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An Experiment on Consumption Responses to Future Prices and Interest Rates

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Wolfgang J. Luhan, Michael W.M. Roos, and Johann Scharler[1]

An Experiment on Consumption Responses to Future Prices and Interest Rates

Abstract

We design an experiment to investigate the influence of announced future variations in interest rates and prices on consumption decisions. In an experimental implementation of the discounted utility model, the subjects learn the entire paths of inflation and interest rates prior to deciding on a consumption path. We decompose the total change in consumption that results from changes in either interest rates or inflation rates into anticipation and impact effects. While impact effects are of similar orders of magnitude as in the model, future changes in inflation or interest rates exert substantially smaller effects on current consumption than predicted by the model.

JEL Classification: D91, E21, C91

Keywords: Consumption; saving; intertemporal utility maximization; macroeconomic experiment

April 2011

1 Wolfgang J. Luhan and Michael W.M. Roos Ruhr-Universität Bochum; Johann Scharler, Johannes-Kepler-Universität Linz. *– We would like to thank Christian Bredemeier, Martin Kocher and seminar/workshop participants at CSU Colorado, JKU Linz, UEA Norwich and UT Dallas for very helpful comments.* *– All correspondence to Wolfgang J. Luhan, Institute for Macroeconomics, Ruhr-Universität Bochum, Universitätsstr. 150, 44801 Bochum, Germany, E-Mail: wolfgang.luhan@rub.de.*

1 INTRODUCTION

The discounted utility model is the backbone of essentially all dynamic stochastic general equilibrium (DSGE) models, no matter whether they are in the real business cycle tradition or New Keynesian. Although these models sometimes also include non-forward looking elements, such as rule-of-thumb behavior, typically a fraction of the household sector is assumed to maximize lifetime utility by choosing a consumption path for all periods of life subject to the intertemporal budget constraint and contingent on currently available information. An interesting implication of this assumption is that households adjust consumption in response to future changes in interest rates and prices already when they learn about those changes and do not wait until the changes have actually happened. The former adjustment is referred to as the *anticipation effect*, the latter as the *impact effect*.

In fact, Gali and Gertler (2007) argue that one of the main differences between New Keynesian DSGE models and earlier contributions arises precisely because of this theoretical result. In New Keynesian DSGE models, consumption decisions, and thus aggregate output and inflation, do not only depend on the interest rate set by the central bank in the current period, but also, and perhaps even more importantly, on the entire expected future path of the interest rate. It follows that the overall effectiveness of monetary policy depends crucially on its ability to steer private sector expectations. Along similar lines, Walsh (2010) argues that the zero lower bound on nominal interest rates is not necessarily a constraint on the effectiveness of monetary policy. Central banks can still influence economic activity via the expectation of future real interest rates. That is, by committing to keeping nominal interest rates low for a substantial period of time – which is equivalent to promising to keep inflation high – aggregate demand can be stimulated even if the nominal interest rate is essentially zero. Again, this argument relies precisely on the idea that future interest and inflation rates influence current consumption.

The purpose of this paper is to explore this link between current consumption choices and future changes in interest and inflation rates in an experimental setting. We design an experiment that allows us to draw clear inference about the causal effect of announced future changes in the real interest rate on consumption.

Our experimental environment is a minute implementation of the standard theoretical model of intertemporal utility maximization. More specifically, the subjects' task is to choose consumption paths for a given level of initial wealth and certain future price level and interest rate paths. By varying future price levels and interest rates, we can observe whether subjects adjust their consumption choices as predicted by the standard discounted utility model. This experimental setting allows us to decompose the total effect of variations in future interest rates and prices into the anticipation effect and the impact effect to isolate and quantify the adjustment of consumption that occurs in anticipation of future changes in interest rates and prices.

The experimental method has a – for our purposes decisive – advantage over more standard economic studies. A problem of econometric studies is that it is essentially impossible to control for all present and future factors that might affect current consumption expenditure, which complicates the isolation of causal effects with field data. We simply do not know whether subjects understood the implications of such information and were aware of it when making spending decisions when analyzing field data. The lab, in contrast, offers a controlled environment where we can focus on a small number of influential factors. It is likely that anomalies observed in an environment which eliminates all sources of confusion and reduces the task to its simplest core are also present in the much more complex world outside the lab.

Our analysis is related to several strands of the existing literature. First, consumption and saving behavior has been analyzed experimentally in a number of studies (e.g. Hey and Dardanoni 1988, Carbone and Hey 2004, Chua and Camerer 2007). The main differences between our experiment and those previous studies are that (i) we eliminate any effects of uncertainty and (ii) ask for the choice of consumption paths instead of consumption levels in individual periods. Both features serve to mirror the theoretical optimization problem as closely as possible. By eliminating uncertainty, we circumvent all potential problems related to risk attitudes and the formation of expectations. We ask for complete consumption paths over an experimental "life" instead of sequential consumption choices in each period. This way we elicit the complete ex ante solution of the utility maximization problem.

Second, previous research has demonstrated that the discounted utility model may not be a good description of actual behavior due to time-dependent discount rates (Frederick et al. 2002). We are not so much interested in the effect of discounting per se, but focus on the distinction between anticipation and impact effect.

Finally, our study is closely related to the empirical literature on the "excess sensitivity of consumption to current income" and "excess smoothness of consumption to future events" (e.g. Flavin 1985, West 1988, Campbell and Deaton 1989, Luengo-Prado and Sørensen 2008, Pasini 2009). While this literature studies the response of consumption to changes in income, we focus on the effects of changes in interest rates and prices, which have not been analyzed before. We conjecture that if subjects do not respond to income changes as predicted by the standard model, they may also fail to respond correctly to changes in prices and interest rates.

We find substantial deviations from the predictions of the discounted utility model. Subjects tend to consume too much in early periods and too little towards the end of an experimental life. Put differently, subjects frequently do not smooth consumption as predicted by theory. These findings essentially confirm earlier studies. In addition, we find that, even if we take these deviations from optimal behavior into account, subjects do not respond to announced changes in future interest rates and prices in a way consistent with discounted utility theory or the behavioral assumptions in DSGE models. In particular, the anticipation effect essentially does not exist. Subjects hardly adjust consumption paths in advance of known future changes in interest rates or prices.

The remainder of the paper is structured as follows: Section 2 discusses the theoretical basis for our experiment while Section 3 presents the experimental design and procedure. In Section 4 we discuss our results and Section 5 concludes the paper.

2 Theory

Models that belong to the class of DSGE models are currently the workhorse model in modern macroeconomics. One of the basic building blocks of essentially all of these models is the so-called forward-looking IS relationship. Although this relationship shares some similarities with the traditional IS curve familiar from introductory textbooks, there are several differences. Most importantly, the forward-looking IS relationship is derived from the equations that characterize an optimal solution to the intertemporal optimization problem of a representative household in the framework of the discounted utility model. In its simplest version, the forward-looking IS relationship describes how the household reallocates consumption over time depending on the nominal interest rate as well as the inflation rate – both captured in the real interest rate.

In this section, we present the version of an intertemporal optimization problem which we implement in the laboratory experiment.

Households' lifetime utility function is modeled as

$$U = \sum_{t=1}^{5} \beta^t u(C_t), \tag{1}$$

where $\beta = \frac{1}{(1+\rho)}$ is the constant discount factor and ρ is the rate of time preference[1].

The period utility function[2] is defined as

$$u(c_t) = c_t^{1-\sigma}/(1-\sigma). \tag{2}$$

We simplify the implementation in the lab by concentrating on the case with a known finite horizon T=5. Similarly, we abstract from potential problems related to the formation of expectations by considering only the perfect foresight case here.

We assume that the household does not earn any income but has an initial nominal wealth endowment of A_0. This way, we avoid two problems related to credit. On the one hand credit constraints constitute a severe complication of the task, which is not necessary for the theoretical model. On the other hand unobservable psychological factors such as debt aversion might influence behavior and thereby blur the empirical results.

In each period t, the household can buy and consume C_t units of a single consumption good at price P_t. Any part of the initial endowment not consumed in period t is saved at a risk-free nominal interest rate R_t. At date 0, all future prices and interest rates are known with certainty.. Therefore, wealth evolves according to

$$A_{t+1} = (1 + R_t)(A_t - P_t C_t). \tag{3}$$

Maximizing the utility function (1) subject to a set of wealth equations (3) by choice of consumption for each period yields the Euler equation

$$\frac{C_t^{-\sigma}}{P_t} = \beta(1 + R_t)\frac{C_{t+1}^{-\sigma}}{P_{t+1}}. \tag{4}$$

---

[1] In principle, we do not need discounting as we are not particularly interested in its effect on consumption. We nevertheless have a positive rate of time discounting in order to balance the positive interest rates. Furthermore, discounting is standard in the macroeconomic literature.

2 Note that the period utility function exhibits constant relative risk aversion which is frequently assumed in business cycle models.

The Euler equation together with the boundary condition $C_5 = A_5/P_5$ characterizes optimal consumption in periods 1,..., 5.

An important implication of (4) is that current consumption depends on all future prices and interest rates. The solution for optimal consumption in the first period is

$$C_1 = \frac{A_0}{P_1 + \sum_{t=2}^{T}\left(P_t \prod_{\tau=2}^{t} \frac{\Omega_{\tau-1}^{\frac{1}{\sigma}}}{1+R_{\tau-1}}\right)} \tag{5}$$

with

$$\Omega_t \equiv \frac{1+R_t}{1+\rho}\frac{P_t}{P_{t+1}}. \tag{6}$$

Consumption in all other periods can be determined recursively using (5) and the Euler equation.

Our experiments will focus on the dependency of consumption on future prices and interest rates. Note that the Euler equation implies that $C_{t+1} = C_t$ if $R_t = \rho$ and $P_{t+1} = P_t$. That is, the optimal consumption profile is flat if the interest rate is equal to the rate of time preference and if the price level is constant. For our experiment, we choose the following baseline calibration: $\rho = 0.2$, $R_t = 0.2$, $P_t = 1$, $A_0 = 1000$, and $\sigma = 0.5$. With this calibration, we obtain a flat baseline consumption path: $C_t = 278.65$ for $t = 1,\ldots,5$.

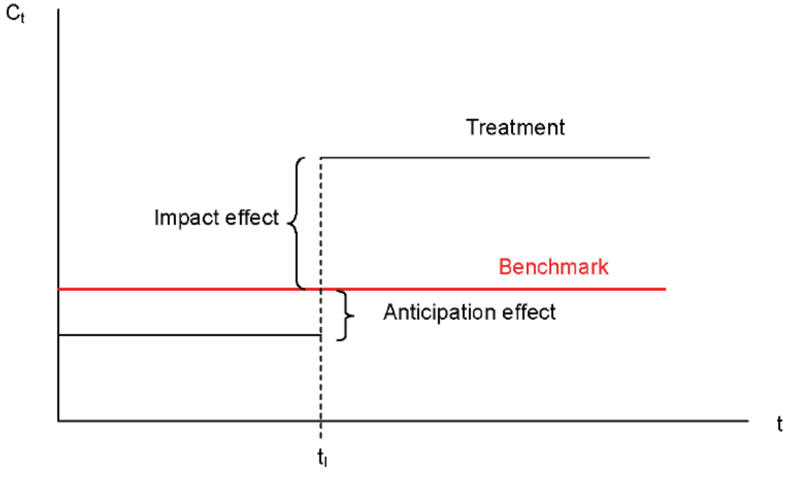
3 Design and Experimental Procedure

We implement the theoretical model as closely as possible in the lab, simplifying the decision task to meet all theoretical assumptions. We change interest rates and prices between treatments to test whether subjects respond as predicted by theory.

In the baseline calibration, interest rates and prices are such that the optimal consumption path is flat, as the real interest rate is equal to the rate of time preference. In the treatments, we systematically vary prices and interest rates to see how subjects deviate from the baseline in response to the changes.

Figure 1 illustrates the idea with the example of a future increase in the real interest rate. If the real interest rate changes at time t_I in the future, the overall consumption response can be decomposed into an anticipation effect, which occurs when the future change becomes known, and an impact effect which occurs when the change actually takes place, i.e. at t_I and later.

Figure 1: Theoretical anticipation and impact effect



Note that in our calibration the anticipation and impact effects move in opposite directions. In case of, e.g., an expected future increase in the real interest rate it is optimal to postpone consumption prior to t_I. Since the increase in the interest rate is certain, the substitution effect leads to lower consumption already in advance of the change in the interest rate. This lower consumption in early periods and higher interest rate payments after t_I generate higher wealth, allowing higher consumption towards the end of the planning horizon.

The basic test idea consists of measuring the observed anticipation and impact effects of real interest rate changes on chosen consumption. First, we want to see whether and in which direction subjects adjust their consumption levels relative to the benchmark. Second, we want to compare whether the size of those changes corresponds to the size of the optimal adjustments predicted by the theoretical model.

Table 1: Treatment overview

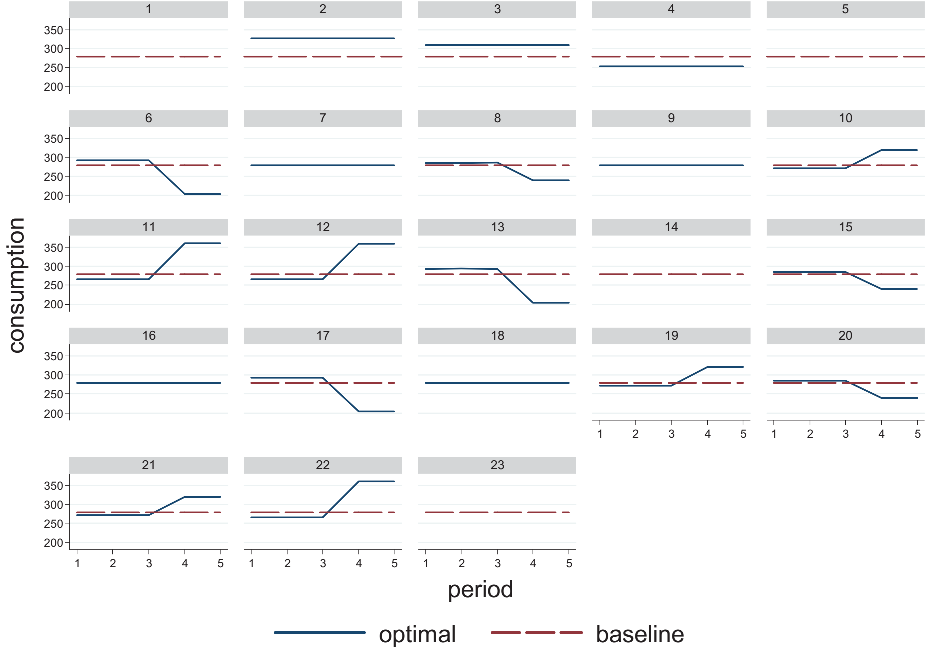
	Δr	Life	Variable	Period 1	Period 2	Period 3	Period 4	Period 5
T1	**$r_{\downarrow 10}$**	8	P_t	1	1	1	1.09	1.09
			R_t	0.2	0.2	0.2	0.2	0.2
T1	**$r_{\uparrow}^{20}$**	12	P_t	1	1	1	0.86	0.86
			R_t	0.2	0.2	0.2	0.2	0.2
T1	**$r_{\downarrow 20}$**	13	P_t	1	1	1	1.2	1.2
			R_t	0.2	0.2	0.2	0.2	0.2
T1	**$r_{\uparrow}^{10}$**	19	P_t	1	1	1	0.92	0.92
			R_t	0.2	0.2	0.2	0.2	0.2
T2	**$r_{\uparrow}^{10}$**	10	P_t	1	1	1	1	1
			R_t	0.2	0.2	0.3	0.2	0.2
T2	**$r_{\downarrow 20}$**	17	P_t	1	1	1	1	1
			R_t	0.2	0.2	0	0.2	0.2
T2	**$r_{\downarrow 10}$**	20	P_t	1	1	1	1	1
			R_t	0.2	0.2	0.1	0.2	0.2
T2	**$r_{\uparrow}^{20}$**	22	P_t	1	1	1	1	1
			R_t	0.2	0.2	0.4	0.2	0.2
T3	**$r_{\downarrow 20}$**	6	P_t	1	1	1	1.1	1.1
			R_t	0.2	0.2	0.1	0.2	0.2
T3	**$r^{=}$**	7	P_t	1	1	1	0.92	0.92
			R_t	0.2	0.2	0.1	0.2	0.2
T3	**$r^{=}$**	9	P_t	1	1	1	1.08	1.08
			R_t	0.2	0.2	0.3	0.2	0.2
T3	**$r_{\uparrow}^{20}$**	11	P_t	1	1	1	0.93	0.93
			R_t	0.2	0.2	0.3	0.2	0.2
T3	**$r_{\downarrow 10}$**	15	P_t	1	1	1	1.2	1.2
			R_t	0.2	0.2	0.32	0.2	0.2
T3	**$r^{=}$**	16	P_t	1	1	1	0.83	0.83
			R_t	0.2	0.2	0	0.2	0.2
T3	**$r^{=}$**	18	P_t	1	1	1	1.17	1.17
			R_t	0.2	0.2	0.4	0.2	0.2
T3	**$r_{\uparrow}^{10}$**	21	P_t	1	1	1	1.08	1.08
			R_t	0.2	0.2	0.4	0.2	0.2

Notes: Each subject had to make decisions in 23 "lives". Each life consists of 5 periods with potentially different interest rates and prices. Lives 1 to 5, 14, and 23 are not contained in the table as they are baseline and training lives in which there were not changes in the focus variables.

In a within-subject design we vary interest rates and prices in future periods according to the scheme in Table 1. We design three different treatment conditions in which we either vary only the price level (T1) or the interest rate (T2) or both (T3). For each price level change in T1 there is an equivalent interest rate change in T2, which generates the same change in the real interest rate. In T3 these changes are created by changing both, the price and the nominal interest rate.

The changes in the real interest rate all take place in the third period and can in turn be divided into five categories: an increase by 10 ($r_{\uparrow}^{10}$) or 20 percentage points ($r_{\uparrow}^{20}$); a decrease by 10 ($r_{\downarrow 10}$) or 20 percentage points ($r_{\downarrow 20}$); or simultaneous changes of inflation- and nominal interest rate that cancel out leaving the real interest rate unchanged ($r^{=}$). As described above, these five different changes in the real interest rate are caused in turn by either T1, T2, or T3. These treatments allow us to observe directly whether subjects respond differently to nominal interest rates and prices

Figure 2: Optimal consumption paths in all lives



Each subject completed all 23 consecutive lives. The first 5 lives exhibited constant nominal- and real interest rates and prices.

These lives were intended as training periods. Figure 2 shows the theoretically optimal consumption paths for the 23 lives. The treatment with a flat consumption path appears four times (life 1, life 5, life 14, and life 23). The flat paths in lives 7, 9, 16, and 18 are the result of offsetting price and interest changes keeping the real interest rate fixed. To see the optimal consumption changes relative to the flat baseline path, we incorporate the baseline path in all graphs.

We conducted four sessions at the RUBex laboratory at the Ruhr-University Bochum in the summer and fall of 2010. The 50 participants were students from economics and other fields. The experiment was run using z-Tree and lasted about two hours.

Upon arrival in the lab, subjects were randomly seated at workstations separated by blinds. Instructions were read aloud and subjects were encouraged to ask questions at any point of the experiment. The instructions contained equations (1), (2), and (3) and verbal explanations. Only one life was randomly chosen for the final payment in order to avoid super-game effects. Subjects had to choose a consumption path for each live. As we wanted subjects to choose the complete path at the beginning of a life, they could enter preliminary consumption choice for each period and change them again if they wanted to. If a preliminary consumption choice for the first period in a life was made, interest earnings were automatically calculated by the program and displayed together with the remaining endowment for the subsequent periods. The same happened in the remaining four periods. If a subject was not satisfied with the preliminary choices made, he or she could reset all the consumption choices and start over in period 1 of that life. Only after confirming the complete consumption path of all five periods of a life, those choices were finalized and became payoff relevant. Subjects did not receive feedback on utility during a life, but only after they had confirmed the finally chosen path. A more detailed description of this procedure can be found in the instructions in the appendix. By eliciting the complete consumption path and providing a calculator as well as the possibility for trial and error, we tried to simplify the intertemporal consumption task. In a sequential setting errors of previous periods cannot be corrected and impede optimal behavior in subsequent periods. In our setting the task is still “quasi sequential” as our subjects enter the consumption levels for each period, observe interest earnings and proceed to the next period. As they observe all previous periods while making their decisions and can reset these at any time, errors can be identified and corrected before confirming the consumption path.

One experimental session lasted on average two hours. Total payoffs ranged from €34 to €18 with an average of €30.3 (about $42.5) including a €4 show-up fee. With the chosen discount rate of 0.2 the life-time utility function used to calculate total utility was

$$U=0.83u_1+0.69u_2+0.58u_3+0.48u_4+0.4u_5. \qquad (7)$$

Equation (7) was also contained in the instructions. The conversion rate was € 0.28 (~$0.39) per utility point.

4 RESULTS

As a first step in our analysis, we study the properties of the actually chosen consumption profiles in the baseline treatment (lives 1, 5, 14, 23). The actually chosen profiles will serve as a benchmark from which we calculate the anticipation and the impact effects. The next step is to relate the observed consumption profiles to present and future interest rates and prices. Then, in a qualitative exercise, we check how often consumption is adjusted in the right direction.

4.1 BENCHMARK CASE; NO CHANGE IN THE REAL INTEREST RATE

We first focus on the four baseline treatments in which prices and interest rates are constant and equal to the rate of time preference over all four periods of a life. In this baseline case, the utility-maximizing consumption path is flat. Figure 3 shows the average consumption of all 50 subjects in each period averaged over the four baseline treatments. The figure clearly shows that subjects do not choose flat consumption profiles but rather declining consumption levels in the course of time.

Table 2 compares the actual mean consumption level in each period with the optimal ones and contains the significance levels of t-tests on the equality of the means with the predicted values. On average, subjects consume too much in the first period and too little in the later ones. This outcome can be interpreted as a result of non-standard discounting or disregard of the compound effects of interest rates, both of which are documented in the literature (Wagenaar and Sagria 1975, Ainslie 1991, Loewenstein and Prelec 1992, Laibson 1997, Stango and Zinman 2009, Christiandl and Fetchenhauer 2009). If subjects underestimate the nonlinear effect of interest on interest relative to the effect of the discount rate, it is very plausible that they do not save enough in the early periods of a life, which is consistent with the observed pattern.

Figure 3: Baseline consumption

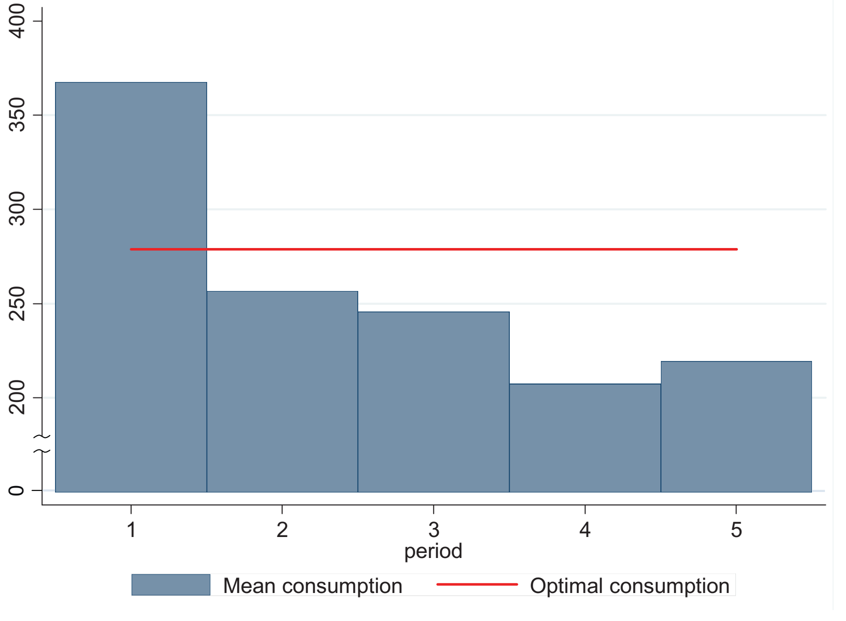


Table 2: Mean consumption by periods

t	1	2	3	4	5	all
C_t^{opt}	278.65	278.65	278.65	278.65	278.65	278.65
C_t	367.53	256.53	245.60	207.24	219.43	259.27
p	0.000	0.003	0.001	0.000	0.001	0.001

Notes: C^{opt} is optimal consumption for the parameters chosen in Section 2. C_t is average consumption of all subjects in the baseline treatments in period t. The p value is the empirical significance level of a t-test on the equality of average and optimal consumption.

Focusing on average consumption can, however, be misleading, since individual heterogeneity may hide behind the average. While some subjects might have declining baseline paths, other might satisfy the basic rationality criterion that the baseline paths should be flat. Therefore, we apply the following procedure: Using OLS we first regress each individual's consumption in the four lives of the baseline treatment on a linear and quadratic time trend and a constant. We then test whether the coefficients of the linear and the quadratic trend term are jointly different from zero using an F-test. At the 5% level, we cannot reject the null for 17 subjects. For these subjects, we then check whether the constant is in the interval [200, 360], which cannot be rejected for 5 subjects.

The interval follows from a basic estimation what a flat consumption path in the baseline treatment should be. If the interest rate is neglected and the initial endowment of 1000 is equally divided over all 5 periods, consumption in each period is 200, which is the lower bound. Assuming that the initial endowment yields interest earning of 200 at the given interest rate of 20% in periods 1 to 4, the lifetime budget is 1800. If this is allocated evenly to all 5 periods, the resulting period consumption is 360. Of course, both calculations are wrong but can serve as a rough estimate of what the true optimal consumption path should be. In fact, the optimal consumption level of 278.65 is almost exactly in the middle of this interval. We hence conclude that 5 subjects out of the total of 50 have a consumption path in the baseline treatments which is flat and close to the optimal one.

4.2 Comparative Statics

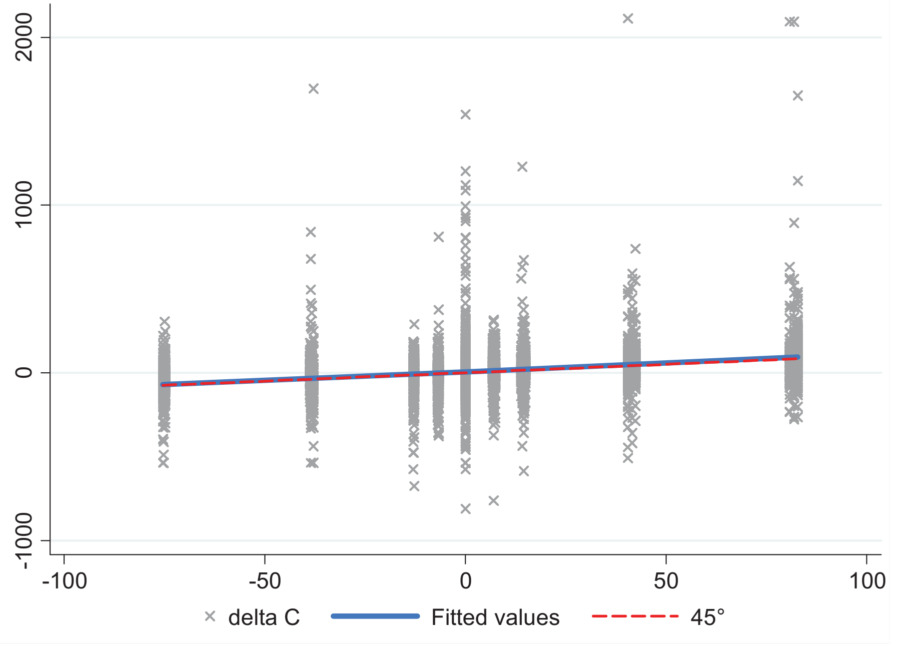
So far, we have demonstrated that most subjects do not allocate consumption intertemporally in a way consistent with the point predictions of the discounted utility model. Nevertheless, it still appears conceivable that responses to changes in interest rates and prices are more in line with the predictions of the model.

Despite the observation that the consumption paths chosen by the subjects deviate from the paths predicted by the model, comparative statistics may be more in line with the theory. In addition to being another dimension along which we can evaluate the theory, analyzing the comparative statistics also allows us to quantify the anticipation and impact effects, which is our primary goal. Even if the model fails to predict the intertemporal allocation of consumption and savings, it may still be an appropriate framework for the evaluation of the effects of monetary policy on private consumption, as long as it correctly predicts how people respond to changes in important variables such as nominal interest rates.

More specifically, we look at changes in actual consumption profiles relative to the individual baselines, $\Delta C_{it} = C_{it} - \bar{C}_{it}$, and compare these deviations to the corresponding, theoretically predicted deviations: $\Delta C_t^{opt} = C_t^{opt} - 278.65$. The individual baselines, $\bar{C}_{it}$, are the chosen consumption levels in each period averaged over the four treatments with constant prices and interest rates (life 1, 5, 14, and 23). Note that the construction of ΔC_{it} takes into account that subjects may already deviate from the optimal path in the baseline case of a flat consumption profile. We are therefore able to isolate the size of the reaction to changes in interest rates and prices.

A first approach to summarize the data is to regress ΔC_{it} on ΔC_t^{opt}. Figure 4 shows the scatter plot with the regression line and the 45° line. Clearly, if ΔC_{it} and ΔC_t^{opt} were equal, the regression line would coincide with the 45° line. The regression line has a slope of 1.02, which is not significantly different from 1 (t-test: $p<0.01$), and the constant is slightly positive (6.68: $p<0.01$). Thus, in the aggregate, the actual changes are practically identical to the changes predicted by the model. Individual deviations from optimal behavior are not systematic.

Figure 4: Actual vs. optimal changes in consumption



From a macroeconomic point of view, this could be seen as good news, as macroeconomic models serve to explain and predict aggregate behavior. However, the low R^2 of 0.05 indicates that while those deviations are not systematic, they are nevertheless very large.

Note that in the previous analysis, we pooled the consumption responses over time. A more disaggregated view is provided by the following regression, which is run for every life:

$$\Delta C_{it} - \Delta C_t^{opt} = \sum_{t=1}^{5} \alpha_t \, d_t^{period} + \varepsilon_{it}. \qquad (8)$$

We subtract the adjustment of consumption predicted by the model from the observed adjustment of the consumption profile and regress this difference on a set of period dummies. Note, that here we compare deviations in each period of an experimental life. Running this regression provides a simple way to compare actual and predictions deviations of consumption from the baseline case involving a constant real interest rate. With t-tests and F-tests, we can analyze whether the actual changes are different from the optimal ones in individual periods and over all periods jointly.

Table 3 contains the results from separate OLS regressions for each life. Δr indicates whether and how the real interest rate changed in the individual lives (treatments). The last column shows the significance level on the F-test that all five period dummies are jointly different from zero.

While we find no significant difference between the actual and the optimal consumption changes in lives 6 – 12, there are significant deviations in the later lives[3] 13 – 22. Even in lives 9, 11, and 12 for which the F-test does not indicate joint difference from zero, the t-tests show that in one period the difference between the actual consumption change and the optimal one is significant. Remarkably, the significant differences typically occur in periods 1 and 5 and are negative in the former and positive in the latter.

The message from this analysis is that in the majority of the treatments, the theoretical model does not predict correctly how subjects respond to changes in prices and interest rates. Overall, we find very little evidence in favor of the hypothesis that subjects react in anticipation of future changes in interest rates and prices.

[3] This apparent pattern seems to be a coincidence and not a systematic effect. If we exclude individual subjects from the sample the pattern becomes more irregular.

Table 3: Difference between actual and optimal changes

	Δr	Life	Period 1	Period 2	Period 3	Period 4	Period 5	p(F)
T1	**$r_{\downarrow 10}$**	8	-15.29	24.78	-6.71	10.78	1.98	.89
	$r_{\uparrow}^{20}$	12	-47.88*	24.34	14.76	-14.54	37.63	.17
	$r_{\downarrow 20}$	13	-23.32	14.07	21.92	33.03*	-17.35	**.03**
	$r_{\uparrow}^{10}$	19	-49.06**	18.40	21.48	.58	30.93*	**.00**
T2	**$r_{\uparrow}^{10}$**	10	-24.86	2.19	23.35	.43	6.69	.90
	$r_{\downarrow 20}$	17	-54.45**	-1.40	-1.69	60.43**	54.23**	**.00**
	$r_{\downarrow 10}$	20	-52.76**	6.93	14.19	38.49**	41.39**	**.00**
	$r_{\uparrow}^{20}$	22	-88.82**	13.34	32.37	50.34*	55.02*	**.00**
T3	**$r_{\downarrow 20}$**	6	2.57	1.39	5.54	19.98	-11.65	.94
	$r^{=}$	7	-14.76	19.47	-43.02	24.46	7.85	.43
	$r^{=}$	9	-58.27*	33.59	1.58	27.09	32.85	.11
	$r_{\uparrow}^{20}$	11	-42.70	11.15	7.21	-5.47	53.43*	.18
	$r_{\downarrow 10}$	15	-45.42**	-4.85	6.72	82.29**	3.35	**.00**
	$r^{=}$	16	-63.52**	-6.26	-7.44	34.61	108.82**	**.00**
	$r^{=}$	18	-62.08**	8.15	0.80	72.59**	31.87	**.00**
	$r_{\uparrow}^{10}$	21	-67.45**	13.52	7.78	61.55**	33.27*	**.00**

Notes: The table shows the estimated coefficients from equation (5). (*, **) means significant from zero at (5%, 1%) in t-test, p(F) is significance level of F-test that all dummies are different from zero, 250 observations in each regression. In all estimations, the constant was omitted. This allows to include dummy variables for all periods without resulting in perfect multicollinearity.

4.3 Announcement and Impact Effects

The main focus of this study lies on how subjects respond to changes in prices and interest rates both in anticipation and on impact. To explore this issue, we examine in this section whether there are systematic responses to interest rates and prices and when these systematic responses occur. To do so, we run the following regression separately for each period:

$$C_i^{period} = \beta_0 + \beta_1 R_3 + \beta_2 P_4 + \varepsilon_i. \quad (9)$$

Theoretically, the optimal consumption levels in each period are functions of interest rates and prices. Although the relations are non-linear (see equation 5), we can approximate them by linear regressions. Since the interest rate changes only in period 3 and prices in periods 4 and 5 are always identical, it is sufficient to include R_3 and P_4 into the regression. All the other variables are captured by β_0. Table 4 contains the results of these regressions for each period.

Table 4: OLS Regression of consumption in each period on prices and interest rates

	C_1	C_2	C_3	C_4	C_5
Constant	211.11**	205.64**	184.91**	455.37**	816.68**
	(63.54)	(35.06)	(44.59)	(52.00)	(91.72)
R_3^{opt}	*-65.96*	*-66.41*	*-65.37*	*377.20*	*376.93*
R_3	-166.93**	-35.74	-5.61	371.83**	404.35**
	(55.46)	(30.60)	(38.92)	(45.39)	(80.05)
P_4^{opt}	*80.05*	*80.65*	*79.12*	*-457.93*	*-458.41*
P_4	154.08**	66.44	65.71	-295.95**	-646.09**
	(65.91)	(36.37)	(46.25)	(53.94)	(95.14)
adj R^2	.008	.002	.000	.066	.048
p(F)	.005	.17	.32	.000	.000
#	1000	1000	1000	1000	1000

Notes: R_3^{opt} and P_4^{opt} stand for the coefficients in a regression of optimal consumption on the interest rate in period 3 and the price in period 4. We do not show the very small standard errors of theses regressions as the relations are linear approximation of the deterministic nonlinear relationships.

The fit of these regressions is very poor.[4] In periods 1-3 future changes in prices and interest rates hardly explain any variation of chosen consumption levels, although the response of consumption in period 1 is quantitatively large and highly significant.

In periods 4 and 5 the adjusted R^2 of the regressions is slightly higher but still very low (.066 and .048). Despite the low R^2, the F-test rejects that R_3 and P_3 have no effect on consumption in period 1 and the coefficients are not statistically different from the optimal ones (F-test, p=.176). The standard errors of the estimates are very large, though. In periods 2 and 3, the coefficients of R_3 and P_4 are not significantly different from zero. The significant coefficients in periods 4 and 5 indicate that there is an effect of price and interest rate changes on impact. Overall we find very little evidence in favor of an announcement effect. However, subjects do respond on impact.

4.4 Directions of adjustment

We have demonstrated that the size of the consumption adjustments in response to interest rates and prices is not as predicted in the majority of the treatments. A more lenient test of the model's predictive power is to check whether it predicts at least the direction of consumption changes correctly.[5]

[4] In contrast, the R^2 of the regressions with the optimal consumption levels are always larger than .98. This proves that the non-linear functions $C_t(R_3,P_4)$ can be well approximated by linear regressions.

[5] This approach is somewhat related to the Learning Direction Theory (Selten and Stoecker 1986, Selten and Buchta 1999). In our setting, however, there is no clear over- or undershooting and no repetition of identical situations.

We coded each individual deviation from the individual's baseline consumption as "-1" if it was negative and "+1" if it was positive. Table 5 summarizes the proportions of adjustments in the predicted direction in the different treatments for the anticipation phase and the impact phase. Since virtually all observed consumption paths deviate from the baseline, we omit the treatments with flat optimal consumption paths. As consumption either goes up or down, we use the binominal test to see whether the proportion of positive or negative changes is significantly larger than 50%, which would be the random proportion.

Table 5 displays once more that subjects do not respond in anticipation of known changes. The only exception is in life 13 in which 58% of the changes were in the theoretically expected positive direction. On impact, subjects' responses are more in line with theory as in 9 out of 12 treatments more than 50% of the adjustments are correct. Notice that impact responses always have the correct sign in the price change treatments T1, but only in 2 of the 4 interest rate treatments T2.

Table 5: Directions of consumption changes

	Δr	**Life**	**Treatment condition**	**Anticipation**			**Impact**		
				sign	**prop**	**p**	**sign**	**prop**	**p**
T1	$\mathbf{r}_{\downarrow 10}$	8	T1	+	.53	.23	-	**.70**	.00
	$\mathbf{r}_{\uparrow}^{20}$	12	T1	-	.51	.47	+	**.68**	.00
	$\mathbf{r}_{\downarrow 20}$	13	T1	+	**.58**	.03	-	**.76**	.00
	$\mathbf{r}_{\uparrow}^{10}$	19	T1	-	.45	.92	+	**.72**	.00
T2	$\mathbf{r}_{\uparrow}^{10}$	10	T2	-	.52	.34	+	.56	.14
	$\mathbf{r}_{\downarrow 20}$	17	T2	+	.43	.96	-	**.59**	.04
	$\mathbf{r}_{\downarrow 10}$	20	T2	+	.53	.34	-	.51	.46
	$\mathbf{r}_{\uparrow}^{20}$	22	T2	-	.54	.18	+	**.84**	.00
T3	$\mathbf{r}_{\downarrow 20}$	6	T3	+	.49	.60	-	**.81**	.00
	$\mathbf{r}_{\uparrow}^{20}$	11	T3	-	.53	.28	+	**.77**	.00
	$\mathbf{r}_{\downarrow 10}$	15	T3	+	.49	.62	-	.50	.54
	$\mathbf{r}_{\uparrow}^{10}$	21	T3	-	.56	.08	+	**.77**	.00

Notes: "sign" indicates whether consumption should increase (+) or decrease (-) relative to the benchmark. "prop" is the proportion of consumption changes in the theoretically predicted direction, "p" is the significance level of a one-sided binomial test that the proportion is small (larger) than 0.5. The treatments in which consumption should be constant are omitted because observed consumption always changed.

5 Conclusions

In this paper, we explore the extent to which subjects react to announced changes in future interest rates and prices when making consumption and saving decisions in a lab experiment. Our first result is that subjects appear to discount future periods more strongly than justified by the experimental design and neglect the compound effect of the interest rate leading to overconsumption in early periods. Taking this into account, we find strong indications for undersensitivity to perfectly anticipated future changes in prices and interest rates. This is reflected in an anticipation effect that is significantly lower than predicted by theory. Despite the fact that future changes in interest rates and price levels are known with certainty, subjects typically do not adjust their consumption decisions at the time of the announcement.

The impact effect is qualitatively in line with the theoretical prediction, or even larger than predicted. The announcement effect is generally substantially smaller than what is typically assumed in state of the art macroeconomic models. Overall, our results can be interpreted as an extension of the "over-sensitivity" literature. It is well-known that consumption follows current income too closely to be consistent with a high degree of intertemporal smoothing. We show that this over-sensitivity to the current economic environment and under-sensitivity to future developments carries over to intertemporal prices. Interestingly, we obtain this result without imposing any form of credit constraint, which are often invoked as an explanation for the observed over-sensitivity of consumption to current income.

The policy implications lie at hand: if the overall reaction to future changes in the real interest rate is smaller than predicted – as suggested by our results – policy makers cannot rely on the positive effects of perfectly credible announcements of future changes in monetary policy, as predicted by standard models.

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APPENDIX: INSTRUCTIONS

Welcome to the experiment. Please do not talk to any other participant from now on. We kindly ask you to use only those functions of the PC that are necessary for the conduct of the experiment.

The purpose of this experiment is to study decision behavior. You can earn real money in this experiment. Your payment will be determined solely by your own decisions according to the rules on the following pages.

The data from the experiment will be anonymized and cannot be related to the identities of the participants. Neither the other participants nor the experimenter will find out which choices you have made and how much you have earned during the experiment.

Task

Your task is to make savings and consumption decisions for a "life ". A life is divided into 5 periods. Your utility – and therefore your payoff in Euros at the end of the experiment – depends on the consumption of a good.

Endowment

At the beginning of a life, in period 1, you receive an endowment of 1000 "taler" which you can either spend on the consumption of a good or save. You will not receive any other income in your life, but you can increase your budget through savings.

Consumption

In each period the consumer good can be bought at a specific price P per unit. If you consume a quantity C of the good, you have to spend $C * P$ taler.

$$Expenditure = C * P$$

Saving

In each period your unspent endowment is automatically saved and earns interest. The interest rate is R. In the subsequent period the remaining budget from the previous period plus interest payments can again be either used to buy the consumption good or saved.

$$remaining\ Budget * (1 + R) = Budget\ next\ period$$

Example: Assume the interest rate is 20% and your remaining budget after consumption is 100 taler. Your budget in the next period would be 100(1.20)= 120* taler.

Period utility

The utility u that is generated by consumption C in one period is defined by the following equation:

$$u = \frac{C^{0.5}}{0.5}.$$

The more you consume in one period the higher will be your utility in that specific period. The increase in utility, however, declines with each consumed unit of the good.

Lifetime utility

Your payoff depends on your *lifetime utility*. This is the total utility you generated in all 5 periods of a life. ***Your remaining budget after the consumption in period 5 will be forfeited and will not generate any utility.*** The lifetime utility is the sum of the period utilities. However, the period utilities are discounted. This means, they receive specific weights in this sum, with the weights being smaller for later periods. In order to achieve the same discounted utility, you would have to consume more in each subsequent period than in the previous period. Formally presented you discount future utilities in period t by the factor

$$\frac{1}{(1+0.2)^t} = 0.8333^t$$

The discounted utility in each period t is therefore calculated as $u_t * 0.8333^t$

The period utility of period 1, for example, is multiplied by 0.833 while the period utility of period 2 is multiplied by 0.833^2=0.694, etc. The respective weights will be displayed on screen.

Lives

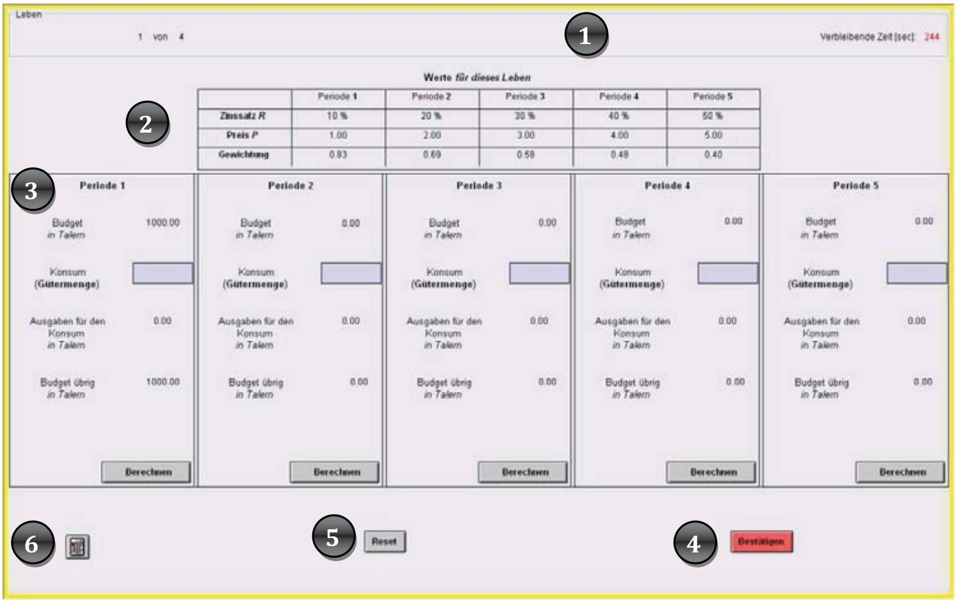
This experiment consists of 23 lives, each in turn consisting of 5 periods. Thus, the planning horizon in each life is 5 periods. The lives are completely independent of one another. You receive an endowment of 1000 taler in each life***. It is not possible to transfer taler or goods between lives.*** Prices and interest rates may change between lives.

Payoff

Your final payoff depends on the lifetime utility of ***one single life***. After you completed all 23 lives, one of these will be randomly selected for payoff. The lifetime utility generated in this life will be converted into Euros. The following conversion rate will apply:

$$1\ utility\ points = 0{,}281\ Euro\ (approx.\ 28\ Cent)$$
$$or\ 1\ Euro = 3{,}6\ utility\ points.$$

Operation instructions



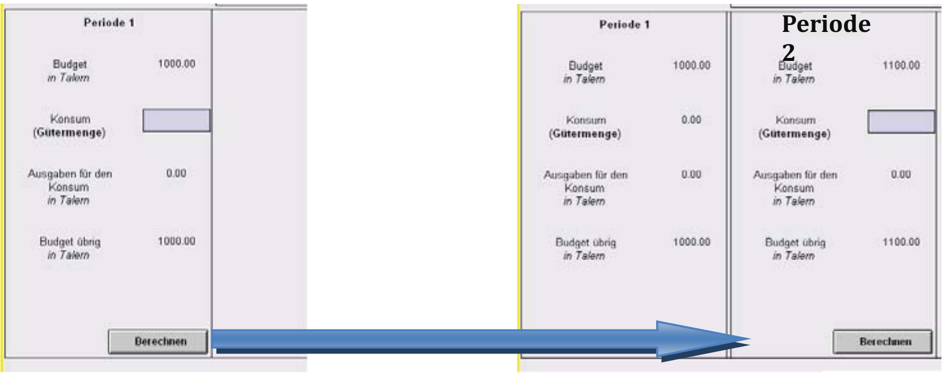
1. Lives/time

At the upper panel of the screen you can find which life you are currently in as well as the remaining time for the input (in seconds).

2. Period values

The actual values of the interest rates *R*, the prices *P*, and the weights for the period utilities are displayed for all 5 periods of the current life. Note that *R* and *P* may be different in each period.

3. Input



At the beginning of a life only the input field for period 1 is displayed. Below the current budget you will find a blue field where you can enter the consumption for period 1. You may enter numbers up to the third decimal place.

When you click the "calculate" button the remaining budget in this period will be displayed and the input field of the next period will open. In the new field the entry “budget” displays the remaining budget from the previous period plus interest

4. Confirming entries

When you have chosen the consumption for all 5 periods, you may either confirm your entry or re-calculate. If you press the red button, your entries for this life are confirmed and your lifetime utility will be displayed on the next screen.

5. Reset

To change your entries, you can use the reset button. This will reset all your consumption entries and you can start over with your input in period 1. You can change your entry as often as you wish.

6. Calculator

If you need a calculator you can open the Windows-calculator by clicking on the symbol in the bottom left corner of the screen.

End

After filling in a short questionnaire you will be called to the imbursement separately. Please bring the receipt and the card indicating your workstation number with you. The payout will be anonymous and private.