute FV deviation (ND), (iii) duration (D)* and *(iv) share turnover (ST).* Let us define more precisely each of the four measures. The *price amplitude (PA)* is defined as the difference between the peak and the trough of mean period prices relative to the FV, normalized by the initial FV. Formally, $PA = max_t\{(P_t - f_t)/f_1\} - min_t\{(P_t - f_t)/f_1\}$, where P_t is the median transaction price in period t and f_t is the FV in period t. In markets without shock $f_t = 300$ for all t. In markets with shock $f_t = 300$ for all t before the shock (i.e. t = 1, …, 8). For all t after the shock (i.e., t = 9,...,15), f_t =200 if the shock is downward and f_t =400 if the shock is upward. The *normalized deviation (ND)* is the sum, over all transactions, of the deviations of prices from the FV, divided by the total number of shares

[13] We opted for the median rather than the closing price or the mean price in order to avoid the problem of single outliers (see figure 6).

outstanding: $ND = \sum_t \sum_i |P_{it} - f_t| / TSU$ where P_{it} is the price of the i^{th} transaction in period t and TSU the total stock of units. The *duration (D)* is the number of periods for which one observes an increase in market prices relative to the FV of the asset (Porter and Smith (1995)). Formally, duration is defined as:

$$D = Max\{m: P_t - f_t < \ P_{t+1} - f_{t+1} < \cdots < \ P_{t+m} - f_{t+m}\}$$

Finally the *Share Turnover (ST)* is equal to the total trading volume over a market divided by the number of shares outstanding (the total stock of units). The number of shares outstanding is always equal to 54 in our experiment.

Table 3 and 4 report the values for each market.

a) Markets without shock

Market 1 serves as a benchmark with respect to which we assess the impact of the shocks on prices and volumes. We therefore need to check first whether the benchmark behavior of markets is the same across treatments. Table 3 reports bubble measures for each session of market 1. We observe that the most of bubble measures do not differ across treatments for market 1. This is stated as result 2.

Result 2. *There is no significant difference in asset mispricing and on measures of trading volume in benchmark markets across treatments.*

Support for result 2: (WMW tests, Table 2)

(Please insert Table 3 **about here)**

According to result 2, the outcome of market 1 does not depend on the treatment, in particular there is no difference between market 1 when shocks are expected and unexpected.

b) Markets with shock (T1 and T2)

Table 3 summarizes the various indicators related to bubbles for markets with shock. After an expected shock we observe a significant decrease in the transaction volume and a significant increase in price amplitude, both for upwards and downwards shocks. However, after an unexpected shock we observe a significant increase in the normalized deviation, both for upwards and downwards shocks. This is summarized as result 3.

Result 3.1 *Expected Shocks affect negatively the volume of transactions and affect positively the price amplitude. By contrast, they do not affect other measures of bubbles (ND and D).*

Result 3.2 *Unexpected Shocks affect positively the normalized deviation (ND). By contrast, they do not affect other measures of bubbles (Turnover, PA and D).*

Result 3.3 *In treatment T0 "No-shock", bubble measures do not differ between the first half and the second half of the market 2.*

Support for result 3: (Wilcoxon rank sum tests, Table 4)

(Please insert Table 4 **about here)**

The effect on transaction volumes is striking whenever the difference of opinions increased after the shock. Before discussing this issue more thoroughly we need first to analyze the impact of the shock on the difference of opinions. Let us be more specific about the effect on the volume of transaction.

V-3 transaction volumes

Surprisingly we observe that the direction of the shock does not affect the magnitude of the depression on the volume of trades. The difference in reduction between positive and negative shocks is not significantly different (WMW, p-value = 0.165). Similarly, we find that the reduction in transaction volume between sequence 1 and sequence 2 does not differ according to the type of shock, expected or unexpected, (WMW, p-value = 0.165).
However, the depression on volume of trades is significantly different between unexpected upward shocks and unexpected downward shocks (WMW, p-value = 0.029), and between expected downward shocks and unexpected downward shocks (WMW, p-value = 0.057), (Table 5).

(Please insert Table 5 **about here)**

We summarize these findings as result 4:

Result 4.1 *Shocks depress equally the volume of transactions, whatever the direction (upwards or downwards) and type (expected or not).*

Result 4.2 *Unexpected upward shocks and unexpected downward shocks do not depress equally the volume of transactions.*

Result 4.3 *Expected downward shocks and unexpected downward do not depress equally the volume of transactions.*

We find no significant difference in the depression on the volume of trades between first markets and second markets, except a significant difference in the depression on the volume of trades between first markets and second markets with unexpected upward shock (Table 6).

(Please insert Table 6 **about here)**

V.4 Underreaction

From Figure 1, we can see that prices underreact in the case of a downward shock in six markets out of seven and remain close to the FV in one market only. In contrast, prices do not react in the case of an upward shock in six markets out of eight and underreact in the two remaining ones. In order to test for significance of underreaction we rely on the same measure as in Weber and Welfens (2007)**,** which depends on the direction of the change in the FV. In case of an upward shift underreaction is measured by *FV - P* (the new value of FV): *if the difference is positive we define it as underreaction*. Symmetrically in case of a downward shift, underreaction is measured by *P - FV*: a *positive difference indicates underreaction*.

We begin testing for underreaction by comparing transaction prices for the post-shock periods. Following an upward jump of FV (positive shock) and regardless of the type of shock (expected or unexpected) the average (median) difference between transaction prices and FV is -10.68 (-0.64) currency units. Only 210 of a total of 847 trades (24.79%) are at underreacting prices (p-value= 0.000)[14]. Following a downward jump of FV (negative shock), transactions lead to average (median) underreaction measures of 14.77 (5.71) currency units above FV. A significant majority of 297 out of 683 trades (43.48%) underreact (p = 0.001).
For more detailed test, we split the after-shock into 7 periods (from period 9 to period 15). We then repeat the same procedure as done for the whole data set for each of these intervals. The following table provides the results.

(Please insert Table 7 **about here)**

Means (medians) slightly underreact in the two first periods that follow the positive shock. If we take into account all periods after the positive shock most transactions do not occur at underreacting prices. The proportion of underreacting prices is equal to 36% in the first period after the shock and falls back to 21% in the last period of the market. Overall the data of positive shocks does not support the underreaction hypothesis.
In contrast, after a negative shock we observe a strong and persistent underreaction. The mean (median) measure of underreaction is equal to 44.13 (40.00) in the first period following the shock and -4.23 (0.00) in the last period after the shock. Although the proportion of underreacting prices decreases steadily over time, even three periods after the shock more than 51 % of all trades are still at prices above FV. The effect is significant for period 9.

Result 5. *Transactions prices underreact following a negative shock. No underreaction is observed after a positive shock.*

This finding is robust when we divide our sample into (expected shock on the one hand and unexpected shock on the other hand) (Table 7).

These findings challenge the predictions of behavioral finance models. Equilibrium market prices are supposed to react symmetrically to positive and negative shocks in FV (Barberis, Shleifer, and Vishny (1998) and Grinblatt and Han (2005)).

V.5 Share turnover and heterogeneity of opinions

[14] Binomial test of all transaction prices for all markets after upward shock. 1 if *(FV - P)* > 0.

We now discuss our key observation, i.e. the sharp drop in trading volume after a shock and its relation to the dispersion of opinions. We focus on a possible change in beliefs after the shock[15]. According to prediction 7, the transaction volume and the difference of opinion are positively related. We expect therefore to observe both a drop in share turnover and in the difference of opinions. We initially considered two different measures for the difference of opinions (DO thereafter): the difference between the most optimistic and the most pessimistic forecast (*f*) in each trading period, i.e. $DO1 = \max f - \min f$, and the standard deviation of the forecasts, i.e. $D0_2 = \sigma_f$. These two measures are however almost perfectly correlated in our data (Spearman rank > 0.90, p = 0.000) in all periods. Therefore we rely exclusively on σ_f .
There is no significant difference between the pre-shock (before) and the post-shock (after) average value of σ_f (37.18 before vs 36.51) (Wilcoxon signed-rank test p-value = 0.932). Note that in market 1 σ_f is significantly lower after period 8 than (75.49 before vs 23.43 after) (Wilcoxon signed-rank test p-value = 0.001) (Table 8).

(Please insert Table 8 about here)

In order to test the hypothesis that DO and the volume of transactions are positively related as stated by prediction 7, we rely on panel regressions[17] (see Table 9). The dependent variable is *Share turnover* and the independent variables are σ_f, *Period_9-15* (equal to 1 if t > 8), *Type_shock* (equal to 1 if the shock is unexpected), and *Direc_shock* (equal to 1 if the direction of the shock is downward). The heterogeneity of beliefs (σ_f) has a significant positive impact on turnover as predicted, but *post-shock* affects negatively (and significantly) turnover. This effect is significant after controlling for the type and direction of the shock. We also observe a smaller drop in turnover when shocks are expected. We summarize these findings as results 6 and 7.

Result 6. *Increasing the difference of opinion increases significantly the turnover.*
Result 7. *Expected shocks significantly depress the turnover.*

(Please insert Table 9 about here)

Support for result 6 & 7: (Table 9)
According to results 6 & 7, differences of opinion affect significantly and positively turnover while shocks tend to reduce it. According to prediction 7, the combination of these two effects leads to suspect that shocks also affect negatively DO. We therefore analyze the changes in the dispersion of difference of opinion. Table 10 reports panel regressions with dependent variable σ_f. Unexpectedly, we observe that shocks affect positively the dispersion of the difference of opinions. Furthermore, when the shock is unexpected there is a slight increase in

[15] Another possibility is a change in preference, specifically risk-aversion, after the shock. However, we have no data about such possibility because risk aversion was elicited only once (at the end of the session).
[17] We used random-effects model, the p-value of Hausman-test of our five regressions (All M2, Expected, Unexpected, Up and Down) are as follows: 0.5165, 0.2021, 0.9038, 0.4873 and 0.0577.

the difference of opinions after the announcement of the shock. However, the direction of the shock has no effect on the difference of opinion.

Result 8. *Shocks affect positively the dispersion of opinions (σ_f).*

Result 8.1 *Downward unexpected shock increase significantly the difference of opinion. (17.25*)*

Result 8.2 *Upward unexpected shock decrease significantly the difference of opinion. (-47.91**)*

Result 8.3 *Significantly decreasing of the difference of opinion after period 8, when we don't have shock. (-29.56*)*

(Please insert Table 10 about here)[19]

Note that Weber and Welfens (2007) and Nosi and Weber (2009) also report a drop in turnover after new information about the FV becomes available. Furthermore, Nosic and Weber (2009) also found a positive relation between difference of opinion and turnover as well as a positive relation of the variation of the difference of opinion and the variation of turnover before and after the shock.

V.6 Shocks affect price deviation

In this part we investigate the impact of the shock on price deviation. We use five panel regressions[20] for market 2 (see Table 11), where *share price deviation (Price deviation)* is the dependent variable. The results display clearly that expected shocks decrease significantly the price deviation.[21] The direction of the shock (Upward or Downward) and the type of the shock (Expected or Unexpected) have no effect on price deviation.

(Please insert Table 11 about here)

VI. Summary of findings

The main question investigated in this paper is whether FV shocks affect asset prices and the formation of bubbles. Moreover, we also investigated outcomes of shocks for trading volume (turnover) and beliefs about the value of a stock (i.e. difference of opinions). We found strong evidence that shocks affect negatively the volume of transactions, positively the difference of

[19] We observed several extreme, « unreasonable », values for σ_f. We consider therefore that values of σ_f above 190 as outliers.

[20] We used random-effects model, the p-value of Hausman-test of our five regressions (All M2, Expected, Unexpected, Up and Down) are as follows: 0.5165, 0.2021, 0.9038, 0.4873 and 0.0577.

[21] This result is not consistent with result 3 that no significant difference between bubble measure ND before and after the shock.

opinions and that they decrease significantly the price deviation, i.e. the difference between stock prices and their FV. However, shocks do not affect the formation of bubbles.

The bulk of the evidence suggests that shocks depress equally the volume of transactions whatever the direction of the shock (upwards or downwards) and whatever the type of shock (expected or unexpected). Our results also show strongly support the conjecture that shocks increase sharply the difference of opinions. These results suggest that shocks, by reducing transaction volumes, entail a convergence of the traders' opinions. This finding is contrary to theoretical predictions and previous experimental evidence on trading volume and differences of opinions, supporting the idea that traders' difference of opinion and trading volume are positively related. In contrast, our findings reject the hypothesis that the difference of opinion explains the drop in trading volume after a shock.

An alternative explanation for the drop in turnover, according to the financial literature, is the heterogeneity in risk attitudes between traders. Unfortunately, our data does not allow to test this hypothesis, because we elicited subjects' risk aversion only once (at the end of the market) and therefore we are unable to measure how the distribution of risk-aversion was eventually affected by the shock.

We also found that price bubbles appear in almost all markets, with FV shock and without FV shocks (baseline). More precisely prices remain above the FV even after the shock in both treatments. In addition, shocks did not significantly affect the various bubble measures. We tentatively conclude that shocks do not affect the formation of bubbles. We thereby provide additional support to the hypothesis that the formation of bubbles is a quite general phenomenon in experimental asset markets, whether the FV is decreasing or constant, whether alternative activities are available or not, and whether shocks affect the FV or not. It seems therefore that the bubble phenomenon is rather driven by the institutional design of the stock market. For instance, Haruvy & Noussair (2006) showed that short-selling reduces sharply the prices leading to frequent trades below the FV.

Concerning transactions prices, although there is no clear tendency after a positive FV shock, they significantly underreact after a negative shock, whatever the type of the shock. The latter finding is not covered by behavioral finance models, as equilibrium market prices are usually assumed to react symmetrically to positive and negative shocks in FV.

Following a downward shock, one phenomenon draws our attention, we observe in both treatments that prices tend to stabilize after two periods. This gradual response to new information may be explained by the price momentum effect or by the disposition effect. This phenomenon is very close to what happened to VW stock after the German car giant has admitted cheating emissions tests in the US in September 2015. However, the volume of transactions did not reduced after the bad news. The decline in volume of transactions in our markets possibly due to the restriction in the asset's lifetime as in almost standard experimental markets. This phenomenon can be checked for financial derivatives characterized by expiration date as stock option or SRD (Deferred Payment Service).

Finally, the effect on bubbles are hardly observed in stock markets, however we can use forecast of analysts to estimate the difference of opinions and to verify where shocks increase difference of opinions as we found in our study.

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REFERENCES

Ackert, L. F., N. Charupat, B. K. Church, and R. Deaves, 2006, Margin, short selling, and lotteries in experimental asset markets, *Southern Economic Journal* 73, 419–436.

Antweiler, Werner, and Murray Z Frank, 2004, Is All That Talk Just Noise ? The Information Content of Internet Stock Message Boards, *The Journal of Finance* LIX, 1259–1294.

Bamber, Linda Smith, Orie E. Barron, and Thomas L. Stober, 1997, Trading volume and different aspects of disagreement coincident with earnings announcements, *Accounting Review* 72, 575–597.

Barberis, Nicholas, Andrei Shleifer, and Robert Vishny, 1998, A model of investor sentiment, *Journal of Financial Economics* 49, 307–343.

Beaud, Mickael, and Marc Willinger, 2014, Are people risk vulnerable ?, *Management Science* 61, 624–636.

Biais, Bruno, Alen Nosic, and Martin Weber, 2009, Overreaction and investment choices : An experimental analysis, *Lehrstuhl für Allgemeine Betriebswirtschaftslehre, Finanzwirtschaft, insbesondere Bankbetriebslehre, Universität Mannheim*.

Bloomfield, Robert, Maureen O Hara, Gideon Saar, Robert Bloomfield, and Gideon Saar, 2009, How Noise Trading Affects Markets : An Experimental Analysis, *The review of financial studies* 22, 2275–2302.

Bloomfield, Robert, Robert Libby, and Mark W. Nelson, 2000, Underreactions, overreactions and moderated confidence, *Journal of Financial Markets* 3, 113–137.

Breaban, Adriana, and Charles N Noussair, 2013, Fundamental value trajectories and trader

characteristics in an asset market experiment, , 1–33.
Cao, H Henry, and Hui Ou-Yang, 2009, Differences of Opinion of Public Information and Speculative Trading in Stocks and Options, *Review of Financial Studies* 22, 299–335.
Charles Figuières, David Masclet, and Marc Willinger, 2013, Weak moral motivation leads to the decline of voluntary contributions, *Journal of Public Economic Theory* 15, 745–772.
Cipriani, Marco, and Antonio Guarino, 2008, Transaction costs and informational cascades in financial markets, *Journal of Economic Behavior and Organization* 68, 581–592.
Corgnet, Brice, Roberto Herna, Praveen Kujal, and David Porter, 2014, The Effect of Earned Versus House Money on Price Bubble Formation in Experimental Asset Markets *, *Review of Finance*, 1–34.
Daniel, Kent, David Hirshleifer, and Avanidhar Subrahmanyam, 1998, Investor psychology and security market under-and overreactions, *The Journal of Finance* 53.
DeBondt, Werner F. M., and Richard Thaler, 1987, Further evidence on investor overreaction and stock market seasonality, *The Journal of Finance* 42(3), 557–581.
DeBondt, Werner F. M., and Richard H. Thaler, 1990, Do security analysts overreact?, *The American Economic Review*, 52–57.
DeGrauwe, Paul, and Marianna Grimaldi, 2004, Bubbles and crashes in a behavioural finance model.
Fama, E. F., 1970, Efficient capital markets - A review of theory and empirical work, *The Journal of Finance* 25, 383–417.
Fischbacher, Urs, 2007, z-Tree: Zurich toolbox for ready-made economic experiments, *Experimental Economics* 10, 171–178.
Gillette, A N N B, Georgia State, Douglas E Stevens, and Susan G Watts, 1999, Price and volume reactions to public information releases : An experimental approach incorporating traders â€™ subjective beliefs *, *Contemporary Accounting Research* 16, 437–479.
Giusti, Giovanni, Janet Hua Jiang, and Yiping Xu, 2012, Eliminating laboratory asset bubbles by paying interest on cash, *Munich Personal RePEc Archive, Munich*.
Gollier, Christian, and John W Pratt, 1996, Risk vulnerability and the tempering effect of background risk, *Econometrica* 64, 1109–1123.
Greiner, Ben, 2004, An Online Recruitment System for Economic Experiments.
Griffin, Dale, and Amos Tversky, 1992, The Weighing of Evidence and the Determinants of Confidence, *Cognitive Psychology* 24, 411–435.
Grinblatt, Mark, and Bing Han, 2005, Prospect theory, mental accounting, and momentum, *Journal of Financial Economics* 78, 311–339.
Gunduz, Caginalp, David Porter, and Li Hao, 2010, Asset market reactions to news: an experimental study.
Haigh, Michael S., and John A. List, 2005, Do Professional Traders Exhibit Myopic Loss Aversion? An Experimental Analysis, *The Journal of Finance* 60, 523–534.
Hales, Jeffrey, 2009, Are investors really willing to agree to disagree? An experimental investigation of how disagreement and attention to disagreement affect trading behavior, *Organizational Behavior and Human Decision Processes* 108, 230–241.
Hanke, Michael, Jürgen Huber, Michael Kirchler, and Matthias Sutter, 2010, The economic consequences of a Tobin tax-An experimental analysis, *Journal of Economic Behavior and Organization* 74, 58–71.
Harris, M., and A. Raviv, 1993, Differences of opinion make a horse race, *Review of Financial Studies* 6, 473–506.

Harrison, J. Michael, and David M. Kreps, 1987, Speculative Investor Behavior In A Stock Market with Heterogenous Expectations, *Tha Quanrterly Journal of Economics* 92, 323–336.
Haruvy, E., C. N. Noussair, and O. Powell, 2013, The Impact of Asset Repurchases and Issues in an Experimental Market, *Review of Finance*, 1–33.
Haruvy, Ernan, and Charles N. Noussair, 2006, The effect of short selling on bubbles and crashes in experimental spot asset markets, *Journal of Finance* 61, 1119–1157.
Hommes, Cars, Joep Sonnemans, Jan Tuinstra, and Henk van de Velden, 2005, Coordination of expectations in asset pricing experiments, *Review of Financial Studies* 18, 955–980.
Huber, Jürgen, and Michael Kirchler, 2012, The impact of instructions and procedure on reducing confusion and bubbles in experimental asset markets, *Experimental Economics* 15, 89–105.
Ikromov, Nuriddin, and Abdullah Yavas, 2011, Cash flow volatility, prices and price volatility: An experimental study, *The Journal of Real Estate Finance and Economics* 44, 203–229.
Jegadeesh, Narasimhan, and Sheridan Titman, 1993, Returns to buying winners and selling losers : Implications for stock market efficiency, *The Journal of Finance* 48, 65–91.
Johnson, Dean, and Patrick Joyce, 2012, Bubbles and Crashes Revisited, *Review of Economics* 2(3), 29–42.
Kahneman, Daniel, and Amos Tversky, 1973, On the psychology of predictions, *Psychological review* 80, 237–251.
Kandel, Eugene, and Neil Pearson, 1995, Differential interpretation of public signals and trade in speculative markets, *Journal of Political Economy* 103, 831–872.
King, R.R., Vernon L. Smith, AW Williams, and Mark V. Van Boening, 1993, The robustness of bubbles and crashes in experimental stock markets, *Nonlinear Dynamics and Evolutionary Economics*, 183–200.
Kirchler, Michael, 2009, Underreaction to fundamental information and asymmetry in mispricing between bullish and bearish markets. An experimental study, *Journal of Economic Dynamics and Control* 33, 491–506.
Kirchler, Michael, Jürgen Huber, and Daniel Kleinlercher, 2011, Market microstructure matters when imposing a Tobin tax — Evidence from the lab, *Journal of Economic Behavior and Organization* 80, 586–602.
Kirchler, Michael, Jurgen Huber, and Thomas Stockl, 2012, Thar She Bursts-Reducing Confusion Reduces Bubbles, *American Economic Review* 102, 865–883.
Lei, Vivian, Charles N. Noussair, and Charles R. Plott, 2001, Nonspeculative Bubbles in Experimental Asset Markets: Lack of Common Knowledge of Rationality vs. Actual Irrationality, *Econometrica* 69, 831–859.
Mannaro, Katiuscia, Michele Marchesi, and Alessio Setzu, 2008, Using an artificial financial market for assessing the impact of Tobin-like transaction taxes, *Journal of Economic Behavior and Organization* 67, 445–462.
Massey, Cade, and George Wu, 2005, Detecting regime shifts: The causes of under-and overreaction, *Management Science* 51, 932–947.
Milgrom, Paul, 1982, Information, trade and common knowledge, *Journal of Economic* 26, 17–27.
Morone, Andrea, and Simone Nuzzo, 2016, Asset Markets in the Lab: A Literature Review.
Morris, Stephen, and Hyun Song Shin, 2002, Social value of public information, *The American Economic Review* 92, 1521–1534.
Nelson, Mark W., Robert Bloomfield, Jeffrey W. Hales, and Robert Libby, 2001, The effect of

information strength and weight on behavior in financial markets, *Organizational Behavior and Human Decision Processes* 86, 168–196.
Nosi, Alen, and Martin Weber, 2009, Overreaction in Stock Forecasts and Prices.
Nosic, Alen, Martin Weber, and Markus Glaser, 2011, Opening the Black Box : From an Individual Bias to Portfolio Performance.
Noussair, Charles N., and Owen Powell, 2010, Peaks and valleys: Price discovery in experimental asset markets with non-monotonic fundamentals, *Journal of Economic Studies* 37, 152–180.
Noussair, Charles N, and Gregers Richter, 2012, Money illusion and nominal inertia in experimental asset markets, *Journal of Behavioral Finance* 13, 27–37.
Noussair, Charles, Stephane Robin, and Bernard Ruffieux, 2001, Price bubbles in laboratory asset markets with constant fundamental values, *Experimental Economics* 4, 87–105.
Noussair, Charles, and Steven Tucker, 2014, Cash inflows and bubbles in asset markets with constant fundamental values.
Noussair, Charles, Steven J Tucker, and Yilong Xu, 2014, Futures market reduces bubbles but allows greater profit for more sophisticated traders, *Pacific Economic Review* 11, 167–184.
Odean, Terrance, 1998, Are investors reluctant to realize their losses?, *The Journal of Finance* 53, 1775–1798.
Oechssler, Jörg, 2010, Searching beyond the lamppost: Let's focus on economically relevant questions, *Journal of Economic Behavior and Organization* 73, 65–67.
Palan, Stefan, 2013, a Review of Bubbles and Crashes in Experimental Asset Markets, *Journal of Economic Surveys* 27, 570–588.
Plott, Charles R., and Shyam Sunder, 1982, Efficiency of Experimental Security Markets with Insider Information: An Application of Rational-Expectations Models, *Journal of Political Economy* 90, 663.
Porter, David P., and Vernon L. Smith, 1995, Futures contracting and dividend uncertainty in experimental asset markets, *The Journal of Business* 68, 509–541.
Powell, Owen, and Natalia Shestakova, 2016, Experimental asset markets: A survey of recent developments, *Journal of Behavioral and Experimental Finance* 12, 14–22.
Robert A. Haugen, 1999, The new finance: The case against efficient markets, *Englewood Cliffs, NJ: Prentice Hall*, 144.
Smith, Vernon L., 1962, An experimental study of compettive market behavior, *The Journal of Political Economy* LXX.
Smith, Vernon L., 1982, Markets As Economizers of Information: Experimental Examination of the "Hayek Hypothesis," *Economic Inquiry* 20, 165–179.
Smith, Vernon L., 2010, Theory and experiment: What are the questions?, *Journal of Economic Behavior and Organization* 73, 3–15.
Smith, Vernon L., Gerry L. Suchanek, and Arlington W. Williams, 1988, Bubbles , crashes , and endogenous expectations in experimental spot asset markets, *Econometrica* 56, 1119–1151.
Smith, Vernon L, Mark Van Boening, and Charissa P Wellford, 2000, Dividend timing and behavior in laboratory asset markets, *Economic Theory* 4, 567–583.
Sorescu, Sorin, and Avanidhar Subrahmanyam, 2006, The cross-section of analyst recommendations, *Journal of Financial and Quantitative Analysis* 41, 139.
Statman, Meir, and Hersh Shefrin, 1985, The disposition to sell winners too early and ride losers too long: Theory and evidence, *The Journal of Finance* 40, 777–790.

Stevens, Douglas E., and Arlington W. Williams, 2004, Inefficiency in earnings forecasts: Experimental evidence of reactions to positive vs. negative information, *Experimental Economics* 7, 75–92.

Stöckl, Thomas, Jürgen Huber, and Michael Kirchler, 2015, Multi-period experimental asset markets with distinct fundamental value regimes, *Experimental Economics* 18, 314–334.

Strážnická, Kateřina, and Martin Weber, 2011, Does Skewness Matter? Evidence from Experimental Asset Markets, .

Thaler, Richard, and Werner F M De Bondt, 1985, Does the Stock Market Overreact?, *Journal of Finance* 40, 793–805.

Thaler, Richard H., and Eric J. Johnson, 1990, Gambling with the house money and trying to break even: The effects of prior outcomes on risky choice, *Management Science* 36, 643–660.

Thomas, Jacob, and Frank Zhang, 2008, Overreaction to Intra-industry Information Transfers?, *Journal of Accounting Research* 46, 909–940.

Tirole, Jean, 1982, On the possibility of rational bubbles, *Econometrica* 50, 1163–1182.

Van Boening, Mark V., Arlington W. Williams, and Shawn LaMaster, 1993, Price bubbles and crashes in experimental call markets, *Economics Letters* 41, 179–185.

Varian, Hal R., 1989, Diffeferences of opinion in financial markets, *Springer Netherlands*, 3–37.

Vieider, Ferdinand M., Mathieu Lefebvre, Ranoua Bouchouicha, Thorsten Chmura, Rustamdjan Hakimov, Michal Krawczyk, and Peter Martinsson, 2014, *Common Components of Risk and Uncertainty Attitudes Across Contexts and Domains: Evidence From 30 Countries Journal of the European Economic Association*.

Weber, Martin, and Frank Welfens, 2007, How Do Markets React to Fundamental Shocks ? An Experimental Analysis on Underreaction and Momentum.