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Abstract

In this paper, we 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. Our results show that the release of public information provokes a crowding out effect on the traders' information demand while it keeps constant market informativeness, but significantly reduces price informativeness. Traders overrely on public information, which has a significant negative impact on the overall market performance. We detect the emergence of the overrelying phenomenon, despite the absence of an explicit incentive to the subjects to coordinate, demonstrating, therefore, that the adverse effects of releasing public information in a financial market are more relevant than generally assumed, based on the results of previous experiments inspired by simple coordination models. Our results pose new questions when a regulatory institution has to decide the appropriate level of transparency of its communication strategy.

Keywords: *Experiments, financial markets, private and public information, overrelying, crowding out.*

JEL Classification: *C92, D82, G14.*

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1 Introduction

The idea that the price system based on competitive markets is able to aggregate different pieces of information dispersed in the economy dates back to the 50's (Hayek, 1945). Economists have understood that prices, in properly designed asset markets, can aggregate and disseminate the collection of disperse information possessed by traders, although they not necessarily do it efficiently.

Instead of leaving the market operating alone in aggregating dispersed information, the release of public information might constitute an option that can facilitate the aggregation and dissemination process. In addition to the information hold privately by traders, one might assume the existence of a disciplining institution that releases public information with the target of enhancing market efficiency. Intuitively, one might think that public information should be beneficial for market performance, if it is assumed that it simply cumulates to the information already present in the market: in this sense, more information is valuable for decision makers. If this is true when an economic agent acts in isolation from others, it might not be the case when a certain strategic interaction among decision makers is introduced. The theoretical literature has shown that, in an economic system where agents have access to private information, noisy public information might be weighted above and beyond its accuracy, possibly driving the economic system far from fundamentals and, ultimately, damaging social welfare. Using a beauty contest coordination game, Morris and Shin (2002) demonstrate that public information might be considered a double edged-instrument: 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. As a consequence, the noisiness of public information can be amplified by the market due to the **overreliance** of the traders to public information. Quoting Morris and Shin (2002), this **overweighting** phenomenon can be characterized by the observation that "public and private information (might) end up being substitute rather than being cumulative".

Overreliance to public information has become a cause of concern to regulatory institutions. The 2008 financial crisis is a good example of such overreaction, if one takes into account the influence that the valuation of rating agencies had on the investors' decisions and their blind behavior in following what turned out to be a misleading advice. Beside overrelying on ratings, it might be possible that their presence has given to the traders fewer incentives to search for independent and alternative sources of information to evaluate innovative financial products. The information provided by the rating agencies might have reduced the information gathering activity of investors, **crowding out** valuable information at their disposal. In order to avoid such perverse effects of ratings, regulatory institutions have proposed new measures to incentivize market participants to improve their internal risk management capabilities in order to reduce overreliance on external credit ratings. In this line, the CRA III Regulation includes a set of measures with the objective of strengthen own credit assessment by relevant actors and reduce the sole reliance on credit ratings (European Commission, 2009). In the US market, the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 was approved by the US Congress to avoid the overreliance to credit ratings by investors and institutions (Chaffee, 2010).

The release of public information is not only related to the activity of credit rating agencies, but it includes also regulatory institutions as central banks, especially considering their forward guidance activity. In the recent years, central banks include and promote in their research agenda the study of how public communications and disclosure policies affect agents' behavior and incentives. In particular, they wonder how disclosure policies can be designed to maximize their impact on desired forms of behavior, such as accurate pricing of risk and proper formation of expectations of inflation (Bank of England, 2015). In this respect, Morris and Shin (2005) illustrate with great clarity how the central bank management of expectations might lead to adverse effects on informational efficiency of prices. They pointed out that the central bank, releasing public information, faces the risk of dominating the dynamics of prices if it ignores the complex interplay between the precision of the released information and the degree of traders' overreliance.

Despite their potential impact and implications, the adverse effects of releasing public information are essentially conjectures derived out of simplistic game theoretical models based on restrictive assumption on the information set and the behavior of players. The few existing experimental evidences are based on those models and, therefore, have limited external validity (for instance, Cornand and Heinemann, 2014; Baeriswyl and Cornand, 2016). Such experiments definitely show that the overweighting effect does exist, although it is milder than predicted by the theory, because of the bounded rationality of the subjects. It has been shown (Cornand and Heinemann, 2014), in fact, that in this kind of experiments the overweighting effect is maximum under fully rationality, significantly milder under bounded rationality. The lower-than-predicted overreaction of subjects to public information renders this effect a second order issue (Baeriswyl and Cornand, 2016).

The aim of our paper consists in testing experimentally whether the adverse effects of public information disclosure, namely crowding out of private information and overweighting of public information, are general phenomena to be observed beyond the coordination environment. Our experimental setting exhibits some features identified by the theoretical literature as responsible for the crowding out of private information and the traders' overreliance on public information. We implement (i) heterogeneous sources of information (private vs. public), (ii) endogenous private information acquisition. However, we do not introduce any explicit coordination incentive to the subjects. Despite the absence of such incentive, we demonstrate that those effects are experimentally measurable and empirically relevant. We show that such adverse effects have a strong negative impact on the market performance, although subjects are not fully rational. Contrary to the present literature, it seems that, in our setting, it is the bounded rationality of subjects one of the main features responsible for the emergence of those phenomena. This is an important result which challenges the current view, posing new theoretical as well as experimental questions to the problems of the release of public information into financial markets. Our contribution gives a more robust back-up to the idea that releasing public information can be harmful for the performance of a financial market, if not properly adapted to the market conditions.

Using laboratory experiments, we investigate the impact of releasing an imperfect, public and costless signal into an asset market where traders have access to costly and imperfect private information about the future prospect of the asset. The introduction of a public signal allows us to study under which conditions the presence of public information may act as a sort of disciplining mechanism in the asset market, promoting the aggregation of noisy information or, instead, may distort the market performance, driving the price far for the fundamentals. The main focus of our experiment 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 how the demand for information responds to the presence of a public signal.

The paper is organized as follows. Section 2 describes the experimental design and Section 3 discusses the theoretical background together with the related literature. Section 4 presents the detailed analysis of the results, divided in the analysis of information and asset market. Here we show that the crowding out and overweighting affects are both measurable and relevant in order to account for the market performances. Finally, concluding remarks are given in Section 5, with particular emphasis to the policy implications for regulatory institutions.

2 The experimental design

Our experimental setting is similar to Hey and Morone (2004) and Ferri and Morone (2014). Each market consists of a 3 minute trading period and it is populated by 15 subjects. At the beginning of the trading period, each subject is endowed with 1000 units of experimental currency (ECU)[1] and 10 units of a risky asset that pays a dividend D at the end of the period. The value of the dividend can be either $D = 0$ or $D = 10$ ECU with equal probability, which is common knowledge among subjects. At the beginning of the trading period, the value of the dividend is randomly determined by the experimenter, but not revealed to the subjects until the end of the period when the subject's payoff is determined. Apart from the dividend paid out, assets are worthless. The asset market is implemented as a single-unit double auction. During the trading activity in each market, subjects are free to introduce their bids and asks for assets or directly accept any other trader's outstanding bid or ask.[2] The reason for adopting this trading mechanism is due to its competitive properties: allocations and prices should rapidly converge to levels near the competitive equilibrium (Smith, 1982).

Parallel to the asset market, we implement an information market where, at any moment within the trading period, a subject can purchase partially informative private signals at a price of 4 ECU per signal (perfectly elastic supply). The purchased signals are private in the sense that they are not observable by the others (Morris and Shin, 2002). The values of all private signals are independent realizations conditional on the

[1]Cash, dividend, prices and profit during the experiments were designated in experimental units (ECU) and converted into € at the end of the session. One experimental currency unit is equivalent to 2 cents of €.

[2]Every bid, ask or transaction concerns only one unit of the asset, although every subject can handle as many as desired as long as she has enough cash or assets (no short sale is allowed).

dividend value. A subject can purchase as many signals as she wishes, as long as she has sufficient available cash. Signals are presented to the subjects taking the value 10 or 0. More precisely, the probability of getting a signal suggesting a dividend 10 is p when the true state of the world is $D = 10$ and the probability of getting a signal suggesting a dividend 0 is $q = 1 - p$.[3] The values of $p > q > 0$ are common knowledge among subjects. For example, if a subject purchases a signal whose realization is 10, she can infer that the dividend is expected to be 10 with probability p and 0 with probability q.

Table 1 summarizes the different treatments as well as the treatment parameters and the number of markets.[4] The treatments where traders have access only to private information constitute our baseline treatments,[5] i.e. $\mathrm{T}_B(0.6)$ and $\mathrm{T}_B(0.8)$. In order to study the impact of the public information on the market performance, we introduce the public information treatment where subjects can purchase private signals and have free access to a *public signal*, namely a signal whose realization is *common* to all subjects and *common knowledge* among them. In those treatments, a public signal is released at the beginning of each market. As in the case of private signals, the realization of the public signal might take the value 10 or 0 and it is positively correlated with the dividend. For example, if subjects observe a public signal equal to 10, they can infer that the dividend is expected to be 10 with probability P and 0 with probability $Q = 1 - P$.[6] We aim at studying how the mere presence of public information impacts the performance of the information and asset markets and, therefore, we do not provide the institution releasing the public signal with any pay-off or target function. The public signal in our setting is, in fact, a binary random variable with a given correlation with the fundamentals and it is not emerging out of a micro-funded strategy of the public authority releasing the signal.

The theoretical literature on coordination setting models hypothesizes the existence of an optimal level of transparency for the public information based on the trade-off between its informative role and its potential distortion effects (Colombo and Femminis,

[3]The value of p represents the precision of a single private signal.

[4]In $\mathrm{T}_B(0.8)$, markets in group 1 are populated by 13 subjects. In $\mathrm{T}_P(0.6,0.8)$, markets in group 2 are populated by 10 subjects. The main results of the paper are not affected by the the different number of subjects in those markets.

[5]The notation $\mathrm{T}_B(\cdot)$ indicates the baseline treatment and the corresponding precision of a single private signal.

[6]The value of $P > Q > 0$ is common knowledge among subjects and it represents the precision of the public signal.

Setting	Treatment	p	P	♯ of markets
Baseline	$T_B(0.6)$	0.6	-	20
	$T_B(0.8)$	0.8	-	20
Public information	$T_P(0.6,0.8)$	0.6	0.8	20
	$T_P(0.8,0.8)$	0.8	0.8	20
	$T_P(0.8,0.7)$	0.8	0.7	20
Common information	$T_C(0.6,0.8)$	0.6	0.8	20
	$T_C(0.8,0.8)$	0.8	0.8	20

Table 1: Experimental design and parameters.

2008; Cornand and Heinemann, 2008; Baeriswyl and Cornand, 2014). Concerning the optimal communication of the monetary authorities, several authors, for example Myatt and Wallace (2014) and Baeriswyl and Cornand (2014), consider the transparency of public information as a control variable when designing the optimal central bank information disclosure policy. They assert that it exists an optimal level of transparency in order to maximize the effectiveness of the communication strategy. Taking stock of it, we implement a set of treatments with different relative precision of the public signal with respect to a single private signal: (i) a public signal more precise than a single private signal, $T_P(0.6,0.8)$,[7] (ii) a public signal with the same precision than a single private signal, $T_P(0.8,0.8)$ and (iii) a public signal less precise than a single private signal, $T_P(0.8,0.7)$.[8] Our experimental setting allows to test whether such trade-off exists in a non-coordination environment. In particular, we can test whether, by acting on the relative precision of public information, regulatory authorities can enhance or mitigate the crowding out effect that a public announcement has on the traders' acquisition of private information and the overweighting of public information.

The theoretical literature, e.g. Morris and Shin (2002), states that is the *double-edged* role of public information (providing information on the fundamentals and coordinating the agents' expectations) that might be responsible for its overweighting in the aggregation of information, at least in a coordination setting with strategic complementarities. In order to disentangle the two elements that renders public information a double-edged instrument, we implement the common information treatment[9] where

[7] The notation $T_P(\cdot,\cdot)$ indicates the treatment with public signal; the first number indicates the precision of the single private signal while the second number indicates the precision of the public signal.

[8] One should consider that each trader can buy several private signals in a way that his/her aggregate private information might be more accurate than the single public signal.

[9] The notation $T_C(\cdot,\cdot)$ indicates the treatment with common signal; the first number indicates the precision

subjects have free access to a *common signal*. We define the common signal as a signal whose realization is *common* to all subjects but *not common knowledge* among them. Thus, they only know that each subject receives one signal with the same precision, but it is not known that all signals share the same realization. The common signal is, therefore, equally informative to all traders about the dividend value, but it is not any more a predictor of the opinion of the other traders, given that each trader does not know that the other traders observe the same signal. As in the case of a public signal, the common signal is released at the beginning of each trading period and it is presented to the subjects taking the value 10 or 0 with precision P. Comparing the results of the treatments with public and common signal allows us to better understand whether it is the commonality nature of public information the main driver of its potential distorting effect on market prices, as suggested by the theoretical literature.

The experiment is programmed using the Z-Tree software (Fischbacher, 2007). When the subjects arrive at the laboratory the instructions are distributed and explained aloud using a Power Point presentation. This is followed by one practice period, so that, subjects get familiar with the software and the trading mechanism.[10] Each subject can only participate in one session. Each session consists of 10 independent trading periods (markets).

At the end of the trading period, dividends are paid out and the subject's profit is computed as the difference between their initial money endowment and the money held at the end of the period. Each subject's final payoff is computed as the accumulated profit in the 10 periods, and paid cash at the end of the session. The average payoff is about 20 € and each session lasts around 90 minutes.[11]

3 Theoretical background and related literature

3.1 Do nothing equilibrium

Our experimental setting, similarly to Hey and Morone (2004) and Ferri and Morone (2014), can be characterized by a "do nothing" equilibrium. If all traders are risk

of a single private signal whereas the second number indicates the precision of the common signal.

[10]In appendix, we show the translated screenshots of the three treatments.

[11]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 3 €, which can be used to offset losses. No subject earned a negative final payoff in any session.

neutral or share the same beliefs and risk aversion, we should observe no 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 constant-sum-game nature of our experimental setting. Essentially, it means that a subject would have incentives to purchase a private signal just in case he/she expects to recover the purchasing cost, making profits at the expense of other traders. Knowing that, the other traders would not trade and, therefore, the incentive for the first trader to purchase private information disappears. As a consequence, no activity in the information as well as in asset markets is expected.

As we will see in the results section, this theoretical equilibrium is never achieved. Conversely, we observe a sustained level of activity in the information market as well as in the asset market, in all treatments. This equilibrium turns out not to be empirically relevant, leaving us with the need of considering other possible benchmarks to shed some light on the market dynamics observed in our experiment.

3.2 Fully revealing benchmark

We introduce the fully revealing benchmark as 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 impossibility of the existence of an equilibrium in a market with fully informative prices and contemporaneously access to costly information. If the information is instantaneously incorporated into the market price as stated by the efficient market hypothesis (hereafter EMH), traders have no incentive to purchase private information. However, if no trader purchases information, it immediately appears a profit opportunity and, therefore, an incentive to gather information. Grossman and Stiglitz (1980), and the literature related to the noisy rational expectations equilibrium, introduce an exogenous noise in order to provide incentives for the acquisition of costly information. The presence of the exogenous noise compensates the costs of purchasing information, so that, it is possible to define an equilibrium in both the assets and the information market. Sunder (1992) shows experimentally that the fully revealing benchmark is a reasonable predictor to describe price behavior in the asset market. Furthermore, he suggests that the double auction mechanism creates enough *endogenous* noise to prevent an instantaneous revelation of information, therefore, creating incentives for the subjects to purchase information even in absence of an exogenous noise. Taking into account that we use a double auction as trading mechanism in the asset market and that traders have access to costly imperfect information, we can rely on Sunder's results to consider the fully revealing benchmark as a possible predictor of the level of prices in our experimental financial markets.

Let us compute the expected price conditioned all available information 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 subjects up to time t, which we denote as $I_t = \{s_1, s_2, ..., s_j ..., s_t\}$. We refer to I_t as the market private information set, which does not take into account the sequential order of signal acquisition. The variable s_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 or common signal suggests a dividend equal to 10 (0) ECU, while it takes the value 0 when we refer to the baseline treatments, where no public or common signal is released.

We denote as $Pr(D = 10|I_t, S)$ the probability of observing a dividend equal to 10 ECU conditioned on the information available at time t:[12]

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

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

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

$Pr(D = 10|S)$ is the prior probability of the event $D = 10$ given the public signal S.[13] The values of this conditional probability 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 or common signal is correct, with $Q = 1 - P$.

  In this sense, treatments in the private information setting, i.e. $\text{T}_B(0.6)$ and $\text{T}_B(0.8)$, can be considered a case where the public information does not bias the

[12] *Mutatis mutandis*, the probability to observe a dividend equal to 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.

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

traders towards any of the two states (and therefore $P = Q = 1/2$), whereas in all the other treatments the public or common 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 I_t.

In the following, when not necessary, we will omit the time variable t from the variables n_t and N_t. Depending on the value of S, the numerator of eq. (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 $H_t = \sum_{j=1}^{t} s_j = 2n_t - N_t$ as the aggregate net private signal available at time t, we obtain the probability that the dividend is equal to 10 as a function of the information present in the market at time t:

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

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

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

3.3 Overweighting of public information

Morris and Shin (2002) and Allen et al. (2006) have been the first to point out 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), in particular, illustrate the overweighting phenomenon within the framework of a beauty contest game assuming fully rationality of players. In such a game, players make a double account of the public information, considering its informational content as well as its role in second guessing the expectations of the other players (commonality). Although similar in spirit, but within a different theoretical framework, Allen et al. (2006) develop 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 renders public information a good predictor for aggregate demand and gives rise to the overweighting phenomenon.

Considering such effect, Morris and Shin (2005), Amato and Shin (2006) or Vives (2014), among others, call attention to a paradox of public information in markets where prices are the main suppliers of endogenous public information. In those markets, the release of more precise public information might reduce the informativeness of prices (as endogenous public signals). That is, there is a crowding out[14] of exogenous public information on endogenous public information due to the fact that the release of public information induces traders to rely less on their private information or, conversely, overrelay on public information. In coordination settings, public information turns out to be overweighted with respect to its informational role, since it carries the additional information on the beliefs of the other traders due to its commonality. Within our laboratory financial market, we can test for the paradox of public information within a more general framework, without any built-in coordination mechanism.

Our experimental setting exhibits the key elements suggested by the theoretical literature based on Morris and Shin (2002) and, especially, Allen et al. (2006) in order to observe traders' overweighting on public information: (i) The access to private and public information. (ii) Heterogeneous expectations due to the endogenous acquisition of noisy private information. Additionally, if subjects consider the beliefs of other subjects when trading, we expect to observe the overweighting phenomenon.

In order to quantify the overweighting phenomenon, let us define the public infor-

[14] A cautionary note is in order here. When we refer to crowding out, we consider the reduction in the demand for private information due to the presence of an additional free signal (public or common). The theoretical and experimental literature refers also to the crowding out of an exogenous public signal on the informativeness of endogenous signals (prices or other statistics) (see, e.g., Amador and Weill, 2010; Vives, 2014). In our paper, we refer to this effect as overweighting of public information in order to clearly distinguish between the two effects.

mation benchmark as the expected price conditional just on the public signal:

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

Note that both the fully revealing benchmark of eq. (6) and the public information benchmark of eq. (7) 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 precisions, the public information benchmark depends exclusively on the precision of public signal. In other words, it assigns a zero weight to the private information in aggregating all available information. Therefore, if the public information benchmark turns out to be a better predictor of actual prices than the fully revealing benchmark, we are able to prove the existence of overweighting phenomenon.

3.4 Crowding out of private information

Considering that in our experimental setting the information acquisition process is endogenous and in perfectly elastic supply, we can characterize the information market analyzing how the demand for private information varies as a function of the information set at the disposal of the subjects.

Colombo et al. (2014), among others, propose a theoretical model that generalizes the Morris and Shin coordination setting introducing the acquisition of costly and noisy private information. They demonstrate the existence of a crowding out effect of public information on the equilibrium acquisition of private information.[15] The intuition behind this result is simple: the presence of a public signal helps investors to better forecast the fundamentals, reducing, therefore, the marginal value of private information and, consequently, its demand. They further study the impact of the equilibrium degree of coordination on the magnitude of the crowding out. More precisely, they show that the higher the equilibrium degree of coordination in a strategic complementarity setting, the higher the magnitude of the crowding out effect. Conversely, in a strategic substitutability setting, the demand for private information increases with the degree of coordination (crowding in). Other contributions in the area include Colombo and

[15] See Corollary 1 in Colombo et al. (2014).

Femminis (2008); Demertzis and Hoeberichts (2007) and Kool et al. (2011).

Our experimental setting does not include an explicit coordination motive for the subjects as in Colombo et al. (2014), among others. We cannot, in fact, sharply characterize our setting within strategic complementarity or substitutability framework. Nevertheless, we consider their predictions useful to shed some light on our experimental results concerning the subjects' behavior in the information market. Following Colombo et al. (2014), we expect to observe a reduction in the acquisition of private information whenever we introduce a free signal into the market, since it provides information on the fundamentals. Furthermore, comparing the public and common treatments, we can infer the role of the commonality of public information on traders' higher-order beliefs and its impact on information demand. We hypothesize that if the common and public treatments exhibit the same reduction in information demand, it is the informative role of the free signal the main driver of the crowding out effect. Significant differences, instead, point to the existence of a strategic interaction among subjects in the acquisition of information (see Hellwig and Veldkamp, 2009).

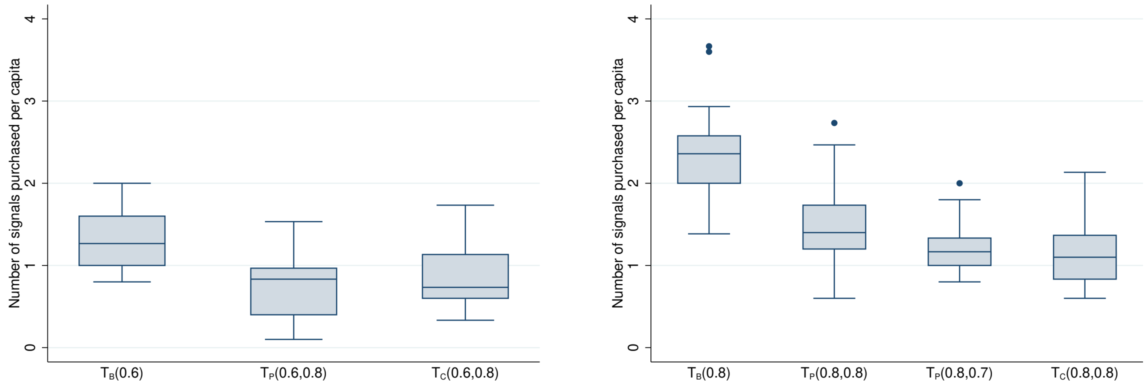
4 Results

Figures from 5 through 18, included in the Appendix, display the trading activity in all markets for all treatments. Each panel of those 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 subjects' trading behavior in any of the implemented treatments. This empirical finding is in line with many experiments on laboratory financial markets characterized by "no-trade equilibrium". Several recent papers study under which conditions subjects do trade in the laboratory despite the theoretical incentives not to do so (Angrisani et al., 2008; Carrillo and Palfrey, 2011). They essentially show that subjects fail to consider the strategic implications of trading within an asymmetric information environment. The failure of "do nothing" equilibrium speaks in favor of a certain degree of bounded rationality of the subjects.

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

4.1 Information demand and market informativeness

A crucial aspect of our experimental design is that the demand for private information is endogenous in a market with perfectly elastic supply. Therefore, in order to characterize the information market, it is sufficient to analyze the demand for private information. We define the demand for private information as the number of signals purchased by the subjects in a given market.



(a) $p = 0.6$

(b) $p = 0.8$

Figure 1: Per capita demand for private information per market across treatments.

4.1.1 Crowding out effect of public information on the demand for private information

Figure 1 and Table 2 show that the release of a free signal, whether public or common, *crowds out* the demand for private information, since traders substitute part of their private information with the information provided by the public signal. This effect can be observed in treatments with low as well as high precision of private information. Our experiment robustly shows that the introduction of a public signal *significantly* reduces the traders' investment in private information.

To the best of our knowledge, this is the first paper in the empirical as well as experimental literature that proves the existence of the *crowding out* effect of public information on the demand for private information, demonstrating that such effect is measurable and empirically relevant. Our results confirm the theoretical prediction of Colombo et al. (2014) on the crowding out effect that public information exerts on the subjects' acquisition of private information in a coordination setting, generalizing their prediction to a more general framework. As pointed out by Colombo et al. (2014), a reduction in the acquisition of private information is not *per se* a negative effect on social welfare if public information compensates for the reduction in the overall market informativeness.[16]

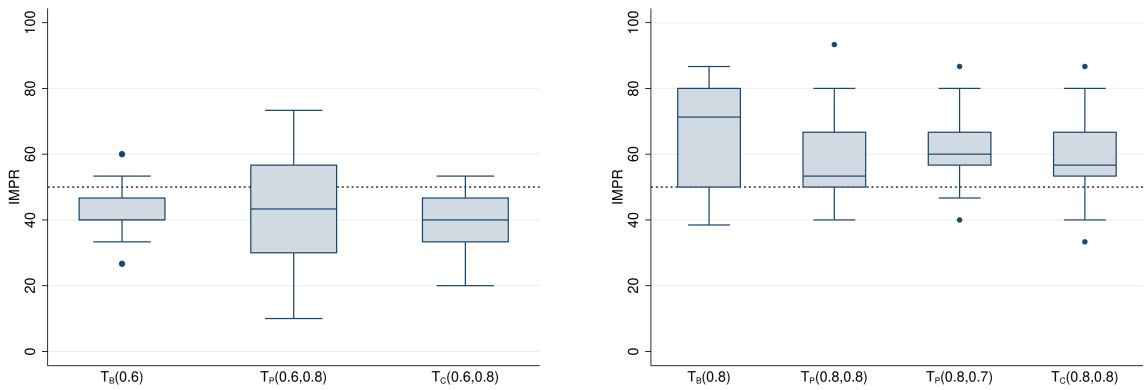
Treatments	MW statistic	p-value
$T_B(0.6)$ vs. $T_P(0.6,0.8)$	3.797	0.000
$T_B(0.6)$ vs. $T_C(0.6,0.8)$	3.523	0.000
$T_B(0.8)$ vs. $T_P(0.8,0.8)$	3.315	0.000
$T_B(0.8)$ vs. $T_P(0.8,0.7)$	5.063	0.000
$T_B(0.8)$ vs. $T_C(0.8,0.8)$	5.061	0.000
$T_P(0.6,0.8)$ vs. $T_C(0.6,0.8)$	-0.474	0.635
$T_P(0.8,0.8)$ vs. $T_C(0.8,0.8)$	2.420	0.016
$T_P(0.8,0.8)$ vs. $T_P(0.8,0.7)$	-2.211	0.027

Table 2: Mann-Whitney test (MW hereafter) for the crowding out effect of public and common signal in the information market.

When evaluating the effect of releasing public information into a financial market it is not only important to evaluate the impact on the demand for private information, but also to determine its impact on the traders' participation in the information market. In our experiment, we observe a high degree of heterogeneity in the participation of subjects in the information market. In particular, the role of uninformed traders, i.e. traders who do not purchase information, can be relevant for the dynamics of the asset market (see section 4.2.2). Bloomfield et al. (2009), for example, show experimentally that uninformed traders provide liquidity to the market, increasing market volume, as well as reducing price informativeness.[17] In order to characterize how the access to public information affects the subjects' participation in the information market, we define the information market participation rate (henceforth denoted IMPR), as the proportion of subjects who purchase at least one signal during the trading activity in a given market (active traders). Considering the IMPR, the crowding out effect in the per capita demand for private information can be decomposed into the combination of two adjustments: (i) a reduction in the IMPR and/or (ii) a reduction in the demand for private information of active traders. In order to disentangle the two possible adjustments, Figure 2 and Table 3 illustrate that the release of a public (or common)

[16]Later in this paper (Section 4.1.2), we will show the effect of the crowding out on market informativeness.
[17]In Bloomfield et al. (2009) the information is exogenously distributed among the market participants.

signal does not significantly affect the IMPR. Therefore, the crowding out is largely caused by the reduction of the private information demand of the active traders. We can summarize our findings as follows:



(a) $p = 0.6$

(b) $p = 0.8$

Figure 2: Boxplot of the IMPR in each market across treatments.

Treatments	**MW statistic**	**p-value**
$T_B(0.6)$ vs. $T_P(0.6,0.8)$	0.068	0.945
$T_B(0.6)$ vs. $T_C(0.6,0.8)$	0.789	0.430
$T_B(0.8)$ vs. $T_P(0.8,0.8)$	1.552	0.121
$T_B(0.8)$ vs. $T_P(0.8,0.7)$	1.107	0.268
$T_B(0.8)$ vs. $T_C(0.8,0.8)$	1.361	0.174
$T_P(0.6,0.8)$ vs. $T_C(0.6,0.8)$	0.560	0.576
$T_P(0.8,0.8)$ vs. $T_C(0.8,0.8)$	-0.539	0.590
$T_P(0.8,0.8)$ vs. $T_P(0.8,0.7)$	1.436	0.151

Table 3: MW test comparing the effect of public information on the IMPR.

Result 1: *The release of public information crowds out the per capita demand for private information: whereas it leaves largely unaffected the proportion of active traders in the information market, it does significantly reduce their demand for private information.*

Such results are compatible with a sort of intrinsic attitude of a fraction of subjects to be informed, which is affected marginally by the presence of the public signal. Instead of not participating in the information market, they adjust their demand purchasing fewer signals. Conversely, the other group of subjects does not purchase private signals, relying on the price chart or other market signals (e.g. bid/ask spread). This categorization of traders resembles the dichotomy fundamentalists/chartists introduced by Beja and Goldman (1980), afterwards developed in the literature of economic agents with heterogeneous expectations (see for instance Lux and Alfarano, 2016; Dieci and He, 2018).

An additional feature that we can test with our experiment is whether the commonality role of the public signal affects the magnitude of the crowding out or it is rather limited to its informational role. We can test for this effect by showing how the information demand varies between the common and public treatments. Note that in $\mathrm{T}_C(\cdot,\cdot)$, the common knowledge of the public information is absent and, therefore, the common signal provides information just on fundamentals, without carrying information on the other traders' expectations. In those treatments, the crowding out is due solely to the informational component of the free signal and not to its commonality component.

Figures 1 and 2, and Tables 2 and 3 compare the crowding out effect in the public and common treatments. It results that the IMPR is not affected by the commonality of the free signal. Concerning the per capita demand, when the private information is of low precision, the magnitude of the crowding out is unaffected by the commonality of the signal. Differently, when private information is of high precision, the magnitude of the crowding out is significantly higher in $\mathrm{T}_C(0.8,0.8)$ than in the $\mathrm{T}_P(0.8,0.8)$. It seems that the crowding out effect depends on the commonality role of the public signal and, additionally, on its relative precision with respect to the private signal. How can we interpret these findings? Following Hellwig and Veldkamp (2009), under strategic substitutability of actions in a coordinating setting "*agents want to know what others do not*". The lower magnitude of the crowding out in $\mathrm{T}_P(0.8,0.8)$ with respect to $\mathrm{T}_P(0.8,0.7)$ might be due to the role of the relative precision of private information with respect to public information. When private and public signals have the same precision, i.e. $\mathrm{T}_P(0.8,0.8)$, an active trader has a higher incentive to purchase private information to be more informed than the privately uninformed traders. On the contrary, the relatively high precision of the private information in $\mathrm{T}_P(0.8,0.7)$ gives to active traders a lower incentive to purchase private information, as compared to $\mathrm{T}_P(0.8,0.8)$.

If our interpretation is correct, we can infer the existence of some strategic substitutability of the action of active traders in the information market. "*Knowing what the others do not*" seems, in fact, a very reasonable behavior in a financial market. Following this reasoning, our conjecture can also account for the significant difference in $T_C(0.8,0.8)$ and $T_P(0.8,0.8)$. In the common information treatment, in fact, an active trader believes to have access to a private signal.

Result 2: *The information demand of active traders is extremly sensitive to the relative precision of public information with respect to private information.*

Our experimental findings indicate that the demand for information is particularly sensitive to the relative precision of the public information. This might be an important feature to take into account when designing communication policies. Before deciding the transparency of the communication policy by the regulator, it would be desirable having a proxy of the average precision of the information available to the traders, in order to evaluate its impact on traders' information demand.

4.1.2 The market informativeness

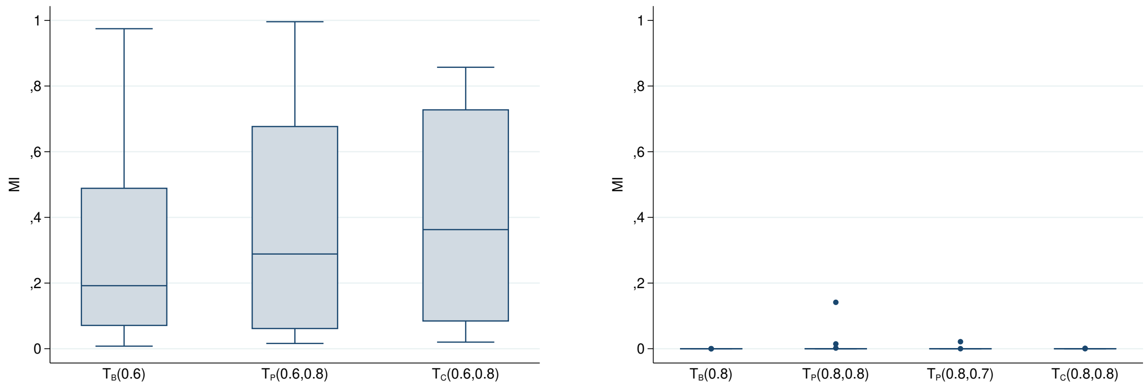
After having analyzed how the release of public information affects the demand for private information, it remains an open question whether the public signal compensates for the reduction in private information due to the crowding out effect. In other words, is the introduction of a public signal neutral, beneficial or detrimental for the overall market informativeness? Stated differently, does the potential of the market to discover the true state of the world in the presence of public information remain unaffected, enhanced or reduced? If the release of a public signal does not result to be detrimental for market informativeness, we might speak in favor of a positive contribution of the crowding out effect to the social value of public information. The same degree of market informativeness can be, in fact, achieved with a reduced investment on private information (See Colombo et al., 2014).

Let us introduce as indicator of market informativeness, the mean absolute deviation between the fully revealing benchmark and the dividend value averaged during the last minute of the trading period:[18]

[18]Note that, in principle, we should introduce an index, indicating the particular market and treatment. We omit such index for notational convinience. The choice of averaging over the last trading minute is a compromise between having a good statistics for market informativeness indicator and a low activity in the information market. In the last minute, in fact, either zero or few signals are purchased and, therefore,

$$MI = \frac{1}{60} \sum_{t=120}^{180} \frac{|FR_t - D|}{10} \, . \tag{8}$$

Recall that the definition of FR_t is based on the EMH. The EMH rests on the idea that the traders make an optimal use of all the available information, without explicitly modeling the traders' incentives to gather such information. Relying on the EMH to compute the market informativeness, it might probably be a strong (behavioral) assumption; however, it allows us not to include *ad hoc* behavioral rules in describing the subjects' trading activity. Moreover, the indicator MI can be thought as the upper bound for the efficiency in the aggregation of available information into prices. The higher the value of MI, the lower is the market informativeness. Instead, a value of MI close to zero indicates that the information present in the market is sufficient to discover the dividend value.



(a) $p = 0.6$ (b) $p = 0.8$

Figure 3: Market informativeness across markets per treatment.

Figure 3 shows how the market informativeness is strongly affected by the precision of the private information. When we consider a low precision of the private signal, market informativeness is sufficient to discover the dividend value only in a few cases.[19] In the majority of cases, the aggregate information provides an imprecise indication of the true state of the world. Conversely, in the case of high precision of the private signal,

the fully revealing benchmark is almost constant over time. Moreover, traders should have enough time to aggregate the information present in the market, giving to the fully revealing benchmark its "best shot" as Plott and Sunder (1988) state. The results are robust to changes in the considered time interval (material upon request). We divided by 10 in order to normalize all distances to be between 0 and 1.

[19] We can arbitrarily state that market informativeness is sufficient to discover the true state of the world when $MI < 0.05$. Different values of this threshold do not change the essential message that the information is sufficient to discover the dividend value in just few cases.

the indicator MI is very close to zero in almost all cases, signaling that the information present in the market is always sufficient to discover the dividend value, regardless of the realization of the public (or common) signal.[20] The market informativeness is just marginally influenced by the presence of the public signal and its specific realization.

Despite the crowding out effect on the demand for private information, we cannot reject the hypothesis that the market informativeness is not significantly affected by the release of a public signal, independently of its precision.[21] This means that within the framework of the EMH, the additional information provided by the exogenous public signal is sufficient to fully counterbalance the effect of the crowding out on private information.

Result 3: *The crowding out effect of public information leaves invariant market informativeness.*

Our experimental analysis on the information market, summarized by Results 1 and 3, confirms the theoretical conjectures of many authors (for instance, Colombo et al., 2014) on the role of public information in competitive markets. In an economy with an endogenous information structure, the release of a public signal may crowd out private information, so that public and private information turns out to be substitutes, rather than cumulatives. Public information might just partially compensate for the crowding out of private information, leading in some cases to a significant reduction in the overall market informativeness.

The implications of our findings are important for regulators: the release of public information might not increase the overall market informativeness. The intervention of the public institutions reduces traders' effort to gather private information at a level that the loss in private information is not compensated by the presence of the public signals. When introducing a new source of public information in a market, in fact, the regulator should pay particular attention to its complex interaction with other sources of information already at the disposal of market participants.

[20]Except for one market in $T_P(0.8,0.8)$, market informativeness always satisfies the condition $MI < 0.05$.

[21]A MW test cannot reject the null hypothesis of equal market informativeness if we compare the baseline treatments with all other treatments.

4.2 Asset market and price informativeness

Until now, we have presented our experimental findings that releasing public information has on the information market. Result 3 shows that the public signal compensates for the crowding out effect on the demand for private information, leaving invariant market informativeness. However, how does the release of public information effectively impact the aggregation of available information into prices? Can we observe the overweighting phenomenon of public information as predicted by the theoretical literature? Can we preserve the beneficial effect of releasing public information, while minimizing its adverse effects?

4.2.1 Overweighting of public information

In this section, we present the results of the impact of releasing a public signal on the market performance in aggregating the available information into prices. Essentially, we analyze how the information disseminated among subjects (market informativeness) is aggregated into prices (price informativeness). According to the EMH in its strong form, we should observe that the market price reflects all available information, so that our measure of price informativeness should be a mere reflection of market informativeness. Taking into account Result 3, therefore, the price informativeness should not be affected by the release of the public signal.

As a measure of price informativeness, we consider the difference between *what traders have done* in a given market and *what they could have done* in aggregating information into prices. In order to analyze how prices reflect all available information in a given market, we evaluate how the fully revealing benchmark FR_t, introduced in Section 3, accounts for market prices. We compute the absolute distance of prices, labeled as PR_t, from FR_t averaged in the last minute of trading activity in a given market:[22]

$$PI = \frac{1}{60} \sum_{t=120}^{180} \frac{|FR_t - PR_t|}{10} , \tag{9}$$

where the subscript t denotes seconds. The maximum level of price informativeness is reached when $PI = 0$ ($PR_t \approx FR_t$), i.e. when market prices reflect correctly all

[22]We consider only the last minute for the same reasons explained in footnote 18. We have normalized the distance PI in eq. (9) to be bounded to 1. We omit the market index for notational convinience.

available information. Significant deviations from this lower bound, instead, indicate a reduction in price informativeness. Recall that in the fully revealing benchmark, all information, private or public, is weighted according to its precision. In order to study the effect that releasing public information has on how private and public information are weighted when actually aggregated into market prices, we introduce an indicator to measure the goodness of fit of the public benchmark. The indicator is the averaged distance of market prices from the public information benchmark:

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

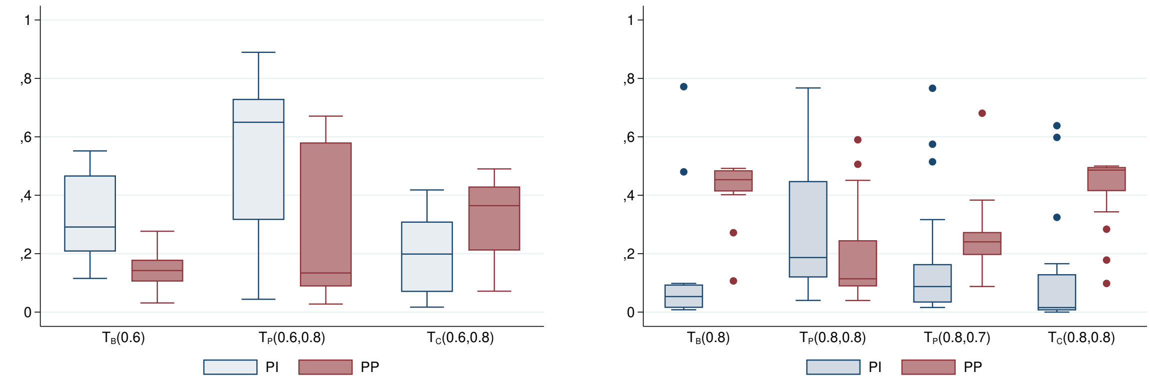
where PB is defined in eq. (7).[23] When the indicator PP is close to zero, $PP \approx 0$, means that market prices fluctuate around the public information benchmark. The indicator of eq. (10) helps us to detect the overweighting phenomenon and to measure its magnitude.

The comparison of the relative performance of the indicators PI and PP in describing market prices can help us to evaluate whether deviations from fully informative prices are systematically favoring public information, as suggested by several theoretical models in the literature (e.g. Allen et al., 2006). When the PP indicator is significantly lower than the PI indicator means that the public information benchmark better accounts for the price dynamics than the fully revealing benchmark. Given that public information alone contributes just partially to the market informativeness (see Figure 3), this condition indicates that the market weights public information well beyond its informational content, being the main determinant of the price level.[24]

We analyze now how releasing public information impacts price informativeness in our laboratory financial market. Figure 4 (a) and Table 4 show that in those markets where traders have access to private information with low precision, releasing a more precise public signal strongly reduce price informativeness with respect to the baseline treatment, i.e. $\mathrm{T}_B(0.6)$ vs. $\mathrm{T}_P(0.6{,}0.8)$. A similar effect on price informativeness is observed when traders have access to more precise private information (see Figure 4 (b)

[23] As for the indicator in eq. (9), we omit the market index for notational convinience. The indicator PP is also normalized to 1. Although PB is constant over time, in eq. (10), we also average during the last minute of trading activity in order to compare both indicators.

[24] Note that such condition is a sufficient but not a necessary condition for detecting the overweighting phenomenon. In principle, we cannot exclude the presence of overweighting of public information even in the case of PI lower than PP.



(a) $p = 0.6$ (b) $p = 0.8$

Figure 4: Performance of price informativeness indicator (PI) and public information indicator (PP) across markets per treatment.

		PI	
Effect	**Treatments**	MW statistic	p-value
Releasing public information	$T_B(0.6)$ vs. $T_P(0.6,0.8)$	-2.597	0.009
	$T_B(0.8)$ vs. $T_P(0.8,0.8)$	-3.949	0.000
	$T_B(0.8)$ vs. $T_P(0.8,0.7)$	-1.731	0.083
	$T_P(0.8,0.7)$ vs. $T_P(0.8,0.8)$	-2.732	0.006
Releasing common information	$T_B(0.6)$ vs. $T_C(0.6,0.8)$	2.597	0.009
	$T_B(0.8)$ vs. $T_C(0.8,0.8)$	1.082	0.279
Public vs. common information	$T_P(0.6,0.8)$ vs. $T_C(0.6,0.8)$	3.760	0.000
	$T_P(0.8,0.8)$ vs. $T_C(0.8,0.8)$	3.544	0.000

Table 4: MW test to compare values of PI indicator among treatments.

	Treatments	$PI\ vs.\ PP$ p-value
Baseline treatments	$T_B(0.6)$	**0.041**
	$T_B(0.8)$	0.000
Public information	$T_P(0.6,0.8)$	**0.000**
	$T_P(0.8,0.8)$	**0.041**
	$T_P(0.8,0.7)$	0.012
Common information	$T_C(0.6,0.8)$	0.263
	$T_C(0.8,0.8)$	0.002

Table 5: Signtest to compare PI and PP indicators. The numbers in bold signal that the PP indicator is significantly lower than the PI indicator.

and Table 4). If we compare $T_P(0.8, 0.7)$ with the baseline treatment, the deterioration of price informativeness is weaker but still present (at least at 10% confidence level).

Result 4: *Releasing public information in a market where traders have access to* *costly private information worsens price informativeness, in some cases, at an impressive magnitude.*

Our result suggests that price informativeness is not a mere reflection of market informativeness. Contrary to what the EMH states, the aggregation of information into prices depends on the nature of the information present in the market (private or public) and the spectrum of information sources at the disposal of the traders.

Why do we observe a deterioration of price informativeness when a public signal is released? We can interpret our experimental results relying on the theoretical literature on overweighting of public information in coordination settings. In those models, the reduction in price informativeness is consequence of the overreliance of subjects on public information because of its commonality property, so that individual actions systematically overweight public information more than justified by its informational content. Under the hypothesis that subjects overrely on public information, we expect that market prices in our experiment are heavily influenced by the public signal. We should observe, therefore, that the PP indicator is significantly lower than the PI indicator in our data. Figure 4 and Table 5 show that our conjecture is confirmed when the public signal is at least as precise as a single private signal, i.e. in $\mathrm{T}_P(0.6,0.8)$ and $\mathrm{T}_P(0.8,0.8)$. In those treatments, the public signal is unambiguously overweighted since it constitutes the main determinant of the price level. When subjects have access to less precise public information than a single private signal, i.e. in $\mathrm{T}_P(0.8,0.7)$, we cannot exclude that public information is overweighted. However, it is not anymore the main determinant of the price level. It is the fully revealing benchmark, in fact, that better accounts for the market prices. In this case, both, private and public information, contribute to the determination of the price level.

To the best of our knowledge, our paper is the first contribution in the literature in observing and measuring the overweighting of public information in a non-coordination setting. Once again, we stress the importance of having generalized such phenomenon to a more realistic environment, proving its robustness and empirical relevance.

Many theoretical contributions in the literature suggest that it might exist a trade-off for regulatory institutions, like central banks, between providing a precise public information to traders in order to take more informative actions and the risk that traders overrely on the public signals. Transparency of public information becomes, then, a control variable in the designing of an optimal disclosure policy.

Our experimental findings suggest that the magnitude of the overweighting effect is strongly influenced by the relative precision of the public signal with respect to the precision of a single private signal. Interpreting the relative precision of the public signal as its transparency, our results speak in favor of the possibility of acting on the relative precision of the public signal to reduce the overweighting effect.

Figure 4 and Table 5 illustrate how lowering the level of transparency, i.e. moving from $\text{T}_P(0.6,0.8)$ to $\text{T}_P(0.8,0.8)$ and, then, to $\text{T}_P(0.8,0.7)$, the magnitude of the overweighting effect is significantly reduced. Interestingly, in $\text{T}_P(0.8,0.7)$, the public signal is not anymore the main driver of market prices.

Result 5: *Depending on its transparency, public information is overweighted when incorporated into the price. Lowering transparency reduces overweighting of public information.*

Our experimental findings generalize previous theoretical and experimental contributions on the role of transparency to an environment beyond the coordination setting. Our results provide a robust back up to the conjecture that acting on the transparency of public information constitutes an effective control instrument at disposal of regulators.

4.2.2 The double-edged nature of public information

In order to interpret the overweighting phenomenon in light of the existing theoretical literature, we rest on the idea that subjects overrely on public information when deciding their trading strategy. Implicitly, we assume that subjects' higher-order beliefs play a role when deciding at what price to trade. In particular, Allen et al. (2006) show that such condition necessarily leads to overweight public information when information is aggregated into prices.

It is not an easy task to directly test whether subjects actually overrely on public information. In order to indirectly test for the overreliance hypothesis, therefore, we implement the common information treatment, where a common signal provides information on the fundamentals without influencing the higher-order beliefs of subjects, since it is not common knowledge. The released signal, not being public, should lose its role as coordination device, and, being informative, should favor price convergence towards the fully revealing benchmark. Thus, with the introduction of the common information treatment, we can disentangle how the *commonality* and the *informative* features of the public signal impact the aggregation of information into prices. If traders overrely on public information, we expect to observe that the overweighting effect disappears or, alternatively, it is strongly attenuated when comparing the common information and the public information treatment.

Figure 4 and Table 4 show that the release of a common signal in $\mathrm{T}_C(0.6,0.8)$ and $\mathrm{T}_C(0.8,0.8)$ significantly improves price informativeness compared to the markets where public information is released, i.e. in $\mathrm{T}_P(0.6,0.8)$ and $\mathrm{T}_P(0.8,0.8)$, respectively. Moreover, the common signal improves price informativeness even with respect to $\mathrm{T}_B(0.6)$. In the case of the private information with high precision, $\mathrm{T}_B(0.8)$ and $\mathrm{T}_C(0.8,0.8)$, price informativeness does not improve being already at its (almost) maximum level. We do not observe a distorting effect of the common signal on price informativeness.

The most striking result concerns the overweighting effect. In all treatments in the common information setting, the overweighting effect is strongly attenuated. Prices turn out to be more informative since, contrary to the public information treatment, the fully revealing benchmark performs by far better than the public information benchmark in describing market prices. Even more, in $\mathrm{T}_C(0.8,0.8)$, the overweighting effect disappears since prices converge, in most cases, to the dividend value (PI close to zero).

Our results confirm that it is the commonality property of the public signal the main responsible for its distorting effect on prices due to the traders' overreliance on public information in the process of aggregating information into prices. Our findings support the intuition of Morris and Shin in defining public information as a double-edged instrument, helping aggregation and enhancing coordination.

Result 6: *The overweighting of public information is a consequence of traders' overreliance on the public signal because of its commonality property.*

Once the commonality feature is eliminated, the common signal does not constitute the main driver of market prices. Contrary to the public signal, the common signal cumulates to the private information when aggregated into the prices, without distorting the aggregation process.

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,[25] let us introduce a simple qualitative idea on how our financial market framework could give the incentive to forecast the other traders' expectations, providing a relevant role for higher-order beliefs in the price formation mechanism. More specifically, if a trader purchases private information that tells him that with some probability the asset dividend is 10, he would be willing to buy assets at any price equal or lower than his expected dividend.[26] He will have higher gains from trade the lower the asset purchasing price. If this trader thinks that the market is populated by a non-marginal fraction of uninformed traders,[27] he has an incentive to bid at a price around what he expects it would be the expectation of the group of uninformed traders, that is, the public information benchmark. Uninformed traders could be willing to buy and sell their assets around their expected dividend, determined solely by the public signal. If the proportion of uninformed traders willing to trade is high enough to provide sufficient liquidity and/or assets, market prices fluctuate around the expected dividend conditional on the public signal. In this case, the public information benchmark better predicts the market price than the fully revealing benchmark. Prices do not reflect the traders' private information, but mostly the expectations of uninformed traders' expectations that are biased towards public information. This couple be a simple mechanism behind the overweighting of public information, based on the impact of public information on the traders' second-order beliefs. Further research will be necessary to investigate the microstructure of this process.

It is evident that our simple idea relies heavily on the bounded rationality of the traders. The overweighting effect has been introduced as an equilibrium outcome of coordination models with fully rational agents, as in Morris and Shin (2002). Cornand and Heinemann (2014) is the only contribution in the literature that analyses the impact of different degrees of rationality on the overweighting phenomenon, within the boundedly rational behavioral framework introduced by Nagel (1995). They show that the higher is the level of boundness in rationality, measured as a reduction in the degree of inductive reasoning, the lower is the overweighting phenomenon. Instead, we

[25]See Cornand and Heinemann (2014) and Baeriswyl and Cornand (2014), among others.

[26]His expected dividend is higher than the public information benchmark, independtly of the realization of the public signal.

[27]In this context, we define uninformed traders as those traders who do not purchase any signal.

observe, in a certain sense, the opposite relationship between the level of rationality and the overweighting of public information. In our setting, fully rationality implies either no-trade equilibrium or, if such equilibrium is broken, a noisy rational expectation equilibrium, following the reasoning of Sunder (1992). In both cases, we should not observe the overweighting effect, since either we have no price or it reflects the information according to its precision. Therefore, detecting this effect as a relevant experimental result seems to be connected to the bounded rationality of the subjects. Our findings on the role of bounded rationality in the emergence of the overweighting effect as a non-equilibrium outcome confirm again the empirical relevance of such distorting effect of public information on prices.

At the aggregate level, subjects in our experimental markets (might) overrely on public information with respect to private information. Since we do not explicitly introduce a coordination setting, our experimental results generalize their main conclusions, showing that they can be also applied to a more general financial 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 along the lines sketched in our simple example. We leave this as an issue for our future research agenda.

In the literature, there are several elegant frameworks to account for deviations from fully rationality, like the cognitive hierarchy model of Camerer et al. (2004) and the coursed equilibrium of (Eyster and Rabin, 2005). In particular, Eyster et al. (2015) apply the cursed equilibrium to a financial market, showing that public information is overweighted when aggregated into market prices. Our experimental results can be cast into those theoretical frameworks, providing an alternative explanation to the phenomenon of overweighting of public information in financial markets within bounded rationality of traders. The differences between our results and the existing literature deserve, therefore, further theoretical as well as experimental research.

5 Discussion and conclusions

The efficient market hypothesis, in its strong form, states that all relevant and available information is correctly incorporated into prices. However, it does not consider how traders allocate resources to obtain information. The noisy rational equilibrium models and the microstructure literature illustrate how the information can actually be incorporated into prices. The main objective of this paper is to study experimentally 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. Such informational setting has been extensively used in the literature to model the intervention of regulatory authorities. The objective of regulatory institutions when releasing public information is essentially to discipline the market, reducing the potential negative effects of asymmetric information. According to the theoretical literature, however, the release of public information might have adverse effects such as overweighting of public information and crowding out of private information. In order to study the effect of public communication and disclosure strategies of regulatory institutions, we have conducted controlled laboratory experiments. We propose an experimental setting to observe the aggregation of information into prices in a simple financial market where traders have access to costly and imperfect private information and a "regulatory institution" releases noisy public information.

Using our simple laboratory financial market, we show that the crowding out effect of public information and traders overreliance on public information do exist. Our findings show that those two effects are measurable and empirically relevant, heavily affecting the market performance. Moreover, in our experimental setting, those effects emerge without an explicit incentive for the subjects to coordinate, as in other experimental studies reproducing the very specific Morris and Shin (2002) theoretical framework. We can infer, therefore, that the crowding out and overreliance are most probably more general phenomena than conjectured by the theoretical literature.

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

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

We strongly believe that our laboratory setting can be used as a realistic testbed in order to assess the performance of different policy instruments, without relying on specific behavioral assumptions and/or ad hoc coordination mechanisms. Several other measures can be also tested, like a sequential release of public information, reducing the level of publicity, increasing the number of institutions releasing public information.

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Appendix A: Trading activity per treatment

Each panel shows the chart of transaction prices. 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 first number at the caption of each panel identifies the market and the second one indicates the value of the dividend (either 10 or 0). The solid line is the trading price. Finally, the dotted line indicates the fully revealing benchmark, while the dashed line indicates the public information benchmark.

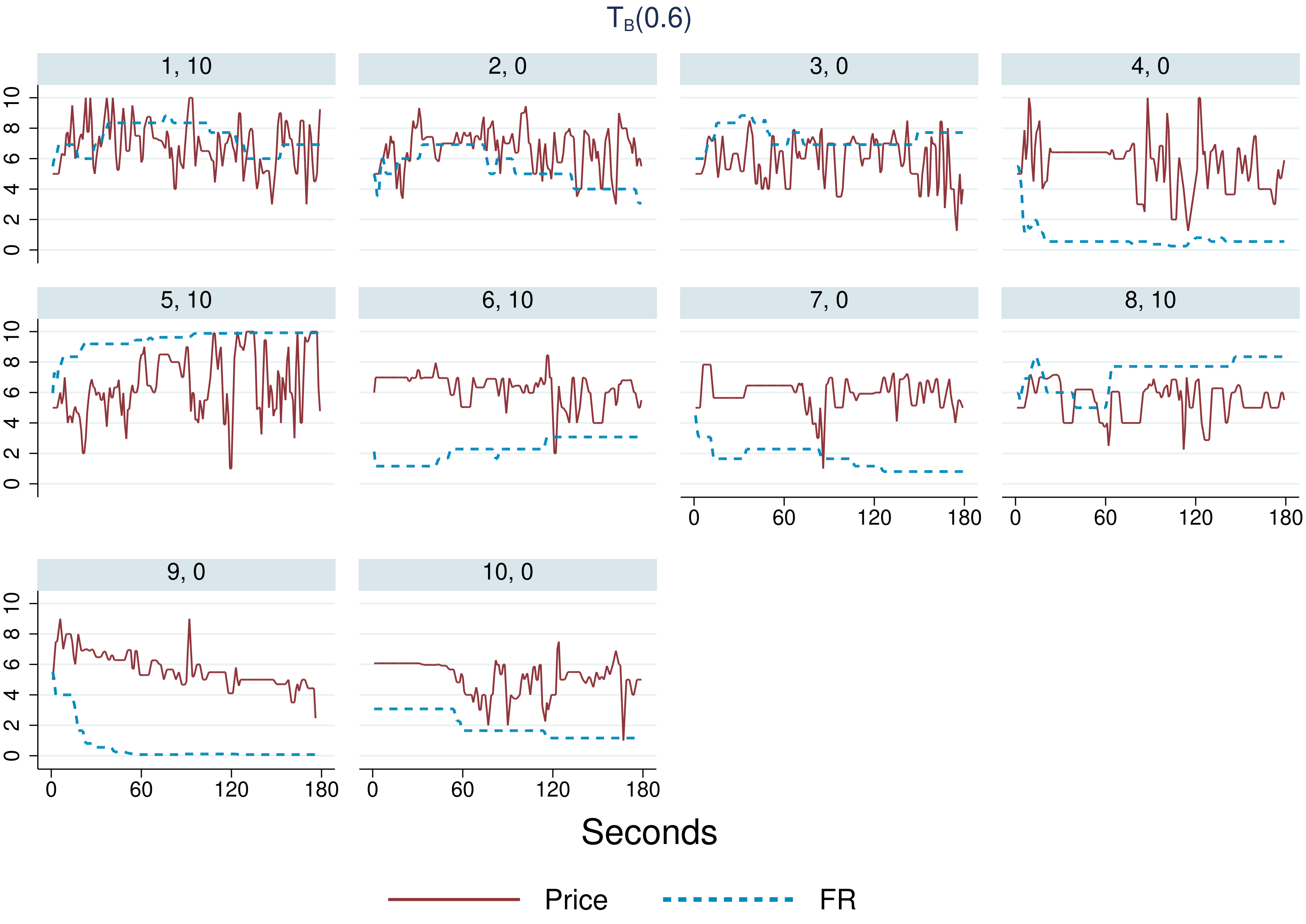

Figure 5: Markets Treatment T(0.6) (Group 1): Private signal with $p = 0.6$.

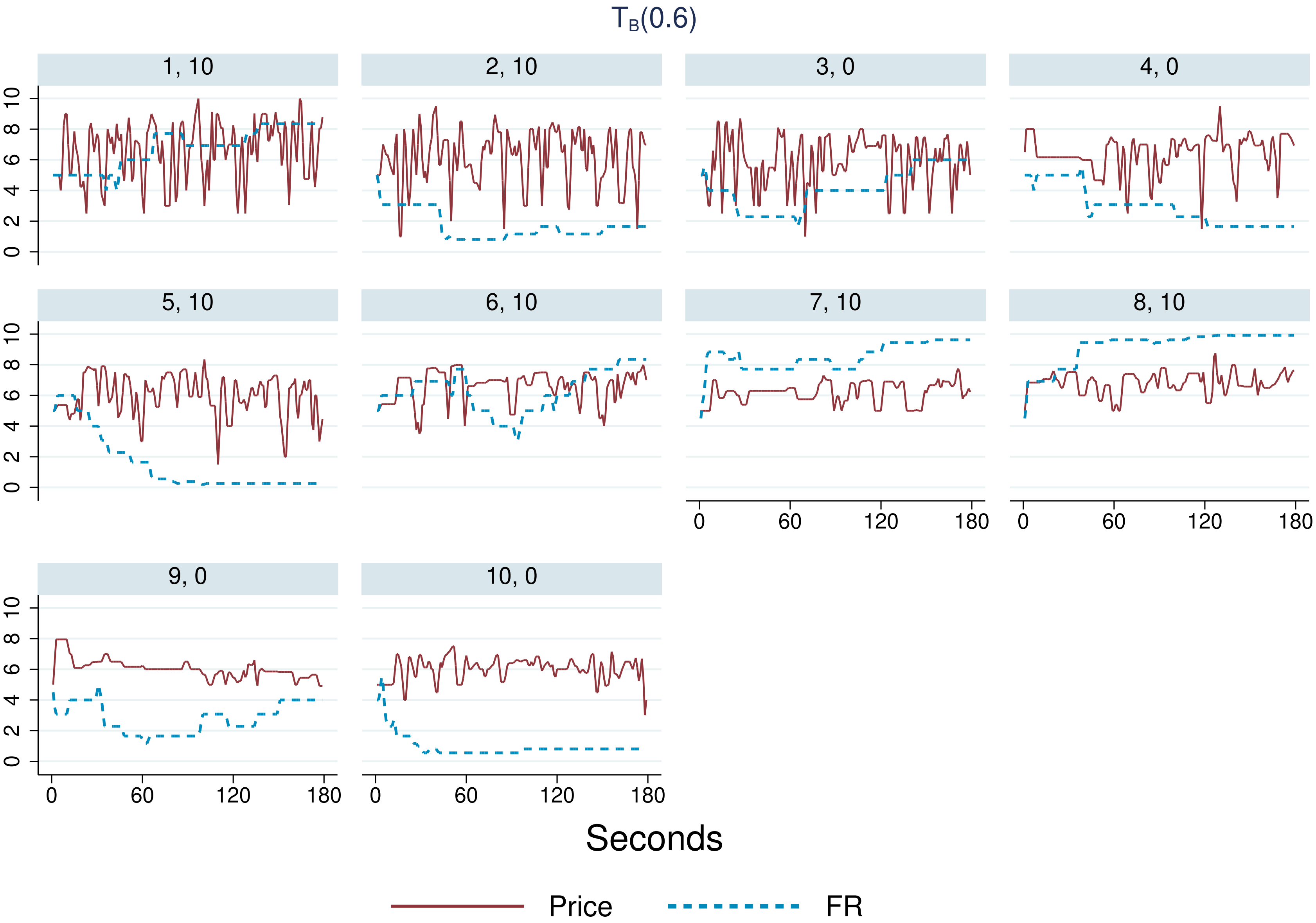

Figure 6: Markets Treatment T(0.6) (Group 2): Private signal with $p = 0.6$.

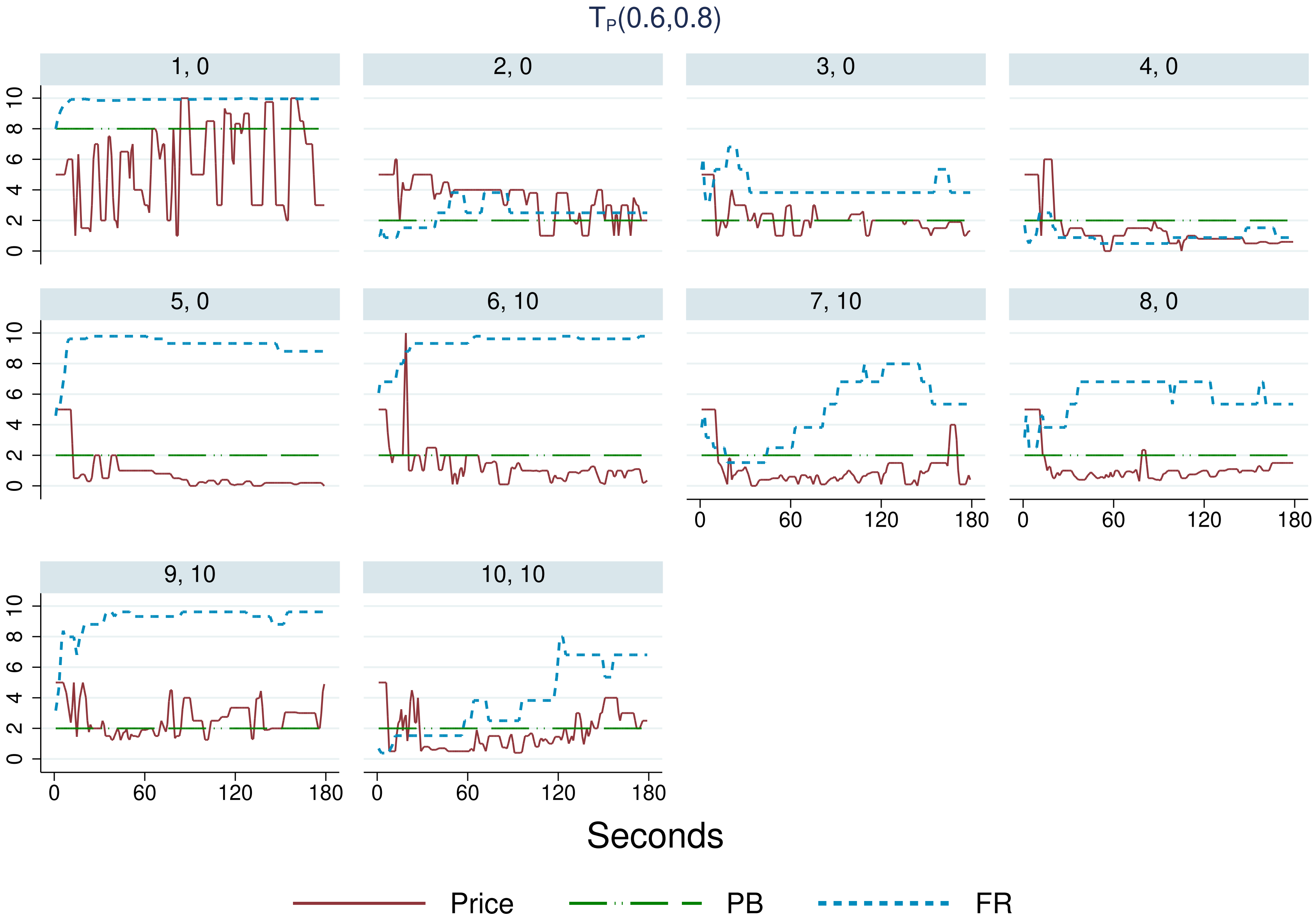

Figure 7: Markets Treatment $T_P(0.6,0.8)$ (Group 1): Private signal with $p = 0.6$ and public signal with $P = 0.8$.

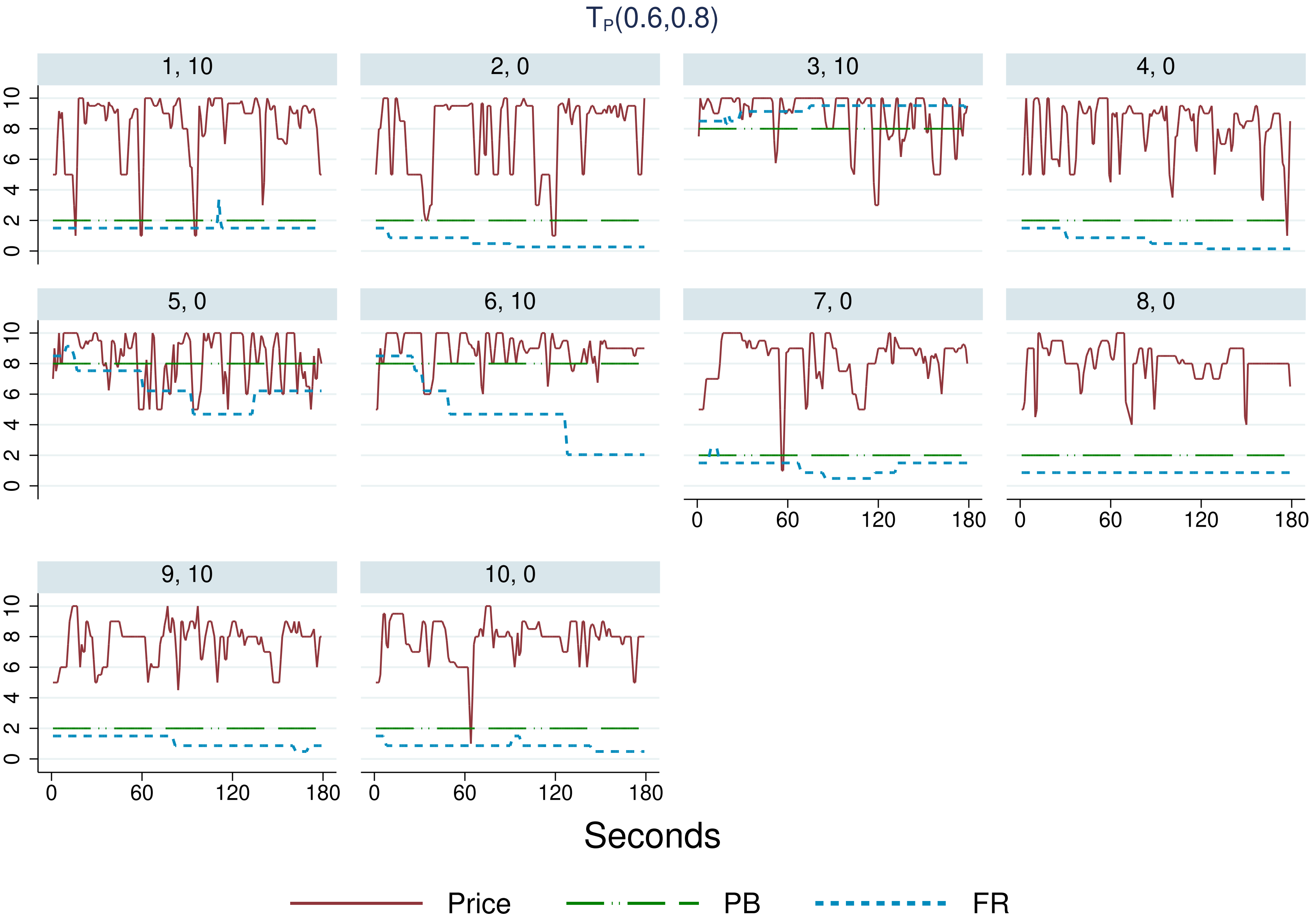

Figure 8: Markets Treatment T$_P$(0.6,0.8) (Group 2): Private signal with $p = 0.6$ and public signal with $P = 0.8$.

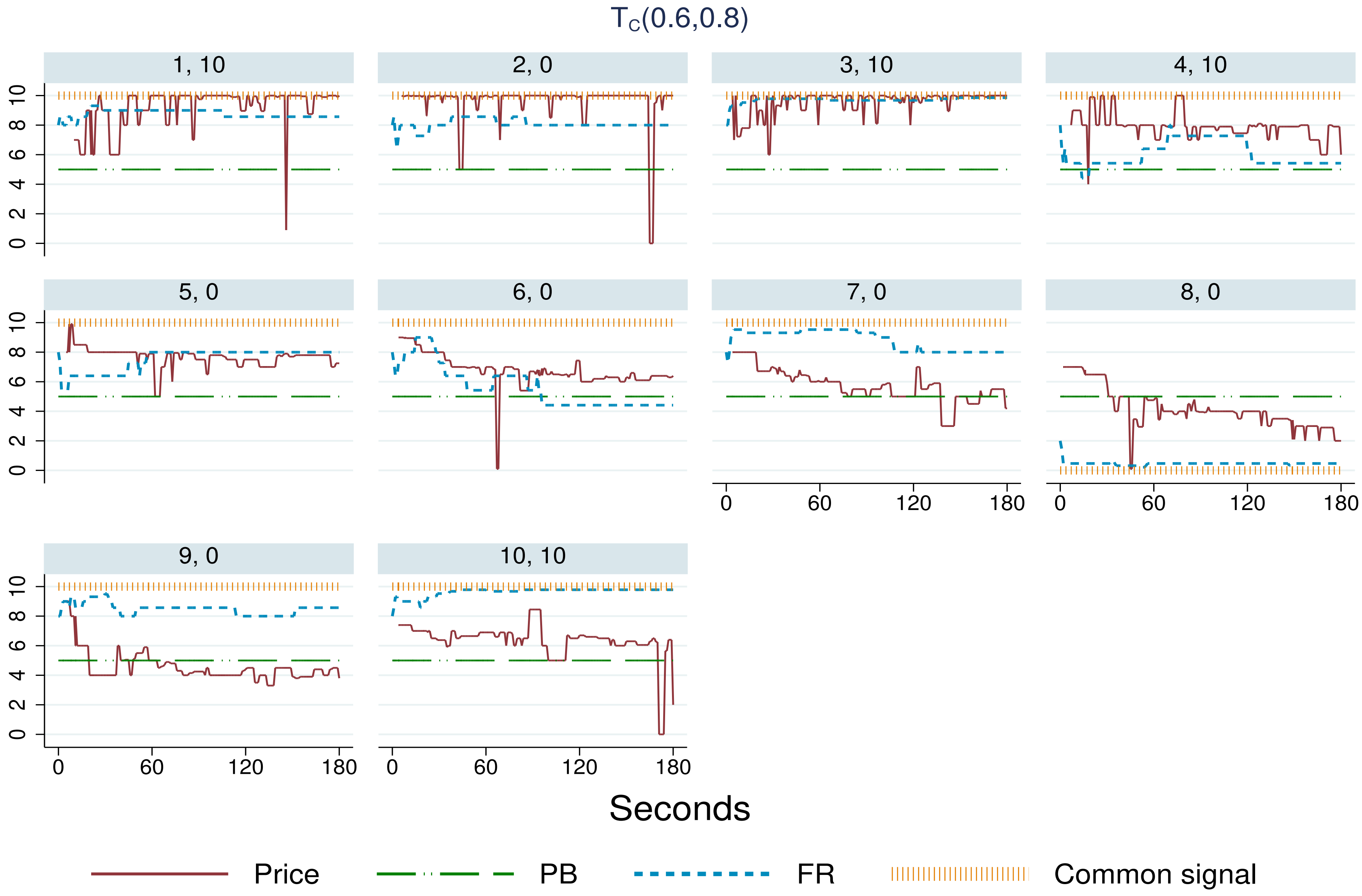

Figure 9: Markets Treatment $T_C(0.6,0.8)$ (Group 1): Private signal with $p = 0.6$ and common signal with $P = 0.8$.

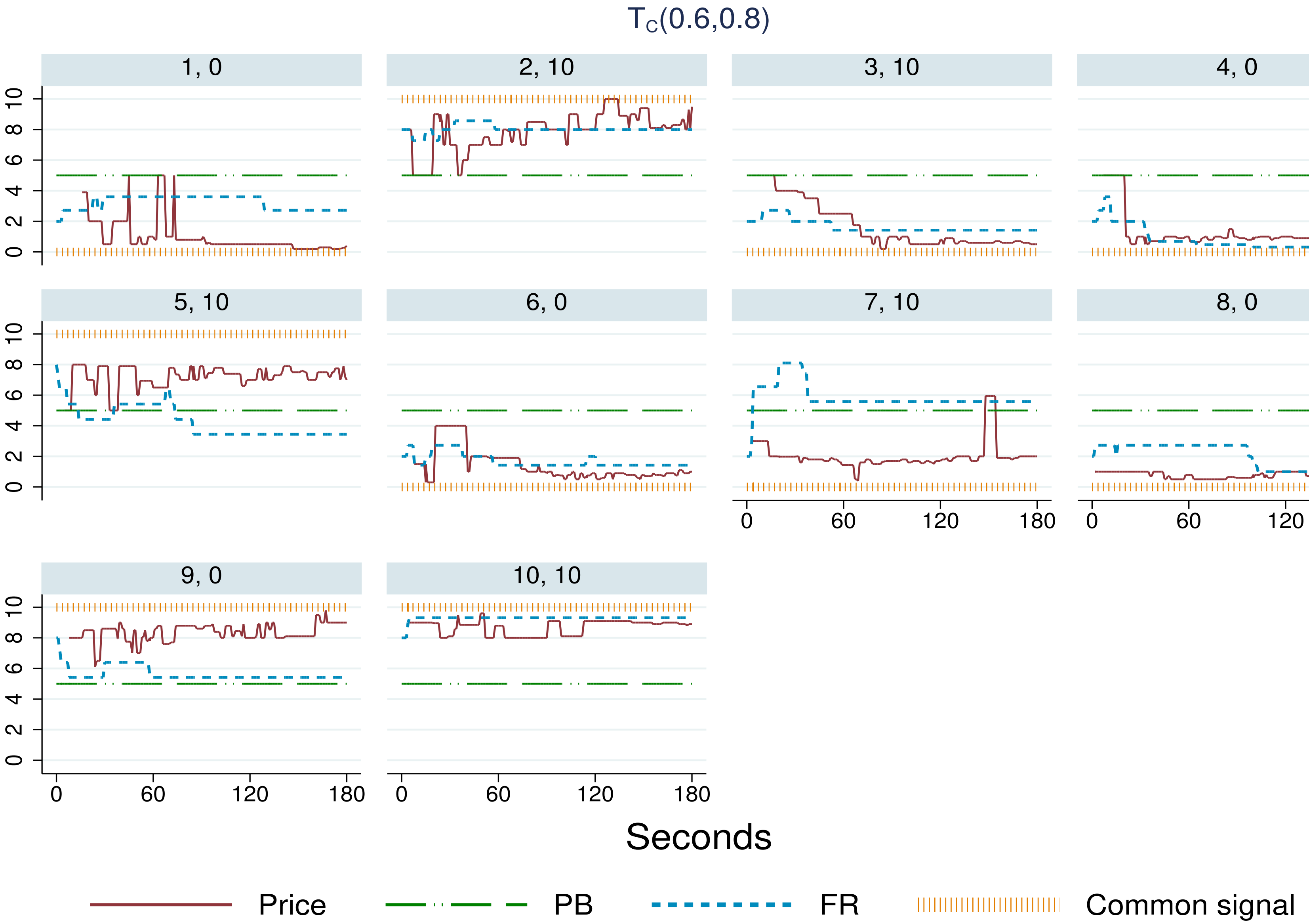

Figure 10: Markets Treatment $\mathrm{T}_C(0.6,0.8)$ (Group 2): Private signal with $p = 0.6$ and common signal with $P = 0.8$.

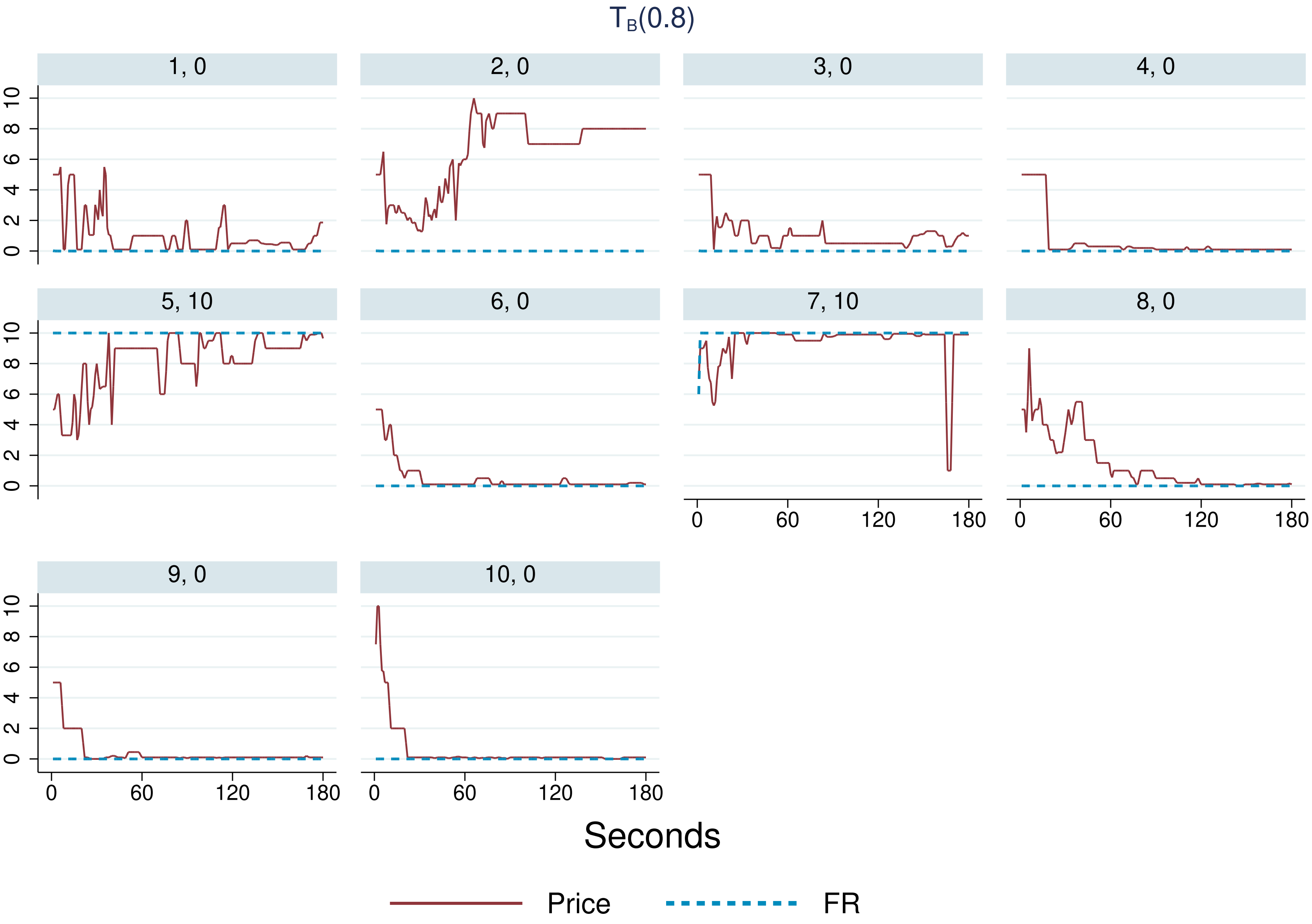

Figure 11: Markets Treatment T(0.8) (Group 1): Private signal with $p = 0.8$.

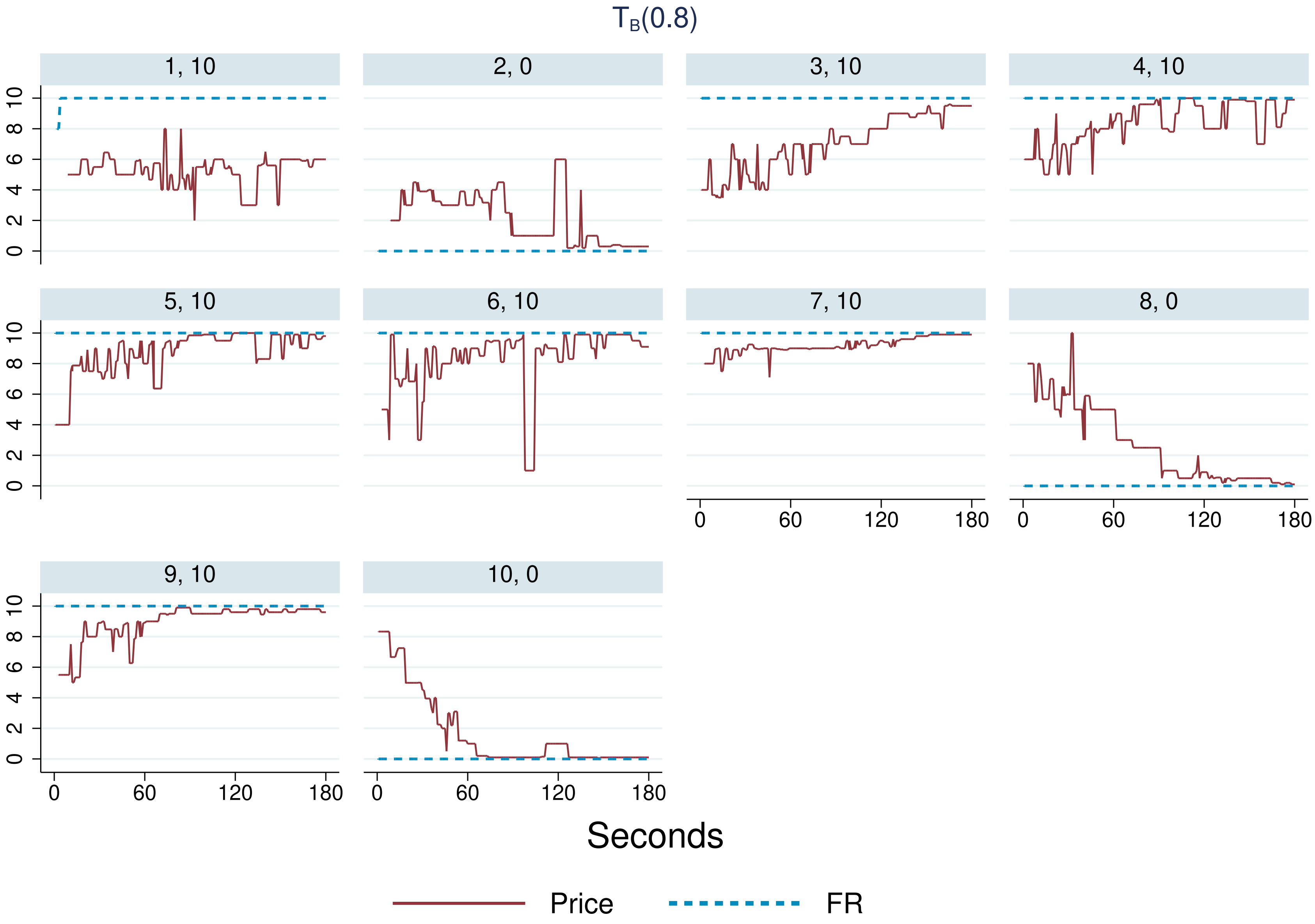

Figure 12: Markets Treatment T(0.8) (Group 2)): Private signal with $p = 0.8$.

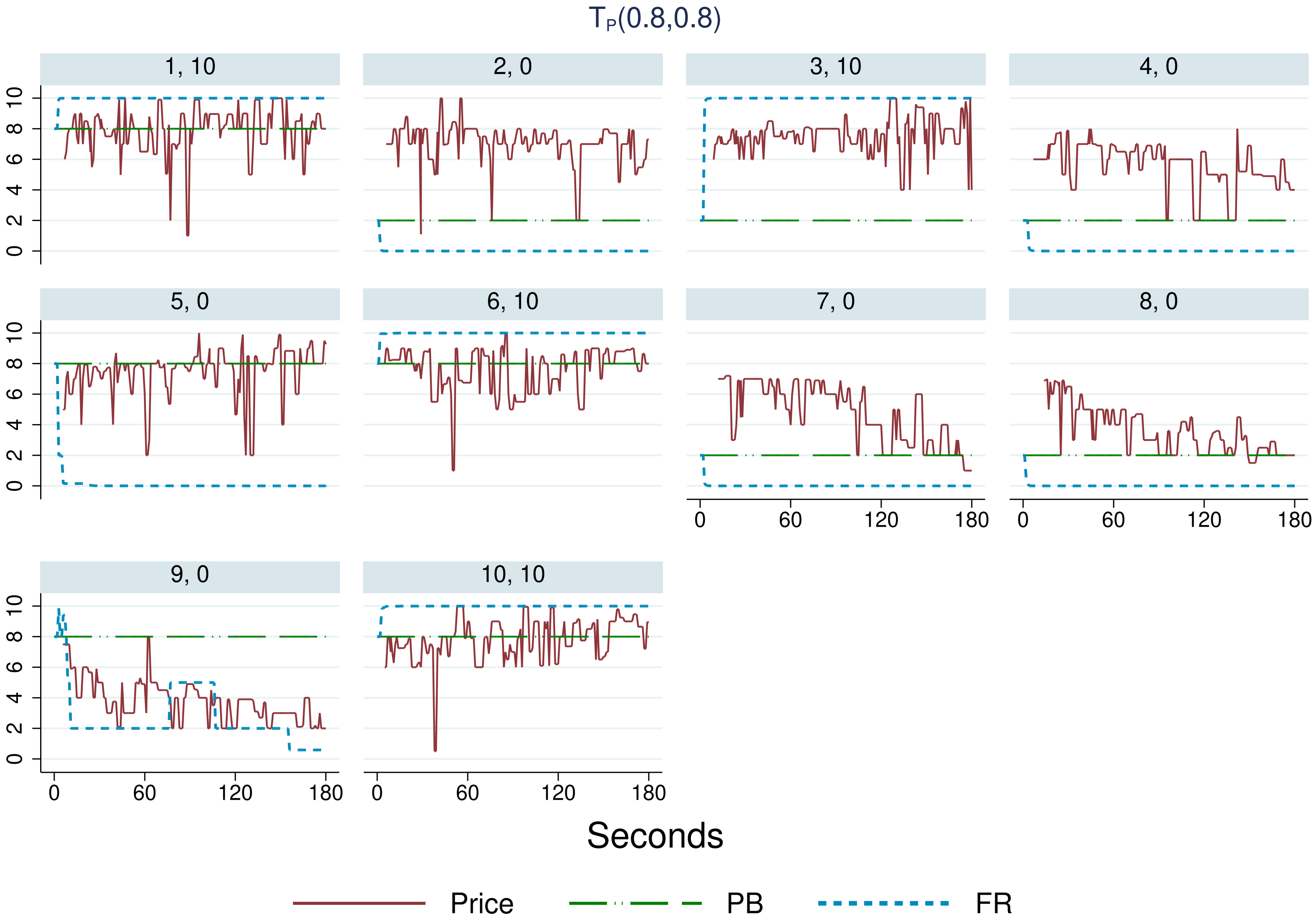

Figure 13: Markets Treatment T_P(0.8,0.8) (Group 1): Private signal with $p = 0.8$ and public signal with $P = 0.8$.

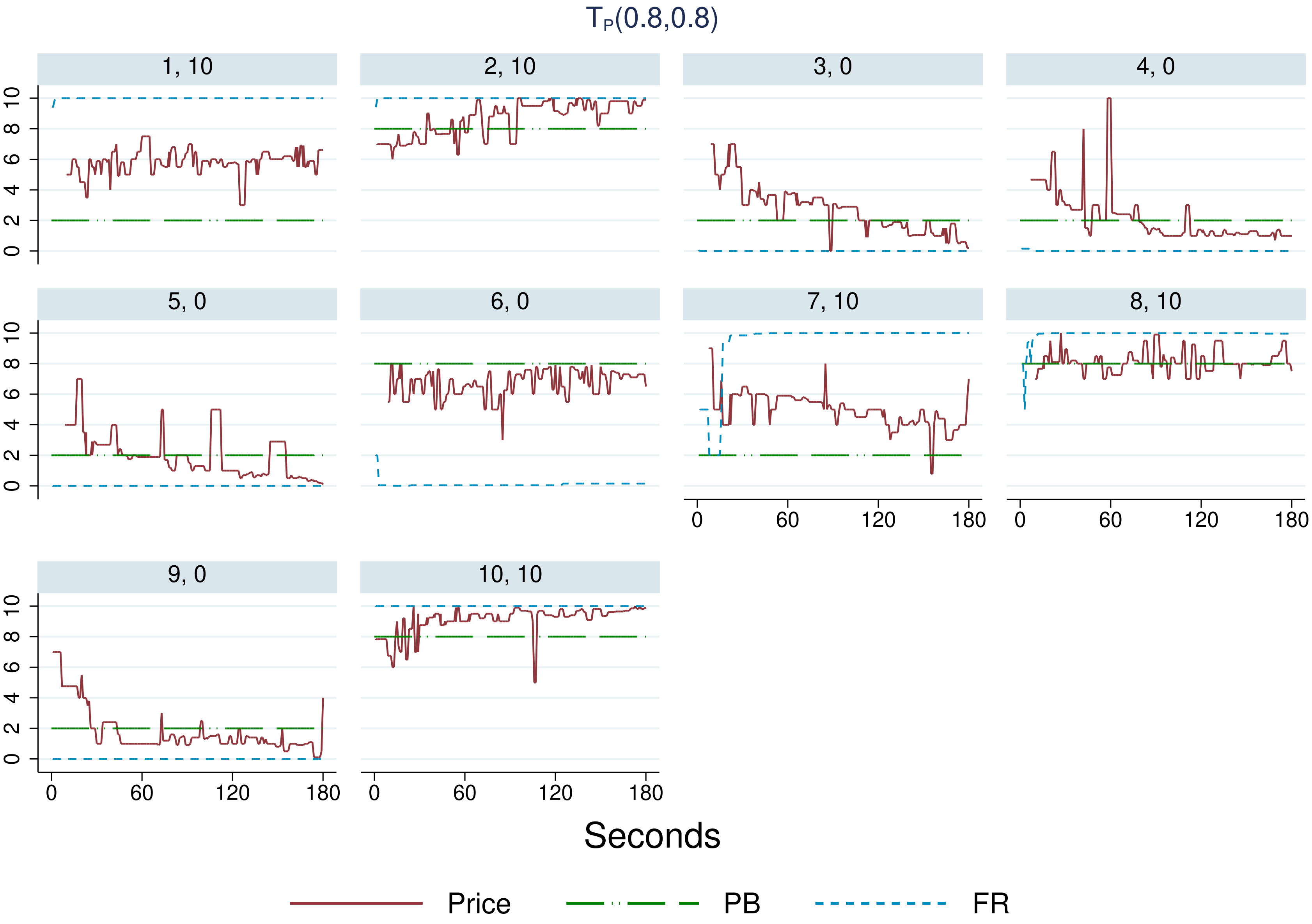

Figure 14: Markets Treatment T_P(0.8,0.8) (Group 2): Private signal with $p = 0.8$ and public signal with $P = 0.8$.

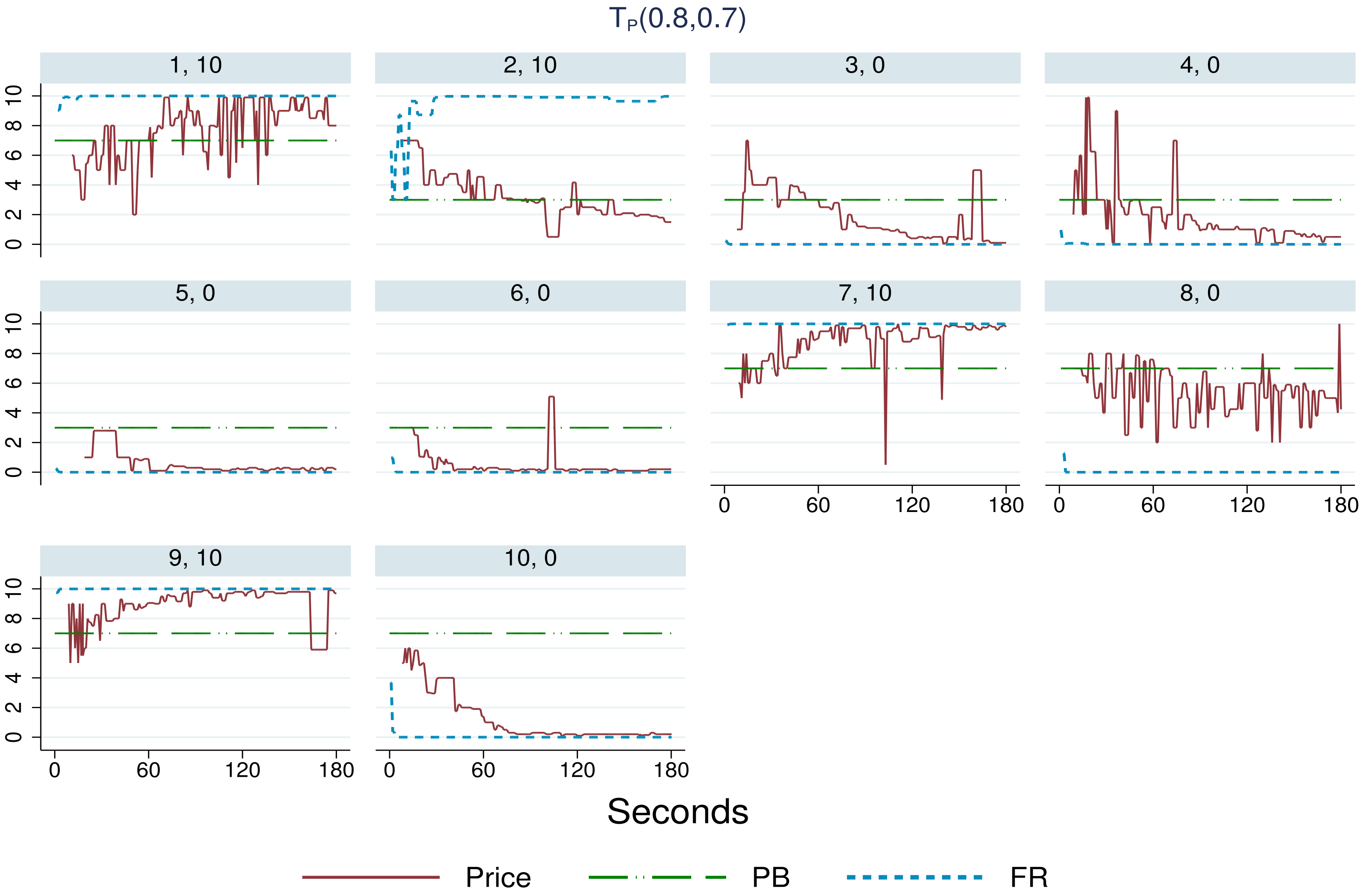

Figure 15: Markets Treatment $T_P(0.8,0.7)$ (Group 1): Private signal with $p = 0.8$ and public signal with $P = 0.7$.

Figure 16: Markets Treatment $T_P(0.8,0.7)$ (Group 2): Private signal with $p = 0.8$ and public signal with $P = 0.7$.

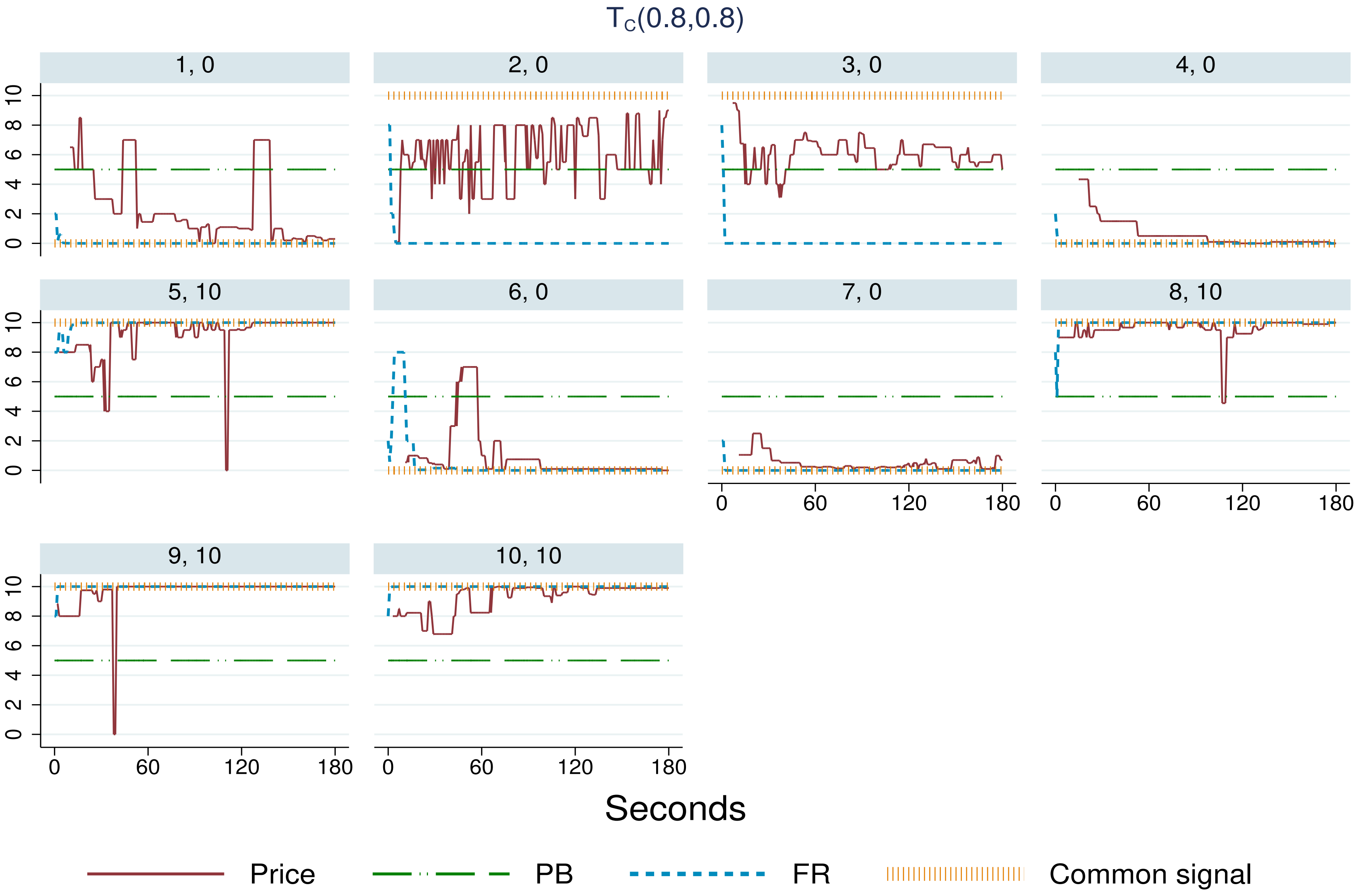

Figure 17: Markets Treatment $T_C(0.8,0.8)$ (Group 1): Private signal with $p = 0.8$ and common signal with $P = 0.8$.

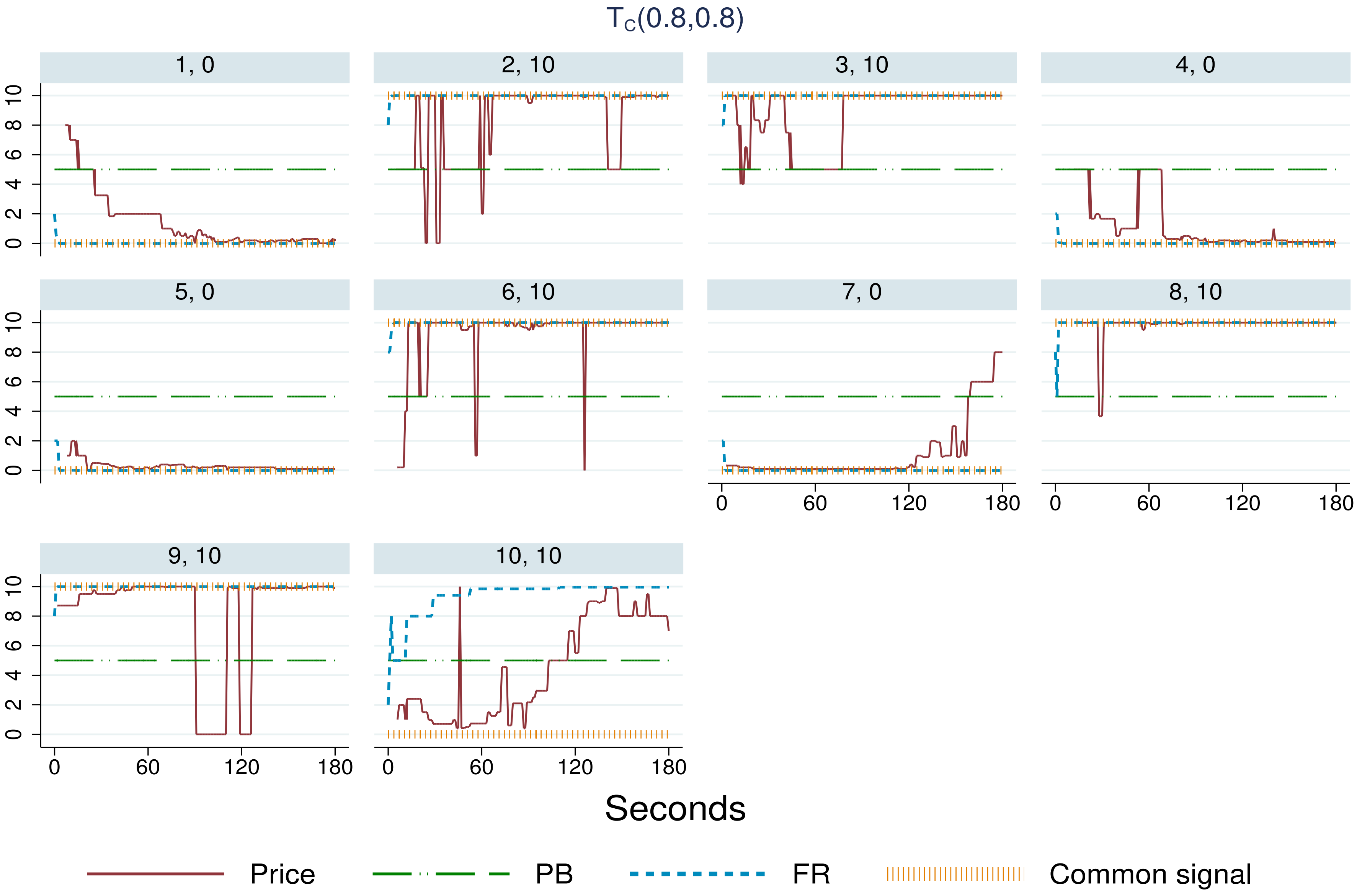

Figure 18: Markets Treatment $T_C(0.8,0.8)$ (Group 2): Private signal with $p = 0.8$ and common signal with $P = 0.8$.

Appendix B: Experimental design

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

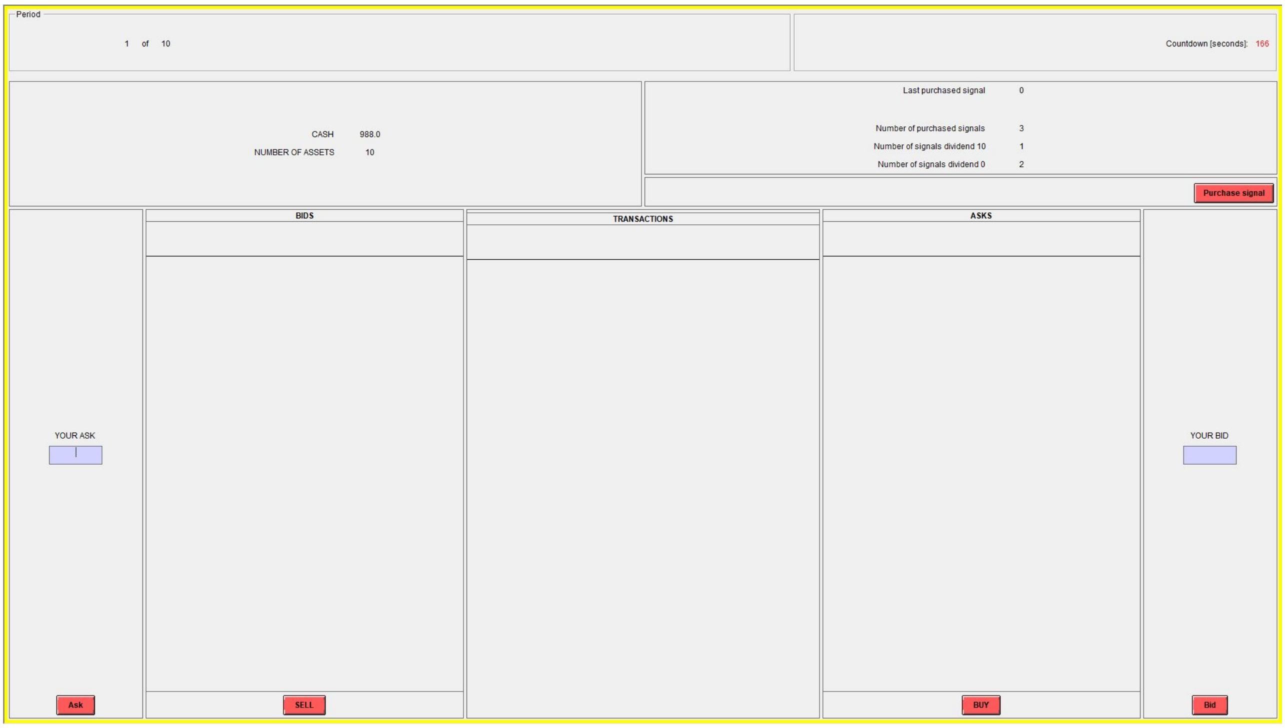

Figure 19: Screenshot of baseline treatments.

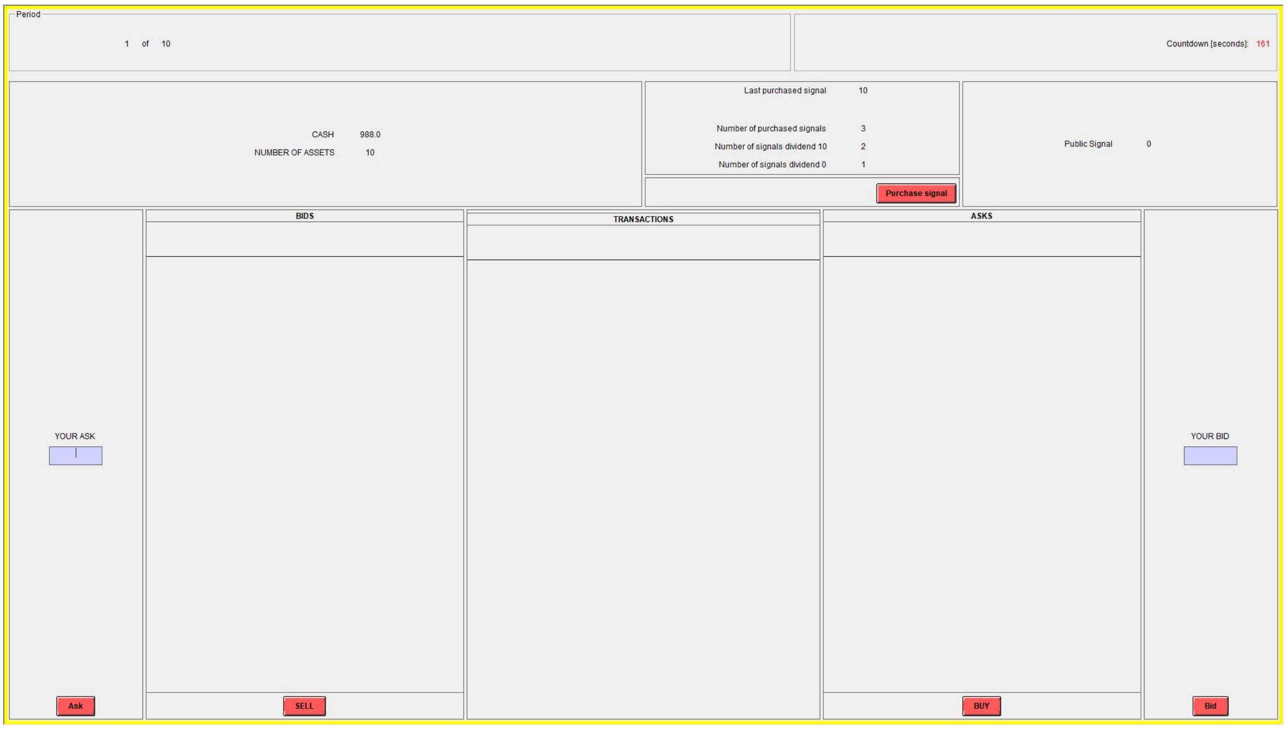

Figure 20: Screenshot of public information treatments.

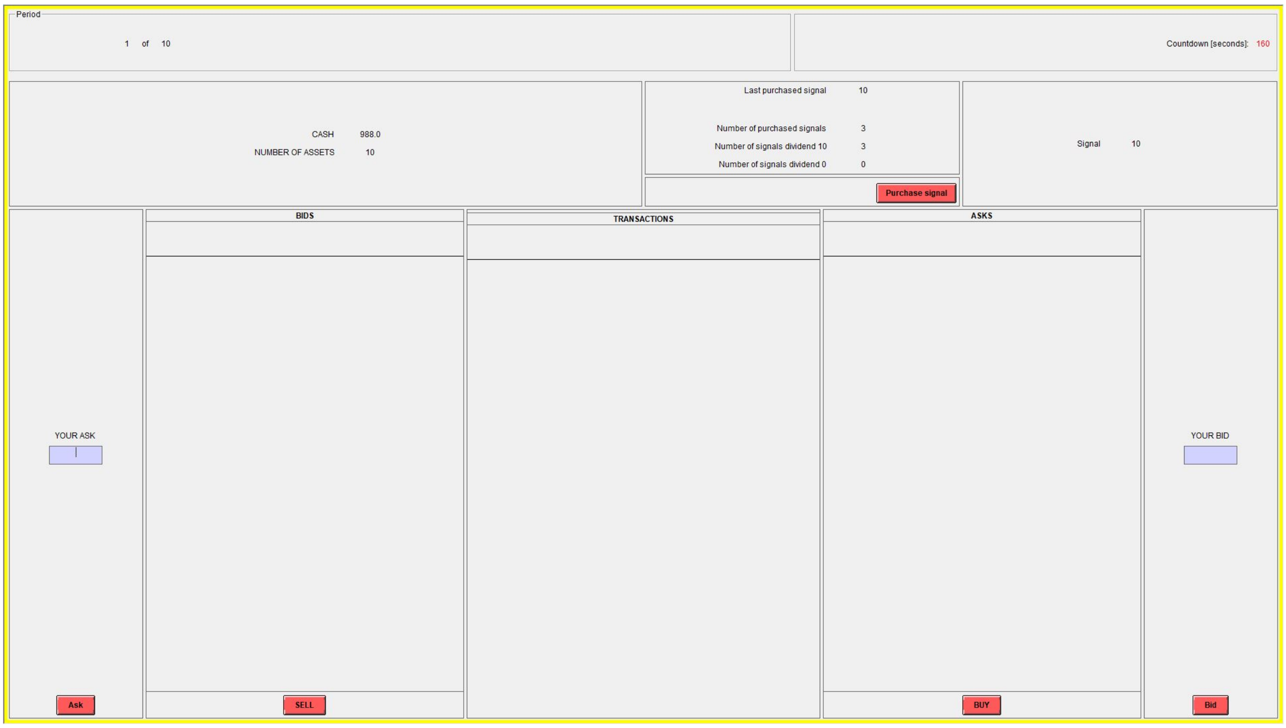

Figure 21: Screenshot of common information treatments.