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Asset Markets in the Lab: a literature review

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Abstract

This paper aims at providing both non-specialist and specialist readers with an overview of the several topics that have been addressed in the field of experimental asset markets. Rather than being exhaustive in any single topic, this review is meant to gather the several research strands and to provide a powerful picture of the main advances on the use of experimental techniques for the study of financial markets.

Keyword: Experimental Asset Markets

1. Motivational Framework

"The social scientist who would like to study in isolation and under known conditions the effects of particular forces is, for the most part, obliged to his "experiment" by the application of general reasoning to abstract models"

Chamberlin (1948)

Because of the real world complexity, field data do not always manage to control for all the factors that are expected to be relevant when a given phenomenon is studied. As a consequence, validating theoretical models predictions by the use of field data might present some limitations. This drawback has led to an increasing body of scientific research focusing on the use of experimental methodologies to test theoretical models in a controlled environment, like a laboratory. The latter, differently from field techniques, allows researchers to keep under control all the variables that are supposed to be prominent[1].

Asset markets are among those fields that best suit a controlled laboratory environment. Indeed, variables like the fundamental value of a financial asset, the information conditions and the asset life period are difficult to be accounted for in real world markets, causing research on asset markets to be unmanageable to carry out through the use of field data. Differently, in a laboratory environment, researchers can exogenously control and observe the key parameters of the market. This latter benefit has been one of the main driver leading research on experimental asset markets. It is task of this article to present a review of this research. Each of the studies collected in this paper has to be read in the light of the peculiar distinctive traits of asset markets. Indeed, as pointed out by Sunder (1995), asset markets mainly differ from other markets for two reasons: the informational role of prices and the duality of the traders behaviour. Differently from good markets, where prices are informative up to the extent they make customers aware of their budget constraint, asset markets prices reflect the information available to each trader at any instant of time. As Plott (2000) highlights, asset markets could be compared to a

[1] Also the external validity of the findings should be taken into account when choosing between the use of field or experimental approaches.

statistician who collects and aggregates the dispersed information and prices are the form in which findings are made public. The second feature refers to the fact that each trader can choose to be a buyer as well as a seller in the same market, depending on his or her expectations on future events. This diverges from classical one life period good markets, where re-sales are not allowed.

This work is organized as follows. Section 2 reviews the early and leading works in which the foundations for later studies have been built up. Section 3 describes issues related with information release and market structure. Section 4 explores some stylized facts related with experimental asset markets. Section 5 reviews the role of market institutions on trading activity. Section 6 reports on the interaction between private and public information. Section 7 deals with the occurrence of bubbles and crashes. Section 8 discusses the role of emotions and bounded rationality on asset markets. Finally, section 9 concludes.

2. Leading Works

Forsythe et al. (1982) investigate a market where a generic asset with a risky payout is traded through a double auction institution[2]. Each market consists of eight repetitions ("years"), each split up in two periods. The authors show that, over replications, actual prices converge toward the predictions supported by the rational expectations equilibrium[3]. Indeed, while trading is initially private information oriented in the first period, across replicating "years", subjects learn to adjust their decisions taking into account the trading insights from the second period. Differently stated, the convergence process improves as traders learn to exploit the market opportunities in the second period and to accordingly update their strategies in the first period. Two years later, Forsythe et al. (1984) show that the convergence process toward the rational expectations equilibrium is augmented when future markets are introduced in the experimental design.

Differently from Forsythe et al. (1982, 1984), some asset markets present a design where some agents (insiders) are fully informed on the asset fair value, while others are

[2] This institution has the property to be symmetric and several studies showed its appropriateness in reaching the efficient equilibrium (Smith, 1962, 1964, 1976; Plott and Smith, 1978; Ketcham, Smith and Williams 1984; Holt, Langan and Villamil, 1986; Davis and Williams, 1986; Smith and Williams, 1989; Gode and Sunder, 1989, 1991; Davids, Harrison and Williams, 1993; Mestelman and Welland, 1992; Holt, 1995)

[3] The rational expectations model assumes that agents are able to infer all the relevant information in the market, i.e each subject trades as if he or she knew his or her information plus others' information

not. In this setting, Plott and Sunder (1982) study the conditions under which information is disseminated from informed to uninformed traders. In a market where a one-period-life asset with a common and risky value is traded through a double auction institution, they show that the rational expectations model performs better than the prior information model[4] in disseminating the pooled information in the market. In other words, non-informed traders were able to infer the information held by informed traders and no relevant differences between informed and non-informed traders' profits were found. Moreover, the convergence process accelerates with subjects' experience.

Contrarily from the information dissemination case, some asset markets involve agents who are all only partially informed and none of them is given enough information to know the future value of the asset. This setting is usually related to information aggregation. In the latter framework, the price convergence process might someway exhibit more pitfalls than in the dissemination one. In fact, if in the dissemination case insiders trades release pretty univocal signals (at least when the presence of insiders is common knowledge), when no traders knows for sure the realized state, the beliefs leading other agents trades may sometimes result ambiguous and challenging to elicit. In this sense, whether or not markets are able to succeed in the complicated task of aggregating the dispersed information is still an open question. In a leading research, Plott and Sunder (1988) study information aggregation in three differently designed markets. In the first market (series A) subjects traded a three-state asset in a single period time framework. Traders were divided into three types and, accordingly, the asset paid out different dividends to each trader type. The dividend distribution was private information. Agents received incomplete and diverse information on the fundamental value of the asset. In the second market (series B) agents traded three single state assets. In particular, each asset paid a strictly positive return only in one contingent case. The third market (series C) was designed like series A markets, with the only difference that all traders belonged to the same class, i.e. dividends were made identical. The authors show that both series B and C markets converged to the rational expectations equilibrium, while series A markets did not. One possible explanation the authors provide for this result deals with the implicit information incorporated in the contingent claims design. The fact that in series B markets

[4] Contrarily from the rational expectations model, the prior information model assumes that agents only mange to process their a priori information without making such an inference of others' information.

the asset pays a strictly positive dividend only in one state establishes a direct line between the purchase or the sale of a security and the expectation on the realization of a certain state. Similarly, in series C markets, if traders know that others have similar preferences to theirs, they can correctly assess others' trades. This feature is, on the contrary, totally absent in series A markets. In conclusion the authors provide the evidence that the knowledge of others' preferences crucially matters for information aggregation, since traders can easily infer the contingent state from other subjects' behaviour.

Forsythe and Lundholm (1990) find that the common knowledge of the dividend distribution and additional sessions of experience are necessary and sufficient conditions to have the dispersed information correctly aggregated.

O'Brien and Srivastava (1991b) show that some further complexity in the experimental design - i.e. multi-period assets and the lack of common knowledge on the information distribution - hinders the information aggregation even when the dividend distribution is uniform and commonly known.

While in the previous studies information is exogenously released, some works deal with markets where information does have an endogenous nature. In this sense, Sunder (1992) explores asset markets performance in a context where a parallel market for information does exist. In this new framework, agents can buy information and use it to trade an uncertain dividend asset. The work is mostly an experimental test on the Grossman and Stiglitz (1980) proposition. The latter states that, when information is costly acquired, an equilibrium level of noise trading must exist in order to allow informed traders to recover the cost of purchasing information by making higher earnings. Sunder (1992) finds that, when information supply is fixed and "news" are sold to the highest bidders, the informational and allocative efficiency predictions of the rational expectations equilibrium outperform the predictions of the Walrasian hypothesis (i.e. prior information model). Indeed, due to a fixed information supply, the observed left demand shift declines the price of information to zero. Differently, when the price of information is fixed, market informativeness allows informed traders to recover the cost of information.

Camerer and Weigelt (1991), investigating the huge amount of volatility that sometimes affects asset prices, designed a double auction market where, in each period, the eventual presence of informed subjects was not common knowledge. In this new experimental design uninformed traders do face an additional challenge. If in standard

contexts (see Plott and Sunder, 1982) the only concern for non-informed traders was to try to infer the available information, in this framework traders could not be sure about the presence of insiders in the market. As a consequence it might be that, even in periods with no insiders, some agents could mistakenly believe that there were insiders in the market. Then, these agents could start trading on the belief that actual prices were reflecting some inside information, inducing, in turn, other traders to mistakenly believe that some information was in the market and so on. This mechanism could lead to the creation of a price pattern named "information mirage". The latter occurs when traders see information even when no information is in the market. As a consequence, actual prices depart from the rational expectations equilibrium level (since they reflect some non-existent information), undermining the overall market efficiency. Information mirages were found to be more likely to occur during early periods, because during late periods traders were able to infer the presence of insiders by processing some non-price information like the speed of trading. Then, information mirages in late trading periods were more sporadic.

Copeland and Friedman (1987) investigate a double-auction asset market where, at a given point during the trading period, traders receive some costless information ("news") on the uncertain current state of nature. Treatments crucially differ in the way in which information is released. While in the "Sim environment" agents receive news simultaneously, in the "Seq environment" information is sequentially released. Furthermore, the news may be the same for all ("Hom environment") or may be different among traders ("Het environment"). The authors find that strong-form-efficiency models a là Fama (1970) perform better than alternatives such as the prior information model and the non-revelation model[5]. Moreover, the simultaneous information arrival is found to perform better than the sequential one.

Copeland and Friedman (1991) extend their 1987's study by proposing a reconciliation between the non-revelation and the full revelation models. Indeed, the authors formalize a partial revelation model where private information is only partially extracted from prices.

Finally, investigating price and allocation of both the purchased information and the traded asset, Copeland and Friedman (1992) find that full revelation models manage to

[5] The non-revelation model assumes that agents combine their own information with public knowledge of prices, but they do not manage to infer others' private information.

correctly forecast the market value of information in simpler frameworks where states of nature are homogeneous. Differently, semi-strong efficiency models outperform in presence of more complex environments such as those where states of nature are heterogeneous.

3. Information Release and Market Structure

Plenty of research has been conducted to shed light on the relationship between market performance and market structure, with a particular focus on how information is released in the market. Indeed, there are some papers where information is polarized, i.e. some subjects are insiders and some others are uninformed (Plott and Sunder, 1982; Camerer and Weigelt, 1991; Brandouy et. al., 2000; Noussair and Yilong Xu, 2015); where subjects can buy information during the trading period (Hey and Morone, 2004; Ferri and Morone, 2014; Alfarano et al., 2015); where a fixed amount of partially trustable information is exogenously provided to all subjects before the trading period starts (Barreda et al., 2016a, 2016b).

Brandouy, Barneto and Leger (2000) provide evidence about price formation, asymmetric information and insider trading influence. They investigate, by mean of a laboratory experiment, the effects of several manipulations of asymmetric information and communication in a double-auction stock market. They find that asymmetric information leads to inefficient trades when it is not revealed to market participants, causing insiders to make higher profits than average. On the contrary, the revelation of the presence of insiders significantly increases market efficiency but only in relation with bad news. Risk averse traders strategies may be responsible for the lower market efficiency when market participants are provided with good news. Communication of uncertain information (agents were forbidden to prove the veracity of their communications) decreases price efficiency, since the consequent rumour weakens insiders signals.

Schnitzlein (2002) studied order-driven dealer markets where there is uncertainty about the number of insiders in the market. Schnitzlein (2002) found that insiders were more likely to compete aggressively when the number of insiders was common knowledge with respect to the treatment in which there was no disclosure. Moreover, the uncertainty about the actual number of insiders causes the convergence towards the fundamental value of the asset to be slower. So, price efficiency is higher when the number of insiders is

publicly known. This occurred because, in the disclosure treatment, the aggressive competition tended to reveal a lot of information and this allowed non-insider subjects to easily infer the insiders information and to accordingly adjust their behaviour. In the no disclosure treatment, non-informed agents do not succeed to make such an inference. Therefore, not only the presence of insiders but also what non-informed traders know about the insider presence affects market performance.

In an extension of Benarjee (1992) and Bickchandani et al. (1992) models, Hey and Morone (2004) studied a (double auction) market where partially trustable information can be purchased at some positive cost. In this framework, on one hand, when information is private, socially undesirable herd behaviour may result; on the other hand private information may be aggregated efficiently through the price mechanism. The authors found that socially undesirable behaviour does result, i.e. misinformed agents acting on their private information mislead the market. Nevertheless, socially undesirable behaviour can be eliminated through the market. Moreover, greater volatility was detected when the reliability and the cost of information were respectively lower and higher. Both conditions were responsible for less information and more noise in the market.

Huber, Kirchler and Sutter (2008) provide additional experimental evidence about the role of privileged information. In a framework where information is cumulatively distributed, the authors study whether having more information does lead to higher returns. While some research (Copeland and Friedman 1992, Ackert et al. 2002) shows that insiders profits outperform the non-informed ones when only two levels of information exist, the authors design an experiment where having more information than others means to have the same plus some extra information. This study shows that there is a wide range of levels of information in which having additional information does not provide benefits in terms of higher returns. A positive relationship between information and higher profits was detected only for very high levels of information.

Hanke et al. (2010) study the economic consequences of the Tobin Tax imposition. The latter tax aims at fighting speculation and stabilizing foreign exchange markets. The experimental design consists of two double-auction markets where a foreign currency can be exchanged for the home currency. Each agent can be simultaneously be active in both the markets. Treatments differ with respect to two features: the market on and the moment when the tax is levied. Results show that volume is negatively affected by the tax

imposition, since transactions move from the taxed to the untaxed market. Market inefficiency does not change when both markets are taxed but significantly increases in the taxed market when only one market is taxed. The latter result confirms the findings of Bloomfield et al. (2009) and Cipriani and Guarino (2008). Finally, market volatility is not affected by the tax imposition.

One year later, Kirchler et al.(2011) show that the impact of the Tobin tax on market volatility depends on the presence of market makers. They show that, when the Tobin tax is levied on one market, volatility increases if no market makers are present. On the contrary, when there are market makers on the unique taxed market, volatility declines. In the last case in which both markets are taxed, no significant effects on volatility are detected.

Noussair and Yilong Xu (2015) studied the occurrence of a financial contagion and its relationship with information mirages in an experimental asset market. Two assets are traded and the value of one of them is, at some point, reduced by an exogenous shock. The correlation between the two assets may be known or unknown with 50% chance. In the former case, only half of the traders know the correlation. The setting differs from that of Camerer and Weigelt (1991) in the fact that the assets correlation and not the asset pay-out is the direct source of knowledge. Noussair and Yilong Xu (2015) show that, during periods when insiders were present, the private information was rapidly revealed by prices. However, during periods with no privileged information, information mirages occurred, reflecting a misleading information on the non-shocked asset value. The latter can be then interpreted as a form of financial contagion, implying that a market specific shock can be transmitted from one asset to another without a justifiable underlying reason.

Barreda et al. (2016a) study the conditions under which information is aggregated in a market where heterogeneously informed traders are given the option to share their informative set before trading starts. The experiment runs over five treatments, which differ in the ex-ante distribution of the partially trustable private information. In treatment 1 all agents received 1 piece of information; in treatment 2 base-informed (BI) agents received 1 piece of information and quasi-insider (QI) agents received 3 pieces of information; in treatment 3 all agents received 3 pieces of information; in treatment 4 base-informed (BI) agents received 1 piece of information and quasi-insider (QI) agents received 9 pieces of information; in treatment 5 all agents received no information. Barreda

et al. (2016a) show that, when information is polarized, base-informed agents do not massively use the cooperation device to increase the number of their per-capita signals and compete against quasi-insider agents. Market efficiency is found to be significantly higher when quasi-insider agents are in the market with respect to the uniform information distribution case. The awareness that someone else is superior informed leads traders to focus more on what others are doing in the same market. Differently, when traders are uniformly informed, they do not recognize the presence of a leader in the market and, as a consequence, they focus more on processing their own private information. In a companion paper, Barreda et al. (2016b) find similar results.

Despite the previous powerful evidence, the systematic relationship between information distribution among traders and market performance is still an open issue. Lux, Morone and Nuzzo (2016) are now providing a further contribution to address the issue. They design a framework where, before trading starts, subjects are exogenously assigned some informative signals. First, treatments differ for the *ex-ante* distribution of the information among subjects and not for the quantity of information in the market. Treatments also differ in the accuracy of the private information exogenously released in the market. This design would allow to study the role played by information and its distribution in promoting market efficiency.

4. Stylized Facts

Over the last three decades, several models - Beja and Goldman (1980), Day and Huang (1990), Chen et al. (2001), Farmer and Joshi (2002), LeBaron (2000), Gaunersdorfer and Hommes (2005), Gaunersdorfer, Hommes and Wagner (2000), Ariofovic and Gencay (2000), Georges (2005) - on dynamic interaction in financial markets have been developed. These models have shed light on some stylized facts of financial markets such as leptokurtic returns and autoregressive dependence in volatility. The latter evidence has led many researchers to reproduce the stylized facts in laboratory artificial markets, leading to the development of heterogeneous agents models (HAM). Outcomes of these models can be found in Arthur (1997), Brock and Hommes (1998), Hommes (2002), Iori (2002), Lux (1995, 1998), Lux and Marchesi (1999, 2000), Raberto et al. (2001). In particular, according to Lux and Marchesi (1999, 2000) fat tails of returns distributions as well as volatility clustering have to be imputed to agents switching their trading strategies. When

the presence of chartists becomes prominent with respect to fundamentalists, extreme returns dominate the market and prices deviate from the asset fundamental value, inducing bubbles or crashes. On the opposite, in times of large price deviations from the asset fair value, fundamental strategies become more profitable, inducing traders to discard chart analysis and to focus on fundamentals. This mechanism slowly leads prices back to the asset fundamental value, causing a decay in the absolute returns autocorrelation function.

In contrast with Lux and Marchesi (1999, 2000), Kirchler and Huber (2007) show that the heterogeneity of fundamental information is the leading driver for fat tails and volatility clustering. More precisely, Kirchler and Huber (2007) find that decreasing absolute returns are positively correlated with the arrival of new fundamental information. Then, neither noise nor switching from chartist/fundamental strategies (as in the HAM framework) play a prominent role in explaining stylized facts.

Morone (2008) compares a "real" asset market with an experimental one in which the quantity of information is endogenously determined while the quality of information is exogenous. The author finds that prices volatility decreases in both the quantity and the quality of information. While information aggregation does occur when the quality of information is relatively high, the leptokurtic level of returns distribution increases in the cost of information.

5. Trading Institutions

Several studies (see Plott ,1982; Holt, 1993; Ockenfels and Roth, 2002) show that market institutions matter for efficiency and convergence to the market clearing outcome. Trading institutions commonly refer to the set of exchange rules that determines how purchase and sale proposals are matched and, consequently, how the price formation process evolves. How Cason and Friedman (1996) state, "market institutions exist in the world in order to solve the incentive, coordination and logistical problems associated with price formation and exchange".

The continuous double auction (CDA) and the single call market (SCM) have been the two most employed trading institutions in both theoretical and experimental works. In a continuous double auction mechanism, each trader, at any moment during the trading period, is free to enter a bid (an offer to buy one unit of the asset for a specific amount of

cash) or a request (an offer to sell one unit of the asset for a specific amount of cash). Submitted proposals appear on the book and become public information. Traders can also accept outstanding bids and asks, closing the transaction and making the relative price public information. These characteristics make the CDA the richest trading institution in terms of trading opportunities and within-period information. On the opposite extreme, in a single call market mechanism, each trader privately submits his purchase or sale order. For a single unit of the asset, the purchase order consists of the highest acceptable purchase price and the sale order represents the lowest acceptable sale price. When the trading period closes, the demand and supply scheme is derived and all the infra-marginal orders are executed at a unique price (clearing price), that is the intersection point of the demand and supply functions. Differently from the CDA, the SCM allows only one trading opportunity per period (reducing the trading strategy space) and information feedback is totally absent within the trading period. Among the several variants of the two main trading institutions, the uniform price double auction[6] (UPDA) and the multiple call market[7] (MCM) have been also widely used (see Cason and Friedman, 1996).

As far as theoretical research is concerned, in regard to call auction modelling, the main contributions can be found in Mendelson (1982), Ho et al. (1985), Satterthwaite and Williams (1993), and Rustichini et al. (1994). About double auction modelling, the main contributions can be found in Friedman (1984, 1991), Wilson (1987), Easley and Ledyard (1993), Glosten (1994).

In any case, not so many experimental studies have been produced on the relationship between trading institutions and market efficiency.

Smith et al. (1982) compared the continuous double auction with several variants of the single call market institution in a stationary environment. The authors found the price convergence process to be more rapid in the continuous double auction. The latter institution also outperformed in terms of allocational efficiency except when a multiple unit recontracting variation of the single call market mechanism was introduced. In this case, the single call market showed the same allocational efficiency as the continuous double auction.

[6] This trading institution preserves the huge and continuous amount of information feedback within the period while limiting to one the number of trading opportunities (like in the SCM).

[7] Differently from the SCM, in the MCM the market is cleared more than once within the period, increasing the number of trading opportunities per period.

In a relevant contribution, Friedman (1993a) studied the impact of both a continuous double auction and a call market trading mechanism (with multiple orders per period) on market performance. Treatments differed in the pay-out contingent states across traders (homogeneous v.s. heterogeneous) and in the sequential rather than simultaneous arrival of information. While the two employed trading institutions exhibited similar performance in terms of informational efficiency, the continuous double auction showed slightly greater allocational efficiency with respect to the call market. Market depth, meant as the difference[8] between the best rejected bid and ask prices, was found to be higher when trading run through the call market rules. On the contrary, market volume, thought as the number of shares sold or bought, was higher when trading was conducted through a double auction mechanism.

Cason and Friedman (1996) compares the performance of four market institutions: the continuous double auction (CDA), the uniform price double auction (UPDA), the single call market (SCM) and the multiple call market (MCM). The authors find that trading efficiency, expressed as the realized percentage of the maximum gains from exchange, is remarkably higher in CDA and MCM sessions, suggesting that multiple trading opportunities within a period (like those allowed in the CDA and MCM mechanisms) stimulate higher trading efficiency. On the opposite, the UPDA and the SCM institutions generate the highest informational efficiency, since they exhibit fewer deviations of transaction prices from the competitive equilibrium prediction levels. Then, the presence of multiple trading opportunities on one hand improves trading efficiency – inducing traders not to underreveal their true values and costs – but, on the other hand, generates greater mispricing with respect to the case in which only one trading opportunity is permitted.

Shnitzlein (1996), in an experimental framework based on Kyle (1985), compares continuous and call auctions under asymmetric information. He finds that, in addition to not be less efficient than continuous auctions, call auctions also enhance market liquidity and imply less adverse selection costs for noise traders.

Theissen (2000) compared continuous double auctions, call markets and dealer markets. The author focused on informational efficiency within a sequential arriving

[8] In the double auction mechanism, the difference between the lowest ask and the highest bid is recalculated every time it changes and depth is computed as the time weighted average when both bids and asks are available in the sub-period.

information framework. He found that, in the call market institution, opening prices were closer to the fundamental value of the asset than opening prices in the continuous auction and in the dealer markets. Concurrently, the call market showed a significant tendency to underreact to the arrival of new information, exhibiting a poor ability to transmit the new information into prices. The continuous auction and the dealer markets were found to be more efficient at the average period price level, in the sense that, on average, these institutions exhibited fewer deviations from the true value of the asset. Nevertheless, the dealer market presented the highest transaction costs.

Van Boening, Williams and LaMaster (1993) showed that the price bubbles and crashes typically observed in the double auction institution were also found with regularity in a 15-round closed-book call market treatment. Trading prices were more likely to track the fundamental value of the asset only when the same group of experienced traders was involved in three consecutive 15-round markets.

In a market where uninformed agents cannot be sure about the presence of insiders, Morone and Nuzzo (2015) investigate the impact of trading institutions on both the occurrence of information mirages and the price discovery process. In this framework, a single-unit double auction institution is compared with a multiple call auction mechanism. The authors show that the likelihood of detecting information mirages significantly increases when trading is conducted through a double auction mechanism. Then, the call auction institution promotes a better convergence toward the efficient price when no insiders are in the market. Contrarily, when insiders are in the market, the double auction mechanism outperforms the call market one in disseminating the available information.
According to the authors, the prominent characteristics of the double auction mechanism - i.e. the continuous type of trading, the absence of limits to the number of traders' proposals, the public sharing of agents' proposals as they are submitted and the continuous update of book orders - are, on one hand, responsible for promoting the information dissemination when insiders are in the market but, on the other hand, they increase the probability to disseminate such information that does not really exist when there are no insiders in the market, with the consequent augmented likelihood of detecting information mirages. Similarly, the main characteristics of the call market mechanism sort the opposite effect.

6. Private and Public Information

While in the research presented so far information does have a private value, we now review a strand of research where public information is someway injected in the market. This research strand is relatively recent and it finds its main theoretical driver in Morris and Shin (2002). In a Keynes' beauty contest reminiscence, the authors build up a model where agents access both private and public information on the underlying fundamentals. If on one hand subjects perform actions appropriate to the fundamentals, they also have incentive to coordinate one another, since the reward increases in the closeness between their actions and the actions of others. Morris and Shin (2002) show that a greater accuracy of the public signal always increases social welfare when no private information is accessible. On the contrary, when subjects can access private information, the greater the accuracy of the latter, the more detrimental an increased provision of public information might be in terms of social welfare. In the following years, many models –i.e. Svensson (2005), Colombo and Femminis (2008), Cornand and Heinemann (2008), Kool et al. (2011), Arato and Nakamura (2011), Chen et al. (2014) – have investigated the role of public information in a market context. To the best of our knowledge, experimental investigations on the relationship between private and public information has been carried out by Ferri and Morone (2008) and Alfarano et al. (2015).

Ferri and Morone (2014) test whether the introduction of a rating agency in a financial market where agents are provided with partially trustable private information does reduce wrong herding (see Hey and Morone, 2004) and stimulate the price convergence toward the fundamental value of the asset. The experimental design crucially differs from Hey and Morone (2004) in the fact that in some treatments agents receive a costless public signal prior the trading start. Both private and public information are not totally informative of the asset fair value. Treatments differ in the precision of both private and public signals. Ferri and Morone (2014) show that the herding likelihood is negatively related with an increase in the accuracy of public information. Furthermore, the public signal also accelerates the price discovery process, producing a benefit in terms of market efficiency.

In a similar framework, Alfarano et al. (2015) test whether investors do rely on public information much more than what the public signal accuracy would require. While in the first two treatments agents can only purchase imperfect private information, in

treatments from three to five subjects also receive an imperfect and costless public signal. Treatments differ in the combination of the precision of both private and public information. Alfarano et al. (2015) show that public information crowds out private information. In other words subjects' demand for private information is downward shifted as a public signal is injected in the market. In spite of the crowding out effect, market informativeness does not significantly change, since the public signal introduction compensates the reduction in the private information demand. As far as market efficiency is concerned, the authors find that, in spite of the unchanged market informativeness, the introduction of a public signal might sort a detrimental effect. Indeed, in presence of poor quality private information, the public signal leads market prices. If this mechanism results to be beneficial for market efficiency when public information is correctly released in the market, undesirable and large deviations from the asset fundamentals may occur in case of incorrect public signal. This result is fully in line with Morris and Shin (2002).

7. Bubbles and Crashes

King et al. (1993) define a bubble as a "trade in high volumes at prices that are considerably at variance from intrinsic values". The asset market property to generate bubbles has been first detected by Smith, Suchanek, and Williams (1988) and has been confirmed in later works, i.e. King et al. (1993), Van Boening, Williams, and LaMaster (1993), Porter and Smith (1995), Fisher and Kelly (2000). In a market where a one-period-life asset with common dividend across subjects is traded, these authors found that prices, instead of tracking the intrinsic asset value, exhibited phases of "boom" and "crash". At that time, the prominent explanation for bubbles and false equilibria was related to Smith et al. (1988) results, according to which bubbles arise because of the possibility to generate capital gains. This idea finds its main source in the hypothesis that agents rationality is not common knowledge. In other words, if a rational trader believes there are some irrational traders willing to buy at prices considerably higher than the asset fair value, he or she could be also willing to buy at prices higher than fundamentals because he or she expects to resell the asset at even higher prices to either an irrational trader or to a rational trader with bull market expectations.

Lei, Noussair and Plott (2000) challenged this idea. The authors designed a market where any possibility of speculation was removed. In this market, subjects could be either

buyers or sellers, so that no one could buy with the aim to resell the asset later. Indeed, the asset payout was the only source of remuneration. Large price departures from the fundamental value at high volume were detected. Then, not the lack of common knowledge on others rationality but traders irrationality itself is the reason leading to bubbles and crashes occurrence. In the same framework, Lei, Noussair and Plott (2002) test the effect on bubbles and crashes of a capital gain tax of 50%. The authors find that bubbles still arise despite of the levied tax. The work provides a further evidence that bubbles are not strictly related with speculation issues.

Ackert et al. (2002) investigate whether bubbles depend on traders' risk attitude. They design an experiment where two assets are simultaneously traded in the same market. The two assets have equal expected value but one exhibits the characteristics of a lottery with large and unlikely payoff, i.e. a skewed payoff distribution. Then, in presence of strong risk-seeking attitude, the lottery asset should trade at levels that incorporate a premium, leading to larger price bubbles. The latter hypothesis is accepted but the willingness to pay too much for the lottery asset decreases when traders are allowed to make short sells and must finance themselves the purchase of the asset.

In a similar experimental design, Ackert et al. (2006) extend the previous work by comparing asset prices in single and multi-period markets. While in the former speculation is not possible, in the latter traders can speculate across periods. The authors find that, when bubbles occur, single-period market asset prices are sensibly lower than corresponding prices in multi-period markets. Then speculation matters for bubbles creation. This result is in contrast with Lei, Noussair and Plott (2000, 2002).

One leading research strand on bubbles studies the relationship between mispricing and traders confusion on market dynamics. In this sense, Sutter, Huber and Kirchler (2012) investigate whether the occurrence, as well as the intensity, of bubbles can be reduced by providing subjects with information about the imminent dividends. The answer is context dependent. Switching from a control treatment where no traders receive information on the future dividend to a treatment where each trader is provided with full information about the dividend value at the end of the period, bubbles are not significantly reduced. Surprisingly, in a third treatment where one third of traders knows for sure the dividends of the next two periods, one third of traders knows the next dividend, and one third of traders does not have any information on future dividends, bubbles occurrence is significantly reduced with

respect to both the first two treatments. The first focal point is in the fact that asymmetric information distributions reduce bubbles. The second point is that fundamentals tracking is not different switching from a situation where inexperienced traders are asymmetrically informed to the case where experienced traders are given no information on the future dividends. Then, experience does not play a major role than information distribution.

Further research shows that confusion can be reduced when fundamental values are displayed in graphical form (Baghstanian and Walker, 2014), when the asset is differently framed (Kirchler et al., 2012) and when pre-market training about dividend payments is implemented (Lei and Vesely, 2009).

Michailova and Schmidt (2011) study the relationship between bubbles and subjects overconfidence. After a pre-experimental overconfidence measurement, subjects resulted to be overconfident were assigned to the "overconfident markets" and the remaining subjects to the "rational markets". The market design resembles the one of Smith, Suchanek and Williams (1988). The authors show that overconfident markets trades were, on average, significantly higher and further from the fundamentals with respect to trades occurred in rational markets. Both volatility and volume trades were found to be lower in rational markets. The overconfidence bias was anyway decreasing as subjects got experience[9].

Cason and Samek (2015) compare the role of passive and active participation in mitigating bubbles occurrence. A passive trader does observe[10] the same information and receive the same payout as a "prior" trader, but he or she does not take decisions. In the experimental design, each passive trader is matched with a trader from a different "prior" market. Cason and Samek (2015) find that passive participation reduces mispricing in subsequent markets, leading to conclude that prices observation can reduce bubbles. Passive observation learning can then be used as a confusion reducing tool.

Cheung et al. (2014) assert that, rather than training on fundamentals, the common knowledge that other agents in the market are trained plays a crucial role in reducing mispricing. When all subjects in the market are trained with decreasing fair values but this

[9] This result is in line with Menkhoff et al., (2006) but in contrast with Kirchler and Maciejovsky, (2002).

[10] The observational learning properties to reduce bias in decision making has been detected in several economic games (Merlo and Schotter, (2003) and Kocher et al., (2015))

is not commonly known, mispricing is not significantly different from the no-training case. Differently, when training is common knowledge, mispricing is sensibly reduced.

Finally, some other related works focusing on the impact of fundamental value patterns on price bubbles have been provided by Noussair and Powell (2010) and Stöckl et al. (2014). Concluding, the research reviewed in this section has shown how both bubbles occurrence and magnitude depend on irrationality, traders cognitive abilities, risk aversion and fundamental value patterns. Probably, one more driving force could be identified in the role of emotions on mispricing. The latter topic is reviewed in the next section.

8. Asset Markets and Emotions

A very recent strand of research links asset market price patterns with agents' emotions and mood. Some empirical data support this strand. Hirshleifer and Shumway (2003) detect a positive correlation between good weather and higher stock returns but, surprisingly, a switch from average to bad weather does not lower asset returns. A similar intuition is recalled by Kamstra et al. (2003), who note relatively low returns associated with fall and winter seasons.

Only few experimental evidence on this topic are available at present time, whose results are not particularly divergent. These works start from the classical design *a là* Smith, Suchanek and Williams (1988) and someway stimulate heterogeneous emotional states in market participants. Before trading starts, Lahav and Meer (2010) set up a treatment where positive mood was induced by showing subjects some comedy video clips. Market prices from this treatment were compared with the ones coming from a control treatment where no video clips were shown. Larger deviations from fundamentals were detected in the video clips treatment.

Similarly, Andrade et al. (2012) use video clips to induce emotions before the market opens. A larger range of emotions is induced with respect to Lahav and Meer (2010). Indeed, Andrade et al. (2012) show traders videos inducing excitement, neutral mood, fear or sadness. A greater average bubble magnitude were produced by subjects undergoing the exciting video clips with respect to subjects to whom neutral, fearful or sad videos were shown.

Breaban and Noussair (2015) provide a real time emotions tracking. Through a face reading software, participants' facial expressions are monitored before and while the market is running. Similar to the previous findings, positive emotions are positively correlated with overpricing and fear leads to declining price patterns.

Kocher et al. (2015) investigate the relationship between market pricing and variations in self-control abilities. Two markets settings are implemented. While in one market agents' self-control is not reduced (control market), in the other market, participants' self-control is reduced[11]. In the latter treatment, significantly larger overpricing is detected. The paper provides evidence that self-control problems can lead to exuberant behaviour and mispricing.

9. Conclusion

This work has provided a review of the main advances on the use of experimental procedures to study financial market performance. The included works perform the task to provide readers with a picture of the prevailing research strands and the relative state of art. As visible, due to the advantage of making relevant variables observable, the use of a laboratory framework to address financial markets study has been widely adopted in the last decades. This makes experimental methodologies a complementary tool to both theoretical and empirical investigation on asset markets.

[11] Exogenous self-control reduction is performed through a Stroop task. Baumeister et al. (1998) have shown the performance of the Stroop task in reducing people's ability to exert self-control.

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