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**Working Paper**

## Do investors rely too much on public information to be justified by its accuracy? An experimental study

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# FinMaP-Working Paper No.30



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FINMAP –

FINANCIAL DISTORTIONS AND MACROECONOMIC  
PERFORMANCE: EXPECTATIONS, CONSTRAINTS AND  
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TITLE

Do investors rely too much on public  
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by: Simone Alfarano, Eva Camacho and Andrea  
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## ABSTRACT

The theoretical approach in dealing with the aggregation of information in markets in general, and financial markets in particular considers information as an exogenous element to the system, focusing just on conditions and consequences of the efficient incorporation of information into prices. The production and acquisition of the information is, therefore, not a major focus of the theoretical as well as the empirical analysis. We take the position that the composition of the spectrum of information sources affects the behavior of the traders in the information gathering process. In this paper we will study experimentally the information aggregation process in a market as a function of the access to different sources of information, namely an imperfect, public and costless signal into a market where the participants have access to costly and imperfect private information. We observe that the release of public information provokes a crowding-out effect on the traders' information demand for private information, it keeps constant market informativeness, but significantly reduces price efficiency in aggregating information. In particular we show that traders overweight public information that dominates the market dynamics. As a policy advise we recommend that eventual reforms on the regulation of financial institutions (for instance the credit rating agencies) should account for the complex interplay between private and public information that we have identified in our experiments and give incentives to the investors (institutional and/or private) to search for alternative sources of information.

*Keywords: Experiments, financial markets, private and public information, rating agencies.*

*JEL Classification: C92, D82, G14.*

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Do investors rely too much on public information to be  
justified by its accuracy? An experimental study

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## Abstract

The theoretical approach in dealing with the aggregation of information in markets in general, and financial markets in particular considers information as an exogenous element to the system, focusing just on conditions and consequences of the efficient incorporation of information into prices. The production and acquisition of the information is, therefore, not a major focus of the theoretical as well as the empirical analysis. We take the position that the composition of the spectrum of information sources affects the behavior of the traders in the information gathering process. In this paper we will study experimentally the information aggregation process in a market as a function of the access to different sources of information, namely an imperfect, public and costless signal into a market where the participants have access to costly and imperfect private information. We observe that the release of public information provokes a crowding-out effect on the traders' information demand for private information, it keeps constant market informativeness, but significantly reduces price efficiency in aggregating information. In particular we show that traders overweight public information that dominates the market dynamics. As a policy advise we recommend that eventual reforms on the regulation of financial institutions (for instance the credit rating agencies) should account for the complex interplay between private and public information that we have identified in our experiments and give incentives to the investors (institutional and/or private) to search for alternative sources of information.

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# 1 Introduction

After the recent financial turmoil, academics and regulators started a debate on the role that the main rating agencies played in the global diffusion of financial instability. It seems that their optimistic recommendations have been followed by the vast majority of investors, while revealing being misleading. However, why have financial investors passively followed recommendations of rating agencies? Did they search for independent and alternative sources of information in evaluating financial products? Might it be that the information provided by the rating agencies has produced a reduction in the information gathering activity of investors?.

Inspired by the recent debate on which role have played rating agencies in the current financial crisis, in our paper we use laboratory experiments to investigate the impact of releasing introduction of an imperfect, public and costless signal into a financial market where traders have access to (independent sources of) costly and imperfect private information about the future prospect of a financial asset. The main focus of the paper is, on the one hand, the analysis of the efficiency of prices in aggregating and disseminating information, studying in particular whether and under which conditions the contemporaneous presence of private and public information enhances or reduces market efficiency. On the other hand, we study the demand for information as a function of the relative precision of the public signal with respect to the noisiness of private information. In a market with these characteristics, using the words of Morris and Shin (2002) “public and private information (might) end up being substitute rather than being cumulative”. More precisely, Morris and Shin (2002) show that in a game-theoretical beauty contest, this substitution effect can significantly decrease the information content in the system that, depending on the noisiness of public information might result in a welfare loss.<sup>1</sup> They demonstrate that public information might be considered a double edged-instrument, i.e. it conveys information on the fundamentals of a financial asset, but, at the same time, it serves as a focal point in coordinating the traders’ activity in a market. They

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<sup>1</sup>Given this double edged nature of public information, other authors have addressed the issue of transparency of public information. For example Amato and Shin (2004), Angeletos and Pavan (2004) or Hellwig (2005),

conclude that the noisiness of public information can be enhanced in the market due to the overreaction of the traders to the disclosure of a public signal. Following the theoretical work of Morris and Shin in a beauty-contest environment, in our paper we want to analyze whether we can observe in a laboratory financial market the complex interaction between public and private information described by Morris and Shin. The experimental literature on laboratory financial markets has paid no attention to such interplay and to the double edged role of public information in the experimental markets, outside the p-beauty context.

Taking into account the experimental literature, we can categorize previous studies on financial markets in a laboratory into two broad groups<sup>2</sup>, on the one hand those studies where information is exogenously given to the traders at no cost. On the other hand, those settings where exists an information market that runs parallel to the asset market. As a representative example of the first category, we can mention the seminal paper of Plott and Sunder (1982), where they study under which conditions *perfect* information is efficiently incorporated into prices. They address the issue of dissemination of information from a group of fully informed agents (i.e. insiders) to a group of uninformed agents and conclude that with replication and experience (even uninformed) traders are able to decipher the true state of the world by simply observing market price.<sup>3</sup> The review of different experimental studies on information aggregation and dissemination in a setting where *imperfect* information is distributed at no cost suggests that aggregation depends crucially on market features such as common knowledge, information distribution or subjects' experience.<sup>4</sup> One important finding is that, even under the best circumstances, information aggregation and/or dissemination (when occurs) is not instantaneous, since traders need some time to observe the market activity, form conjectures, test them and modify their strategies. Therefore, there is an incentive for costly information creation due to the noisy revelation of information in asset markets.<sup>5</sup>

As an example of the second category is the paper of Sunder (1992), who studied

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<sup>2</sup>See Plott (2002) and Sunder (1995) for a thoughtful survey on experimental asset markets.

<sup>3</sup>Watts (1993) replicates the Plott and Sunder's experiments where the presence of insiders is random, and finds that the price convergence to the rational expectations equilibrium worsens.

<sup>4</sup>See Sunder (1995) for an detailed survey on this issue.

<sup>5</sup>See Grossman and Stiglitz (1980).

experimentally the impact of the contemporaneous presence of an information market and an asset market. In a first setting, the price of information is endogenous whereas the number of perfectly informed traders is fixed (i.e. a given number of perfect signals were auctioned off). In a second experimental setting, the price of information is fixed, whereas the number of informed traders is endogenous (and not known by traders). A series of experimental studies using different settings inspired by Sunder (1992) conclude that when the distribution of (perfectly) informed traders is not common knowledge in the market, it is harder for the prices to reveal information.<sup>6</sup>

However, in all the previous experiments informed subjects are *insiders*, since the information received is always perfect or certain. Within this framework Hey and Morone (2004) develop a very simple experimental setting where heterogeneous and imperfectly informed agents have to trade a risky asset whose dividend depends on two equiprobable states of the world. In their setting, each trader can buy, at any moment during the trading period, as many signals as (s)he wants. Their results suggest that the aggregation process improves when the quality and quantity of information in the market are higher.<sup>7</sup>

Typically, as we have seen, the experimental literature focuses on the problem of market efficiency in aggregating private information into prices. Whereas, it has not been experimentally investigated so far, the impact of a public signal, for example the rating agencies' recommendations or a central bank disclosure on traders' behavior and/or market efficiency.

Contrary to the experimental literature, in the empirical literature, several papers deal with the market impact of the rating agencies. Among these contributions, Millon and Thakor (1985) demonstrate that information gathering agencies may arise in a world of informational asymmetries and moral hazard. According to them, in a setting in which true firms' values are certified by screening agents whose payoffs depend on noisy ex-post monitors of information quality, the formation of information gathering agencies is justified because it: (i) enables screening agents

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<sup>6</sup>See Copeland and Friedman (1991, 1992) or Camerer and Weigelt (1991), among others.

<sup>7</sup>For a recent survey on financial markets in the laboratory see Noussair and Tucker (2013).



to diversify their risky payoffs, and (ii) allows for information sharing.<sup>8</sup> Still on theoretical grounds, referring to a multiple equilibria set up, Boot et al. (2006) show that the rating is a coordinating mechanism, providing a “focal point” for firms and investors. However, Carlson and Hale (2006) reach opposite conclusions. Using a game theoretic model, they predict that introducing a rating agency to a market that otherwise would have the unique equilibrium, can bring about multiple equilibria.

Taking stock of all these contributions on the role that public and private information might have in a financial market, our paper aims at contributing to this debate by experimentally analyzing which role public information (e.g. information provided by a rating agency or a central bank) plays in the aggregation process of private information in a financial market. In particular, do subjects demand less private information if they have access to public information? Additionally, does public information play a role in the aggregation of available information into prices? If yes, is it detrimental or beneficial for market efficiency?

## 2 The Experimental Design

In this section we describe the main characteristics of the experimental setting and design as well as the trading mechanism. Each market is populated by 15 subjects. At the beginning of each trading period, each subject is endowed with 1000 units of experimental currency (ECU)<sup>9</sup> and 10 units of an asset that pays a dividend  $D$  at the end of the trading period. Apart from the dividend paid out, assets are worthless. The value of the dividend will take the value 0 or 10 with a 50% probability. At the beginning of each trading period the true dividend is randomly determined by the experimenter, but not revealed to the subjects until the end, when the period payoff is determined. It is common knowledge to all subjects that the two possible dividend values are equiprobable.

At any moment within a given trading period, subjects can buy a private signal paying a cost of 4 ECU per signal. Additionally, only in those treatments with public

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<sup>8</sup>However, Millon and Thakor (1985) assume perfect knowledge by the information gathering agency about the underlying risk of the borrower.

<sup>9</sup>Earnings, as well as asset value and dividend, during the experiments were designated in experimental units (EU) and converted into € at the end of the session.

information, subjects have free access to a public signal whose value is common knowledge among subjects within a market. Such signal is made public before the trading period starts. Both (private and public) signals are partially but not totally informative of to the true dividend value, and are presented to the subjects taking the value 10 or 0. If a subject purchases a signal that results to be 10 (0), he can infer that the dividend is expected to be 10 (0) with probability  $p$  and 0 (10) with probability  $q = 1 - p$ . Following the same reasoning regarding the public signal, if a subject observes a public signal equal to 10 (0), he/she can infer that the asset dividend at the end of the trading period will be 10 (0) with probability  $P$  and 0 (10) with probability  $Q = 1 - P$ . Both, the value of  $p$  and  $P$  is common knowledge among subjects.

The different treatments implemented as well as the parameters used and the number of sessions conducted are displayed in table 1:

Treatment	$p$	$P$	# of sessions
1	0.6	0.5	2
2	0.8	0.5	1
3	0.6	0.8	2
4	0.8	0.8	2
5	0.8	0.7	2

Table 1: The experimental design and parameters.

Treatments 1 and 2 constitute our baseline treatments, where traders have access to an unbiased public signal on the dividend value, to evaluate the impact of the release of a public signal of higher precision when compared to Treatments 3 and 4, where the quality of the public signal is at least as good as a single private signal. However, one should consider that each individual trader can buy several private signals in a way that his/her aggregate private information might be more accurate than the single public signal, since all private signals are independent realizations of a given distribution. We use Treatment 5 to evaluate a situation where a single private signal as a higher precision than the public signal. Taking into account the literature on the release of public information and its effects on market performance, the relative precision of public information plays a crucial role on the traders's over-

weighting of public information. Several authors, in fact, consider the precision of public information as a control variable when designing the optimal central bank disclosure policy. Although, the relative precision of public information in our setting is not emerging out of a micro-funded strategy of the public authority, the comparison of Treatments 3, 4 and 5 can shed some light on whether the relative precision of public information can enhance or mitigate the crowding out effect on private information and traders' overweighting of public information. In order to be closer to the existing theoretical and experimental literature we consider the cost of being privately informed constant and independent of the precision of the private signals.

The experiment is programmed using the Z-Tree software (Fischbacher (2007)). When the subjects arrive to the laboratory the instructions are distributed and explained aloud using a Power Point presentation. This was followed by one practice auction period for subjects to get familiar with the software and the trading mechanism.

Each subject can only participate in one session. Each session consists of 10 independent trading periods (markets) lasting 3 minutes each. The asset market is implemented as a double auction. During each trading period subjects are free to introduce their bids and asks for assets or directly accept any other trader's outstanding bid or ask. Every bid, ask, or transaction concerns only one unit of the asset, but every subject can handle so much as desired as long as she/he has enough cash or assets (no short sale is allowed). Parallel to the asset market, we implement an information market where subjects can purchase at a given price (perfectly elastic supply) as many private signals as he/she wants during a given trading period, as long as he/she has enough cash.

After each trading period, dividends are paid out and the subject profit is computed as the difference between their initial money endowment and the money held at the end of the trading period. Essentially the net profit consist of the gains or losses generated by the trading activity, the dividend and the private information cost. Each subject's final payoff is computed as the accumulated profit in the 10

trading periods, and paid cash at the end of the session.<sup>10</sup>

## 3 Theoretical Background

### 3.1 Do Nothing Equilibrium

Following Hey and Morone (2004), we can identify a unique equilibrium in which no agent does anything. If all agents are risk neutral or share the same beliefs and risk aversion, we should not observe any transaction in the asset market and no purchase of private signals in the information market. The basic reasoning underlying the “do nothing” equilibrium lies in the zero-sum-game nature of our experimental setting. It means essentially that the a subject would have incentives to purchase private information just in case he/she expects to recover the cost with profits made at expense of the other traders. Knowing that, the other traders would not trade and therefore, the incentives of our first trader to buy private information disappears. As a consequence, no activity in the information and asset market is expected. The original results by Hey and Morone (2004) is generalized by Ferri and Morone (2014) for a market where traders’ have access to (biased) public and private information.

As we will see in the results’ section, this theoretical equilibrium is never realized, since we observe a sustained level activity in the information and asset markets. This equilibrium turns out not to be empirically relevant, leaving us with the need to consider other possible benchmarks to shed some light on the market dynamics observed in our experiments.

### 3.2 Crowding Out of Private Information

In our experimental setting we implement an information market that supplies private information to the traders at a given price. Colombo et al. (2014)<sup>11</sup> demonstrate

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<sup>10</sup>One experimental currency unit is equivalent to 2 cents of €. The average payoff is about 20 € and each session last around 90 minutes. Note that subjects can make losses. To avoid some of the problems associated with subjects making real losses in experiments, we endow all subjects with a participation fee of 5 €, which can be used to offset losses. No subject earn a negative final payoff in any session.

<sup>11</sup>See Corollary 1 in Colombo et al. (2014)

theoretically the crowding out effect that public information provokes on the equilibrium acquisition of private information.

The intuition behind this result is simple: An increase in the precision of public information will help the investors to better forecast the fundamentals, as well as the other investors' expectations. In this case the value of a private signal for the subjects is lower, while the cost is constant. We expect then a reduction in the acquisition of private information in the information market, that is, we should observe a crowding out effect on private information demand when a public signal is introduced in the market.

### 3.3 Fully Revealing Benchmark

Taken for granted the traders' behavior in the information market, we introduce the fully revealing benchmark, that is, the expected price conditional on all information present in the market. Note that, whereas the "do nothing" prediction is an equilibrium in a strict economic sense, the "fully revealing" is not. Grossman and Stiglitz (1980) show the non-existence of a fully revealing equilibrium with access to costly information. We are aware that if the information is instantaneously incorporated into the market price, traders' have no incentive to buy private information. Grossman and Stiglitz (1980) and the literature related to the noisy rational expectations equilibrium introduce an exogenous noise to overcome this problem and provide incentives for costly information acquisition. On the other hand, Sunder (1992) suggests that the asset trading mechanism creates enough endogenous noise to prevent an instantaneous revelation of information. Taking into account that we use a double auction as trading mechanism in the asset market and that traders' have access to imperfect information, we can guess that if a trader purchases information he/she is able to recover the cost from the trading activity in the market.

Using the Bayesian inference, we compute the probability that the dividend is equal to 10 ECU conditioned on the series of signals purchased by all subjects up to time  $t$ , which we denote as  $I_t = \{i_1, i_2, \dots, i_j, \dots, i_t\}$ . We refer to  $I_t$  as the market information set, which does not take into account the sequential order of signal acquisition. The variable  $i_j$  takes the value  $-1$ , when the signal suggests that the

dividend is worth 0 ECU, or 1, if it suggests that the dividend is worth 10 ECU. Additionally, we introduce the variable  $S$  which takes the value 1 ( $-1$ ) if the public signal suggests a dividend equal to 10 (0) ECU, while it takes the value 0 when we refer to the treatments with unbiased public signal.

We denote as  $Pr(D = 10|I_t, S)$  the probability of observing the dividend equal to 10 conditioned on the information set available at time  $t$ :<sup>12</sup>

$$Pr(D = 10|I_t, S) = \frac{Pr(I_t|D = 10) \cdot Pr(D = 10|S)}{Pr(I_t, S)}. \quad (1)$$

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

$$Pr(I_t, S) = Pr(I_t|D = 10) \cdot Pr(D = 10|S) + Pr(I_t|D = 0) \cdot Pr(D = 0|S). \quad (2)$$

where  $Pr(D = 10|S)$  is the prior probability of the event  $D = 10$  given the public signal  $S$ , analogously for  $D = 0$ . The values of this conditional probabilities are defined later on.

Let us now compute the expression for the different terms of eq. (1) as a function of:

- $p$ , the probability that a single private signal is correct, with  $q = 1 - p$ ;
- $P$ , the probability that the public signal is correct, with  $Q = 1 - P$ . Note that this parameter represents the common prior of the dividend value, taking the value  $1/2$  when the public information is unbiased.

In this sense, Treatments 1 and 2 can be considered as a case where the public information does not biased the traders towards any of the two states, whereas in all the other treatments the public signal biases the uniform prior towards one of the states depending on the realized value.

- $N_t$ , the number of signals in the information set available up to time  $t$ ;
- $n_t$  is the number of 1s and  $N_t - n_t$  is the number of -1s in the information set.

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<sup>12</sup>*Mutatis mutandis*, the probability that the dividend is worth 0 ECU is  $Pr(D = 0|I_t, S) = 1 - Pr(D = 10|I_t, S)$ , since we have just two possible states of the world.

In the following, when not necessary, we will omit the time variable  $t$  from the variables  $n_t$  and  $N_t$ . Depending on the value of  $S$ , the numerator of eq. (1) is given by:

$$\begin{aligned}
Pr(I_t|D = 10) \cdot Pr(D = 10|S = 1) &= p^n \cdot q^{N-n} \cdot P, \\
Pr(I_t|D = 10) \cdot Pr(D = 10|S = -1) &= p^n \cdot q^{N-n} \cdot Q, \\
Pr(I_t|D = 10) \cdot Pr(D = 10|S = 0) &= p^n \cdot q^{N-n} \cdot \frac{1}{2}.
\end{aligned} \tag{3}$$

The marginal probability in eq. (2) takes then form:

$$\begin{aligned}
Pr(I_t, S = 1) &= P \cdot p^n \cdot q^{N-n} + Q \cdot p^{N-n} \cdot q^n, \\
Pr(I_t, S = -1) &= Q \cdot p^n \cdot q^{N-n} + P \cdot p^{N-n} \cdot q^n, \\
Pr(I_t, S = 0) &= \frac{1}{2}p^n \cdot q^{N-n} + \frac{1}{2}p^{N-n} \cdot q^n.
\end{aligned} \tag{4}$$

Combining eqs. (1), (2), (3) and (4), and defining  $\eta_t = \sum_{j=1}^t i_t = 2n_t - N_t$  as the aggregate net private signal available at time  $t$ , we obtain the probability that the dividend is equal to 10 as a function of the information set present in the market at time  $t$ :

$$Pr(D = 10|I_t, S) = \left[ 1 + \left( \frac{Q}{P} \right)^S \left( \frac{q}{p} \right)^{\eta_t} \right]^{-1}. \tag{5}$$

Using the eq. (5) the fully revealing benchmark for the price under risk neutrality assumption, is given by:

$$FR_t = 10 \cdot Pr(D = 10|I_t, S) + 0 \cdot Pr(D = 0|I_t, S) = 10 \left[ 1 + \left( \frac{Q}{P} \right)^S \left( \frac{q}{p} \right)^{\eta_t} \right]^{-1}. \tag{6}$$

### 3.4 Public Information Benchmark

Morris and Shin (2002) and Allen et al. (2006) show that if higher order expectations play a role in pricing an asset, public information will be overweighted with respect to its precision. Morris and Shin (2002) model the overreliance phenomenon within the framework of a beauty contest game. In such a game, players make a double account

for the public information, considering its informational content as well as its role in second guessing the expectations of other players. Although similar in spirit but within a different theoretical framework, the paper of Allen et al. (2006) develops an intertemporal asset pricing model with heterogeneous expectations where higher order beliefs enter into the aggregate market demand function, without an explicit coordination motive. The fact that public information enters in all traders' demand function makes the public information a good predictor for aggregate demand. These two papers teach us that a public signal might constitute a good approximation for the aggregate behavior of prices.

Our experimental setting exhibits the key elements suggested by the theoretical literature in order to observe traders' overreliance on public information. (i) The access to private and public information. (ii) Heterogeneous expectations due to the endogenous acquisition of noisy private information. (iii) Key role of higher order expectations in traders' demand. Since we do not provide subjects with any explicit coordination motive as in Morris and Shin (2002) and the experimental studies based on their model<sup>13</sup>, let us clarify how our financial market framework gives the incentive to forecast other traders' expectations, providing in this way a role for higher order beliefs in driving price dynamics.

If a trader purchases private information that tells him with a high probability that the asset dividend will be 10, he will be willing to buy assets at any price equal or lower than his expected dividend. He will expect to have higher gains from trade the lower the asset purchasing price. If this trader thinks that in the market there are non privately informed traders, he has an incentive to bid at a price around what he expects it would be the expectation of the non privately informed traders, that is, the public information. If non privately informed traders consider the existence of incorrectly informed traders, they could be willing to buy and sell around their expected dividend, determined solely by the public signal. If the proportion of non privately informed traders willing to trade is high enough, market prices will fluctuate around the expected dividend based just on the public signal. In this case, the public information will a better predictor for the market price compared to the

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<sup>13</sup>See Cornand and Heinemann (2014) and Baeriswyl and Cornand (2014), among others.



fully revealing benchmark, given that prices do not reflect the traders' private information, but the expectations of the other traders' expectations that, according to Morris and Shin (2002) are biased towards public information. This is essentially the possible mechanism behind the overweighing of public information in our experiment.

Finally, let us define the public information benchmark as the expected price conditional just on the value of the public signal:

$$PB = 10 \cdot Pr(D = 10|I_0, S) + 0 \cdot Pr(D = 0|I_0, S) = 10 \left[ 1 + \left( \frac{Q}{P} \right)^S \right]^{-1}. \quad (7)$$

## 4 Results

Figures from 6 through 13, included in the Appendix, display the trading activity in all markets for all treatments. Each panel of these figures refers to one particular market. A simple inspection of the market activity shows that the “do nothing” equilibrium is not a meaningful description of the trading behavior of the subjects in any of the implemented treatments, since subjects purchase private information as well as post bids and asks in the market.

In the following we will present our results focusing on two main aspects: the information demand and the price dynamics in the asset market. In particular, we are interested in describing how the access to public information impacts the information market as well as the asset market price.

### 4.1 Analysis of Information Market

A crucial aspect of our experimental design is that the quantity of information available in the market (the market informativeness) is endogenous, since subjects can buy as many signals as they want at a fixed price.

We analyze whether or under which conditions the information available to the traders in the market is sufficient to discover the true dividend value.

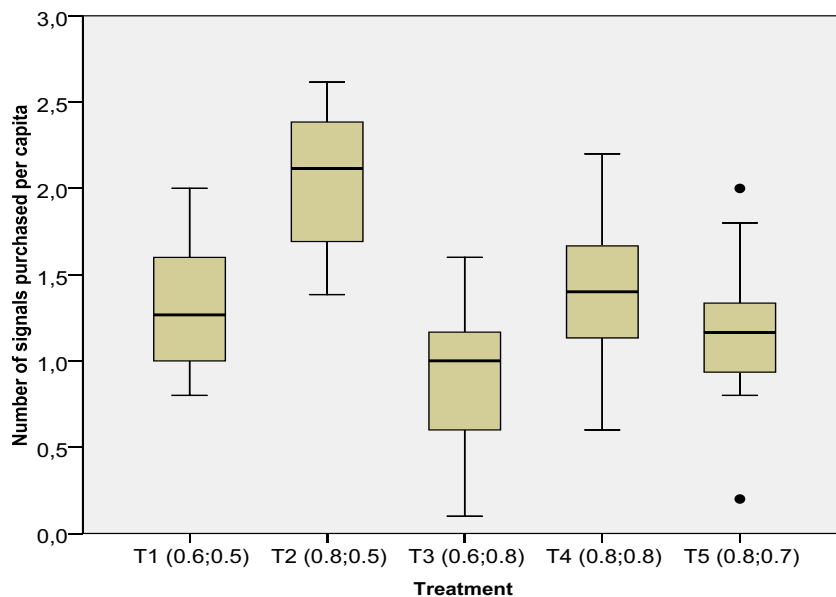


Figure 1: Number of private signals purchased per capita.

#### 4.1.1 Information demand

As a first step, we analyze the demand for private information as a function of its quality. Figure 1 shows the distribution of the private signals purchased per capita across markets per treatment showing that an increase in the quality of the private signal increases the traders' demand for private information and, as a consequence, traders possess not only more accurate information but also more information. Indeed, the number of purchased signals is *significantly* higher in Treatment 2 ( $p = 0.8$ ) as compared to Treatment 1 ( $p = 0.6$ ).<sup>14</sup> This picture does not change with the introduction of a public signal, since the same pattern is confirmed, as shown in Figure 1, when comparing Treatments 3 ( $P = 0.8, p = 0.6$ ) and 4 ( $P = 0.8, p = 0.8$ ).<sup>15</sup> Treatment T5 confirms the positive relationship between the quality of private information and the individual demand. We conclude then that the demand for private signals increases with their quality, independently of the presence of public information. This finding confirms the results of Hey and Morone (2004) and generalizes them in a setting with public information.

Fixing the quality of the private signal, we observe that the introduction of a

<sup>14</sup>A Mann-Whitney test rejects the null hypothesis of equal mean at a 1% significance level.

<sup>15</sup>A Mann-Whitney test rejects the null hypothesis at a 1% significance level.

public signal *significantly* reduces the demand for private information<sup>16</sup>, see Figure 1. This phenomenon is observed for both, low and high quality private information. In our experiment the release of public information provokes a *crowding-out* effect on the demand for private information, i.e. a substitution of part of market information provided by several private signals with a single public signal. To our knowledge this is the first time that such *crowding-out* effect is observed.

When evaluating the effect of introducing public information into a financial market it is not only important to evaluate the impact on the aggregate demand for private information, but it is extremely important to determine the impact on the proportion of uninformed traders participating in the market. Bloomfield et al. (2009) use economic experiments to show that uninformed traders provide liquidity to the market, increasing market volume, as well as reduce the market informational efficiency.<sup>17</sup> In order to account for such impact, we define the information market participation rate as the number of traders purchasing at least one signal over the total number of traders in the asset market. The crowding-out effect is the sum of two effects: (i) a reduction in the information market participation rate, and (ii) a reduction in the per capita demand of the information market participants. In order to disentangle the two possible adjustments, Figure 2 presents the distribution of the information market participation rate across markets for each one of the implemented treatments. It clearly illustrates that the release of public information essentially does not affect the information market participation rate, but significantly reduces the per capita information demand of information market participants.

We can summarize our findings as follows:

**Result 1:** *The release of public information creates a crowding-out effect on the aggregate information market demand: whereas it leaves unaffected information market participation rate, it significantly reduces the individual demand for private*

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<sup>16</sup>A Mann-Whitney test rejects the null hypothesis of equal mean at a 1% significance level.

<sup>17</sup>In their experimental setting the information is exogenously distributed among the market participants.

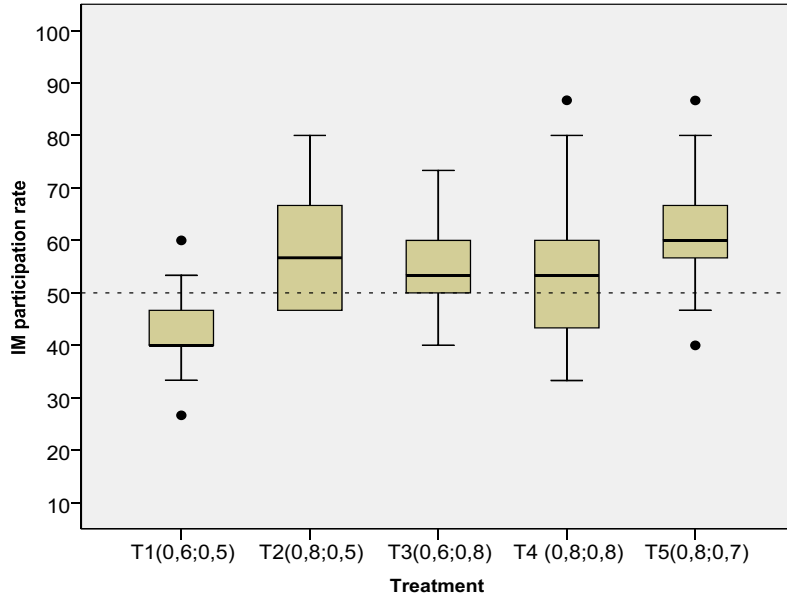


Figure 2: Information market participation rate per treatment.

*information of the informed traders.*

#### 4.1.2 The Market Informativeness

It remains an open question whether the presence of a public signal compensates for the reduction in the demand for private information due to the crowding-out effect. In other words, is the introduction of a public information neutral, beneficial or detrimental for the overall market informativeness?

In order to address this question let us quantify how close the traders are to discover the true value of the dividend. We rely then on the fully revealing benchmark ( $FR_t$ ) computed in eq. (6).<sup>18</sup> Let us introduce the following measure of market informativeness:<sup>19</sup>

<sup>18</sup>The efficient market hypothesis is based on the idea that the traders make an optimal use of all the available information. This might probably be a strong (behavioral) assumption. However, such an assumption allows us not to consider any *ad hoc* behavioral rules in describing the trading activity of the subjects. Moreover, the efficient market benchmark can be thought as the upper bound of the efficiency in the utilization of the market information.

<sup>19</sup>The choice of averaging over the last trading minute is a compromise between having good statistics for  $E_{FRD}$  and analyzing the last part of the trading activity, where the number of purchased private signals is very low (between zero and few signals depending on the market) and 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.

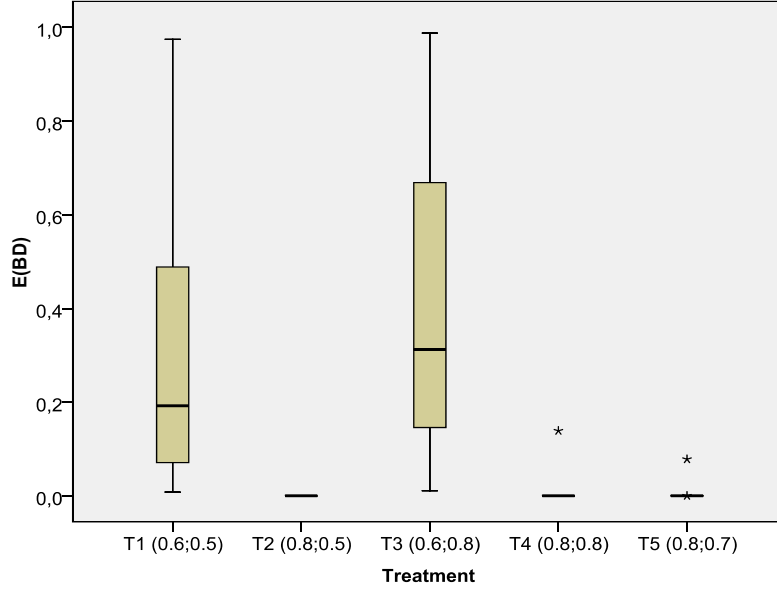


Figure 3: Market informativeness per treatment.

$$E_{FRD} = \frac{1}{60} \sum_{t=120}^{180} \frac{|FR_t - D|}{10}, \quad (8)$$

Using eq. (8) we can evaluate whether the introduction of a public signal is beneficial or detrimental for the overall market informativeness.

Figure 3 shows the distribution of  $E_{FRD}$  across the different markets per treatment. A Kolmogorov-Smirnov test cannot reject the null hypothesis that the distribution of  $E_{FRD}$  is not affected by the release of a public signal, i.e. comparing T1 (T2) to T3 (T4 and T5). This means that the introduction of a public signal does not alter the market potential to discover the true dividend value. The presence of public signal entirely compensates for the crowding-out effect, i.e. the additional information provided by the public signal is sufficient to counterbalance the reduction in the number of private signals present in the market, within the fully revealing benchmark.

**Result 2:** *The information conveyed by the public signal compensates for the crowding-out effect on the private information: the release of public information does not affect market informativeness.*

With results 1 and 2 we conclude that in our experiment public and private information result to be *perfect substitutes*, since the reduction in the demand for private signals is fully compensated by the public information, keeping the market informativeness constant. The perfect substitutability property might be just limited to our experiment. In fact, we cannot apply our result to a more general framework. The theoretical literature<sup>20</sup> explains which might be the determinants of the partial substitution of private with public information. The implication of our findings could be relevant for policy makers. The release of public information might not increase the overall market informativeness, since the intervention of the public institutions reduces traders' effort to gather private information. Therefore, when introducing a new public information source in a market one should consider its complex interaction with the information already present.

## 4.2 Analysis of the Asset Market Price Efficiency

Result 2 shows that the public signal compensates for the crowding-out effect on the private signal, leaving invariant market informativeness. As a first evaluation of the market performance we measure the difference between *what the traders have done* and *what they could have done*. We introduce, then, the distance between the market price  $PR_t$  and the dividend value  $D$ :

$$E_{PRD} = \frac{1}{60} \sum_{t=120}^{180} \frac{|PR_t - D|}{10} \quad (9)$$

This measure is essentially an *ex-post* evaluation of market price convergence to the true dividend value according to the information present in the market. Figure 4 shows the distribution of this measure across markets for all implemented treatments. From figure 3 we expect in treatments T2, T4 and T5 to observe prices close to the true dividend value, given that the information present in the market,

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<sup>20</sup>See Colombo et al. (2014).

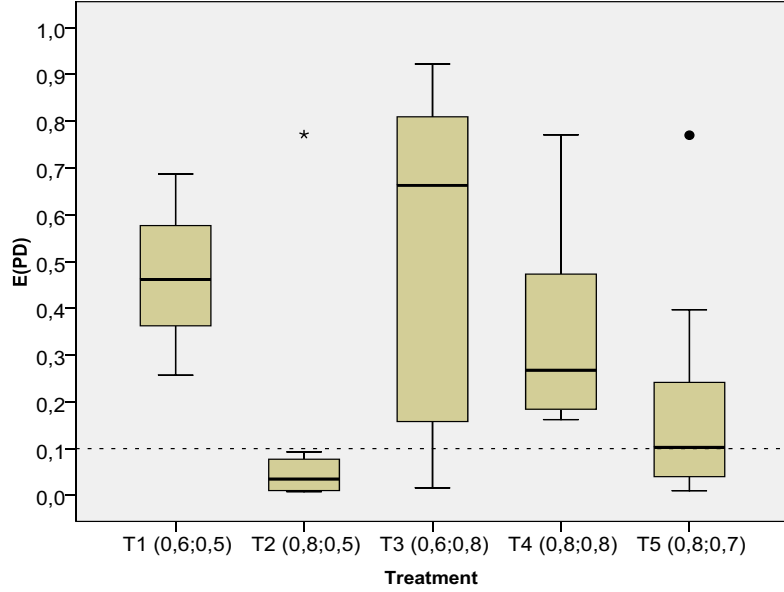


Figure 4: Distribution of  $E_{PRD}$  across markets per treatment.

if correctly aggregated into the price, is enough to discover the true dividend value. Instead, we observe that prices do not behave as expected, since their distance from the true dividend value varies across treatments and significantly worsens when the accuracy of the public signal increases.<sup>21</sup> Concerning treatments T1 and T3 we observe that prices do not converge to the true dividend value, as expected given the information present in the market. Interestingly, the data show the same systematic pattern when the accuracy of public signal is higher, that is, a significant worsening in the  $E_{PRD}$  measure.<sup>22</sup>

**Result 3:** *The presence of public information distorts the price performance the higher the precision of the public signal.*

If market informativeness remains constant, independently of the a public signal precision, why price efficiency worsens? How does the presence of public information impact the aggregation of all the available information into prices?

<sup>21</sup>If we consider the distribution of  $E_{PRD}$  in T2 as an acceptable level of convergence to the dividend, given that in treatments T4 and T5 we observe the same informativeness, we should observe a similar value for the difference between prices and dividend in T4 and T5, since also in these treatments the information present in the market is enough to discover the true dividend value.

<sup>22</sup>A Mann-Whitney test rejects the null hypothesis at a 1% significance level.

### 4.2.1 Overweighting of public information

To answer to these questions we will show that the worsening of price efficiency is due to the overweighting of public information. In order to demonstrate such effect, we compare how the two benchmarks introduced in section 3 can account for the market price dynamics: the fully revealing benchmark and the public information benchmark.

As a measure of the goodness of the fully revealing benchmark ( $FR_t$  from eq. (6)) in describing the market price we define:

$$E_{FRPR} = \frac{1}{60} \sum_{t=120}^{180} \frac{|FR_t - PR_t|}{10}, \quad (10)$$

Analogously to the previous definition, we introduce a measure of how close market prices are to the public information benchmark ( $PB$  from eq. (3.4)) as:

$$E_{PBPR} = \frac{1}{60} \sum_{t=120}^{180} \frac{|PB - PR_t|}{10}. \quad (11)$$

Note that the two benchmarks take into account the presence of public information. The main difference is that, while in the fully revealing benchmark private and public information are weighted according to their respective accuracy, the public information benchmark considers only the public signal. In other words, it assigns a weight zero to the private information. This means that the public information benchmark represents quite an extreme case in the weighting of public and private information. Therefore, if it is better in describing the market price, we are in the safe side by inferring the existence of overweighting of public information.

Figure 5 shows the distribution of  $E_{FRPR}$  and  $E_{PBPR}$  across markets for all implemented treatments.

Under the hypothesis that traders overweight the public signal according the mechanism proposed in section 3.4, we expect the value for  $E_{PBPR}$  to be systematically and significantly lower than the value for  $E_{FRPR}$ . Our hypothesis is confirmed



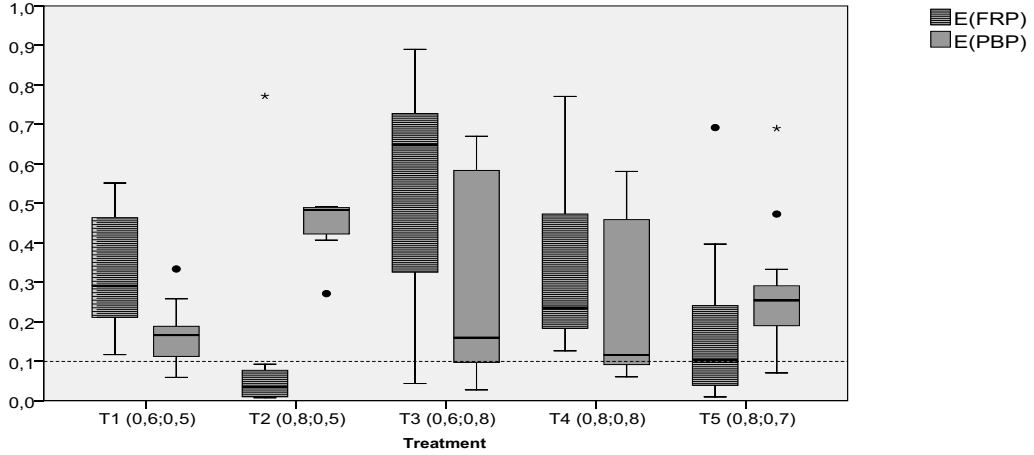


Figure 5: Fully revealing and public information benchmarks across treatments.

when traders have access to low quality private information. That is, in treatments T1 and T3 the public benchmark is always significantly better<sup>23</sup> in describing market prices, independently of the precision of the public information. A more complex situation emerges when traders have access to more precise private information in treatments T2, T4 and T5. In this case the higher the precision of the public signal, the higher is the weight traders' put on public signal when pricing the asset. Moving from T2 to T5, and then to T4, we observe that the descriptive power of the fully revealing benchmark reduces and, at the same time, it increases the price convergence to the public information benchmark, up a point where there is a significant overweighting<sup>24</sup> of public information in treatment T4, where private and public information have the same accuracy.

**Result 4:** *Traders overweight public information if they have access to low quality private information. If the private information is of high precision overweighting is limited to the case of the release of a high quality public signal.*

<sup>23</sup>A Mann-Whitney test rejects the null hypothesis at a 1% significance level.

<sup>24</sup>A Mann-Whitney test rejects the null hypothesis at a 1% significance level.

This result confirms the intuition of Morris and Shin in defining public information as a double edged instrument. On the one hand it helps the market in aggregating information and driving market prices towards the correct fundamentals, when correct. On the other hand, the public signal acts as a coordination device for the traders' expectations and, when incorrect, might drive the market towards the wrong state of the world, even when the market informativeness is sufficient to discover it as occurred in many markets in treatment T4.

At the aggregate level, subjects in our experimental markets overweight public information with respect to private information as in the game theoretical framework proposed by Morris and Shin. Since we do not explicitly introduce a beauty contest, in some sense, our experimental setting generalizes their main conclusion, showing that can be also applied in a market setting. It would be interesting then to investigate which are the minimal conditions for the emergence of such complex interplay between private and public information in financial markets. We leave this as an issue for our future research agenda.

## 5 Conclusion

The efficient market hypothesis states that all relevant and available information is correctly incorporated into prices. However, the efficient market hypothesis considers only the incorporation of information into prices, leaving out the way this information is generated and/or its origin. Taking stock of this idea, the main objective of the paper is the analysis of the aggregation of information in financial markets as a function of the access of the traders to different sources of information, namely costless public and costly private information.

The objective of regulatory institutions when releasing public information is essentially to discipline the market, reducing the potential negative effects of asymmetric information. Recently, Morris and Shin (2002) have pointed out the double-edged role of public information in both, conveying information on the fundamentals of a financial asset and coordinating traders' expectations in the market. Therefore, in

the presence of a noisy public signal, the noisiness of public information might be enhanced in the market due to the overreliance of the traders on the disclosure of a public signal. The presence of a public signal, therefore, might have a distortive effect on the market price formation.

Following this line of reasoning and inspired by the debate on the role of rating agencies in the recent financial crisis, we study how the release of a noisy public signal affects the efficiency of prices in aggregating information in a laboratory financial market. In our experimental setting we implement an asset market where traders can exchange a risky asset and an information market that provides noisy and costly private signals on the future value of the asset. What we observe is that the introduction of a public signal in the market reduces the traders' information demand because of a crowding out of the public information on the private information. It is the first time that this crowding out effect is observed and measured, thanks also to the peculiarities of the experimental method in precisely control for the information available to each trader at each moment during their trading activity.

Despite the reduction in the private information (the crowding out effect), we observe an essentially unchanged level of informativeness in the market. It means that the reduction of private information is compensated by the presence of a public signal. Surprisingly, even if market informativeness is not affected by the introduction of a public signal, there is a significant reduction in the efficiency of the market prices in incorporating the available information. We interpret our experimental results following the line of reasoning of Morris and Shin (2002). We observe, in fact, that the public signal becomes a focal point, i.e. it seems that the prices follow the prediction based on just the public signal, disregarding partially the private information. As a conclusion of our experiment, we observe that if the private information is of poor quality, the public information dominates the market in the sense of driving the price. If this market regime might be beneficial in the case of correct release of public information, the case of an incorrect public signal might lead the market towards a price disconnected from fundamentals.

Some policy implications can be derived out of our simple experiment. Policy makers should be aware that a release of public information might have a distortive

effect on the aggregation of information into prices. Far of being against the presence of public institutions in regulating financial markets, we stress the complex interaction between private and public information.

## **Acknowledgement**

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## A Appendix: Market Trading Activity per Treatment

On each panel the vertical axis shows the price at which the trade took place and the horizontal axis shows the time (in seconds) at which the trade took place. The solid line is the trading price, the bold solid line (either 10 or 0) above each market period shows the true dividend (revealed to the participants just at the end of the trading period). The less erratic line indicates the fully revealing benchmark. The squares indicate the public signal (either on 10 or 0), available to the subjects at the beginning of the trading period.



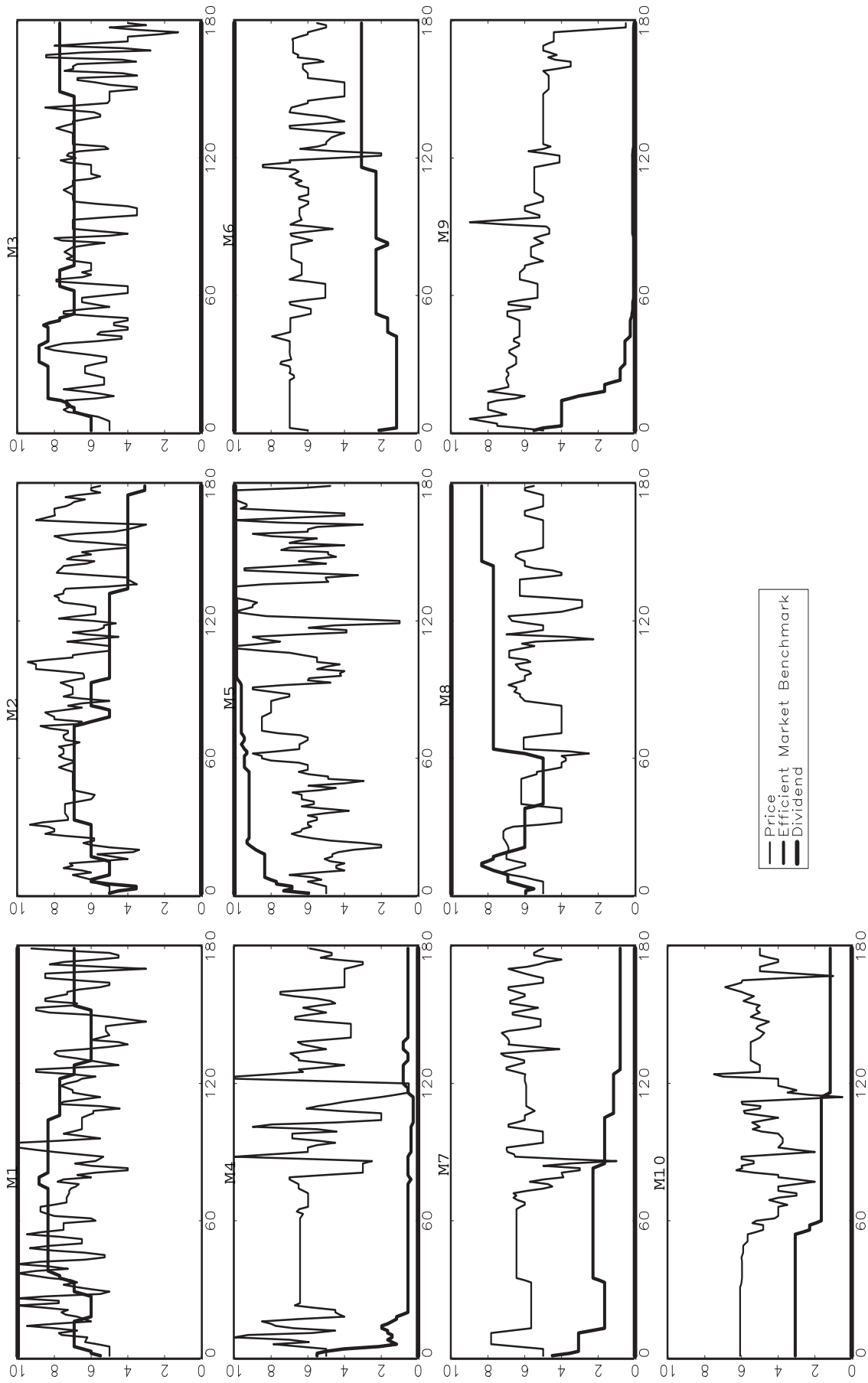


Figure 6: Markets Treatment 1 (Session 1: Private signal with  $p = 0.6$ ).

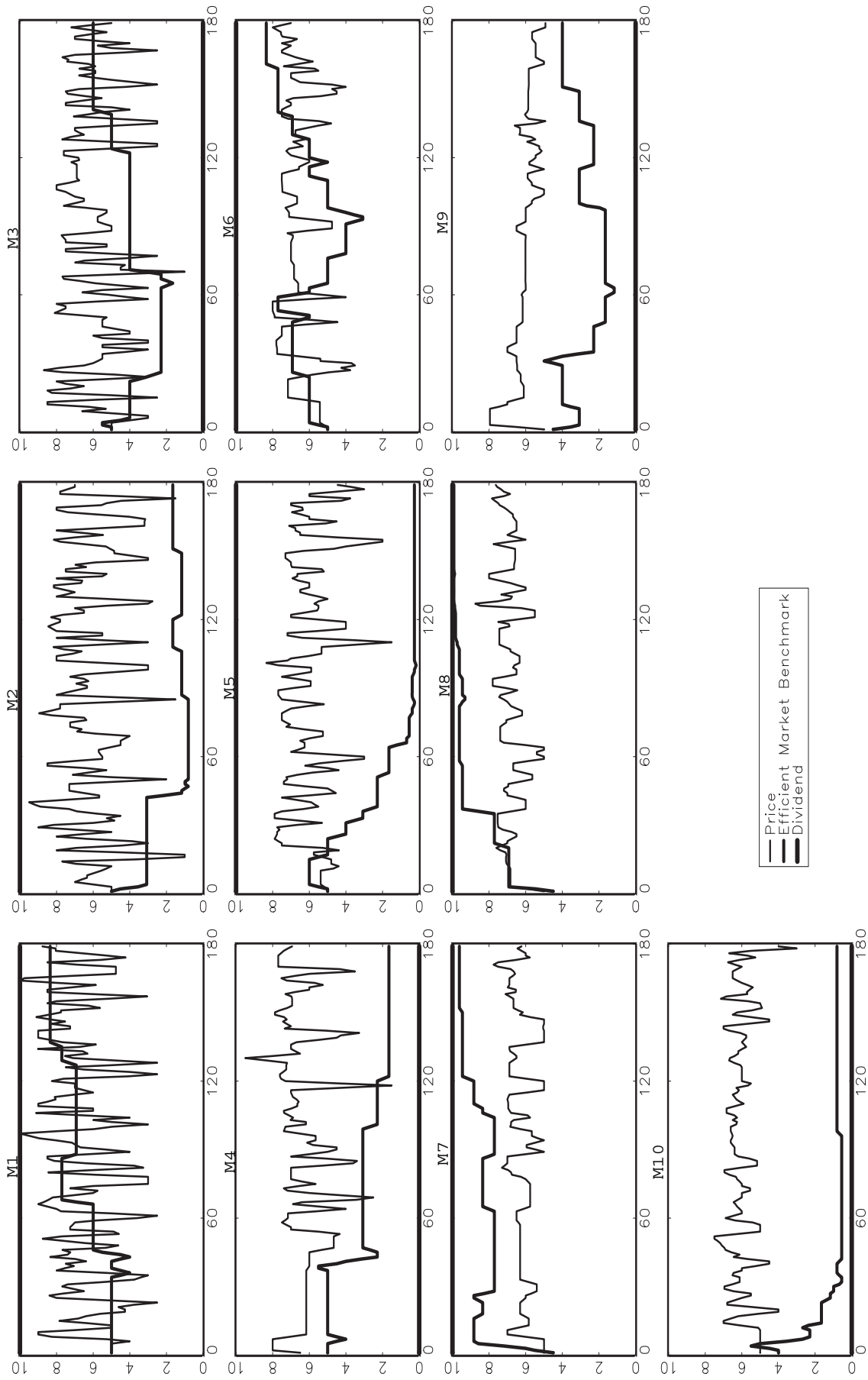


Figure 7: Markets Treatment 1 (Session 2): Private signal with  $p = 0.6$ .

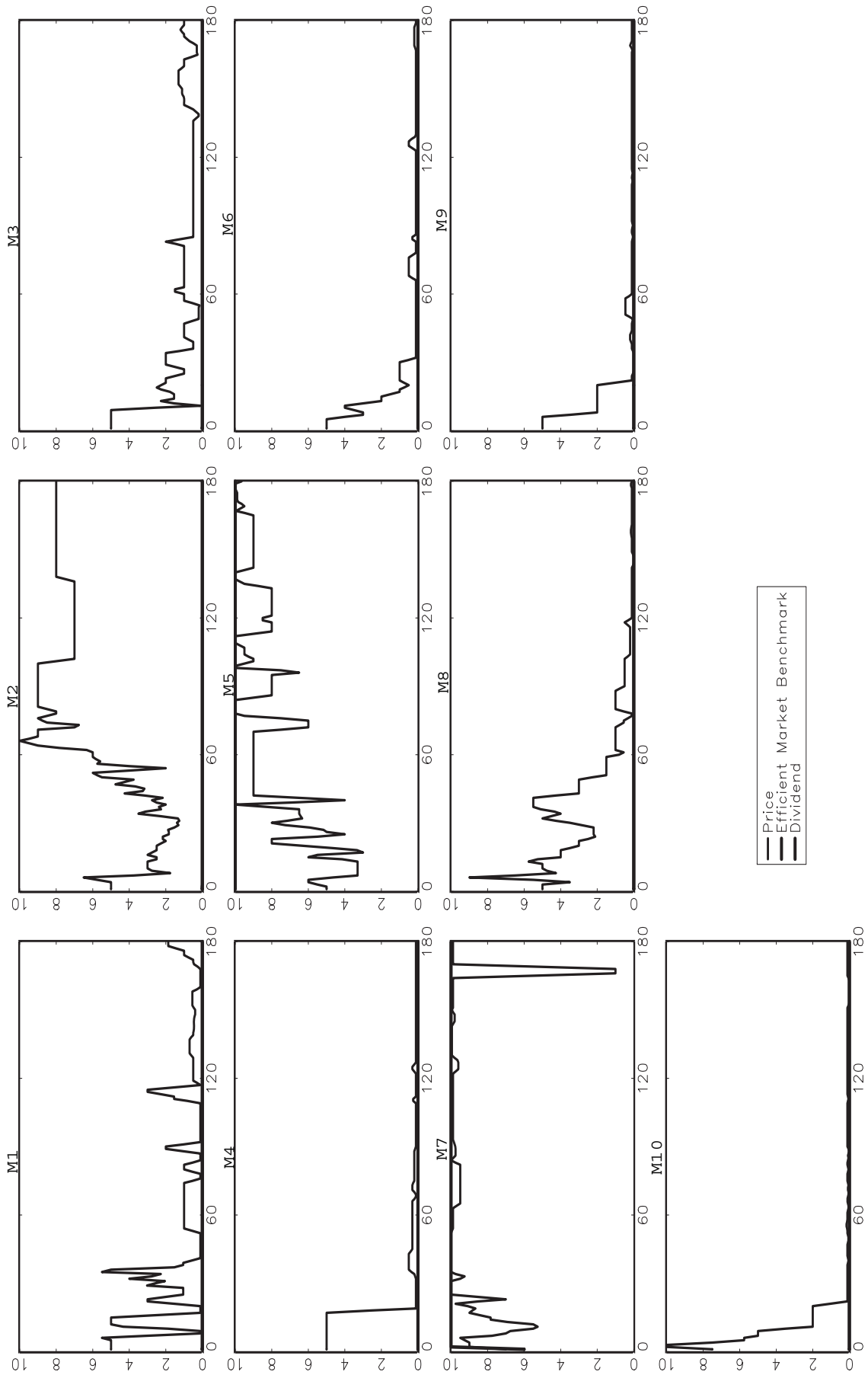


Figure 8: Markets Treatment 2: Private signal with  $p = 0.8$ .

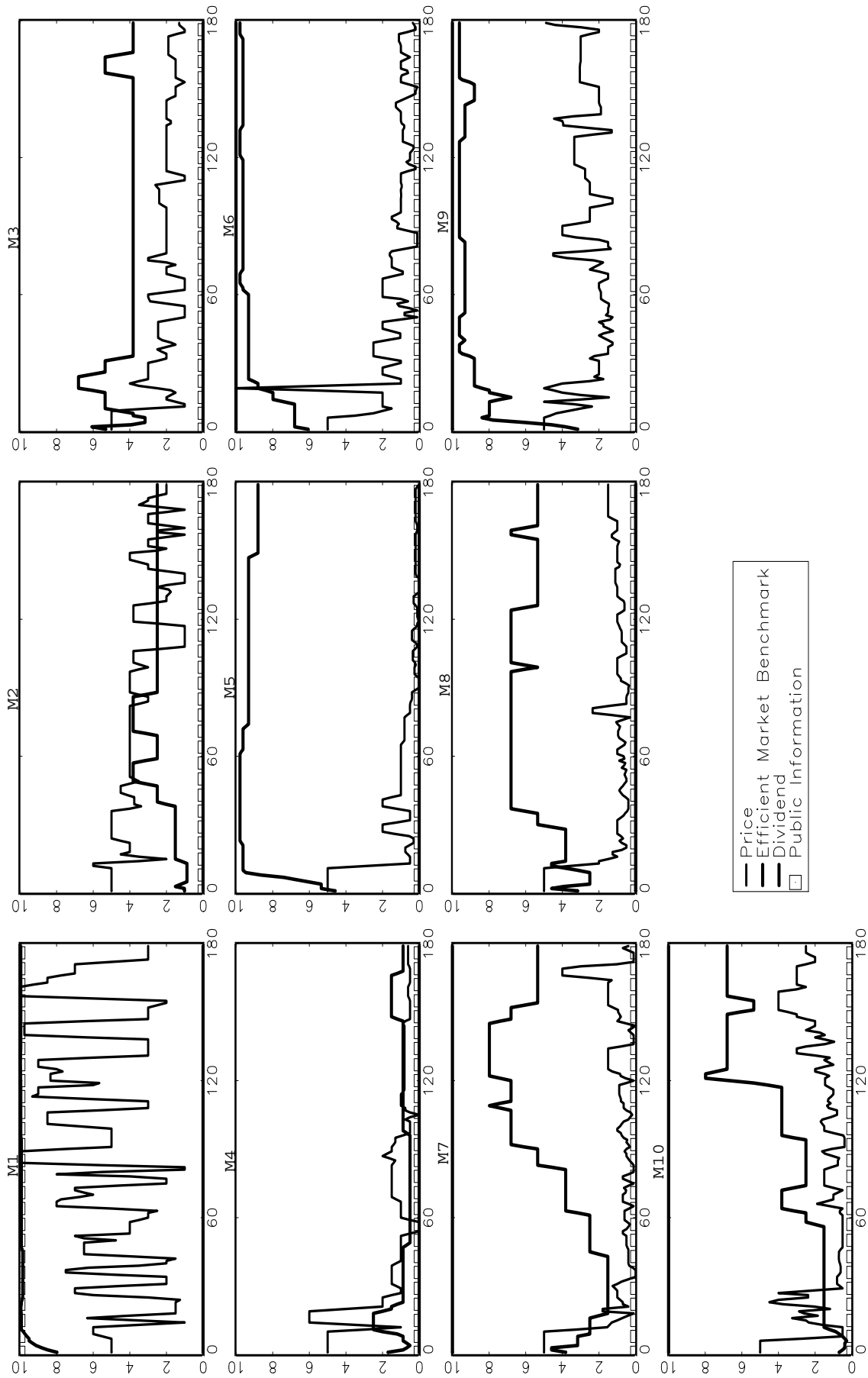


Figure 9: Markets Treatment 3 (Session 1): Private signal with  $p = 0.6$  and public signal with  $P = 0.8$ .

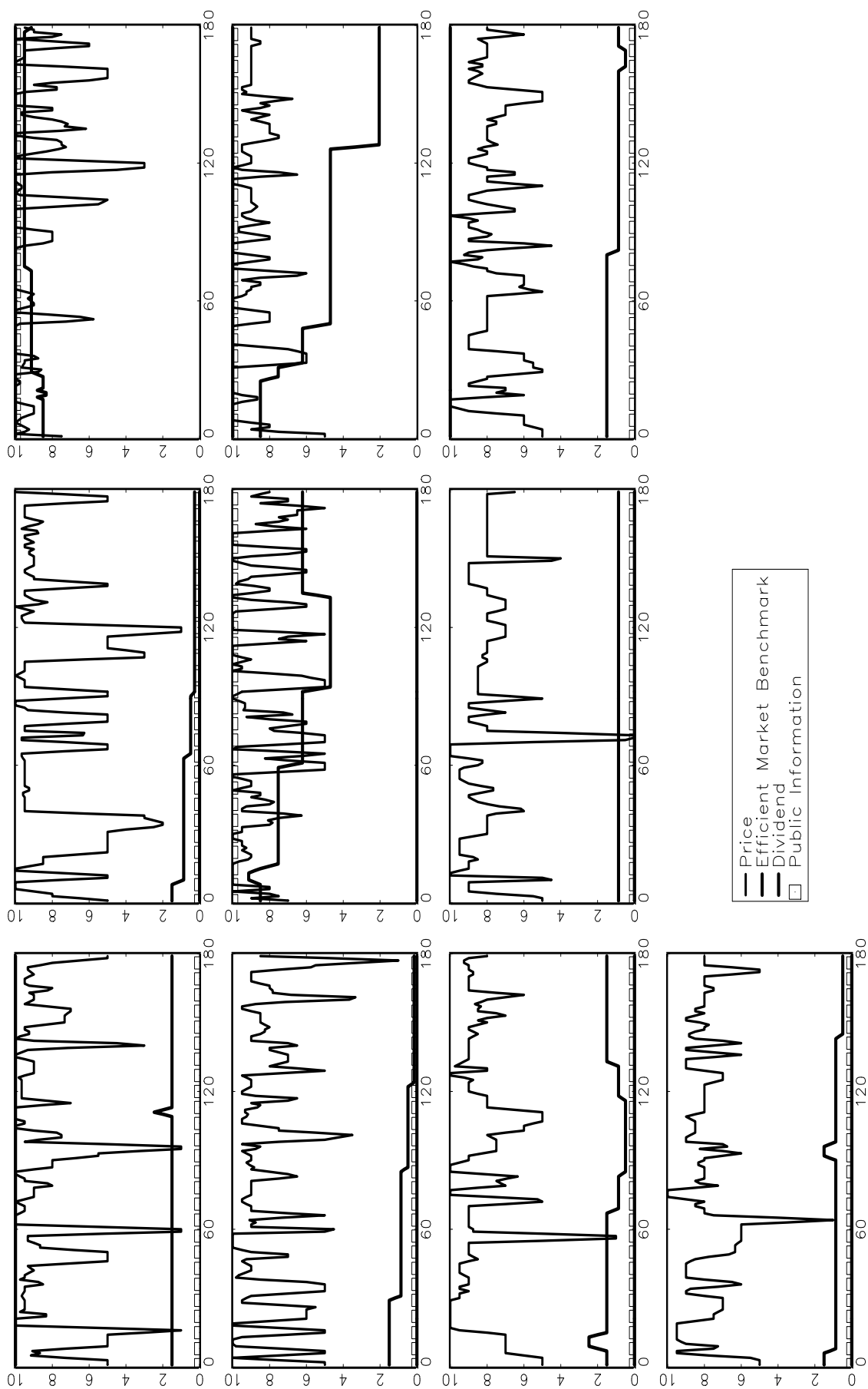


Figure 10: Markets Treatment 3 (Session 2): Private signal with  $p = 0.6$  and public signal with  $P = 0.8$ .

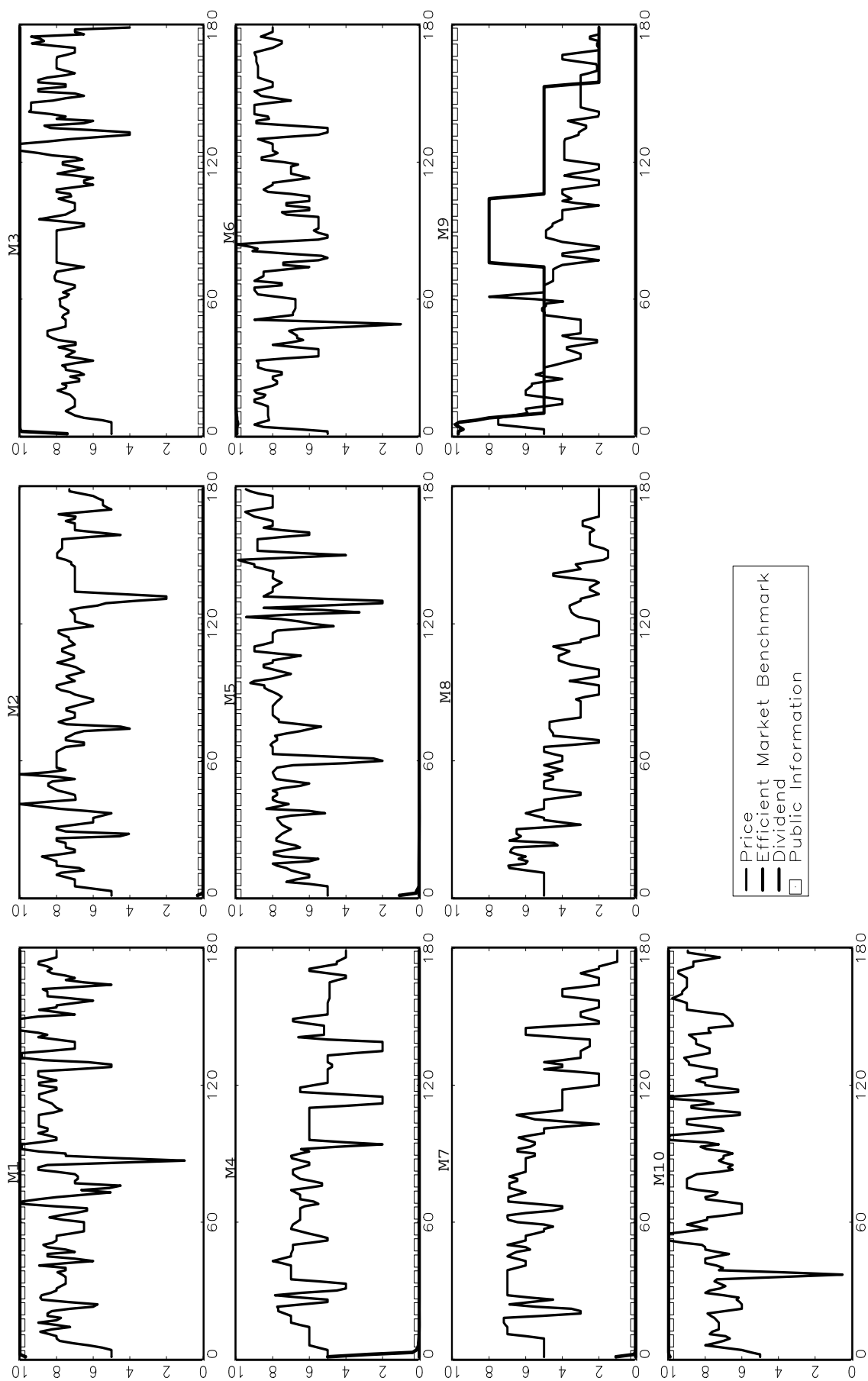


Figure 11: Markets Treatment 4 (Session 1): Private signal with  $p = 0.8$  and public signal with  $P = 0.8$ .



Figure 12: Markets Treatment 5 (Session 1): Private signal with  $p = 0.8$  and public signal with  $P = 0.7$ .



Figure 13: Markets Treatment 5 (Session 2): Private signal with  $p = 0.8$  and public signal with  $P = 0.7$ .