Michael W.M. Roos and Wolfgang J. Luhan

As if or what? – Expectations and Optimization in a Simple Macroeconomic Environment

#55

Ruhr Economic Papers

technische universität dortmund

Ruhr Economic Papers

Published by

Ruhr-Universität Bochum (RUB), Department of Economics
Universitätsstraße 150, 44801 Bochum, Germany

Technische Universität Dortmund, Department of Economic and Social Sciences
Vogelpothsweg 87, 44227 Dortmund, Germany

Universität Duisburg-Essen, Department of Economics
Universitätsstraße 12, 45117 Essen, Germany

Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI Essen)
Hohenzollernstrasse 1/3, 45128 Essen, Germany

Ruhr Economic Papers #55

Responsible Editor: Wolfgang Leininger

ISSN 1864-4872 (online) – ISBN 978-3-86788-058-9

Ruhr Economic Papers

#55

Michael W.M. Roos and Wolfgang J. Luhan

As if or What? – Expectations and Optimization in a Simple Macroeconomic Environment

technische universität
dortmund

Bibliografische Information der Deutschen Nationalbibliothek
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.

ISSN 1864-4872 (online)
ISBN 978-3-86788-058-9

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

As if or What? – Expectations and Optimization in a Simple Macroeconomic Environment

Abstract

In this paper we report the results of a laboratory experiment, in which we observed the behavior of agents in a simple macroeconomic setting. The structure of the economy was only partially known to the players which is a realistic feature of our experiment. We investigate whether subjects manage to approach optimal behavior even if they lack important information. Furthermore, we analyze subjects' perceptions of the model and whether their behavior is consistent with their perceptions. The full information model predicts changes of employment correctly, but not the level of employment. In the aggregate, subjects have correct perceptions, although individual perceptions are biased. We finally show that deviations from the full information solution are due to optimization failures than than misperceptions.

JEL Classification: D01, D83, D84, B41, C91

Keywords: Methodology, macroeconomic experiment, perceptions, optimization, expectations

July 2008

* Michael W.M. Roos, Technische Universität Dortmund, Wirtschafts- und Sozialwissenschaftliche Fakultät, 44221 Dortmund, Germany, e-mail: Michael.Roos@uni-dortmund.de; Wolfgang J. Luhan, Universität Oldenburg, Zentrum für Methoden der Sozialwissenschaften, Institut für Soziologie 26129 Oldenburg, Germany.

1 Introduction

In many economic models, agents are assumed to behave *as if* they knew the structure of the model and *as if* they were perfectly rational utility or profit maximizers. Most economists argue that every model must exclude large part of real world complexity to facilitate the discovery of underlying processes. They furthermore resort to the Friedmanian argument not to claim that agents really behave this way but that this as-if-assumption produces correct predictions (Friedman 1953). Other models do not assume that agents know the model, but that they learn its structure over time (see Evans and Honkapohja 2001, Marcet and Sargent 1989). This branch of the learning literature explores the conditions under which model assumptions, learning mechanisms, or formation of expectations lead to Rational Expectations Equilibria. Most microfounded macroeconomic models, however, are silent about how agents reach the Rational Expectations Equilibrium, which is the generally applied solution concept in New Classical and New Keynesian macroeconomics.

We address the fundamental methodological question whether rational expectations models or more specifically models with perfectly foresighted agents really live up to Friedman's requirement of predicting well what real subjects do. This issue cuts to the very heart of economic methodology as these models are common practice in most economic fields and especially in macroeconomics. It is notoriously difficult to assess the predictive power of economic models with field data (see e.g. Sutton 2002), which is in fact one of the most important arguments in favor of economic experiments. Most economic experiments can be understood as tests of the predictive power of economic as-if models, and many have produced robust rejections of this hypothesis[1]. Our experiment differs from most of the experimental economic literature in its focus on market or macroeconomic behavior rather than the behavior of individuals. So far, only few researcher have used the method of economic experiments to test macroeconomic models (see Duffy 2006 for a survey).

Many prominent theories from the realm of Macroeconomics might appear suitable choices for experimental examination. However, in order to examine the fundamental assumptions of profit or utility maximization and rational

[1] Roth (1995) coined the term "speaking to theorists" and sees this class of experiments a part of a dialogue between theorists and experimenters. While we want to speak to theorists, there is also an element of "searching for facts" in our experiment.

expectations one might want to use the simplest textbook-like model. Otherwise too many auxiliary assumptions might blur the connection between the fundamental assumptions and the resulting predictions. The only purpose of this model is to generate predictions derived from the usual assumptions, which are then tested in the laboratory. Hence our contribution is methodological rather than macroeconomic.

One important innovation of our experiment is that we observe both subjects behavior and their perceptions of the economic environment. In addition to subjects' actions, we elicit their expectations on which they base their decisions. This allows us to analyze whether potential failures of the model to predict subjects' behavior correctly are rooted in misperceptions of the economic environment or in subjects' failures to maximize their payoff functions. Furthermore, we can analyze if the model makes correct predictions for the aggregate of subjects, even if it fails for individuals.

Our experiment is related to the work of Lian and Plott (1998), who investigate whether a full-fledged general equilibrium model with production, trade, and money can be implemented in the laboratory and whether a static Walrasian general equilibrium model is able to capture what is observed in a rather complex experimental economy. Lian and Plott also see their experiment as a test of as-if assumptions, most of which are clearly not satisfied. They find that, despite the violation of many assumptions, the data in their experimental economy converge to the magnitudes predicted by the static general competitive equilibrium model. There is also some relation to Vernon Smith's work on markets as economizers of information (Smith 1982). In his double auction experiments Smith shows that the predictions of the theory of competitive markets can be observed in the laboratory, although many of the theoretical assumptions are not satisfied.

In contrast to Lian and Plott (1998) and Smith (1982), we establish highly structured markets and use a partial equilibrium setting without the possibility of disequilibrium. We focus on maximization behavior as a core element of every modern mainstream model and need both a well-structured benchmark model to determine the objective maximization solution and subjects' perceptions of the model in order to see if they maximize with respect to their perceived model. We test maximization in an objective version, where the true underlying model is the benchmark, and a subjective version, which rests on the beliefs or expectations of subjects. As we observe how subjects form expectations in a macroeconomic setting, our work also relates to several recent experimental studies on expectation formation (Adam 2007, Bernasconi and Kirchkamp 2000, Bernasconi et al., 2004, Heemeijer et al. 2007, Hommes et al. 2005a,b, 2007, forthcoming, Sonnemans et al. 2004, 2005). While the analysis of subjective expectations and their formation process is clearly important for macroeconomics, it is not the main objective of this paper.

This paper seeks to answer the following research questions. First, how well does the full information model describe subjects' behavior and the observed data? This question is in the tradition of Lian and Plott (1998) and Smith (1982). Second, how do subjects perceive their economic environment? With this question we complement the theoretical literature on model uncertainty (see Evans and Honkapohja 2001), which analyzes how subjects' misperceptions influence the model equilibria. A common assumption is that subjects do know the functional forms of relationships between variables, but do not know the parameters. We want to explore if such an assumption is justified. Third, we ask if behavior is consistent with expectations in that subjects' decisions maximize their objective functions for the expressed expectations. In a sense, this research question combines questions 1 and 2. People might have correct or rational expectations, but do not optimize which would lead to deviations from the model's predictions. The experimental literature on expectations usually separates decision making and expectation formation and requires subjects to form expectations only, while the decision problem is solved by the computer (see Marimon et al. 1993). We argue that it is a more natural setting if subjects both have to think about the consequences of their decisions and form expectations not for its own sake but with the goal of making good decisions.

2 Model

Our model 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[2]. δ_i is a scaling factor and γ is the weight given to 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. To determine the equilibrium under these assumptions and to do comparative statics

[2]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.

on the equilibrium is the standard textbook approach in economic analysis.

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

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

which is, of course, constant.

3 Experimental design and procedure

The main objective of the experiment is to observe what subjects do in the economy characterized by equations (2) - (5) and to learn how the perceive the model.

Obviously, in real world markets full information is a way too strong assumption, since this would mean perfect knowledge of all functional forms and parameters. The assumption that firms can exactly deduce the price for a given level of supply is maybe the most unrealistic feature of the full information model.

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 therefore 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 hyothetical 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[3]. 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

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

for workers and

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

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"

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

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 Results for firms

We present the results for subjects in the role of firms in this section and those for workers in the next section. In both sections, we first analyze the descriptive power of the full information model, move on to the perceived product demand function of firms and the perceived model of workers, and finally examine if subjects maximize their objective functions.

4.1 Full information

We start our analysis with an examination of the *as-if*-assumption. Do the subjects in our experiment behave *as if* they were perfectly informed and perfectly rational? Assume that all agents (firms) have complete information and are perfectly rational. Then the model predicts the firms to choose the profit maximizing full information employment level according to (7) for any wage w set by the workers. With our parametrization of $A = 8, \alpha = 1$, and $\varepsilon = 4$, equation (7) yields

$$L^{fi} = \beta_0 w^{\beta_1}, \tag{12}$$

with $\beta_0 = 8^{\frac{6}{5}} \left(\frac{3}{8}\right)^{\frac{8}{5}} \approx 2.524$ and $\beta_1 = -1.6$. This prediction can be tested by estimating

$$\ln L_{jt} = \widehat{\beta}_{j0} + \widehat{\beta}_{j1} \ln w_{jt} + \nu_{jt} \tag{13}$$

for all subjects j and comparing estimates $\widehat{\beta}_0$ and $\widehat{\beta}_1$ with the theoretical values β_0 and β_1. We find the model to fit the data remarkably good[4] (see Table 8). For 8 subjects, the adjusted R^2 is at least 0.8 and only for 3 subjects[5] it does not exceed 0.1. The good fit is fairly surprising, because the demand function is non-linear and if anything one might expect subjects to assume linear functions if the functional form of a relationship is unknown.

In 12 cases, the estimated wage elasticity of employment, $\widehat{\beta}_1$, is not significantly different from the model prediction, $\beta_1 = -1.6$. Among the six remaining cases, for which the elasticity differs significantly from the predic-

[4] We skipped the first 3 observations to control for learning and adjustment effects. For subject 16 in session 1 and subject 8 in session, we get remarkably better estimates, if we skip observation 4. The behavior of subject 6 in session becomes stable from period 10 onward.

[5] Subject 16 in session 2 is a special case, because this person chose a constant employment level from period 5 until the end.

tion, are the three subjects, for whom the model does not fit (according to the low R^2). The estimated intercept, $\widehat{\beta}_0$, is different from β_0 in the majority of cases. The point estimates are systematically too large[6] (between 26% and 73%). With the exception of subject 16 in session 2, it is never significantly too low. These results show that subjects generally chose employment levels that are higher than optimal, but respond to changes in the wage as predicted by the theoretical full information model.

Table 1 contains the results of panel estimations of (13), that summarize the results of the individual estimations[7]. Regardless of which panel model we estimate, the general message is the same: on average the scaling factor $\widehat{\beta}_0$ is too large, but the wage elasticity of labor demand is very close to the theoretical value. Only in two cases, the estimated elasticity differs significantly from -1.6, but in column (3) the 5% level is almost reached and the pooled OLS estimation in (9) is clearly inferior to the fixed effects model in (11).

Another way to analyze the predictive power of the full information model for behavior of subjects is to estimate

$$L_{it} = \gamma_{i0} + \gamma_{i1} L_{it}^{fi} + \xi_{it}, \tag{14}$$

which is the standard approach to test if a prediction is unbiased. If the model were a perfect description of the observed behavior, $\widehat{\gamma}_0 = 0$, and $\widehat{\gamma}_1 = 1$ would hold. F-tests on the joint restriction on the two parameters always reject the null with the exception of subject 18 in session 1. In a strict sense, the experimental evidence rejects the full information model as a reliable predictor of agents' behavior. However, in 8 cases, a t-test on the restriction $\widehat{\gamma}_1 = 1$ alone cannot reject the null at the five percent level. Table 2 presents the panel estimations of (14). Again we find actual employment to be larger than the optimal one. In all panel estimations, $\widehat{\gamma}_1$ is clearly larger than 1, however, the elasticity of L with respect to L^{fi}, $\eta_L^{L^{fi}}$, is always 1 indicating that the full information model fails to predict the *level* of employment that is chosen, but successfully predicts the *change*.

[6] $\ln(2.524) = .926$.

[7] In the panel estimations, the four subjects S1-10, S2-6, S2-14, and S2-16 are excluded. S2-6 shows very erratic behavior in the first 10 periods. The model does not fit for the other subjects at all.

Table 1: Panel estimations, full information model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
depvar	$ln(L)$	$ln(L)$	$ln(L)$	$ln(L)$	$ln(L)$	$ln(L)$	$ln(L)$	$ln(L)$	$ln(L)$	$ln(L)$	$ln(L)$	$ln(L)$
$cons$	1.31	1.43	1.23	1.25	1.23	1.34	1.19	1.20	1.48	1.55	1.32	1.35
	(.03)	(.10)	(.03)	(.05)	(.05)	(.17)	(.05)	(.08)	(.02)	(.09)	(.03)	(.05)
$ln(w)$	-1.62	-1.86	-1.47*	-1.51	-1.53	-1.75	-1.45	-1.47	-1.85**	-1.98	-1.55	-1.60
	(.05)	(.18)	(.06)	(0.6)	(.07)	(.32)	(.08)	(.08)	(.04)	(.15)	(.06)	(.06)
R^2	.73	.90	.63	.74	.66	.84	.60	.66	.93	.98	.82	.93
$p(F)$	.00	.00	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00
$p(FE)$			.00				.00				.00	
$p(H)$				.03				.37				.00
$p(\text{Re})$				.00				.00				.00
Session	1&2	1&2	1&2	1&2	1	1	1	1	2	2	2	2
#	378	378	378	378	216	216	216	216	162	162	162	162
	pOLS	be	fe	re	pOLS	be	fe	re	pOLS	be	fe	re

Notes: $p(F)$ significance level of F-test on $\widehat{\beta}_0 = .926$ and $\widehat{\beta}_1 = -1.6$, $p(FE)$ significance level of F-test that all fixed effects are zero, $p(H)$ significance level of Hausman specification test on random vs. fixed effects, $p(\text{Re})$ significance level of Breusch-Pagan Lagrange multiplier test for random effects, pOLS: pooled OLS, be: between effects, fe: fixed effects, re: random effects, all observations for $t > 3$ without subjects S1-10, S2-6, S2-32. S2-34, [*,**] different from theoretical value at [5 %, 1 %]

Table 2: Biasedness of full information prediction, panel estimations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
depvar	L	L	L	L	L	L	L	L	L	L	L	L
$cons$	.11	-.04	.17	.15	.10	-.05	.16	.14	-.10	-.22	.02	.00
	(.08)	(.23)	(.08)	(.12)	(.13)	(.37)	(.13)	(.21)	(.06)	(.25)	(.07)	(.10)
L^{fi}	1.47**	1.57**	1.43**	1.44**	1.46**	1.56*	1.42**	1.43**	1.68**	1.77*	1.57**	1.59**
	(.04)	(.14)	(.05)	(.04)	(.06)	(.21)	(.06)	(.06)	(.04)	(.19)	(.05)	(.05)
$\eta_L^{L^{fi}}$	.95	1.02	.92*	.93	.96	1.02	.93	.94	1.05	1.11	.99	1.00
	(.04)	.11	(.04)	(.05)	(.05)	(.16)	(.05)	(.08)	(.03)	(.13)	(.04)	(.05)
R^2	.78	.91	.73	.78	.77	.90	.72	.77	.91	.96	.85	.91
$p(F)$	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
$p(FE)$							.00				.00	
$p(H)$				.33				.53				.32
$p(\text{Re})$				.00				.00				.00
Session	1&2	1&2	1&2	1&2	1	1	1	1	2	2	2	2
#	378	378	378	378	216	216	216	216	162	162	162	162
	pOLS	be	fe	re	pOLS	be	fe	re	pOLS	be	fe	re

Notes: $\eta_L^{L^{fi}}$ elasticity of L with respect to L^{fi}, $p(F)$ significance level of F-test on $\widehat{\gamma}_0 = 0$ and $\widehat{\gamma}_1 = 1$, $p(FE)$ significance level of F-test that all fixed effects are zero, $p(H)$ significance level of Hausman specification test on random vs. fixed effects, $p(\text{Re})$ significance level of Breusch-Pagan Lagrange multiplier test for random effects, pOLS: pooled OLS, be: between effects, fe: fixed effects, re: random effects, all observations for $t > 3$ without subjects S1-10, S2-6, S2-32. S2-34, [*,**] different from 1 at [5 %, 1 %]

Table 3: Mean deviations of optimum employment

	Session 1		Session 2	
Subject	$m(Dev_L^{L^{fi}})$	$m(Dev_\pi^{\pi^{fi}})$	$m(Dev_L^{L^{fi}})$	$m(Dev_\pi^{\pi^{fi}})$
2	1.04**	-.16**	.64**	-.06**
4	.73**	-.11**	.19**	-.01**
6	.32**	-.03**	.82**	-.11**
8	.55**	-.11**	.46**	-.03**
10	2.24**	-.47**	.56**	-.05**
12	.43**	-.05**	.59**	-.05**
14	.27**	-.02**	1.29**	-.28*
16	.58**	-.05**	1.79**	-.51
18	.25*	-.06**	.85**	-.11**
all	.71**	-.12**	.99**	-.22**

Notes: periods 4 to 30, [*,**] different from theoretical value at [5 %, 1 %]

This is also visible in Figure 1 and Figure 2, which show the predicted employment levels based on the estimation of (13) and the full information optimal employment as functions of the wage rate. For both sessions, the fitted curves lie above the theoretical ones, but their shapes are very similar.

We found that subjects systematically chose too high employment levels. But how costly is this deviation from the optimal employment level? Table 3 presents the percentage deviations of employment and profits from their respective optimal (full information) levels:

$$Dev_L^{L^{fi}} = \frac{L - L^{fi}}{L^{fi}} \tag{15}$$

$$Dev_\pi^{\pi^{fi}} = \frac{\pi - \pi^{fi}}{\pi^{fi}}. \tag{16}$$

While employment deviates considerably from its optimum (on average 71% in session 1 and 99% in session 2), the forgone profits are moderate. In session 1, subject 10 incurs largest loss with 47% relative to the full information profits. The largest loss of 51% in session 2 accrues to subject 16 who simply set a constant employment level after period 4. The three subjects with the largest profit deviations are those with the worst fit of equation (13). 10 subjects have very low forgone profits of 6% or lower although all of them chose employment by more than 19% too high. For them, either the estimated coefficients are not significantly different from their theoretical values or the too high $\widehat{\beta}_0$ is counterbalanced by a $\widehat{\beta}_1$ which is significantly lower (in absolute terms) than its optimal value of 1.6.

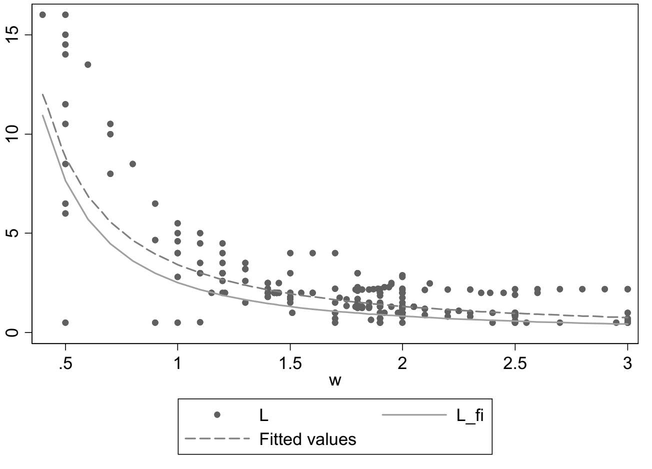


Figure 1: Actual and optimal employment, session 1

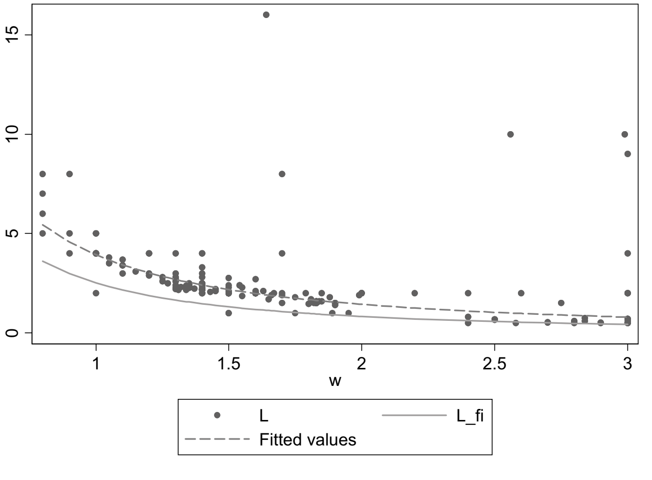


Figure 2: Actual and optimal employment, session 2

We conclude that in general the full information model with perfectly rational agents describes the behavior of the subjects in the role of firms in our experiment surprisingly well. Although all subjects set employment above its optimal level, the resulting losses are relatively small. The full information model does not do a good job predicting the level of employment, but it makes fairly accurate predictions of employment changes in response to changes of the nominal wage.

4.2 Perceived demand function

If subjects in the role of firms knew the demand function, their decision problem would be relatively straightforward. Given the production function, they could compute output as a function of any level of employment and plug this into the demand function to get the price. Using the profit calculator they could determine the optimal employment level. Subjects should hence have a strong incentive to learn the demand function.

The actual demand function is

$$\begin{aligned} p &= \alpha Y^{-\frac{1}{\epsilon}} \\ &= Y^{-\frac{1}{4}}. \end{aligned} \tag{17}$$

We estimate the log of (17) with the expected price p^e instead of the actual price p and test for $\widehat{\lambda}_0 = \ln \alpha = 0$ and $\widehat{\lambda}_1 = -\frac{1}{\varepsilon} = -.25$. We also perform the Ramsey RESET test for misspecification or omitted variables and MacKinnon-White-Davidson PE test for a log-log model against a linear model and vice versa[8]. A perceived linear demand function appears a natural assumption if the true functional form is not known. In contrast to the previous subsection, it is interesting to focus here on the individual results rather than the aggregate results for the whole panel. Though theoretical macroeconomic models are used to explain and to predict aggregate behavior, we examine the individual perceptions next.

[8] In addition, both fixed and random effects are rejected.

Table 4: Perceived demand functions

	Session 1							Session 2						
Subject	$\widehat{\lambda}_0$	$\widehat{\lambda}_1$	$\overline{R}^2$	$p(F)$	$p(R)$	$H_0:\log$	$H_0: lin$	$\widehat{\lambda}_0$	$\widehat{\lambda}_1$	$\overline{R}^2$	$p(F)$	$p(R)$	$H_0:\log$	$H_0: lin$
2	.14	-.31	.70	.13	.00	.00	.00	.60	.00**	-.04	.00	.00	.01	.01
	(.11)	(.04)						(.11)	(.04)					
4	.04	-.72**	-.03	.00	.03	.01	.01	.17	-.35	.61	.18	.00	.02	.01
	(.07)	(.19)						(.10)	(.05)					
6	-.28	-.13**	.25	.02	.42	.42	.60	-.89	.14**	.48	.00	.00	.00	.00
	(.10)	(.04)						(.07)	(.03)					
8	-.25	-.16**	.61	.00	.03	.02	.59	.17	-.32	.73	.01	.31	.91	.63
	(.07)	(.03)						(.09)	(.04)					
10	.93	-.62*	.38	.06	.00	.04	.05	-.07	-.21	.32	.00	.91	.58	.50
	(.40)	(.16)						(.16)	(.06)					
12	-.16	-.19	.44	.06	.41	.37	.90	-.46	-.04**	-.01	.00	.00	.00	.00
	(.09)	(.04)						(.11)	(.04)					
14	-.04	-.23	.31	.95	.10	.04	.11	-.04	-.23	.28	.94	.43	.74	.62
	(.14)	(.06)						(.19)	(.07)					
16	-.25	-.13**	.34	.00	.10	.03	.03	-.60	.	.	.	.	.	.
	(.08)	(.04)						(.)	(.)					
18	.14	-.31	.78	.12	.80	.52	.13	-.22	-.16*	.36	.03	.92	.90	.32
	(.07)	(.03)						(.10)	(.04)					
all pOLS	-.04	-.24	.67	.21	.24			-.03	-.23	.77	.01	.76		
	(.03)	(.01)						(.03)	(.01)					

Notes: $\ln p^e_{it} = \lambda_0 + \lambda_1 \ln Y_{it} + \varrho_{it}$, standard errors in parentheses, p(F) significance level of F test on $\widehat{\lambda}_0 = 0$ and $\widehat{\lambda}_1 = -.25$, p(R): significance level of RESET test, $H_0:\log$ significance level of PE test of log-log model against linear model, $H_0: lin$ significance level of PE test of linear model against log-log model, [*,**] significantly different from -.25 at [5%, 1%], t>3, p_exp<1, pooled OLS regressions exclude subjects S1-4 and S2-2, S2-6, S2-12, and S2-16

Only the subjects[9] S1-12, S1-14, S1-18, and S2-14 perceive a demand function that does not differ significantly from the true one (see Table 4). For all other subjects, either the F-test rejects that the parameters are equal to the true ones or the RESET test rejects the specification. In most cases, the log-log form is not favored against the linear model by the PE test, but the reverse is also true.

Interestingly, the pooled regressions without the subjects for whom the models obviously does not fit[10] deliver parameter estimates, which are very close to the theoretical ones. This means that the aggregate perception of the demand function is correct event though individual perceptions might be fairly different. In Figure 3, the estimated demand function using the expected prices is practically indistinguishable from the true demand function. Apart from some subjects that have very wrong perceptions and some obvious outliers[11], subjects did not misperceive the demand function systematically. In the aggregate, individual misperceptions about the demand function cancel out.

4.3 Profit maximization

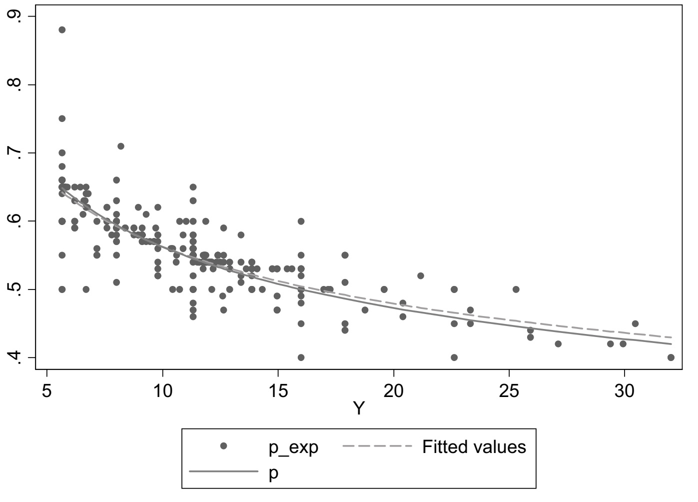
We have demonstrated that the comparative statics of the full information model predict well how subjects in the role of firms change their labor demand, although individual subjects do not have a correct perception of the product demand function. It is interesting that actual profits in several cases are not much smaller than the maximal ones despite the misperceived demand functions. Full profit maximizing behavior implies to consider that the choice of employment has an impact on the product price, since every firm is a monopolist. Obviously, this is difficult if firms perceive their demand functions incorrectly. We therefore can rule out fully rational behavior. But subjects might be boundedly (restrictedly) rational in the sense that they take the price expectation as given and choose the employment level that maximizes profits for that price expectation which is what price takers would do. To find the profit maximizing employment for a given price expectation was easy in the experiment, because the experimental program offered a profit calculator to firms that calculated the hypothetical profit for any combination of the expected price and the employment choice subjects had entered.

[9] Sx-y means subject y in session x.

[10] Subjects S1-4, S2-2, S2-6, S2-12, and S2-16.

[11] In several cases, subjects entered a price expectation of about 55. This seems to be an obvious typing error, because often the actual price was about 0.55. We excluded all price expectations larger than 1

Figure 3: Actual and perceived demand function



Most subjects used the profit calculator regularly. Only subject S1-10 never used the calculator and S2-6, S2-12, S2-14 used it less than 25 times. The calculator saves the last profit calculation for the expected price and the employment level the subject has entered. Comparing the hypothetical profit saved by the calculator with the expected profit resulting from the actual employment choice and the expected price, we find rather high correlations (at least .9 in 13 cases). In most cases, subjects entered the price expectation and the employment level, for which they had made the last profit calculation. This suggests that they experimented with different levels of employment for a given price expectation until the profit calculator delivered hypothetical profits that seemed reasonable to the subjects. Given this evidence, we conclude that most subjects tried to find the profit maximizing employment level for the given price expectation. They expected to receive the profit that they had calculated.

How successful were they in finding the profit maximizing employment level for the given price expectation? In Table 5 we compare the mean employment level chosen with the optimal one and the resulting profits. Profit maximizing firms must chose the level of employment for a given nominal wage and the expected price according to

$$L^{opt/p^e} = \left(\frac{p^e}{w}\frac{A}{2}\right)^2. \tag{18}$$

Only five subjects chose employment such that its mean differs significantly (at p=.05) from the mean of the profit maximizing employment path for given expectations and only in four cases are mean profits significantly different. The chosen employment path of several subjects (S1-6, S1-8, S1-10, S1-14, S1-18, S2-4, S2-14) is more strongly correlated with the optimal path than with the one of maximizing price takers, suggesting that the full information model is a better predictor of their behavior.

A pooled OLS regression and a random effects regression of actual employment on L^{opt/p^e} shows that in the aggregate subjects maximize profits for expected prices[12]. The pooled OLS regression has an R^2 of 0.5 and the hypothesis that both the intercept equals zero and the slope coefficient (0.98) equals one is only rejected at p=0.0495. The preferable RE model cannot reject the joint hypothesis (p=.19) and has a slope coefficient of 0.93. For all subjects, profit maximization for given price expectations is a good model.

At least in a statistical sense, especially in session 2, many subjects appear to maximize profits for given price expectations. However, the comparison of means and the estimation of the panel model hide in some cases considerable deviations from the profit maximizing employment levels. We define the following profit measures:

$$\pi = pY(L) - wL \tag{19}$$
$$\pi^e = p^eY(L) - wL \tag{20}$$
$$\pi^{opt/p^e} = p^eY(L^{opt/p^e}) - wL^{opt/p^e} \tag{21}$$
$$\pi^{opt/p} = pY(L^{opt/p^e}) - wL^{opt/p^e} \tag{22}$$
$$\pi^{fi} = pY(L^{fi}) - wL^{fi} \tag{23}$$

(19) is simply the actual profit earned in each period, (20) is the hypothetical profit for the given price expectation and the actually chosen employment L, (21) is the maximum profit for the expected price, (22) would be actually

[12] We excluded S1-8 from the estimations because of very strange behavior in the last 5 periods. This subject did almost perfectly the opposite of what profit maximization for given expected prices demanded. The fixed effects are statistically different form zero. The Hausman test does not reject random effects. The Breusch-Pagan test also indicates random effects.

Table 5: Mean deviations of optimum employment and profit

Subject		Session 1 L	π	$\rho_{L,L^{opt}}$	Session 2 L	π	$\rho_{L,L^{pe}}$
2	actual	4.59	3.10		2.23	3.09	
	given p	3.19	3.16	.94	2.24	3.29	.88
	full information	2.28*	3.69	.95	1.34**	3.30**	.85
4	actual	2.58	3.04		.55	2.21	
	given p	2.36	3.19	.88	.80**	2.30*	.23
	full information	1.47**	3.37*	.77	.47**	2.23	.51
6	actual	1.70	3.15		2.76	.63	
	given p	2.19**	3.28	.75	1.47	2.67	-.22
	full information	1.30**	3.24	.80	.93**	2.86*	-.08
8	actual	4.60	3.74		2.09	3.25	
	given p	6.14	4.35	.57	2.35**	3.36	.92
	full information	3.40	4.21	.78	1.42**	3.38	.88
10	actual	2.18	1.41		2.79	3.50	
	given p	.98**	2.12**	.15	3.04	3.77**	.97
	full information	.72**	2.60**	.24	1.78**	3.68**	.97
12	actual	1.29	2.60		1.51	2.76	
	given p	1.40	2.57	.95	1.54	2.83	.95
	full information	.88	2.72	.96	.94**	2.90**	.86
14	actual	1.20	2.84		4.19	3.07	
	given p	1.58**	2.91	.64	3.47	3.69	.26
	full information	.95**	2.90	.68	2.17**	3.91*	.40
16	actual	1.22	2.58		2.00	2.78	
	given p	1.26	2.60	.77	1.92	3.00	.
	full information	.78**	2.71**	.71	1.19**	3.14	.
18	actual	1.41	2.83		2.80	3.06	
	given p	2.05	3.30*	.35	2.52	3.27	.94
	full information	1.13	3.03	.71	1.55**	3.40*	.93

Notes:$\rho(L, L^{opt})$ bivariate correlation of L with L^{fi} or L^{opt/p^e}, [*,**] significantly different actual value at [5%, 1%]

earned by a subject optimizing to a given price expectations, and (23) is the full information profit.

We can use these profit definitions to measure how strongly subjects deviate from rational behavior. The previous analysis has shown that most subjects deviate significantly from the full information prediction. We have argued before that the mean profit loss is relatively small. Using the sum[13] of deviations of actual from full information profits, $\sum_t(\pi_t - \pi_t^{fi})$, we see in Table 6 that foregone profits are sizeable for a number of subjects.

But this benchmark may be too demanding, since the full information solution might be difficult to find for the participants even if all information were available. The profit maximum for given price expectations might be a more realistic benchmark for the subjects' rationality. Subjects can easily find the optimal employment level by entering different values for employment into the profit calculator and tracking the evolution of the hypothetical profits. $\sum_t(\pi_t - \pi_t^{opt/p})$ measures how much actual total profits differ from the profits a subject would have received if he had chosen the optimal employment for his expected price. These losses usually differ from the losses relative to the full information solution and some subjects (S1-16, S2-2, S2-8, S2-10, S2-12) are very close to the partial profit maximum. The partial maximum profits are in most cases smaller than the full information profits, but in some cases they are higher due to the large deviation of the expected from the actual prices. The losses relative to the partial maximum can be decomposed in losses due to wrong expectations and those from failures to optimize:

$$\sum_t(\pi_t - \pi_t^{opt/p}) = \underbrace{\sum_t(\pi_t - \pi_t^e) + \sum_t(\pi_t^{opt/p^e} - \pi_t^{opt/p})}_{\text{expectation errors losses}} \tag{24}$$

$$+\underbrace{\sum_t(\pi_t^e - \pi_t^{opt/p^e})}_{\text{optimization loss}}. \tag{25}$$

The optimization loss $\sum_t(\pi_t^e - \pi_t^{opt/p^e})$ is avoidable, as it results from deviations of employment from the optimal level, which subjects could have determined using the profit calculator. It is an ex ante loss, because it is calculated on the basis of the expected price, and hence unrelated to the

[13] In all analyses using these profits measures, we exclude the first three periods as a learning phase. Furthermore, we exclude the periods, in which some subjects had entered price expectations > 1 which are clear outliers.

expectation error. In session 1, these losses are large for subjects 2, 8, 10, and 18, and in session 2 for 6, 14, and 16. Among these subjects, the means between actual employment and optimal employment were only significantly different for subject S1-10, who never used the profit calculator. According to the data, at least 7 out of 18 subjects did not maximize profits for their expected price and incurred considerable losses that they could have avoided by using the calculator.

The loss due to expectations errors consists of two parts: $\sum_t(\pi^{opt/p^e} - \pi^{opt/p})$ is the loss that would accrue even with the optimal employment choice and $\sum_t(\pi_t - \pi_t^e)$ is the difference between realized and expected profits for the actual employment decision. Obviously, if the employment choice were always optimal, all loss would be measured by $\sum_t(\pi_t - \pi_t^e)$. In most cases, the total expectation error losses are very close to zero (S1-4, S1-10, S1-12, S1-14, S1-16, S2-2, S2-4, S2-8, S2-10, S2-12, S2-16, S2-18), which means that the foregone profits result to the largest part from subjects' failure to optimize. In three cases (S1-2, S1-18, S2-14), the optimization loss was partially offset by the profit deviation due to the price expectation error. Clearly, positive values of $\sum_t(\pi_t - \pi_t^e)$ result from systematic underpredictions of the actual price and strongly negative values from large overpredictions.

Examining the correlation between the random effects estimated for the complete sample (except for subject S1-8) and the measures of foregone profits, we find the random effects (column (7)) to be practically unrelated to $\pi - \pi^e$ ($\rho = .05$) and $\pi^{opt/p^e} - \pi^{opt/p}$ ($\rho = -0.21$), which are the losses due to price expectation errors. The random effects are strongly correlated with $\pi - \pi^{fi}$ ($\rho = -0.77$), $\pi^e - \pi^{opt/p^e}$($\rho = -0.61$), and $\pi - \pi^{opt/p}$ ($\rho = -0.59$), confirming that systematic deviations from the optimal employment (optimization errors) are responsible for the bulk of the losses. A simple regression of the optimization losses on the random effects shows that losses are larger if employment is too high than if it is too low, which is reasonable, given the positive correlation between the losses and the random effects.

5 Results for workers

We examine subjects' behavior with respect to the same research questions: Is their behavior predicted by the full information model? How do they perceive the model? Do they behave consistently to their perceptions?

While we can analyze these questions in a similar way as before, there are important differences that make the analysis more difficult. The optimization

Table 6: Foregone profits

Subject	$\sum$	(1) π	(2) $\pi - \pi^{fi}$	(3) $\pi - \pi^{opt/p}$	(4) $\pi^e - \pi^{opt/p^e}$	(5) $\pi - \pi^e$	(6) $\pi^{opt/p^e} - \pi^{opt/p}$	(7) RE
S1-2		80.67	-15.37	-5.19	-7.14	5.76	-3.81	1.16
S1-4		79.20	-8.55	-1.78	-1.83	-1.99	2.04	.07
S1-6		85.19	-2.29	-2.36	-2.26	-1.13	1.03	-.56
S1-8		97.35	-12.14	-17.79	-14.5	-1.13	-2.15	.
S1-10		32.45	-27.40	-15.87	-15.70	-.58	.42	.82
S1-12		70.10	-3.37	-1.95	-1.77	2.36	-2.54	-.27
S1-14		76.79	-1.49	-2.18	-1.95	.11	-.34	-.50
S1-16		69.68	-3.44	-.21	-.14	-.54	.47	-.22
S1-18		76.53	-5.18	-9.75	-11.42	-1.09	2.76	-.70
S2-2		80.27	-5.54	-.40	-.33	-4.95	4.88	-.14
S2-4		59.79	-.51	-1.92	-2.02	-.21	.31	-.43
S2-6		17.09	-60.10	-52.33	-46.83	-8.28	2.78	.95
S2-8		87.77	-3.44	-.42	-.39	-2.46	2.43	-.34
S2-10		84.06	-4.17	.10	-.19	-6.14	6.44	-.29
S2-12		74.39	-4.04	-.04	-.03	-2.08	2.08	-.20
S2-14		82.78	-22.66	-13.64	-15.33	-1.45	3.14	.58
S2-16		58.55	-7.49	-3.40	-3.36	-1.13	1.09	-.07
S2-18		82.54	-9.35	-1.87	-2.00	-3.84	3.97	.14

Notes: $t > 3$ and $p^e < 1$, RE estimated random effects task is more complicated in that the optimal wage choice depends on the expected behavior of all other subjects in their group. The employment level is determined by the firm player in their industry and the price level depends on the employment choice in all industries, which are, in turn, functions of the other wages. In contrast to the analysis of the firms' behavior, there is no theoretical benchmark for the workers' optimal behavior. Workers' decisions are more difficult both ex ante for subjects and ex post for us to examine.

5.1 Full information

In the full information model, the utility maximizing wage is constant, because there are no dynamics or stochastic shocks. From equations (2) - (5) $w^{fi} = 0.5235$ follows to be the utility maximizing wage only if all firms maximize profits for this given wage. If firms choose employment levels that are higher than optimal, the utility maximizing wage is also higher. In the extreme case that firms do no respond to wage changes, the optimal strategy is the maximal wage of 3.

All of the workers chose a wage whose mean over all 30 periods was statistically different from w^{fi}. But as subjects did not have full information, we cannot expect them to set the optimal wage right from the start. They might have been able to find the optimal wage during the course of the experiment. In that case, we should observe convergence of the wage to its optimal level. Table 7 presents the mean and the standard deviation of w for $t \leq 20$ and $t > 20$.

The wages of eight subjects converge in the last part of the experiment as measured by the standard deviation (lower than .1 and significantly lower than in the first part). However, only the wage of subject S1-7 converges to the optimal level, all other wages are significantly too high. For the majority of subjects, we do not even find convergence to some stable wage. The standard deviation for four subjects is even increasing in the second phase of the experiment.

Given this evidence, the full information model is not suited to predict subjects' behavior. Not only does the wage generally converge to different levels than predicted; for the majority of subjects, the wage does not converge at all to any constant level.

5.2 Perceived model

The model has two components that are important for the workers' decision problem. First, workers must form some perception of the labor demand

Table 7: Means and standard deviations of nominal wages

		Session 1		Session 2	
		$\overline{w}$	$sd(w)$	$\overline{w}$	$sd(w)$
S1	$t \leq 20$	1.93**	.39	1.76**	.59
	$t > 20$	.85**††	.30	1.62**	.49
S3	$t \leq 20$	1.62**	.43	2.93**	.14
	$t > 20$	1.38**	.59	2.82**	.20
S5	$t \leq 20$	1.71**	.44	2.08**	.53
	$t > 20$	1.62**	.32	1.66**††	.13††
S7	$t \leq 20$	2.02**	.74	1.74**	.52
	$t > 20$	**.52**††	**.06**††	**1.32****††	**.02**††
S9	$t \leq 20$	1.98**	.13	1.47**	.26
	$t > 20$	2.67**††	.25††	**1.13****††	**.08**††
S11	$t \leq 20$	2.65**	.29	2.02**	.40
	$t > 20$	1.69**††	.71††	**1.83****†	**0**††
S13	$t \leq 20$	1.97**	.38	1.31**	.39
	$t > 20$	**1.82****†	**.03**††	1.20**	.63†
S15	$t \leq 20$	2.23**	.34	2.17**	.74
	$t > 20$	**2.05****†	**.03**††	**1.51****††	**.07**††
S17	$t \leq 20$	1.93**	.16	1.53**	.57
	$t > 20$	1.73**	.79††	**1.60****	**0**††

Notes: [*,**] significantly different from theoretical value at [5%, 1%], [†,††] significantly different from value in $t \leq 20$ at [5%, 1%], bold numbers indicate convergence function and s econd, they need some idea of how their wages influence the price level. The labor demand function is relatively easy to learn, as it only depends on the actions of one other player. The relationship between one worker's wage and the price level, is more complicated.

Table 8 contains the parameter estimates from an estimation of

$$\ln L^e_{it} = \widehat{\beta}_{i0} + \widehat{\beta}_{i1} \ln w_{it} + \nu_{it} \tag{26}$$

and the p-values of an F-test on the equality of the estimated coefficients with their counterparts from the actual labor demand functions (columns (1) and (2)) and the p-value of the RESET test. The perceived labor demand function of four workers (S1-9, S1-15, S2-5, S2-9) cannot be described by equation (26), given the R^2 of the regressions . For six additional workers (S1-5, S1-11, S2-7, S2-11, S2-13, S2-17) the model fit is acceptable, but the RESET tests indicate either the wrong functional form or omitted variables. Eight perceived labor demand functions display a reasonable fit and are not rejected by the RESET test. Among these, two (S1-1 and S1-7) have a remarkably good fit and appear not to be statistically different from the actual labor demand functions. The estimates of six further perceived demand functions do not differ from the true ones, but only one of these estimations passes the RESET test. Contrary to the firms, workers do not perceive the actual labor demand function correctly in the aggregate, as the pooled OLS estimations show. In both session, the coefficients of the actual labor demand function and the coefficients of the perceived one differ significantly. Summing up, we conclude that most workers perceive a labor demand function that is close to the actual one, but only two subjects have correct perceptions. Aggregation does not remove biases here.

Table 8: Actual and perceived labor demand functions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Session 1								Session 2							
Subject	$\widehat{\beta}_0^f$	$\widehat{\beta}_1^f$	$\overline{R}^2$	$\widehat{\beta}_0^w$	$\widehat{\beta}_1^w$	$\overline{R}^2$	$p(F)$	$p(R)$	$\widehat{\beta}_0^f$	$\widehat{\beta}_1^f$	$\overline{R}^2$	$\widehat{\beta}_0^w$	$\widehat{\beta}_1^w$	$\overline{R}^2$	$p(F)$	$p(R)$
S1-1	1.61**	-1.66	.87	1.54	-1.49	.91	.40	.88	1.54**	-1.90*	.90	1.23	-1.02	.49	.00	.34
	(.07)	(.13)		(.05)	(.09)				(.06)	(.13)		(.10)	(.20)			
S1-3	1.26*	-1.25	.34	1.16	-.58	.19	.05	.48	.39	-.94	.21	1.47	-1.83	.27	.00	.77
	(.15)	(.33)		(.10)	(.22)				(.35)	(.33)		(0.61)	(0.57)			
S1-5	1.15	-1.52	.64	1.05	-.53	.18	.00	.00	1.53**	-1.69	.46	.30	.41	-.04	.09	.05
	(.11)	(.22)		(.10)	(.21)				(.27)	(.40)		(.49)	(.73)			
S1-7	1.15	-1.33	.55	1.42	-1.45	.92	.19	.33	1.17**	-1.25**	.93	1.01	-.75	.68	.00	.00
	(.16)	(.23)		(.06)	(.08)				(.03)	(.07)		(.04)	(.10)			
S1-9	.94	-.17**	.06	1.22	-.40	.10	.00	.21	1.37**	-1.61	.93	1.20	-.76	.11	.09	.01
	(.08)	(.10)		(.17)	(.21)				(.02)	(.09)		(.10)	(.36)			
S1-11	1.33**	-1.71	.80	1.05	-1.14	.47	.09	.00	1.42**	-1.65	.87	1.26	-1.43	.29	.72	.00
	(.14)	(.16)		(.20)	(.24)				(.08)	(.13)		(.26)	(.42)			
S1-13	1.01	-1.38	.47	.83	-.84	.56	.00	.45	1.43**	-.50**	.08	1.61	-1.07	.35	.30	.03
	(.18)	(.28)		(.09)	(.14)				(.09)	(.27)		(.09)	(.28)			
S1-15	1.23**	-1.40**	.92	.38	-.26	-.02	.00	.78	.55**	.35**	.10	.38	.89	.29	.01	.15
	(.06)	(.08)		(.24)	(.33)				(.12)	(.18)		(.17)	(.26)			
S1-17	.86	-1.34	.29	.85	-.86	.38	.10	.40	1.47**	-1.48	.83	1.39	-1.39	.48	.64	.03
	(.25)	(.39)		(.13)	(.21)				(.06)	(.13)		(.13)	(.29)			
all pOLS	1.23**	-1.55	.65	1.34	-1.35	.69	.00	.04	1.48**	-1.86**	.93	1.37	-1.52	.65	.00	.14
	(.05)	(.08)		(.04)	(.07)				(.02)	(.04)		(.05)	(.09)			

Notes: standard errors in parentheses, $p(F)$ significance level of F-test on $\widehat{\beta}_0^w = \widehat{\beta}_0^f$ and $\widehat{\beta}_1^w = \widehat{\beta}_1^f$, $p(R)$: significance level of RESET test ,t>3, pooled OLS regressions without subjects S1-9, S1-15, S2-5, S2-13, and S2-15, [*,**] significantly different from theoretical value at [5%, 1%]

The second key element of workers' perceived model is the relation between the nominal wage w and the general price level P. As said before, this relationship is less direct than the one between the nominal wage and employment, which can be seen in Table 11. In eight cases (S1-5, S1-13, S1-15, S2-1, S2-3, S2-5, S2-13, S2-15), there is basically no systematic influence of the nominal wage on P. Interestingly, in most of the remaining cases, the estimated relationships are very similar with $\widehat{\theta}_0$ between -.57 and -.70 and $\widehat{\theta}_1$ between .06 and .14. An increase of the wage by 10 percent led to an increase of the price level of about 1 percent. Of the eight systematic relationships between wages and the price level, only three are correctly perceived by workers (S1-1, S1-3, S1-17)[14]. This is clear evidence that most subjects do not perceive the impact of their wage setting behavior on the price level correctly. However, in the aggregate there is no significant difference between the estimated coefficients, so that individual errors cancel out. But notice that the R^2 for estimation of workers' perceived relationship is very low.

[14] The perception of S2-9 is similar, but statistically different.

Table 9: Actual and perceived price level as a function of the nominal wage

	Session 1									Session 2								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Subject	$\widehat{\theta}_0$	$\widehat{\theta}_1$	$\overline{R}^2$	$p(R)$	$\widehat{\theta}_0^w$	$\widehat{\theta}_1^w$	$\overline{R}^2$	$p(F)$	$p(R)$	$\widehat{\theta}_0$	$\widehat{\theta}_1$	$\overline{R}^2$	$p(R)$	$\widehat{\theta}_0^w$	$\widehat{\theta}_1^w$	$\overline{R}^2$	$p(F)$	$p(R)$
S1	-.65	.07	.61	.13	-.63	.08	.47	.20	.37	-.57	.04	.03	.14	-.57	-.02	-.03	.02	.10
	(.01)	(.01)			(.01)	(.02)				(.02)	(.03)			(.02)	(.05)			
S3	-.65	.09	.31	.10	-.63	.06	.14	.25	.14	-.58	.03	-.04	.97	-.84	.29	.07	.26	.69
	(.01)	(.03)			(.01)	(.03)				(.12)	(.12)			(.18)	(.17)			
S5	-.64	.06	.03	.10	-.66	.17	.08	.18	.56	-.54	-.01	-.04	.42	-.47	-.03	-.04	.62	.86
	(.02)	(.04)			(.05)	(.10)				(.02)	(.03)			(.20)	(.30)			
S7	-.60	.07	.58	.24	-.63	.04	.17	.02	.00	-.64	.09	.78	.00	-.74	.17	.01	.01	.15
	(.01)	(.01)			(.01)	(.01)				(.00)	(.01)			(.06)	(.15)			
S9	-.44	-.20	.29	.00	-.69	.05	-.03	.00	.75	-.63	.11	.77	.03	-.64	.14	.47	.02	.06
	(.05)	(.06)			(.08)	(.10)				(.00)	(.01)			(.01)	(.03)			
S11	-.70	.14	.60	.21	-.62	.09	.10	.00	.04	-.67	.10	.33	.03	-.43	-.27	.44	.00	.02
	(.02)	(.02)			(.04)	(.04)				(.02)	(.03)			(.04)	(.06)			
S13	-.55	.03	-.02	.68	-.57	.08	.24	.03	.00	-.65	.03	.03	.06	-.71	.12	.23	.00	.13
	(.02)	(.04)			(.02)	(.03)				(.01)	(.02)			(.01)	(.04)			
S15	-.58	.06	-.01	.52	-.29	-.44	.02	.02	.42	-.64	-.01	-.02	.20	-.63	-.06	.06	.12	.20
	(.06)	(.08)			(.28)	(.37)				(.01)	(.02)			(.02)	(.04)			
S17	-.57	.06	.41	.66	-.59	.07	.37	.30	.72	-.67	.06	.27	.00	-.55	-.04	-.04	.41	.50
	(.01)	(.01)			(.01)	(.02)				(.01)	(.02)			(.11)	(.22)			
all pOLS	.07	-.62	.25	.00	.05	-.62	.07	.33	.23	.07	-.63	.20	.01	.09	-.64	.03	.47	.61
	(.01)	(.01)			(.01)	(.01)				(.01)	(.01)			(.03)	(.02)			

Notes: standard errors in parentheses, $p(F)$ significance level of F test on $\widehat{\theta}_0^w = \widehat{\theta}_0$ and $\widehat{\theta}_1^w = \widehat{\theta}_1$, p(R): significance level of RESET test,t>3

5.3 Utility maximization

We hardly observe any convergence of nominal wages, if anything the constant value differs from the optimal full information wage. If wages reach a more or less constant level after several periods they are also not optimal for the implied perceived models with parameter estimates for $L^e = \theta_0 w^{\theta_1}$ and $P^e = \eta_0 w^{\eta_1}$. The optimal wage for this model, given by $w = \left(\frac{-\gamma\eta_0\theta_1}{\theta_0(1-\eta_1)}\right)^{\frac{1}{1+\theta_1-\eta_1}}$, was not chosen by any of our participants in the last third of the experiment (see Table 10, columns (1) and (3)).

The price level is determined by the actions of many agents, that are potentially difficult to predict. We have shown that in many cases it is only weakly related to individual wages and that, even if it is, subjects rarely detect this relationship. Since subjects knew that their employment level was chosen by the firm player in their industry, learning might have been concentrated on their counterparts' reactions to their wages and largely ignored the more complex impact on the price level. Such a perception of the market would imply to choose the wage that maximizes the utility function for a given expected price level and the perceived labor demand function in the respective industry,

$$w^{opt/P^e} = \left(\frac{-\gamma\widehat{\beta}_1^w P^e}{\widehat{\beta}_0^w}\right)^{\frac{1}{1+\widehat{\beta}_1^w}}. \tag{27}$$

But, as Table 10 shows, subjects' behavior cannot be described by the assumptions leading to w^{opt/P^e}. The mean wage is always statistically different from the optimal wage[15] and except for subject S2-11, the correlation between w and w^{opt/P^e} is very low or even negative. Many workers seem to have underestimated the employment responses to their wages, resulting in optimal wages higher than the possible maximum of 3. Nevertheless, most wages were significantly smaller than 3, which means that those subjects did not choose the wage consistent with their expectations.

The bounded rationality version of the model also fails to describe what subjects in the role of workers did in the experiment. Subject did neither choose utility maximizing wages that considered both the effect on the price level and employment nor did they chose utility maximizing wages for given price level expectations and perceived labor demand functions.

As with the firm players, this behavior led to considerable ex ante utility losses due to the optimization failure (see column (6)). These losses, which

[15] In several cases, the optimal wage was larger than 3.

are measured in the same unit of account as the foregone profits, are much larger than those of firms. However, the optimization problem of workers is more difficult than that of firms. For a given wage, firms only had to form expectations on the demand function in order to maximize their profits. This makes it easy to find the profit maximizing employment for the given price expectation. Workers, however, needed to form expectations both on the price level and on the employment level. Bot depended on the chosen wage in a non-deterministic way in contrast to the price for firms, which was a deterministic function of employment. The large ex ante utility losses are hence not surprising. As every concept of optimal wage depends on estimates of expected or real behavior of firms, all measures of optimal wages are subject to considerable estimation errors. We therefore abstain from utility loss decompositions analogous to the decompositions of foregone profits.

6 Conclusions

Our experiment provides a unique opportunity to study the economic behavior of subjects in a simple macroeconomic environment and their perceptions of this environment. Separately and in comparison, we can assess whether subjects behave consistently with the expectations they form, and if failure to optimize stems from misperception or misbehavior.

We find that the predictive capacity of our textbook-like model is limited. For firms, the model's predictive performance is fair. Although firms employ systematically too much labor, the observed elasticity of labor demand to the nominal wage is exactly as predicted by the model. Not only does the model predict the direction of change directly, but also the size, given the deviation in levels. The model clearly fails to predict, what workers do. Only 8 out of 18 workers set a more or less constant wage in the last phase of the experiment, but only in one case this wage is not significantly different from the theoretical optimum.

Whether subjects behave as the model predicts or not, may depend on their ability to perceive the model correctly and their optimization skills. While most individual firms misperceive the unknown demand function, in the aggregate the model predictions fits the observations, which means that individual biases are not correlated. The individual errors cancel out, just as generally argued in the theoretical literature. The same is true for workers' perceptions of the relationship between their wage and the price level. In the aggregate the perception is correct, while individual perceptions are wrong.

Table 10: Actual and optimal wages, foregone utility

	(1) w	(2) w^{opt/P^e}	(3) w^{opt}	(4) $\rho(w, w^{opt/P^e})$	(5) $\sum U$	(6) $\sum U(w^{L^e}) - U(w^{opt/P^e})$
S1-1	.85	2.29**	1.70**	-.62	119.20	-31.90
	(.10)	(.09)	(0)			
S1-3	1.38	3**	3**	.	79.03	-264.71
	(.19)	(0)	(0)			
S1-5	1.62	3**	3**	.	35.57	-247.28
	(.10)	(0)	(0)			
S1-7	.52	2.09**	1.69**	-.34	-40.52	-39.80
	(.02)	(.08)	(0)			
S1-9	2.67	3**	3**	.	309.54	-170.75
	(.08)	(0)	(0)			
S1-11	1.69	2.44*	2.21*	-.41	-80.94	-18.40
	(.22)	(.22)	(0)			
S1-13	1.82	3**	3**	.	-52.67	-61.95
	(.01)	(0)	(0)			
S1-15	2.05	3**	3**	.	32.12	-183.03
	(.01)	(0)	(0)			
S1-17	1.73	3**	3**	.	-176.07	-67.34
	(.25)	(0)	(0)			
S2-1	1.62	3**	3**	.	70.65	-108.42
	(.15)	(0)	(0)			
S2-3	2.82	1.07**	.99**	-.32	-312.18	-311.05
	(.06)	(.01)	(0)			
S2-5	1.66	3**	3**	.	84.87	-287.12
	(.04)	(0)	(0)			
S2-7	1.32	3**	3**	.	98.00	-214.55
	(.01)	(0)	(0)			
S2-9	1.13	3**	3**	.	111.01	-246.38
	(.02)	(0)	(0)			
S2-11	1.83	1.35**	3**	.74	95.25	-12.33
	(0)	(0)	(0)			
S2-13	1.20	3**	3**	.	158.25	-269.73
	(0.20)	(0)	(0)			
S2-15	1.51	3**	3**	.	210.97	-395.80
	(0.02)	(0)	(0)			
S2-17	1.6	2.09**	1.57**	.12	146.29	-21.05
	(0)	(0.01)	(0)			

Notes: [*,**] significantly different from actual value at [5%, 1%], $t > 3$

The strength of the labor demand response to the nominal wage is generally underestimated by workers, both on the individual and on the aggregate level. Nevertheless, workers' perceptions of the labor demand functions are not too unrealistic, which suggests that in our experiment, misperceptions of the model economy may not be the main reason why the theoretical predictions and the observed behavior do not always coincide.

Both workers and firms do not optimize for given expectations, which is, at least for firms, the major reason why their behavior differs from the theoretical prediction. While virtually all workers failed to set wages consistent with their price level expectations, only 5 of the 18 firms chose an employment level which was statistically different from the one which was optimal for given expectations. But this statistical similarity hides that many firm players incurred foreseeable profit losses due to optimization failure, although optimization for given expectations was very easy, since they had profit calculator at their disposal. They did, of course, also forego profits, because they did not realize to have market power an set monopoly prices. Given that several firms did perceive the unknown demand function fairly correctly, the case for imperfect optimization is even stronger. Kirchkamp and Reiß (2007) find a very similar result in a completely different experimental setup.

Though firms were not always successful in their attempt to maximize profits, they obviously tried do so, even if only in a restricted sense, as they did not exploit their price-setting power. The strategies of the workers, on the other hand, remain obscure after the analysis performed in this paper. It might be an enlightening exercise to examine their behavior more closely and to find out if it is possible to describe it by simple heuristics or behavioral models. Workers' behavior is particularly interesting, because they face more model uncertainty than firms. Another question this paper cannot answer is the robustness of our result that subjects do not optimize within an economic framework, although their perception of it is fairly accurate. We believe that much more work on the relation between beliefs and optimizing behavior in different setups is necessary, before the usefulness of the as-if-approach based on perfect information and maximizing behavior can be assessed.

References

Adam, K.(2007) Experimental evidence on the persistence of output and inflation, Economic Journal 117, 603-635.

Bernasconi, M., O. Kirchkamp, P. Paruolo (2004). Do fiscal variables affect fiscal expectations? Experiments with real world and lab data. SFB 504 discussion paper 04-27.

Bernasconi, M., O. Kirchkamp (2000). Why do monetary policies matter? An experimental study of saving and inflation in an overlapping generations model. Journal of Monetary Economics 46, 315 - 343.

Duffy, J. (2006). Experimental Macroeconomics. In. S. Durlauf and L. Blume (eds). New Palgrave Dictionary of Economics, 2nd edition.

Evans, G. W., S. Honkapohja (2001). Learning and Expectations in Macroeconomics, Princeton University Press, Princeton.

Friedman, M. (1953). The methodology of positive economics. In Essays in positive economics, Chicago University Press, Chicago.

Heemeijer, P., C. Hommes, J. Sonnemans, J. Tuinstra (2007). Price Stability and Volatility in Markets with Positive and Negative Expectations Feedback: An Experimental Investigation, working paper.

Hommes, C., J. Sonnemans, J. Tuinstra, H. van de Velden (forthcoming). Learning in Cobweb Experiments. Macroeconomic Dynamics

Hommes, C., J. Sonnemans, J. Tuinstra, H. van de Velden (forthcoming). Expectations and Bubbles in Asset Pricing Experiments. Journal of Economic Behavior and Organization

Hommes, C., J. Sonnemans, J. Tuinstra, H. van de Velden (2005a). A strategy experiment in dynamic asset pricing. Journal of Economic Dynamics and Control 29, 823-843

Hommes, C., J. Sonnemans, J. Tuinstra, H. van de Velden (2005b). Coordination of expectations in asset pricing experiments. Review of Financial Studies 18(3), 955 - 980.

Lian, P., C.R. Plott (1998). General Equilibrium, Markets, Macroeconomics and Money in a Laboratory Experimental Environment. Economic Theory 12, 21-75.

Kirchkamp, O., J. P. Reiß (2007). Expectations in first-price auctions, working paper.

Marcet, A., T. J. Sargent (1989). Convergence of Least-Squares Learning in Environments with Hidden State Variables and Private Information. Journal of Political Economy 97(6): 1306-22.

Marimon, R., S. E. Spear, S. Sunder (1993). Expectationally driven market volatility: An experimental study. Journal of Economic Theory 61, 74-103.

Roth, A. E. (1995). Introduction to experimental economics. In J. H Kagel, A. E. Roth (eds.) Handbook of Experimental Economics, Princeton University Press, Princeton.

Smith, V. L (1982). Markets as Economizers of Information: Experimental Examination of the "Hayek Hypothesis. Economic Inquiry, 20(2), 165-79.

Smith, V. L (1991). Rational Choice: The Contrast between Economics and Psychology. Journal of Political Economy 99(4), 877-97.

Sonnemans, J., P. Heemeijer, C. Hommes (2005). Price expectations in the laboratory in positive and negative feedback systems. paper presented at Computing in Economics and Finance 2005 165, Society for Computational Economics.

Sonnemans, J., C. Hommes, J. Tuinstra, H. van de Velden (2004). The instability of a heterogeneous cobweb economy: a strategy experiment on expectation formation. Journal of Economic Behavior & Organization, Elsevier, 54(4), 453-481.

Sutton, J. (2002). Marhall's Tendencies: What Can Economists Know? MIT Press, Cambridge, MA.