Price Stability and Volatility in Markets with Positive and Negative Expectations Feedback: An Experimental Investigation

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Abstract:

The evolution of many economic variables is affected by expectations that economic agents have with respect to the future development of these variables. Here we show, by means of laboratory experiments, that market behavior depends to a large extent on how the realized market price responds to an increase in average price expectations. If it responds by decreasing, as in commodity markets, prices converge quickly to their equilibrium value, confirming the rational expectations hypothesis. If the realized price increases after an increase of average expectations, as is typical for financial markets, large fluctuations in realized prices are likely.

Keywords: market behavior, coordination, expectations feedback, experimental economics

JEL-codes: D02, G12, C92

A key difference between natural and social sciences is that in social systems individual expectations or beliefs can affect the outcome. An investor buys a stock that he expects to go up in the future, a chip-manufacturer builds a new production facility because she expects that demand and therefore prices will be high after goods have been produced. Expectations determine behavior of economic agents and the actual market outcome (i.e., price and traded quantity, following from demand and supply) is an aggregation of individual behavior. Simultaneously, economic agents form their expectations on the basis of market history. Therefore, a market, like other social environments, has the properties of an expectations feedback system: past market behavior determines individual expectations that, in turn, determine current market behavior and so on. The structure of an expectations feedback system can be characterized as either positive or negative. In demand-driven financial markets the feedback is positive and self-confirming: if many agents expect the price of an asset to rise and therefore start buying the asset, aggregate demand will increase, and so, by the law of supply and demand, will the asset price. When a majority of investors expects markets to go down, this belief will be self-fulfilling and the market will go down. In supply-driven commodity markets the feedback is negative: if many producers expect future prices to be high they will increase production. This leads to low prices and firms will, in their disappointment, decide to decrease production only to find that they were wrong again. To investigate how expectations feedback affects aggregate market behavior we designed experimental market environments that differ only in the sign of the expectations feedback but are equivalent along all other dimensions. We compare these markets with respect to the coordination of expectations and convergence to the market equilibrium price.

The difference between positive and negative expectation feedback systems is related to the concept of, respectively, strategic complements and substitutes as introduced by John Haltiwanger and Michael Waldman (1985). When actions are strategic complements, rational decision-makers better imitate irrational individuals. This is the case in the asset market where predicting a price close to the predictions of the other participants is most profitable. This coordination enhances the impact of the irrational participants upon the realized prices and convergence to the equilibrium price is unsure. In the negative feedback markets rational decision-makers have an incentive to predict high (low) prices when irrational individuals predict prices below (above) the equilibrium price. Here actions are strategic substitutes: the impact of irrational individuals will be limited and convergence to the equilibrium price more likely. Coordination of predictions will only take place after convergence.

Ernst Fehr and Jean-Robert Tyran (2002, 2005) report on a related experiment in which they study the adjustment of nominal prices after an anticipated money shock in a price setting game with positively (complements) or negatively sloped (substitutes) reaction curves. They find much faster convergence in the substitute condition, in line with our results.[1]

In Section I we discuss two well-known expectations feedback models from economics and set out the experimental design. Section II describes the experimental results and Section III concludes. The appendices contain a description of the experimental instructions and detailed estimation results of the individual prediction strategies.

I. Expectations Feedback and Experimental Design

The market with negative expectational feedback used in the experiment is based on the classical cobweb or hog cycle model (see Mordecai Ezekiel, 1938, Marc Nerlove, 1958, Richard B. Freeman, 1975, 1976, Gary A. Zarkin, 1985 and Paul R. Krugman, 2001). Its key

[1] Another related study concerning strategic substitutes versus strategic complements is Jan Potters and Sigrid Suetens (2005). Their focus, however, is more on social behavior than on convergence and coordination. Cournot games and Betrand games are both social dilemma situations (the Nash equilibrium is Pareto-inefficient), but in Cournot games actions are strategic substitutes while in Bertrand games they are strategic complements. Potters and Suetens design two games with the same Nash equilibrium, the same social optimum and the same absolute (but opposite) slope of the reaction curve. They find more cooperation in the case of strategic complements than when actions are strategic substitutes.

feature is a fixed production lag, so production decisions by price-taking firms are based on a forecast of the market price in the next time period. Let $D(p_t)$ be a nonnegative and monotonically decreasing demand function and let $S(p^e_{h,t})$ be the nonnegative supply function of firm *h*. Supply of firm *h* in the next period depends upon the expected price, $p^e_{h,t}$, for that period by that firm. The second order condition for profit maximization implies that S is a non-decreasing function. Moreover, we assume that all firms have the same supply function. In the model equality between demand and supply in each period is not required, but in each period the market price is adjusted in the direction of the excess demand, the trade gap itself being absorbed by a hypothetical market maker. An increase of the price forecast leads to increasing production, a decreasing excess demand and therefore a lower market price. The following price-adjustment formula was used:

(1) $$p_t = p_{t-1} + \lambda\left(D(p_{t-1}) - \sum_{h=1}^{H} S(p^e_{h,t})\right) + \varepsilon_t .$$

The expression between brackets represents excess demand, where the market maker uses demand in period *t-1* as a proxy for demand in period *t*. We assume there are *H* suppliers, only differing in the way they form expectations. In the laboratory experiment we take $H=6$. The market maker adjusts the market price proportionally to the excess demand, with a positive price adjustment coefficient λ. The term ε is a random term, representing e.g. small uncertainties in demand; in the laboratory experiment $\varepsilon_t \sim N(0,1/4)$. In the cobweb treatment in the experiment, the participants act as advisors to the producers in the market, so their individual price expectations $p^e_{h,t}$ determine aggregate supply. The demand function is taken to be linearly decreasing, $D(p_t) = a - bp_t$, and the supply function is linearly increasing, $S(p^e_{h,t}) = sp^e_{h,t}$. Note that a linearly increasing supply function can be derived from the profit maximization problem of producers with a quadratic cost function.

For the laboratory experiments we chose parameter values *s=1/6* and *b=21/20*, *λ=1/b=20/21* and, for the intercept of the demand function, *a=123*. The price adjustment rule then becomes:

$$p_t = \frac{20}{21}\left(123 - \overline{p}_t^e\right) + \varepsilon_t, \tag{2}$$

where $\overline{p}_t^e = \frac{1}{6}\sum_{h=1}^{6} p_{h,t}^e$ is the average prediction of the six participants in the experimental market.

The second market in our laboratory experiment consists of a standard asset-pricing model (see Keith Cuthberson, 1996, John Y. Campbell et al. 1997, and William A. Brock and Cars H. Hommes, 1998). Demand of speculators for a risky asset depends positively upon the asset's expected price increase. Investors can either invest in a risk-free asset (e.g. a government bond) with a fixed gross return *1+r*, or invest in a risky asset (e.g. a stock) paying an uncertain dividend y_t in each period. In this model, excess demand for the risky asset leads to an increase in the asset price, and an excess supply to a decrease (see Avraham Beja and M. Barry Goldman, 1980). Since in the experiment demand was taken to be an increasing function of the price predictions, as would be natural in the case of a stock or some other financial asset, our asset pricing treatment was driven by positive expectations feedback, which, to a certain extent, confirmed any tendency in the participants' beliefs about future prices. As in the cobweb model above, a market maker adapts prices in proportion to excess demand and the actual development of prices is given by

$$p_t = p_{t-1} + \lambda\left(\sum_{h=1}^{H} \frac{E_{h,t}\left(p_t + y_t - (1+r)p_{t-1}\right)}{a\sigma^2} - z^s\right) + \varepsilon_t. \tag{3}$$

Excess demand is given by aggregate demand, which consists of the sum of individual demand functions of the traders in the market, minus the supply z^s of shares of the risky asset, assumed to be constant. The expression for the demand function is standard and obtained from mean-variance maximization of next period's expected wealth, where a equals the coefficient of risk aversion and σ^2 is the belief about the conditional variance of excess returns, here assumed to be constant for all periods and all traders. Each participant in the experiment acts as an advisor to a trader (say a large pension fund) informing them of their predictions $p^e_{h,t}$, which the trader then uses to calculate her demand function. Six participants form a group in the experiment, i.e. $H = 6$.

To achieve symmetry between the positive and negative feedback treatment, we choose parameters such that these treatments only differ in the sign of the expectations feedback. Fixing parameters values at $r = 1/20$, $a\sigma^2 = 6$, $z^s = 1$, $\lambda = 20/21$ and assuming $E_{h,t}(y_t) = 4$ for all h and t we get, for the positive feedback treatment, the following price adjustment rule:[2]

$$p_t = \frac{20}{21}\left(3 + \overline{p}^e_t\right) + \varepsilon_t, \tag{4}$$

where p_t and $\overline{p}^e_t$ are defined as above. As before, $\varepsilon_t \sim N(0,1/4)$ is a random term, representing e.g. small random fluctuations in the supply of the risky asset.

The two treatments are perfect symmetric opposites. One may easily check that the rational expectations equilibrium price of (2) and (4) is $p^* = 60$, and that if all participants would forecast $p^e_{h,t} = 60$, then $p_t = 60 + \varepsilon_t$. Both price series (2) and (4) are generated as a linear function of the average predictions of six participants, the realization of the random shocks is

[2] Notice that we have chosen parameters in both treatments in such a way that the dependence of p_t on p_{t-1} cancels out, and prices are determined by price expectations alone. In this way we can isolate the effect of the expectations feedback, without any interference from price feedbacks.

exactly the same and the absolute value of the slope of the relation between p_t and $\overline{p}_t^e$ is equal to $20/21$ for both treatments. The only difference between the treatments is the sign of this slope. Note also that $p^* = 60$ is a stable steady state under naïve expectations, $p_{h,t}^e = p_{t-1}$, since the absolute value of the slope of (2) and (4) is given by 20/21 and smaller than one.

Thirteen experimental markets of 50 periods were created, six with negative and seven with positive feedback. In each market six students participated, who earn more money if they predict market prices more successfully (the earnings in a period are based on the quadratic error of the prediction). Every period the participants see the previously realized prices and their own previous predictions and have to predict the next price, without being able to observe each other's predictions. Their payment (on average about 22 euro in approximately 90 minutes) was based upon their quadratic prediction error (see Appendix C for details on instructions).

II. Aggregate Market Behavior and Individual Prediction Strategies

Results are shown in Figures 1 (negative feedback) and 2 (positive feedback). Each individual panel shows, for one experimental market, the realized prices and the six time series of individual predictions. Two characteristics of the data catch the eye immediately. First, in the negative feedback market prices tend to go through an initial phase of high volatility, neatly converging afterwards to the equilibrium price 60, only to be disturbed occasionally by the impact of a mistake by one of the group members. Allowing for an initial learning phase, for all six negative feedback markets average prices are statistically not significantly different at a 5% level from what the rational expectations hypothesis predicts. Volatility is not significantly different at a 5% level from the volatility under rational expectations for the first

(N1) and fourth (N4) market. In contrast, in the positive feedback markets, although the heterogeneity of predictions decreases in a much shorter period, a quick convergence to the equilibrium price does not occur. Rather, most groups show a slow oscillatory movement around the equilibrium price of 60, and come close to it only in the very long run. Average prices and volatility in all positive feedback groups are significantly different at a 5% level from the price and volatility under rational expectations. Second, in both treatments there is little dispersion between individual predictions within experimental markets, which is particularly remarkable for the non-converging positive feedback treatment. Participants in the positive feedback treatment quickly coordinate on a common non-equilibrium prediction rule.

Convergence of prices and coordination of expectations is demonstrated in more detail in Figure 3. The upper panel shows the median of the absolute difference between the market price and the equilibrium price of 60 for both treatments. We find a much higher degree of convergence to the equilibrium price in the negative feedback treatment after period two (statistically significant at 5% in 44 of the 48 periods, Wilcoxon test). Coordination of expectations is measured by the standard deviation of the individual expectations of the market participants. The lower panel shows the median over 6 or 7 markets of these standard deviations for each period. A low standard deviation implies a high level of consensus among the participants about the future price. We find that the standard deviation is higher (and therefore coordination is less) for the negative feedback treatment in the early periods 2-7 (statistically significant at 5%, Wilcoxon test). After period 7, coordination is very high in both treatments. Note that, outside of equilibrium, it pays off for participants in the negative feedback treatment to ‘disagree’ with the majority: if the average prediction is high, the realized price will be low. This drives the heterogeneity in predictions in the early periods and the fast convergence to the equilibrium price. In the positive feedback treatment, on the other hand, ‘agreeing’ with the majority pays off since the market price will be close to the average price prediction. This quick coordination of price predictions in the positive feedback treatment is surprising, since participants were not able to observe each others predictions during the experiment, making the coordination itself "blind". Individual price predictions and aggregate market prices can concisely be summarized as exhibiting "slow coordination and fast convergence" in the negative feedback treatment, and "fast coordination and slow convergence" in the positive feedback treatment.

Linear prediction rules of the form

(5) $$p^e_{h,t} = c + \sum_{i=1}^{3} o_i p_{t-i} + \sum_{i=1}^{3} s_i p^e_{h,t-i} + \nu_t,$$

were estimated for each individual participant. Predictions of 71 out of 78 participants could be described successfully this way (see Appendix B), which suggests that participants use simple linear forecasting rules based on recent information to form predictions. In fact, for 40 of the 78 participants predictions can be described by an even simpler “first order heuristic”

(6) $$p^e_{h,t} = \alpha_1 p_{t-1} + \alpha_2 p^e_{h,t-1} + (1-\alpha_1-\alpha_2)60 + \beta(p_{t-1} - p_{t-2}) + \nu_t.$$

For these participants predictions are formed as a weighted average between the equilibrium price of 60, the last observed price, the participants last own price prediction and a trend term $\beta(p_{t-1} - p_{t-2})$, measuring how participants respond to the last price change. Figure 4 represents these 40 prediction rules in a prism of first-order heuristics. In the positive feedback environment (21 prediction rules, black dots) participants tend to base their prediction on a weighted average of the last price and prediction and extrapolate trends in past prices from there ($\alpha_1, \alpha_2 > 0$, $\alpha_1 + \alpha_2$ close to 1 and $\beta > 0$) without taking the equilibrium price into account. On the other hand, most of the estimated prediction rules from the negative feedback treatment (19 prediction rules, yellow dots) lie along the α_1-axis (α_2 and β close to 0) implying that typically predictions in that treatment are a weighted average between the last observed price and the equilibrium price level.

III. Discussion

Neo-classical economic theory assumes that people form expectations rationally (John F. Muth 1961, Robert E. Lucas and Edward Prescott, 1972). This implies that on average market participants make correct price forecasts and that prices quickly converge to their market clearing equilibrium values, thereby leading to an efficient allocation of resources (Eugene F. Fama, 1970, 1991). However, large fluctuations of prices on financial markets have fueled the debate whether this is indeed a good description of economic behavior (Robert J. Shiller, 1981, Werner F. DeBondt and Richard H. Thaler, 1985 and Peter M. Garber, 1990). Our findings show that whether rational expectations gives a good description of aggregate market behavior depends upon the underlying expectations feedback structure. In fact, commonly observed differences between experimental commodity and financial markets (Vernon L. Smith, 1962, Vernon L. Smith et al. 1988, Dhananjay K. Gode and Shyam Sunder, 1993 and Cars H. Hommes et al. 2005) can be attributed to a large extent by this feedback structure. Prices in a production market will be much more stable and closer to the equilibrium value when the product (and production technology) has been around for a while and prices can fluctuate wildly only for relatively new products (e.g. computer chips, The Economist, 1996a,b, 2001). The fact that some established commodity markets regularly exhibit fluctuations is consistent with our conclusions since these fluctuations may be attributed to the presence of demand-driven speculators (Paul Cashin et al. 2002, and W. Bruce Canoles et al. 1998). In contrast, due to the positive feedback structure, financial markets can easily diverge from the equilibrium price and be relatively unstable and excessively volatile.

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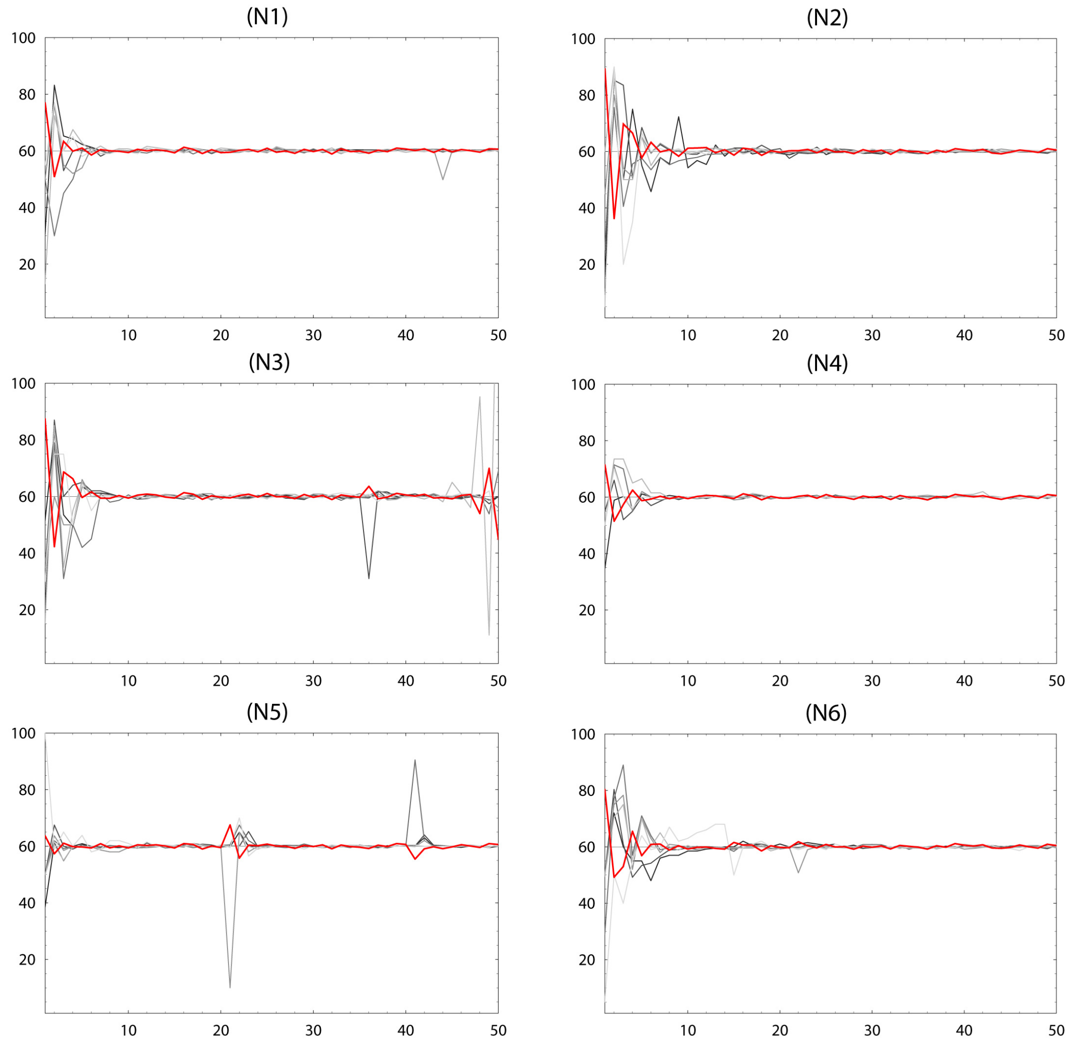
Figure 1: Prices and predictions in the negative feedback treatment. Each panel contains, for one experimental market, time series for the realized price (in red) and the time series of individual prediction of the six participants.

Figure 2: Prices and predictions in the positive feedback treatment. Each panel contains, for one experimental market, time series for the realized price (in red) and the time series of individual prediction of the six participants.

Figure 3: Upper panel gives the median, over the different groups, of the absolute difference between the market price and the equilibrium price; the lower panel gives the median, over the different groups, of the standard deviations of individual predictions. Solid lines correspond to the negative feedback treatment, broken lines correspond to the positive feedback treatment.

Figure 4: Prism of First-Order Heuristics containing the parameter vectors of the prediction rules of the form $p_{h,t}^{e} = \alpha_1 p_{t-1} + \alpha_2 p_{h,t-1}^{e} + (1-\alpha_1-\alpha_2)60 + \beta(p_{t-1} - p_{t-2}) + \nu_t$. The smaller graph on the right is a top-down view of the prism. Yellow dots depict prediction rules from participants in the negative feedback treatment and black dots depict rules from participants in the positive feedback treatment. Positive (negative) values of β correspond to a trend following (trend reversing) prediction rule. The special cases “naivety”, “fundamentalism” and “obstinacy” correspond to $p_{h,t}^{e} = p_{t-1}$, $p_{h,t}^{e} = 60$ and $p_{h,t}^{e} = p_{h,t-1}^{e}$, respectively. Finally, “adaptation” refers to a prediction rule of the form $p_{h,t}^{e} = \alpha p_{t-1} + (1-\alpha)p_{h,t-1}^{e}$, with $0 < \alpha < 1$.



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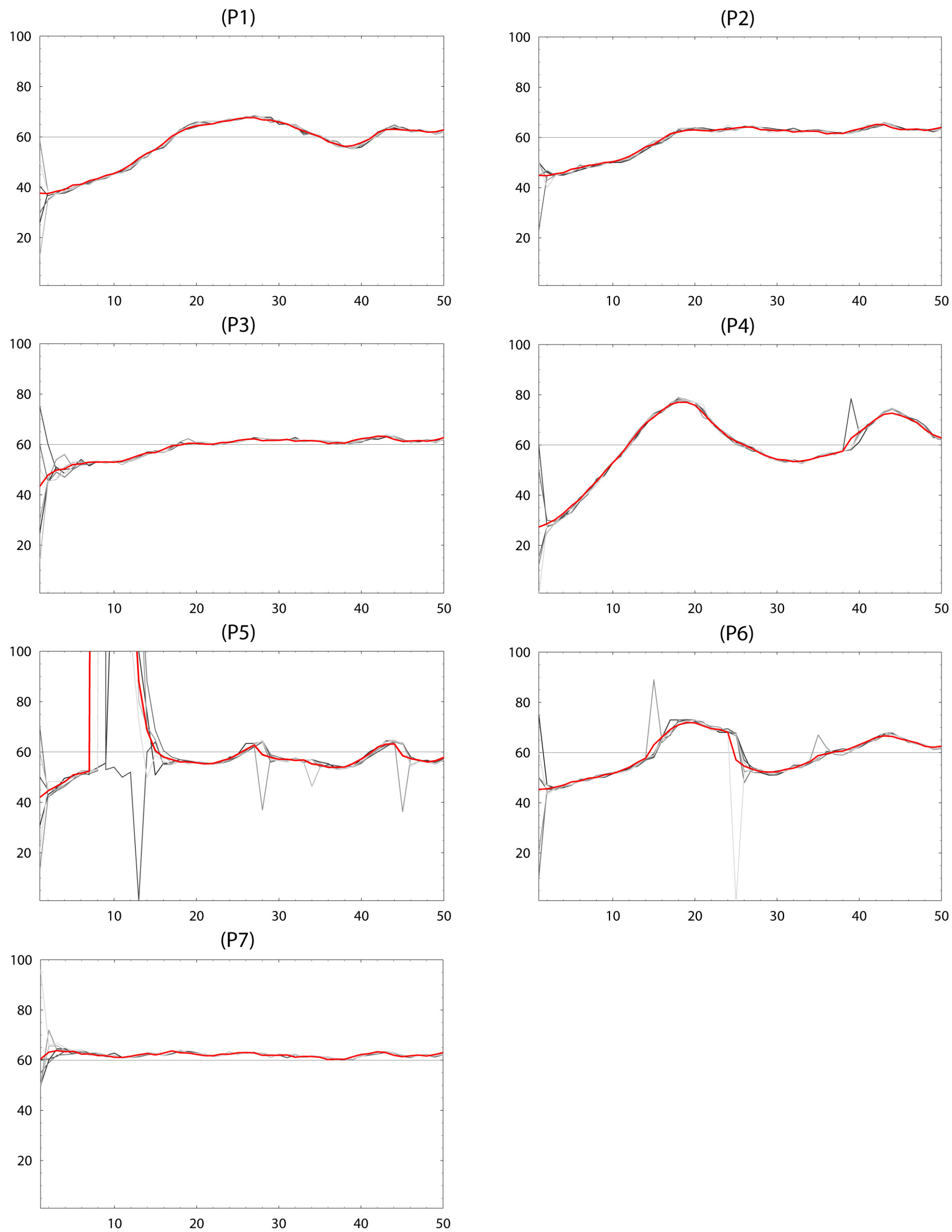

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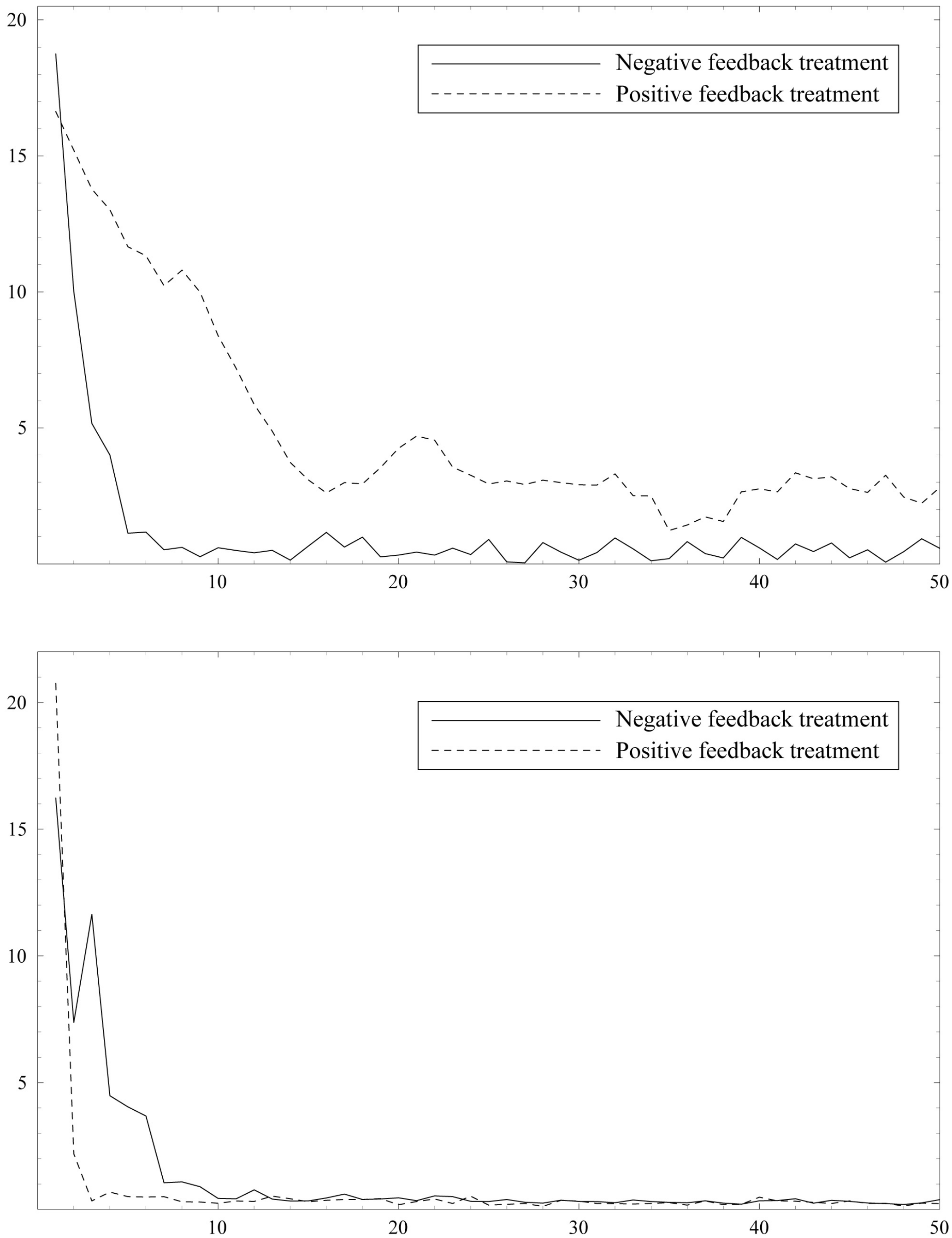

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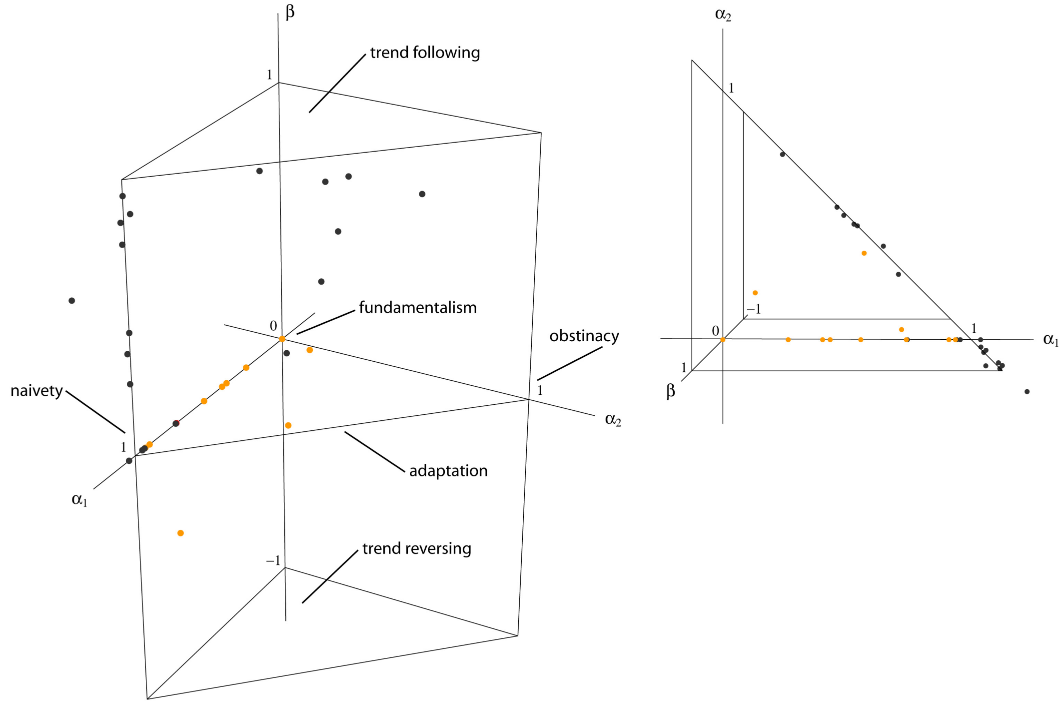

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Appendix A: The Main Experimental Computer Screen

The main experimental computer screen is given in Figure A.1. The figure shows the actual development of one of the experimental markets, in this case an Asset Pricing market, from the perspective of one of the participants. The participant observes both a graphical and a numerical representation of the realized market prices and his previous price predictions, in the upper left and right panel respectively. In the middle left panel information is displayed regarding the total earnings so far of the participant, his earnings in the last period and the present time period of the experiment. The participant submits his price prediction for the next period in the lower middle panel.

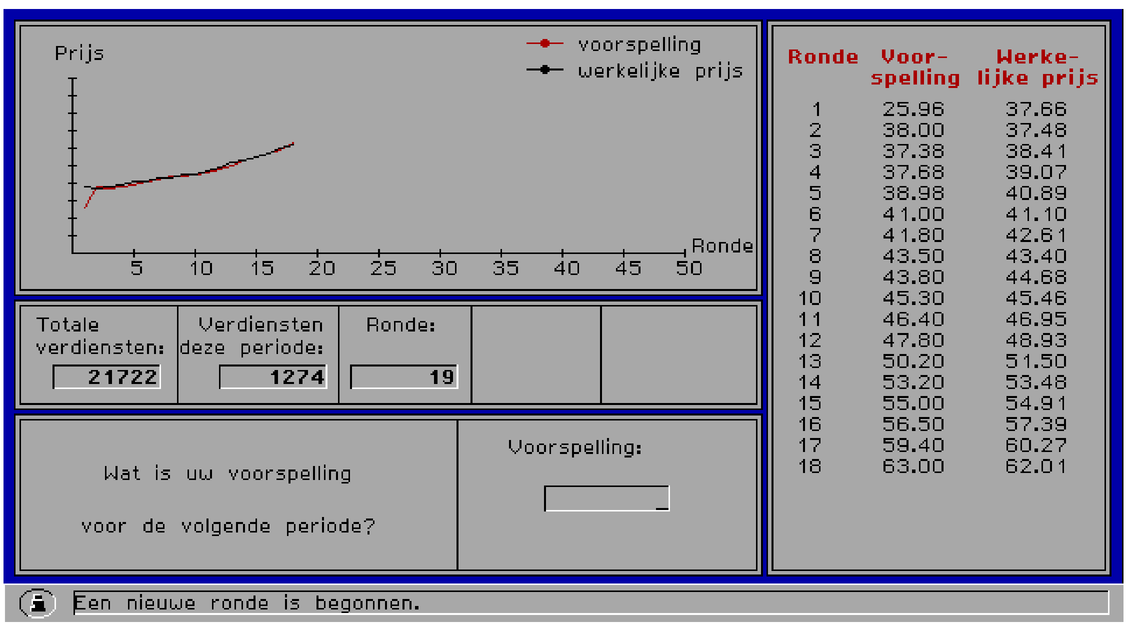

Figure A.1: The main experimental computer screen. The Dutch labels translate as follows: "prijs" = price; "voorspelling" = prediction; "werkelijke prijs" = market price; "ronde" = round; "totale verdiensten" = total earnings; "verdiensten deze periode" = earnings this period; "Wat is uw voorspelling voor de volgende periode?" = What is your prediction for the next period?; "Een nieuwe ronde is begonnen" = A new round has started.

Appendix B: Coefficient Estimates for Equations (5) and (6)

Part.no.	c	p_{-1}	p_{-2}	p_{-3}	p_{-1}^e	p_{-2}^e	p_{-3}^e	R^2	AC
1	53.67	0.1080	0	0	0	0	0	0.2013	No
2	29.75	0.7002	0	0	0	-0.1957	0	0.8795	No
3	25.47	0	0.2431	0	0	0	0	0.0983	No
4	23.30*	0.4213	0	0	0	0	0	0.1385	No
5	32.90*	0.3919	-0.3136	0	0.3750	0	0	0.3077	No
6	39.48	0.3255	0.2009	0	-0.5089	0	0.3240	0.6504	No
7	87.60	0	0	0	0	-0.1772	-0.2876	0.3478	No
8	10.26*	0.0111	0	0	0.0306	0	0	0.1912	No
9	32.15	0.0953	0	0	0	0	0.3662	0.7756	Yes
10	29.38	0.2818	0.2317	0	0	0	0	0.2821	No
11	16.13	0.2697	0.1532	0	0	0.3088	0	0.4381	No
12	20.81	0.6534	0	0	0	0	0	0.5102	No
13	-0.489*	0.3003	0.4690	0	0	0.2218	0	0.7600	No
14	59.15	0	0	0	0	0	0	0.0000	No
15	7.433	0.8692	0	0	0	0	0	0.9412	No
16	31.26	0	0.4799	0	0	0	0	0.4220	No
17	-170.6	0	0	0	-1.356	1.538	3.671	0.9670	No
18	82.00	-0.7656	0.3995	0	0	0	0	0.7943	No
19	34.40	0.4264	0	0	0	0	0	0.5653	No
20	45.60	0.2423	0	0	0	0	0	0.3077	No
21	60.00	0	0	0	0	0	0	0.0000	No
22	20.97	0.6489	0	0	0	0	0	0.7385	Yes
23	16.56	0.3326	0.3946	0	0	0	0	0.2316	No
24	60.00	0	0	0	0	0	0	0.0000	No
25	44.31	0.2653	0	0	0	0	0	0.2074	No
26	23.03	-0.2041	0.4658	0	0.3586	0	0	0.6671	No
27	60.98	0	0	0	0	0	0	0.0000	No
28	58.89	0	0	0	0	0	0	0.0000	No
29	45.38	0	0	-0.0898	0	0	0	0.5408	No
30	5.533*	0.9115	0	0	0	0	0	0.7367	No
31	5.767*	0.5157	0	0	0	0.3906	0	0.7284	No
32	27.21	0.4251	0.1179	0	0	0	0	0.6324	No
33	90.46	0	0	0	0	0	-0.5047	0.2533	No
34	59.66	0	0	0	0	0	0	0.0000	No
35	45.71	0.2338	0	0	0	0	0	0.2004	No
36	60.48	0	0	0	0	0	0	0.0000	No

Table B.1: Prediction rules for the 36 participants of the negative feedback treatment (least squares estimation of equation (5)). The first column shows participants' numbers, clustered according to group; the second through eighth column show coefficient estimates; the last two columns show the R-squared statistic and report on autocorrelation in the residuals up to the 20^{th} order (Ljung-Box Q-statistics, 5% level). Insignificant variables were eliminated one by one, largest p value first, until all p values were below 5%. An asterisk in the second column indicates that the constant is insignificant.

Part.no.	c	p_{-1}	p_{-2}	p_{-3}	p_{-1}^e	p_{-2}^e	p_{-3}^e	R^2	AC
1	-0.790*	1.675	0	-0.4329	-0.2324	0	0	0.9965	No
2	-0.682*	1.340	-0.5007	0	0.4642	-0.2914	0	0.9980	No
3	-1.176*	1.724	0	-0.3995	-0.3069	0	0	0.9932	No
4	-1.121	1.893	-0.8748	0	0	0	0	0.9971	No
5	0.417*	1.443	-0.8745	0	0.4264	0	0	0.9975	No
6	-0.817*	1.787	-0.7724	0	0	0	0	0.9982	No
7	0.742*	1.184	0	-0.1698	0	0	0	0.9964	Yes
8	-0.179*	1.463	-0.4552	0	0	0	0	0.9938	No
9	0.657*	1.220	-0.7315	0	0.5006	0	0	0.9969	No
10	0.339*	1.285	0	0	0	-0.2887	0	0.9969	No
11	0.693*	1.368	-0.8523	0	0.4743	0	0	0.9948	No
12	0.223*	1.851	0	0	-0.3270	-0.3533	-0.1723	0.9926	No
13	0.040*	1.450	-0.4504	0	0	0	0	0.9870	No
14	0.164*	1.069	-0.4708	0	0.4000	0	0	0.9943	No
15	-0.251*	1.275	-0.2989	-0.2706	0	0.2984	0	0.9981	No
16	2.170*	1.232	0	0	0	-0.2662	0	0.9780	No
17	-0.985*	1.251	0	-0.2345	0	0	0	0.9900	No
18	-0.1026	1.219	-0.5430	0	0.4372	0	0	0.9942	No
19	2.411	1.084	0	0	0.2635	0	-0.3910	0.9940	No
20	1.956*	-0.9115	0	0	0	0	0	0.8975	No
21	1.382	1.641	-0.9729	0	0.3084	0	0	0.9978	No
22	2.687	1.6274	-0.4900	0	0	0	-0.1816	0.9934	No
23	1.475	1.441	0	-0.4659	0	0	0	0.9948	No
24	0.062*	1.943	-0.9439	0	0	0	0	0.9953	No
25	34.27	0	0.1203	0	0.3421	0.2670	-0.3179	0.9892	Yes
26	173.7*	0	0	0	0	0	0	0.0000	No
27	2.601	1.000	0	-0.1972	-0.0384	0.1215	0.0682	1.0000	Yes
28	4.160	1.005	0	0	0	-0.1025	0	0.9981	No
29	15.71	1.004	0	0.5544	-0.2446	-0.4973	-0.1217	0.9981	Yes
30	13.52	1.062	-0.5319	0.3410	0.2280	-0.0978	-0.2084	0.9995	No
31	2.295*	0.8857	0	-0.4284	0.5064	0	0	0.9866	No
32	0.7813*	1.117	-0.7796	0	0.6513	0	0	0.9927	No
33	-0.946*	1.767	-0.8572	0.1052	0	0	0	0.9937	No
34	8.501*	1.130	0	-0.4372	0	0	0	0.6584	No
35	1.851	1.182	0	-0.5068	0	0.2952	0	0.9931	Yes
36	14.01*	0.7478	0	0	0	0	0	0.2058	No
37	-3.020*	1.0498	0	0	0	0	0	0.9363	No
38	1.560	0.9728	0	0	0	0	0	0.9316	No
39	6.501	1.1315	-0.2359	0	0	0	0	0.9656	No
40	2.584*	1.043	0	0	0	-0.1619	0.0780	0.9719	No
41	1.739*	1.383	-0.4099	0	0	0	0	0.9443	No
42	1.113*	0.9327	-0.2968	0	0.3471	0	0	0.9569	No

Table B.2: Prediction rules for the 42 participants of the positive feedback treatment (least squares estimation of equation (5) in the paper). See the caption for Table B.1 for more information.

PFOH Part.no.	α_1	α_2	β	Orig. part.no.	Orig. gr.no.	Label
1	0.7389	0	0	2	N1	Naive Fundamentalist
2	0	0	0	3	N1	None
3	0.9362	0	0	4	N1	Naive & Fundamentalist
4	0.1350	0.1923	0.0605	5	N1	Fundamentalist
5	0.5689	0.3480	0	8	N2	None
6	0.5553	0	0	12	N2	Naive Fundamentalist
7	0.7391	0	-0.4444	13	N3	None
8	0	0	0	14	N3	Naive & Fundamentalist
9	-0.3770	0	-0.3762	18	N3	Naive Fundamentalist
10	0.4016	0	0	19	N4	Naive Fundamentalist
11	0	0	0	21	N4	Fundamentalist
12	0	0	0	24	N4	Fundamentalist
13	0.2633	0	0	25	N5	Fundamentalist
14	0	0	0	27	N5	Naive & Fundamentalist
15	0	0	0	28	N5	Naive & Fundamentalist
16	0.9101	0	0	30	N5	Naïve
17	0	0	0	34	N6	Fundamentalist
18	0.4321	0	0	35	N6	None
19	0	0	0	36	N6	None
20	1.5096	-0.5238	0	3	P1	Naive Trend Follower
21	1.0177	0	0.8591	4	P1	Naive Trend Follower
22	0.5227	0.4711	0.9118	5	P1	Adaptive Trend Follower
23	1.0142	0	0.7818	6	P1	None
24	0.4888	0.5000	0.7290	9	P2	Adaptive Trend Follower
25	0.4670	0.5269	0.9210	11	P2	Adaptive Trend Follower
26	0.9994	0	0.4609	13	P3	Naive Trend Follower
27	0.5369	0.4627	0.5587	14	P3	Adaptive Trend Follower
28	1.0090	0	0.2765	15	P3	Naive Trend Follower
29	0.9557	0	0	20	P4	Naive Trend Follower
30	0.6669	0.3089	0.9696	21	P4	None
31	0.9616	0	0.8678	22	P4	None
32	0.9989	0	0.9437	24	P4	Naive & Adaptive Tr.Foll.
33	0	0	0	26	P5	Naive & Adaptive Tr.Foll.
34	0.2831	0.7045	0.8266	32	P6	Adaptive Trend Follower
35	1.1366	-0.1226	0.6077	33	P6	Naive Trend Follower
36	0.7428	0	0	36	P6	Naive Trend Follower
37	1.0376	0	0	37	P7	None
38	0.9419	0	0	38	P7	None
39	1.0155	0	0.2907	41	P7	Naive Trend Follower
40	0.6370	0.3842	0.3182	42	P7	Adaptive Trend Follower

Table B.3: Prediction rules for both treatments (least squares estimation of equation (6)) for the Prism of First-Order Heuristics. The first column is the number of relevant participants, clustered according to treatment; the second, third and fourth columns show coefficient estimates, estimated by eliminating the least significant variable until all p values were below 5%. This procedure was applied only to the linear prediction rules statistically equivalent to a rule in the Prism (Wald restriction test, 5% level). The fifth and sixth columns show the participant's original number and group (cf. Tables B.1 and B.2); the seventh checks for statistical equivalence with canonical rules (Wald restriction test, 5%).

Appendix C: Experimental Instructions

During each of the four experimental sessions, a short welcoming message was read aloud from paper, after which the participants were randomly assigned to a cubicle in the computer lab. In each cubicle there was a computer, some experimental instructions on paper and some blank paper with a pen. The two treatments had similar instructions that differed only in their description of the market environment. When all the participants were seated, they were asked to read the instructions on their desks. After a few minutes, they were given the opportunity to ask questions regarding the instructions, after which the experiment started. When the 50 time periods were completed, the participants were asked to remain seated and fill in the questionnaire, which was subsequently handed out to them. After a reasonable amount of time, the participants were called to the ante-room one by one to hand in the questionnaire and receive their earnings, in cash. The participants left the computer lab after receiving their earnings.

The experimental instructions the participants read in their cubicles consisted of three parts, totalling five pages. The first part contained general information about the market the experiment was about to simulate, which was of course treatment-specific. The second part contained an explanation of the computer program used during the experiment. The third part displayed a table relating the absolute prediction error made in any single period to the amount of credits earned in that period. The conversion rate between credits and euros, being 2600 credits to 1 euro, was made public by announcement, since it was not listed with the table. The questionnaire after the experiment contained 19 questions, the first 10 of which could be answered only by the integers 1 through 5. The experimental instructions will be translated below.

Translation of experimental instructions for negative feedback treatment

Experimental instructions

The shape of the artificial market used by the experiment, and the role you will have in it, will be explained in the text below. Read these instructions carefully. They continue on the backside of this sheet of paper.

General information

You are an advisor of an importer who is active on a market for a certain product. In each time period the importer needs a good prediction of the price of the product. Furthermore, the price should be predicted one period ahead, since importing the good takes some time. As the advisor of the importer you will predict the price P(t) of the product during 50 successive time periods. Your earnings during the experiment will depend on the accuracy of your predictions. The smaller your prediction errors, the greater your earnings.

About the market

The price of the product will be determined by the law of supply and demand. The size of demand is dependent on the price. If the price goes up, demand will go down. The supply on the market is determined by the importers of the product. Higher price predictions make an importer import a higher quantity, increasing supply. There are several large importers active on this market and each of them is advised by a participant of this experiment. Total supply is largely determined by the sum of the individual supplies of these importers. Besides the large importers, a number of small importers is active on the market, creating small fluctuations in total supply.

About the price

The price is determined as follows. If total demand is larger than total supply, the price will rise. Conversely, if total supply is larger than total demand, the price will fall.

About predicting the price

The only task of the advisors in this experiment is to predict the market price P(t) in each time period as accurately as possible. The price (and your prediction) can never become negative and always lies between 0 and 100 euros in the first period. The price and the prediction in period 2 through 50 is only required to be positive. The price will be predicted one period ahead. At the beginning of the experiment you are asked to give a prediction for period 1, V(1). When all participants have submitted their predictions for the first period, the market price P(1) for this period will be made public. Based on the prediction error in period 1, P(1) - V(1), your earnings in the first period will be calculated. Subsequently, you are asked to enter your prediction for period 2, V(2). When all participants have submitted their prediction for the second period, the market price for that period, P(2), will be made public and your earnings will be calculated, and so on, for 50 consecutive periods. The information you have to form a prediction at period t consists of: All market prices up to time period t-1: {P(t-1), P(t-2), ..., P(1)}; All your predictions up until time period t-1: {V(t-1), V(t-2), ..., V(1)}; Your total earnings at time period t-1.

About the earnings

Your earnings depend only on the accuracy of your predictions. The better you predict the price in each period, the higher will be your total earnings. The attached table lists all possible earnings.

When you are done reading the experimental instructions, you may continue reading the computer instructions, which have been placed on your desk as well.

Translation of experimental instructions for positive feedback treatment

Experimental instructions

The shape of the artificial market used by the experiment, and the role you will have in it, will be explained in the text below. Read these instructions carefully. They continue on the backside of this sheet of paper.

General information

You are an advisor of a trader who is active on a market for a certain product. In each time period the trader needs to decide how many units of the product he will buy, intending to sell them again the next period. To take an optimal decision, the trader requires a good prediction of the market price in the next time period. As the advisor of the trader you will predict the price P(t) of the product during 50 successive time periods. Your earnings during the experiment will depend on the accuracy of your predictions. The smaller your prediction errors, the greater your earnings.

About the market

The price of the product will be determined by the law of supply and demand. Supply and demand on the market are determined by the traders of the product. Higher price predictions make a trader demand a higher quantity. A high price prediction makes the trader willing to buy the product, a low price prediction makes him willing to sell it. There are several large traders active on this market and each of them is advised by a participant of this experiment. Total supply is largely determined by the sum of the individual supplies and demands of these traders. Besides the large traders, a number of small traders is active on the market, creating small fluctuations in total supply and demand.

About the price

The price is determined as follows. If total demand is larger than total supply, the price will rise. Conversely, if total supply is larger than total demand, the price will fall.

About predicting the price

The only task of the advisors in this experiment is to predict the market price P(t) in each time period as accurately as possible. The price (and your prediction) can never become negative and lies always between 0 and 100 euros in the first period. The price and the prediction in period 2 through 50 is only required to be positive. The price will be predicted one period ahead. At the beginning of the experiment you are asked to give a prediction for period 1, V(1). When all participants have submitted their predictions for the first period, the market price P(1) for this period will be made public. Based on the prediction error in period 1, P(1) - V(1), your earnings in the first period will be calculated. Subsequently, you are asked to enter your prediction for period 2, V(2). When all participants have submitted their prediction for the second period, the market price for that period, P(2), will be made public and your earnings will be calculated, and so on, for 50 consecutive periods. The information you have to form a prediction at period t consists of: All market prices up to time period t-1: {P(t-1), P(t-2), ..., P(1)}; All your predictions up until time period t-1: {V(t-1), V(t-2), ..., V(1)}; Your total earnings at time period t-1.

About the earnings

Your earnings depend only on the accuracy of your predictions. The better you predict the price in each period, the higher will be your total earnings. The attached table lists all possible earnings.

When you are done reading the experimental instructions, you may continue reading the computer instructions, which have been placed on your desk as well.

Translation of computer instructions

Computer instructions

The way the computer program works that will be used in the experiment, is explained in the text below. Read these instructions carefully. They continue on the backside of this sheet of paper.

The mouse does not work in this program.

Your earnings in the experiment depend on the accuracy of your predictions. A smaller prediction error in each period will result in higher earnings.

To enter your prediction you can use the numbers, the decimal point and, if necessary, the backspace key on the keyboard.

Your prediction can have two decimal numbers, for example 30.75. Pay attention not to enter a comma instead of a point. Never use the comma. Press enter if you have made your choice.

The better your prediction, the more credits you will earn. On your desk is a table listing your earnings for all possible prediction errors.

For example, your prediction was 13.42. The true market price turned out to be 12.13. This means that the prediction error is: 13.42 – 12.13 ≈ 1.30. The table then says your earnings are 1255 credits (as listed in the third column [this is a typing error, it should be second column]).

The available information for predicting the price of the product in period t consists of: All product prices from the past up to period t-1; Your predictions up to period t-1; Your earnings until then.

[The caption of the figure.]

The computer screen.

The instructions below refer to this figure.

In the upper left corner a graph will be displayed consisting of your predictions and of the true prices in each period. This graph will be updated at the end of each period.

In the rectangle in the middle left you will see information about the number of credits you have earned in the last period and the number you have earned in total. The time period is also displayed here, possibly along with other relevant information.

On the right hand side of the screen the experimental results will be displayed, that is, your predictions and the true prices for at most the last 20 periods.

At the moment of submitting your price prediction, the rectangle in the lower left side of the figure will appear. When all participants have subsequently submitted their predictions, the results for the next period will be calculated.

When everyone is ready reading the instructions, we will begin the experiment. If you have questions now or during the experiment, raise your hand. Someone will come to you for assistance.