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

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Abstract

We conduct laboratory experiments to study whether increasing the number of independent public 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.

Keywords Experiments; Financial markets; Public information; Information acquisition; Multiple disclosures

JEL codes C92, D82, G14

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1 Introduction

Prior to the financial crisis of 2008, the commonly accepted paradigm in Financial Economics was characterized by a strong believe in the self-regulating forces of unrestrained financial markets, the efficiency of asset-price formation, and the increased effectiveness in risk allocation and sharing through the introduction of ever more complex financial instruments. Within the efficient market paradigm, trading in stock markets has been usually associated to the transmission and dissemination of information about the risk of the underlying assets. Before the crisis, the risk evaluation for such products was outsourced to rating agencies and typically, the buyer of CDO tranches would not have spent any effort himself on information acquisition concerning his far away counterparts. The information transmission and the effort of gathering independent "pieces" of information, therefore, seemed to have broken down in the case of structured financial products. The transition from a decentralized information gathering effort of financial investors to its outsourcing to rating agencies or other relevant public institutions might have contributed to enhance the fragility of the entire financial system before the crisis. The optimistic recommendations of rating agencies, for instance, were "blindly" followed by the vast majority of investors, which led to a detrimental underestimation of certain risks.

In order to reduce the fragility of the financial system, the disclosure of information has been at the forefront of regulatory efforts to improve financial market stability. With the aim at providing an environment with more precise public information, regulatory measures have been introduced in order to increase the reliability of credit ratings and the quality and quantity of disclosures of macroeconomic information (see Goldstein et al., 2014). For example, the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 aims at increasing the general level of transparency, improving financial stability and consumers protection (Baily et al., 2017). The European Central Bank further intensified its forward guidance activity, disclosing more information about its future monetary policy intentions. However, these measures may have potentially unintended consequences, reducing considerably their effectiveness. In particular, the disclosures of regulatory institutions may crowd out traders' effort to gather independent information, reducing the information available in the market (Goldstein and Yang, 2019). Furthermore, markets can overreact to disclosures of public information, distorting the asset prices and transmitting misleading information (Goldstein and Yang, 2019).

One of the issues in the current discussion on the reforms of the financial architecture is related to the way to disclose public information by regulatory institutions (Bank of England, 2015). The academic literature is quite ambiguous about the overall effect of disclosures. Although it is well understood that information disclosures can increase market efficiency, much has been written about their potential unintended consequences. The crowding out of private information production and the promotion of destabilizing beauty-contest incentives, are two identified collateral effects of disclosures. In this respect, market over-reaction to public information and traders' over-reliance on disclosures have been interpreted as a source of market instability and financial risk.

Effects of disclosures have been modeled within coordination frameworks in the theoretical literature (Morris and Shin, 2002; Angeletos and Pavan, 2004, 2007; Myatt and Wallace, 2011; Colombo et al., 2014) as well as within market frameworks (Kool et al., 2011; Goldstein and Yang, 2019). Several experimental studies tested the coordination models in the laboratory, given the impossibility of monitoring information held by economic agents in the real world. Their main conclusions support the theoretical conjectures that decision makers over-rely on public information (Cornand and Heinemann, 2014; Shapiro et al., 2014). Nevertheless, relatively little experimental research has been conducted to analyze the effects of releasing public information in a market environment. Middeldorp and Rosenkranz (2011) find evidence that disclosures crowd out private information and reduce price informativeness. They give support to the hypothesis proposed by Kool et al. (2011) that the reduced price informativeness is a direct consequence of the crowding out of private information. Alternatively, Ruiz-Buforn et al. (2020) show that the overweighting of public information is the main cause of the reduction in price informativeness.

The academic literature is not conclusive about the desirability and the effects that public disclosures have on an economy with endogenous private information. In this respect, our paper contributes to the literature by exploring measures to reduce financial risks caused by public release of information in financial markets. Particularly, we aim at devising more robust market architectures trying to make sure that private information (and private information acquisition) is not discarded by market participants in the presence of public information. In our contribution, we try to shed some light on pros and cons of different disclosure configurations, answering to the questions: What types of disclosure are most beneficial to promote market efficiency and reduce the financial risk related to market overreaction? What is the effect of disclosures in an economy with endogenous private information?

With this objective, we conduct laboratory experiments using an information market because of its capability for aggregating information and providing accurate predictions on fundamentals (Wolfers and Zitzewitz, 2004; Healy et al., 2010; Page and Clemen, 2013). In particular, we compare different configurations of disclosures varying the number and the relative precision of independent public signals. Our results suggest that releasing public information does not necessarily improve market efficiency when traders have access to costly private information. The way information is disclosed affects private information acquisition with the consequent risk of price distortions: a single disclosure crowds out information acquisition while multiple disclosures might increase traders' information acquisition. This effect on traders' information acquisition translates into a significant over-reaction to disclosures, that might lead to a reduction in the price accuracy. We claim that studying how market reacts to different configurations of information disclosure is fundamental for understanding how to regulate 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 to prevent 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.[1] 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

We will analyze the impact of releasing public information in a laboratory asset market. 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 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 conjecture that it is the aggregate precision of public information that affects the traders' demand for private information. Note that our conjecture is a direct consequence of the EMH, since it is the overall information available to the traders, and not the way is released, which determines market prices.

Hypothesis 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 by releasing 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 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 et al. (2011); Colombo et al. (2014); Han et al. (2016) and Goldstein and Yang (2019). Moreover, recent experimental studies show that traders endowed with precise and conclusive 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.

[1] See Sunder (1995) and Plott (2000) for a survey.

Hypothesis 2 *The release of conclusive public information crowds out private information.*

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 et al. (2014); Page and Siemroth (2017); Corgnet 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 asset value. Under the EMH, we expect prices to be closer to the fundamentals the more information is available to the traders.

Hypothesis 3 *More information in the market improves price accuracy.*

Furthermore, following the EMH, we conjecture that the configuration of disclosures do not affect price informativeness, since it should be independent of the quantity or quality of the information available to the traders.

Hypothesis 4 *Price informativeness does not depend on the configuration of disclosures.*

On the other hand, market prices may overreact to the release of public information and deviate significantly from fundamentals, as conjectured by Allen et al. (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 over-reliance of traders to information disclosures. While the theoretical literature counts with several contributions, the experimental literature regarding the overweighting in laboratory asset market experiments is scarce.[2] Ackert et al. (2004) report the existence of market overreaction to low precise disclosures. In a recent study, Ruiz-Buforn et al. (2020) find experimental evidence about the overweighting of public information when disclosed as a single signal. Moreover, they note that this effect is reinforced by the crowding out on the traders' demand for private information. Those experiments 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 3 and 4:

Hypothesis 5 *Market prices overweight public information, resulting in a reduction of price informativeness.*

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 et al., 2011; Page and Siemroth, 2017; Ruiz-Buforn et al., 2020).

Hypothesis 6 *Informed traders gain the same profit as uninformed traders.*

[2] 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; Shapiro et al., 2014; Baeriswyl and Cornand, 2014, 2016), which is not a market environment.

3 Experimental design and procedure

Our experimental setting is similar to other contributions from the literature on laboratory financial markets and prediction markets.[3] We implement an asset market populated by 15 traders.[4] At the beginning of each market, traders are endowed with 1000 units of experimental currency (ECU)[5] and 10 risky assets, paying a dividend D when market close. The assets have a one-market life. The asset market is implemented as a 3 minute 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 on 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 minutes 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 $P_B = 0.70$; (iii) Multiple Strong Asymmetric Disclosures treatment (MSA), where the precision of the two public signals is $P_A = 0.6$ and $P_B = 0.75$.

[3]See, for example, Ackert et al. (2002); Hey and Morone (2004); Ferri and Morone (2008); Deck et al. (2013); Fellner and Theissen (2014); Page and Siemroth (2017) and Halim et al. (2019).

[4]10 markets out of the 20 markets included in the Single disclosure treatment are populated by 10 traders.

[5]Earnings, as well as asset value and dividend, during the experiments were designated in experimental currency units (ECU) and converted into € at the end of the session.

Table 1: Experimental design and parameters. With p we denote the precision of a private signal, and P_A and P_B denote the precision of each individual public signal, when present.

Treatment	p	P_A	P_B	♯ of markets
B	0.6	-	-	20
S	0.6	0.8	-	20
MS	0.6	0.66	0.66	30
MWA	0.6	0.64	0.70	20
MSA	0.6	0.6	0.75	20

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:

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

where $Pr(D = 10|S_A, S_B)$ 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.

Table 2: Probability of the event $D = 10$ given the configuration of the public signals. P_A and P_B (S_A and S_B) denote the precision (configurations) of the disclosures.

Treatment	P_A	P_B	S_A	S_B	$Pr(D = 10\|S_A, S_B)$
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

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, in particular, 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 MS_d and B 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).[6] 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.[7]

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 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 MS treatment, 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

[6]Translated instructions and screenshots in the implemented treatments are available upon request.

[7]One experimental currency unit is equivalent to 2 cents of €. The average payoff was about 20€ and each session lasted around 90 minutes. 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.

at least one private signal in the information market. Again, S treatment presents the lowest proportion of informed traders while the largest number of informed traders is in MS treatment. Regarding the activity in the asset market, we observe a wide variability of trading volume across treatments, with the most trades in treatment B.

Table 3: Summary statistics

	B		**S**		**MS**		**MSA**		**MWA**	
Variables	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	

[a]Informed traders refers the fraction of traders acquiring at least one signal.

4.2 Information Market: Information acquisition and market informativeness

4.2.1 Information acquisition

We start our analysis looking into 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.[8] 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 information market participation rate as a function of the different disclosure scenarios.

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 1 the demand for private information should be roughly homogeneous in those scenarios with similar aggregate precision of public information.

A first glance at Figure 1 reveals that we can reject Hypothesis 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.[9] 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'

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

[9]A Mann-Whitney (MW hereafter) tests: B *vs* MS_d $p < 0.01$; S *vs* MS_c $p < 0.01$; S *vs* MWA_c $p = 0.00$.

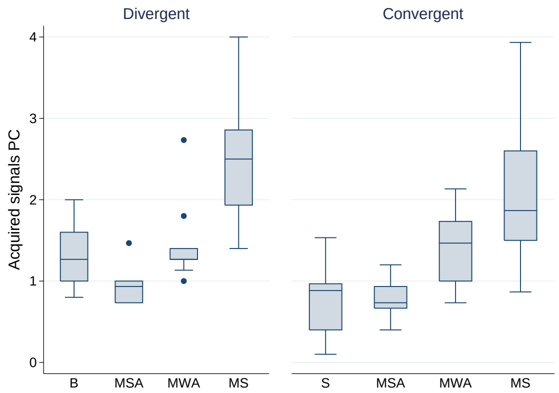

Figure 1: Per capita information acquisition.

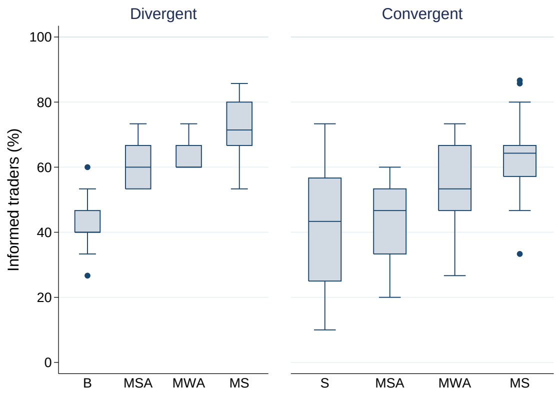

Figure 2: Information market participation rate.

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 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.*

An interesting result is that the traders' demand for private information is not significantly different in treatments S and MSA, independently of the two signals being convergent or divergent. Our results are, therefore, not compatible with an aggregation of public information using a Bayesian rule implied by eq. (1).[10] Such deviation from a Bayesian aggregation leads us to conjecture that, in markets with multiple strong asymmetric disclosures, prices overweight the higher-precise signal while they underweight the lower-precise signal. In simple terms, the more precise public signal can be considered a "dominant" signal. We will come back to this point in Section 4.3.1.

Turning now to Hypothesis 2, it states that if the public information is conclusive, this should crowd out the demand for private information. We should therefore observe that traders acquire fewer signals in all configurations but MS_d, compared to the Baseline treatment. We can reject Hypothesis 2 since the release of multiple symmetric signals, either divergent or convergent, crowds in private information. At the same time, no crowding-out effect is observed in case of multiple weak asymmetric and convergent disclosures.[11] Instead, we observe a clear crowding out of private information in those markets with a single disclosure or multiple strong asymmetric disclosures. This speaks in favor of our conjecture about the dominance of the more precise signal.

[10] In this respect, it is striking the significant difference between the B and MS_d treatments. In these markets, two divergent and equally precise signals should be informationally equivalent to the absence of a public release.

[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_c, a MW test shows no significant difference in the demand for private information.

Result 2 *The disclosure of information crowds out private information if a single or multiple strong asymmetric signals are released.*

Figure 2 reveals that the information market participation rate also depends on the particular configuration of disclosures. Releasing multiple signals increases the participation of traders in the information market with respect to the absence of public information.[12]

Result 3 *The disclosure of 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 asset value and the Fully Revealing price FR_t, which is the expected price when all information (public and private) is 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:[13]

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

We compute market informativeness E_{FRD} as:[14]

$$E_{FRD} = \frac{1}{60} \sum_{t=120}^{180} \frac{|FR_t - D|}{10} . \tag{3}$$

Figure 3 confirms that market informativeness significantly improves in case of convergent multiple disclosures compared to a single disclosure.[15] However, it is worth to note that a single disclosure does not improve market informativeness compared to the market with no public information.[16]

Result 4 *Disclosures, at worst, leave invariant market informativeness. Market informativeness significantly improves when multiple convergent signals are released.*

[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, $p = 0.00$).

[13] We redefine the variables s_i, S_A and S_B. They will take the value 1 (-1) if the signal's realization is equal to 10 (0).

[14] We average E_{FRD} 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_c $p < 0.05$; S *vs* MWA_c $p < 0.05$; S *vs* MS_c $p < 0.01$.

[16] MW test: S *vs* B $p = 0.43$

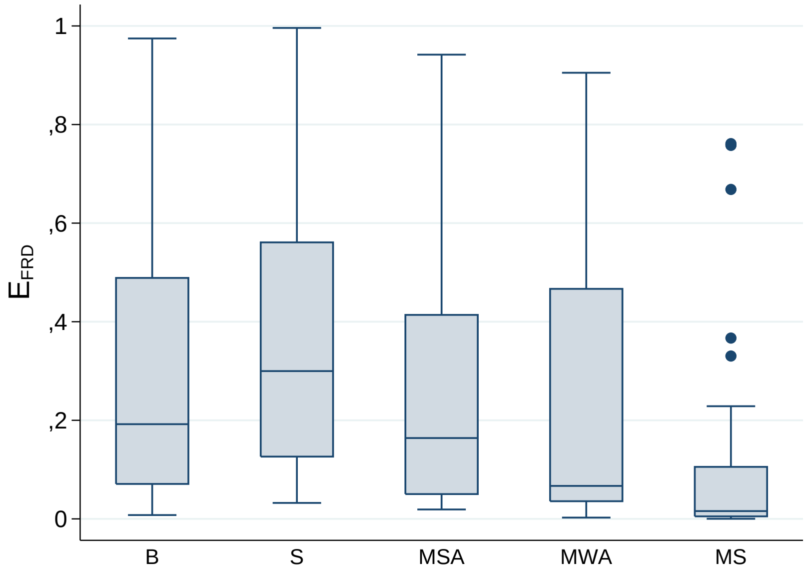

Figure 3: Market informativeness: convergent *vs* divergent public disclosures.

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 reflected in market prices? How do the considered configurations 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 from eq. (2) and (ii) the public benchmark, PB, defined as the expected price conditional on the value of the released public signals, i.e. $PB = 10 \cdot Pr(D = 10|S_A, S_B)$ (see eq. (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 is a measure of the distance between observed prices and the fully revealing benchmark, and (ii) PP is a measure of the distance between observed prices and the public benchmark PB:[17]

$$PI = \frac{1}{60} \sum_{t=120}^{180} \frac{|Price_t - FR_t|}{10} \,, \tag{4}$$

$$PP = \frac{1}{60} \sum_{t=120}^{180} \frac{|Price_t - PB|}{10} \,. \tag{5}$$

[17]See footnote 14 for further explanations on the formulas (4) and (5).

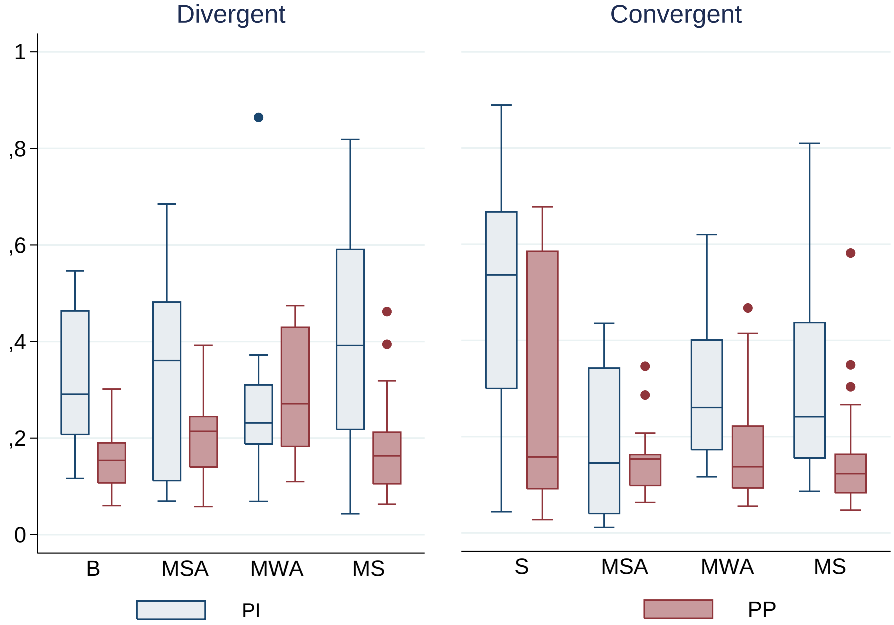

Figure 4: Aggregation of information in each market by treatment and configurations of disclosures.

The PI indicator allows us to evaluate how prices aggregate information across the different configuration of disclosures. It is a measure of the price informativeness. In line with the existing literature in Experimental Finance, our results confirm that prices imperfectly aggregate the information available to the traders.

Result 5 *Prices imperfectly aggregate the information available to the traders.*

Looking at Figure 4, we can reject Hypothesis 4, since price informativeness significantly differ across the different configurations of disclosures. In particular, price informativeness worsens significantly in the case of a single disclosure, whereas multiple the strong asymmetric convergent disclosure outperforms all other configurations in terms of price informativeness.[18] We can, therefore, conclude:

Result 6 *The configuration of disclosures affects price informativeness.*

We observe some discrepancies between the market informativeness and the price informativeness, indicating some degree of inefficiency in aggregating information into prices. In particular, we observe that those markets 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). Moreover, in Figure 3, markets with a single disclosure and absence of public information exhibit a similar market informativeness. Price informativeness, instead, is significantly lower in the case of a single disclosure (MW $p < 0.05$).

In order to explain such discrepancies, we rely on Hypothesis 5, which states that prices systematically weight public information above its precision, leading to a reduction

[18]MW tests: S *vs* B $p < 0.05$; MSA_c *vs* all other disclosures $p < 0.05$, except MWA_c that is $p < 0.1$.

in price informativeness. Comparing the indicators PI and PP allow us to detect the overweighting of public information. When the PP indicator significantly outperforms the PI indicator, it suggests that prices overweight public information.

Figure 4 supports our conjecture on the overweighting of public information in most of the configurations of disclosures. We cannot reject Hypothesis 5 in treatment S (one-side sign test, $p = 0.00$). This result also extends to the behavior of prices in the MS treatment, 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, since the crowding-in of private information significantly improves the market informativeness in those markets. However, the enhanced market informativeness is not sufficient to overcome the strong influence that symmetric convergent disclosures have on prices.

Nevertheless, 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]. 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. The most precise public signal is, in fact, slightly more informative than the other public signal. We can conclude that, when releasing information in a financial market, the overweighting phenomenon is a very pervasive effect.

Result 7 *The overweighting phenomenon is a quite robust effect of the release of public information.*

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.[20] We divide the time interval of a market in 6 time intervals. Figure 8 illustrates the time evolution of the price error (see Bossaerts et al., 2014) averaged in different subsequent time-intervals, computed as:

$$E_{DP_j} = \frac{1}{T} \sum_{t=1+(j-1)T}^{jT} \frac{|Price_t - D|}{10} \qquad j = 1, 2, ..6 \; . \tag{6}$$

[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 eq. (5). For example, we refer with $PP75$ to the PP indicator considering just the public signal with precision $P = 0.75$.

[20]Figures from 9 to 14 in the appendix A display the time evolution of the price error in each market.

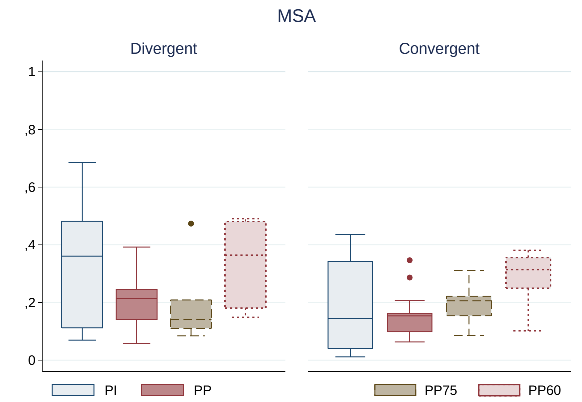

Figure 5: FR and public benchmarks in Treatment MSA.

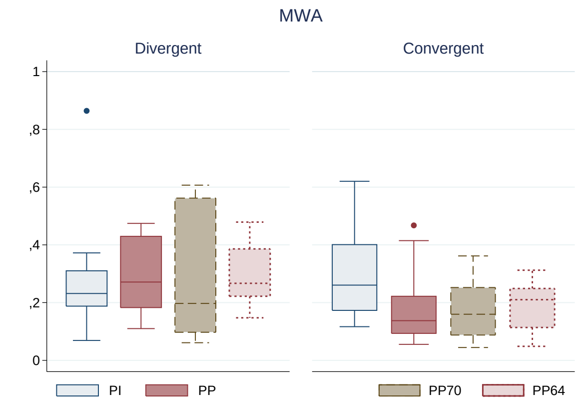

Figure 6: FR and public benchmarks in Treatment MWA.

In figures 7 and 8, we compare the time evolution of the price accuracy with the equivalent time evolution of the market informativeness per treatment. The latter is computed as:

$$E_{MI_j} = \frac{1}{T} \sum_{t=1+(j-1)T}^{jT} \frac{|FR_t - D|}{10} \qquad j = 1, 2, ..6\ . \tag{7}$$

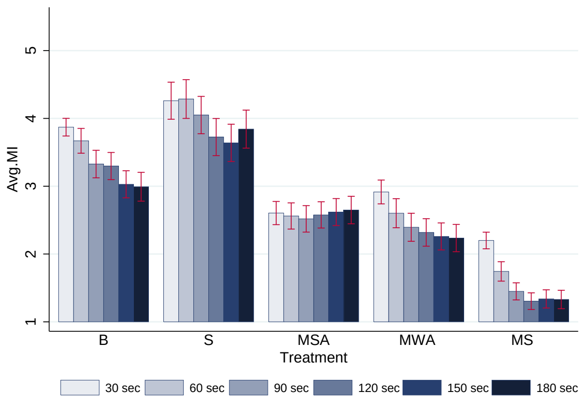

Figure 7: Time evolution of market informativeness per treatment. Vertical bars depict 95% confidence interval.

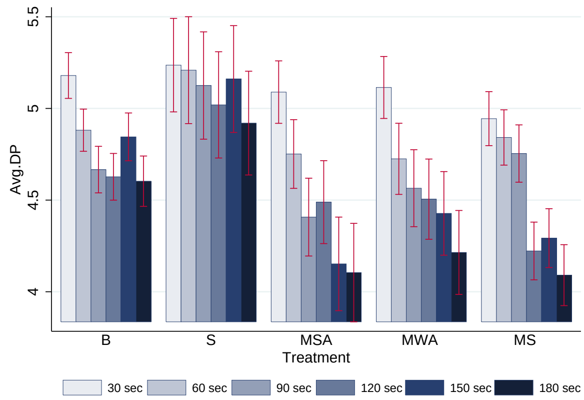

Figure 8: Time evolution of price accuracy per treatment. Vertical bars depict 95% confidence interval.

A first glance to both figures shows a close correspondence between the quantity of information present in the market and the price accuracy. Therefore, we cannot reject Hypothesis 3, which states that a higher price accuracy is achieved with more information into the market. In particular, we observe that the lowest level of price accuracy is achieved in the Single disclosure treatment, 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 the Single disclosure and the B treatment, when we confront the corresponding values in the last time subinterval (see the error bars in Figure 8).

Result 8 *Multiple disclosures drive market prices systematically closer to the fundamentals than the single disclosure.*

Interestingly, the treatments with multiple disclosures exhibits similar levels of price accuracy, despite a significantly different level of market informativeness (see the error bars in Figure 7). 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 guarantees the lowest private information gathering effort.

Result 9 *Given the price accuracy, the strong asymmetric multiple disclosure is characterized by the lowest aggregate cost in information acquisition.*

4.4 Profits

Hypothesis 6 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:

$$NetProfit_{mi} = (C^{180}_{mi} - C^{0}) + D_m \cdot Assets^{180}_{mi} \ , \tag{8}$$

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 $Assets^{180}_{mi}$ 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.

Table 4: Gross profit and net profit per configuration of disclosures.

	Gross Profit				Net Profit			
	Informed		Uninformed		Informed		Uninformed	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
B	54.2	74.1	46.9	77.7	41.7	73.6	46.9	77.7
S	48.1	100.5	37.2	68.92	35.4	97.4	37.2	68.9
MSA_c	60.5	75.7	35.0	51.1	53.4	75.8	35.0	51.1
MSA_d	80.4	98.5	57.8	46.8	74.1	97.8	57.8	46.8
MWA_c	70.7	70.9	55.9	52.8	59.8	71.0	55.9	52.8
MWA_d	35.8	66.5	29.0	53.0	26.6	66.4	29.0	53.0
MS_c	55.7	92.3	46.5	88.5	42.7	95.0	46.5	88.5
MS_d	22.4	89.1	23.9	74.9	8.4	91.7	23.9	74.9

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.

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 profits 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 6 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 in 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 10 *In markets with convergent disclosures there is a tendency to observe the same net profits for informed and uninformed traders.*

Result 11 *In markets with divergent disclosures informed traders' might outperform uninformed traders if market informativeness is low.*

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		169		169
R^2	0.031	0.031	0.039	0.039

Robust standard errors in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

5 Conclusion

We experimentally investigate to what extent the new regulation related to the 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 policies, keeping constant its precision, 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 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.

Acknowledgment

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A 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 $DP = |D - price|$ 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), $DFR = |D - FR|$, and the 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.

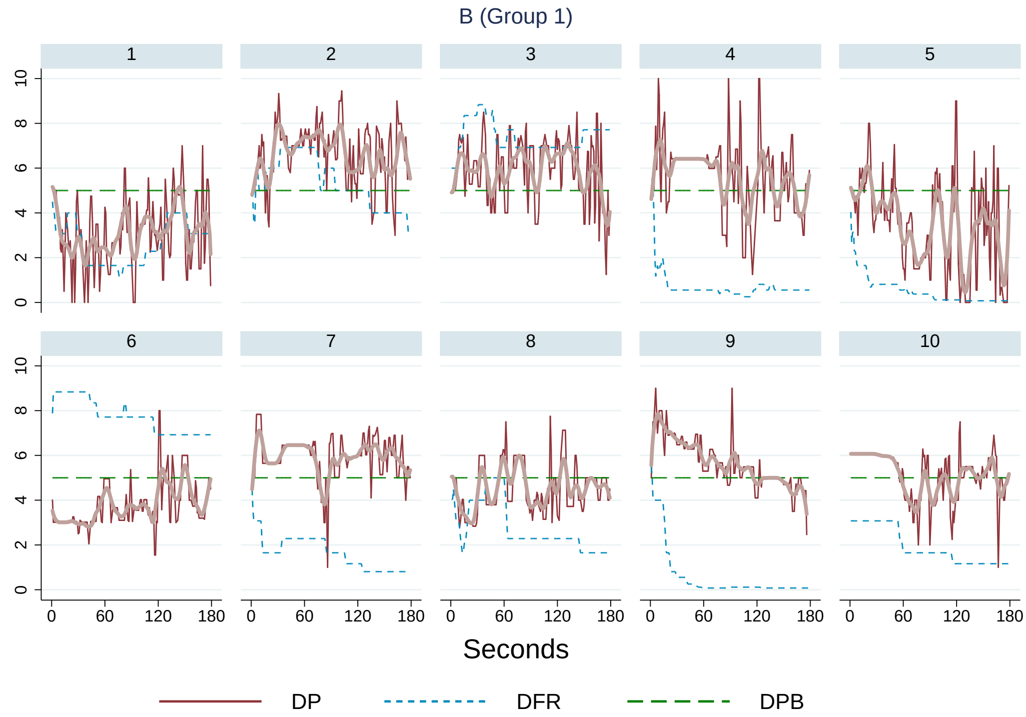

Figure 9: Trading activity over time in Treatment B (group 1).

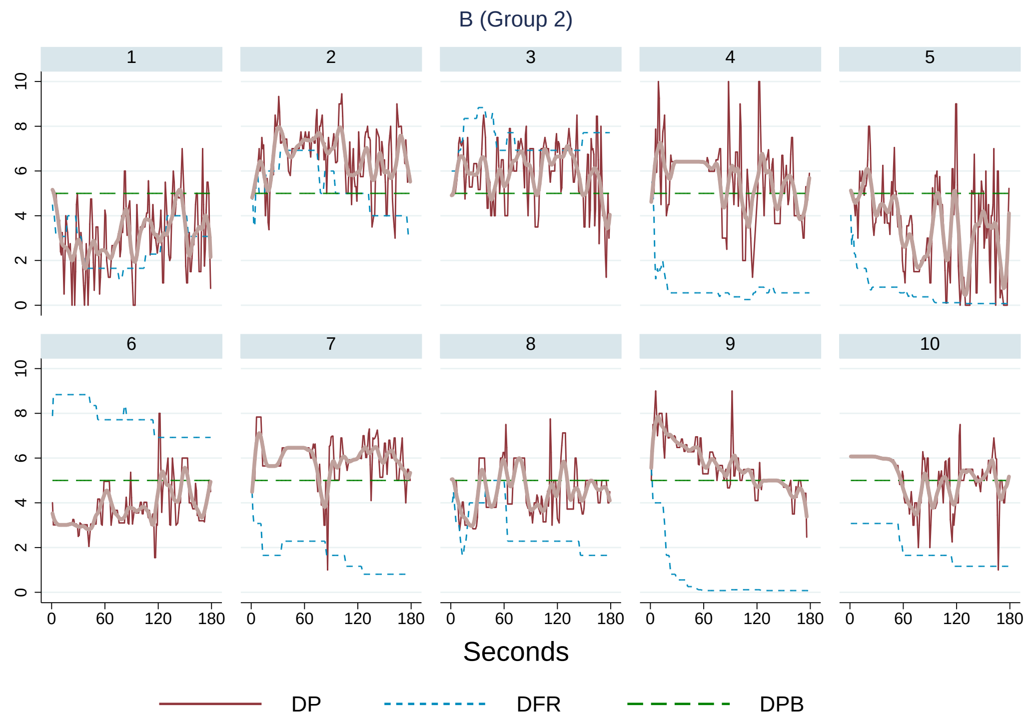

Figure 10: Trading activity over time in Treatment B (group 2).

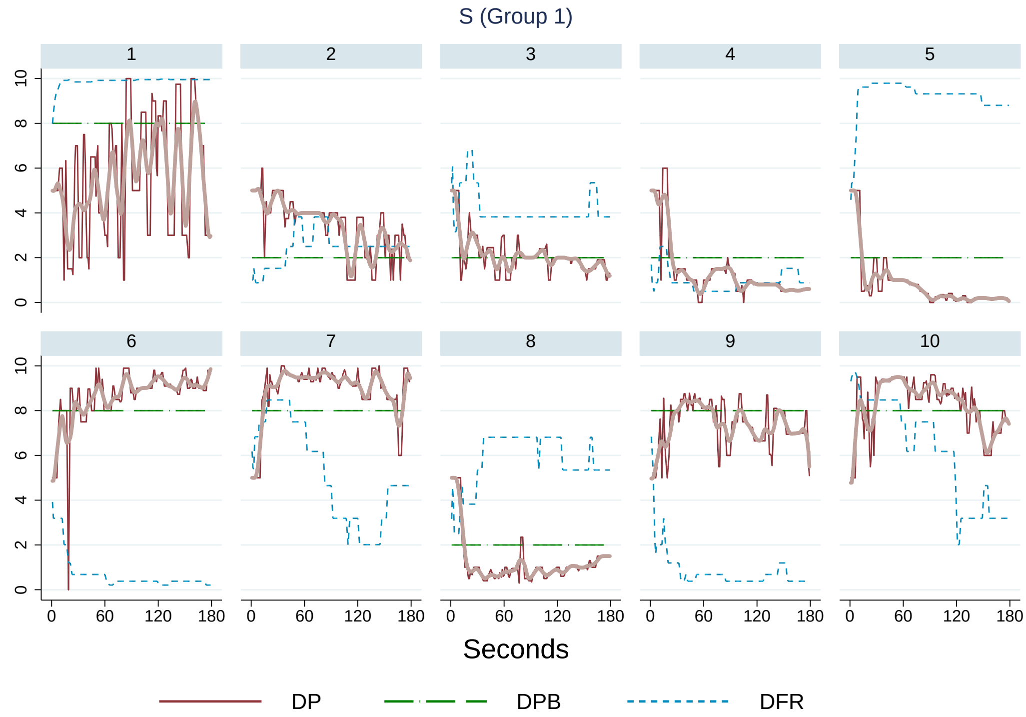

Figure 11: Trading activity over time in Treatment S (group 1).

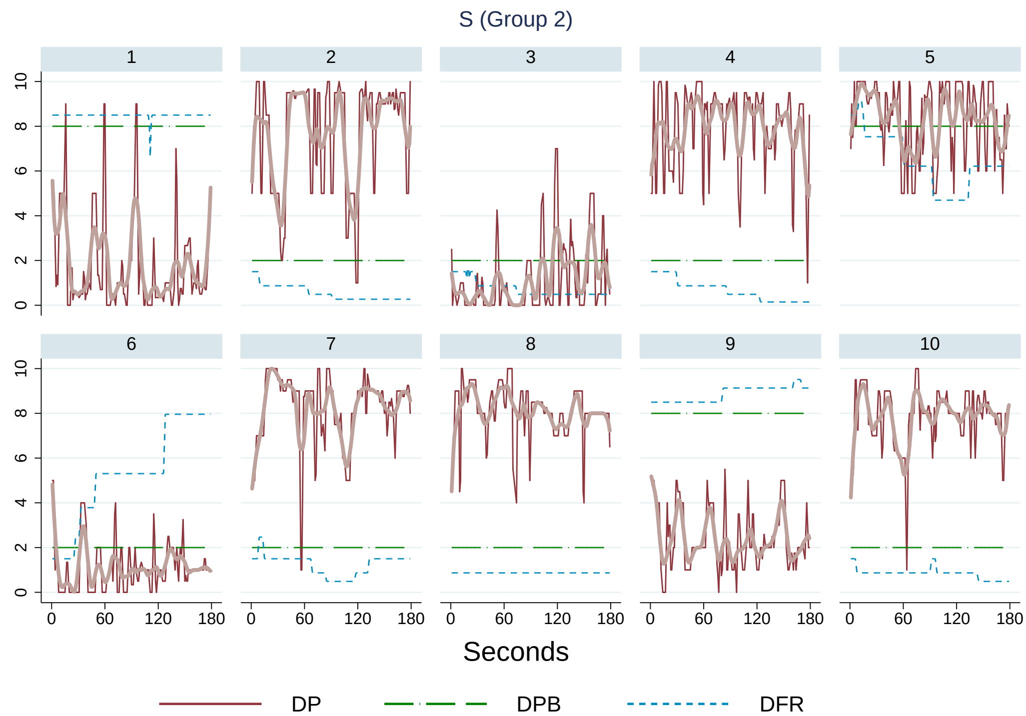

Figure 12: Trading activity over time in Treatment S (group 2).

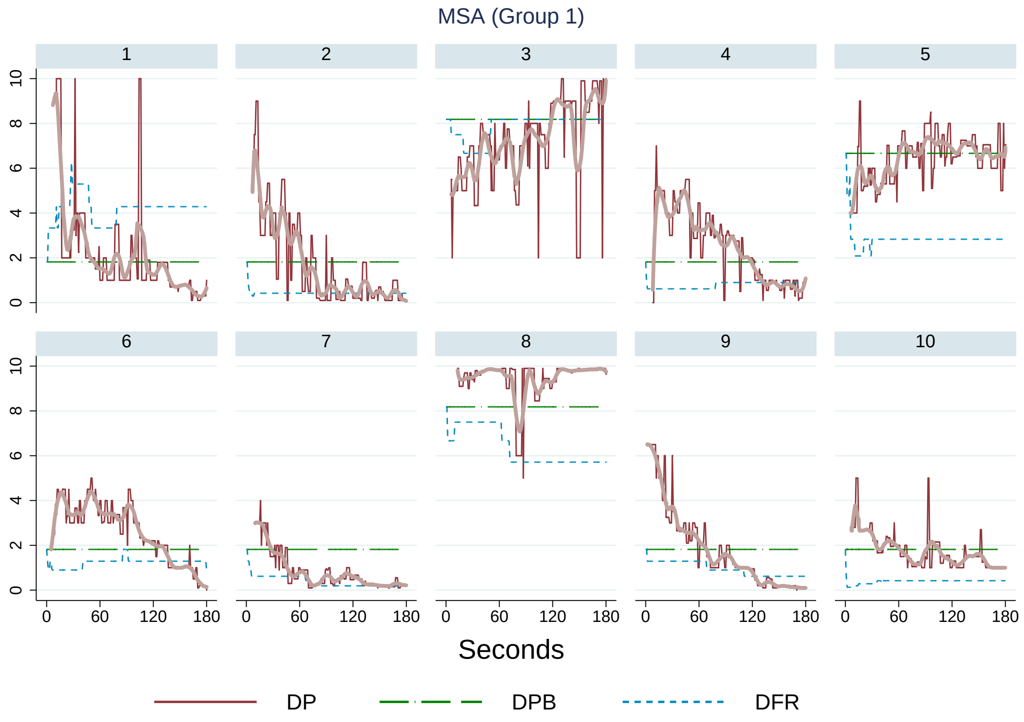

Figure 13: Trading activity over time in Treatment MSA (group 1).

Figure 14: Trading activity over time in Treatment MSA (group 2).

Figure 15: Trading activity over time in Treatment MWA (group 1).

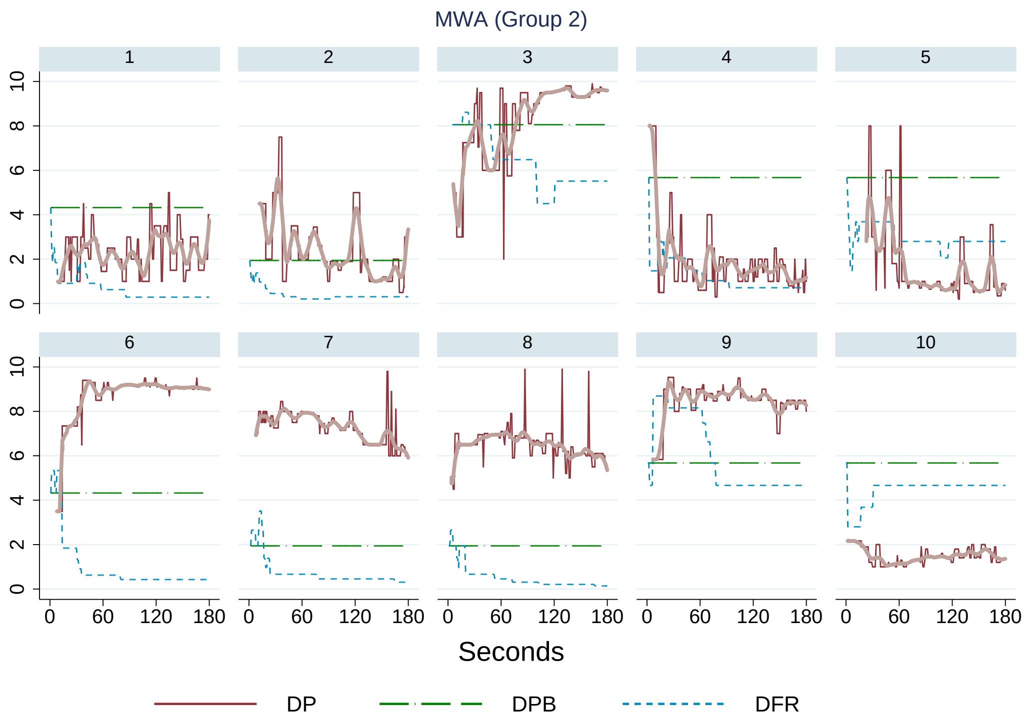

Figure 16: Trading activity over time in Treatment MWA (group 2).

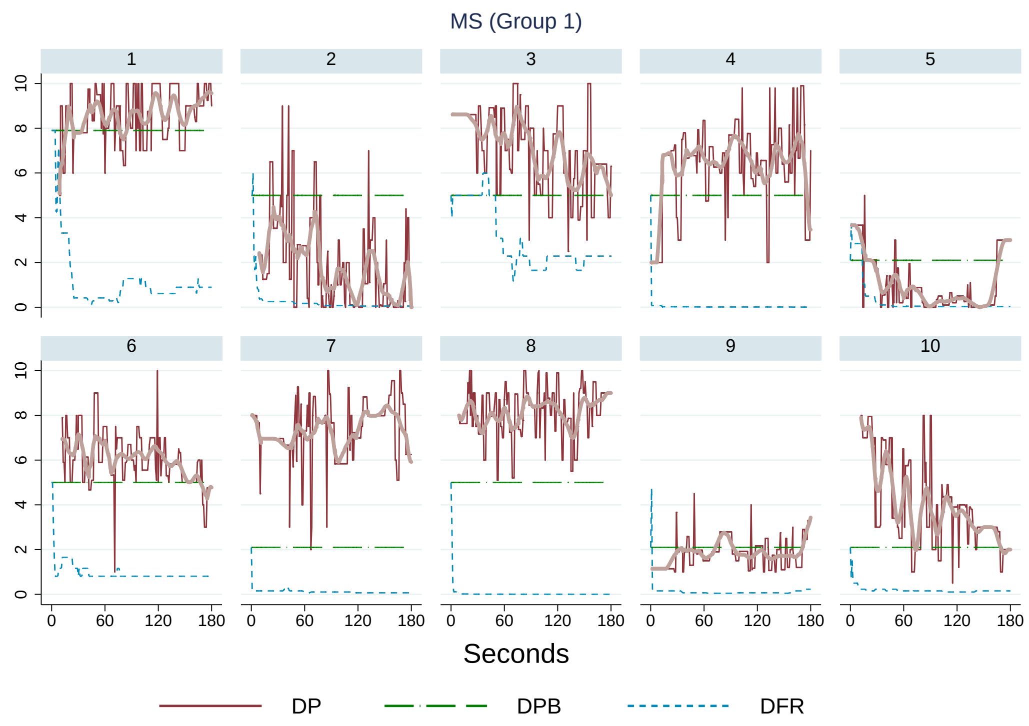

Figure 17: Trading activity over time in Treatment MS (group 1).

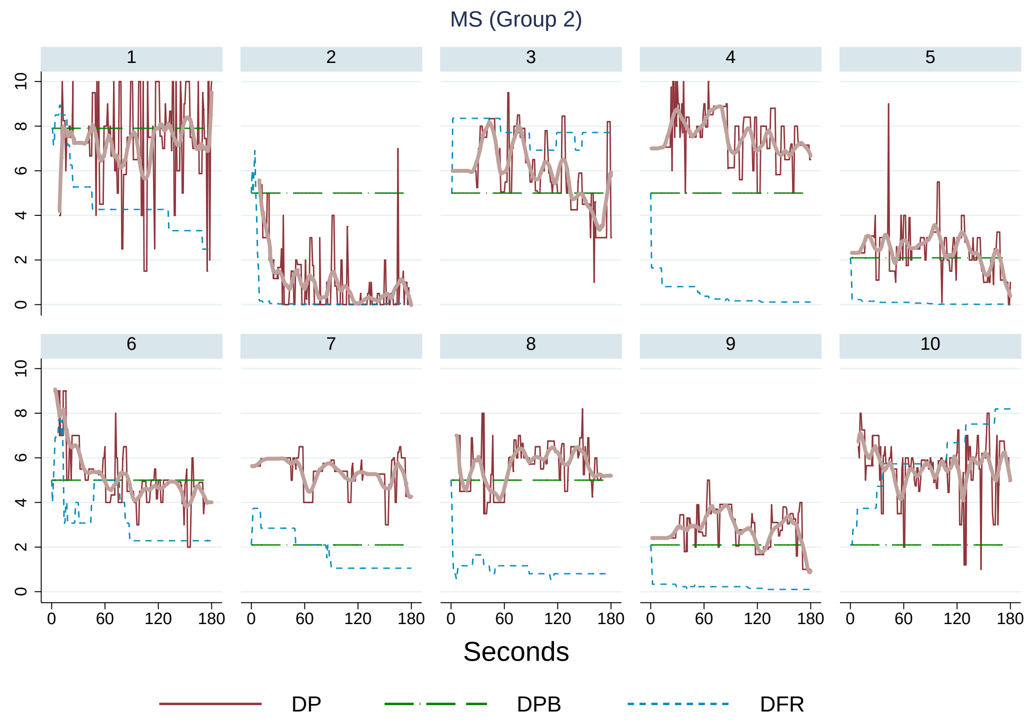

Figure 18: Trading activity over time in Treatment MS (group 2).

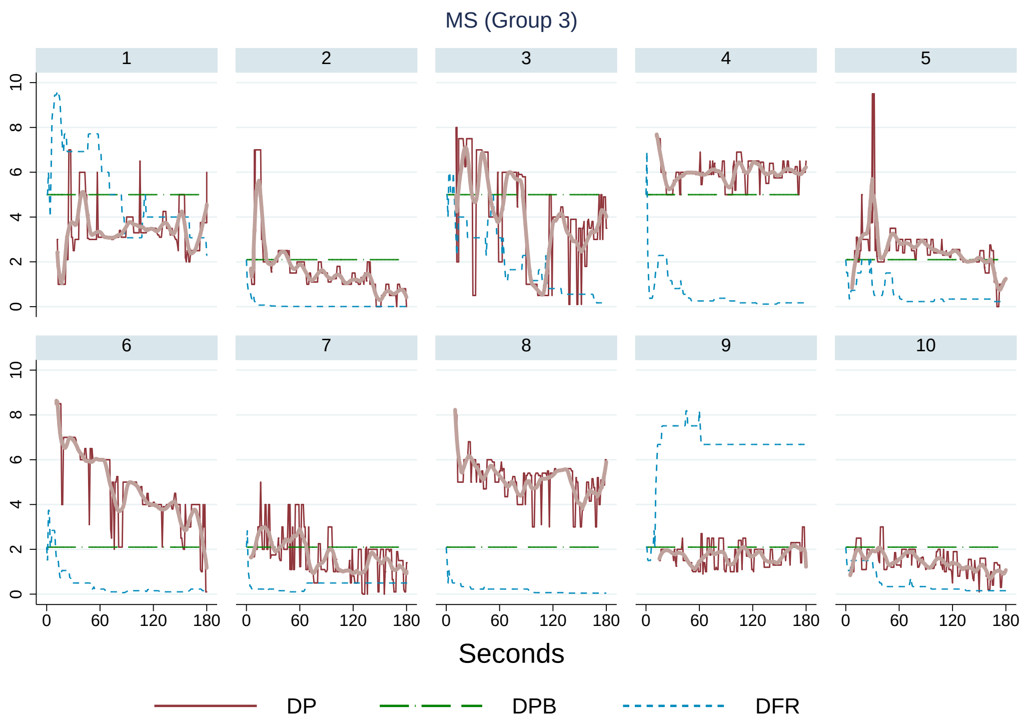

Figure 19: Trading activity over time in Treatment MS (group 3).