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Expectations structure in asset pricing experiments

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Expectations structure in asset pricing experiments

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Abstract

Notwithstanding the recognized importance of traders' expectations in characterizing the observed market dynamics, for instance the formation of speculative bubbles and crashes on financial markets, little attention has been devoted so far by economists to a rigorous study of expectation formation in the laboratory.

In this work we describe a laboratory experiment on the emergence and coordination of expectations in a pure exchange framework. We largely base our study on previous experiments on expectation formation in a controlled laboratory environment by Cars Hommes, Joep Sonnemans, Ian Tuinstra and Henk van de Velden (2002a).

We consider a simple two asset economy with a riskless bond and a risky stock. Each market is composed of six experimental subjects who act as financial advisors of myopic risk-averse utility maximizing investors and are rewarded according to how well their forecasts perform in the market. The participants are asked to predict not only the price of the risky asset at time $t+1$, as in Hommes et al. (2002a), but also the confidence interval of their prediction, knowing the past realizations of the price until time $t-1$. The realized asset price is derived from a Walrasian market equilibrium equation, unknown to the subjects, with feedback from individual forecasts. Subjects' earnings are proportional to the increase in their wealth level. With respect to previous experiments that did not include an explicit evaluation of risk by participants, we observe a higher price volatility, a decreased likelihood of bubble dynamics and, in general, a higher heterogeneity of predictions.

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1 Introduction

It is by now largely acknowledged that investors' expectations play a key role in the formation of speculative bubbles and crashes on financial markets. However, notwithstanding the recognized importance of trying to asses the dynamics that govern the formation of expectations and their response to information and experience, little attention has been devoted so far by economists to a rigorous study of expectation formation in the laboratory.

There are several experimental studies on asset markets (see, among others, King et al. (1993), Noussair et al. (2000), Porter and Smith (1995), Smith et al. (1988), Smith et al. (2000). However, most of these studies' main focus is the process of trading and the way in which trading activity itself may push prices far above or below the asset's fundamental value, although in several cases information about the participants' expectations is collected as well (see Sunder (1995) for a review).

In this work we describe a simple laboratory experiment on the emergence and coordination of expectations in a financial market, in which no trading takes place and in which subjects' only task is to form predictions about the future return of an asset and give a confidence range of their prediction. We largely base our study on a previous experiment of this type by Hommes et al. (2002a,b) on expectation formation in a controlled laboratory environment. In their experiment, each market is composed of six experimental subjects who are asked to predict the price of a risky asset at time t+1 knowing the past realizations of the price until time t-1, the mean dividend at each period and the risk-free interest rate. Subjects' earnings are a function of their forecasting errors, and the realized asset price is derived from an unknown market equilibrium equation with feedback from individual forecasts. The authors find out that in most markets prices diverge significantly from the (constant) fundamental value; moreover, speculative bubbles emerge endogenously due to *positive feedback expectations.* Finally, subjects belonging to the same market tend to coordinate on a common prediction strategy.

We replicate their experimental design but changing some important features. First and most importantly, we ask our subjects to predict not only the future price of the asset, but also the confidence interval of their prediction, which we use as an estimate of the forecasted variance of the returns. In this way subjects are asked to provide an estimation of the risk associated with their prediction and we are recreating a framework that is more similar to the ones really faced by financial advisors. We believe that adding information about the forecasted variance in the model may affect the dynamics observed in the experimental market compared to the baseline case of Hommes et al. (2002a,b).

Secondly, in our experiments a subject's earnings do not depend on his forecasting errors, but are proportional to the increase in the wealth level of a hypothetical investor (played by the computer program) who makes trading decisions according to a mean-variance approach taking as inputs the subjects' forecasts and acting with the time horizon of one step. In other words, experimental subjects act as financial advisors of myopic risk-averse utility maximizing investors and are rewarded according to how well their forecasts perform in the market. This experimental design allows us to focus exclusively on the dynamics of subjects' expectations, as in the original experiment by Hommes et al; in fact, our subjects are not engaged in any trading, which is done automatically by the computer program on the basis of the predictions they provide; however, the payoff assignment rule that we adopt is more correspondent to what happens in real financial markets, where prediction accuracy only matters inasmuch as it leads to 'correct' trading decisions.

Finally, we inform subjects of the positive feedback mechanism governing the dynamics of price. In particular, subjects know that the price at time t is a positive function of all market participants' forecasted returns at time $t + 1$, and a negative function of the forecasted variability of the predicted returns. Subjects are also informed about the way in which the computer program calculates their personal demand functions for shares on the basis of their predictions, and on the nature of the asset pricing equation. In other words, subjects know that the price level at each time step - and the corresponding return - is generated by their own forecasting activity in a deterministic way. With such additional information, there is the possibility for groups to coordinate on a common expectation strategy. Section 2.1 and Section 3 respectively describe our model of asset pricing and our experimental design and implementation. Section 4 discusses the results and Section 5 offers some concluding remarks.

2 The Model

As previously said, participants in our experiment are asked to act as financial advisors for mean-variance utility maximizer speculators with a short (one time step) time horizon. We consider a simple economy with one risky stock paying constant dividend D at each trading round and a riskless bond with a constant return R. At each round of the experiment the participants are asked to provide prediction for the risky asset price return in the next round, i.e. for the relative price increase between the present and the next round, together with a confidence interval for their prediction. The participants prediction are then used as inputs to drive the investment decision of synthetic risk averse traders, played by the computer, that finally determine the asset price at each time step. In this section we describe the behavior of these synthetic traders in order to derive the explicit rules by which the participants' predictions about future returns do actually generate the present price. We begin by describing the traders' demand function following Bottazzi (2002) and, afterward, see how these different demand functions are merged to obtain the asset pricing equation.

2.1 Personal demand function

Let $W(t)$ be the trader wealth at the beginning of time t and let x the fraction of wealth he wants to invest in the risky asset. If the price of the asset is $p(t)$ and $A(t)$ is the number of possessed shares then $W(t)\,x = p(t)\,A(t)$.

The future trader wealth (i.e. its wealth at the beginning of the next round) depends on the future return on the stock price $h(t) = p(t+1)/p(t) - 1$ and reads

$$W(t+1; h(t)) = x\,W(t)\,(h(t) - R + D/p(t)) + W(t)\,(1+R) \tag{1}$$

where the dividends D are paid after the payment of the riskless interest R at the end of round t.

We choose as the expression of the agent utility the simplest function of the expected return and variance

$$U(t) = E_{t-1}[W(t+1)] - \frac{\beta}{2} V_{t-1}[W(t+1)] \tag{2}$$

where $E_{t-1}[.]$ and $V_{t-1}[.]$ stand respectively for the expected return and variance computed at the beginning of round t, i.e. with the information available at time $t-1$, and where β is the "risk-aversion" parameter.

Using the expression for W in (1) one obtains

$$E_{t-1}[W(t+1)] = x\,W(t)\,(E_{t-1}[h(t)] - R + D/p(t)) + W(t)\,(1+R) \tag{3}$$

and

$$V_{t-1}[W(t+1)] = x^2\,W(t)^2\,V_{t-1}[h(t)] \quad . \tag{4}$$

Substituting (3) and (4) in (2) one obtains

$$U(t) = x\,W(t)\,(E_{t-1}[h(t)] - R + D/p(t)) - x^2\,\frac{\beta}{2}\,W(t)^2\,V_{t-1}[h(t)] + W(t)\,(1+R) \tag{5}$$

whose maximum, remembering the definition of x provides the agent's demand of asset at times t, $A(t)$ that reads

$$A(t) = \frac{E_{t-1}[h(t)] - R + D/p(t)}{\beta\,V_{t-1}[h(t)]\,p(t)} \tag{6}$$

2.2 Aggregate demand and pricing equation

Consider a population of N heterogeneous traders. Let β_i (with $i \in \{1, \ldots, N\}$) the risk aversion of the i-th trader and $E_{t-1,i}$ and $V_{t-1,i}$ respectively his forecasted return and variance. If the total amount of risky asset is A_{tot} its price can be determined under the condition of reducing the excess demand to zero. One has that the price $p(t)$ must solve

$$\sum_{i=1}^{N} \frac{E_{t-1,i} - R + D/p(t)}{\beta_i \, V_{t-1,i} \, p(t)} \; = \; A_{\text{tot}} \tag{7}$$

that reduces to a second order equation whose positive root reads

$$p(t) = \frac{\bar{E}_{t-1}}{2} \; + \; \sqrt{\left(\frac{\bar{E}_{t-1}}{2}\right)^2 + \bar{D}_{t-1}} \tag{8}$$

where

$$\bar{E}_{t-1} = \sum_{i=1}^{N} \frac{E_{t-1,i} - R}{A_{\text{tot}} \, \beta_i \, V_{t-1,i}} \tag{9}$$

is an average expected excess return weighted with respect to the inverse risk and

$$\bar{D}_{t-1} = \sum_{i=1}^{N} \frac{D}{A_{\text{tot}} \, \beta_i \, V_{t-1,i}} \tag{10}$$

is the analogously weighted expected dividend.

Notice that (8) provide a positive price for the risky asset even if the average expected excess return $\bar{E}_{t-1}$ is negative. Note that the above pricing equation has been obtained without considering any budget constraint for the agents. The A_{tot} can be reabsorbed in an overall rescaling of the parameter β_i.

2.3 The skeleton of the experiment

We conducted experiments with a given number of subjects acting as advisors for identical traders, in particular having an equal degree of risk aversion β. The experiment structure can be roughly described as follows:

- each participant is asked to provide a range within which she predicts, with a high degree of probability[1], the future return will lay. Let a_i, b_i the range provided by participant $i \in \{1, \ldots, N\}$.

[1] Roughly 95%, equivalent to the 2 standard deviation range of a normal distribution

- for each participant range we compute the mid value and take it as an estimate of its forecasted return $E_i = (b_i + a_i)/2$. The forecasted variance of player i is set to $V_i = (b_i - a_i)^2/4$, i.e. the provided range is put equal to the $2 - \sigma$ range of an (assumed) underlying normal distribution.

- (8) is used to fix the present price $p(t)$, then (6) is used to determine the present market position of the synthetic trader, implied by the predictions of i-th participant, $A_i(t)$.

- once the present price is determined, from the trader's position in the previous time step $A_i(t-1)$ and from the past price $p(t-1)$ it is possible to determine the present value of her past position. The profit earned by the prediction of the i-th participant reads:

$$\pi_i(t) = A_i(t-1)\ (p(t) + D - p(t-1)(1+R)) \tag{11}$$

Notice that the total number of assets and the synthetic traders's degree of risk aversion (as measured by the parameter β) can be used to tune the impact of the forecasted variance on the price of the asset. At the end of the round t each participant receives information about: the new price $p(t)$, the new return $h(t)$, and the realized profit from the previous round π_t. In the next Section a detailed description of the experimental design is provided.

3 The experimental design and implementation

The experiment was entirely computerized and it took place in one of the computer rooms of the Computable and Experimental Economics Lab of the University of Trento on May 7, 2003. We conducted two sessions of the experiment, with three cohorts of 6 subjects each participating in the first session and two cohorts of six participants in the second session, for a total of 30 subjects, which were recruited through ads posted at the various department buildings.

Subjects were mostly undergraduate students in economics and had never participated in experiments of this type before. Before the experiment began, subjects received paper copies of the instructions which were read aloud by the experimenter to make sure that the rules of the market were common knowledge among participants[2]. In addition, a handout with a summary of the market functioning together with the specification of the relevant parameters was also given to every subject. All subjects could see each other but were prevented from looking at each other's computer screens by wooden separators. They were told that they would participate in a financial market composed of six participants in which their task was to

[2] A complete translation of the instructions given to subjects is available upon request.

predict the expected price return of a hypothetical asset and its range of variability for a total of 50 periods. Their earnings would depend on the increase in the value of an initial endowment X that they would have at the beginning of every period. Instructions explained to subjects how their given forecasts of the expected price return at time $t+1$ $E_i(t+1)$ and the confidence interval $V_i(t+1)$ would be utilized by the software to compute their personal demand function in every round, and how the sum of the personal demand functions of all six participants would determine the market price of the asset in period t. It was explained to subjects that the range V would be the interval of values that according to them would contain the forecasted return with a probability roughly equal to 95%.

Finally, instructions also explained that their earnings at the end of each period would consist of the capital gain achieved (which of course depended on the realized price return), the dividends paid and the fixed interest rate R gained on the residual of their endowment. It was made clear that there was no dependence between the investment choices made in different rounds, as a new, initial endowment X would be available to them at the beginning of every period. In other words, subjects acted as financial advisors of different investors, each of which acted as a mean-variance optimizer with a time horizon of one step.

Subjects were told that their demand of shares could be negative or zero in some rounds, meaning that they could hold short positions or invest all of their endowment in the acquisition of bonds that would yield the riskless rate R. Their final earnings would be determined by the sum of their earnings in every round, and converted into cash as follows: the participant within the group that had achieved the highest cumulative payoff would receive an amount of €25, while the participant with the minimum cumulative payoff would receive an amount of €5. All other would get a payoff proportional to the maximum achieved. Subjects were informed of the payoff assignment rule but did not have any information throughout the experiment about other participants' earnings, therefore such payoff assignment rule gave them the highest incentive to maximize their earnings. Finally, although subjects knew that the market would be composed of six participants, they did not know the identity of the other five participants.

Sessions lasted one hour and a half each. The initial endowment X was set equal to 100 experimental schillings, the risk-less interest rate R was equal to 5%, the dividend was equal to 3 schillings. Finally, the parameter β and A_{tot} were fixed respectively to the value of 100 and 1.

4 Results

In Fig. 1 we report the observed asset prices for the 5 different groups together with the asset fundamental value. As can be seen from the plots, price volatility is very high but, expect for the final rounds of groups 3 and 5, it oscillates around the fundamental value. Moreover, notice that the price increase observed in group 3 and 5 is inconsistent with an idea of rational bubble, since it does not display the expected exponential growth. Hence, these can be plausibly interpreted as "speculative" bubbles. Their appearance toward the end of the experiment is probably due to a more 'extremist' behavior of some of the participants as the end of the experiment is approaching.

The behavior of the asset price in our experiment is remarkably different from the one observed in Hommes et al. (2002a,b) with a higher volatility and a substantial lack of creation of relatively stable bubbles.

In Fig. 2 the autocorrelation structure of asset price returns for the 5 groups is shown (bold line) together with the autocorrelation of expected returns. The former is analogous in all groups except group 5, showing a tendency toward anti-correlation at 1 time lag. As far as the forecasted returns are concerned, one can notice that their autocorrelation structure is rather heterogeneous, with, however, a general tendency toward positive correlation, in contrast with the observed structure in price returns.

The heterogeneity in the participants' forecasts can be better judged from Fig. 3 and Fig. 4 that report the forecasted returns and forecasted variances of all the participants. We have eliminated the very beginning and end of the experiment in which some of the participants exhibit strange behaviors, probably due to lack of learning in the former case and end-of-experiment effects in the latter. As can be seen, not only predictions are quite heterogeneous, but they do no display any tendency to converge. Their volatility is group-specific, but it is in general very high and stationary. Forecasted variances seem to exhibit a higher persistence, in contrast to the forecasted returns. The more risk averse participants can be clearly perceived, and seem to behave consistently over time.

Finally in Fig. 5 we report the lagged cross correlation between the agents forecasted returns and the realized price returns. In this way one can analyze both how participants take the past returns into account when formulating their predictions, and how the participants' predictions themselves impact on the asset price. As expected, there is a strong correlation at lag 0. A high prediction of tomorrow returns formulated today generates a price increase and, consequently, a positive realized return today. Interestingly, the correlation between today's forecasts and tomorrow's prices is negative, suggesting a tendency to over-react to market fluctuations. This is plausibly the reason of the observed 1 lag negative autocorrelation in Fig. 2, i.e. of price "bouncing" dynamics. The correlation structure between the participants' predicted returns and past price returns is extremely heterogeneous and only a low degree of persistence can be observed in some cases.

5 Conclusions

In this paper we have described a simple asset pricing experiment in which participants must forecast both the expected future price return of an asset and its variance. Our results show that, with respect to previous experiments in which subjects had to predict only the future price value, - and the pricing equation was linear with positive feedbacks from individual predictions - we find no evidence of coordination on common expectations, no evidence of persistent speculative bubbles, and a high volatility in the realized price around the asset's fundamental value. We suggest that it is the nonlinear structure of our pricing equation to determine such dynamics; in fact, the inclusion of the forecasted variance determines a dynamic by which small changes in the predicted confidence range determine large fluctuations in the realized price, which in turn makes it very difficult for subjects to coordinate on a common strategy. Note that in our model we adopted the simplifying assumption of an equal degree of risk aversion for our subjects. Future experiments should aim at introducing further heterogeneity by taking into account the - presumably - different risk attitudes of the participants in the experimental market. Taken together, our results confirm the importance of the market institutional details - and in particular the nature of the expectations feedback structure - in determining the observed market dynamics.

6 Acknowledgments

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References

Bottazzi, G. "A Simple Micro-Model of Market Dynamics Part I: The "Homogeneous Agents" Deterministic Limit" L.E.M. Working Paper n. 2002-10, Pisa, 2002.

Hommes, C., J. Sonnemans, J. Tuinstra and H. van de Velden "Expectations and Bubbles in Asset Pricing Experiments" CeNDEF Working Paper, Amsterdam, 2002.

Hommes, C., J. Sonnemans, J. Tuinstra and H. van de Velden "Coordination of Expectations in Asset pricing Experiments" CeNDEF Working Paper, Amsterdam, 2002.

King, R.R., V.L. Smith, A.W. Williams and M. van Boening "The Robustness of Bubbles and Crashes in Experimental Stock Markets" in *Nonlinear Dynamics and Evolutionary Economics*, I. Prigogine, R. Day and P. Chen (Eds.), Oxford: Oxford University Press, 1993.

Noussair, C.N., S. Robin and B. Ruffieux "Price Bubbles in Laboratory Asset Markets with Constant Fundamental Values", *Experimental Economics*, 2001, vol.4, (1), 87-105.

Porter, D.P., V.L. Smith "Futures Contracting and Dividend Uncertainty in Experimental Asset Markets", *Journal of Business*, 1995, 68, 509-541.

Smith, V.L., G.L. Suchanek and A.W. Williams "Bubbles, Crashes, and Endogenous Expectations in Experimental Spot Asset Markets", *Econometrica*, 56, 1119-1151.

Smith, V.L., M. van Boening and C.P. Wellford "Dividend Timing and Behavior in Laboratory Asset Markets", *Economic Theory*, 2000, 16, 567-583.

Sunder, S. "Experimental Asset Markets: A Survey", in J. Kagel, A. Roth (Eds.), *Handbook of Experimental Economics*, Princeton, NJ, Princeton University Press, 445-500.

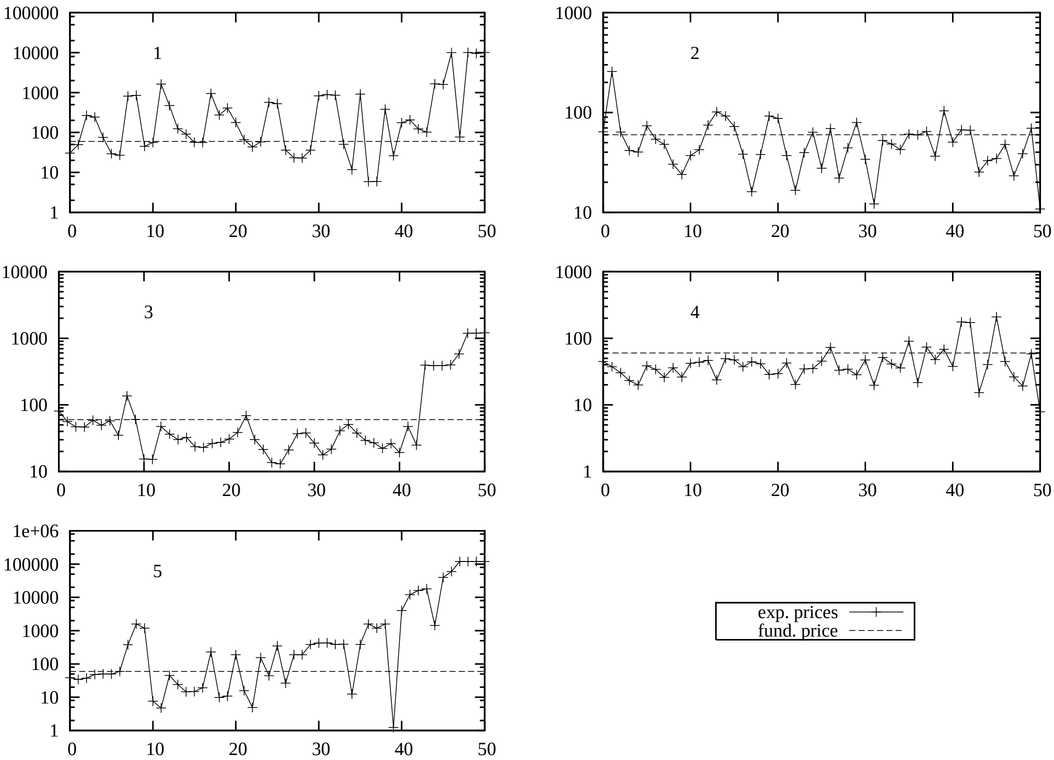

Figure 1: Price history for the 5 groups.

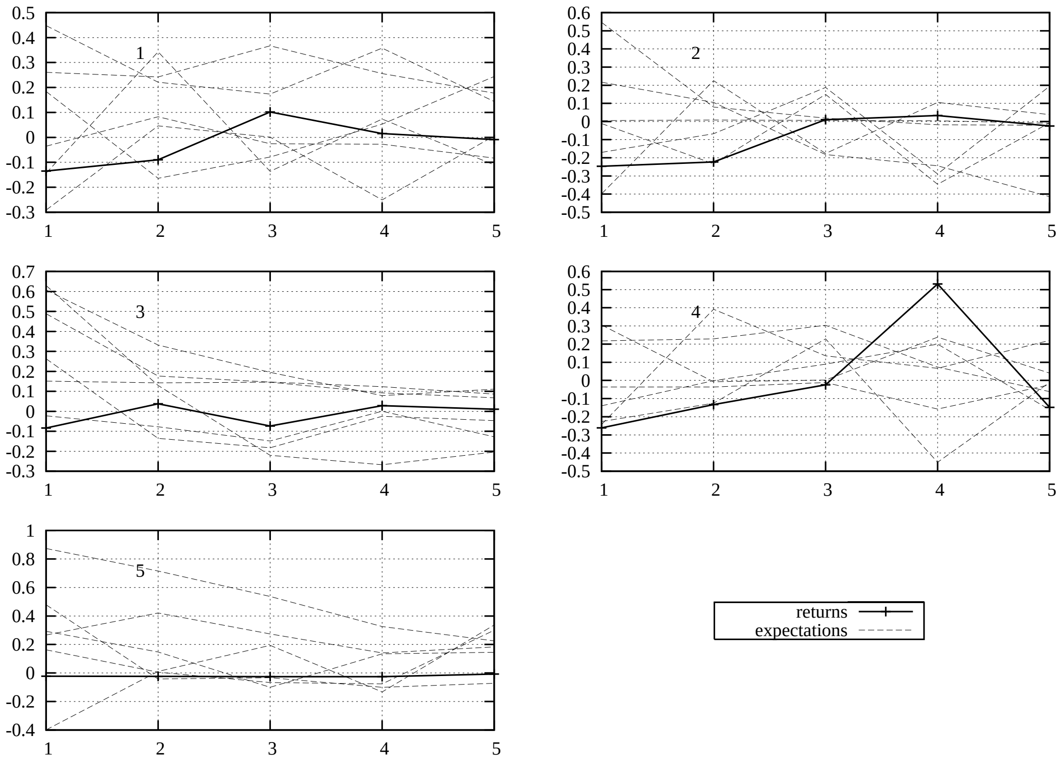

Figure 2: Returns autocorrelogram for the 5 groups.

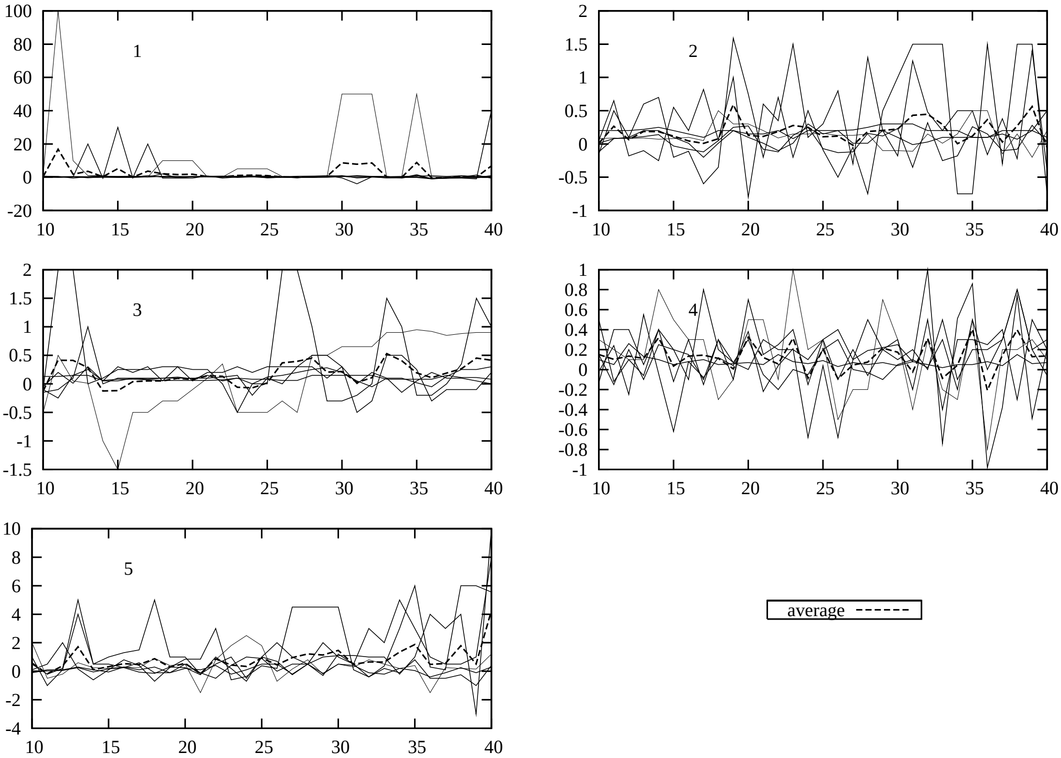

Figure 3: Forecasted returns for the 5 groups. Each line corresponds to the forecast of one agent.

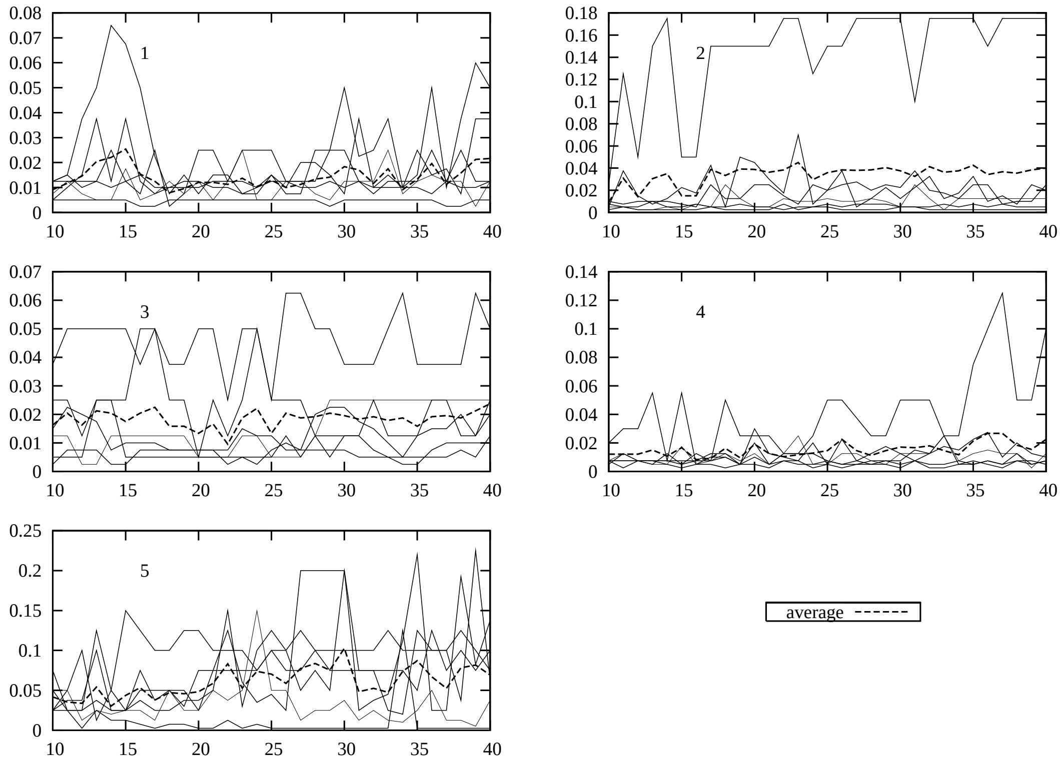

Figure 4: Forecasted variances for the 5 groups. Each line corresponds to the forecast of one agent.

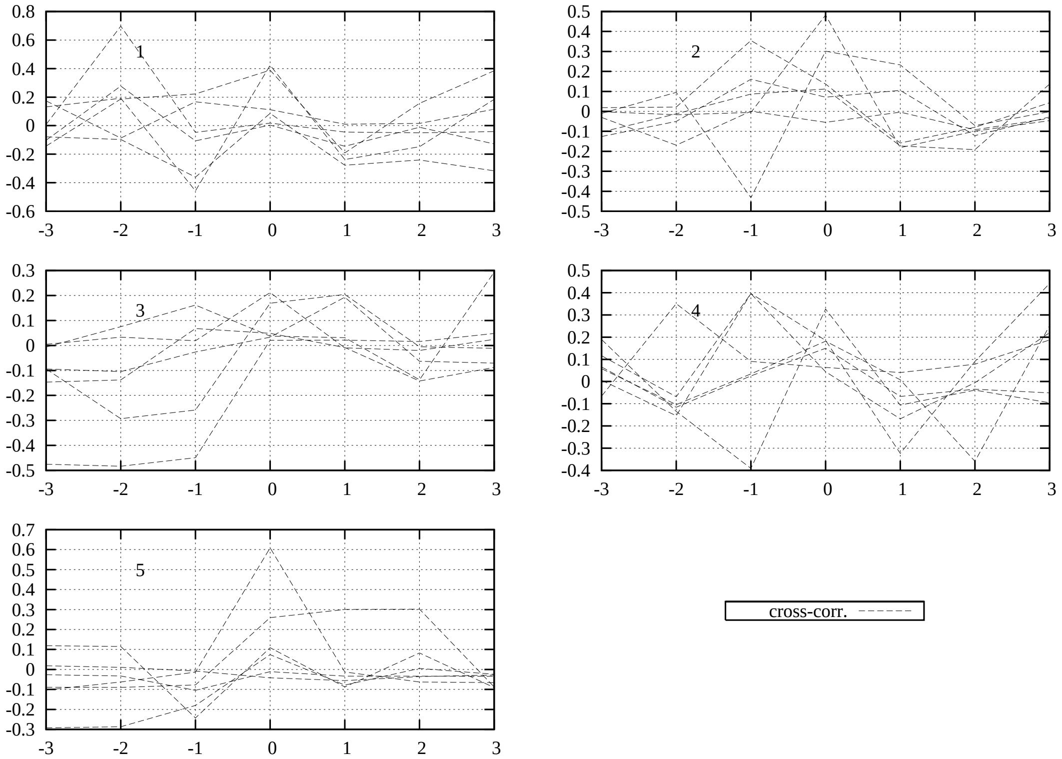

Figure 5: Cross-correlogram between agents forecasted returns and realized returns.