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# Long-run expectations in a Learning-to-Forecast Experiment

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## Abstract

We conduct a Learning to Forecast Experiment (LtFE) using a novel setting in which we elicit subjects' short and long-run expectations on the future price of an asset. We find that: (i) the rational expectations equilibrium (REE) is not a meaningful description for subjects' expectations, (ii) which are, instead, better described by an adaptive learning scheme. (iii) Subjects exhibit a higher degree of inertia when revising long-run expectations *vis-à-vis* short-run expectations.

**JEL:** D84, E37, G12

**Keywords:** Experiment, Expectations, Coordination

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## 1. Introduction

Several contributions have stressed the importance of taking into account the whole time spectrum of agents' expectations when designing effective economic policies. In this respect, the idea of forward guidance of the central bank [7] implies a continuous monitoring of short and long-run inflation expectations of consumers and investors. The understanding of how economic

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agents revise their short and long-run expectations, therefore, is a very active research area in the empirical, theoretical and experimental literature.

In order to study the evolution of the whole spectrum of expectations, in this paper we use controlled laboratory experiments, which have the advantage of a perfect monitoring of the information available to the agents at any period of time. Few experimental papers have already elicited long-run expectations within a market environment. [1] is the first attempt to elicit long-run expectations in an asset market with bubbles. Focusing just on predictions with no trading activity, LtFEs, introduced by [5], provide a simple and manageable laboratory setting to study expectations formation. In LtFEs subjects submit (one step-ahead) predictions about future values of economic variables, typically prices, which are endogenously determined as a function of those predictions. Subjects are rewarded based on their forecast accuracy alone. The empirical evidence of LtFEs with strong positive feedback between expectations and realized market price shows a persistent coordination of short-run predictions, although not always on the REE (see [3] for a review). Behavioral adaptive rules, instead, provide a better description of the experimental results.

The aim of our paper is to incorporate into the LtFEs the elicitation of long-run expectations in order to study the dynamics of the whole time spectrum of expectations. Such modification will allow us to have a more comprehensive understanding of the agents' expectations formation mechanism.

## 2. Experimental design

In each of the 7 sessions of our LtFE, 6 subjects submit their predictions for the price of an asset for 20 periods. At the beginning of period  $t$ , subject  $i$  submits her short-run prediction for the asset price at the end of period  $t$ , denoted as  ${}_i p_{t,t}^e$ , as well as her set of long-run predictions for the price at the end of each of the  $20 - t$  remaining periods. Long-run predictions are denoted as  ${}_i p_{t,t+k}^e$  with  $1 < k \leq 20 - t$ . When submitting their predictions, subjects are informed about: (i) the constant interest rate ( $r$ ) and average dividend ( $d$ ), (ii) the asset prices until period  $t - 1$ , (iii) all their own (short and long-run) past predictions. However, they are not informed about the predictions submitted by the other subjects and have just qualitative information on the price generating mechanism: there is a positive relationship between their one-step ahead predictions and the next realized price (see the instructions). To keep our setting simple, we explicitly exclude long-run expectations from the price generating mechanism. We expect, therefore, the elicitation of subjects' long-run expectations not to have a significant impact on the price dynamics. On the

contrary, we do expect an influence of price dynamics on the formation and evolution of subjects' long-run expectations. In particular, we can study how price dynamics is incorporated in the short and long-run expectations. Do short and long-run expectations follow the same pattern? If subjects learn to coordinate their short-run expectations, as shown in the LtFEs literature, how their long-run expectations behave? Do they converge to the asset fundamental price?

Following [2], the price generating mechanism is:

$$p_t = p_f + \frac{1}{1+r}(\bar{p}_{t,t}^e - p_f) + \xi_t, \quad (1)$$

where  $p_f = \frac{d}{r}$  is the asset fundamental value, which constitutes the REE.  $\bar{p}_{t,t}^e = \frac{1}{6} \sum_{i=1}^6 {}_i p_{t,t}^e$  is the average of individual short-run predictions and  $\xi_t \sim N(0, 0.25)$  is an iid Normal shock. Individual earnings at the end of each period depend on both, short and long-run prediction errors and are computed as  ${}_i \pi_t = {}_i \pi_t^s + {}_i \pi_t^l$ . We denote as  ${}_i \pi_t^s$  the subject payoff that depends on her short-run prediction error:

$${}_i \pi_t^s = \frac{250}{1+\beta} \quad \text{with} \quad \beta = \left( \frac{{}_i p_{t,t}^e - p_t}{2} \right)^2 \quad (2)$$

and as  ${}_i \pi_t^l$  the subject payoff that depends on long-run predictions error. We define  ${}_i \pi_t^l = \sum_{j=1}^{t-1} {}_i \pi_{t-j,t}^l$ , where  ${}_i \pi_{t-j,t}^l$  represents the individual profit associated with the accuracy of the prediction submitted by subject  $i$  at the beginning of period  $t-j$  about the asset price in period  $t$ , where  $1 \leq j \leq t-1$ . It is computed according to the following payment schedule:<sup>3</sup>

$${}_i \pi_{t-j,t}^l = \begin{cases} 25 & \text{if } {}_i \delta_{t-j,t} \leq 5 \\ 12 & \text{if } {}_i \delta_{t-j,t} \leq 10 \\ 5 & \text{if } {}_i \delta_{t-j,t} \leq 15 \\ 0 & \text{otherwise} \end{cases}$$

where  ${}_i \delta_{t-j,t} = |{}_i p_{t-j,t}^e - p_t|$ . The final payment of each subject is the sum of payoffs across all periods.<sup>4</sup> Note that subjects have an immediate feedback about the accuracy of their short-run predictions, while they experience a delay in evaluating the accuracy of their long-run predictions.

The experiment involved 42 undergraduate students and it was conducted in the Laboratory of Experimental Economics at University Jaume I. Each session lasted approximately 40 minutes and the average gain was 20 Euro.

<sup>3</sup>We used a payoff mechanism similar to [1].

<sup>4</sup>We calibrated the parameters of the payoff functions such that approximately  $\max \sum_{t=1}^{20} {}_i \pi_t^s = \max \sum_{t=1}^{20} {}_i \pi_t^l$ , in order to give to the subjects the same incentive to provide accurate predictions in the short and in the long-run.

### 3. Results

Figures 1 and 2 show the evolution over time of the asset price and individual short and long-run predictions, respectively.<sup>5</sup> The qualitative properties of the dynamics of short-run predictions are in line with the literature of LtFEs (See [2]): (i) a strong coordination of the individual short-run predictions after few periods; (ii) a slow convergence of the price towards the fundamental value, following a monotonically or oscillatory pattern. As expected, we observe that eliciting long-run expectations does not affect the dynamical properties of short-run expectations, and therefore, the price dynamics.

#### 3.1. Coordination and convergence

As a measure of coordination of expectations, we use the (within-group) variance of individual predictions at a given time horizon. Figure 3 shows the evolution over time of the average variance of individual predictions for two different time horizons: one-step-ahead and 5-steps-ahead.<sup>6</sup> We clearly observe that the coordination of short and long-run expectations increases over time. However, we find a lower level of consensus among subjects concerning their long-run predictions as compared to their short-run predictions.

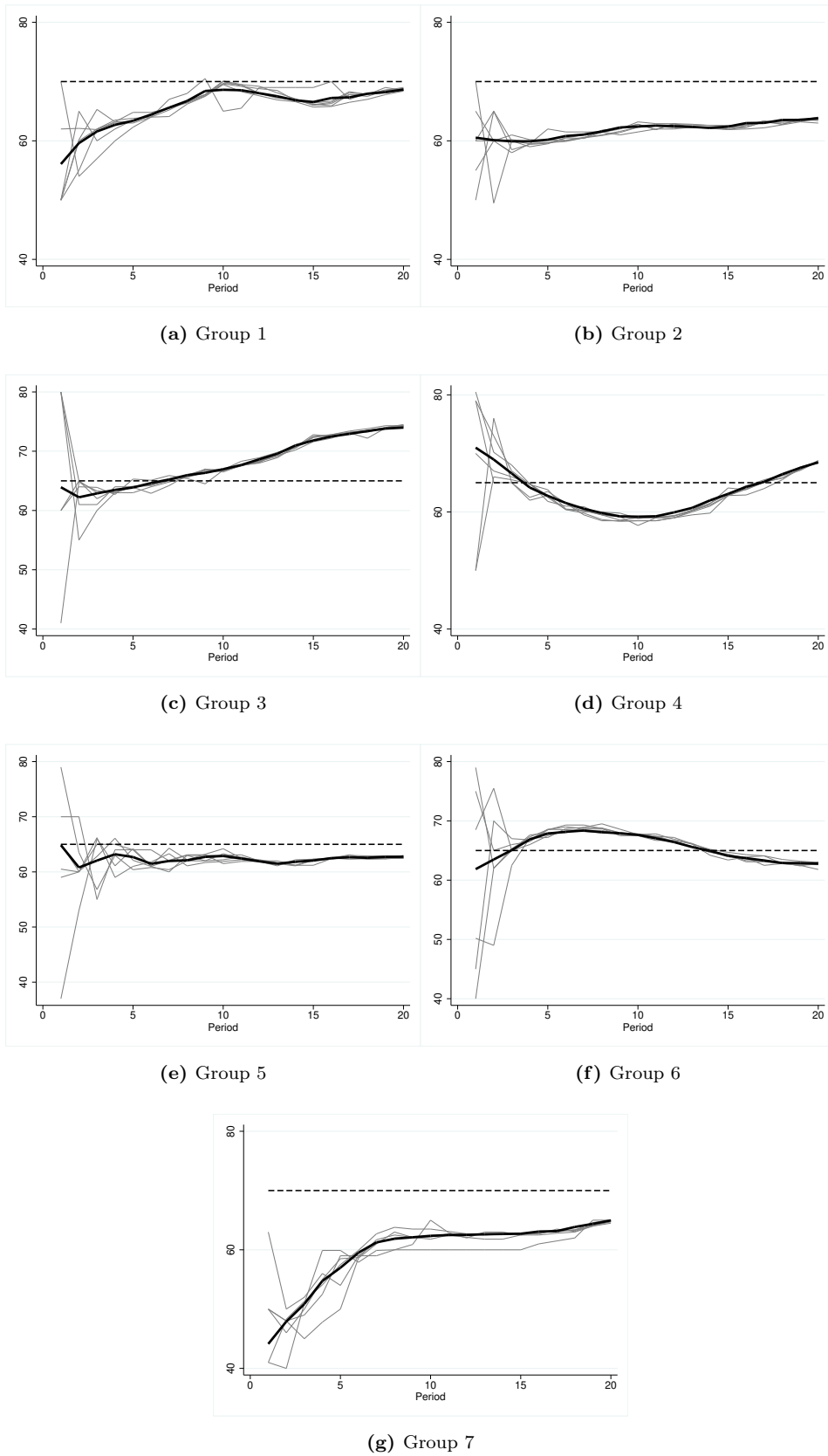
To measure the convergence of subjects' expectations to REE, we use their Relative Mean Square Deviation (RMSD) from the asset fundamental value. Figure 4 shows a slower convergence of long-run expectations, measured as subjects' predictions of the price at the end of period 20, compared to short-run predictions. The dispersion of subjects' expectations within a group is consistently lower than the deviation of the price from REE. We conclude, then, that the REE does not provide a particularly accurate description of subjects' expectations neither for short-run nor for long-run expectations.

If it is known in the LtFE literature that subjects' short-run expectations coordinate but not necessarily to the fundamentals. We generalize those results showing that long-run expectations exhibit similar characteristics. However, both the degree of coordination and convergence of long-run expectations is systematically lower compared to short-run expectations.

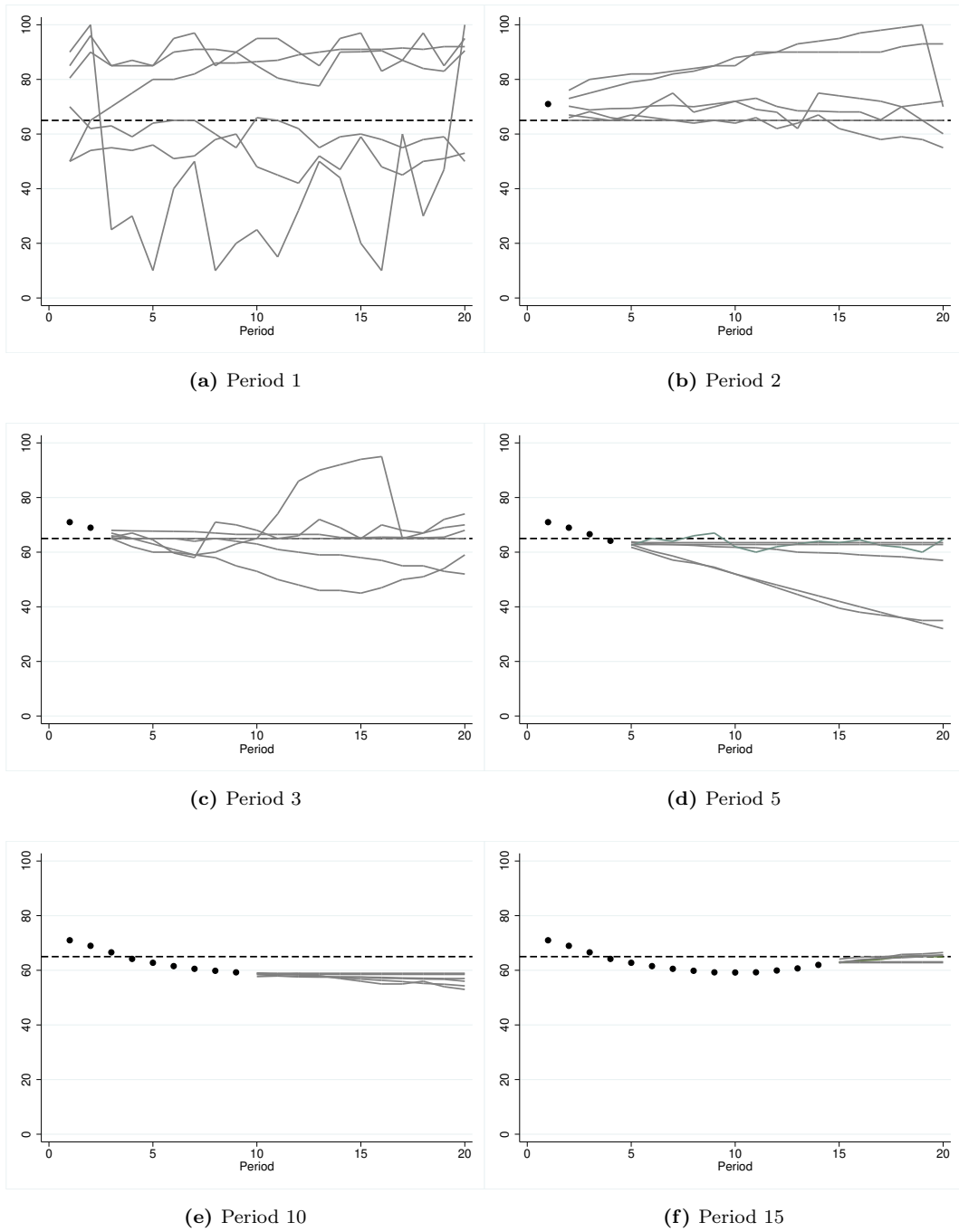
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<sup>5</sup>In Figure 2 we show one group as an example, since the qualitative features of the other groups are very similar.

<sup>6</sup>We choose 5 periods as a good compromise between having sufficient number of observations and a sufficiently long time horizon for the subjects' predictions.



**Figure 1:** Time series of prices (thick line), short-run individual predictions (thin lines) and asset fundamental value (broken line) per group.



**Figure 2:** Prices (dots), the asset fundamental value (broken line) and long-run individual predictions (lines) submitted in periods 1, 2, 3, 5, 10 and 15 of Group 4. The horizontal axis in each panel represents the prediction time horizon.

### 3.2. Expectations' formation

In this section we provide with a tentative behavioral explanation for the empirical identified asymmetry between the dynamics of short and long-run expectations. Our results on coordination of expectations and convergence to the fundamentals allow us to conjecture that, when forming their expectations, subjects give different weights to the available information depending on the forecasting horizon. In order to formalize and test our conjecture, we estimate a GMM dynamic panel, regressing short and long-run individual expectations on past prices and past individual predictions. We distinguish between short and long-run explanatory variables. As a proxy for the subjects' long-run expectations in period  $t$ , we consider  ${}_i\bar{p}_{t,t+5}^e = (1/5) \sum_{k=1}^5 {}_i p_{t,t+k}^e$ , which is the moving average of the expected prices for the next 5 periods. As a proxy for the recent past dynamics of prices, we use  $\bar{p}_{t-2,t-6} = (1/5) \sum_{j=2}^6 p_{t-j}$ , which is the moving average of past prices considering a time window of 5 periods.<sup>7</sup>

From the results of our regression in Table 1, we infer that subjects short-run predictions follow a simple linear adaptive rule anchored in the last realized price, where the learning component depends on short-run variables only:<sup>8</sup>

$${}_i p_{t,t}^e = p_{t-1} + \hat{\alpha} ({}_i p_{t-1,t-1}^e - p_{t-1}) \quad \text{where } \hat{\alpha} = 0.38. \quad (3)$$

Turning to the long-run expectations formation, our results show that subjects follow again an adaptive rule anchored in the last realized price, where the learning component depends now only on long-term prediction variables:

$${}_i \bar{p}_{t,t+5}^e = p_{t-1} + \hat{\gamma} ({}_i \bar{p}_{t-1,t+4}^e - \bar{p}_{t-2,t-6}) \quad \text{where } \hat{\gamma} = 0.6. \quad (4)$$

Although subjects use an adaptive learning scheme independently of the forecasting horizon, the learning parameters are significantly different, i.e.  $\hat{\gamma} > \hat{\alpha}$ . This asymmetry can be related to the different coordination dynamics of short and long-run expectations (see Figure 3). We can use eqs. (3) and (4) to compute recursively the time evolution of the variances of short- and long-run predictions within a group:

$$\text{Var}[_i p_{t,t}^e] = \hat{\alpha}^2 \text{Var}[_i p_{t-1,t-1}^e] + \hat{\sigma}_\eta^2, \quad (5)$$

$$\text{Var}[_i \bar{p}_{t,t+5}^e] = \hat{\gamma}^2 \text{Var}[_i \bar{p}_{t-1,t+4}^e] + \hat{\sigma}_\epsilon^2, \quad (6)$$

<sup>7</sup>Note that, in the moving average  $\bar{p}_{t-2,t-6}$ , we exclude  $p_{t-1}$  to avoid collinearity problems in the regression.

<sup>8</sup>Since we cannot reject the null hypothesis that (a)+(b)=1 (see Table 1), the value of  $\hat{\alpha}$  is computed as  $0.5[(1 - 0.68) + 0.43]$ .



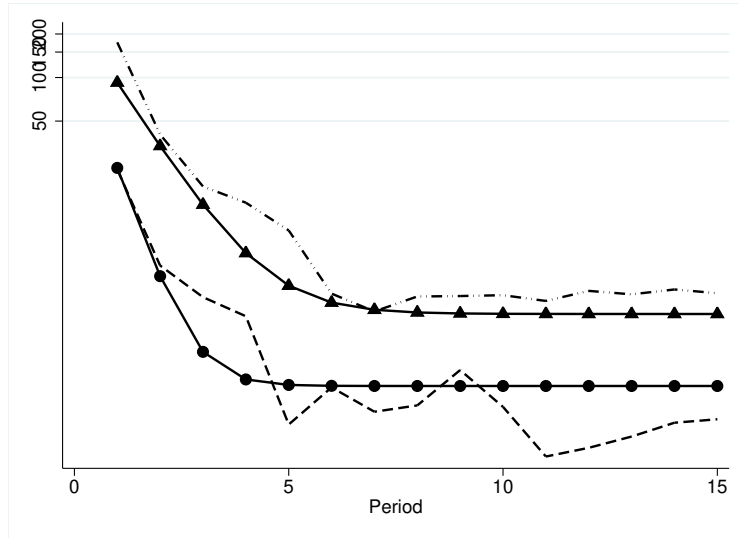
where  $\hat{\sigma}_\eta^2$  and  $\hat{\sigma}_\varepsilon^2$  are the estimated variances of the error term of the regressions in Table 1. Figure 3 shows the good qualitative agreement between our theoretical prediction, derived from eqs. (5) and (6), and the experimental data, confirming that the estimated adaptive rules, described in eqs. (3) and (4), do capture relevant structural elements of the subjects' expectation formation mechanism.

**Table 1:** Estimation results

	Short-run ( ${}_i p_{t,t}^e$ )		Long-run ( ${}_i \bar{p}_{t,t+5}^e$ )	
	Coefficient	(p-value)	Coefficient	(p-value)
(a) ${}_i p_{t-1,t-1}^e$	0.43**	(0.02)	0.05	(0.89)
(b) $p_{t-1}$	0.68**	(0.02)	0.79**	(0.03)
(c) ${}_i \bar{p}_{t-1,t+4}^e$	-0.01	(0.94)	0.67***	(0.00)
(d) $\bar{p}_{t-2,t-6}$	-0.13	(0.31)	-0.52***	(0.00)
N	420		210	
AR(1)	-1.76	(0.07)	-2.89	(0.06)
AR(2)	-1.43	(0.15)	1.64	(0.10)
Sargan	8.52	(0.29)	27.65	(0.7)
Hansen	2.81	(0.9)	0.15	(1.00)
$H_0$	$(a) + (b) = 1$		$(c) =  (d) $	
F-test	0.1	(0.75)	1.42	(0.23)
$\sigma$	$\hat{\sigma}_\eta = 0.51$		$\hat{\sigma}_\varepsilon = 1.21$	

#### 4. Discussion and conclusion

Our results show that subjects' expectations are not consistent with the REE, neither in the short nor in the long-run. Subjects expectations, instead, can be described using an adaptive learning scheme. Interestingly, subjects' predictions are centered in the last price, independently of the horizon. The last realized price constitutes, then, a time-varying anchor or, using the terminology of [6], a focal point for subjects' expectations coordination. Moreover, when revising their expectations, subjects consider their past prediction errors computed within time window "proportional" to their prediction horizon, see eqs. (5) and (6). Interestingly, we observe a significantly asymmetry in the speed of adjustment ( $\hat{\alpha} < \hat{\gamma}$ ), which ultimately is responsible for



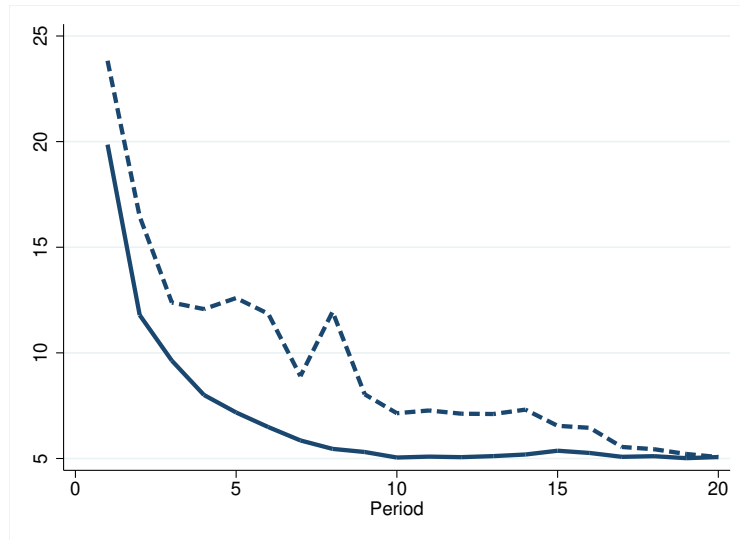
**Figure 3:** Average variance of subjects' predictions within a group in the short and the long-run in a log-linear scale.

the lower level of consensus of subjects' long-run expectations. This asymmetric adjustment could be a consequence of the fact that subjects experience an immediate feedback on the accuracy of their short-run predictions, while there is a delay when evaluating the accuracy of their long-run predictions. These results are also compatible with a sticky information framework ([4]) where the degree of stickiness depends on the prediction horizon. An alternative explanation can be cast into a modified version of the heuristic switching model (see [3]) which accounts for the long-run expectations dynamics. All those issues are the focus of current research.

We believe that our novel experimental setting is a valuable tool to study the whole time spectrum of subjects' expectations and test different hypotheses on expectations formation. Future research will be devoted to conduct experiments where new information at the disposal of subjects is not limited to the time series of prices, but includes other information sources, such as aggregate information on subjects' long-run expectations, public announcements of policy measures or future changes of the fundamentals.

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**Figure 4:** RMSE of the individual short and long-run predictions.

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