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An Experimental Investigation

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Michael W.M. Roos and Wolfgang J. Luhan*

Are Expectations Formed by the Anchoring-and-adjustment Heuristic? – An Experimental Investigation

Abstract
Previous experimental investigations have shown that expectations are not perfectly rational due to bias. Traditional adaptive models, however, in many cases do not perfectly describe the formation of expectations either. This paper makes two contributions to the experimental literature on the formation of expectations: First, we investigate whether subjects who have more information about the economic model than in previous studies also form biased expectations. Second, we argue that in some cases macroeconomic expectations might be formed by the anchoring-and-adjustment heuristic, which is well known in psychology. We find that subjects' expectations are biased although the design might be more favorable to rational expectations. The anchoring-and-adjustment model of expectations gets some support by our data, but the best model encompasses both the anchoring-and-adjustment model and the traditional adaptive model.

JEL Classification: D84, D83, C99

Keywords: Expectations, heuristics, beliefs, mental models, macroeconomic experiment

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1 Introduction

Theoretically, little is known about how agents form economic expectations. The predominant theory of rational expectations is silent on the *process* of expectation formation and rather makes predictions about the long-run result of those processes. The path toward a long-run rational expectations equilibrium, however, may be very relevant for the analysis of business cycles dynamics.

Recently many papers used experimental methods to analyze the formation macroeconomic expectations (Adam 2007, Bernasconi and Kirchkamp 2000, Bernasconi et al. 2004, Heemeijer et al. 2007, Hey 1994, Hommes et al. 2005a,b, 2007, forthcoming, Sonnemans et al. 2004, 2005). Common questions of those papers are whether expectations are rational and how the formation process can be described by simple models. The general results of those experimental studies are that expectations are not perfectly rational, but that they are not well described by very simple models either.

We also performed an economic laboratory experiment in order to study how expectations are formed. While we also analyze the rationality of the expectations, we are more interested in the question of how the expectations are formed. The main contributions of our paper are twofold: First, we propose the anchoring-and-adjustment heuristic as a plausible model of how subjects form expectations and look whether our experimental data support this hypothesis. Second, we use a design to study expectations that differs strongly from the designs in the cited papers. We argue that our design has some advantages over what has been done in previous work.

While the macroeconomic theory of rational expectations does not model the process of expectations formation, there are models that explore whether rational expectations equilibria can be learned by agents that behave like econometricians and employ some rational learning method like least square learning or Bayesian learning (see Evans and Honkapohja 2001, Marcet and Sargent 1989, Feldman 1987, El-Gamal and Sundaram 1993). This branch of the learning literature explores the conditions under which different learning mechanisms or expectation formation processes lead to rational expectations equilibria. Evidence suggests, however, that economic lay people both have very different theories of how the economy works compared to economists and poor statistical competencies. In such a case, models with statistical learning may not be good descriptions of what boundedly rational agents do. They may have biased subjective models of the economy, estimate spurious relationships, or use inconsistent estimation methods. An even stronger departure from the learning approach is to assume that agents do not only make mistakes when they estimate economic models, but that they do not even try to estimate a model at all. The use of heuristics is an alternative to the model estimation approach. Agents may have simple rules of thumbs that guide their economic behavior, especially when the economic environment is complex and uncertainty is involved, which is typically the case in macroeconomic decision making. While the use of simple heuristics may be a reasonable device to economize on cognitive resources, it also opens the door to systematic errors. There is a considerable body of literature on the widespread use of heuristics in microeconomic contexts and the associated biases (Kahneman, Slovic, Tversky 1982) but also on the reasonableness of heuristic behavior in many cases (Gigerenzer and Todd 2000).

The idea that agents use heuristics to form macroeconomic expectations is not at all new. The adaptive or extrapolative models of expectation formation that were common in Keynesian economics can be interpreted as heuristics. Those models have been explored excessively both in theory and empirically and are common alternative models to rational expectations in the experimental literature. Somewhat typical for this literature is the conclusion in Hey (1994) that "subjects are trying to behave rationally, but frequently in a way that appears adaptively" (p. 329). We propose the anchoring-and-adjustment heuristic as a way to connect agents' inclination to use relatively simple rules-of-thumb to their desire to behave rationally. The anchoring-and-adjustment heuristic (Tversky and Kahneman 1974) is well known in the psychological literature, which has shown that it is often used to estimate unknown or uncertain quantities. We simply transfer this standard heuristic to a macroeconomic context and apply it to the formation of macroeconomic expectations.

The tentative result of previous experimental studies that expectations are not rational may in part be a consequence of several specific features of those experiments that lead to a systematic bias against rational expectations. In all of the cited studies, subjects have very little information on the lab economy. In most cases, subjects did not know how the variables to be predicted were determined. If subjects' knowledge about the economic model is very limited, it is very difficult to learn and use the true data generating process to form expectations. In Hey (1994) there is not even an economic model that generates the data but only a simple stochastic process. Furthermore, it is common practice to separate the study of expectations from decision making. If expectations are the focus of the experimental study, subjects usually do not have to make economic decisions but only make forecasts. But the motivation of subjects to make good forecasts may be higher if they need those forecasts to make good decisions. It may also be easier to think about the future evolution of the variables, if they also think about the consequences of decisions they make. In order to give rational expectations a better chance, we make subjects form expectations in a simple economic model, which is almost completely known to them and in which they also have to make economic decisions.

In Section 2, we present our model economy. The experimental design and procedure are explained in Section 3. Section 4 discusses different models of expectation formation. In particular, we introduce the anchoring-and-adjustment heuristic and derive the hypotheses we want to test with our experimental data. Section 5 contains the results, which are discussed in Section 6. We conclude in Section 7.

2 Model economy

Our model economy is deliberately very simple in order to give subjects a good chance to understand how it works and how variables are determined. The economy consists of a labor market and a product market. The labor market determines the nominal wage and the level of employment and the product market determines the prices of goods. Production is directly linked to employment via the production function. The economy consists of three identical industries, each producing a good for which there is a deterministic demand function. In each industry, there are only two agents: a monopoly union and a monopoly firm. In a sequential two stage game, first the union sets the nominal wage and the firm subsequently chooses the level of employment for the given wage. In the following, we first describe the model in detail. The next section presents the implementation in the laboratory.

In the first stage, in each industry i, a representative worker or union sets the nominal wage w_i. The union's objective function is given by

$$U_i = \delta_i \left(\frac{w_i}{P} - \frac{\gamma}{L_i} \right), \tag{1}$$

which is a function of the real wage, $\frac{w_i}{P}$, and employment L_i. Since U_i is increasing in the level of employment, it can be interpreted as a utility function of a union that cares for the employment status of its members. The marginal utility of employment is positive, but decreasing. The additive separability of the arguments ensures that the utility function has an inner maximum for the given production function and the product demand function[1]. δ_i is a scaling factor and γ is the weight given to

[1] This function may not be the standard utility function in union models, but it confronts workers with the intended trade-off between the real wage and the employment level.

employment.

Next, the firm learns the wage level in the respective industry and determines the industry employment. The profits of firm i are given by

$$\pi_i = p_i Y_i - w_i L_i. \tag{2}$$

Output Y_i is a function of productivity A_i and the chosen employment level L_i

$$Y_i = A_i \sqrt{L_i}. \tag{3}$$

The product price p_i is determined by an exogenous and deterministic demand function

$$p_i = \alpha_i Y_i^{-\frac{1}{\varepsilon_i}}, \quad \varepsilon_i > 1. \tag{4}$$

The aggregate price level P is the geometric mean of all industry prices

$$P = \sqrt[n]{\prod_{i=1}^{n} p_i}. \tag{5}$$

Since P depends on the actions of all workers and firms, it is an aggregate variable.

The economy is fully characterized by the equations (1) - (5). As a theoretical benchmark, we derive the equilibrium nominal wage and the equilibrium employment level for homogeneous firms and workers under the assumptions of full information and strict maximization of profits and utility.

The first order condition for fully informed profit maximizing monopolistic firms requires to equate the real producer wage with the markup times the marginal productivity of labor

$$\frac{w_i}{p_i} = \frac{A_i}{2\sqrt{L_i}} \left(1 - \frac{1}{\varepsilon_i}\right). \tag{6}$$

Using the production function and the demand function, we derive labor demand as a function of the nominal wage

$$L_i^* = A_i^{\frac{2(\varepsilon_i - 1)}{\varepsilon_i + 1}} \left(\frac{\alpha_i(\varepsilon_i - 1)}{2\varepsilon_i}\right)^{\frac{2\varepsilon_i}{\varepsilon_i + 1}} w_i^{-2\left(\frac{\varepsilon_i}{\varepsilon_i + 1}\right)}. \tag{7}$$

Assuming identical industries, the price level in equilibrium is equal to each industry price

$$P^* = \left[\frac{2w\varepsilon\alpha^{\varepsilon}}{A^2(\varepsilon - 1)}\right]^{\frac{1}{\varepsilon+1}}. \tag{8}$$

Substituting (7) and (8) into (1) and taking the derivative with respect to w, we obtain the utility maximizing wage

$$w^* = \left(\frac{\left(\frac{A^2(\varepsilon-1)}{2\varepsilon\alpha^{\varepsilon}}\right)^{\frac{1}{\varepsilon+1}} A^{\frac{2(\varepsilon-1)}{\varepsilon+1}} \left(\frac{\alpha(\varepsilon-1)}{2\varepsilon}\right)^{\frac{2\varepsilon}{\varepsilon+1}}}{2\gamma} \right)^{\frac{\varepsilon+1}{\varepsilon}}, \qquad (9)$$

which is, of course, constant.

3 Experimental design and procedure

In order to introduce an element of uncertainty and to require subjects to form beliefs about the model and expectations about the consequences of their actions, we gave subjects only the rudimentary information of a negative relationship between the output and the price in each industry, but did not inform them neither about the parameters nor the functional form of the demand function. Otherwise, to find the equilibrium would only be a matter of computations.

Equations (2), (3), (1), and (5) were equal for all industries and known to subjects. It was also common knowledge that everybody had this information. In addition to the uncertainty about the model, workers also faced uncertainty about the behavior of firms and consequently about L and w, when setting the nominal wages. While the relationship between w and L is relatively easy to learn, the relation between w and P is complex and intransparent. It appears plausible that real unions only have a limited understanding how their wage setting behavior acts on the general price level.

The experiment was implemented computerized using z-tree (Fischbacher 2007) with networked PCs separated by blinds. Participants were 36 students from different departments of the University of Innsbruck. Upon arrival in the lab, subjects were randomly assigned to their role as worker or firm and to the economy with fixed assignments throughout the whole experiment (partner design). Instructions (see Appendix) were read aloud and participants were given the opportunity to ask questions before the start of the experiment. During the training phase, participants could check with a test program whether they had understood how their payoffs would be calculated.

A session consisted of 30 rounds or periods with three stages in each round. In the first stage, workers had to chose a nominal wage for the current period from the interval [0, 3]. To assist the wage setting decision, workers could use a utility calculator that displayed the hypothetical value of the utility function for the nominal wage w, and hypothetical employment and price levels L and P the subject had entered. Subjects were free to recalculate their utility as often as they wished within the given time limit of 90 seconds. The entered wage level was then actively confirmed by the subjects. Simultaneously to the wage decision of the workers, each firm had to enter a wage expectation for the current round.

In the second stage firms had to decide, how much labor to employ (from the interval [0.5, 16]) and to state and expectation for their commodity price. Analogous to workers, firms could use a profit calculator that displayed the hypothetical profit for any combination of employment and expected price. While firms were making their decision on employment, workers were requested to enter the expectation for the price level P and for the level of employment in their industry. The second stage also lasted 90 second.

In the final stage, all subjects learned the realizations of w, L, Y,and p in their industry in the current round. They were also informed about P, the value of their objective function π or U, the expectations they had entered, and the payoff for their expectation[2]. All subjects were asked if they would like to buy information to be displayed in the first two stages of the next round. If they chose to buy no information, only the previous round's realizations of w, L, Y,and p in their industry, P, and the value of their own objective function were displayed. From the second period onward, this information was automatically displayed on the top of the first two stages' screens. In addition to this information, they could opt to buy time-series information, cross-section information, or both. The price of either the time series or the cross-section was 0.1 "taler" (the experimental currency unit, in which both profits and utility was measured). The price for information was very low and served mainly as a threshold to deter subjects from constantly requesting all available information. In case of the time-series option, they obtained not only the realizations of the variables in the industry of the previous period, but of all previous periods. If they decided for the cross-section, they were shown the realization of all variables in the previous round in all industries.

Subjects' payoffs in euros were calculated based on total profits or utility cumulated (both in "taler") over all periods and earnings from good expectations (also in "taler"). Earnings from expectations were determined by

$$S_{ti}^{w} = \max(1 - .5(P_t - P_{ti}^{e})^2 - .5(L_{ti} - L_{ti}^{e}), 0) \qquad (10)$$

for workers and

$$S_{ti}^{f} = \max(1 - .5(p_t - p_{ti}^{e})^2 - .5(w_{ti} - w_{ti}^{e}), 0) \qquad (11)$$

[2]We explain below, how expectations were incentivized.

for firms in each period. Forecast earnings were also cumulated over all rounds and added to total profit (utility).

We conducted 2 sessions with of about 2.5 hours each with three economies in each session and with an average remuneration of 30€ per participant including a 5€ show-up payment. In each session, we paid out the fixed sum of 540€ to be divided conditional on experimental performance. After subtracting 90€ paid for the show-up, the remaining 450€ were divided by the total number of "taler" earned to determine the conversion of "taler" to euros. Subjects received their payoffs private and in cash directly after the experiment. The payoff scheme was common knowledge and explained in detail before the experiment.

4 Models of expectation formation

As a starting point of our analysis, we ask whether expectations fulfill the rationality requirement of unbiasedness which means that the expected value of the expectation error is zero. The standard test for unbiasedness is to regress the realization of a variable x_t on a constant and the expectation x_t^e and to test for the constant to be zero and the slope to be one (see Lovell 1986 for a discussion). This is the typical test for Muth's (1961) model of rational expectations. Alternatively, one can test for unbiasedness by running the opposite regression

$$x_t^e = \rho_0 + \rho_1 x_t + \epsilon_t. \tag{12}$$

If the expectation is unbiased then the null hypothesis $\widehat{\rho}_0 = 0$ and $\widehat{\rho}_1 = 1$ cannot be rejected by an F-test. This model of expectations was called *implicit expectations* by Mills (1957). While these two models look very similar, there is a crucial difference concerning the assumption about the independence between the error term and the independent variable which is necessary for OLS regression coefficients to be unbiased. If we estimate the implicit expectations model but the error is not independent of x_t but of x_t^e, $\widehat{\rho}_1$ will be downward biased potentially leading to a false rejection of unbiasedness. Of course, the same is true in the opposite case.

We prefer to regress the expectation on the realization here in order to facilitate comparisons with later regressions. In addition, similar to Hey (1994) it is hard to argue that the expectation error is correlated with the realization, but not with the expectations as would be the case in the Muth model. Since there are no stochastic shocks in the model and the demand function is deterministic at least for prices the only source of errors are misunderstandings of the underlying forces in the model and not random developments between the time the forecast is made and the actual realization. But in addition to this a-priori argument, there is also an way to test which model is appropriate. It is a basic statistical principle that the variance of the sum of two uncorrelated variables is the sum of the two individual variances. Since variances cannot be negative, the variance of the dependent variable must be larger than the variance of the independent variable. In the rational expectations model, $var(x_t) > var(x_t^e)$ should hold. But if we test for equality of variances against the alternative hypothesis of $var(x_t) < var(x_t^e)$, we get four rejections of the null and three non-rejections. Only in one case, $var(x_t)$ is significantly larger than $var(x_t^e)$ as required by the rational expectations model. We therefore feel safe to estimate (12) instead of the reversed model.

The analysis of biasedness in expectations, however, does not tell us, how subjects might have formed their expectations. Two simple models might be interesting to analyze, namely a standard model from the macroeconomic literature and an alternative model based on the "anchoring-and-adjustment heuristic". A standard descriptive model of expectation formation is the model of adaptive expectations:

$$\begin{aligned} x_t^e &= x_{t-1}^e + \lambda(x_{t-1} - x_{t-1}^e) \\ &= \lambda x_{t-1} + (1-\lambda)x_{t-1}^e. \end{aligned}$$

According to this model, people correct their past expectation by a fraction λ of the expectation error. If the adaptive model is a good description of the expectation formation process, we should not be able to reject the null of $\widehat{\omega}_1 + \widehat{\omega}_2 = 1$ after the estimation of

$$x_t^e = \omega_1 x_{t-1} + \omega_2 x_{t-1}^e + \epsilon_t. \tag{13}$$

The adaptive model has the drawback of being purely backward-looking. It is hard to imagine that subjects who have some knowledge of their economic environment do not use this knowledge at all when they form their expectations. While it may be too extreme to assume that agents use all information (including information about the model) perfectly and form rational expectations, it is likewise extreme to assume the opposite that they do not use any information about relationships between variables.

Alternatively, subjects might form expectations using the anchoring-and-adjustment heuristic (see Tversky and Kahneman 1974). The anchoring-and-adjustment heuristic has been shown to be a commonly used method to estimate unknown or uncertain quantities. With such a heuristic, people choose a salient anchor as a starting point and then adjust the expectations until they reach a satisfactory result. An anchoring-and-adjustment model of expectation formation could be

$$x_t^e = x_{t-1} + A^x(\Omega_{t-1}),$$

where Ω_{t-1} is the information set available at time $t-1$ and $A^x(.)$ is the adjustment function. x_{t-1} is a very salient and obvious anchor, if it is easy to observe and the evolution of x is not too erratic. The adjustment function may include some information about the model or changes of variables observed in the past that are believed to be related to x. If subjects have complete information about the model and use it rationally, then the adjustment function would be $A^x(\Omega_{t-1}) = E_{t-1}x_t - x_{t-1}$, where E is the mathematical expectation[3]. Of course, the adaptive model discussed earlier, can also be interpreted as the result of the anchoring-and-adjustment heuristic. In this chase, the anchor is x^e_{t-1} and the adjustment as a specific form. If x_{t-1} is easily observable, we consider it a more natural anchor than x^e_{t-1}.

Interestingly, such a procedure to form expectations was already suggested by Keynes: "... it is sensible for producers to base their expectations on the assumption that the most recently realized results will continue except in so far as there are definite reasons for expecting a change" (1936, p. 51). Furthermore, Hey (1994) found in his experimental data, that many subjects used the previous realization as a starting point and adjusted this value by fractions of previously observed changes.

One characteristic of rational adjustment is that the expectation is unbiased. We can test for rational adjustment by estimating

$$x^e_t = \sigma_1 x_{t-1} + \sigma_2(x_t - x_{t-1}) + \epsilon_t. \tag{14}$$

If subjects use the observation of the last period as the anchor, $\sigma_1 = 1$ must hold statistically. If the adjustment is unbiased, we cannot reject $\sigma_2 = 1$.

It is more likely, however, that the adjustment is not perfectly rational. The psychological literature on adjustment provides plenty of evidence that adjustment is generally insufficient and biased towards the anchor. There are at least two explanation for this bias (Epley and Gilovich 2001, 2004, 2006). First, with externally provided anchors, subjects seem to consider only new information that is consistent with the anchor and neglect other information that would force them to adjust more strongly. Such a behavior is common for most people who usually seek to confirm their hypothesis rather than to reject them.

Alternatively, if the anchor is self-generated, i.e. not provided by another person, people adjust the value to be estimated until they reach the outer bound of values they consider plausible. The self-chosen anchor serves as a first rough estimate which is refined through the adjustment

[3] If it is possible to compute the correct value of x_t using the information at $t-1$ and the knowledge of the model, then $E_{t-1}x_t = x_t$. This is the case if there are no stochastic shocks.

process. In this case, adjustment is often insufficient because it entails costs in terms of thinking and because people prefer to make cautious errors rather than rash ones.

Epley and Gilovich (2005) have demonstrated that incentives induce subjects to adjust more, if their anchor is self-generated, but not if it is externally provided. Externally provided anchors trigger automatic psychological processes which are unaffected by manipulations to increase mental effort. Self-generated anchors, on the other hand, differ from externally provided anchors because they are known from the beginning to be wrong and thus do not need to be considered as possible answers to the target question. They do not activate automatic processes, but instead initiate a process of effortful serial adjustment that modifies the initial anchor in a direction that seems appropriate until a plausible estimate is reached. That subjects respond to incentives means that they are willing to exert effort to make good adjustments if it pays off to do so.

In the case of the formation of expectations, people generate their anchors themselves and hence use it only as the basis of the estimation process. The following adjustment to the final estimate is subject to cost-benefit considerations in which the costs are costs of thinking and of processing information and the benefits depends in the incentives to form good expectations. In our experiment, expectations were both incentivised directly via the payoff functions and indirectly, because correct expectations helped to make good decisions.

Since benefits and costs of expectations in our experiments differ between variables, we expect adjustment to be differently strong. For firms, it is very valuable to have correct price expectations, because their profit depends on the value of sales which is a function of the product price. At the same time, the costs of forming price expectations are relatively low, because the price depends only on the employment choice of the respective firm and the demand function is deterministic and can in principle be observed in the course of time. We therefore expect σ_2^p in equation (14) to be relatively large, i.e. adjustment close to rational.

Quite the opposite is true for firm's wage expectation. The only incentive to make good wage predictions come from the payoff function for estimations, which generates identical incentives for all expectations. There is no further motivation to make a good wage prediction, because firms learn it at the next stage and base the employment decision of the actual, not the expected nominal wage. The costs of forming good expectations on the nominal wages are high, because the player has to anticipate what his opponent will do. Even with a rational opponent this is difficult, because the player would have to solve the opponent's maximization problem. But if the opponent is not maximizing his objective function, there is no obvious alternative model predicting his actions. Since benefits are low and costs are high, we expect almost no adjustment away from the anchor, or low σ_2^w.

The cost-benefit ratios of workers' expectations are between those of firms' expectations. The benefits of good predictions of both employment and the price level are high, since these variables are in the objective function and workers must make their decision before they know the realizations. The costs of forming these expectations are also high in both instances, because the potentially irrational behavior of other players is involved. It might be that the cost-benefit ratio for the price level expectation is a bit higher than for employment, since the price level depends on the behavior of all players (not only of one) and the impact of an individual wage on the price level is smaller than on industry employment.

We summarize these considerations in the following hypothesis

$$1 \geq \sigma_2^p > \sigma_2^L \geq \sigma_2^P > \sigma_2^w \geq 0. \tag{H1}$$

In addition to knowing the degree of rationality of the adjustment, we would also like to learn more about which variables influence the adjustment. It may be difficult to make any general statements, as adjustments are likely to be context-dependent. However, we hypothesize that salient variables play a role, because they may trigger mental processes and are cheap to acquire. In our experiment, w_{t-1}, L_{t-1}, p_{t-1}, P_{t-1}, and the π_{t-1} or U_{t-1} were very salient, because they were displayed on each decision screen. However, it is hard to imagine that the past values of the respective objective functions have an impact on the adjustment of expectations. Furthermore, subjects also knew their choice of their decision variable w_t and L_t respectively, when they entered their expectation[4]. We restrict our further attention to w_{t-1}, L_{t-1}, p_{t-1}, P_{t-1} and w_t and L_t when they are already known by subjects.

We imagine the adjustment process to work as follows. Subjects have mental models of the experimental environment that specifies perceived causal relationships between variables. These mental models are partly derived from the experimental instructions, which contain all model equations except for the demand function. But the information from the instructions is not sufficient to obtain the necessary causal relationships, even if it were complete. The instructions contain only structural equations, not the reduced forms. Furthermore, the model is only helpful

[4] With the exception of w_t^e which had to be entered by firms before they made their employment choice.

with the auxiliary assumption of rational players. For this reason, subjects modify and extend the model as it is presented in the instructions to mental models that appear plausible and useful to them. The mental models are useful if they allow subjects to make satisfactory choices and predictions that are not utterly wrong most of the times. Notice that the adjustment functions $A^x(.)$ are identical to the expected change of the variable x relative the its past value

$$A^x = x_t^e - x_{t-1}.$$

Their subjective models must help subjects to predict these expected changes. We will now discuss, how such a subjective model might look like.

The expected price change involves beliefs about the demand function. From the instructions, subjects knew that there was a negative relation between the industry output and price and that output was positively related to employment. A rational subjective model should therefore relate the expected price change negatively to the current change in employment. While in the true model, no other variable has an influence on price, subjects might perceive other determinants, too. An obvious candidate is the change of the nominal wage. Subjects might believe in the Keynesian purchasing power argument of nominal wages, which is not part of modern macroeconomic theory, but very popular among trade unions (Jerger and Michaelis, 2003), lay persons, and left-wing politicians. According to such a belief, higher nominal wage would lead to increase in aggregate demand, which, for given employment and output, would lead to higher prices. We therefore hypothesize the adjustment to the expected price to be a function of the change in employment and the change of the nominal wage

$$p_t^e - p_{t-1} = A^p(\underset{(-)}{\Delta L_t}, \underset{(+)}{\Delta w_t}) \tag{H2}$$

and estimate a simple linear version of this function.

How firms form expectations of the nominal wage change is not obvious. Theoretically, the optimal nominal wage is constant, so that there should be no wage change. However, subjects might first have to learn the optimal wage implying some adjustment toward the optimal value. If firms want to make good predictions of the wage adjustment, they must consider the workers' learning process, which is likely to be difficult. The expected wage change might depend positively on the past value of employment, if workers want to induce the firm to increase employment when employment is low and to use the opportunity to obtain utility when employment is high. It might also be a positive function of the past price level, if workers interpret the price level - which enters their utility function directly - as a proxy for inflation. We test the linear version of

$$w_t^e - w_{t-1} = A^w(\underset{(+)}{P_{t-1}}, \underset{(+)}{L_{t-1}}). \tag{H3}$$

It is fairly clear that the employment change expected by workers should depend negatively on the change of the nominal wage. Workers knew the instructions and hence the objective function of firms in which the nominal wage enters negatively. Since other dependencies on the salient variables are difficult to rationalize so that we hypothesize this adjustment function only to depend the wage change

$$L_t^e - L_{t-1} = A^L(\underset{(-)}{\Delta w}). \tag{H4}$$

The prediction of the change of the aggregate price level - or inflation - is difficult in our experiment. There is no direct feedback between one worker's actions and the realization of the price level. Workers know that the price level is an average of all prices, but all prices are derived from the unknown demand function. As the actions of firms and workers in other industries are not easily observable, we expect the price level adjustment to depend positively on the change of the nominal wage. As argued before, workers should see that a wage increase creates an incentive for firms to lower employment and they know that at least the price in their industry is a negative function of the industry output. If workers additionally believe in the purchasing power argument of the nominal wage, they have a second rationale why they wage increase might increase the price level, hence

$$P_t^e - P_{t-1} = A^P(\underset{(+)}{\Delta w_t}). \tag{H5}$$

These predictions can be tested in linear regressions. In principle, there could be a constant in all adjustment functions, meaning that subjects would perform some constant autonomous adjustment, which would be justified, if there were some kind of trend growth. But as our model does not generate any trend growth, we expect subjects to realize this and not to perform autonomous adjustment with constant rates.

5 Results

The analysis was conducted with pooled data, i.e. we estimated the equations by pooled OLS for each session. We consider this procedure as a summary of the individual estimations, which are not so interesting in the context of the formation of macroeconomic expectations.

Table 1: Biasedness of expectations

		(1) p^e	(2) w^e	(3) L^e	(4) P^e
Session 1	ρ_0	.06	.72***	.61**	.29***
		(.04)	(.10)	(.14)	(.05)
	ρ_1	.89	.60***	.88***	.47***
		(.07)	(.05)	(.05)	(.08)
	$\overline{R}^2$	.552	.538	.674	.095
	$p(F)$	.283	.000	.000	.000
	$p(R)$	.387	.000	.021	.490
	$\#obs$	236	243	243	243
Session 2	ρ_0	.15***	.48***	1.01***	.01
		(.04)	(.09)	(.29)	(.07)
	ρ_1	.74***	.74***	.71**	.96
		(.06)	(.06)	(.13)	(.13)
	$\overline{R}^2$	.564	.557	.302	.143
	$p(F)$	.000	.000	.000	.270
	$p(R)$	.158	.000	.000	.164
	$\#obs$	233	243	243	241

pooled samples, robust standard errors in parentheses, $p(F)$: significance level of F-test on $\widehat{\rho}_0 = 0$ and $\widehat{\rho}_1 = 1$, $p(R)$: significance level of Ramsey RESET test on omitted variables, asterisks indicate significant difference from $\widehat{\rho}_0 = 0$ and $\widehat{\rho}_1 = 1$ in t-test at 10%, 5%, and 1% for *, **, and *** respectively

5.1 Biasedness

Most aggregate expectations are clearly biased as Table (1) shows. Only for the price expectation in session 1 and the price level expectations in session 2, the F-test does not reject the null of unbiasedness. But notice that the adjusted R^2 of the price level regression is fairly low, which is also true in session 1. For all other expectations, unbiasedness is rejected. A basic condition for rational expectations is therefore generally violated in our experiment.

Since we have only 9 subjects of each type in each session, it is conceivable that a few very irrational subjects have a strong impact on the pooled regressions. But regressions at the individual level show that the expectations of most subjects individually are also biased (see Table (2)). In session 1, there are only two subjects that have unbiased expectations. In session 2, the number of unbiased individual expectations is only one for p and P, but five for the other two variables. The typical

Table 2: Biasedness of expectations, summary of individual estimations

		(1) p^e	(2) w^e	(3) L^e	(4) P^e
Session 1	$p(F)_{\rho_0=0,\rho_1=1} < .05$	6	8	7	8
	$p(F)_{\rho_0=0,\rho_1=1} > .1$	2	1	2	0
Session 2	$p(F)_{\rho_0=0,\rho_1=1} < .05$	5	3	3	8
	$p(F)_{\rho_0=0,\rho_1=1} > .1$	1	5	5	1

pattern among the other subjects is that ρ_0 is estimated be significantly positive and ρ_1 to be smaller than one.

We have found evidence that aggregate expectations for the four variables are generally not rational due to bias. But maybe subjects learn over time and remove the bias from their expectations. In order to test for this possibility, we re-estimated the regressions with the sample split in two halves (from period 4 to period 15 and from period 16 to 30). In fact, there is a tendency to remove the bias. In all cases, the intercept was smaller and the slope coefficient closer to one in the second half compared to the first half. However, even in the second half of the sessions, subjects still produced biased estimates, with the exception of the price expectations in session 1.

5.2 Adaptive expectations

The traditional model of adaptive model fits the data better than the benchmark model of rational expectations in terms of the information criteria AIC (see Table 7). The only exception are the price expectations in session 1, for which the information criteria are considerable lower for equation (12) than for equation (13). Rather the being really adaptive, price expectations in Table (3) are naive, because the joint hypothesis of $\omega_1 = 1$ and $\omega_2 = 0$ cannot be rejected, which is also true for P^e in session 2 (at the 5% level). While the coefficient on p^e_{t-1} is generally significantly positive, the sum of the two coefficients, $\omega_1 + \omega_2$, is only equal to one in four cases, as required by the adaptive model. For w^e and L^e in session 1 and p^e in session 2 the adaptive model's parameter restriction is violated.

We conclude that the traditional adaptive model of expectation formation can only explain P^e in session 1 and w^e and L^e in session 2. It is somewhat puzzling that the expectation formation process seems to be different for w^e, L^e, and P^e between the two sessions.

Table 3: Adaptive expectations, pooled samples

		(1)	(2)	(3)	(4)
		p^e	w^e	L^e	P^e
Session 1	ω_1	.99	.61***	.93	.60***
		(.01)	(.06)	(.08)	(.11)
	ω_2	.00	.37	.14	.40
		(.00)	(.06)	(.09)	(.11)
	$\overline{R}^2$	.992	.990	.924	.995
	$p(F)_{\omega_1+\omega_2=1}$	.236	.000	.000	.554
	$p(F)_{\omega_1=1,\omega_2=0}$	.091	.000	.011	.000
	$\#obs$	236	243	243	243
Session 2	ω_1	1.01	.64***	.76***	.96**
		(.00)	(.08)	(.08)	(.02)
	ω_2	.01	.36	.28	.03
		(.00)	(.08)	(.08)	(.02)
	$\overline{R}^2$	.998	.988	.904	.988
	$p(F)_{\omega_1+\omega_2=1}$	.000	.722	.190	.170
	$p(F)_{\omega_1=1,\omega_2=0}$	.000	.000	.000	.165
	$\#obs$	233	243	243	241

pooled samples, robust standard errors in parentheses, $p(F)$: significance level of F-tests, asterisks indicate significant difference from $\widehat{\omega}_1 = 1$ in t-test at 10%, 5%, and 1% for *, **, and *** respectively

Table 4: Anchoring-and-adjustment model, pooled samples

		(1) p^e	(2) w^e	(3) L^e	(4) P^e
Session 1	σ_1	1.00	.97***	1.09***	1.00
		(.00)	(.01)	(.03)	(.01)
	σ_2	.74**	.14***	.24***	.26***
		(.10)	(.05)	(.10)	(.09)
	$\overline{R}^2$	.995	.985	.929	.994
	$p(F)$	.036	.000	.000	.000
	$\#obs$	236	243	243	243
Session 2	σ_1	1.01***	1.00	1.09***	.99
		(.00)	(.01)	(.03)	(.01)
	σ_2	.34***	.14***	.24***	.18***
		(.08)	(.06)	(.07)	(.18)
	$\overline{R}^2$	.998	.982	.888	.988
	$p(F)$	.000	.000	.000	.000
	$\#obs$	233	243	243	243

pooled samples, robust standard errors in parentheses, $p(F)$: significance level of F-test on $\widehat{\sigma}_1 = 1$ and $\widehat{\sigma}_2 = 1$, asterisks indicate significant difference from $\widehat{\sigma}_1 = 1$ and $\widehat{\sigma}_2 = 1$ in t-test at 10%, 5%, and 1% for *, **, and *** respectively

5.3 Anchoring-and-adjustment heuristic

Table (4) shows that the estimated coefficient $\widehat{\sigma}_1$ of the past observation as potential anchor is always close to one and not significantly different from one in four cases. These significant deviations from one for the whole sessions are caused by only a few individuals. Regressions at the individual level show that in session 1, $\widehat{\sigma}_1$ differs significantly (at 5%) from one for three subjects in the case of w^e and four in the case of L^e. In session 2, there are three significant deviations for p^e and 2 for L^e. Altogether, most subjects seem to have chosen the last period's value as an anchor for the estimation of the current value. Anchoring on the last observed realization appears prevalent in the formation of expectations among our subjects.

Except for the price level in session 2, subjects adjust their expectation after choosing the anchor as the first estimate. The aggregate result for P^e in session 2 is also confirmed by the individual results, which show that 7 out of 9 subjects do not adjust at all, meaning that they form those expectations naively with one lag and a coefficient on this lag close to one. In line with the psychological literature, adjust-

Table 5: Significance levels of tests on the equality of adjustment

	H_0	(1) $\sigma_2^p = \sigma_2^w$	(2) $\sigma_2^p = \sigma_2^L$	(3) $\sigma_2^p = \sigma_2^P$	(4) $\sigma_2^w = \sigma_2^L$	(5) $\sigma_2^w = \sigma_2^P$	(6) $\sigma_2^L = \sigma_2^P$
$S1$	p	.014	.001	.000	.407	.221	.882
$S2$	p	.588	.403	.529	.520	.376	.436

ment is not sufficient so that expectations are biased toward the anchor. In both sessions and for all variables, $\widehat{\sigma}_2$ significantly smaller than one, which would mean perfect adjustment. The F-tests always reject the joint null hypothesis of $\widehat{\sigma}_1 = 1$ and $\widehat{\sigma}_2 = 1$.

The point estimates of the adjustment parameter have the properties as described in hypothesis (H1): σ_2^p is largest, σ_2^w is smallest, and the two other estimates lie in between. To test for the statistical significance of those differences, we stacked all four sets of variables into one large system and estimated a non-continuous spline regression for each pair of variables. Table (5) contains the p-values of the respective dummy variables. In the first session, the adjustment of the price expectation is clearly the stronger than the adjustment for the other expected variables. The size of adjustment of the other expectations are not significantly different from each other, which is also true for all variables in session 2. The support for the hypothesis (H1) is only partial.

Whether the evidence supports our hypotheses concerning the determinants of the adjustment - (H2) - (H5) - can be seen in Table (6). The hypothesis about what determines the price expectation adjustment is strongly supported, because we find a negative effect of the employment change and a positive effect of the wage change. The adjustment of the wage expectation is poorly explained by the hypothesized variables. P_{t-1} is insignificant and the coefficient of L_{t-1} changes its sign between the two sessions. But as discussed earlier, for the wage expectation, the adjustment is very weak anyway, which is consistent with low explanatory power of the potential determinants. As we had expected and as it is rational, the adjustment of the expected employment level depends negatively on the wage change. But strangely, we also estimate significantly positive constants, which indicates an employment expectation that is always by a constant amount larger than the last observed employment level. Notice also that the coefficient of determination is very low. Finally, the adjustment of the price level expectation cannot be explained by the wage change in line with the earlier result that in session 2, there is no adjustment away from anchor at all.

Table 6: Adaptive expectations, pooled samples

		(1) A^p	(2) A^w	(3) A^L	(4) A^P
Session 1	*cons*	-.00	-.27	.30***	-.00
		(.00)	(.34)	(.07)	(.00)
	ΔL_t	-.01***			
		(.00)			
	Δw_t	.06***		-.58***	-.00
		(.01)		(.10)	(.01)
	L_{t-1}		.04***		
			(.01)		
	P_{t-1}		.26		
			(.59)		
	$\overline{R}^2$	.414	.143	.04	-.004
	#obs	236	243	243	243
Session 2	*cons*	.01***	.80	.20***	-.01
		(.00)	(.52)	(.07)	(.00)
	ΔL_t	-.005***			
		(.00)			
	Δw_t	.012*		-.95***	.01
		(.00)		(.31)	(.01)
	L_{t-1}		-.05**		
			(.02)		
	P_{t-1}		-1.24		
			(.90)		
	$\overline{R}^2$	.138	.086	.096	.006
	#obs	233	243	243	243

pooled samples, robust standard errors in parentheses, asterisks indicate significant difference from zero in t-test at 10%, 5%, and 1% for *, **, and *** respectively

Table 7: Model comparison by AIC

		Restriction	(1) p^e	(2) w^e	(3) L^e	(4) P^e
Session 1	IE		-843.0	158.2	920.8	-819.3
	AD		-728.5	-120.1	720.7	-880.7
	AAH		-858.9	-16.7	704.5	-828.6
	AD	$\omega_1 + \omega_2 = 1$	-729.0	**-105.9**	**730.9**	**-882.3**
	AAH	$\sigma_1 = 1, Det$	**-855.8**	-25.3	**731.2**	406.7
Session 2	IE		-984.0	245.1	992.3	-649.4
	AD		-1059.7	-72.9	727.1	-672.0
	AAH		-1111.3	22.6	764.1	-669.8
	AD	$\omega_1 + \omega_2 = 1$	-1044.8	**-74.7**	**727.7**	**-671.9**
	AAH	$\sigma_1 = 1, Det$	**-1071.2**	14.9	766.0	399.2

IE: implicit expectations, AD: adaptive expectations, AAH: anchoring-and-adjustment model, *Det* : determinants of adjustment function included as in Table 6

5.4 Comparison of models

If we understand the adaptive model and the anchoring-and-adjustment model as competing models, it is natural to ask which one is better. One way to do this is to use information criteria such as the Akaike Information Criterion (AIC). According to the AIC (and to the BIC as well), the model of adaptive expectations dominates the anchoring-and-adjustment model for the expectations of wages, employment, and the price level (see Table (7)). However, in several cases the AIC is lower for the unrestricted adaptive model than for the one restricted to have coefficients summing up to one, which means that the purely adaptive model with $\omega_1 + \omega_2 = 1$ can be improved. The anchoring-and-adjustment model with the proposed determinants of adjustment is clearly the best model for the price expectations of firms. While in session 1, the AAH model cannot be improved by dropping the constraint $\sigma_1 = 1$ (AIC -853.9), there is some improvement in session 2 (AIC -1091.9). Notice that the implicit expectations model is always inferior to either the adaptive or the anchoring-and-adjustment model.

Another way to compare the alternative models is to estimate an encompassing model and to test the encompassing model against the alternative hypotheses of the individual models (see Hey 1994). As encompassing model we estimate

$$x_t^e = \omega_1 x_{t-1} + \omega_2 x_{t-1}^e + \boldsymbol{\alpha}\mathbf{A}_t + \epsilon_t, \qquad (15)$$

where $\mathbf{A}_t$ is the vector of adjustment determinants. Using this estimated model, we can test for the alternative individual models. If expectations are formed in a purely adaptive manner, we cannot reject the joint hypothesis $\omega_1 + \omega_2 = 1$ and $\boldsymbol{\alpha} = 0$ (hypothesis AD). If subjects use the anchoring-and-adjustment heuristic as described above, we cannot reject $\omega_1 = 1$ and $\omega_2 = 0$ (hypothesis AAH). Finally, the encompassing model also allows us to test if expectations are naive, which would imply $\omega_1 = 1$, $\omega_2 = 0$, and $\boldsymbol{\alpha} = 0$ (hypothesis N).

Table (8) contains the results of this exercise. Confirming the results of the AIC comparisons, the F-tests do not reject the anchoring-and-adjustment model for p^e in session 1, but strongly reject hypotheses AD and N. In session 2, results are mixed, because all hypotheses are rejected. This means that the encompassing model is better than any individual model which is also reflected in the low AIC. Notice, however, that according to individual t-tests $\omega_1 = 1$, $\omega_2 > 0$, and $\alpha_{\Delta L} > 0$ hold. This is consistent with an anchoring-and-adjustment heuristic that comprises the past expectation as an adjustment determinant.

For the wage expectation, all individual models are rejected (but the AD hypothesis only slightly in session 2). Wage expectations seem to be formed by a kind of adaptive model with P_{t-1} as a corrective component. Interestingly, the coefficient of P_{t-1} is significant and similar in size in both sessions, but was not significant in the estimations of adjustment determinants.

Employment expectations are also best explained by the encompassing model. But the character of the encompassing model is very different between the two sessions. In session 1, ω_1 individually is not different from one, while ω_2 is not different from zero making the model very similar to the AAH model. In session 2, ω_1 individually is significantly smaller than one and ω_2 is positive, as it should be in the adaptive model.

Finally, we get fairly clear results for the expectations of the price level. Subjects in session 1 form adaptive expectations, because hypothesis AD cannot be rejected, but hypotheses AAH and E are. The AIC of the encompassing is slightly higher than that of the previously estimated adaptive models. In session 2, the adaptive model is also not rejected, but neither are the AAH model and the purely extrapolative model. Given that in individual t-test ω_2 and $\alpha_{\Delta w}$ are not different from zero and ω_1 is not different from one, the naive model is the most compelling one.

6 Discussion

In our experiment, subjects' expectations are clearly not rational, because the fundamental requirement of unbiasedness is systematically violated. Our findings confirm previous experimental results and also some

Table 8: Encompassing model, pooled samples

		(1)	(2)	(3)	(4)
	x_t^e	p_t^e	w_t^e	L_t^e	P_t^e
Session 1	x_{t-1}	1.000***	.603***	.936***	.597***
		(.005)	(.055)	(.077)	(.108)
	x_{t-1}^e	.000*	.276***	.132	.401***
		(.000)	(.058)	(.086)	(.109)
	ΔL_t	-.011***			
		(.002)			
	Δw_t	.059***		-.606***	.000
		(.012)		(.110)	(.007)
	L_{t-1}		.007		
			(.008)		
	P_{t-1}		.312**		
			(.136)		
	R^2	.995	.991	.929	.995
	AIC	-852.0	-138.1	710.0	-878.7
	$p(F)_{AD}$	.00	.00	.00	.77
	$p(F)_{AAH}$	.10	.00	.01	.00
	$p(F)_N$	.00	.00	.00	.00
	$\#obs$	236	243	243	243
Session 2	x_{t-1}	1.009***	.634***	.760***	.957***
		(.003)	(.069)	(.073)	(.023)
	x_{t-1}^e	.004***	.311***	.273***	.033
		(.001)	(.054)	(.072)	(.019)
	ΔL_t	-.005***			
		(.001)			
	Δw_t	.012		-.917***	.015
		(.007)		(.299)	(.015)
	L_{t-1}		-.029**		
			(.014)		
	P_{t-1}		.306**		
			(.136)		
	R^2	.998	.989	.916	.988
	AIC	-1091.3	-88.3	698.4	-672.3
	$p(F)_{AD}$	.00	.09	.00	.25
	$p(F)_{AAH}$	.00	.00	.00	.18
	$p(F)_N$	.00	.00	.00	.22
	$\#obs$	233	243	243	241

pooled samples, robust standard errors in parentheses, $p(F)$: significance level of F-test on the restrictions of the respective models, asterisks indicate significant difference from zero in t-test at 10%, 5%, and 1% for *, **, and *** respectively econometric analyses of consumer expectations.

There is no single answer to the question of how subjects form their expectations. None of the proposed model dominates its rivals in all cases. Subjects seem to form expectations differently for different variables. The model of adaptive expectations fits quite well for w, L, and P, but the parameter restriction of the purely adaptive model, $\omega_1 + \omega_2 = 1$, is not always fulfilled. The traditional adaptive model is the best model for the expectations of the general price level in session 1.

The anchoring-and-adjustment model dominates the adaptive model for the price expectations of firms. Furthermore, it has a similar fit as the adaptive model for the employment expectations in session 1. This model is definitely not useful to explain how the expectations of w and P are formed. In the estimations of the AAH model, the coefficient of the past observation of the respective variables is always close to one, supporting the idea that this variables is chosen as an anchor. As expected, the adjustment away from the anchor is insufficient in all estimated models and as hypothesized it is larger for prices than for the other variables (significantly so in session 1). As the adjustment is very imperfect, especially for w and P, it is not surprising that it cannot be well explained by the proposed determinants. Price level expectations in session 2 are best modeled as naive expectations, which is a special case of anchoring and adjustment ($\sigma_1 = 1, \sigma_2 = 0$) and adaptive expectations.

In the majority of cases, however, neither the adaptive model nor the anchoring-and-adjustment model best describe the formation of expectations, but rather the model encompassing both individual models. Two of those encompassing models are close to the AAH models (session 1, L^e, and session 2, p^e), because in individual t-tests, $\widehat{\omega}_1$ is not significantly different from 1 and $\widehat{\omega}_2$ is either small or insignificant. The three remaining encompassing models (session 1, w^w,session 2, w^e and L^e) are more like adaptive models as $\widehat{\omega}_1$ is significantly smaller than 1 and the sum of $\widehat{\omega}_1$ and $\widehat{\omega}_2$ is close to 1. Those models could be interpreted as augmented adaptive models which also incorporate some knowledge about the data generating process.

Having found that subjects used different models to form expectations, we would like to answer the question what determines the use of the respective expectation formation model. Unfortunately, the data of the present experiment do not enable us to make strong conclusions about those determinants. We can only try to formulate tentative hypotheses which should be tested in new experiments that are especially designed for this purpose. In order to get some intuition, what might be relevant factors for the use of the different models, we must look at the crucial differences between the models of expectation formation and at the differences between ways in which the realizations of the variables to be predicted are determined.

The most important feature that distinguishes the anchoring-and-adjustment model from the adaptive and the extrapolative model is that it may incorporate other variables reflecting theories about the process generating the data. The adaptive and the naive model are simple mechanistic rules using a minimum of information. They are purely backward-looking and can be applied in every situation. The anchoring-and-adjustment model, however, may contain a fairly complicated adjustment function that uses many objectively and subjectively relevant variables. Rather than being purely mechanic, the adjustment is the result of a deliberate cognitive process that evaluates the plausibility of the estimation of the unknown realization. As said before, the anchoring-and-adjustment heuristic is a cognitive process in which the anchor is taken as a first rough estimate which is known to be imprecise and which is then adjusted to a sufficiently plausible estimate.

Probably the main difference between variables is the degree to which the determination of realizations is deterministic. The price p, which subjects predict using the anchoring-and-adjustment heuristics, depends only on the own actions of the subjects who form the expectation and is hence determined in a highly deterministic way. In fact, the demand function is deterministic and includes only employment as an argument, although this is not known by subjects. In particular, prices do not depend directly on the actions of other subjects. This is different for all other variables, which are typically predicted by adaptive models. Subjects knew that both wages and levels of employment were directly set by one other individual. Forming expectations for those variables hence was synonymous to expecting what the other subject would do which implies a much larger degree of uncertainty than the prediction of prices. The actions of other subjects could be motivated by rational considerations, misperceptions, emotions, or simply by chance. But even if a subject knew that the other subject is perfectly rational, it is fairly difficult to solve his optimization problem which is necessary to predict his actions. Finally, the determination of the price level P is most intransparent, because it is a function of the unknown demand functions and depends on the actions of more than one subject.

Combining the specific features of the expectation models and the data generating processes, we propose the following hypothesis about when subjects use the anchoring-and-adjustment heuristic and when they resort to the simpler models of adaptive or naive expectations. Simple models such as the adaptive model will be used when little is known about the data generating process or agents have only a poor understanding of their economic environment. More complex methods such as the anchoring-and-adjustment heuristic will be applied if agents believe to know much about the data generating process and to understand well how the economy works[5]. In this case, agents can develop a subjective model that helps them to make the adjustments necessary to correct the first rough estimate. If one knows little about the economy, it is hard to make adjustments of first rough estimates and to assess the plausibility of the adjustment. On the other hand, if an agent believes to understand how a variable is determined and how other observable variables affect the variable in question, this information should be used which is not possible in very simple expectation models.

In our experiment, subjects might have gained a comparatively good intuition about the determination of the price, while they not have understood what determined the other variables. Although they did not know the demand function, they knew in advance that the price would be a negative function of output and thus of employment. It seems very unreasonable to ignore this information completely and to use the mechanistic rule of the adaptive model to predict the price.

Of course, we cannot claim to have provided strong empirical evidence for the proposed hypothesis about the use of different expectation formation models. Clearly, a more systematic exploration of the conditions under which subjects use different expectation models is necessary. In order to test the proposed hypothesis, one would have to vary systematically the environment, maybe starting with a very simple model and making it more and more complex and to check whether subjects start with the anchoring-and-adjustment heuristic and switch to simpler models if the economy becomes to complicated for the. Such an experiment is left for future work.

7 Conclusions

Although we use a design that is supposed to be more favorable to rational expectations than the designs of other studies, our experiment confirms the result of previous experimental studies that expectations are often not rational, because they are systematically biased. We also confirm that models of adaptive expectations are fairly good descriptions of how subjects for expectations. Our results also show that the traditional adaptive model, in which the current expectation is a convex

[5] Alternatively, one might think that the choice of method to form expectations depends on the variation or the degree of autocorrelation of the variable to be predicted. A natural presumption is to expect a strong dependency on the past observation if the variation is low and/or the autocorrelation is high. Yet, this plausible hypothesis is not supported by our data.

combination of the last observation and the last expectation, is often rejected and more flexible models describe our data better.

The anchoring-and-adjustment model based on the anchoring-and-adjustment heuristic, which we propose as an alternative model to describe expectation formation processes, also gets some support by our data. Contrary to the adaptive model, the anchoring-and-adjustment model can incorporate subjects' knowledge about the economy, which makes it more rational than models than only use past observations and expectations in a purely mechanistic way. It seems that this model is superior to the adaptive model, when the benefits of good expectations are high, the costs of forming them are low, and the data generating process is easy to understand.

In many cases, however, an encompassing model with features of both models fits the data best. From that we conclude that while the anchoring-and-adjustment model as proposed here may not be the best model, traditional adaptive models are neither. Subjects seem to be willing to perform more reasoning than necessary to apply mechanistic heuristics. In order to understand better, what they do and which expectation formation processes are invoked under which conditions, more experimental work is necessary.

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