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Overweighting of public information in financial markets: A lesson from the lab

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Abstract

We experimentally study the information aggregation process in a laboratory financial market when a public signal is released. The public disclosure crowds out information demand and reduces price informativeness. The latter effect is primarily caused by the overweighting of public information into prices. We are the first in providing evidence that strategic pricing concerns trigger the overweighting effect and the consequent market overreaction to public disclosures. From an economic policy perspective, we give support that, when deciding their communication strategy, the regulator can mitigate the market overreaction by properly setting the level of information transparency.

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1 Introduction

The idea that the price system based on competitive markets can aggregate information dispersed in the economy dates back to the 1950s (Hayek, 1945). Economists have understood that in properly designed asset markets, prices can aggregate and disseminate the information possessed by traders, although this is not necessarily done efficiently. Instead of leaving the market operating alone, public disclosures might facilitate the information aggregation and dissemination process. We can ask whether and how the presence of a disciplining institution that releases public information can be beneficial for market performance. Intuitively, if it is assumed that public information simply accumulates to the information already present in the market, more information should be valuable for decision makers. However, when there exist strategic interactions among decision makers, public disclosures may lead to unintended consequences.

In this respect, the theoretical literature has shown that, in an economic system where agents have access to costly private information, noisy public information might be weighted above and beyond its precision[1] (*overweighting effect*), and its disclosure might reduce the production of private information (*crowding-out effect*). As a consequence, the noise in the information released can be amplified at the aggregate level driving the economic system far from the fundamentals and eventually damage social welfare.[2]

An extended line of research explores the primitives to observe those effects and their

[1]According to the Bayesian update of noisy signals, each signal has to be weighted proportionally to its precision.

[2]The classical papers of Hirshleifer (1971) and Hakansson et al. (1982). More recently, these are the papers of Colombo et al. (2014), Vives (2014), and Goldstein and Yang (2017), among others.

consequences in different economic environments. Several contributions are centered on coordination games based on Keynes' beauty contest metaphor.[3] In this category of models, agents' payoff depends on the distance from i) the fundamentals, and ii) agents' average opinion, which accounts for the *beauty contest* interaction. Thus, agents adjust toward the fundamentals while trying to coordinate among themselves. In such a framework, Morris and Shin (2002) (hereafter MS) show that public information is a double-edged instrument, conveying information on the fundamentals and, at the same time, providing information on other agents' beliefs. Public information, thus, carries an informational component and a commonality component. Because of this double role, agents overrely on public information and, as a consequence, the market overreacts to public information.

Other papers analyze the consequences of public disclosures in a market environment, without introducing an explicit coordination motive.[4] In such models, decision makers maximize their payoff from trading in the market. Particularly, Allen et al. (2006) are the first to directly connect the overweighting of public information with traders' excessive reliance on public information, outside the coordination framework. In an overlapping generation model, they illustrate how the role of second- and higher-order beliefs in pricing the asset generates the overweighting effect. More precisely, they show that asset prices overweight public information relative to private information when traders' willingness to pay is related to their beliefs on the average opinion.

[3]See Morris and Shin (2002), Myatt and Wallace (2011), Angeletos and Pavan (2004, 2007), and Colombo et al. (2014).

[4]For example, Allen et al. (2006), Bacchetta and Van Wincoop (2008), Amador and Weill (2010), and Goldstein and Yang (2019).

Instead of being limited just to an academic debate, overreliance on public information has become a cause of concern for regulatory institutions. The 2008 financial crisis is a good example of excessive reliance if one takes into account the influence that the valuation of credit rating agencies (CRA hereafter) had on investors' financial decisions, who blindly followed what turned out to be misleading advice. Besides the overreliance on ratings, it might be possible that their presence gave to traders fewer incentives to search for independent and alternative sources of information for evaluating innovative financial products. Thus, the information provided by rating agencies might have reduced the information gathering activity of investors, crowding out valuable information at their disposal. In order to avoid such perverse effects of ratings, regulatory institutions proposed new measures to incentivize market participants toward improving their internal risk management capabilities and reducing overreliance on external credit ratings. Along this line, the CRA III Regulation included a set of measures to strengthen own credit assessment by relevant actors and reduce reliance on credit ratings alone (European Commission, 2009). In the US market, the Dodd-Frank Wall Street Reform and the Consumer Protection Act of 2010 were approved by the US Congress to avoid overreliance on credit ratings by investors and institutions (Chaffee, 2010).

The adverse effects of releasing public information are not only relevant for the activity of CRA, but they also include regulatory institutions as central banks considering, for instance, the level of transparency in their forward guidance activity or the disclosure of banks' stress-tests results. Morris and Shin (2005) illustrate how central bank management of expectations might lead to adverse effects on the informational efficiency of prices in financial markets. They point out that central banks face the risk of dominating the dynamics of prices if they ignore the complex interplay between the precision of the released information and the degree of traders' overreliance. In recent years, central banks have included in their research agenda the study of how public communications and disclosure policies affect agents' behavior and incentives. In particular, they wonder how disclosure policies can be designed to maximize their impact on the desired forms of behavior, such as the accurate pricing of risk and the proper formation of expectations of inflation (Bank of England, 2015).

Despite the awareness of regulatory institutions of the excessive reliance on public information, there is no empirical evidence supporting its relevance beyond an anecdotal narrative.[5] Thus, the laboratory provides a suitable platform to study the adverse consequences of public information disclosures in markets, in general, and in financial markets, in particular. It is possible, in fact, to control and observe all information in the hands of decision makers, together with their trading activity. While the determinants and consequences of information acquisition have been studied in several market experiments,[6] the experimental literature on market overreaction to public disclosures on financial markets is limited. Ackert et al. (2004) and Middeldorp and Rosenkranz (2011) are the only contributions dealing directly with this issue. Indeed, most of laboratory contributions related to overreliance on public information are limited to stylized game theoretical coordination models based on MS' seminal paper.[7]

[5] The paper of MS started a debate on whether the excess of reliance is an empirically relevant effect for central banks' communication. The empirical relevance of overreliance for monetary policy has been questioned by several prominent scholars, such as Svensson (2006) and Blinder et al. (2008).

[6] See, for example, the most recent contributions: Page and Siemroth (2017), Corgnet et al. (2018), and Asparouhova et al. (2017).

[7] See, for example, Baeriswyl and Cornand (2014), Cornand and Heinemann (2014b), Dale and Morgan (2012), and Shapiro et al. (2014). For a survey see, e.g., Cornand and Heinemann (2014a).

Within this framework, Cornand and Heinemann (2014b) and Shapiro et al. (2014) show that the overweighting phenomenon can be observed, although it is milder than predicted by the theory. In this class of experiments, the overweighting effect is maximum under full rationality and weaker under bounded rationality. The lower-than-predicted overweighting of public information renders this effect a second-order issue (Baeriswyl and Cornand, 2016), at least in a coordination framework.

This paper aims at experimentally testing whether the adverse effects of the disclosure of public information are general phenomena to be observed in a market context beyond the coordination environment. With this aim, we investigate the impact of releasing an imperfect, public, and costless signal into an asset market where traders have access to imperfect and costly private information about the future prospect of the asset. This setting allows us to study under which conditions the presence of public information may act as a sort of disciplining mechanism, promoting the aggregation of information or, by contrast, systematically distorting market performance, thus driving the price far from the fundamentals. To the best of our knowledge, our paper is the first experimental contribution without an explicit coordination motive to detect the overweighting effect in a market context.

In particular, we analyze under which conditions the overweighting of public information reduces price informativeness and is the source of market overreaction to public disclosures. Several experimental papers, such as those of Ackert et al. (2002), Page and Siemroth (2017, 2019), and Halim et al. (2019), have reported a reduction in price informativeness in a market with released public information. However, such a reduction in price informativeness has been attributed to a similar reduction in the quantity of information present in the market due to the overweighting effect. In our paper, we instead show that it does not exist a straightforward relationship between the quantity of information and the price informativeness. Prices are systematically biased towards the public signal, resulting in the overweighting effect that leads to a deterioration in price informativeness, and market overreaction to the release public information.

Contrary to the theoretical literature on the overweighting of public information, it seems that the bounded rationality of traders is a key feature responsible for the emergence of such a phenomenon in our experiment. Full rationality in our setting implies either a *do nothing equilibrium* or a market price that weights each signal, private and public, according to its precision (*fully or partially revealing benchmark*). In both cases, public information is never overweighted compared to its precision. Thus, the observation of a systematic deviation toward the public signal challenges the current *rational* view similar to that in the MS framework, posing new theoretical and experimental questions on the problems of how to release public information into financial markets. Moreover, we provide experimental support to the conjecture of Allen et al. (2006) on the role of higher-order beliefs as the main driver of the emergence of the overweighting phenomenon. Finally, when lowering the precision of public disclosures, which represents the level of transparency, we observe that the overweighting effect is lessened. Our result gives a robust back-up to the idea that releasing public information can be harmful for the performance of a financial market if it is not properly tailored to market conditions.

The rest of the paper is organized as follows. Section 2 describes the experimental design, and Section 3 discusses the theoretical background together with the related literature. Section 4 presents a detailed analysis of the results in the information and asset markets. Section 5 discusses the behavioral insights of our experimental findings. Finally, the concluding remarks are given in Section 6, with particular emphasis on the policy implications for regulatory institutions.

2 Experiment design and procedures

2.1 Experiment design

Our experimental setting is similar to other contributions from the literature on laboratory financial markets and prediction markets.[8] Each market consists of a three-minute trading period, and it is populated by 15 traders.[9] At the beginning of the trading period, each trader is endowed with $C^0 = 1,000$ units of experimental currency (ECU)[10] and $A^0 = 10$ Arrow-Debreu assets that pay a dividend $D \in \{0, 10\}$ at the end of the market with 50–50 chances, which is common knowledge among traders. Assets live only for a single trading period, i.e. one market, and they are worthless apart from the dividend paid out. The value of the dividend is randomly determined by the experimenter before the market starts, but it is not revealed to the traders until the end of the market when traders' payoff is determined. The asset market is implemented as a double auction, where traders are free to introduce their bids and asks for assets or directly accept any other trader's outstanding bid or ask. Every bid, ask, or transaction concerns only one unit of the asset, although every trader

[8]See, for example, Ackert et al. (2002), Hey and Morone (2004), Deck et al. (2013), Fellner and Theissen (2014), Ferri and Morone (2014), Page and Siemroth (2017), and Halim et al. (2019).

[9]In the baseline treatment, group 1 is populated by 13 traders.

[10]The cash, dividends, prices, and profits during the experiments are designated in experimental units (ECU) and converted into € at the end of the session. One experimental currency unit is equivalent to 2 cents of €.

can handle as many as desired as long as he/she has enough cash or assets (no short sale is allowed).

Parallel to the asset market, we implement an information market where, at any moment within the trading period, traders can acquire partially informative private signals at a price of 4 ECU per signal. Private signals are independent realizations conditional on the dividend value, and they are presented to traders with a value of 10 or 0. More precisely, the probability of getting a signal suggesting a dividend 10 is p when the state of the world[11] is $D = 10$, and the probability of getting a signal suggesting a dividend 0 is $q = 1 - p$. We refer to p as the precision of the signal. Table 1 summarizes the treatment parameters and the number of markets. In the baseline treatment (B), traders have access only to costly private information.

We aim at studying how the mere presence of public information affects the performance of the information and asset markets. We do not provide the institution releasing the public signal with any pay-off or target function. The public signal is the realization of a binary random variable with a given correlation with the fundamentals, and it does not emerge out of a micro-funded strategy of the regulatory authority releasing the signal. To study the impact of public information on market performance, we introduce the public information treatment (PS80) in which traders can acquire private signals and have free access to a *public signal*, which is released at the beginning of each market and whose realization is identical to all traders and is common knowledge.[12] Similar to private signals, the realization of the public signal might take a value of 10 or 0 with precision P.

[11] *Mutatis mutandis* for the state of the wold $D = 0$.

[12] PS80 denotes that the precision of the public signal is 80%.

Table 1: Experimental design and parameters.

Setting	Treatment	p	P	♯ of markets
Baseline	B	0.8	-	20
Public information	PS80	0.8	0.8	20
	PS70	0.8	0.7	20
Common information	CS80	0.8	0.8	20

An important issue of the experiment is the evaluation of the impact of public disclosures on traders' beliefs. To disentangle the two elements that render public information a double-edged instrument, we implement the common information treatment (CS80) in which traders observe a costless signal whose realization is identical to all of them, but it is not common knowledge.[13] In other words, they only know that each trader receives one signal with the same precision, but they do not know that the realization of that signal is identical to all traders. Hereafter, we will refer to this signal as the *common signal.* The common signal is therefore equally informative to all traders about the dividend value, but it is no longer a predictor of the opinion of the other traders as the public signal is. Interestingly, the impact of a common signal on asset markets has never been analyzed so far in the theoretical and experimental literature.

Comparing the results of the treatments with the PS80 and CS80 treatments allows us to understand whether the commonality component of public information serves as the main driver of its potential distorting effect on market prices, as suggested by the theoretical literature. It is worth noting that traders' first-order beliefs on the dividend value are

[13]CS80 denotes that the precision of the common signal is 80%.

identical in the PS80 and CS80 treatments. However, the absence of common knowledge about the free signal in the CS80 treatment makes traders' second- (or higher-) order beliefs different compared with the public information treatment. The comparison of the PS80 versus CS80 treatments constitutes a clever design to disentangle the role of the first- and second- (or higher-) order beliefs of traders (see Section 4.5) in pricing the asset. Similar to the public signal, the common signal is released at the beginning of each trading period, and it is presented to traders with a value of 10 or 0 with precision $P = 0.8$.

Moreover, we study the effect of the relative precision of public information with respect to private information. Concerning the optimal communication of monetary authorities, several authors, such as Myatt and Wallace (2014) and Baeriswyl and Cornand (2014), consider the transparency of public information as a control variable when designing the optimal central bank information disclosure policy. The theoretical literature hypothesizes the existence of an optimal level of transparency for public information based on the trade-off between its informational role and its potential distortion effects.[14] Taking stock of it, we implement a public information treatment in which the precision of the public signal is lower than that of the private information. In treatment PS70, the public signal has a precision of $p = 0.7$. Our experimental design allows the testing of whether the overweighting phenomenon depends on the relative precision of private and public information. In particular, we can test whether regulatory authorities might enhance or mitigate the crowding-out effect and the market overreaction to public disclosures.

[14] See other papers, such as those of Colombo and Femminis (2008), and Cornand and Heinemann (2008).

2.2 Experiment procedures

The experiment is programmed using the Z-Tree software (Fischbacher, 2007) and it is conducted at the *Laboratori d'Economia Experimental* in University Jaume I in Castellón. A total of 118 undergraduate students from economics, finance, and business administration in at least their second year of study are recruited. When subjects arrive at the laboratory, the instructions are distributed and explained aloud using a PowerPoint presentation.[15] This is followed by one practice period so that the subjects become familiar with the software and the trading mechanism. Each subject can only participate in one session, which consists of 10 markets. At the end of every market, dividends are paid out, and the subjects' profit is computed as the difference between their initial cash endowment and the cash held at the end of the market. Each subject's final payoff is computed as the accumulated profit in the 10 markets, and each subject is paid cash at the end of the session. The average payoff is about 20 €, and each session lasts around 90 minutes.[16]

3 Theoretical background and related literature

3.1 Do nothing equilibrium

Our experimental setting can be characterized by a do nothing equilibrium. If all traders are risk neutral or share the same beliefs and risk aversion, we should observe no transaction

[15] A copy of the translated instructions is available upon request.

[16] Note that the subjects can incur losses. To avoid some of the problems associated with subjects making real losses in experiments, we endow all the subjects with a participation fee of 3 €, which can be used to offset losses. No subject earns a negative final payoff in any session.

in the asset market and no information acquisition. The basic element underlying the do nothing equilibrium is in the constant-sum nature of our setting. Essentially, it means that a trader would have incentives to acquire a private signal just in case he/she expects to recover the acquisition cost, therefore making profit at the expense of some other traders. Taking stock of this, the other traders who have not acquired private signals would not trade with him. Therefore, the incentive for the first trader to acquire private information disappears, and there will be no activity in the information and asset markets. As we will see in Section 4, this equilibrium is never achieved. Conversely, we always observe a sustained level of trading activity.

3.2 Information acquisition

The experimental and theoretical literature on information acquisition in asset markets is extensive.[17] We focus here on the part of the literature describing the crowding-out.

Within a coordination environment, several authors, such as Hellwig and Veldkamp (2009), Myatt and Wallace (2011), and Colombo et al. (2014), propose a theoretical model that generalizes MS's setting introducing the acquisition of costly and noisy private information in the presence of public information. Hellwig and Veldkamp (2009) study the role of information choice in price-setting models. They conclude that the incentive of agents to acquire costly information is stronger when others also acquire information and there are strategic complementarities in their actions. Myatt and Wallace (2011) go one step further

[17]See the surveys of Sunder (1995), Deck and Porter (2013), Powell and Shestakova (2016), and Nuzzo and Morone (2017) on experimental asset markets, as well as that of Goldstein and Yang (2017) on theoretical models.

and introduce endogenous costly attention. Agents pay attention to the clearest signal available, even if its precision is the lowest. If the complementarity of agents' actions rises, the acquired information is more public in nature. Colombo et al. (2014) show the determinants of a crowding-out effect of public information on the equilibrium acquisition of private information.

Outside the coordination framework, Kool et al. (2011) introduce a rational expectations asset market model to prove that public information crowds out costly private information. As a consequence, prices become less informative about future interest rates. Note that they attribute the reduction in price informativeness to the reduction in the quantity of information available in the market because of the crowding-out effect. Middeldorp and Rosenkranz (2011) find experimental evidence of the relevance of the crowding-out of private information and a contemporaneous reduction in price informativeness, as stated by Kool et al. (2011). In our experiment, we will show that it is the overweighting of public information, as hypothesized by Allen et al. (2006), that is responsible for the reduction in price informativeness instead of crowding-out.

To form a working hypothesis, we can rely on the experimental literature on the acquisition of information in prediction markets. Recently, Page and Siemroth (2017) have studied different aspects of information acquisition in a prediction market similar to our setting. They report that traders acquire information despite the incentive to not to do it. Hence, we should also observe a notable acquisition of information in our experiment. The release of the free signal[18] helps investors to forecast the fundamentals, reducing the marginal value of private information and then its demand. Taking stock of it, we expect that the acquisition

[18]When it is irrelevant to differentiate between public and common signal, we denote it as *free signal*.

of private information decreases when a free signal is released in the market.

Hypothesis 1 *The release of a free signal crowds out the demand for private information.*

Comparing the public and common information treatments, we can study the role of the commonality of public information on the demand for private information. The common signal does not carry information on other traders' beliefs, so the crowding-out in CS80, if present, is due solely to the information on the fundamentals provided by the free signal. We hypothesize that if the PS80 and CS80 treatments exhibit the same reduction in information demand, the informational component of the free signal is the main driver of the crowding-out effect.

Hypothesis 2 *The informational component of the free signal is the primary cause of the crowding-out effect.*

Significant differences instead point to the existence of strategic interactions among traders in the acquisition of information (Hellwig and Veldkamp, 2009; Page and Siemroth, 2017).

3.3 Information aggregation

Turning to the asset market, an alternative to the do nothing equilibrium is the fully revealing benchmark that we compute as the expected price conditional on all information present in the market. Note that whereas do nothing is an equilibrium in a strict economic sense, the fully revealing benchmark is not. Grossman and Stiglitz (1980) show the impossibility of the existence of an equilibrium in a market with fully informative prices and contemporaneous access to costly information. If the information is instantaneously incorporated into the market price, as stated by the efficient market hypothesis (EMH hereafter), traders have no incentive to acquire private information. However, if no trader acquires information, it immediately appears as a profit opportunity and, therefore, an incentive to gather information. Grossman and Stiglitz (1980) resolve this paradox by introducing exogenous noise to provide incentives for the acquisition of costly information. The presence of exogenous noise compensates for the costs of acquiring information so that it is possible to define an equilibrium in both the asset and information markets.

Addressing experimentally the Grossman-Stiglitz paradox, Sunder (1992) shows that the fully revealing benchmark is a reasonable predictor to describe price behavior in a laboratory asset market. He suggests that the double auction mechanism creates enough *endogenous* noise to prevent an instantaneous revelation of information, creating incentives for traders to acquire information even in the absence of exogenous noise. Taking into account that we use a double auction as a trading mechanism in the asset market and that traders have access to costly imperfect information, we can rely on Sunder's conjecture to consider the fully revealing benchmark as a possible predictor of the level of prices. We compute the fully revealing benchmark (FR) as the Bayesian conditional probability ($Pr(\cdot|\cdot)$) of $D = 10$ given all information available at time t in a given market m:

$$FR_{mt} = Pr(D = 10|H_{mt}, S_m) = 10 \left[1 + \left(\frac{q}{p}\right)^{H_{mt}} \left(\frac{Q}{P}\right)^{S_m} \right]^{-1}, \tag{1}$$

where H_{mt} refers to the net private signals available up to time t and S_m denotes the realization of the free signal.[19]

[19]See Appendix A for the derivation of the fully revealing benchmark. Note that there is no free signal in the B treatment, so we pose $S_m = 0$.

Hypothesis 3 *The fully revealing benchmark accurately predicts market prices.*

Hypothesis 3 implies that the information is fully incorporated into the price, independently of its nature (public or private). Essentially, we rely on the EMH in its strong form (Fama, 1970). As a consequence, if the information present in the market is sufficient to discover the dividend value, prices should converge to the dividend independently of the realization of the public signal and its precision.

Nevertheless, many experimental contributions on laboratory financial markets show that information aggregation is imperfect, and, therefore, prices are just partial indicators of the fundamental value.[20] Inspired by Sunder (1992), a series of experimental studies explores the informational efficiency of prices in the presence of information acquisition, concluding that prices hardly reveal information when the distribution of (perfectly) informed traders is not common knowledge in the market (Copeland and Friedman, 1991, 1992; Camerer and Weigelt, 1991). More relevant for our experiment, several experiments analyze information aggregation in Arrow-Debreu asset markets with acquisition of imperfect information (Hey and Morone, 2004; Page and Siemroth, 2017; Corgnet et al., 2018; Halim et al., 2019). Generally, this strand of literature finds limited evidence that prices aggregate all information. Hey and Morone (2004) suggest that the aggregation process improves when the precision and quantity of information in the market are higher. Page and Siemroth (2017) analyze the impact of exogenous signals (private or public) allocated at the beginning of the market. They attribute the observed informational inefficiency to the quantity of acquired information by traders. Following Page and Siemroth (2017), Corgnet et al. (2018) observe that prices are

[20]See the surveys of Sunder (1995), Plott (2000), and Noussair and Tucker (2013) on experimental asset markets.

not more informative than what is predicted by the prior information model. Huber et al. (2011) design an asset market with five costly information levels, from uninformed to insider traders. They observe that traders learn to choose the most advantageous information level. While previous contributions explore price informativeness in a double auction market, other authors, such as Asparouhova et al. (2017) and Halim et al. (2019), focus on decentralized markets to study whether prices can reflect costly information and how it affects the decision of information acquisition. Considering this experimental literature, we expect to observe some deviations from the fully revealing benchmark. The contribution of our paper is to evaluate whether those deviations are systematically pointing to the public signal.

3.4 Overweighting of public information

We explicitly test whether public information is overweighted in the market price with respect to its precision, reducing the informativeness of prices. Contrary to EMH, we conjecture that the efficiency of information aggregation in prices depends on the nature of the information, namely whether it is private or public.

Morris and Shin (2002) and Allen et al. (2006) are the first to point out that public information is overweighted with respect to its precision. In the coordination model of MS, agents make a double account of the public signal, considering its informational content, as well as its role in second-guessing the beliefs of other agents. The incentive to coordinate renders public information a predictor of the beliefs of other agents, and, therefore, they overrely on that information. In Allen et al. (2006), higher-order beliefs play a role in pricing the asset. Since public information enters in all traders' demand function, it constitutes a predictor for aggregate demand beyond its information about fundamentals. Allen et al.

(2006) show that market prices systematically tend to be driven by public disclosures more than being justified solely by their informational content. When information is aggregated into prices the overweighting effect reduces price informativeness.

From an experimental point of view, Page and Siemroth (2019) use a meta-analysis on experimental data to show that public information is almost completely incorporated in prices, but little private information is reflected in prices. Their finding is compatible with the overweighting phenomenon, although they did not explicitly mention this effect in their paper.

Our experimental setting exhibits the key elements suggested by the theoretical literature to observe overweighting of public information on market prices: (i) access to private and public information, (ii) heterogeneous expectations because of the endogenous acquisition of noisy private information, and (iii) the beauty contest element following the Keynes' metaphor in describing a financial market (see Section 5 for an illustrative example). Considering those three points, we rely on the result of Allen et al. (2006) that states that prices overweight public information if traders take into account the average belief of the other traders when deciding their reservation price. We introduce the following alternative hypothesis:

Alternative Hypothesis 3 *Prices overweight public information.*

To account for the overweighting phenomenon, let us define here the public information benchmark (PB) as the expected price conditional just on public information:[21]

[21] The announcement that the two states of the world are equally probable constitutes the public signal in B and CS80 treatments.

$$PB_m = Pr(D = 10|V_m) = 10\left[1 + \left(\frac{Q}{P}\right)^{V_m}\right]^{-1}. \qquad (2)$$

where $V_m = 0$ in B and CS80 treatments, whereas $V_m = S_m$ in PS80 and PS70 treatments. Note that both the fully revealing benchmark of Eq. (1) and the public information benchmark of Eq. (2) take into account the public signal. The main difference is that the fully revealing benchmark weights all pieces of information according to their respective precisions following the Bayesian rule, whereas the public information benchmark assigns a zero weight to private information.

3.5 The role of second-order beliefs

It could be that at the stage of guessing the dividend, traders are already biased toward the public signal, i.e., they overweight the public signal in their first-order beliefs on the dividend value. Therefore, the margnitude of the overweighting effect depends on the informational component of the free signal. We can further assume that such a bias accounts for the whole overweight of the public signal in the market price, instead of a sort of strategic consideration based on second-order beliefs, as suggested by Allen et al. (2006).

The CS80 treatment allows us to evaluate whether it is the role of the second-order beliefs in shaping the overweighting effect or it is a bias in the first-order beliefs. Recall that the common signal provides the same information on the fundamentals as the public signal, but without influencing traders' higher-order beliefs since this signal is not common knowledge. Therefore, if traders base their trading strategy on second-order beliefs, we expect to observe that the overweighting effect disappears in CS80 treatment, or at least it is strongly attenuated as compared to PS80 treatment.

To put it differently, under the hypothesis of a first-order belief bias of the free signal, we should observe that

Hypothesis 4 *The overweighting effect exhibits the same magnitude in PS80 and CS80 treatments.*

Alternatively, when the magnitude of this effect is significantly higher in PS80 than CS80, second-(or higher-) order beliefs play a predominant role in the emergence of the overweighting effect.

3.6 Traders' profits

Traders' profits are closely related to information acquisition and the aggregation of information into prices. In the noisy rational expectations equilibrium (REE) proposed by Grossman and Stiglitz (1980), informed traders can make profit only to cover information acquisition costs, as prices only partially reveal information to uninformed traders. As Sunder (1992) states, the features of double auctions allow the attainment of a noisy REE with costly information.

As a working hypothesis, we conjecture that informed traders recover the cost of information acquisition, earning the same net profits as uninformed traders in all treatments.

Hypothesis 5 *Traders earn the same net profits independently of the number of acquired signals.*

4 Results

Figures 5 through 12, included in Appendix B, show the trading activity in all markets for all treatments. Each panel of figures refers to one particular market. A simple inspection of market activity shows that the do nothing equilibrium is not a meaningful description of traders' behavior in any of the implemented treatments. This empirical finding is in line with many experiments on laboratory financial markets characterized by *no-trade equilibrium*.[22]

In the following, we present our results focusing on how access to public information affects the information and asset markets.

4.1 Information acquisition

Figure 1 illustrates the per capita acquisition of signals in each market for each treatment. As is evident from the figure, releasing a free signal *crowds out* the demand for private information. A Mann-Whitney test (hereafter MW) shows that differences between treatment B and each of the other treatments are significant (MW test, $p = .00$). Therefore, we cannot reject Hypothesis 1 that releasing a free signal reduces information acquisition.[23]

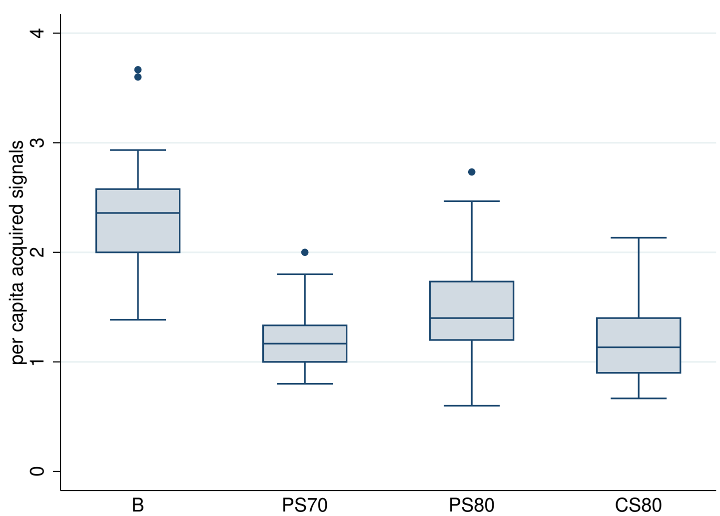

Figure 1: Per capita demand for private information per market and treatment.

[22]Several recent papers study under which conditions subjects do trade in the laboratory despite the theoretical incentives not to do so (Angrisani et al., 2008; Carrillo and Palfrey, 2011).

[23]Note that the fraction of traders acquiring information is not significantly different among treatments. More than 50% of traders acquire at least one signal (material upon request).

Result 1 *Releasing a free signal crowds out private information.*

The magnitude of the crowding-out effect differs among treatments. We observe that information acquisition is lower in CS80 treatment than in PS80 (MW test, $p < .02$). The release of a public instead of a common signal creates a *crowding-in* effect, suggesting that the nature of the free signal significantly affects the magnitude of the crowding-out. Interestingly, Page and Siemroth (2017) report a similar result, observing that traders are more likely to acquire signals when their initial information is public rather than private. In CS80 treatment, in fact, traders believe that they have access to a private signal.

Moreover, information acquisition depends on the relative precision between public and private signals. We find that when private and public signals have the same precision, i.e., PS80, traders acquire significantly more private signals than in PS70 treatment (MW test, $p < .05$). This finding is also compatible with the intuition that traders acquire more private information to know more than the other traders, depending on the symmetry (or perceived symmetry) of their initial information (Page and Siemroth, 2017, pag. 361) .

Result 2 *The magnitude of the crowding-out effect depends on two characteristics: i) the commonality of the free signal and ii) the relative precision with respect to the private signal.*

Considering Result 2, we can reject Hypothesis 2 and state that our findings are compatible with the presence of some strategic interactions among traders in the acquisition of information. Paraphrasing Hellwig and Veldkamp (2009), traders want to know what the others do not know.

4.2 Market informativeness

After having analyzed how public disclosure affects the demand for private information, we address whether the public signal compensates for the reduction in private information. To evaluate the impact of public information on the potential to discover the true state of the world, we introduce the market informativeness indicator.

We define market informativeness (MI) as the mean absolute deviation (MAD hereafter) of the fully revealing benchmark about the dividend, averaged during the last minute of the market. The label m indicates the given market, and t indicates the time:[24]

$$MI_m = \frac{1}{60} \sum_{t=120}^{180} \frac{|FR_{mt} - D_m|}{10} . \quad (3)$$

The maximum level of market informativeness is reached when $MI_m = 0$. The higher the value of MI_m, the lower the market informativeness. Thus, a value of MI close to zero indicates that the information present in the market is sufficient to discover the dividend value.

As one can infer from Figures 5 through 12, market informativeness always satisfies the condition $MI_m < .05$.[25] Therefore, the information present in the market is always sufficient to discover the dividend value at a reasonable confidence level. Despite the crowding-out effect on the demand for private information, the potential of the market to discover the true

[24]The choice of averaging over the last trading minute is a compromise between having sufficient statistics for the market informativeness indicator and having a low activity in the information market. In the last minute, in fact, either zero or few signals are acquired, and, therefore, the fully revealing benchmark is almost constant over time. Moreover, traders should have enough time to aggregate the information present in the market, giving to the fully revealing benchmark its *best shot* as Plott and Sunder (1988) state. We divided by 10 in order to normalize all distances to be between 0 and 1.

[25]Except for market 9 of group 1 in treatment PS80, which is equal to 0.14.

state of the world is not affected by the release of a free signal, and it is independent of its realization.

Result 3 *The crowding-out effect leaves invariant the potential of the market to discover the true state of the world.*

4.3 Price informativeness

We explore now how the release of a public signal affects the aggregation of information into prices (price informativeness). According to Hypothesis 3, prices should aggregate all the information in the market. Moreover, given Result 3, prices should converge to the dividend in most of the markets independently of the realization of the free signal.

As a measure of price informativeness, we evaluate how the fully revealing benchmark, Eq. (1), accounts for the market prices for each treatment. We proxy the price informativeness by computing the MAD of the market price (PR_t) about the fully revealing benchmark, averaged among all markets ($M = 20$) for each treatment:

$$MAD_t^{FR} = \frac{1}{M} \sum_{m=1}^{M} \frac{|FR_{tm} - PR_{tm}|}{10} \ . \tag{4}$$

The maximum level of price informativeness is given when $MAD_t^{FR} = 0$. Significant deviations from the lower bound, instead, indicate a lower level of price informativeness.

Figure 2 plots the average price informativeness per second for each treatment. The observed price informativeness is downsloping over time for all treatments, suggesting that prices tend to gradually aggregate information improving the price accuracy.[26] However,

[26]We define as price accuracy the distance between the average price across markets and the dividend. Essentially, we can compute price accuracy by replacing FR_{tm} in Eq. (4) with the corresponding value of the dividend D_m. Note that, considering Result 3, price informativeness and price accuracy are almost identical over the trading period (material available upon request).

in none of the treatments, the price converges to the dividend, as predicted by the fully revealing benchmark; therefore, we can reject Hypothesis 3.

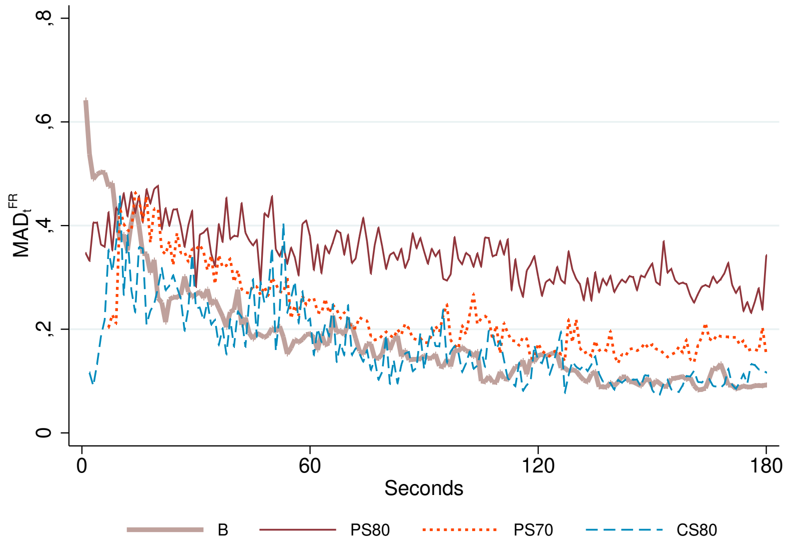

Figure 2: Average price informativeness over time (MAD_t^{FR}).

Result 4 *Prices imperfectly aggregate the information present in the market.*

Our findings indicate that prices partially aggregate the information in all treatments, which is compatible with the observed behavior in previous contributions in similar settings (Hey and Morone, 2004; Page and Siemroth, 2017; Corgnet et al., 2018), and laboratory asset markets with endogenous costly private information in general.

Nevertheless, differences among treatments are evident. While prices in treatment B quickly aggregate most of the information and eventually reach an accuracy of almost 90% of the dividend, treatments with public disclosure exhibit a smoother improvement of price informativeness over time. Prices forecast approximately 70% and 80% of the dividend in treatments PS80 and PS70, respectively. In the CS80 treatment, prices reach an accuracy comparable with that in the B treatment. In sum, public disclosure worsens the dissemination of information, leading to the deterioration of price informativeness compared with treatment B.

Result 5 *Public disclosures worsen price informativeness.*

Remark: One might wonder whether the reduction in acquired information is the cause of the reduction in price informativeness. If the level of crowding-out is the main determinant of the reduction in price informativeness, MAD^{FR} should be the lowest in the B treatment, followed by the PS80, PS70, and CS80 treatments (see Figure 1). Instead, the average price informativeness in CS80 reaches a similar level as that in the B treatment despite the number of acquired signals being significantly lower than that in PS80 (MW test, $p < .05$). Furthermore, the price informativeness is higher in treatment PS70 than in PS80, even though it should be the opposite, given the corresponding magnitude of the crowding-out. We provide evidence that the reduction in price informativeness is not in a one-to-one relation with the crowding-out effect. Our results imply that a higher acquisition of private information is not *per se* a condition of increasing price informativeness.

Result 6 *More information does not always improves the informational efficiency of prices.*

Contrary to the EMH, our findings point out that the nature of the free signal plays a crucial role in determining the efficiency of the market.

4.4 Overweighting of public information

After rejecting Hypothesis 3, we rely on Alternative Hypothesis 3 to explain the observed reduction in price informativeness. We conjecture that prices systematically weight public information more than justified by its informational content, leading to a reduction in price informativeness.

To evaluate the overweighting of public information, we measure the goodness of fit of the fully revealing benchmark and the public information benchmark as follows:[27]

$$MAD_m^{FR} = \frac{1}{60} \sum_{t=120}^{180} \frac{|FR_{tm} - PR_{tm}|}{10} \,, \tag{5}$$

$$MAD_m^{PB} = \frac{1}{60} \sum_{t=120}^{180} \frac{|PB_m - PR_{tm}|}{10} \,. \tag{6}$$

When MAD_m^{PB} is close to zero, prices fluctuate around the public information benchmark.

Figure 3 illustrates the distributions of MAD^{FR} and MAD^{PB} across treatments.[28] We confirm Result 5 that releasing a public signal reduces price informativeness. A MW test shows that MAD^{FR} is significantly larger in treatment PS80 than in treatment B ($p = .00$). If we compare treatments B and PS70, the deterioration of price informativeness is weaker but still present, at least at the 10% significance level.[29]

The comparison of MAD^{FR} and MAD^{PB} helps us evaluate whether deviations from fully informative prices systematically favor public information. When the MAD^{PB} statistic is significantly lower than the MAD^{FR} statistic, it means that the public information benchmark better accounts for prices than the fully revealing benchmark does. Recall that the realization of the public signal has just a marginal impact on the value of FR_{tm}. Therefore,

[27] We consider only the last minute for the same reasons explained in footnote 24. Again, we have normalized MAD_m^{FR} and MAD_m^{PB} to be bounded to 1.

[28] Note that, while Figure 2 displays the time evolution of price informativeness averaged across markets, Figure 3 plots the crossectional distribution of price informativeness in the last minute.

[29] The observed results persist when one considers the entire trading period (material available upon request).

a significant difference between MAD^{FR} and MAD^{PB} indicates that the market weights public information well beyond its informational content, being the main determinant of the price level.[30] In such a scenario, the market overreacts to public disclosures.

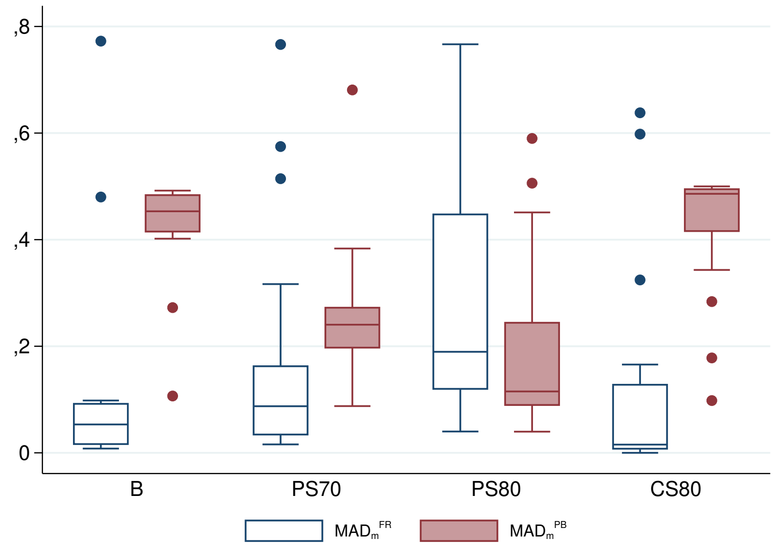

Figure 3: MAD^{FR}_m and MAD^{PB}_m for each market by treatment.

Comparing now MAD^{FR} and MAD^{PB} in each treatment, we observe that when the public signal is of high precision (PS80), it is unambiguously overweighted (sign-test, $p < .05$). In PS70 treatment, we cannot exclude that public information is overweighted. However, it is not anymore the main determinant of the price level. Indeed, it is the fully revealing benchmark that better accounts for market prices.

We cannot reject Alternative Hypothesis 3, as we detect overweighting of the highly precise public signal. On the other hand, we do not have enough evidence to conclude that prices do not overweight the less-precise public signal.

[30] Note that such a condition is a sufficient but not a necessary condition for detecting the overweighting phenomenon. In principle, we cannot exclude the presence of the overweighting of public information even in the case of MAD^{FR} being significantly lower than MAD^{PB}.

Result 7 *Prices overweight the public signal when it has the same precision of the private signal.*

Differences between PS80 and PS70 suggest that the magnitude of the overweighting effect is strongly influenced by the relative precision of the public signal with respect to a single private signal. Interpreting the relative precision of the public signal as its transparency, we provide evidence in favor of the possibility that controlling transparency of the information allows to smooth the market overreaction to public disclosures. Our results provide a robust back-up to the conjecture that setting the transparency of public information constitutes an effective control instrument at the disposal of regulators.

Remark: The reader might wonder whether markets with an incorrect public signal determine our results in PS80 treatment. As Figure 13 in the Appendix C illustrates, the deterioration in price informativeness and the overweighting of public information persist when we only consider markets with a correct signal. MAD^{FR} is significantly larger in PS80 than in B (MW test, $p < .01$), and the MAD^{FR} is significantly higher than MAD^{PB} in PS80 treatment (sign-test, $p < .05$). In PS70 treatment, MAD^{FR} of the correct signal is not significantly larger than in B treatment. So, in the PS80 treatment, the public signal distorts the aggregation process independently of its realization. The market always overreacts to the highly precise public signal.

4.5 The role of second-order beliefs

Releasing the common signal in CS80 treatment significantly improves price informativeness compared with the PS80 treatment (MW test, $p = .00$). Indeed, the overweighting effect disappears in the CS80 treatment, as prices converge to the dividend in most markets.[31] Once the commonality component is eliminated, the free signal does not constitute the main determinant of market prices. Contrary to the public signal, the common signal cumulates to the private information when aggregated into prices, without distorting the aggregation process. We therefore reject Hypothesis 4.

Result 8 *The commonality component of the public signal is the main determinant of the overweighting effect.*

The previous result suggests that first-order beliefs bias does not determine of the overweighting effect. Although we cannot exclude its existence, we can exclude that it is the primary cause the reduction in price informativeness. We can instead conclude that the overweighting effect is related to the commonality of the public signal.

To the best of our knowledge, this is the first contribution to the literature that observes and measures the overweighting effect of public information in a market environment. Furthermore, we are the first to provide empirical evidence compatible with the conjecture that traders' strategic pricing concerns trigger the overweighting of public information beyond the MS framework.

4.6 Traders' profits

We analyze traders' profit as a function of their information acquisition and the characteristics of the free signal. To that aim, we compute the net profit (π) of trader i in market m:

[31] To evaluate the robustness of our results, we define an additional benchmark including the common signal in Eq. (2). The absence of the overweighting effect persists even if we consider this alternative benchmark (material upon request).

$$\pi_{mi} = (C_{mi}^{180} - C^0) + D_m \, Assets_{mi}^{180} \, , \tag{7}$$

where $(C_{mi}^{180} - C^0)$ is the cash held at the end of the market after paying back the initial endowment, and $Assets_{mi}^{180}$ denotes the number of assets held at the end of the market. The difference in cash accounts for the cost of the private signals.

We define the trader's relative net profit as follows:[32]

$$x_{mi} = \frac{\pi_{mi}}{\frac{1}{N}\sum_{i=1}^{N} \pi_{mi}} \, . \tag{8}$$

The variable x_{mi} allows us to evaluate whether a trader or a category of traders exhibits higher profit relative to the other traders in a given market m. Following Hypothesis 5, a relative net profit of one is the benchmark against which we evaluate the relative performance of traders. Figure 4 shows the 95% confidence interval about the mean of the relative profit in each treatment.

We see that the release of a free signal strongly affects the pattern of profit distribution among information levels. In B treatment, uninformed traders and traders who acquired up to two signals make significantly higher profits than the benchmark (Wilcoxon-signed rank tests, $p < .02$), at expense of the other traders. Acquiring three or more signals does not allow the recovery of the information cost. In treatments with a free signal, uninformed traders perform significantly better than the average of the market (Wilcoxon-signed rank tests, $p < .03$). A different scenario emerges in the market with the released free signal.

[32] To compare the markets with dividend 0 and 10, we redefine the net profit, i.e. $(\pi_{mi} + 50)$ if $D = 0$ and $(\pi_{mi} - 50)$ if $D = 10$. The value 50 is the expected value of the portfolio of the assets at the beginning of the market.

In all three treatments, traders who acquire two signals outperform the market (Wilcoxon-signed rank tests, $p < .10$ or better). However, traders who acquire one signal do not earn significantly higher profits than the average. The introduction of a free signal leads to a non-monotonic relationship between profits and number of acquired signals.[33]

Result 9 *Uninformed and traders that acquire two signals earn higher net profits than the average.*

Thus, we can reject the Hypothesis 5.

[33] Huber (2007) observes an analogous non-monotonic relationship between profits and information.

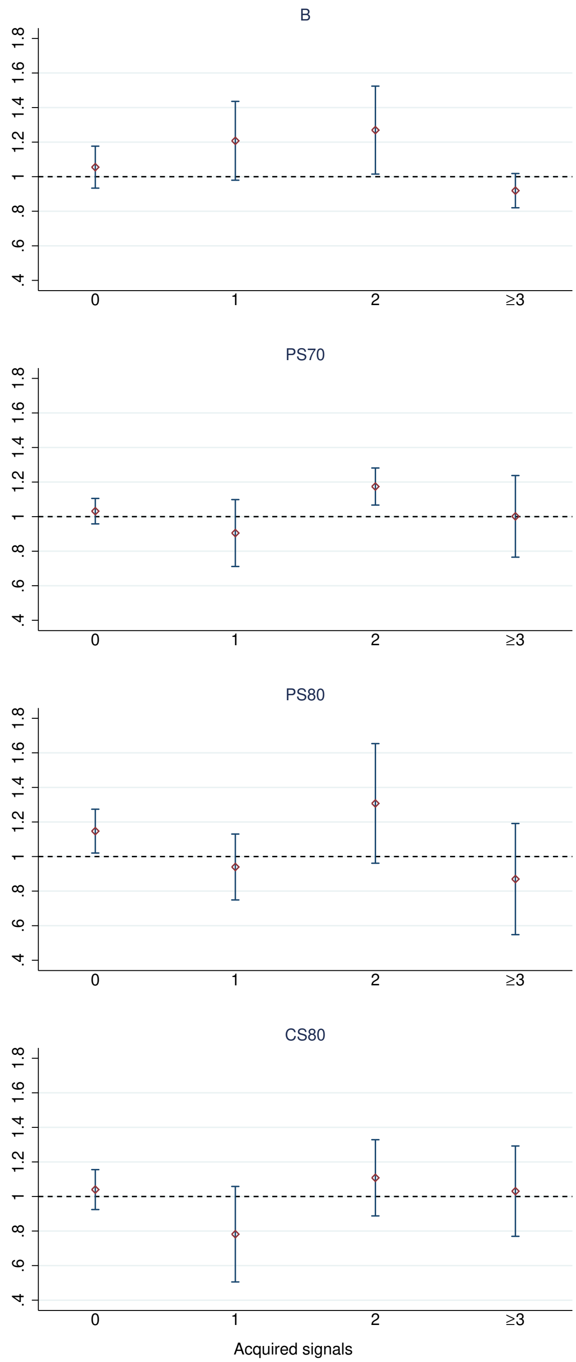

Figure 4: Relative net profit as a function of information acquisition by treatment.

5 Bounded rationality, overweighting, and higher-order beliefs

Following Allen et al. (2006), public information may have an excess impact on prices when higher-order beliefs play a role in the determination of prices, since a public signal provides information on the dividend and information on the other traders' beliefs.

Let us introduce a qualitative idea on how traders could have the incentive to forecast other traders' expectations in our financial market. Assuming that the market is populated by prior-information traders with some degree of bounded rationality, an informed trader whose private signals suggest a dividend of 10 is willing to buy assets at any price equal to or lower than his/her expected dividend.[34] He/She expects to make high profit buying the asset at a low price. In particular, if this trader believes that there is a non-marginal fraction of uninformed traders,[35] he/she has the incentive to bid around his/her belief of uninformed traders' expected dividend, i.e., the public information benchmark. Uninformed traders could be willing to buy and sell their assets around their expected dividend, determined solely by the public signal.

When the proportion of uninformed traders willing to trade with informed traders is high enough to provide sufficient liquidity and/or assets, market prices fluctuate around the expected dividend conditional on the public signal. As a consequence, prices do not reflect traders' private information, but they reflect mostly the expectations of and about uninformed traders' beliefs, which are biased toward public information. In this case, the public information benchmark better predicts the market price than the fully revealing benchmark

[34] Note that in this case, his/her expected dividend is higher than the public information benchmark independently of the realization of the public signal.

[35] In this context, an uninformed trader is a trader who does not acquire any signal.

does.

What we have just sketched could be a simple mechanism behind the overweighting of public information, on the basis of the impact of public information on traders' second-order beliefs. Further research will be necessary to experimentally investigate the microstructure details of this process and account for the results we have identified in our experiment. Particularly, ongoing research is exploring the behavior of traders in an environment with exogenous allocation of information. This simplification of the experimental setting allows for a detailed analysis of traders' trading behavior as a function of the level of information, which is invariant over time.

The previous reasoning essentially rests on the bounded rationality of traders. By contrast, the literature has introduced the overweighting effect as an equilibrium outcome of coordination models with fully rational agents, as in MS. Cornand and Heinemann (2014b) and Shapiro et al. (2014) are two contributions that analyze the impact of different degrees of rationality on the overweighting phenomenon within the boundedly rational behavioral framework introduced by Nagel (1995). They show that the higher the level of bounded rationality, which is measured as the degree of inductive reasoning, the lower the overweighting phenomenon. Note, however, that we observe the opposite relationship between the level of rationality and the overweighting of public information. In our setting, fully rationality implies either a no-trade equilibrium or a noisy rational expectation equilibrium, following the argument of Sunder (1992). In both cases, we should not observe the overweighting effect, as we have no trade or the price partially reflects the information according to its precision. Therefore, the bounded rationality of traders seems to be a necessary condition to detect the overweighting of public information in a market environment. As we do not explicitly introduce a coordination setting, our experimental results generalize the existent literature, showing that the overweighting effect is a relevant phenomenon in a market setting with bounded rational traders rather than being a marginal effect observed in coordination environments.

In the literature, several elegant frameworks account for deviations from full rationality, such as the cognitive hierarchy model of Camerer et al. (2004) or the cursed equilibrium of Eyster and Rabin (2005). In particular, Eyster et al. (2019) apply the cursed equilibrium to a financial market, showing that public information is overweighted when aggregated into market prices. Similar to such a theoretical contribution, our paper provides experimental support to the overweighting effect within the framework of bounded rationality. More research is necessary to cast our results in the existing theoretical frameworks of bounded rationality.

Other important contributions as a particular modelization of bounded rationality are found in the literature on noise traders. A cornerstone is the paper on noise trading of De Long et al. (1990). They theoretically show that the interaction between informed traders (arbitrageurs) with a limited trading horizon and noise traders could give rise to an equilibrium price that deviates from the fundamentals. To obtain such a result, they exogenously imposed a correlation among noise traders,[36] justified by the presence of an optimistic *market mood* or *market sentiment*. Without being too rigorous and based on our experimental results, the existence of such a systemic correlation can be alternatively related

[36]In the original paper of De Long et al. (1990), this correlation is introduced assuming that the representative noise trader's misperception is a normal random variable with mean ρ^*. The presence of a non-vanishing mean can be interpreted as the presence of a market-wide correlation among noise traders related to public news.

to the presence of noisy public information, influencing systematically the formation of noise traders' beliefs.

6 Conclusions

The main purpose of this paper is to study experimentally the aggregation of information in financial markets as a function of the access of traders to different sources of information, namely costless public and costly private information. Such an informational setting has been extensively used in the literature to model the intervention of regulatory authorities. The objective of regulatory institutions when releasing public information is essentially to discipline the market, reducing the potential negative effects of asymmetric information. According to the theoretical literature, however, the release of public information might have adverse effects, such as the overweighting of public information and the crowding-out of private information.

In particular, we show that the overweighting of public information on market prices exists, and it is measurable and empirically relevant, heavily affecting market performance. Moreover, in our experimental setting, such effect emerges without an explicit incentive for the subjects to coordinate, as in other experimental studies reproducing the very specific Morris and Shin (2002) theoretical framework. We illustrate that traders' overreaction to public information is a more general phenomena than conjectured by the literature. By investigating the dual role of public information, we find that the commonality component is mainly responsible for the overweighting phenomenon. Introducing public information negatively affects the aggregation of information into prices, as prices are biased toward the public signal. Conversely, providing a common signal to all traders improves the aggregation of information.

Some general warnings for regulators can be derived out of our set of experiments. Policymakers should be aware that the release of public information might have distorting effects on traders' effort to find alternative sources of information and on the aggregation of information into prices. Such effects might be extremely significant, as demonstrated by the role that credit rating agencies had on the spread of the 2008 financial crisis. Far from being against the activity of public institutions in releasing information to discipline financial markets, we stress the unintended effects of the complex interaction between private and public information on market performance.

As policy advise, we recommend that ongoing reforms on the regulation of financial institutions (for instance, credit rating agencies) should account for such a complex interplay, that we have identified in our experiments. In particular, they should provide incentives for investors (institutional and/or private) to actively search for alternative sources of information. In order to take stock of the regulatory advantages of releasing public information and smoothen its potential adverse effects, we give some guidelines for the design of public communication and disclosure strategies: (i) More precise public information does not necessarily help the market align with the fundamentals, as public information does not cumulate, but it substitutes private information because of crowding-out and overweighting effects. (ii) It is not always optimal to reveal all the information possessed by public institutions. It might be better to release an informative signal that it is not perceived as too precise by investors to avoid market overreaction. In this respect, it is important to know the characteristics of the private information. The level of transparency of public information, in fact, should be tuned considering the precision of the private information at the disposal of traders. Therefore, it is advisable to use econometric techniques for developing some proxies for the precision of traders' private information, based, for instance, on survey data. Interestingly, if we interpret the common information setting as a disclosure strategy, the most effective measure we have identified to enhance market efficiency and, at the same time, reduce the cost of gathering private information, is whispering in the ears of investors, i.e., to spread common information among investors without being common knowledge. However, we understand that this measure is unrealistic to be implemented in real financial markets.

Finally, we strongly believe that our laboratory setting can be used as a realistic testbed for evaluating the performance of different policy instruments, without relying on specific behavioral assumptions and/or ad hoc coordination mechanisms. As a result, our conclusions can be far more robust than those based on experimental settings currently used. Several other measures can also be tested, such as sequentially releasing public information, reducing the level of publicity, or increasing the number of regulatory institutions. Studying the effects of these measures is the focus of ongoing research.

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A Fully revealing price

Let us compute the fully revealing benchmark in our setting. Using Bayesian inference, we compute the probability that the dividend is equal to 10 ECU conditioned on the series of signals purchased by subjects up to time t. We refer to I_t as the market private information set $I_t = \{s_1, s_2, ..., s_j..., s_t\}$. s_t takes a value of -1 when the private signal indicates that the dividend is 0. Conversely, s_t takes a value of 1 when the private signal suggests that the dividend is 10. Additionally, we introduce the variable $S \in \{-1, 1\}$ in the public information and common information treatments. Following the previous reasoning, $S = -1$ when the public or common signal predicts a dividend 0 and $S = 1$ otherwise.

$Pr(D = 10|I_t, S)$ denotes the probability of observing a dividend equal to 10 ECU conditioned on the information available at time t:[37]

$$Pr(D = 10|I_t, S) = \frac{Pr(I_t|D = 10) \cdot Pr(D = 10|S)}{Pr(I_t, S)} , \tag{9}$$

where $Pr(I_t, S)$ is the marginal probability computed as

$$Pr(I_t, S) = Pr(I_t|D = 10) \cdot Pr(D = 10|S) + Pr(I_t|D = 0) \cdot Pr(D = 0|S). \tag{10}$$

$Pr(D = 10|S)$ is the prior probability of the event $D = 10$, given the public signal S.[38] The values of this conditional probability are defined later on.

Let us now compute the formula of Eq. (9) as a function of

- p, the probability that a single private signal is correct, with $q = 1 - p$;

[37] *Mutatis mutandis*, the probability of observing a dividend equal to 0 ECU is $Pr(D = 0|I_t, S) = 1 - Pr(D = 10|I_t, S)$, as we have two possible states of the world.

[38] $Pr(D = 0|S)$ indicates the prior probability of the event $D = 0$.

- P, the probability that the public or common signal is correct, with $Q = 1 - P$;
- N_t, the number of signals in the information set available up to time t and
- n_t, the number of 1s, and $N_t - n_t$, the number of -1s in I_t.

In the following, when not necessary, we will omit the time variable t from the variables n_t and N_t. Depending on the value of S, the numerator of Eq. (9) is given by:

$$\begin{aligned} Pr(I_t|D=10) \cdot Pr(D=10|S=1) &= p^n \cdot q^{N-n} \cdot P \ , \\ Pr(I_t|D=10) \cdot Pr(D=10|S=-1) &= p^n \cdot q^{N-n} \cdot Q \ , \text{and} \\ Pr(I_t|D=10) \cdot Pr(D=10|S=0) &= p^n \cdot q^{N-n} \cdot \frac{1}{2} \ . \end{aligned} \tag{11}$$

The marginal probability in Eq. (10) takes the following form:

$$\begin{aligned} Pr(I_t, S=1) &= P \cdot p^n \cdot q^{N-n} + Q \cdot p^{N-n} \cdot q^n \ , \\ Pr(I_t, S=-1) &= Q \cdot p^n \cdot q^{N-n} + P \cdot p^{N-n} \cdot q^n \ , \\ Pr(I_t, S=0) &= \frac{1}{2} p^n \cdot q^{N-n} + \frac{1}{2} p^{N-n} \cdot q^n \ . \end{aligned} \tag{12}$$

Combining Eqs. (9), (10), (11), and (12) and defining $H_t = \sum_{j=1}^{t} s_j = 2n_t - N_t$ as the aggregate net private signal available at time t, we obtain the probability that the dividend is equal to 10 as a function of the relevant information present in the market at time t:

$$Pr(D=10|H_t, S) = \left[1 + \left(\frac{q}{p} \right)^{H_t} \left(\frac{Q}{P} \right)^{S} \right]^{-1} \ . \tag{13}$$

Finally, using Eq. (13), the fully revealing benchmark for the asset price under risk neutrality assumption is given by:

$$FR_t = 10 \cdot Pr(D = 10|H_t, S) + 0 \cdot Pr(D = 0|H_t, S) = 10 \left[1 + \left(\frac{q}{p}\right)^{H_t} \left(\frac{Q}{P}\right)^{S} \right]^{-1} . \quad (14)$$

B Trading activity

Every panel plots the chart of transactions. The vertical axis shows the price at which the transaction took place, and the horizontal axis shows the time (in seconds) at which the transaction took place. The first number at the caption of each panel identifies the market, and the second one indicates the value of the dividend (either 10 or 0). The solid line is the trading price. Finally, the dotted line indicates the fully revealing benchmark, whereas the dashed line, if present, indicates the public information benchmark.

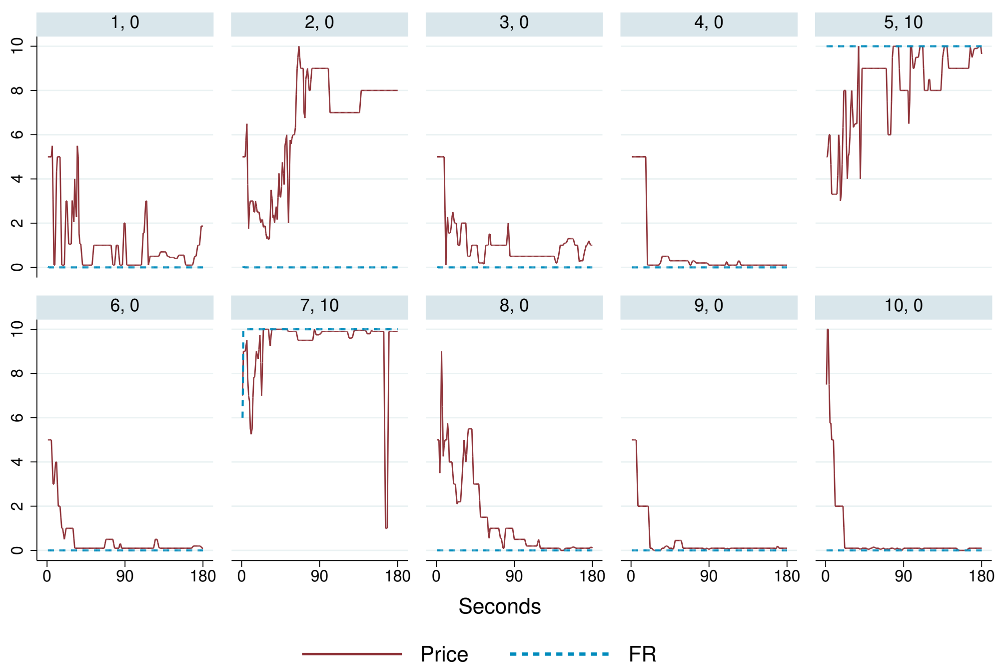

Figure 5: Treatment B (Group 1).

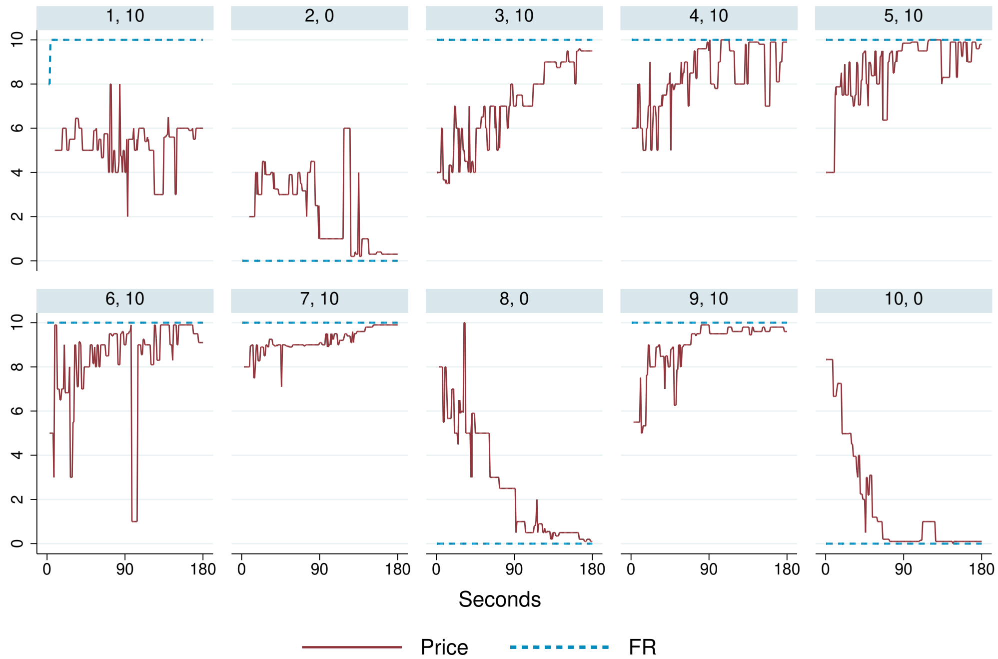

Figure 6: Treatment B (Group 2).

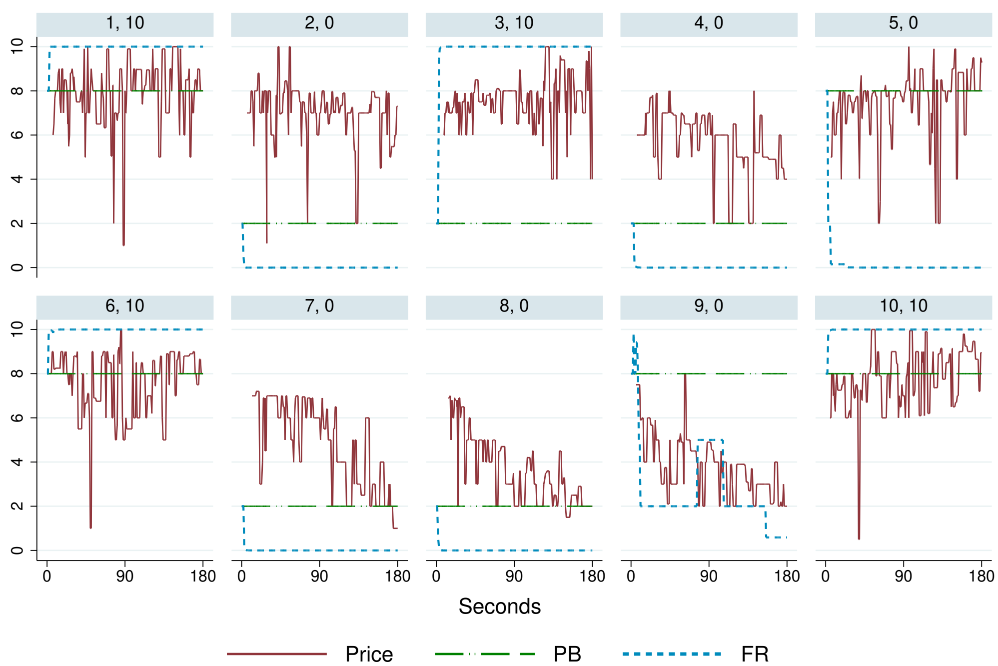

Figure 7: Treatment PS80 (Group 1).

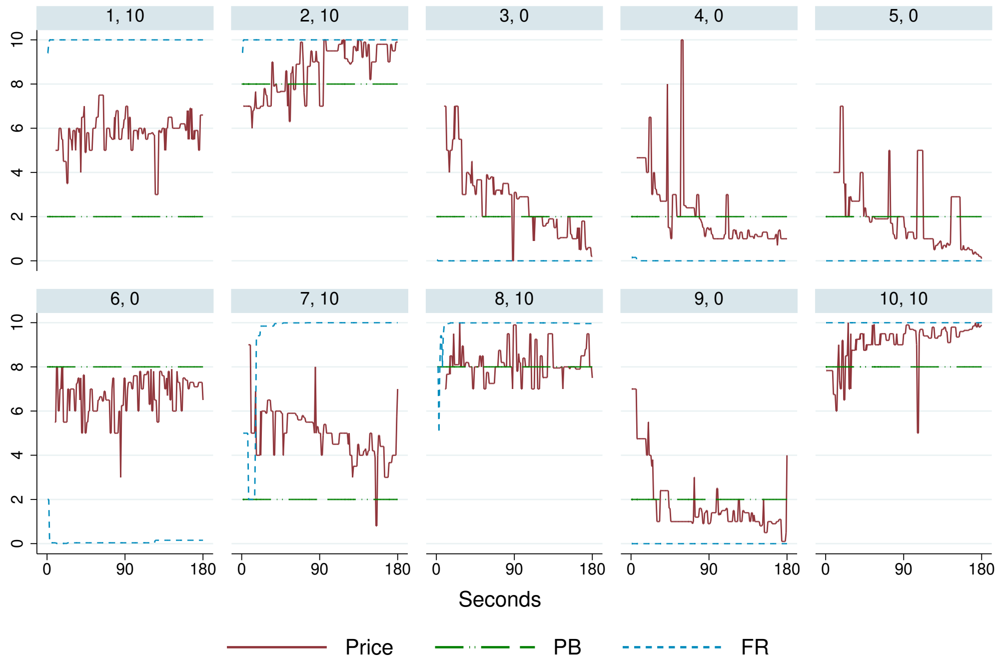

Figure 8: Treatment PS80 (Group 2).

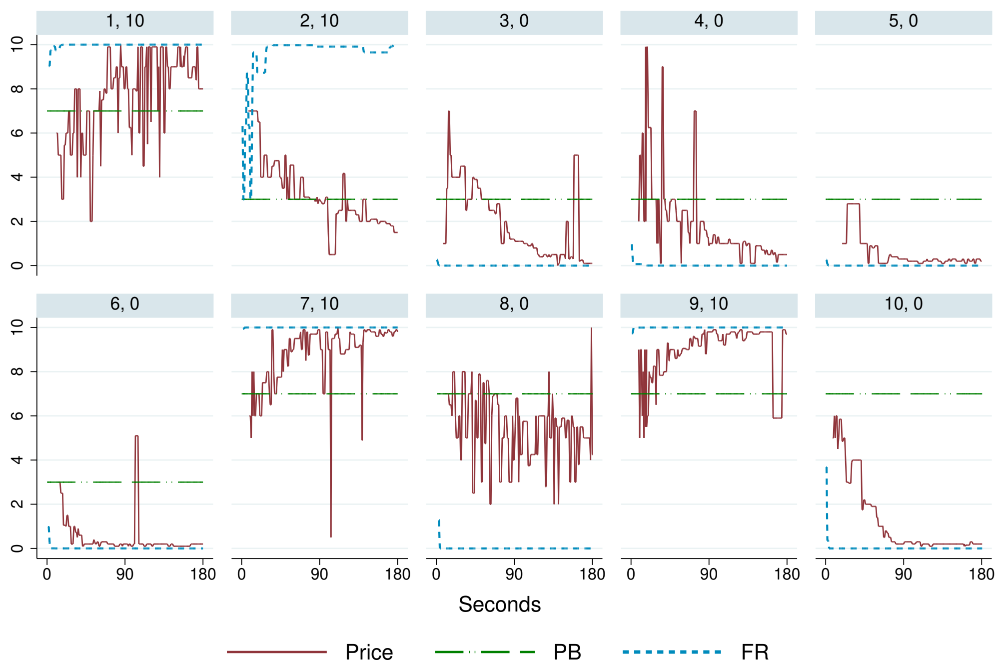

Figure 9: Treatment PS70 (Group 1).

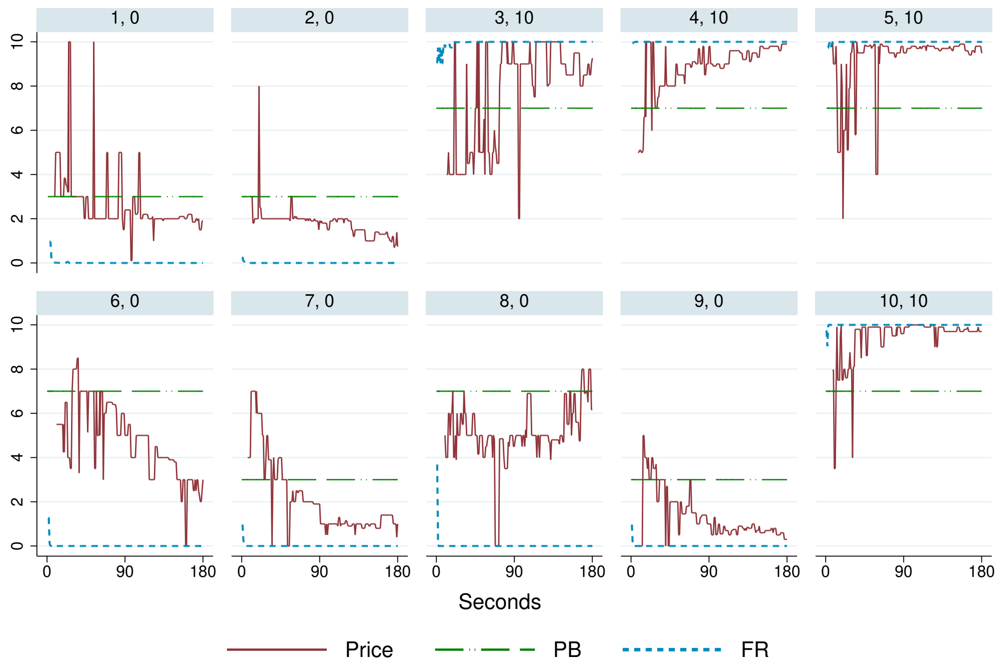

Figure 10: Treatment PS70 (Group 2).

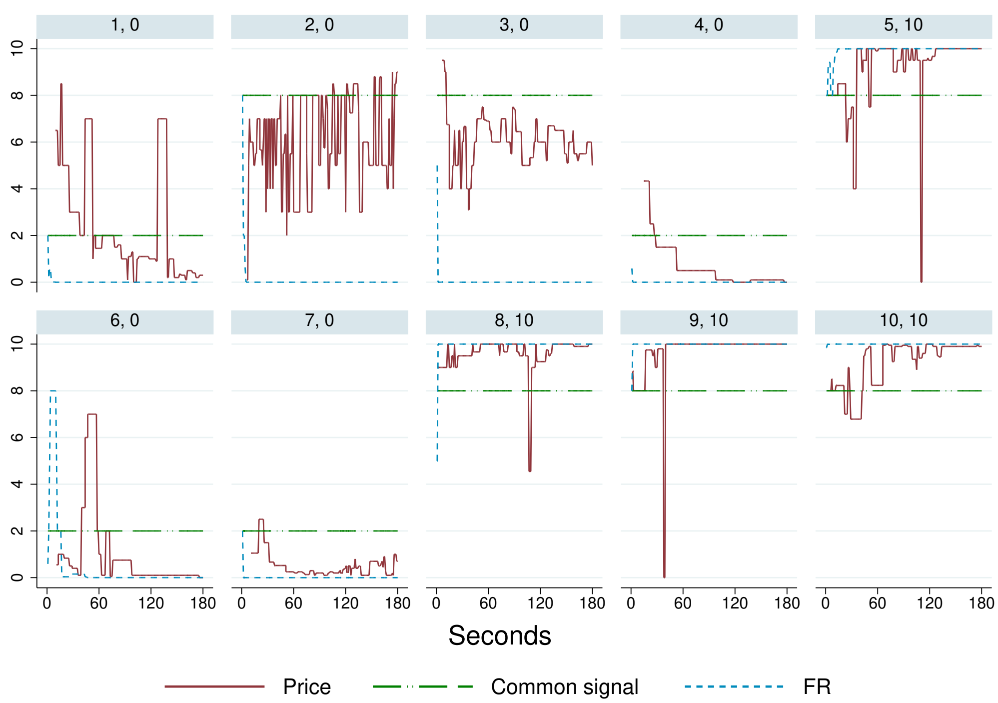

Figure 11: Treatment CS80 (Group 1).

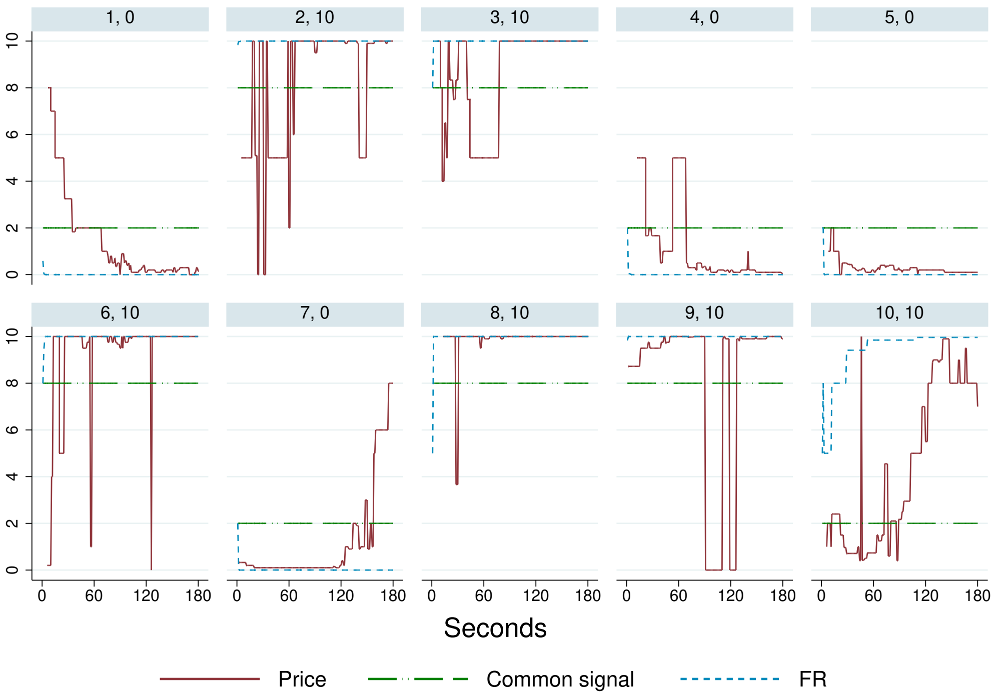

Figure 12: Treatment CS80 (Group 2).

C Information aggregation and overweighting of public information

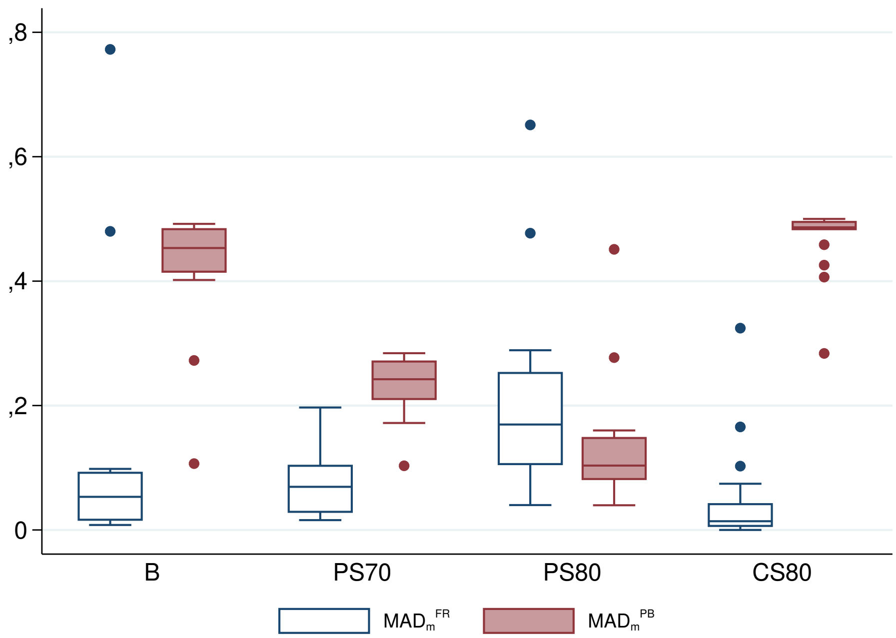

Figure 13: MAD_m^{FR} and MAD_m^{PB} of the last minute when the free signal is correct, for each market by treatment.