

# Monetary and Fiscal Policy Design at the Zero Lower Bound – Evidence from the Lab

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## Abstract

The global economic crisis of 2007-8 pushed many advanced economies into a liquidity trap, i.e., a macroeconomic scenario characterised by nominal interest rates at, or close to, the zero lower bound, low inflation and output below trend. In this paper we design an experiment to generate evidence on the effectiveness of policy measures aimed at managing expectations against liquidity traps in a controlled laboratory environment where expectations are elicited directly from human subjects. Our results suggest that monetary policy alone is not sufficient to insulate the economy from the risk of falling in a liquidity trap, even if it preventively cuts the interest rate when inflation threatens to fall below a certain threshold. On the other hand, such policy augmented with a fiscal switching rule succeeds in avoiding liquidity trap episodes. Finally, our results suggest larger-than-unity fiscal multipliers when monetary policy is constrained by the zero lower bound.

**JEL codes:** C92, D83, D84, E52, E62

**Keywords:** Experimental Macroeconomics, Monetary Policy, Fiscal Policy, Expectations, Zero Lower Bound, Liquidity Traps.

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# 1 Introduction

The economic experiences in the aftermath of the 2007–8 global financial crisis have highlighted the issue of appropriate macroeconomic policy in deep recession. In reaction to a sharp fall of aggregate demand, the FED lowered its policy rate to 0.25% in December 2008. The Bank of England hit the lower bound on its short-term interest rate target of 0.5% in March 2009 and, as low inflation threatens recovery in the Euro area, the ECB cut the interest rate to 0.05% in September 2014 (see Fig. 1).

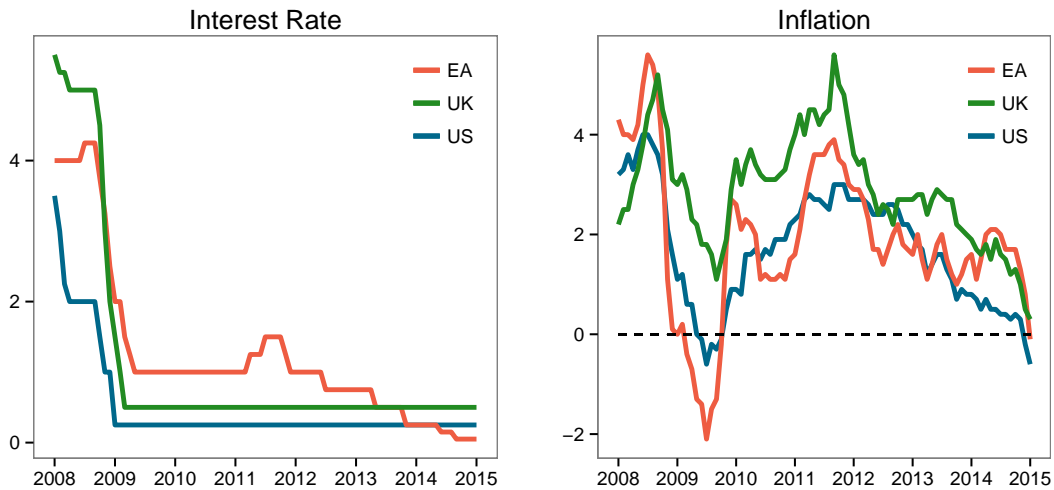


Figure 1: Macroeconomic scenarios in the Euro Area, US and UK.

This scenario characterised by depressed aggregate activity, low inflation and monetary policy unable to stimulate the economy due to policy rates set at, or close to, the zero lower bound (ZLB) is often referred to as *liquidity trap*. Recent research developments (see for example Benhabib et al. (2001a,b), Eggertsson and Woodford (2003), Werning (2012) and Mertens and Ravn (2014) among others) have described liquidity traps in models with rational expectations (RE) as unintended low-inflation equilibria, additional to the targeted steady state, generated by “active” Taylor-type interest rate rules subject to a binding ZLB constraint. In models featuring multiple equilibria under RE, stability under learning has often been used as an equilibrium selection device (see Marcet and Sargent (1989) and

Evans and Honkapohja (2001) among others), based on the view that RE equilibria should be thought of as the long-run outcome of some learning and updating process (see, e.g., Lucas (1978, 1986), Sargent (1993), Grandmont (1998)).

Evans et al. (2008) and Benhabib et al. (2014) study the stability of the above mentioned RE equilibria under adaptive learning finding that the targeted steady state is locally stable under learning while the unintended low inflation equilibrium is unstable under learning. Therefore, large pessimistic shocks may push the economy away from the target and result in liquidity traps taking the form of deflationary spirals in which output and inflation decline over time.<sup>1</sup>

In this paper we design a series of learning-to-forecast laboratory experiments (LtFEs) to empirically assess the plausibility of aggregate dynamics in a New Keynesian model which presents multiple equilibria under RE. In particular, we test the predictions of a class of learning models in describing the emergence of liquidity traps as a result of adverse expectational shocks, and assess the effectiveness of monetary and fiscal policies targeted at avoiding/escaping the ensuing deflationary episodes.

In recent years laboratory experiments have become an increasingly important tool to address macroeconomic issues (see Duffy (2012) for a recent overview). LtFEs, a design first proposed by Marimon and Sunder (1993), are an ideal environment to study expectations' dynamics as the experimenter has full control over the model underlying the artificial economy, timing and magnitude of shocks, and information sets. LtFEs represent therefore an ideal test bed for policies aimed at managing expectations against liquidity traps. Recently, a number of LtFEs have been conducted within the context of linearised New Keynesian models to investigate inflation persistence (Adam (2007)), the appropriate design of Taylor rules (Pfajfar and Zakelj (2011), Assenza et al. (2011)), disinflationary policies (Cornand

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<sup>1</sup>Evans et al. (2008) use short-horizon learning based on Euler equations, while Benhabib et al. (2014) use infinite-horizon learning in which agents' decisions are based on forecasts over the entire future. Christiano and Eichenbaum (2012) and Mertens and Ravn (2014) also consider sunspot equilibria taking the form of a two-state Markov process, with the target outcome as an absorbing state.

and M'Baye (2013)) and the importance of expectational channel for macroeconomic stabilisation (Kryvtsov and Petersen (2013)); see also Assenza et al. (2014) for a survey of LtFEs in macroeconomics.

In our experiment subjects play the role of professional forecasters with the task of submitting forecasts for inflation and output. Forecasts are then aggregated and used as expectational input in the New Keynesian model describing the dynamics of inflation and output. By not making any a-priori assumption on expectations' dynamics and eliciting them, instead, directly from paid human subjects, we test the learnability of the targeted equilibrium and investigate the likely outcome of adverse expectations dynamics triggered by pessimistic expectational shocks.

In this context, we study the effectiveness of monetary and fiscal policies aimed at insulating the laboratory economies from the risk of falling into liquidity traps. Following Evans et al. (2008), we consider policies that maintain the Taylor rule in “normal times”, but augment it by switching to aggressive monetary and fiscal policies if inflation falls below some thresholds.<sup>2</sup> In particular, we first consider an aggressive monetary policy in which the interest rate is preventively cut at the ZLB when inflation falls, or threatens to fall, below a certain threshold level. We then compare results with a treatment in which the aggressive monetary policy is augmented with a fiscal switching rule that raises public expenditures in order to prevent a fall in inflation below a certain threshold each time the cut in the interest rate is not enough to revert the decelerating inflation path. By comparing the two treatments, we ask whether an aggressive monetary policy is enough to prevent the fall in a liquidity trap. If not, we ask whether the addition of fiscal policy measures can avoid deflationary outcomes.

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<sup>2</sup>Recent literature has proposed other types of monetary and/or fiscal policies aimed at avoiding or escaping liquidity traps. Some authors proposed policies that make use of announcements and commitment to future policy actions (see, e.g., Krugman (1998), Woodford (2005) Eggertsson and Woodford (2003, 2004)) to control agents' expectations and avoid the effects of persistent deflationary outcomes. Other authors suggested fiscal or monetary policies leading to violations of the transversality conditions in order to rule out deflationary outcomes (see, e.g., Benhabib et al. (2002)). More recently, a significant strand of the literature analysed the effectiveness of standard fiscal policies when monetary policy is at the ZLB (see, e.g., Christiano et al. (2011), Woodford (2011), Eggertsson (2010) and Braun et al. (2012)).

Our findings can be summarised as follows. First, adaptive learning models are good predictors of the emergence of liquidity traps as a result of severely pessimistic expectations. As predicted by theoretical models under learning, when expected inflation ( $\pi^e$ ) and expected net output ( $c^e$ ) fall in a well-identified region of the  $(c^e, \pi^e)$ -space, learning dynamics result in a self-reinforcing deflationary process in which inflation and output decline over time. The intuition for this result is that low enough expectations of future inflation and output imply low aggregate demand, due to high real interest rate values under a Taylor rule subject to the ZLB constraint. High real interest rates, combined with low expected output imply reduced levels of economic activity and lead to realisations of inflation below expectations. Expectations are thus revised further downward, pushing the economy deeper into the deflation trap. In this sense the initial fear of deflation is self-fulfilling.

Second, we find that liquidity traps in the form of deflationary spirals only arise in treatments that consider monetary policy alone, while they are never observed when monetary policy is augmented with the fiscal switching rule. The implementation of the fiscal switching rule leads to the disappearance of the low-inflation steady state and to a change in the expectational feedback of the model by interrupting downward trends in inflation and output, avoiding therefore coordination on destabilising trend-following forecasting behaviour.

Finally, we analyse the impact of fiscal policy at the ZLB and estimate larger-than-unity fiscal multipliers.

Recently, Arifovic and Petersen (2015) ran a parallel LtFE to study liquidity traps in laboratory economies. The experimental design of the two papers is similar in spirit, but differs in the following important dimensions. First, while Arifovic and Petersen (2015) use a linear approximation of the New Keynesian model to describe the experimental economies, we use the actual nonlinear specification consistently with the work of Evans et al. (2008), Mertens and Ravn (2014) and Benhabib et al. (2014) among others. The rationale for this choice is the fact that linearised

models may provide poor approximation of inflation and output dynamics in the presence of large deviations from steady state, as in the case of liquidity trap episodes.<sup>3</sup> Second, Arifovic and Petersen (2015) impose large negative shocks to aggregate demand to generate a liquidity trap environment. In contrast, we use small IID shocks to our experimental economies. The reason for this choice is that we are interested in testing the predictions of learning models describing the emergence of liquidity traps as a result of shifts in expectations which produce sufficient deflationary pressures to cause the ZLB to bind. By having only small IID shocks affecting actual realisations of inflation and output, the risk of falling in a liquidity trap arises only from adverse *expectational* shocks.<sup>4</sup> Moreover, the noise term in Arifovic and Petersen (2015) follows an AR(1) process. In such an experimental environment it is not clear whether fluctuations in inflation and output are expectations driven or solely driven by exogenous shocks. On the other hand, in our experimental economies with only small IID shocks, any observed large fluctuations in aggregate variables must be endogenously driven by expectations. Third, Arifovic and Petersen (2015) focus on the role of communication strategies of central banks near the ZLB while we test the effectiveness of aggressive monetary policy and fiscal switching rules.

The rest of the paper is organised as follows. Section 2 describes the theoretical framework underlying the experimental economies. Section 3 provides details on the design of the experiment. Section 4 presents the experimental outcomes while Section 5 further discusses the results and contributes to a recent policy debate about a possible increase in the FED rates. Finally Section 6 concludes.

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<sup>3</sup>The dangers of relying on linear approximations to study liquidity trap dynamics are documented, for example, in Judd et al. (2012), Fernandez-Villaverde et al. (2012), Braun et al. (2012) and Aruoba et al. (2013).

<sup>4</sup>Mertens and Ravn (2014) point out that the impact of exit strategies from liquidity trap episodes depend on whether the liquidity trap is caused by non-fundamental expectational shocks or by fundamental shocks. Aruoba et al. (2013) estimate a model with fundamental and non-fundamental shocks. Using data from Japan they find that the country experienced the fall to a deflation regime in 1999 due to adverse non-fundamental confidence shocks. Finally, Schmitt-Grohé and Uribe (2013) emphasise the role of expectational shocks to explain the joint occurrence of liquidity traps with jobless growth recovery.

## 2 Theoretical Framework

### 2.1 A Nonlinear New Keynesian Model

The experimental economy is based on a standard New Keynesian (NK) framework with a private sector producing differentiated output under monopolistic competition and price frictions. In order to study exact global dynamics in regions of the state space which are far from the targeted steady state, as in the case of liquidity trap episodes, we follow Evans et al. (2008), Braun et al. (2012) and Benhabib et al. (2014) among others, and interpret price frictions as stemming from adjustment costs *à la* Rotemberg (1982). This price-setting environment allows us to use the actual nonlinear NK model specification without introducing additional endogenous state variables, while delivering the same functional form for the linearised model around the targeted steady state as in the often used pricing model *à la* Calvo (1983).<sup>5</sup>

The key equations describing aggregate dynamics (see Evans et al. (2008) for a detailed derivation) are given by

$$c_t = c_{t+1}^e \left( \frac{\pi_{t+1}^e}{\beta R_t} \right)^{1/\sigma} \quad (1)$$

$$\pi_t(\pi_t - 1) = \beta \pi_{t+1}^e (\pi_{t+1}^e - 1) + \frac{v}{\alpha \gamma} (c_t + g_t)^{\frac{1+\epsilon}{\alpha}} + \frac{1-v}{\gamma} (c_t + g_t) c_t^{-\sigma}. \quad (2)$$

Eq. (1) describing the dynamics of net output  $c_t$  (i.e., output minus government consumption of the aggregate good) is a standard Euler equation, where  $c_{t+1}^e$  and  $\pi_{t+1}^e$  denote respectively expectations of future net output and inflation,  $R_t$  is the nominal interest rate set by the central bank,  $0 < \beta < 1$  is the discount factor and  $\sigma > 0$  refers to the intertemporal elasticity of substitution.

Eq. (2) is a New Keynesian Phillips Curve describing the dynamics of inflation  $\pi_t$ , where  $g_t$  is government consumption of the aggregate good,  $\epsilon > 0$  refers to the marginal disutility of labour,  $0 < \alpha < 1$  is the return to labor in the production

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<sup>5</sup>See Christiano and Eichenbaum (2012) for details.

function,  $\gamma > 0$  is the cost of deviating from the inflation target under Rotemberg price adjustment costs, and  $\nu > 1$  is the elasticity of substitution between differentiated goods. The term  $\pi_t(\pi_t - 1)$  in Eq. (2) arises from the quadratic form of the adjustment costs. Let  $\pi_t(\pi_t - 1) = Q_t$ . The appropriate root for given  $Q$  is  $\pi \geq 1/2$  and so we need to impose  $Q \geq -1/4$  to have a meaningful model.

For the experimental implementation of the economy described by Eqs. (1)–(2) we follow the parameters’ calibration of Benhabib et al. (2014). The time discount rate is set to  $\beta = 0.99$ , the labour share is set to  $\alpha = 0.7$ , and parameter  $\nu$  is set to 21. The parameter  $\gamma$ , measuring the cost of deviating from the inflation target under Rotemberg pricing, is related to the price rigidity parameter of Calvo pricing, denoted by  $\phi$ , according to  $\gamma = \frac{(\nu-1)\phi}{(1-\phi)(1-\beta\phi)}$ . Following Benhabib et al. (2014), we consider a Calvo pricing parameter  $\phi$  of approximately 0.8, corresponding to  $\gamma = 350$  under their calibration. Preferences are assumed to be logarithmic so that  $\sigma = \epsilon = 1$ .

## 2.2 Monetary and Fiscal Policy

Following Evans et al. (2008), we consider an *aggressive* monetary policy of the form

$$R_t = \begin{cases} 1 + (R^* - 1) \left( \frac{\pi_{t+1}^e}{\pi^*} \right)^{\frac{AR^*}{R^*-1}} \left( \frac{c_{t+1}^e}{c^*} \right)^{\frac{\phi_y R^*}{R^*-1}} & \text{if } \pi_t \geq \tilde{\pi} \\ \tilde{R} & \text{if } \pi_t < \tilde{\pi} \end{cases}, \quad (3)$$

where  $\tilde{R} = 1.0001$  corresponds to the ZLB on the nominal interest rate.<sup>6</sup> This monetary policy rule is defined as aggressive since, while in “normal” times ( $\pi_t \geq \tilde{\pi}$ ) it follows a forward-looking Taylor rule, it preventively cuts the nominal interest rate to the ZLB each time inflation drops below a given threshold  $\tilde{\pi}$ .<sup>7</sup> We set the

<sup>6</sup>We set  $\tilde{R}$  to a number small but positive in order to keep money demand finite, see Evans et al. (2008) for details.

<sup>7</sup>The main results below would also hold in the case of a contemporaneous Taylor rule as emphasised by Evans et al. (2008). Using a forward-looking specification for the Taylor rule facilitates the experimental implementation due to the nonlinear nature of the model.



reaction coefficients in the interest rate rule to  $\phi_\pi = 2$  and  $\phi_y = 0.5$ , which are in line with empirical estimates, see, e.g., Taylor (1999), Judd and Rudebusch (1998), Clarida et al. (2000) and Orphanides (2003) among others. This parameterisation ensures local determinacy of the targeted steady state  $(\pi^*, c^*)$  under RE. However, as emphasised by Benhabib et al. (2001b), “active” Taylor rules imply the existence of a second unintended low-inflation steady state  $(\pi_L, c_L)$ , which is locally indeterminate under RE. Given our parameterisation, there are no steady states other than the intended steady state  $(\pi^*, c^*)$  and the unintended low-inflation steady state  $(\pi_L, c_L)$ .

Fiscal policy is specified as

$$g_t = \bar{g}, \tag{4}$$

where  $\bar{g}$  is fixed. As in Evans et al. (2008), we set  $\pi^* = 1.05$  which implies a net output steady state value of  $c^* = 0.7454$ .<sup>8</sup> Under the aggressive monetary policy in Eq. (3) the low-inflation steady state is given by  $(\pi_L, c_L) = (0.99, 0.7428)$ . The two equilibria of the model are depicted in Fig. 2a. The low inflation steady state  $(\pi_L, c_L)$  is denoted by a blue “L”, while the targeted steady state  $\pi^*, c^*$  is denoted by a green “T”.

We also consider the fiscal policy design proposed by Evans et al. (2008) to prevent liquidity traps and deflationary spirals. The *fiscal switching rule* prescribes an increase in public expenditures  $g$  each time monetary policy fails to achieve  $\pi_t > \tilde{\pi}$ . Evans et al. (2008) show that in model (1)–(2), given expectations  $\pi_{t+1}^e$  and  $c_{t+1}^e$ , any level of inflation  $\pi_t$  can be achieved by setting  $g_t$  sufficiently high.<sup>9</sup> Therefore the fiscal switching rule is specified as follows: if the inflation bound  $\tilde{\pi}$

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<sup>8</sup>We chose an inflation target of 1.05 to clearly separate the intended and unintended steady state in the experimental economies. Qualitative results are robust to alternative target values.

<sup>9</sup>Moreover, Evans et al. (2008) show that any level of inflation  $\pi_t$  (above 0.5) corresponds to a unique value of  $g_t$  through Eq. (2).

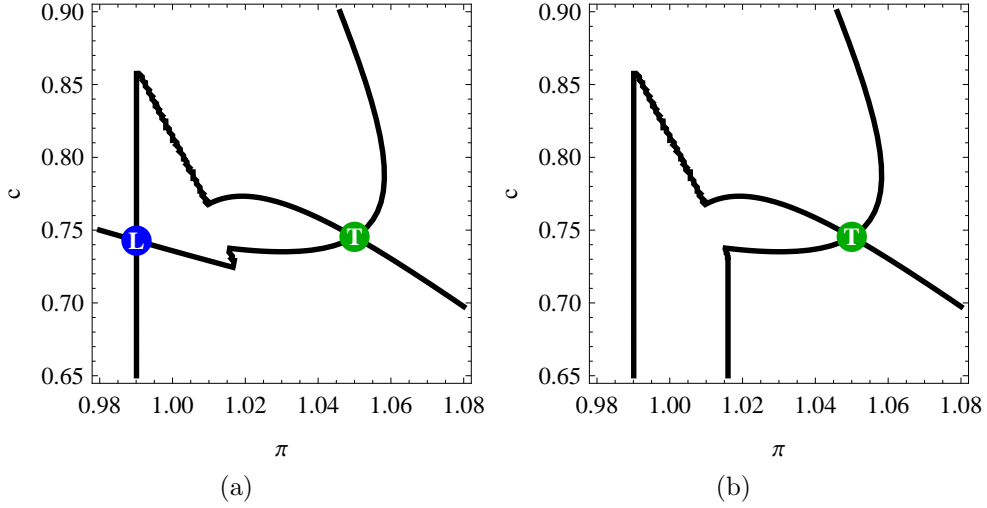


Figure 2: **Panel (a)**: Multiple equilibria under aggressive monetary policy. **Panel (b)**: Unique equilibrium under combined monetary policy and fiscal switching rule.

is not achieved under the aggressive monetary policy in Eq. (3), then we

$$\left\{ \begin{array}{l} \text{(i) compute the interest rate } \hat{R}_t \text{ consistent with Eqs. (1)–(2) and } \pi_t = \tilde{\pi} \\ \text{(ii) set } R_t = \max[\hat{R}_t, \tilde{R}] \\ \text{(iii) if } R_t = \tilde{R} > \hat{R}_t, \text{ then } g_t \text{ is adjusted upward such that } \pi_t = \tilde{\pi} (+\epsilon), \end{array} \right. \quad (5)$$

where  $\epsilon$  is a small tolerance parameter set to 0.001. As shown by Evans et al. (2008), setting  $\pi_L < \tilde{\pi} < \pi^*$  ensures the uniqueness of the targeted steady state. In our experimental design we set  $\tilde{\pi} = 1.016$ , which is above the low-inflation unintended steady state but low enough considering the 1.05 inflation target. The equilibrium of the system under combined monetary (Eq. (3)) and fiscal policy (Eq. (5)) is described in Fig. 2b.

The idea behind the monetary-fiscal policy mix is the following. If the inflation target is not achieved under a standard Taylor rule, monetary policy is relaxed in order to stimulate the economy. If the ZLB constraints the effectiveness of monetary policy, aggressive fiscal policy is activated.

### 2.3 Learning, E-Stability and Equilibrium Selection

In the presence of multiple equilibria and uncertain impact of policy changes, some have argued for dismissing equilibria that yield unstable dynamics under alternative assumptions about the formation of expectations, see, e.g., McCallum (2003), Adam (2003), Lettau and Van Zandt (2003) among others, and Christiano and Eichenbaum (2012) for an application to liquidity trap contexts. In recent years it became increasingly common practice in the literature to study the “learnability” of equilibria in order to sharpen the predictions of RE models. A commonly used criterion is the expectational stability, or E-stability, of the system of expectational difference equations underlying the model, due to the fact that E-stability is closely related to dynamic stability under simple recursive learning schemes, such as least squares or constant gain learning (Marcet and Sargent (1989), Evans and Honkapohja (2001)). Rational expectations and adaptive learning can thus be viewed as complementary approaches: rational expectations allows one to identify the steady states, cycles, or other patterns that might be collectively learnable in the long run, and then adaptive learning allows one to test their stability and learnability.

As in Evans et al. (2008), Mertens and Ravn (2014) and Benhabib et al. (2014), we consider the following constant gains learning rules

$$\pi_{t+1}^e = \pi_t^e + \delta(\pi_{t-1} - \pi_t^e) \tag{6}$$

$$c_{t+1}^e = c_t^e + \delta(c_{t-1} - c_t^e) \tag{7}$$

to formulate predictions of the model under learning to be tested in our experimental setup. Rules (6)–(7) are Perceived Law of Motions (PLMs) consistent with the MSV solutions of our simple experimental economy setup. Equilibria whose expectations can be acquired via simple learning rules, such as Eqs. (6)–(7) are widely believed to constitute more plausible model predictions than equilibria that would require more sophisticated coordination devices.

The first goal of the paper is to test experimentally whether adaptive learning

models are good predictors of the emergence of liquidity traps when the expectational input to the model follows more realistic dynamics and it is provided directly by human subjects. E-stability is determined by the Jacobian matrix of the so called T-map, i.e., the mapping from the PLM to the corresponding Actual Law of Motion (ALM), evaluated at the steady state (see Evans and Honkapohja (2001) for details). For the E-stability condition to be satisfied, both eigenvalues of the Jacobian matrix must be less than one in absolute value. Evans et al. (2008) show that under the aggressive monetary policy regime of Eq. (3) and the constant fiscal policy rule of Eq. (4), the targeted steady state  $(\pi^*, c^*)$  is locally stable under learning, while the low-inflation steady state  $(\pi_L, c_L)$  is locally unstable under learning, taking the form of a saddle point. In fact, given the parameterisation of our experimental economy, the eigenvalues computed at the low-inflation steady state are, in absolute value, equal to  $(1.53, 0.67)$ , while for the targeted steady state we have complex eigenvalues with modulus equal to  $(0.7, 0.7)$ . Dynamics under learning are represented in Fig. 3.

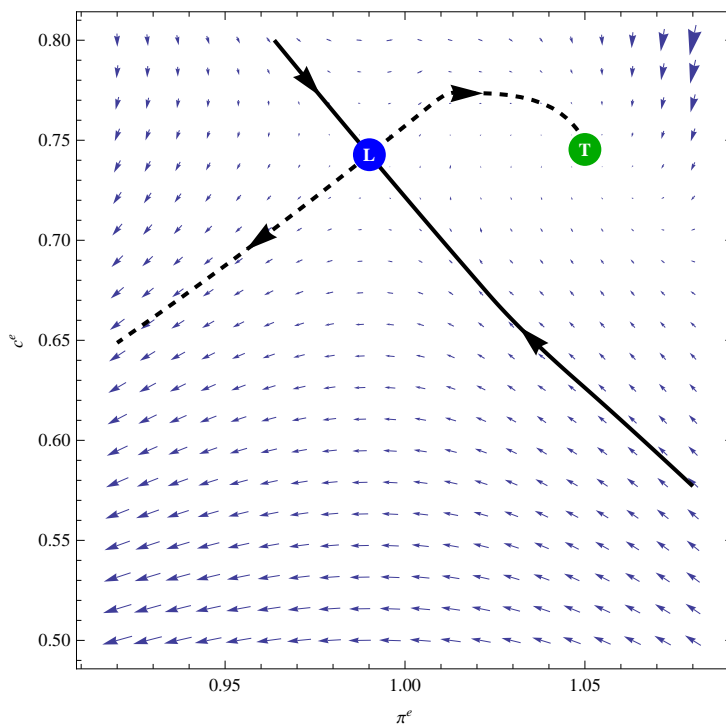


Figure 3: Learning dynamics under aggressive monetary policy and constant fiscal policy.

The solid black line and the dashed black line in Fig. 3 depict respectively the stable and unstable manifold of the saddle low-inflation equilibrium (blue “L”). The stable and unstable manifolds have been obtained as numerical approximations of learning dynamics converging to the low-inflation steady state  $(\pi_L, c_L)$  respectively in forward and backward time. The E-stability analysis shows that although the intended steady state is locally stable under learning, the saddle property of the low-inflation steady state creates a region in the phase space in which inflation and output decline over time. In particular, the stable manifold divides the phase space in two regions: the region below the manifold, characterised by deflationary dynamics, and the region above the manifold, characterised by convergence to the intended steady state  $(\pi^*, c^*)$ . The previous analysis shows that adverse expectational shocks may cause liquidity traps taking the form of deflationary spirals. Large pessimistic shocks may in fact push expectations into regions of the phase space leading to a self-reinforcing process in which inflation and output decline over time.

On the other hand, when the aggressive monetary policy is augmented with the fiscal switching rule described in Eq. (5), the intended steady state is globally stable under learning.

In the experiment we are interested in testing the predictions of the learning model in describing the occurrence of liquidity traps. Details on the experimental design are provided in the next section.

### 3 Experimental Design

The experiment is a LtFE with a between subject design and within session randomisation. In the beginning all participants are divided into groups (experimental economies) of six. Subjects only interact with people in their experimental economy. The only task for subjects is to make two-period-ahead forecasts of inflation and net output for 50 periods. Average forecasts are then used as input to model

(1)–(3), with fiscal policy defined by either (4) or (5) (see below for a description of treatments), in order to compute realisations of inflation and net output.

In each period  $t$ , when making forecasts for period  $t + 1$ , the information set visualised on screen includes all realisations of inflation, net output, interest rate and government expenditures up to period  $t - 1$ , their own forecasts of inflation and net output up to period  $t$ , and their scores reporting how close their past forecasts were to realised values up to period  $t - 1$ . Fig. 11 in Appendix B shows the computer interface as visualised by participants in the experiment.

Subjects' payments depend on their forecasting performance. At the end of the experiment it is randomly determined for each participant whether she is paid for inflation forecasting or net output forecasting. The total score for inflation or net output forecasting is the sum of the respective forecasting over all periods. The score of subject  $i$  in each period for e.g., inflation forecast is determined as  $100/(1 + |\pi_{i,t}^e - \pi_t|)$ , where  $\pi_{i,t}^e$  denotes subject  $i$ 's forecast for period  $t$  and  $\pi_t$  is the realised value of inflation in period  $t$  (the score is computed in an analogous way for net output). Therefore subjects' payment decrease with the (absolute) distance of realisations from their forecasts.<sup>10</sup>

In the instructions subjects receive a qualitative description of the economy, explaining the mechanisms governing the model equations, but they do not receive quantitative information on the exact values of e.g., the structural parameters of the economy. This is a standard strategy in LtFE aiming at testing the learnability of RE equilibria (see Duffy (2012) and Hommes (2011)). In order to prevent perfect coordination of subjects on the deterministic steady states, we buffet the economy with small additive white noise shocks to Eqs. (1)–(2) with a standard deviation of 0.0025. Subjects are informed that realisations inflation and net output are affected by these small random shocks. The complete instructions can be found in Appendix A.

As noticed in Section 2, the model underlying the experimental economies is

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<sup>10</sup>See also Adam (2007), Pfajfar and Zakelj (2011) and Assenza et al. (2011) who use an analogous payoff function.

well defined if condition  $Q \geq -1/4$  is satisfied. Therefore we impose  $\pi^e \in [0.8, 1.2]$  and  $c^e \in [0.35, 0.9]$ . Given the calibration of the experimental economy described in Section 2, these restrictions ensure that condition  $Q \geq -1/4$  is satisfied throughout the experiment. In the experiment the restrictions were implemented as a message popping up in the subjects' screen in case their forecasts were outside the allowed range.<sup>11</sup>

Finally, in order to keep the experimental setup as simple as possible for subjects, we did not introduce the concept of gross inflation which might be confusing and harder to explain. Instead, we elicited forecasts in percentage points and translated them to gross inflation as input to the model. For the same reason, we elicited values of net output forecasts scaled up by a factor of 100 and translated them to the appropriate format as input to the model.

### 3.1 Treatments and Hypotheses

We implement a  $2 \times 2$  experimental design with 4 treatments which differs in the following dimensions. First, we consider two policy regimes (*Policy* dimension): a policy regime, labeled as M, which is characterised by aggressive monetary policy (Eq. (3)) and a fixed amount of public expenditures (Eq. (4)); a second policy regime, labeled as F, which is instead characterised by the same aggressive monetary policy augmented with the fiscal switching rule (Eq. (5)). The second dimension concerns origin and timing of adverse expectations dynamics causing the ZLB to bind (*Expectations* dimension). In one scenario, labeled as P, below-target expectations are induced at the beginning of the experiment in the form of initial severe pessimism (see below for details). In the other scenario, labeled as S, pessimistic shifts in expectations are induced later in the experiment, i.e., when

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<sup>11</sup>During the experiment these constraints were never binding, aside from the cases of liquidity traps in the form of deflationary spirals. In these cases the inflation rate fell below  $-20\%$  and output dropped to levels lower than  $50\%$  of the equilibrium value. This scenario was enough for us to show the occurrence of liquidity traps in the form of deflationary spirals. Wild oscillations following the periods in which subjects reached the minimum value they were allowed to submit as forecasts are not meaningful from an economic point of view.

the experimental economies are already moving along a converging path and are in the proximity of the target equilibrium (see below for details). The  $2 \times 2$  matrix describing the 4 treatments implemented in the experiment is reported in Table 1.

<b>Policy</b>	<b>Expectations</b>	
	Severe Pessimism (P)	Expectational Shock (S)
Aggressive Monetary (M)	MP	MS
Fiscal Switching (F)	FP	FS

Table 1: Four treatments' summary

Within the context of the first policy regime labeled as “Aggressive Monetary” (M) in Table 1, we are interested in testing the predictions of adaptive learning models about the occurrence and characteristics of liquidity trap episodes, summarised in the following proposition:

**Proposition 1.** *Under the policy regime M (described by Eqs. (3)–(4)), pessimistic expectations falling in the “unstable” region described by the area in the  $(\pi^e, c^e)$ -space below the stable manifold, caused by either initial severe pessimism (treatment MP) or by adverse expectational shocks (treatment MS), lead to the emergence of liquidity traps in the form of deflationary spirals.*

In order to consider situations in which, due to adverse expectations about future macroeconomic conditions, the economy is in the “unstable” region where adaptive learning reinforces pessimistic expectations, we adopt the following strategies. In one case, denoted as “Severe Pessimism” (P) in Table 1, we play with the starting level of pessimism in the experimental economy. Recall that, as the experiment involves making two-period-ahead-forecasts, subjects are asked in the beginning of the experiment to enter forecasts for periods 1 and 2 simultaneously. Subjects receive therefore some indication of reasonable values by being told in the instructions that in economies similar to the one they are participating in, inflation and net output have historically been within certain numerical intervals. In order to reproduce a situation of severe pessimism we provide the historical range



of  $[0.92, 1.08]$  for inflation (given a targeted steady state of 1.05) and the historical range of  $[0.60, 0.80]$  for net output (given a targeted steady state of about 0.74). In this case the point with coordinates given by the middle points of the historical ranges, which typically acts as a focal point for subjects' forecast in the initial phases of the experiment, lies in the "unstable" region.

In the other case labelled as "Expectational Shocks" (S) in Table 1, the historical range provided to subjects in the instructions for inflation is  $[0.95, 1.08]$ , while the range for net output is unchanged. In this case the focal point for initial expectations lies in the "stable" region, theoretically leading to convergence to the targeted equilibrium. Therefore, in order to provoke an expectational shock, some "bad news" pop up on the participants' screen in the form of newspaper reports with experts' opinions about future economic conditions (see Experimental Instructions in Appendix A for details).<sup>12</sup> Subjects are informed in the instructions that a newspaper is operating in the economy which may announce from time to time news about experts' opinions on the economy, and we explicitly tell subjects that the experts' opinions have no impact on actual realisations of the aggregate variables describing the experimental economy, and that it is up to them to determine whether and how to use the newspaper information. In treatments MS and FS the expectational shocks, i.e., pessimistic news announcements, were repeatedly given in periods 8, 9 and 10, due to the two-period-ahead nature of the forecasting task.

In the context of the second policy regime labeled as "Fiscal Switching" (F) in Table 1, we are interested in testing the effectiveness of the fiscal switching rule in combating liquidity traps. In particular we want to test the following:

**Proposition 2.** *Under the policy regime F (described by Eqs. (3) and (5), liquidity traps in the form of deflationary spirals do not occur as a result of neither initial severe pessimism (treatment FP), nor expectational shocks (treatment FS).*

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<sup>12</sup>Notice also that subjects in the *Severe Pessimism* treatments were also informed about the possibility of news announcements, so experimental instructions were the same for both the *Severe Pessimism* and the *Expectational Shocks* treatments, with the exception of the historical ranges for inflation. No news announcements appeared in the *Severe Pessimism* treatments.

In our experiment adverse expectations represent the only source of deflationary pressure causing the ZLB to bind, without imposing any large exogenous shock to the fundamentals of the economy. Eventual liquidity traps are therefore entirely driven by expectations. Most of the theoretical frameworks used in the literature to think about liquidity trap episodes assume that the economy is pushed at the ZLB as a result of a sustained exogenous negative preference shock modelled as a two-state Markov process with an absorbing value at the “normal” level which, therefore, disappears in finite time (see e.g., Eggertsson and Woodford (2003) among others). On the other hand, our experimental design makes the occurrence of liquidity traps and the potential recovery path completely endogenous and dependent on the policy’s impact on expectations’ dynamics. (see further discussion in Section 5).

## 3.2 Implementation

The experiment was programmed in Java using the PET software<sup>13</sup> and it was conducted at the CREED laboratory at the University of Amsterdam in October 2014. A total of 168 subjects recruited from the CREED subject pool took part in the experiment (28 experimental economies of 6 subjects each). During the experiment, “points” were used as currency. Points were exchanged for euros at the end of each session at an exchange rate of 0.75 euros per 100 points. The experiment lasted for about two hours and participants earned on average ??? euros. The series of small IID shocks buffeting the experimental economies were the same for all groups.<sup>14</sup>

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<sup>13</sup>PET software was developed by AITIA, Budapest, and is available at <http://pet.aitia.ai>.

<sup>14</sup>The actual experiment included one more group that we exclude from the analysis (including this group, the experiment was conducted with 174 subjects). This group was excluded due to severe misunderstandings of one subject who was in an “altered state” and made non sensible predictions, systematically far away from actual realisations (thereby also losing a lot of money). The results for this group are reported for completeness in Appendix D.

## 4 Experimental Results

An overview of the experimental results is reported in Fig. 4 (the data for each group including interest rate, government expenditure and expectations dynamics are reported in Appendix C). Each line corresponds to realised inflation (left panels) and net output (right panels) in one experimental economy (7 economies per treatment), tracked over all 50 periods of the experiment.<sup>15</sup>

In treatment MP, initial pessimistic expectations lead to realised inflation and net output well below target, causing the central bank to set the interest rate to the ZLB in the attempt to stimulate the economy. In 2 out of 7 economies this policy measure suffices to ensure recovery, avoiding deep recessions and leading to convergence to the targeted steady state  $(\pi^*, c^*)$ , at least in the long run (see Fig. 4a). In the remaining 5 out of 7 groups, pessimistic expectations are so severe that monetary policy alone is not enough to revert the decelerating inflation path. These economies experience liquidity traps characterised by inflation and output trajectories declining over time. Eventually, inflation and net output expectations hit the lower bound imposed to ensure well-defined model equations, i.e., inflation rate of  $-20\%$  and net output lower than  $50\%$  of the equilibrium value. The ensuing wild oscillations are not meaningful from an economic point of view and are not reported in Fig. 4a.<sup>16</sup>

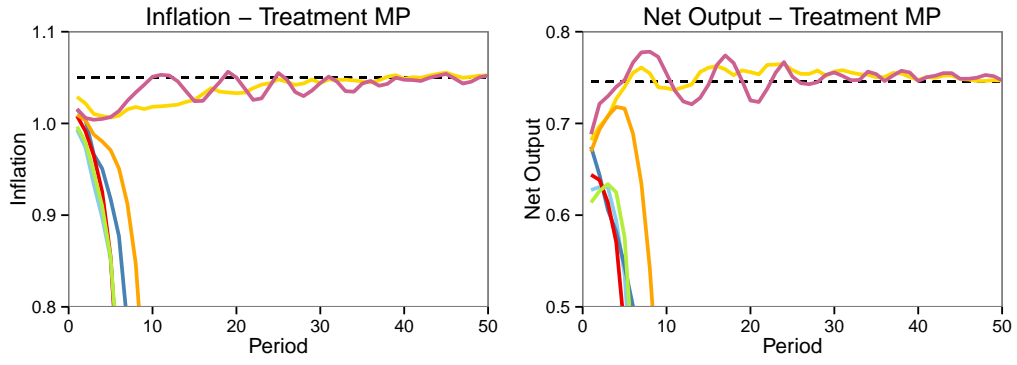
In treatment MS, all economies start converging to the intended equilibrium in the initial phases of the experiment. However, the expectational shocks in the form of “bad news” occurring in periods 8 – 10 (shaded areas in Fig. 4b) lead to the emergence of a liquidity trap in 4 out of 7 economies.<sup>17</sup> In these groups, the shift in expectations produces sufficient deflationary pressures to cause the ZLB to bind. Low expectations of future inflation imply high real interest rates at the ZLB which, combined with low expected output, imply low realisations of aggregate output and

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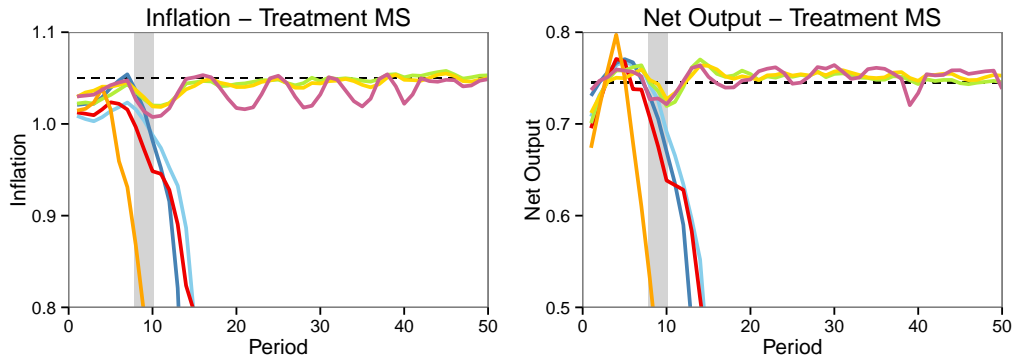
<sup>15</sup>Experimental economy 6 in treatment FS ended at period 35 due to a server error.

<sup>16</sup>For the sake of completeness, we reported the complete time series in Appendix C.

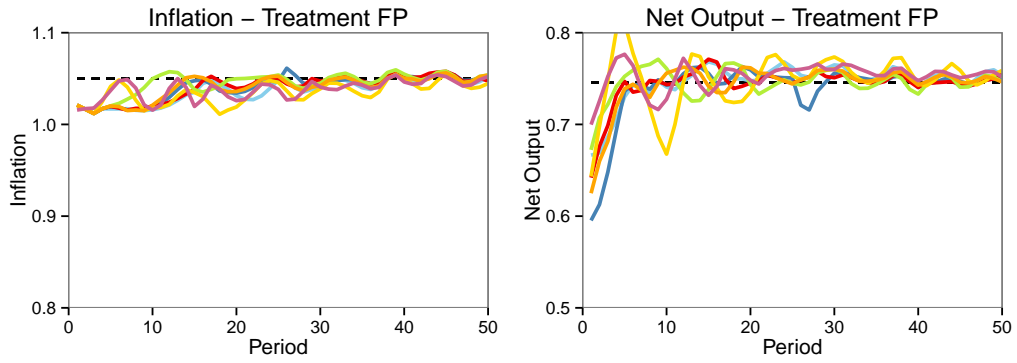
<sup>17</sup>In group 6 the fall in the liquidity trap starts before the expectational shock due to the forecast of one subject who attempted to stop the converging trend in inflation/net output, and it is reinforced by the bad news announcement.



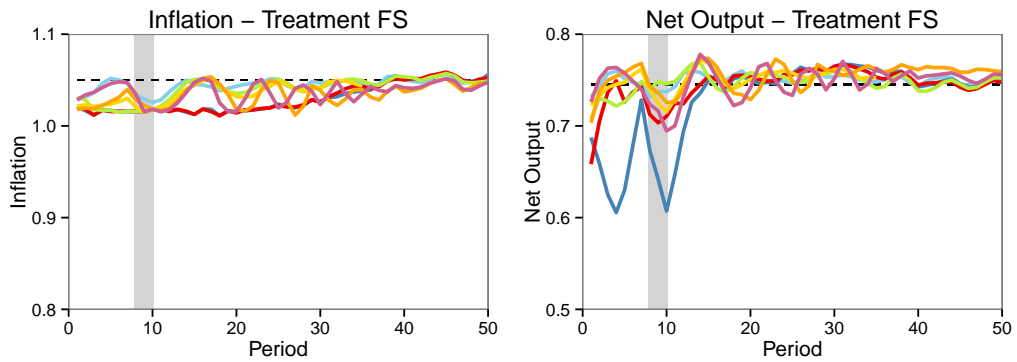
(a) Treatment MP



(b) Treatment MS



(c) Treatment FP



(d) Treatment FS

Figure 4: Overview of experimental results. **Left panels:** realised inflation. **Right panels:** realised net output. Dashed lines depict targeted equilibrium levels.

lead to actual inflation below expected inflation. Expectations are revised further downward causing accelerating deflation and deep recessions. Moreover, in one of the three economies that do not fall in a liquidity trap after the adverse expectational shock, the deflationary outcome is avoided thanks to the implementation the aggressive monetary policy which preventively cut the interest rate and succeeded in stimulating the economy, while in the other two economies the standard Taylor rule suffices in steering the economy towards the desired equilibrium.

In treatments FP and FS we do not observe the occurrence of liquidity traps, neither as a result of initial severely pessimistic expectations, nor as a result of adverse expectational shocks (see Figs.4c – 4d). In fact, in 12 out of 14 economies of treatments FP and FS, the fiscal switching rule is activated and government expenditures increase in reaction to low level of inflation and net output caused by pessimistic expectations (see Figs. 14 – 16 in Appendix C). The expansionary fiscal interventions prevent the experimental economies from falling into liquidity traps, confirming the theoretical results of Evans et al. (2008) and Benhabib et al. (2014). In fact, the fiscal switching rule described in Eq. (5) has an impact on the *expectations feedback system* underlying the experimental economies by interrupting downward trends in inflation and net output caused by very pessimistic expectations.<sup>18</sup> Observation of realised inflation ( $\tilde{\pi}$ ) above (pessimistic) expectations leads subjects to revise upward their forecasts, implying therefore an increase in inflation and net output. The reversal of the negative trend eventually pushes the experimental economies away from the ZLB, leading to converge to the targeted steady state. When the fiscal switching rule is implemented, we observe two qualitatively different types of convergence patterns, namely oscillatory convergence to the target (groups 4, 5 in treatment FP and groups 5, 6, 7 in treatment FS) and slow convergence with interest rates at, or close to, the ZLB and inflation stuck

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<sup>18</sup>The importance of the nature of the feedback at play between expectations and realisations has been recognised in earlier experimental works, see e.g., Heemeijer et al. (2009), Fehr and Tyran (2008) among others. See also Assenza et al. (2011) for an experimental investigation of the impact of alternative monetary policies on the expectations feedback system in New Keynesian economies.

at low levels for an extended period of time (groups 1, 2, 3, 6 in treatment FP and groups 2, 3, 4 in treatment FS). The latter scenario can be described as an *almost self-fulfilling* equilibrium (see Hommes (2013)) arising as a consequence of the implementation of the fiscal switching policy. The intuition for the emergence of such (temporary) state is the following. Any downward trend in inflation and expectations below the threshold  $\tilde{\pi}$  is interrupted by stabilizing inflation around  $\tilde{\pi}$ . Therefore, the inflation level  $\tilde{\pi}$  may act as an anchor for subjects' expectations preventing on the one hand drops in inflation expectations below such level but not necessarily ensuring a rise of expectations above  $\tilde{\pi}$ . In other words, the fiscal switching rule may not be enough to quickly *revert* expectations. In fact, while fiscal policy ensures a level of inflation around  $\tilde{\pi}$ , net output adjusts slowly towards equilibrium. As long as realisations and expectations of net output are low enough for the fiscal switching rule to be activated, inflation expectations remain focused at  $\tilde{\pi}$ . However, as net output increases further in the adjustment towards equilibrium, the fiscal rule will be no longer activated and inflation realisations will be above  $\tilde{\pi}$ . Subjects then revise their inflation expectations upward, until convergence to equilibrium.

Therefore adverse expectational dynamics can be very persistent and the recovery driven by the mix of aggressive monetary policy and fiscal policy rule can be slow.

We now turn to the test of the learning model's predictions in describing the occurrence and characteristics of liquidity trap episodes, summarised in Propositions 1 – 2. Figs. 5 – 7 display experimental data in the  $(\pi, c)$ -space. The plots report the numerical approximation of the stable manifold of the system under the learning dynamics described in Section 2.3 which divides the phase space in two regions, namely the region below the stable manifold labelled as “unstable”, and the region above the stable manifold labelled as “stable”. According to Proposition 1, expectations which are pessimistic enough to fall in the “unstable” region lead to the occurrence of a liquidity trap in the form of a deflationary spiral in treatments

MP and MS, while according to Proposition 2 liquidity traps should never occur in treatments FP and FS when the fiscal switching policy regime is implemented.

Severely pessimistic expectations are induced in treatment MP at the beginning of the experiment by providing historical ranges for inflation and net output such that middle points of the intervals lie in the “unstable” region. Fig. 5a plots subjects’ average expectations in period 2 for the seven experimental economies in treatment MP.<sup>19</sup>

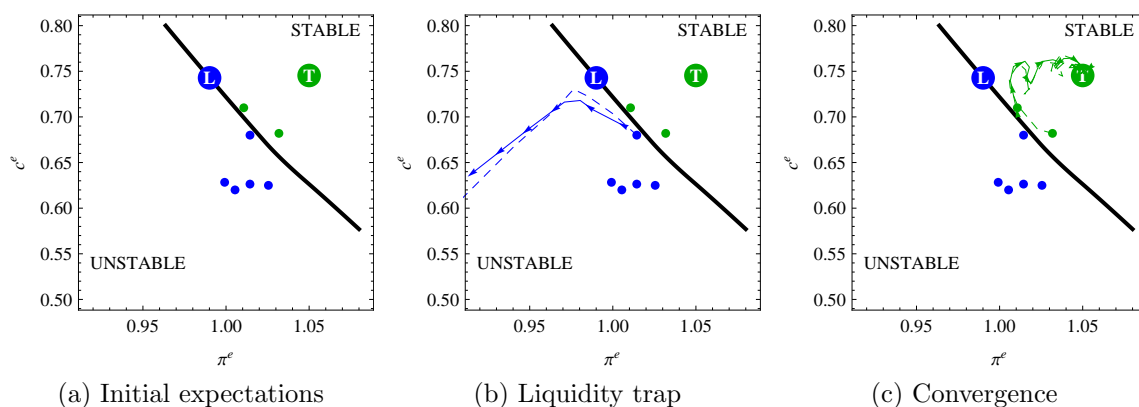


Figure 5: Treatment MP

The five blue points correspond to experimental economies that experience a liquidity trap, while the two green points correspond to the experimental economies that converge to the intended equilibrium. From the graphical analysis it is clear that all economies in which initial expectations are pessimistic enough to lie in the “unstable” region fall in a liquidity trap, while all economies in which expectations are less pessimistic and lie instead in the “stable” region converge to the target. Additionally, Fig. 5b provides an example of deflationary dynamics (group 6) and Fig. 5c an example of converging dynamics (group 5). In Figs. 5b and 5c, solid lines refer to realisations of inflation and net output while dashed lines depict expectations’ dynamics. Fig. 5b shows that the initial stimulus provided by the aggressive monetary policy which sets the interest rate to the ZLB from the beginning of the experiment in reaction to very pessimistic expectations causes an initial rise in net

<sup>19</sup>We plot average expectations in period 2 because this is the first period in which subjects observe realised inflation and net output, receiving therefore a feedback on their forecasts and having a clearer idea of the order of magnitudes of inflation and net output.

output. However the stimulus to the economy deriving from the accommodative monetary policy is not enough to offset very pessimistic expectations. Deflationary expectations lead in fact to high real interest rates causing eventually both inflation and net output to fall.

Fig. 6 refers to treatment MS. In this treatment initial expectations are only mildly pessimistic, in the sense that the middle points of the historical ranges for inflation and net output provided to subjects in the instructions lie in the “stable” region. Therefore, as expected, initial average forecasts in all experimental economies lie in the “stable” region as shown in Fig. 6a and all groups start converging to the intended steady state.

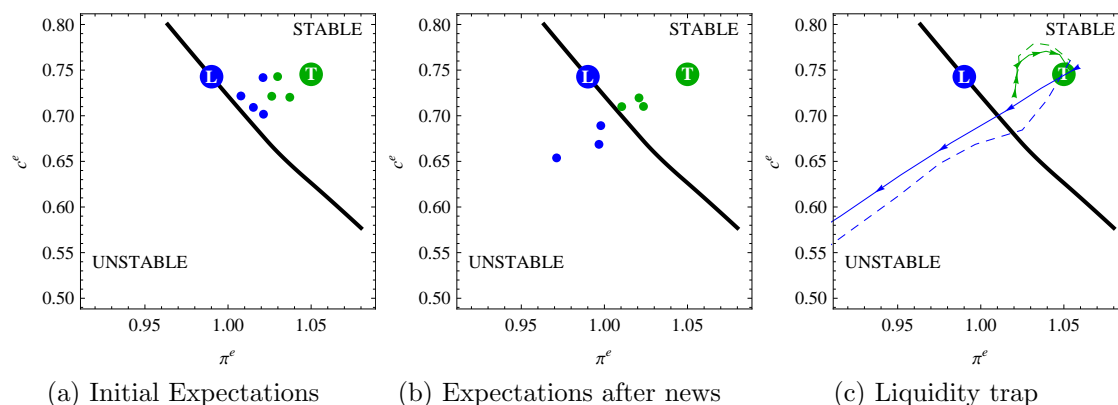


Figure 6: Treatment MS

However, the expectational shocks lead to a shift in the average sentiment about the economic conditions, causing expectations to move towards the bottom left corner of the phase space, i.e., lower expected inflation and net output. Fig. 6b plots average expectations after the expectational shocks (period 11) for all experimental economies in treatment MP. All groups in which expectations are pushed in the “unstable” region (characterised again by blue points) fall in a liquidity trap, while all economies in which expectations remain in the “stable” region eventually recover and converge to the targeted equilibrium.<sup>20</sup> Fig. 6c displays an example of deflationary dynamics following the expectational shocks in group 2 (once again

<sup>20</sup>As mentioned above, in one experimental economy (group 6) the fall in the liquidity trap starts before the expectational shocks and thus, by period 11, expectations are beyond the boundaries of Fig. 6b, explaining why we only observe 6 instead of 7 points.



solid lines refer to actual inflation and net output dynamics while dashed lines depict dynamics of expectations). The green lines show the dynamics of aggregate variables and expectations before the expectational shocks, clearly converging to the target. After the “bad news” announcements, expectations shift downward (blue dashed line), entering the “unstable” region and starting a self-reinforcing process leading to collapse of output and deflationary outcomes (blue solid line).

Fig. 7 refers to treatments FP and FS, in which the fiscal switching policy rule is implemented. Fig. 7a displays the average initial expectations in all economies of treatment FP, characterised by initial severe pessimism, while Fig. 7b displays the average forecasts after the expectational shocks in all economies of treatment FS.

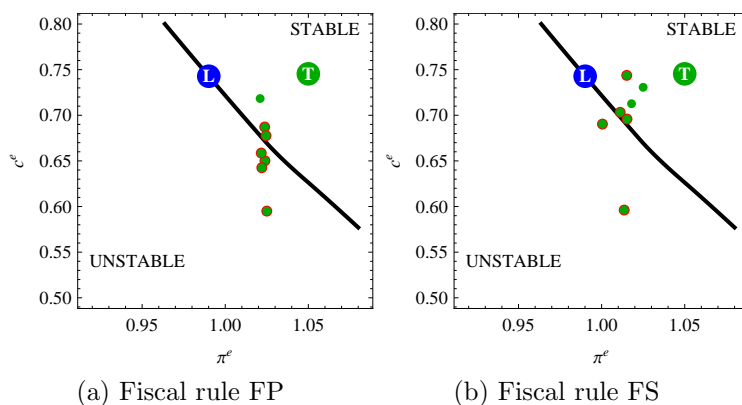


Figure 7: Treatments FP (left) and FS (right)

In both figures, all points are represented in green as all groups converge to the targeted steady state. Points circled in red refer to experimental economies in which the fiscal switching rule has been activated. Several points lie in the “unstable” area, indicating that these economies might have fallen in a liquidity trap in the absence of an active fiscal switching rule.

Overall, we find that the predictions of the learning model in describing the occurrence of liquidity trap are validated by the experimental results. In particular, we find that under the policy regime (3) – (4), adverse expectations expectations caused either by a severe level of initial pessimism or by an expectational shock,

lead to the emergence of liquidity traps in the form of deflationary spirals (Proposition 1). In other words, an aggressive monetary policy alone, which preventively cuts the interest rates to the ZLB when inflation falls below a certain threshold, is not enough to avoid liquidity traps. E-stability under learning rules (6) – (7) provides a rather accurate description of how pessimistic expectations need to be for the economy to fall in a liquidity trap, or in other words, a prediction of when the stimulus provided by monetary policy, as a function of average expectation level, is enough to avoid deflationary outcomes. If average expectations fall in the “unstable” region, the presence of the ZLB makes monetary alone powerless at correcting adverse expectations dynamics and avoiding liquidity traps. On the other hand, our experimental results suggest that an aggressive monetary policy augmented with a fiscal switching rule can be successful in affecting the expectations feedback system and prevent the occurrence of deflationary outcomes (Proposition 2). In the next section we analyse in more detail the effects of fiscal policy in the experimental economies.

#### 4.1 Estimation of the Impact of Fiscal Policy at the ZLB

We now analyse the impact of temporary increases in public expenditures on output in the experimental economies. In particular, we are interested in estimating the effect of fiscal policy at the ZLB. We therefore consider economies in treatments FP and FS in which the fiscal switching rule has been activated while the interest rate is set at the ZLB. In order to obtain a proxy for the fiscal multiplier in our experimental environment where no a-priori assumptions are made on how agents form expectations and where we verified that liquidity trap episodes take the form of deflationary spirals, we use data from economies that fell in a liquidity trap due to a binding ZLB in treatments MP and MS as counterfactual. In particular, following the empirical approach of Aruoba et al. (2013), we compute the multiplier

$$\mu_t^* = \frac{y_{t+1}^{F^*} - y_{t+1}^{M^*}}{g_t^{F^*} - \bar{g}}, \quad (8)$$

respectively for economies where the binding ZLB is caused by initial severe pessimism ( $* = P$ ) and expectational shocks ( $* = S$ ). In Eq. (8),  $y_{t+1}^F$  denotes the average value of output ( $y = c + g$ ) in period  $t + 1$  for economies where the fiscal switching rule has been activated in period  $t$ ,  $y_{t+1}^M$  denotes the average value of output for economies that experienced a liquidity trap due to a binding ZLB, and  $g_t^F$  refers to the average path of government expenditures under the fiscal rule in Eq. (5). Notice that in the numerator of Eq. (8) we included the values of output realised in period  $t + 1$ , i.e., immediately after the fiscal shock  $g_t$ . This is due to the fact that realisations of output in period  $t$  are not affected by public expenditures in period  $t$  (see Eq. (1)), but only depend on expectations formed at the beginning of period  $t$ , i.e., before the implementation of fiscal policy. The values of the multipliers for treatments FP and FS are reported respectively in Fig. 8 and 9.

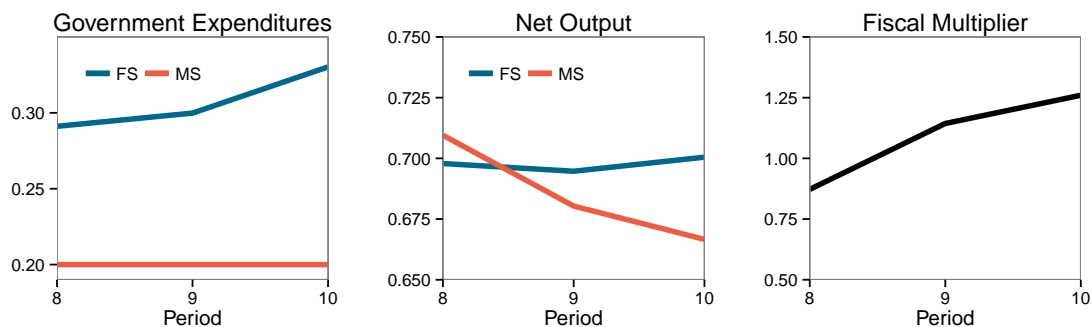


Figure 8: Treatment FP. **Left panel:** Government Expenditures. **Middle panel:** Net Output. **Right panel:** Fiscal multipliers.

The cumulated multiplier over periods 1 – 4 for treatment FP is about 1.77, while for treatment FS the cumulated multiplier over periods 8 – 10 is roughly 1.1. Overall, the estimated values above 1 suggest that expansionary fiscal policy crowds in private consumption through a rise in inflation expectations (which decreases the real interest rate) and a rise in expected net output.

The difference in the magnitude of the multiplier between the two treatments is due to the following. In treatment MS the bad news shocks causing pessimistic expectations occur in periods 8 – 10, i.e., when the economies are already converging towards the intended equilibrium and expectations are of course in the “stable”

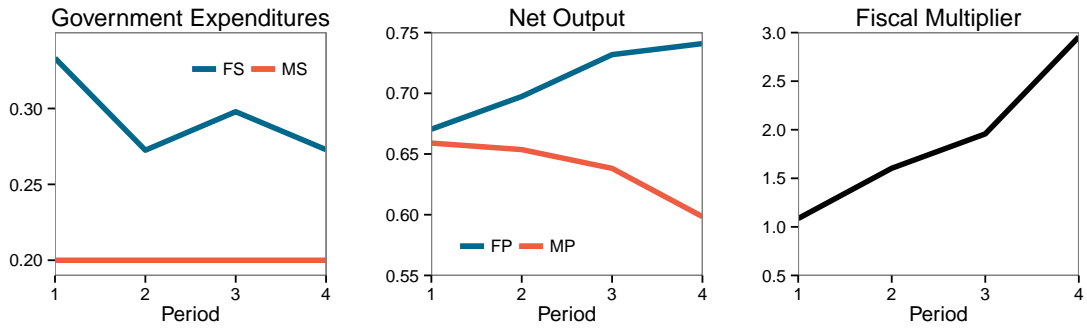


Figure 9: Treatment FS. **Left panel:** Government Expenditures. **Middle panel:** Net Output. **Right panel:** Fiscal multipliers.

region. Therefore, in the initial phases of the expectational shift, output and inflation do not drop dramatically as beliefs are still within the “stable” region. It is only after the last bad news announcements that expectations fall in the “unstable” region, triggering thus an accelerating deflationary process and large drops in output. These periods of deep recession leading to higher values of the numerator in Eq. (8) do not have an impact in the computation of the multiplier as typically the fiscal switching rule succeeds in creating inflationary expectations immediately after the last expectational shock. On the other hand, in treatment MP expectations are severely pessimistic, i.e., within the “unstable” region, already at the beginning of the experiment implying high perceived real interest rates and causing large drops in consumption which lead to higher values of the numerator in Eq. (8).

In the computation of the multiplier for treatment FS we did not include group 6 from treatment MS in the counterfactual data because the process leading to the fall in the liquidity trap started before, and got reinforced by, the “bad news” announcement (see footnote 17). Levels of net output were already much lower than average by the time the first expectational shock hit the economy due to increasingly pessimistic expectations’ dynamics in the “unstable” region. Inclusion of group 6 in the computation of the multiplier leads to an estimated cumulated multiplier of about 1.65. Therefore the magnitude of the multiplier increases when the fiscal policy rule is activated in reaction to accelerating deflationary pressures

in the “unstable” region.

## 5 Discussion

In this section we compare our results on the effect of fiscal policy at the ZLB with the existing literature and, in the light of our findings, we briefly comment on the recent policy debate on whether the FED should raise its target rate in the short/medium run.

There are only few, and no consensual estimates of the fiscal multipliers during a recession in the literature. This is mainly due to technical difficulties (see Parker (2011) for a discussion). Episodes of deep recessions are rare and thus available data are limited. Furthermore, fiscal multipliers are usually estimated using linear VAR models or linearized DSGE models, which do not allow for state-dependence and non-linearities between the output effects of government spending and the size of the fiscal action. On the empirical front, one exception is Auerbach and Gorodnichenko (2012). Using a structural VAR model with regime switching, they find that fiscal multipliers are much higher in recessions than in expansions and conclude in favour of values ranging between 1 and 1.5 in a recession (see also Tagkalakis (2008) and Braun et al. (2012)). On the theoretical front, once accounting for the zero-lower bound in a DSGE model, fiscal multipliers may be typically larger than one during economic downturns, especially when the ZLB is binding (Christiano et al. (2011)), or if the liquidity trap is expected to be long-lasting (Erceg and Lindé (2014)). Christiano et al. (2011) find values as high as 3.7 in their baseline model. Furthermore, Mertens and Ravn (2014) find larger multiplier values on the transitory adaptive learning dynamics towards rational expectations equilibrium than in the case of rational expectations.<sup>21</sup> In our experiment the estimated values of the fiscal multipliers at the ZLB are largely consistent with these findings. Moreover, we stress that the expectational channel of fiscal policy is the crucial in

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<sup>21</sup>However, their estimate are lower than one in both cases.

our experimental setting. In fact, in the experimental economies, net output  $c$  is not directly influenced by  $g$  (see Eq. (1)), but depends on expected net output and the real interest rate. The possibility for fiscal policy to crowd in or out private consumption then works entirely through the *expectation feedback mechanism*.

Analysing how policies affect this expectation feedback mechanism in a set-up where the occurrence of liquidity traps and the time to the recovery are endogenous, and no specific assumption has to be made on expectations is one of the major contributions of our experiment. This approach contrasts with most models of liquidity trap *à la* Eggertsson and Woodford (2003). In those models, an exogenous shock causes the ZLB to bind, and fiscal policy aims at mitigating the output losses in the liquidity trap which lasts for an exogenous, *policy-invariant* period of time.<sup>22</sup> However, the model properties and the policy implications can be quite sensitive to this design (Aruoba et al. (2013)). In such a framework, Mertens and Ravn (2014) oppose confidence-driven and fundamental-driven liquidity traps, and show on the contrary that fiscal stimulus is deflationary in a confidence-driven liquidity trap. One crucial difference with our experimental approach, though, is that liquidity traps arise endogenously in the experiments, and the policy mix influences the economy through the expectation feedback mechanism, which in turn endogenously determines the transitory dynamics along the recovery. The impact of fiscal policy and the expectations' dynamics observed in our experiment are therefore closer to the effects of fiscal policy discussed in Eggertsson (2010): fiscal expansion can counteract a deflationary spiral by creating inflationary pressures, which translate into a drop in the real interest rate if the ZLB is binding, and stimulate private consumption. In this case, the fiscal multiplier can be larger than one at the ZLB due to the impact of fiscal policy on expectations.

Recent policy debate has focused on whether the FED should raise its target rate in the short/medium run. Some economists suggested that mid-2015 would be a good timing, while others suggested to postpone the implementation of the

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<sup>22</sup>Exceptions include Evans et al. (2008), Erceg and Lindé (2014) and Aruoba et al. (2013).

policy measure to 2016 (see minutes FOMC Meeting March 2015). However, in the minutes of last FOMC meeting at the time of writing (April 2015) it is stated that:

*Consistent with its previous statement, the Committee judges that an increase in the target range for the federal funds rate remains unlikely at the April FOMC meeting. The Committee anticipates that it will be appropriate to raise the target range for the federal funds rate when it has seen further improvement in the labor market and is reasonably confident that inflation will move back to its 2 percent objective over the medium term. This change in the forward guidance does not indicate that the Committee has decided on the timing of the initial increase in the target range.*

Although the Fed removed from its statement an assurance to "be patient" when considering an initial bump in its near-zero benchmark rate, Fed Chair Janet Yellen told Congress that to raise rates, Fed officials must simply be "reasonably confident" that inflation will drift toward the Fed's target in the medium-term. Accordingly, some economists suggest to remain cautious about raising rates "until you see the whites of inflation's eyes". For example, Krugman states that "if it turns out that the Fed has waited a bit too long, inflation might overshoot 2 percent for a while, but that wouldn't be a great tragedy, but if the Fed moves too soon, we might end up losing millions of jobs we could have had."

We can use the framework described in Section 2.3 to evaluate the proposal of raising the interest rate. A bump in the interest rate, given inflation below the threshold  $\tilde{\pi}$ , i.e., before the implementation of a state dependent Taylor rule, corresponds to an increase in  $\tilde{R}$  in the policy rule described by Eq. (3). Possible consequences of this policy measure are described in Fig. 10.

Suppose expectations are still below target but fall within the "stable" region before the policy implementation, say at point A. From this point, the economy would probably follow a recovery path leading to the targeted equilibrium. An increase in the rate  $\tilde{R}$  causes an upward shift of the stable manifold, moving the

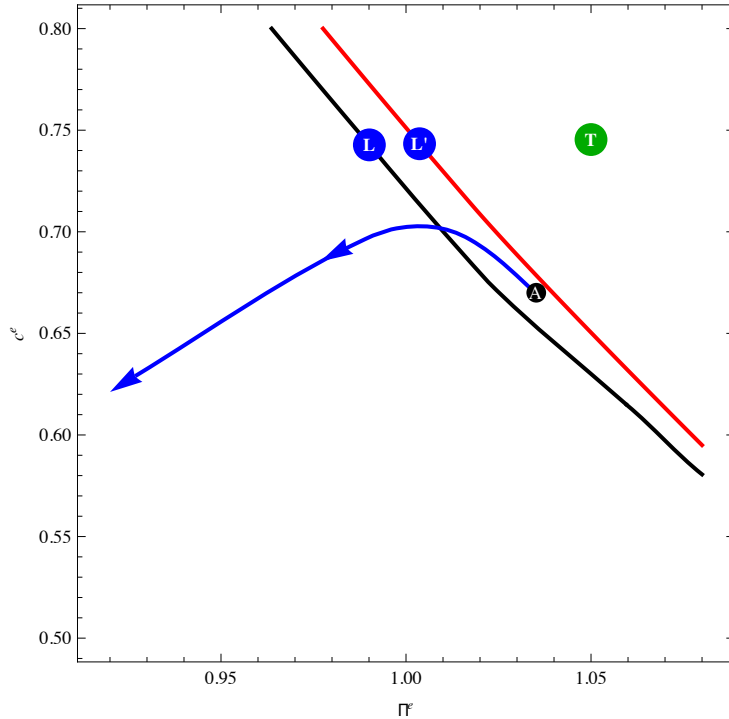


Figure 10: Effect of interest rate's raise.

low-inflation steady state from point  $L$  to  $L'$ . After the implementation of the new policy point  $A$  lies in the new “unstable” region. The increase in the interest may potentially trigger adverse macroeconomic dynamics and push the economy on a deflationary path. Although highly stylised, dynamics in this simple model confirm Krugman’s view about the disruptive potential of such raise in the interest rate and provide a rationale for a prudent FED’s policy.

## 6 Conclusions

The aftermath of the 2007-8 experiences, as well as the earlier case of Japan since the 1990s, have underscored concerns about deflation and appropriate policy design when nominal interest rates are constrained by the ZLB. In this paper we use a controlled laboratory environment where expectations’ dynamics are directly elicited from paid human subjects as a test bed for policies against deflationary outcomes. In particular, we use a LtFE to evaluate the effectiveness of monetary and fiscal policies aimed at combating expectations-driven liquidity traps.



Our results show that, in line with the results obtained in the macro literature where agents learn using an econometric model, liquidity traps in the form of deflationary spirals can emerge as a result of severely pessimistic expectations, even if monetary policy preventively cuts the interest rate when inflation threatens to fall below a certain threshold. In the experiment, adverse expectational shifts create the possibility of a self-reinforcing feedback loop in which sufficiently pessimistic expectations result in low output and inflation, leading to high real interest rates because of the ZLB, which then causes a downward revision of expectations, strengthening the downward pressure on output and inflation.

On the contrary, the implementation of a fiscal switching rule at the ZLB which adjusts upward public expenditures when inflation threatens to fall below a certain threshold is successful in avoiding the occurrence of liquidity traps. We find that fiscal interventions may lead to oscillating convergence to target as well as to almost self-fulfilling equilibria, i.e., long transition dynamics in which inflation remains below target and interest rate are near the ZLB for an extended period of time before converging to the intended steady state.

We further analyse the impact of fiscal policy at the ZLB, finding values of the fiscal multiplier larger than one. We emphasise that the ability of fiscal stimulus to crowd in private consumption works through the expectation feedback mechanism in the experimental economies.

We also briefly discuss the recent policy propose of increasing the FED rates in the US in the light of the experimental results. Evidence from our artificial economies suggests prudence in implementing such policy, in line with the actual strategy of the FOMC.

Further research will focus on the implementation of “infinite horizon” learning economies and on the study of alternative fiscal policies, e.g., fiscal stimulus versus austerity, in such an experimental environment.

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# Appendix

## A Experimental Instructions (Treatment P [S])

Welcome to this experiment! The experiment is anonymous, the data from your choices will only be linked to your station ID, not to your name. You will be paid privately at the end, after all participants have finished the experiment. After the main part of the experiment and before the payment you will be asked to fill out a short questionnaire. On your desk you will find a calculator and scratch paper, which you can use during the experiment.

**During the experiment you are not allowed to use your mobile phone. You are also not allowed to communicate with other participants. If you have a question at any time, please raise your hand and someone will come to your desk.**

### General information and experimental economy

All participants will be randomly divided into groups of six people. The group composition will not change during the experiment. You and all other participants will take the roles of statistical research bureaus making predictions of inflation and the so-called “net output”. The experiment consists of 50 periods in total. In each period you will be asked to predict inflation and net output for the next period.

The economy you are participating in is described by four variables: inflation  $\pi_t$ , net output  $y_t$ , interest rate  $i_t$  and public expenditure  $g_t$ . The subscript  $t$  indicates the period the experiment is in. In total there are 50 periods, so  $t$  increases during the experiment from 1 to 50.

**Inflation** ( $\pi_t$ ) measures the percentage change in the price level of the economy. In each period, inflation depends on inflation predictions of the statistical research bureaus in the economy (that is on your own forecast as well as on the forecasts of the other

bureaus in the experiment), on net output, on public expenditure and on a small random term. There is a positive relation between the actual inflation and the inflation predictions, the actual net output and the public expenditure. This means that if the inflation predictions of the research bureaus, the actual net output or the public expenditure increase, then actual inflation will also increase (everything else equal). In economies similar to this one, inflation has historically been between  $-5\%$  [ $-8\%$ ] and  $8\%$ .

**Net output** ( $y_t$ ) represents the amount of goods produced by firms and consumed by households in the economy. In each period, net output depends on inflation predictions and net output predictions of the statistical research bureaus in the economy (that is on your own forecast as well as on the forecasts of the other bureaus in the experiment), on the interest rate and on a small random term. There is a positive relation between the actual net output and both the inflation and net output predictions. This means that if the inflation predictions or net output predictions of the research bureaus increase, then actual net output will also increase (everything else equal). There is a negative relation between net output and the interest rate. This means that if the interest rate increases, then actual net output will instead decrease (everything else equal). In economies similar to this one, net output has historically been between 60 [50] and 80.

**Interest rate** ( $i_t$ ) measures the cost of borrowing money and is determined by the central bank. In each period, if inflation and net output forecasts are considered too high, the central bank increases the interest rate. If inflation and net output forecasts are considered too low, the central bank decreases the interest rate. The interest rate cannot take negative values.

**Public expenditure** ( $g_t$ ) measures the amount of goods produced by firms and purchased by the public sector in the economy, and is determined by the government. If actual inflation is considered too low, the government might temporarily increase the public expenditure.



# Prediction task

Your task in each period of the experiment is to predict inflation and net output in the next period. When the experiment starts, you have to predict inflation and net output for the first two periods, i.e.  $\pi_1^f$  and  $\pi_2^f$ , and  $y_1^f$  and  $y_2^f$ . The superscript  $f$  indicates that these are forecasts. When all participants have made their predictions for the first two periods, the actual inflation ( $\pi_1$ ), the actual net output ( $y_1$ ), the interest rate ( $i_1$ ) and the public expenditure ( $g_1$ ) for period 1 are announced. Then period 2 of the experiment begins. In period 2 you make inflation and net output predictions for period 3 ( $\pi_3^f$  and  $y_3^f$ ). When all participants have made their predictions for period 3, inflation ( $\pi_2$ ), net output ( $y_2$ ), interest rate ( $i_2$ ) and public expenditure ( $g_2$ ) for period 2 are announced. This process repeats itself for 50 periods.

Thus, in a certain period  $t$  when you make predictions of inflation and net output for the next period  $t + 1$ , the following information is available to you:

- realised values of inflation, net output, interest rate and public expenditure, up to and including period  $t - 1$ ;
- Your predictions up to and including period  $t$ ;
- Your prediction scores up to and including period  $t - 1$ .

Additionally, a newspaper operates in this economy, and may announce from time to time news about the opinion of economic experts about future scenarios in the economy. These announcements might pop up on your screen as newspaper reports. The experts' opinions have no impact on actual realisations of the four variables describing this economy, and it is up to you to determine whether and how to use this information. Below you can see examples:



# Payments

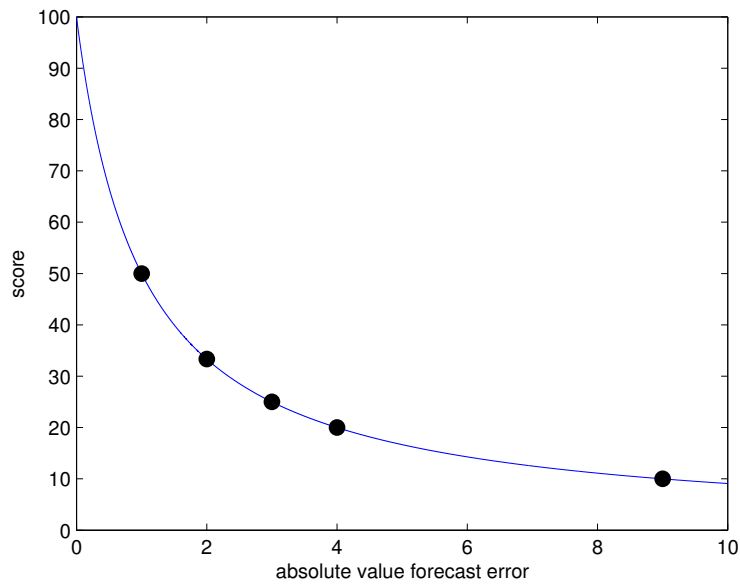
Your payment will depend on the accuracy of your predictions. You will be paid either for predicting inflation or for predicting net output. The accuracy of your predictions is measured by the absolute distance between your prediction and the actual values (this distance is the prediction error). For each period the prediction error is calculated as soon as the actual values are known; you subsequently get a prediction score that decreases as the prediction error increases. The table below gives the relation between the prediction error and the prediction score. The prediction error is calculated in the same way for inflation and net output.

Prediction error	0	1	2	3	4	9
Score	100	50	33.33	25	20	10

**Example:** If (for a certain period) you predict an inflation of 2%, and the actual inflation turns out to be 3%, then you make an absolute error of  $3\% - 2\% = 1\%$ . Therefore you get a prediction score of 50. If you predict an inflation of 1%, and the actual inflation turns out to be negative, for example  $-2\%$ , you make a prediction error of  $1\% - (-2\%) = 3\%$ . Then you get a prediction score of 25. For a perfect prediction, with a prediction error of zero, you get a prediction score of 100.

The figure below shows the relation between your prediction score (vertical axis) and your prediction error (horizontal axis). Points in the graph correspond to the prediction scores in the previous table. At the end of the experiment, you will have two total scores, one for inflation predictions and one for net output predictions. These total scores simply consist of the sum of all prediction scores you got during the experiment, separately for inflation and net output predictions. **When the experiment has ended, one of the two total scores will be randomly selected for payment.**

**Your final payment will consist of 0.75 euro for each 100 points in the se-**



lected total score (200 points therefore equals 1.50 euro). This will be the only payment from this experiment, i.e. you will not receive a show-up fee on top of it.

## Computer interface

The computer interface will be mainly self-explanatory. The top right part of the screen will show you all of the information available up to the period that you are in (in period  $t$ , i.e. when you are asked to make your prediction for period  $t + 1$ , this will be actual inflation, net output, interest rate and public expenditure until period  $t - 1$ , your predictions until period  $t$ , and the prediction scores arising from your predictions until period  $t - 1$  for both inflation (I) and net output (N)). The top left part of the screen will show you the information on inflation and net output in graphs. The axis of the inflation graph shows values in percentage points (i.e. 3 corresponds to 3%). **Note that the values on the vertical axes may change during the experiment and that they are different between the two graphs – the values will be such that it is comfortable for you to read the graphs.**

In the bottom left part of the screen you will be asked to enter your pre-

dictions. When submitting your prediction, use a decimal point if necessary (not a comma). For example, if you want to submit a prediction of 2.5% type “2.5”; for a prediction of -1.75% type “-1.75”. The sum of the prediction scores over the different periods are shown in the bottom right of the screen, separately for your inflation and net output predictions. At the bottom of the screen there is a status bar telling you when you can enter your predictions and when you have to wait for other participants.

# B Computer Interface

**Charts**

**Information table**

Turn	Inflation	Your Inflation Forecast	Net Output	Your Net Output Forecast	Interest Rate	Government Expenditure	Inflation Score	Net Output Score
3		0.80		72.00				
2	0.80	1.50	73.31	70.50	0.01	20.22	53.68	16.77
1	0.77	1.00	71.59	71.00	1.14	20.00	93.81	68.04

**Player Actions**

You are now in period 3

Enter your forecast for inflation in period 4

Enter your forecast for net output in period 4

Please submit your forecast.

**Player Information**

Your total score for inflation forecast is 147.50

Your total score for net output forecast is 84.82

Figure 11: Screenshot

## C Experimental Results

Figs. 12 – 16 report the experimental results for each group in all treatments. In Figs. 12 – 16, the left panels contain the time series of realised inflation (thick solid gold lines), average inflation forecasts (dashed black lines) and interest rate (solid red line), while the right panels contain the time series of realised net output (thick solid gold lines), average net output forecasts (dashed black lines) and government expenditure (scaling on right y-axis) when the fiscal switching rule is implemented, i.e., in treatments FP and FS, (red solid lines). The horizontal dashed lines depict the targeted values of inflation (left panels) and net output (right panels). The shaded areas in Figs. 13 and 16 denote the periods in which expectational shocks in the form of “bad news” announcements occur.



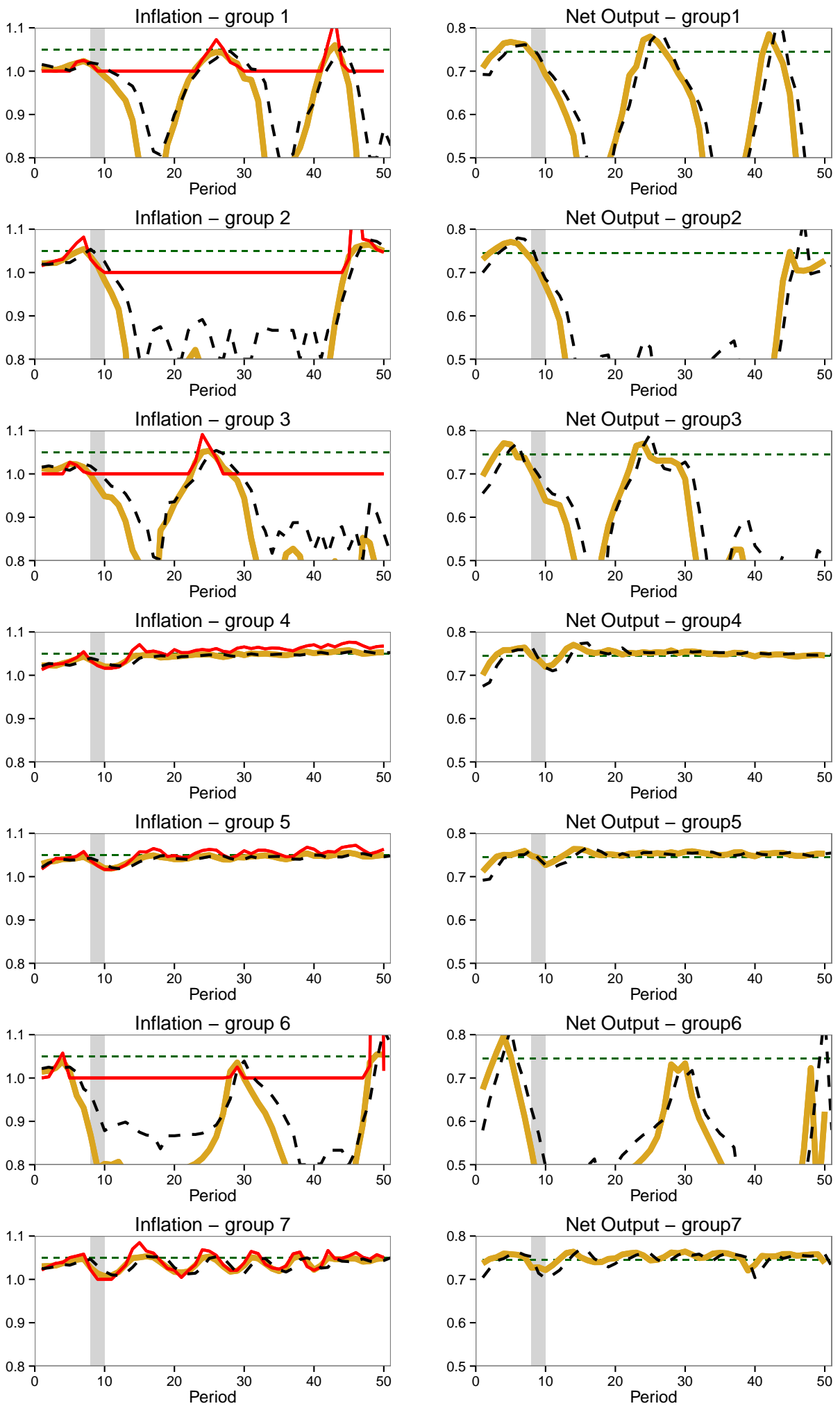


Figure 13: Treatment MS



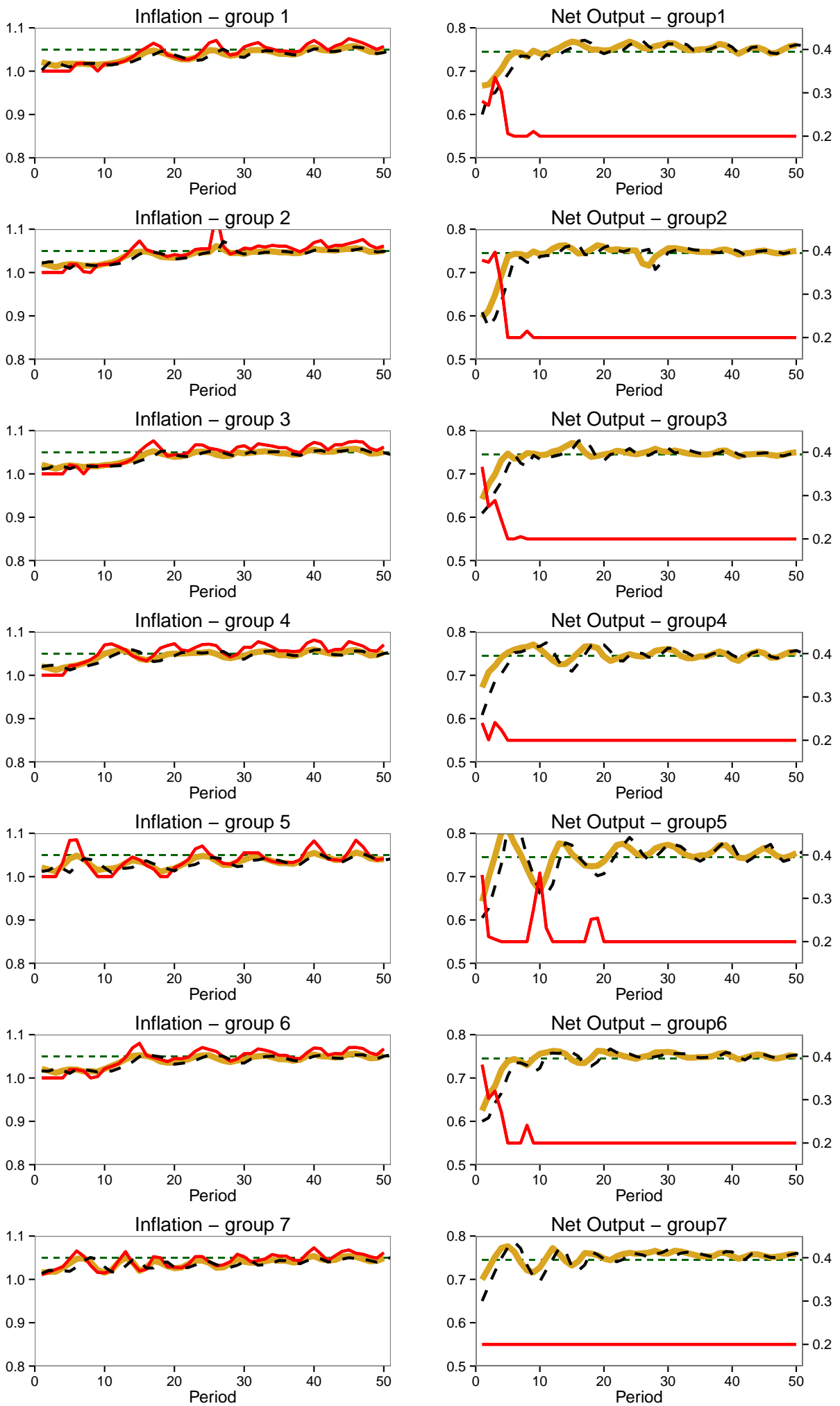


Figure 14: Treatment FP

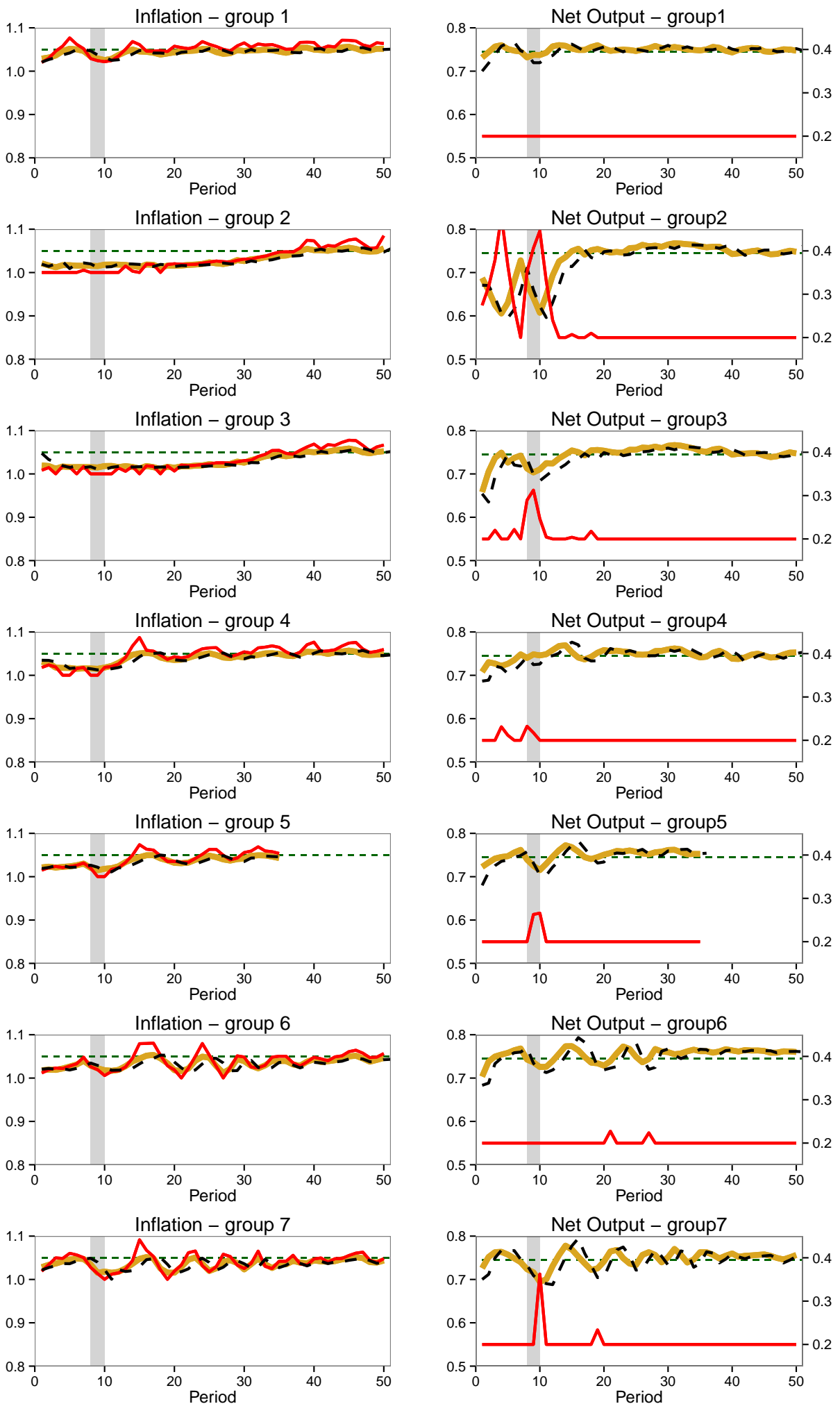


Figure 15: Treatment FS

## D Additional Experimental Results

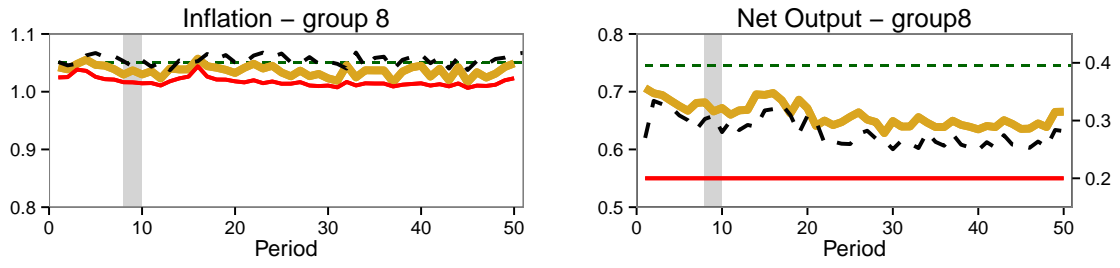


Figure 16: Treatment FS, anomalous group.