Single vs. multiple disclosures in an experimental asset market with information acquisition

Alba Ruiz-Buforn\textsuperscript{a}, Simone Alfarano\textsuperscript{a}, Eva Camacho-Cuena\textsuperscript{a} and Andrea Morone\textsuperscript{b}

\textsuperscript{a}Department of Economics, Universitat Jaume I, Castelló de la Plana, Spain; \textsuperscript{b}Department of Economics, Management and Law, Università degli Studi Aldo Moro, Bari, Italy

\section*{ABSTRACT}

We conduct laboratory experiments to study whether increasing the number of independent private signals in an economy with endogenous private information is an effective measure to promote the acquisition of information and to enhance price efficiency. We observe that the release of public information crowds out the traders’ demand for private information under a single disclosure while favoring private information acquisition under multiple disclosures. The latter measure improves price accuracy in forecasting the asset fundamental value. However, multiple disclosures do not eliminate the adverse effect of market overreaction to public information, becoming a potential source of fragility for the financial system.

\section*{1. Introduction}

Prior to the financial crisis of 2008, the commonly accepted paradigm in Financial Economics was characterized by a strong belief in the self-regulating forces of unrestrained financial markets, the efficiency of asset-price formation, and the effectiveness in the allocation and sharing of risk through the introduction of ever more complex financial instruments. During the pre-crisis period, the risk evaluation for those complex financial products was almost entirely outsourced to rating agencies, which contributed to enhance the fragility of the entire financial system. The optimistic recommendations of rating agencies were ‘blindly’ followed by the vast majority of investors, which led to a detrimental underestimation of certain risks. Thus, the access to publicly available ratings might have reduced the effort to gather independent private information (crowding-out effect), especially in the case of structured financial products. Furthermore, the investors ‘overreacted’ to the ratings, while suppressing the information content of their private signals. Public information, therefore, turned-out to be overweighted with respect to its information content (overweighting effect).

In order to reduce the dependence of the financial system to few rating agencies, after the 2008 financial crisis, the careful disclosure of information by regulatory institutions has been at the forefront of efforts to increase financial market stability. With the aim of providing an environment with more precise public information, the new regulatory measures pursued increasing the reliability of credit ratings and the quality and quantity of disclosures of macroeconomic information (see Goldstein and Sapra 2014). For example, the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 aim at increasing the general level of transparency, improving financial stability and consumers protection (Baily, Klein, and Schardin 2017). The European Central Bank further intensified its forward guidance activity, disclosing more information about its future monetary policy intentions.

However, the release of public information from regulatory institutions might end up provoking the same detrimental effects as the ratings in the pre-crisis period. One of the issues in the discussion on the reforms of
the financial architecture is, therefore, centered on how regulatory institutions should release public information to manage the expectations of economic agents. In its research agenda, the Bank of England explicitly mentioned the crowding-out of private information and the overreliance on public information as two detrimental effects that should be attenuated using an augmented communication strategy when devising monetary policy measures (Bank of England 2015).

Turning to the academic debate, the pertinent literature is quite ambiguous about the overall impact that noisy public information disclosures have on financial markets. Although it is well understood that information disclosures can increase market efficiency, several contributions specifically account for their potential unintended consequences. In their survey paper, Goldstein and Yang (2017) list some models where disclosures crowd out traders’ effort to gather private information, reducing the overall available information. Furthermore, markets may overreact to the information disclosures, distorting the asset prices and transmitting misleading information. In this respect, Morris and Shin (2002) illustrate that public information can be considered a double-edge instrument: it conveys information on the fundamentals (informational component) while it provides information on the others’ beliefs (commonality component). Using a beauty-contest coordination game, they show that, because of the dual nature of public information, traders double account the noisy public signal, underweight private information and overreact to the public signal. As a consequence, the noisy content of the public signal can be magnified at market level ‘to such a large extent that public information ends up by causing more harm than good’ (cf. Morris and Shin 2002). Other theoretical models on the effects of disclosures have been proposed within game-theoretical coordination frameworks (Morris and Shin 2002; Angeletos and Pavan 2004, 2007; Myatt and Wallace 2011; Colombo, Femminis, and Pavan 2014) as well as within market frameworks (Allen, Morris, and Shin 2006; Kool, Middeldorp, and Rosenkranz 2011; Goldstein and Yang 2019).

The conjectures introduced in the theoretical literature have been experimentally tested in the laboratory, given the advantage of precisely monitoring private and public information held by economic agents. The main conclusions support the conjectures based on coordination models that decision makers overreact to public information, underweighting private information (Cornand and Heinemann 2014; Shapiro, Shi, and Zillante 2014, among others). It is, instead, scarce the experimental research focusing on the effects of releasing public information in a market environment, in which traders have no explicit incentives to coordinate. Middeldorp and Rosenkranz (2011) give support to the hypothesis proposed by Kool, Middeldorp, and Rosenkranz (2011) that the reduced price informativeness is a direct consequence of the crowding-out of private information. On the contrary, Ruiz-Buforn et al. (2020) show that it is the overweighting of public information the main cause of the reduction in price informativeness. Their experiment illustrates that it is the impact of public information on the traders’ higher-order beliefs which, in turn, generates the overweighting effect and the consequent reduction in the price efficiency. They show, in fact, that the market price mostly reflects the informed traders’ beliefs on the expectations of uninformed traders, being the latter biased towards public information.

Taking for granted the unintended consequences of information disclosures, we can find in the literature various theoretical as well as experimental contributions suggesting potential measures to smooth the overreaction effect in a coordination environment, e.g. Cornand and Heinemann (2008), Arato and Nakamura (2011, 2013), Baeriswyl and Cornand (2014), and Banerjee and Maier (2016). Several characteristics of the disclosures are considered: publicity, transparency, precision and ambiguity. Essentially, those features can be optimally tuned to dim the commonality component of the public signal and, thus, to reduce its coordination power, while preserving its informational component. Naini and Naderian (2016) review the theoretical literature regarding central bank communication policy. They conclude that the strategies reducing the common knowledge of public information can smooth the overreaction effect.

To the best of our knowledge, there are no experimental papers exploring potential measures to reduce the adverse effects caused by public information disclosures in a market environment. Our paper fills this gap by evaluating experimentally whether the contemporaneous releasing of multiple noisy public signals can smooth the adverse effects of information disclosures. We aim at exploring measures to reduced financial risks caused by public release of information in financial markets. In particular, we aim at devising more robust market architectures to provide market participants with incentives not to discard private information when noisy public information is released. With this objective, we test in a laboratory asset market whether multiple
disclosures can reduce the overweighting effect, and the consequent reduction in price informativeness. Our contribution sheds some light on pros and cons of different disclosure configurations, answering to the question: What types of disclosure are the most beneficial to promote market efficiency and reduce the financial risk related to market overreaction? We conduct laboratory experiments using the experimental setting of Ruiz-Buñorn et al. (2020), where the crowding-out of private information demand and the overweighting of public information are identified as significant and empirically relevant effects.

In our paper, we compare the effects on the market performances of disclosing public information as a unique imperfect signal or composed by two independent and imperfect signals with different relative precision. Our intuition is that the release of two public signals, instead of a single one, introduces a higher degree of uncertainty in what subjects think about the others’ expectations, in particular of the expectations of uninformed subjects. Under the hypothesis that not all subjects are Bayesian, they can, in fact, have different interpretations of the precision of the cumulative public information. We conjecture that such heterogeneity in the interpretation of the cumulative precision of public information, induced by the multiple disclosure, blurs the commonality component of the public signal, reducing its coordination power together with its distorting effect on prices. In our experiment, therefore, we expect to observe a lessen overweighting effect in markets with multiple disclosures with respect to the case of a single disclosure. We claim that studying how market reacts to different configurations of information disclosure helps to improve the regulation of financial markets.

We organize the remainder of the paper as follows. Section 2 briefly reviews the related literature and introduces the working hypotheses. Section 3 describes the experimental design and procedure. Section 4 presents the results of the impact of the disclosures on the information and asset market, as well as on price accuracy. Section 5 concludes.

2. Theoretical background and hypotheses

2.1. Theoretical background

Grossman and Stiglitz (1980) state that, under rational expectations, decision makers have neither incentives to acquire costly information nor to trade when prices are fully informative. Competitive markets, therefore, cannot be informationally efficient if all information is instantaneously aggregated in the price, as stated in the strong version of the Efficient Market Hypothesis (EMH). Grossman and Stiglitz (1980) solve this paradox by introducing some noise in the market. In their version of a noisy rational expectations equilibrium model (REE), prices are just partially informative, giving to traders incentives to acquire costly information since they can recover their costs. In his seminal paper, Sunder (1992) tests experimentally some consequences of the noisy REE, showing that a double auction mechanism generates an endogenous noise that prevents prices to fully reveal information. In particular, he shows that the noisy REE can be attained under quite restrictive conditions, such as perfect information and a known number of insiders. Many additional experimental contributions have tested the consequences of the noisy REE, showing that information aggregation is imperfect, and, as a consequence, market prices are just partial indicators of the fundamental value. Regarding the experimental analysis of the conditions enhancing market efficiency, we focus attention on the release of public information as a possible instrument to help price convergence to the fundamental value. Until now, very little research effort has been devoted to this important issue.

2.2. Hypotheses

Our research question primarily focuses on the study of the effect of different disclosure scenarios on market performance. In particular, we consider alternative configurations when introducing public signals with different precision into a financial market. In an economy where investors have access to costly private information, we analyze how increasing the number of independent and noisy released public signals affects: (i) traders’ acquisition of private information, (ii) efficiency and accuracy of market prices, and (iii) traders’ profits.

Regarding the traders’ effort to gather information, we start with the working hypothesis that it is the aggregate Bayesian precision of public information that affects the traders’ demand for private information.
Hypothesis 2.1: The demand for private information depends on the Bayesian aggregate precision of public information.

In other words, it is not relevant whether a given aggregate precision of public information is achieved with a single signal or multiple (independent) signals of different precision. An important aftermath of this hypothesis implies that there is no role in the implementation of alternative disclosing scenarios when managing the release of public information.

The economic literature predicts that traders’ demand for costly (private) information strongly depends on their initial information. Several theoretical models state that information disclosures reduce the production of costly information. See, for example, Diamond (1985), Kool, Middeldorp, and Rosenkrantz (2011), Colombo, Femminis, and Pavan (2014), Han, Tang, and Yang (2016) and Goldstein and Yang (2019). Moreover, recent experimental studies show that traders endowed with precise and conclusive\(^2\) initial information reduce their effort in gathering new information (Page and Siemroth 2017; Ruiz-Buforn et al. 2020). We, therefore, conjecture that, when conclusive, the presence of public information has a negative effect on the demand for private information.

Hypothesis 2.2: The release of conclusive public information crowds out private information.

It is important to evaluate whether the information content of the public signals compensates for the crowding-out of private information, leaving invariant the market informativeness, i.e. the overall information present in the market.

Concerning the traders’ behavior in the asset market, experimental contributions have repeatedly found limited aggregation of information into prices, which turns into price deviations from fundamentals. Nevertheless, many contributions show that more information in the market leads to higher price informativeness and price accuracy (e.g. Sunder 1992; Bossaerts, Frydman, and Ledyard 2014; Page and Siemroth 2017; Corngnet et al. 2018; Alfarano et al. 2020). We define as price informativeness a measure of the informational content of prices, while price accuracy measures how well prices predict the fundamental value. Under the EMH, we expect prices to be closer to the fundamentals the more information is available to the traders.

Hypothesis 2.3: More information in the market improves price accuracy.

According to this hypothesis, public information enhances price accuracy, if it increases the overall market informativeness. Within the EMH, the effect of public information on market informativeness is ultimately related to the magnitude of the crowding-out effect.

Following the EMH, we conjecture that the configuration of disclosures does not affect price informativeness, since it should be independent of the quantity and nature of the information available to the traders.

Hypothesis 2.4: Price informativeness does not depend on the configuration of disclosures.

Departing from the EMH, market prices may overreact to the release of public information and deviate significantly from fundamentals, as conjectured by Allen, Morris, and Shin (2006) and Goldstein and Yang (2019). An existing strand of the theoretical as well as experimental literature relates such deviations from fundamentals to the overweighting of public information in market prices, due to the overreliance of traders on information disclosures. While the theoretical literature counts with several contributions, the experimental literature regarding the overweighting in laboratory asset market experiments is scarce.\(^3\) Ackert, Church, and Gillette (2004) report the existence of market overreaction to low precise disclosures. In a recent study, Ruiz-Buform et al. (2020) find experimental evidence about the overweighting of public information when disclosed as a single signal. The intuition behind their results is based on the conjecture put forward by Allen, Morris, and Shin (2006): public information is overweighted when higher-order beliefs play a role in the determination of prices, since a public signal provides information on the fundamentals and on other traders’ beliefs. Ruiz-Buform et al. (2020) provide experimental evidence that confirm this conjecture. In particular, they show that, when the fraction
of uninformed traders in the market is sufficiently high, prices tend to fluctuate around the value suggested by public information. In second-guessing the uninformed traders beliefs, informed traders put more weight to the (single) public signal, not justified by its informational content. Moreover, they note that this effect is reinforced by the crowding-out on the traders’ demand for private information. They report a non-monotonic relation between the quantity of information present in the market and the price informativeness. We formulate, therefore, an alternative hypothesis to Hypotheses 2.3 and 2.4:

**Hypothesis 2.5:** Market prices overweight public information, resulting in a reduction of price informativeness.

The existing literature highlights that dimming the commonality component of disclosures, leaving invariant the informational component, lessens the overreaction effect, while it enhances the correct aggregation of information. Our proposal of giving access to multiple sources of public information adds to the measures already suggested in the literature, such as partial publicity and ambiguity. The basic idea is to provide access to public information from multiple sources instead of a single one. Keeping the overall information of the cumulative signal invariant, we conjecture that the commonality component of the public signal is blurred compared to the single disclosure. In their second-guessing activity, it is easier, in fact, for informed traders to guesstimate the expectations of uninformed traders when the public information is released as a single signal. Assuming that traders are not Bayesian, the multiplicity of signals generates a higher degree of uncertainty when informed traders guesstimate the expectations of uninformed traders, reducing the commonality component of public information. Therefore, multiple disclosures rather than a single one may reduce the coordination power of public information and, therefore, the overweighting effect and consequent price distortion.

**Hypothesis 2.6:** Multiple disclosures lessen the overweighting effect compared to a single disclosure, improving price informativeness.

Note that, to support the previous hypothesis, it is not necessary that all traders are not Bayesian, but it is sufficient that traders assume that not all the other traders behave as Bayesian.

In a noisy REE framework, informed traders can make profits only to cover information acquisition costs, as prices only partially reveal information to uninformed traders. We should expect, therefore, that informed traders can recover the cost of information acquisition, gaining the same net profits as uninformed traders. Nevertheless, some experimental contributions report that uninformed traders outperform informed traders (Huber, Angerer, and Kirchler 2011; Page and Siemroth 2017; Ruiz-Buforn et al. 2020). As a working hypothesis, we state:

**Hypothesis 2.7:** Informed traders gain the same profit as uninformed traders.

### 3. Experimental design and procedure

Our experimental setting is similar to other contributions from the literature on laboratory financial markets and prediction markets. We implement an asset market populated by 15 traders. At the beginning of each market, traders are endowed with 1000 units of experimental currency (ECU) and 10 risky assets, paying a dividend \( D \) when a market closes. The assets have a one-market life. The asset market is implemented as a 3 min double auction where traders can submit bids and asks or directly accept any other trader’s outstanding offer. Every bid, ask or transaction concerns only one unit of the asset, but every trader can handle as many as desired as long as he/she has enough cash or assets (no short sale is allowed).

**States of nature** Before the market starts, the computer randomly determines one of the two equiprobable states of nature. In one state of nature the dividend is 0 and in the other is 10, \( D \in \{0, 10\} \). The asset value at the end of the market is equal to the dividend. At the end of the market, the realization of the state of nature is revealed and assets pay the corresponding dividend. It is common knowledge to all traders that the two states of nature are equiprobable.
Private Information  Endogenous private information is implemented in an information market. At any moment during the 3 min of the market, traders can acquire imperfect information about the value of the dividend. They can acquire (independent) private signals at the cost of 4 ECU each. Each private signal takes the value 0 or 10, $s_i \in \{0, 10\}$, and it is correct with probability $p$, and incorrect with probability $q = 1 - p$. We refer to $p$ as the precision of the signal. We set $p = 0.6$ in all treatments.

Disclosures In markets where public information is released, traders observe, at the beginning of each market, either one or two imperfect public signals about the value of the dividend. We refer to those public signals as disclosures. Each public signal takes the value 0 or 10, $S \in \{0, 10\}$, being correct with probability $P$, and incorrect with probability $Q = 1 - P$. It is common knowledge among traders the value of $P$ and the realizations of the disclosures. We refer to $P$ as the precision of the public signal.

Treatments We implement different treatments varying the number of disclosures and their precision. Our experimental setting allows us to test the consequences that different disclosure scenarios have on the traders’ information acquisition, the efficiency of the market in aggregating information into prices, and traders’ profits. Table 1 summarizes the implemented treatments. In the Baseline treatment (B), no public signal is released. In the Single disclosure treatment (S), one public signal with a precision of $P_A = 0.8$ is released. Then, we implement three additional treatments where two independent public signals are released: (i) Multiple Symmetric disclosures treatment (MS), where two public signals with equal precision ($P_A = P_B = 0.66$) are released at the beginning of each market; (ii) Multiple Weak Asymmetric Disclosures treatment (MWA), where the precision of the two public signals is $P_A = 0.64$ and $P_B = 0.7$; (iii) Multiple Strong Asymmetric Disclosures treatment (MSA), where the precision of the two public signals is $P_A = 0.6$ and $P_B = 0.75$.

In the treatments with multiple disclosures, the joint precision of the public information depends on whether disclosures are convergent or divergent. We consider disclosures as convergent when the two public signals point to the same dividend value, whereas we consider disclosures as divergent, if they point to opposite values of the dividend. Using the Bayesian inference, we compute the probability that the asset value is equal to 10 as a function of the realizations of the public signals $S_A$ and $S_B$:

$$\Pr(D = 10 \mid S_A, S_B) = \left[ 1 + \left( \frac{Q_A}{P_A} \right)^{S_A} \left( \frac{Q_B}{P_B} \right)^{S_B} \right]^{-1},$$

(1)

Table 2. Probability of the event $D = 10$ given the configuration of the public signals.

| Treatment | $P_A$ | $P_B$ | $S_A$ | $S_B$ | Pr($D = 10 \mid S_A, S_B$) |
|-----------|-------|-------|-------|-------|--------------------------|
| B         | 0.6   | -     | 0     | 0     | 0.5                      |
| MS$_d$    | 0.66  | 0.66  | 1     | -1    | 0.5                      |
| MWA$_d$   | 0.64  | 0.70  | 1     | -1    | 0.57                     |
| MSA$_d$   | 0.6   | 0.75  | 1     | -1    | 0.66                     |
| S         | 0.8   | -     | 1     | 0     | 0.8                      |
| MS$_c$    | 0.66  | 0.66  | 1     | 1     | 0.8                      |
| MWA$_c$   | 0.64  | 0.70  | 1     | 1     | 0.81                     |
| MSA$_c$   | 0.6   | 0.75  | 1     | 1     | 0.82                     |

Notes: $P_A$ and $P_B$ ($S_A$ and $S_B$) denote the precision (configurations) of the disclosures. The lowercase letters $c$ and $d$ indicate convergent and divergent, respectively.
where \( \Pr(D = 10 \mid S_A, S_B) \) is the probability of the event \( D = 10 \), given the realization of the public signals \( S_A \) and \( S_B \). The variables \( S_A \) and \( S_B \) take the value 1 (−1) if the public signal suggests an asset value equal to 10 (0), while they take the value 0 if there is no public signal. Mutatis mutandis, we can compute the probability of the event \( D = 0 \). Table 2 shows the probability of the event \( D = 10 \) given the realizations of the public signals \( S_A \) and \( S_B \) for each one of the implemented treatments.

Our experimental setting allows us to study how the different configurations of the disclosures affect the outcome of the information market and the asset market. In particular, we can evaluate whether the relative precision of the two public signals, in the multiple disclosure treatments, affects the market performance. In the treatments with asymmetric disclosures, we can study different stylized scenarios where the disclosures released by regulatory institutions have different relative precision. In the Multiple Strong Asymmetric treatment, we can analyze the effect of releasing one 'dominant' public signal on market performance. Such stylized scenarios describe the prominent role of a leading regulatory institution releasing public information, like central banks, parallel to other sources releasing noisier information. Note that the less precise signal has the same precision as a single private signal. Contrary to a single disclosure, multiple disclosures might be divergent, allowing us to study the reaction of the market to two opposite public forecasts about the value of the dividend.

Considering the Baseline treatment as a benchmark, we can study the impact of a single disclosure of a given precision (B vs S). Furthermore, we can confront those results with the disclosure of two convergent signals of equal or different precision (S vs MS_c, S vs MWA_c and S vs MSA_c). Note that in treatments S, MSA_c, MWA_c and MS_c, the overall precision of public information is approximately invariant and close to 0.8 (see Table 2). Additionally, a direct comparison can be performed between B and MS_d treatments.

Procedure The experiment was conducted at the Laboratori d’Economia Experimental at University Jaume I in Castellón. We recruited 159 undergraduate students from Economics, Finance, and Business Administration in at least their second year of study. Each subject only participated in one session that consisted of 10 markets. When subjects arrived at the laboratory, instructions were distributed and explained aloud. This was followed by one practice market for subjects to get familiar with the software, which was programmed using the Z-Tree software (Fischbacher 2007). After explaining the instructions and during the practice period, subjects can privately ask questions about the experiment. Appendix 1 includes the translated instructions as well as the screenshots in the implemented treatments.

Profits After each market, dividends were paid out and subjects’ profit was computed as the difference between their initial money endowment and the money held at the end of the trading period. Each subject’s final payoff was computed as the accumulated profit in all markets, and paid cash at the end of the session.

4. Results

4.1. Summary statistics

Table 3 provides summary statistics of the activity in the information and asset markets in the five treatments. On average, traders acquire between 0.83 and 2.26 signals per capita, depending on the treatment. The fewest acquisitions correspond to treatment S, where the public information is released as a single disclosure, while the most acquisitions are in treatment MS, where two independent and equally precise public signals are released. Moreover, we observe that, depending on the treatment, between 42% and 67% of traders acquire at least one private signal in the information market. Treatment B presents the lowest proportion of informed traders while the largest number of informed traders is in treatment MS. Regarding the activity in the asset market, we observe a wide variability of trading volume across treatments, with the most trades in treatment B.

4.2. Information market: information acquisition and market informativeness

4.2.1. Information acquisition

We start our analysis looking at the traders’ behavior in the information market considering two dimensions: (i) the number of acquired signals per capita and (ii) the information market participation rate, computed as the
fraction of informed traders. Furthermore, we distinguish all possible disclosure scenarios, namely absence of public signal, single public signal and multiple convergent and divergent signals. Figure 1 shows the distribution of the per capita demand for private information, whereas Figure 2 illustrates the percentage of informed traders as a function of the different disclosure scenarios.

### Table 3. Summary statistics.

| Variables          | B       | S       | MS      | MSA     | MWA     |
|--------------------|---------|---------|---------|---------|---------|
|                    | Mean    | Std. dev.| Mean    | Std. dev. | Mean    | Std. dev. | Mean    | Std. dev. | Mean    | Std. dev. |
| Informed traders\(^a\) | 0.42    | 0.08    | 0.46    | 0.21    | 0.67    | 0.13    | 0.49    | 0.13    | 0.57    | 0.12    |
| Acquired signals   | 1.32    | 2.24    | 0.83    | 1.25    | 2.26    | 3.04    | 0.84    | 1.14    | 1.44    | 1.99    |
| Trading volume     | 138.70  | 25.48   | 109.60  | 23.19   | 52.13   | 25.52   | 86.45   | 13.09   | 65.35   | 14.04   |
| Gross profit       | 50.00   | 76.19   | 39.52   | 83.59   | 39.55   | 89.54   | 55.00   | 71.92   | 50.00   | 64.23   |
| Net profit         | 44.73   | 75.94   | 36.40   | 83.09   | 30.51   | 91.50   | 51.64   | 71.22   | 44.23   | 63.99   |
| Observations       | 300     | 250     | 440     | 300     | 300     | 300     | 300     | 300     | 300     | 300     |

\(^a\) *Informed traders* refers to the fraction of traders acquiring at least one signal.

---

**Figure 1.** Distribution of per capita number of acquired signals over treatments.

**Figure 2.** Distribution of the percentage of informed traders over treatments.
We focus first on the traders’ per capita demand for private information as a function of the aggregate precision of the public information. According to Hypothesis 2.1, the demand for private information should be roughly homogeneous in those scenarios with similar Bayesian aggregate precision of public information. Operatively, when comparing treatment S and all treatments with multiple convergent signals or treatment B to MS$_{d}$, we should observe a comparable demand for private information.

A first glance at Figure 1 reveals that we can reject Hypothesis 2.1. Keeping constant the aggregate precision, we observe significant differences in the demand for private information depending on the configuration of the disclosures. In particular, for a given aggregate precision of the public information, traders acquire a significantly larger amount of private information in treatment MS$_{d}$ when compared to treatment B, and in treatments MS$_{c}$ and MWA$_{c}$ when compared to treatment S.$^{10}$ Comparing the markets with multiple convergent disclosures, the demand for information (in median) steadily increases the more symmetric is the precision of the two public signals. The relative precision of the two public signals is, therefore, an important determinant of the traders’ demand for private information. We conclude that, despite having the same aggregate precision, the configuration of the disclosures does affect the traders’ effort to gather private information.

**Result 4.1:** Given the aggregate precision of disclosures, releasing public information with a single or multiple disclosures plays a role in the traders’ effort to gather private information.

Turning now to Hypothesis 2.2, it states that conclusive public information should crowd out the demand for private information. We should, therefore, observe that, compared to treatment B, traders acquire a lower number of private signals in all treatments but MS$_{d}$. The per capita number of acquired signals in treatment S and in treatment MSA$_{c,d}$ is significantly lower than in treatment B. Conversely, if we look at treatments MS$_{c,d}$, the number of acquired signals is significantly higher than in treatment B. At the same time, no crowding-out effect is observed in case of multiple weak asymmetric and convergent disclosures.$^{11}$ We can reject Hypothesis 2.2 since the release of multiple symmetric signals, either divergent or convergent, crowds in private information.

**Result 4.2:** The disclosure of information crowds out private information only if released as a single signal or as multiple strong asymmetric signals.

The clear crowding-out of private information in those markets with multiple strong asymmetric disclosures leads us to conjecture that the more precise public signal can be considered a ‘dominant’ signal. We will come back to this point in Section 4.3.1.

Surprisingly, when the information is released as two symmetric signals, we observe a crowding-in of private information, independently of the signals being divergent or convergent. The intuition driving these results is inspired by the psychology literature. Harkins and Petty (1981, 1987) experimentally identified the multiple source effect. They analyze the effect of the number of information sources on subjects’ scrutiny and message processing. They found that increasing the number of sources enhances thinking about the message content and information processing. Particularly, subjects exposed to weak information from multiple sources are less persuaded than subjects who read the same low-quality arguments released by one source. If we evaluate our results through the lens of Harkins and Petty (1981), public signals with 0.66 precision can be considered as weak arguments, using their terminology. Thus, traders observing two weak public signals are more ‘stimulated’ to acquire information than those who observe one public signal.

Considering the participation of subjects to the information market, Figure 2 reveals that the information market participation rate depends on the particular configuration of disclosures. Releasing multiple signals stimulate the participation of traders in the information market with respect to the absence of public information.$^{12}$

**Result 4.3:** Disclosing multiple signals increases the information market participation rate.
4.2.2. Market informativeness

Given the impact that releasing public information has on the traders’ information acquisition, particularly considering the role of the crowding-out effect, we address the following question: Is the release of public information neutral, beneficial or detrimental for the overall market informativeness?

We measure market informativeness as the distance between the fundamental value and the Fully Revealing price $FR_t$, which is the expected price when all information (public and private) is fully aggregated. Let $H_t = \sum_{i=1}^{t} s_i$ denote the net private information available up to time $t$ in a market, given the sequence of realizations of the private signals acquired up to time $t$. $S_A$ and $S_B$ denote the realization of public signals, if present. The Fully Revealing price can be computed as:

\[
FR_t = 10 \Pr(D = 10 \mid H_t, S_A, S_B) = 10 \left[ 1 + \left( \frac{q}{p} \right)^{H_t} \left( \frac{Q_A}{P_A} \right)^{S_A} \left( \frac{Q_B}{P_B} \right)^{S_B} \right]^{-1}. \tag{2}
\]

We compute market informativeness $MI$ as:

\[
MI = \frac{1}{60} \sum_{t=120}^{180} \frac{|D - FR_t|}{10}. \tag{3}
\]

Figure 3 illustrates the distribution of market informativeness according to Equation (3) by treatments, differentiating between divergent and convergent disclosures. Figure 3 confirms that the market informativeness significantly improves in case of multiple disclosures compared to a single disclosure. However, it is worth to note that a single disclosure does not improve market informativeness compared to the market with no public information.

Result 4.4: Disclosures, at worst, leave invariant market informativeness. Market informativeness significantly improves when multiple convergent signals are released.

4.3. Asset market

We focus now on the asset market, analyzing first how prices aggregate private and public information held by traders. Next, we measure price accuracy to test whether the release of public information renders market prices better predictors for the asset value.
4.3.1. **Aggregation of information into prices: price informativeness**

If market informativeness remains constant or improves when public information is released, how is private and public information aggregated into market prices? Does the configuration of disclosures affect the aggregation of information into prices?

To assess the performance of prices to aggregate private as well as public information, we consider two benchmarks: (i) the fully revealing benchmark, $FR_t$ from Equation (2) and (ii) the public benchmark, $PB$, defined as the expected price conditional on the value of the released public signals, i.e. $PB = 10 \cdot \Pr(D = 10 \mid S_A, S_B)$ (see Equation (1)). Note that both benchmarks depend on the realizations of the public signals. However, the fully revealing benchmark weights the public and the private signals according to their precision, whereas the public benchmark assigns zero weight to private information.

We introduce two indicators to evaluate the goodness-of-fit of the two benchmarks: (i) the $PI$ indicator measures the distance between observed prices and the fully revealing benchmark; (ii) the indicator $PP$ measures the distance between observed prices and the public benchmark $PB$. The two indicators are defined as:

$$PI = \frac{1}{60} \sum_{t=120}^{180} \frac{|Price_t - FR_t|}{10},$$

$$PP = \frac{1}{60} \sum_{t=120}^{180} \frac{|Price_t - PB|}{10}. \quad (4)$$

Figure 4 shows the distribution of $PI$ and $PP$ indicators, computed according to Equations (4) and (5) for each disclosure scenario. The $PI$ indicator is a measure of the price informativeness and it allows us to evaluate how prices aggregate information across the different configuration of disclosures. In line with the existing literature in Experimental Finance, our results confirm that prices imperfectly aggregate the information available to the traders.

**Result 4.5:** Prices imperfectly aggregate the information available to the traders.

Looking at Figure 4, we can reject Hypothesis 2.4, since price informativeness significantly differs across the different configurations of disclosures. In particular, price informativeness worsens significantly in the case of a single disclosure, whereas the multiple strong asymmetric convergent disclosure outperforms all other configurations in terms of price informativeness. We can, therefore, conclude:
**Result 4.6:** The configuration of disclosures does affect price informativeness.

According to the EMH, differences in price informativeness across treatments should be a direct consequence of equivalent differences in market informativeness. Comparing Figures 3 and 4, we observe that treatments with convergent multiple disclosures exhibit a similar level of market informativeness (see Figure 3), while they differ significantly concerning their price informativeness (see Figure 4 and endnote 18). Moreover, treatments B and S exhibit similar levels of market informativeness, whereas price informativeness is significantly lower in treatment S (MW test, $p < 0.05$).

We rely on Hypothesis 2.5 to account for the observed discrepancies between market informativeness and price informativeness. Hypothesis 2.5 states that prices systematically weight public information above its precision, leading to a reduction in price informativeness. Comparing the $PI$ and $PP$ indicators allow us to detect the overweighting of public information. We consider that prices overweight public information, when the $PP$ indicator significantly outperforms the $PI$ indicator in describing market prices.

Figure 4 supports our conjecture on the overweighting of public information in most of the configurations of disclosures. We cannot reject Hypothesis 2.5 in treatment S (one-side sign test, $p = 0.00$). This result also extends to the behavior of prices in treatment MS, regardless of whether disclosures are conclusive or inconclusive (one-side sign tests, $p \leq 0.05$). The observed overweighting effect in treatment MS is particularly relevant if one considers that the crowding-in of private information significantly improves market informativeness.

Further analysis is needed for those markets with multiple asymmetric disclosures. Recall that, in those treatments, the two public signals have a different precision: in treatment MWA the precisions are 64% and 70%, whereas in treatment MSA the precisions are 60% and 75%. From Table 2, we can see that, if convergent, their joint Bayesian precision is 81% and 82%, respectively. Instead, when divergent their Bayesian precision reduces to 57% and 66%, respectively. It might occur that, in case of being divergent, prices follow the ‘dominant’ signal. To measure this effect, we introduce two additional ‘public benchmarks’, where the public signals are considered individually to account for price formation.19

Figures 5 and 6 illustrate the distribution of $PI$ and $PP$ indicators together with $PP75$ in and $PP60$ indicators in treatment MSA, and $PP70$ and $PP64$ in the MSA treatment. Figure 5 shows that in the treatment MSA, when signals are divergent, the public benchmark $PP75$ better describes prices compared to the Fully Revealing benchmark (sign test, $p = 0.06$). In this case, prices overweight the ‘dominant’ signal. Conversely, we do not observe the dominance of the more precise signal in case of treatment MWA in Figure 6. Note, however, that the released signals are weakly asymmetric. We can conclude that, when releasing information in a financial market, the overweighting phenomenon is a very pervasive effect.

![Figure 5](image-url) Distribution of $PI$ and $PP$ indicators together with $PP75$ and $PP60$ indicators, which consider only one of the public signals $PA = 0.75$ or $PB = 0.6$, in treatment MSA.
Figure 6. Distribution of PI and PP indicators besides PP70 and PP64 indicators, which consider only one of the public signals $P_A = 0.7$ or $P_B = 0.64$, in treatment MWA.

Figure 7. Distribution of PI and PP indicators by treatment.

**Result 4.7:** The overweighting phenomenon is a robust effect of the release of public information.

Hypothesis 2.6 states that the access to multiple sources of public information helps in reducing the overweighting effect and in improving price informativeness. Figure 7 shows the distribution of the PI and PP indicators per treatment. We can see that the overweighting effect is present in all treatments, excluding the treatment MSA.\(^\text{20}\) However, in treatments with multiple disclosures, price informativeness significantly improves compared to treatment S. We cannot reject, then, Hypothesis 2.6. Qualitatively, we observe that an asymmetry in the precision of the released public signals tends to reduce the distortive effect of public information. Such tendency should mirror into a higher degree of price accuracy.

**4.3.2. Ability of prices to predict the asset value: price accuracy**

We define the price error $DP$ as the absolute difference between market prices and the asset value, $DP = |Price_t - D|$. We consider the mean price error as a proxy for price accuracy.\(^\text{21}\) Figure 9 illustrates the time evolution of the price error (see Bossaerts, Frydman, and Ledyard 2014) averaged in different subsequent time-intervals ($\tau$)
of 30 s ($T = 30$), computed as:

$$DP_\tau = \frac{1}{T} \sum_{t=1+(\tau-1)T}^{\tau T} \frac{|Price_t - D|}{10} \quad \tau = 1, 2, \ldots, 6. \quad (6)$$

In Figures 8 and 9, we compare the time evolution of the price accuracy to the time evolution of the market informativeness per treatment. The latter is computed as:

$$MI_\tau = \frac{1}{T} \sum_{t=1+(\tau-1)T}^{\tau T} \frac{|FR_t - D|}{10} \quad \tau = 1, 2, \ldots, 6. \quad (7)$$

A first glance to these figures shows a close correspondence between the quantity of information present in the market and the price accuracy. Therefore, we cannot reject Hypothesis 2.3, which states that a higher price accuracy is achieved with more information in the market. In particular, we observe that the lowest level of price accuracy is achieved in treatment S, which is characterized by the highest magnitude of the crowding-out effect (see Figure 1) and the strongest overweighting effect (see Figure 4). Both are detrimental effects for price accuracy. The treatments with multiple disclosures exhibit the highest level of price accuracy, significantly higher than treatment S and B, when we confront the corresponding values in the last time subinterval (see the error bars in Figure 9).

**Result 4.8:** Multiple disclosures drive market prices systematically closer to the fundamentals than the single disclosure does.

Interestingly, the treatments with multiple disclosures exhibit similar levels of price accuracy, despite a significantly different level of market informativeness (see the error bars in Figure 8). In particular, the crowding-in effect we observe in the MS treatment does not translate into a higher level of price accuracy. Given the similar level of price accuracy of the treatments with multiple disclosures, the MSA disclosure exhibits the lowest private information gathering effort.

**Result 4.9:** Given the price accuracy, the strong asymmetric multiple disclosure is characterized by the lowest aggregate cost in information acquisition.
4.4. Profits

Hypothesis 2.7 states that, in a noisy REE framework, informed traders can generate a sufficient level of gross profits to recover the cost of information acquisition. As a consequence, we should observe no significant difference in traders’ net profit between informed and uninformed traders.

The net profit of trader $i$ in market $m$ is given by:

$$
NetProfit_{mi} = (C_{180}^{mi} - C^0) + D_m \cdot Assets_{mi}^{180},
$$

where $(C_{180}^{mi} - C^0)$ is the cash held at the end of the market after paying back the initial endowment $C^0$, and $Assets_{mi}^{180}$ denotes the number of assets held at the end of the market. $D_m$ denotes the value of the asset at the end of market $m$.

Table 4 reports the mean and standard deviation of gross and net profits of informed and uninformed traders in each treatment depending on the configurations of disclosures. On average, informed traders gain systematically higher gross profits than uninformed traders, except in MS$_d$. However, after accounting information costs, they gain lower net profits than uninformed traders in most of the treatments. These differences suggest that the configuration of disclosures affects informed traders’ ability to recover the cost of acquiring information through trading.

To provide further insights into the effect that the configuration of disclosures has on traders’ net profit, we regress traders’ net profit considering as explanatory variables dummies for the different configurations of disclosures, using as a baseline the traders’ profits in treatment B. Table 5 reports the results of the regressions.

![Figure 9. Time evolution of price accuracy per treatment. Vertical bars depict 95% confidence interval.](image-url)
Table 5. OLS regression results for net profits.

| Dependent variable: net profit | (I)     | (II)     | (III)    | (IV)    |
|--------------------------------|---------|---------|----------|---------|
| S                              | -8.333  | -8.333  |          |         |
|                                | (6.849) | (8.377) |          |         |
| MSA_c                          | -1.701  | -1.701  |          |         |
|                                | (6.324) | (6.449) |          |         |
| MSA_d                          | 22.883**| 22.883**|          |         |
|                                | (9.067) | (9.918) |          |         |
| MWA_c                          | 13.205**| 13.205**|          |         |
|                                | (6.565) | (6.608) |          |         |
| MWA_d                          | -17.270**| -17.270**|          |         |
|                                | (6.880) | (6.701) |          |         |
| MS_c                           | -0.637  | -0.637  |          |         |
|                                | (7.337) | (9.102) |          |         |
| MS_d                           | -31.775***| -31.775***|          |         |
|                                | (7.675) | (9.510) |          |         |
| Acq.Signals in B               | -0.476  | -0.476  |          |         |
|                                | (1.800) | (1.933) |          |         |
| Acq.Signals in S               | 3.391   | 3.391   |          |         |
|                                | (6.473) | (8.064) |          |         |
| Acq.Signals in MSA_c           | 3.250   | 3.250   |          |         |
|                                | (4.312) | (4.188) |          |         |
| Acq.Signals in MSA_d           | 17.043**| 17.043**|          |         |
|                                | (7.658) | (7.423) |          |         |
| Acq.Signals in MWA_c           | 2.925   | 2.925   |          |         |
|                                | (2.265) | (2.251) |          |         |
| Acq.Signals in MWA_d           | -4.713* | -4.713* |          |         |
|                                | (2.798) | (2.496) |          |         |
| Acq.Signals in MS_c            | -3.975  | -3.975  |          |         |
|                                | (2.698) | (3.255) |          |         |
| Acq.Signals in MS_d            | -9.004***| -9.004***|          |         |
|                                | (2.478) | (1.643) |          |         |
| Constant                       | 44.733***| 44.733***| 43.139***| 43.139***|
|                                | (4.388) | (5.456) | (2.225)  | (2.664) |
| Cluster SE                     | No      | Yes     | No       | Yes     |
| Observations                   | 1,590   | 1,590   | 1,590    | 1,590   |
| Clusters                       | 159     | 159     | 159      | 159     |
| $R^2$                          | 0.031   | 0.031   | 0.039    | 0.039   |

Note: Robust standard errors in parentheses. *** $p < .01$; ** $p < .05$; * $p < .1$.

Models I and II show no significant differences in net profits in most of the configurations with convergent disclosures. Conversely, in markets with divergent disclosures, traders’ gain significantly higher profits in case of strong asymmetric signals, whereas in markets with weak asymmetric or symmetric disclosures, traders' gains are significantly lower compared to treatment B.

In Models III and IV, we regress traders’ net profit considering as independent variables the number of acquired signals. We cannot reject Hypothesis 2.7 in the configurations with convergent disclosures, since informed traders do not gain higher profits compared to uninformed traders. Recall that market informativeness and price accuracy is higher in the markets with convergent disclosures and, therefore, it is more difficult for them to outperform uninformed traders gaining higher net profits. Instead, in those markets with divergent disclosures, traders’ profit differ between informed and uninformed traders. In treatment MSA_d informed traders outperform uninformed traders gaining net profits, whereas in treatments MWA_d and MS_d informed traders gain lower net profits compared to uninformed traders. To explain these results, we consider the different level of market informativeness in those markets. In markets with divergent and strong asymmetric disclosures, a significant crowding-out of private information is observed. As a consequence, market informativeness worsens in these markets allowing informed traders get an advantage over uninformed traders. On the contrary, in markets with divergent and symmetric disclosures, a crowding-in of the demand for private information is observed, increasing significantly market informativeness. As a result, in these markets traders’ investment on private
information is too high to recover the cost of information through trading in the asset market. Consequently, informed traders gain lower net profits compared to uninformed traders.

**Result 4.10:** In markets with convergent disclosures there is a tendency to observe the same net profits for informed and uninformed traders.

**Result 4.11:** In markets with divergent disclosures informed traders’ outperform uninformed traders if market informativeness is low.

5. Conclusion

We experimentally investigate to what extent the new regulation related to the disclosure of public information in financial markets, put in place after the 2008 financial crisis, is effective. Its basic goals are to enhance the precision of public information released by regulatory institutions and to incentivize the effort of investors in gathering alternative information to develop their own systems of risk evaluation and management. The potential twin-increase in the availability of information due to the new regulation, from the public and private domains, should, in principle, improve the stability of the whole financial system, avoiding overreliance on few exogenous signals (e.g. credit rating agencies). To test those sound ideas, we conduct an asset market experiment with endogenous private information. In other words, traders decide how much information to acquire at a given cost and, at the same time, they trade a risky asset, whose value depends on a random state of nature. Using this setting, we compare different disclosure scenarios, keeping constant the aggregate precision of public information, while varying the configuration of the public signals released in the market. We find that the way public information is released has relevant consequences for the market performance: it has a strong impact on traders’ demand for private information and affects significantly price efficiency. The theoretical arguments based on the EMH suggest, on the contrary, that the different configurations in disclosing public information should not affect neither the asset market efficiency nor the traders’ effort in gathering private information.

Our results show that single disclosures crowd out private information, bringing market prices far from fundamentals. Conversely, we find that, when the release of public information is performed in multiple disclosures, the traders’ effort to acquire private information increases. However, more information in the market does not always translate into a more efficient price system.

In line with the previous literature, we find that prices only partially aggregate the information available to the traders. We further observe that information disclosures might have unintended consequences, reducing their effectiveness and increasing the financial risk of persistent deviations from fundamentals. The market overreacts to a single disclosure creating a source of price distortion. Instead, when increasing the number of institutions releasing public information, we observe a reduction in the overweighting effect and an increase in price informativeness and accuracy. In these markets, prices are, in fact, good predictors of the realization of the future state of nature, driving markets close to fundamentals.

We conclude that, if the objective of the regulator is to reduce the outsourcing of the investors’ information gathering effort (like in the case of the few credit rating agencies), increasing the number of institutions releasing public information is an effective policy measure.

**Notes**

1. See Sunder (1995) and Plott (2000) for a survey.
2. We define as conclusive information when the Bayesian aggregate information points to a state of the world.
3. The vast majority of experimental papers on the overweighting of public information are based on the seminal paper of Morris and Shin in a beauty contest framework (see, for example, Cornand and Heinemann 2014; Baeriswyl and Cornand 2014; Shapiro, Shi, and Zillante 2014; Baeriswyl and Cornand 2016), which is not a market environment.
4. See Cornand and Heinemann (2008), Arato and Nakamura (2011), and Baeriswyl and Cornand (2014), among others.
5. See, for example, Ackert, Church, and Zhang (2002), Hey and Morone (2004), Deck, Lin, and Porter (2013), Fellner and Theissen (2014), Ferri and Morone (2014), Page and Siemroth (2017) and Halim, Riyanto, and Roy (2019).
6. Ten markets out of the 20 markets included in the Single disclosure treatment are populated by 10 traders.
7. Earnings, as well as asset value and dividend, during the experiment were designated in experimental currency units (ECU) and converted into € at the end of the session.
8. One experimental currency unit is equivalent to 2 cents of €. The average payoff was about 20€ and each session lasted around 90 min. Note that subjects could make losses. To avoid some of the problems associated with subjects making real losses in experiments, we endowed all subjects with a participation fee of 5€. No subject earned a negative final payoff in any session.

9. We define as informed a trader who purchases at least one private signal in a given market.

10. A Mann-Whitney (MW hereafter) tests: B vs MSA, p < 0.01; S vs MSA, p < 0.01; S vs MWA, p = 0.00.

11. A MW test shows that the number of acquired signals is significantly larger in treatment MS than in treatment B, regardless whether the signals are convergent or divergent (MW test, p < 0.01). Comparing treatment B to treatment MWA, a MW test shows no significant difference in the demand for private information. Comparing treatment B to treatment S, we observe a significance difference (MW test, p = 0.00). Finally, comparing treatment MS to treatment B, we find a significance difference, (MW test, p < 0.01).

12. MW test shows that the information market participation rate in B treatment and in MWA, MSA and MS treatments is significantly different, both for convergent and divergent signals (MW test, p = 0.00).

13. The variables s1, s4 and s8 take the value 1 (−1) if the signal’s realization is equal to 10 (0).

14. We average MI over the last trading minute when the activity in the information market is low. Traders acquire between zero and few signals depending on the market. Therefore, the Fully Revealing price is almost constant over time. The results are robust with respect to the considered time interval. We divided by 10 in order to normalize all distances to be between 0 and 1.

15. MW tests: S vs MSA, p < 0.05; S vs MWA, p < 0.05; S vs MS, p < 0.01.

16. MW test: S vs B p = 0.43.

17. See endnote 14 for further explanations on Equations (4) and (5).

18. MW tests: S vs B p < 0.05; MSA, vs all other disclosures p < 0.05, except MWA, that is p < 0.1.

19. Essentially, we consider the conditional probability of the event \( D = 10 \) conditionally on the value of each single public signal taken individually. Then we compute the goodness-of-fit of such benchmark, following Equation (5). For example, we refer with PPT5 to the PP indicator considering just the public signal with precision \( P = 0.75 \).

20. We perform sign-rank tests comparing the PI and PP indicators for each treatment. In particular, B, p < 0.01; MSA, p = 0.14; MWA, p = 0.03; MS, p < 0.01; S, p < 0.01.

21. Figures from A4 to A9 in the Appendix 2 display the time evolution of the price error in each market.

22. The values of the different probabilities are changed in accordance to the different treatments.

Acknowledgments
We thank the two anonymous referees for their helpful comments. We are also thankful to Charles Noussair for thoughtful suggestions during the early stage of the paper.

Disclosure statement
No potential conflict of interest was reported by the author(s).

Funding
The authors are grateful for the funding by the Universitat Jaume I under the project UJI-B2018-77, and the funding by the Ministerio de Ciencia, Innovación y Universidades under the Project RTI2018-096927-B-I00. Moreover, authors acknowledge financial support from Cátedra de Nova Transició Verda (Generalitat Valenciana). Alba Ruiz-Buforn acknowledges financial support of the Ministerio de Educación, Cultura y Deporte (FPU2014/01104).

References
Ackert, L. F., Bryan K. Church, and A. B. Gillette. 2004. “Immediate Disclosure Or Secrecy? The Release of Information in Experimental Asset Markets.” Financial Markets, Institutions & Instruments 13 (5): 219–243.

Ackert, L. F., B. K. Church, and P. Zhang. 2002. “Market Behavior in the Presence of Divergent and Imperfect Private Information: Experimental Evidence From Canada, China, and the United States.” Journal of Economic Behavior & Organization 47 (4): 435–450.

Alfarano, S., A. Banal-Estanol, E. Camacho-Cuena, G. Iori, and B. Kapar. 2020. Centralized vs Decentralized Markets in the Laboratory: The Role of Connectivity. MPRA Paper 99129, University Library of Munich, Germany.

Allen, F., S. Morris, and H. S. Shin. 2006. “Beauty Contests and Iterated Expectations in Asset Markets.” The Review of Financial Studies 19 (3): 719–752.

Angeletos, G.-M., and A. Pavan. 2004. “Transparency of Information and Coordination in Economies with Investment Complementarities.” The American Economic Review 94 (2): 91–98.

Angeletos, G.-M., and A. Pavan. 2007. “Efficient Use of Information and Social Value of Information.” Econometrica 75 (4): 1103–1142.

Arato, H., and T. Nakamura. 2011. “The Benefit of Mixing Private Noise Into Public Information in Beauty Contest Games.” The BE Journal of Theoretical Economics 11 (1).
Appendices

Appendix 1. Material of the experiment

English translation of instructions as well as English translation of the computer screens as seen by the subjects in each treatment.

A.1 Instructions of the experiment

Welcome. This is an economic experiment on decision-making in financial markets. The instructions are simple and if you carefully follow them, you can earn a considerable amount of money. Your earnings will be personally communicated to you and paid in cash at the end of the experiment.

During the experiment your gains will be measured in experimental units (ECU) that will be translated into Euro at the end of the experiment using an exchange rate of 1€ for every 50 ECU accumulated, plus a fixed amount for participating 3€. The corresponding amount in € will be paid in cash at the end of the experiment.

At the beginning of the experiment, it has been assigned a number to each one of you. From now on, that number will identify you and the rest of the participants. Communication is not allowed among the participants during the session. Any participant who does not comply will be expelled without payment.

The market. You are in a market together with 14 other participants. At the beginning of each period, your initial portfolio consists of 10 assets and 1000 ECU as cash. Each participant has the same initial portfolio.

The experiment consists of 10 periods of 3 min each. In each period, you and the other participants will have the opportunity to buy and sell assets. You can buy and sell as many assets as you want, although each bid or ask involves the exchange of a single asset. Therefore, the assets are bought and/or sold one at a time.

Information and dividends. At the end of each period, you will receive a specific dividend for the assets you hold in your portfolio. The value of the dividend can be 0 or 10 with the same probability. Thus, without additional information, the value of the assets can be 0 or 10 with a probability of 50%.

Moreover, you can acquire a private signal on the value of the dividend at the end of the period. The signal you will receive will be 0 or 10:

- A private signal equal to 0 means that with a probability of 60% the value of the dividend will be 0 at the end of the period.22
- A private signal equal to 10 means that with a probability of 60% the value of the dividend will be 10 at the end of the period.

The cost of the signal is 4 ECU. During each period, you can buy as many signals as you wish. This will be your private information and therefore you will be the only one able to see it.

[Only in the Single disclosure treatment (S):] In addition, you will have a public signal that will be correct with a probability of 80%, that is:

- A public signal equal to 0 means that with a probability of 60% the value of the dividend will be 0 at the end of the period.
- A public signal equal to 10 means that with a probability of 60% the value of the dividend will be 10 at the end of the period.

[Only in the Multiple Strong Asymmetric disclosure treatment (MSA):] In addition, you will have two public signals that will be correct with different probability, that is:

- A public signal equal to 0 means that with a probability of 64% the value of the dividend will be 0 at the end of the period.
- A public signal equal to 10 means that with a probability of 75% the value of the dividend will be 10 at the end of the period.

[Only in the Multiple Weak Asymmetric disclosure treatment (MWA):] In addition, you will have two public signals that will be correct with different probability, that is:

- A public signal equal to 0 means that with a probability of 64% the value of the dividend will be 0 at the end of the period.
- A public signal equal to 10 means that with a probability of 70% the value of the dividend will be 10 at the end of the period.
[Only in the Multiple Symmetric disclosure treatment (MS):] In addition, you will have two public signals that will be correct with same probability, that is:

- A public signal equal to 0 means that with a probability of 66% the value of the dividend will be 0 at the end of the period.
- A public signal equal to 10 means that with a probability of 66% the value of the dividend will be 10 at the end of the period.

At the end of each period, your profit will be the cash you have at the end of the period plus the dividends for the assets you own, minus the cash you had at the beginning of the period, that is, 1000 ECU.

Your payment at the end of the session corresponds to the accumulated profit during the 10 periods.

If at any time you have any questions or problems, do not hesitate to contact the experimenter. Remember that it is important that you understand correctly the operation of the market, since your earnings depend both on your decisions and on the decisions of the other participants in the market.

### A.2 Screenshots

**Figure A1.** Screenshot of treatment B.

**Figure A2.** Screenshot of treatment S.
Appendix 2. Market price accuracy

Every panel plots the evolution of the price accuracy. In order to render the markets with different dividends comparable, in fact, we plot the price accuracy $DP_t = |D - Price_t|$ instead of transaction prices (solid line), and smoothed price accuracy (thick-solid line). We also show the time evolution, the difference between dividend and fully revealing price (dotted line), i.e. market informativeness, $MI_t = |D - FR_t|$, and the constant difference between dividend and public benchmark (dashed line), $DPB = |D - PB|$. The horizontal axis shows the time (in seconds) at which the transaction took place. The number at the caption of each panel identifies the market.

![Figure A3. Screenshot of treatment MSA, MWA, and MS.](image)

![Figure A4. Trading activity over time in treatment B (group 1).](image)
Figure A5. Trading activity over time in treatment B (group 2).

Figure A6. Trading activity over time in treatment S (group 1).
Figure A7. Trading activity over time in treatment S (group 2).

Figure A8. Trading activity over time in treatment MSA (group 1).
Figure A9. Trading activity over time in treatment MSA (group 2).

Figure A10. Trading activity over time in treatment MWA (group 1).
Figure A11. Trading activity over time in treatment MWA (group 2).

Figure A12. Trading activity over time in treatment MS (group 1).
**Figure A13.** Trading activity over time in treatment MS (group 2).

**Figure A14.** Trading activity over time in treatment MS (group 3).