Stabilizing Expectations at the Zero Lower Bound: Experimental Evidence

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Abstract

Our study demonstrates how agents' expectations can interact dynamically with monetary and fiscal policy at the zero lower bound. We study expectation formation near the zero lower bound using a learning-to-forecast laboratory experiment under alternative policy regimes. In our experimental economy, monetary policy targets inflation around a constant or state-dependent target. We find that subjects' expectations significantly over-react to stochastic aggregate demand shocks and historical information, leading many economies to experience severe deflationary traps. Neither quantitatively nor qualitatively communicating the state-dependent inflation targets reduce the duration or severity of economic crises. Introducing anticipated and persistent fiscal stimulus at the zero lower bound reduces the severity of the recessions. When the recovery of fundamentals is sufficiently slow, participants' expectations become highly pessimistic and neither monetary nor fiscal policy are effective at stabilizing the economy.

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1 Introduction

How should monetary and fiscal policy be conducted when nominal interest rates are close to zero? This question is important because once interest rates reach zero and cannot be reduced further — the *zero lower bound (ZLB)* — central banks lose an important tool for stimulating the economy. In an economy already in recession and close to the ZLB, a further negative demand shock could make for a dire situation, in which case a central bank may not be able to lower interest rates sufficiently to stimulate the economy. If the recession is persistent and severe, households and firms are likely to be pessimistic about the ability of the central bank to provide the stimulus needed to turn the situation around. The appearance of the ZLB has the potential to generate a prolonged self-fulfilling macroeconomic crisis, often referred to as a *liquidity trap*.

Macroeconomists and policy makers generally agree that policies which create an expectation of inflation would alleviate the severity and duration of liquidity traps. For example, Eggertsson and Woodford (2003, 2004) show that creating expectations for inflation by promising to keep nominal interest rates low by way of increased inflation targets, even after the economy has recovered, can reduce the duration of a liquidity trap.[1] In order to reinforce the central bank's commitment to higher future inflation, the communicated state-dependent inflation target would be adjusted upward when inflation fails to achieve past targets. Such policy combined with forward guidance has the potential to successfully alleviate recessions if agents form rational expectations and if the central bank can credibly commit to a long-run price-level target. However, previous work (e.g., Evans et al., 2008) has shown that fiscal stimulus at the ZLB can stimulate particular forms of adaptive expectations.

The goal of this paper is to identify the ways in which alternative monetary and fiscal policies can influence individual and aggregate expectation formation at the ZLB. This is an empirically challenging task given that some of the policies and communication strategies we are interested in studying have never been implemented by central banks. Even if such policies were found to have been implemented, it would be difficult to disentangle the actual effects of contemporaneous policies on the economy from the effects of past policy.

In order to circumvent the limitations of observational data, we design a series of learning-to-forecast laboratory experiments so that we can gain a better understanding of the extent to which state-dependent inflation targeting and expansionary fiscal policy are effective in stimulating expectations at the ZLB. The laboratory provides a convenient testbed to explore

[1] The other policy option is quantitative easing. Note that the effect of quantitative easing could, in part, go through expectations as well.

the robustness of policy and central bank communication on the expectations of "real" people in an environment where we can have precise control over the structure of the economy, the information available to individuals, and the implementation and communication of policy. This controlled environment enables us to more readily identify the effects of economic disturbances, policies, and communication strategies on individual and aggregate expectations as well as the overall economy.

Our experimental macroeconomy follows a linearized New Keynesian data-generating process whereby output and inflation evolve in response to subjects' incentivized reported expectations and exogenous observed disturbances. We exogenously impose large, persistent, and unanticipated negative demand shocks to drive the economy down to the ZLB in order to examine the process whereby expectations are formed, and to experiment with alternative stabilization strategies. In our baseline treatment, the automated central bank follows a conventional Taylor rule with a constant inflation target.

In two additional treatments, we implement a state-dependent inflation target that rises when lagged inflation levels are below target. The inflation target is communicated either quantitatively, as a numerical target, or qualitatively, as a reference to its trajectory (e.g., "positive" or "negative"). Our fourth and final treatment extends the baseline environment to explore the stabilizing effects of fiscal stimulus at the ZLB. The expansionary government expenditure is implemented at the outset of the negative demand shock and dissipates as fundamentals return to the steady state.

We observe that expectations become negative in the face of a large negative demand shock, and often remain negative despite fundamentals steadily recovering. These pessimistic expectations lead to persistent recessions at the ZLB. In many cases, the decline in expectations accelerates even as fundamentals return to their steady-state values. We find that neither quantitative nor qualitative forms of communication of state-dependent inflation targets leads to a significant reduction in the severity or duration of liquidity traps. By contrast, fiscal stimulus at the onset of the large negative demand shock reduces the duration of economic crises and significantly reduces their severity. However, in the face of very slow recovering fundamentals, neither monetary nor fiscal policy is effective at stabilizing expectations.

2 Policy and Communication: Theory and Evidence

Our research investigates whether monetary and fiscal policy can stabilize expectations at the ZLB. Recent work suggests that, even when the ZLB on interest rates binds, central banks are still able to influence the economy by affecting expectations with respect to future policy.[2] Inflation targeting policies can reduce crises at the ZLB if accompanied by a credible promise of future inflation. Eggertsson and Woodford (2003) show that an optimal commitment policy would involve a moving price-level target that would increase in response to historical inability to achieve its target. Because of the state-dependent nature of the target, interest rates would remain at zero even as the economy improves. This, in turn, should provide a signal to agents that the central bank is willing to accept higher inflation in the future, and thereby generate rational expectations of inflation. However, the authors acknowledge that the credibility of the central bank might suffer if the private sector sees the central bank failing to reach its target while continually raising it for the following period. Nakov (2008) applies global solution methods to study a standard dynamic stochastic sticky-price model with an occasionally binding ZLB on interest rates. He compares alternative non-optimal instrument rules to optimal policy under commitment and discretion and finds that price-level targeting proposed by Eggertsson and Woodford's framework performs better than simple Taylor rules.[3] Our paper makes an important contribution by providing insight into how expectations respond and evolve in response to moving inflation targets.

A good deal of theoretical work has demonstrated that expansionary fiscal policy can stabilize expectations at the ZLB. In the event that monetary authority lacks credibility in generating inflation, Krugman (1998) and Eggertsson (2011) argue that fiscal expenditures offer the only way out of a liquidity trap. Fiscal stimulus does not suffer from commitment problems to the same extent as an expansionary monetary policy. Evans et al. (2008) demonstrate that agents' adaptive expectations can be stabilized with fiscally generated aggregate demand. Benhabib et al. (2014) show that, with adaptive behavior on the part of agents, a fiscal switching rule that automatically triggers fiscal stimulus when inflation or the expectation of inflation falls below a threshold can be effective in stabilizing expectations and aggregate activity.

The public's understanding of the central bank's objectives and policy rules in the future is a critical component of effective monetary policy (Woodford, 2005; Eusepi and Preston, 2010, Eusepi 2010). If agents form rational expectations, they should correctly infer the policy rule that the central bank is following and adjust their spending and pricing decisions accordingly. However, if agents have to adapt or learn in the process, or if they possess

[2]See Walsh (2009) for a detailed discussion on the ability of inflation promises to stabilize expectations.

[3]These state-dependent rules are also consistent with the policy advice given (though not taken) to Japan when it faced the ZLB — e.g., Krugman (1998), McCallum (2000), Auerbach and Obstfeld (2005). Price-level targeting policies achieve relatively greater economic stability than inflation targeting policies in environments where central banks mistakenly see the expectations of private agents as rational (e.g., Preston, 2008).

imperfect information or understanding, a need for effective central bank communication arises.[4]

Central banks face risks when they communicate to the public. As Woodford (2005) points out, communication of a central bank goal may well be misperceived by the public as a promise. This is why many central banks, including the Federal Reserve, have historically communicated very little to the public.[5]

Our experiment draws attention to the distinction between quantitative and qualitative forward guidance because the forward guidance generally provided by the central bank has been fluctuating between quantitative and qualitative announcements since 2008, a communication strategy that has become progressively less effective at influencing market expectations (Filardo and Hofmann, 2014). Surveys of households and professional forecasters are used widely as direct evidence for expectation formation. Mankiw et al. (2003), and Coibion and Gorodnichenko (2012) discuss recent studies of expectations based on surveys of professional forecasters. While survey data provide important insights into naturally-occurring expectations, they afford limited opportunity to identify either the information sets on which agents rely, or the data-generating process itself.

Laboratory experiments provide a useful and complementary tool for understanding expectation formation and have the advantage of allowing for greater control of the conditions under which subjects form their expectations. Additionally, such experiments provide an opportunity to study policies for which there is little data, or policies which may not have been previously implemented.[6]

We discuss learning-to-forecast (LTF) experiments related to central bank communication and the ZLB. The experiment presented here builds directly from that described by Kryvtsov and Petersen (2015) who investigate the robustness of the expectations channel of monetary

[4]In their recent survey of the literature on monetary policy design formulated under imperfect knowledge, Eusepi and Preston (2016) point out that, in the post-financial crisis macroeconomic environment, many questions have been raised regarding the efficacy of monetary policy and, particularly, the ability of central banks to influence expectations.

[5]For example, in December 2011, the Federal Reserve made an unusual announcement that it would keep interest rates low for at least a) as long as the unemployment rate remained below 6.5 percent, b) the outlook for inflation one to two years ahead remained at or below 2.5%, and c) longer-term inflation expectations remained well anchored. This forward guidance was intended to create long-run inflation expectations within an economy that was perceived as being stuck in a liquidity trap.

[6]The use of laboratory experiments to study expectations and policy are well established — e.g., Marimon and Sunder, 1993; Arifovic and Sargent, 2003; Arifovic et al., 2013, Arifovic et al., 2014; Duffy, 2008, 2016; Adam, 2007; Hommes et al., 2008; Pfajfar and Žakelj, 2014. Hommes (2011, 2013) reviews the literature that examines evidence for the heterogeneous expectations hypothesis in experimental economies; Chakravarty et al., (2011) review the growing literature on experimental macroeconomics; Cornand and Heinemann (2014) provide a survey of experiments on monetary policy, and Amano et al. (2014) provide a discussion of the ways in which the Bank of Canada is using laboratory experiments to study expectations and monetary policy.

policy. The key difference in their examination is the absence of a ZLB on nominal interest rates. Central bank forward guidance in the form of multi-period projections of future nominal interest rates is initially effective at coordinating expectations and strengthening the expectations channel, but over time subjects stop adjusting their behavior according to the information and their expectations become more volatile. Mokhtarzadeh and Petersen (2017) extend this work by exploring other types of projections and find that macroeconomic projections of output and inflation are relatively easier for subjects to employ and are more effective at coordinating expectations than nominal interest rate projections. Cornand and M'Baye (2016) find that explicit communication of inflation targets can improve macroeconomic stability if the central bank faces a dual mandate.

Hommes et al. (2015) provide the only other paper in the experimental literature that looks at the effects of monetary and fiscal policies at the ZLB. Where we use a linearized version of the New Keynesian economy, they examine the behavior of human subjects in a nonlinear specification of the New Keynesian environment with a ZLB. Rational expectations versions of this model have low inflation rational expectations equilibria, i.e., liquidity traps, and a targeted steady state that results from the implementation of an "aggressive" Taylor-type interest rate rule subject to a binding ZLB constraint. We noted earlier that Evans et al. (2008), and Benhabib et al. (2014) examine the stability of a multiple rational expectations equilibrium when agents learn adaptively. Their results show that the targeted steady state is locally stable while the low inflation equilibrium is unstable where learning occurs. Given these stability results, large pessimistic shocks to agents' expectations can move the economy away from the target and into a liquidity trap characterized by deflationary spirals of ever-declining output and inflation. Evans et al. also show that, under this scenario, an aggressive monetary policy is not sufficient to take the economy out of a liquidity trap. However, an aggressive monetary policy accompanied by a fiscal stimulus can take the economy out of a deflationary spiral. Thus, additional fiscal stimulus alleviates deflationary spirals and encourages convergence toward the high inflation steady state.

By eliciting subjects' forecasts on inflation and output, Hommes et al. (2015) test the predictions of the Evans et al. model with adaptive agents. They employ a 2x2 experimental design. One of the treatment variables is the initialization and timing of the adverse expectations dynamics that can cause the ZLB to bind (expectations dimension). They consider two policy regimes (policy dimension): one policy regime is characterized by aggressive monetary policy and a fixed amount of pubic expenditure; the other policy regime, in addition to the aggressive monetary policy, implements a fiscal-switching rule. Their findings show that aggressive monetary policy alone cannot take an experimental economy out of its liquidity trap.

Only the combination of an aggressive monetary policy and a fiscal-switching stimulus can take an experimental economy out of a deflationary spiral. They find that additional fiscal stimulus alleviates deflationary spirals and encourages convergence toward the high inflation steady state. Their results provide evidence that adaptive learning models are good predictors of behavior in environments where liquidity traps arise as a result of large expectational shocks and thereby lend weight to the view that monetary and fiscal policies can be effective.

Both our study and the Hommes et al. study use the LTF experimental design, but the focus and the objectives of the studies are different. Where we focus on the effectiveness of creating expectations of future inflation in the laboratory (suggested in the literature as a way to get economies out of a liquidity trap) and look at ways in which communication of this policy will affect subjects' behaviors, Hommes et al. focus on testing predictions of a model with adaptive agents, and examine the effect of aggressive monetary policy and the fiscal-switching rule. With respect to the way in which fiscal policy is implemented, we put in place a treatment where monetary policy is characterized by a constant inflation target with expansionary fiscal policy. By contrast, the treatment implemented by Hommes et al. combines aggressive monetary policy with the fiscal-switching rule. Where we use a large negative shock to the natural rate of interest in order to create a liquidity trap, Hommes et al. use expectational shocks to create a liquidity trap. In order to "generate" a large expectational shock, Hommes et al. confront their subjects with “bad news” (on their computer screens) in the form of newspaper reports that include expert opinions about future economic conditions.

3 Experimental Design and Implementation

We designed a laboratory experiment to study expectation formation in the presence of the ZLB under alternative monetary and fiscal policies. The experimental economy that subjects interacted in followed a data-generating process derived from a linearized version of the New Keynesian framework with optimizing households and firms.[7] Specifically, the economy

[7] Specifically, the model assumes that agents have identical information and the same initial starting wealth, and that they will form expectations rationally. The homogeneous rational expectations version of the New Keynesian model we implemented would not be correct if subjects' expectations were not rational. Instead, heterogeneous expectations versions of the model (e.g., Preston, 2008; Woodford, 2013) would be more appropriate. However, versions of the model that employ heterogeneous expectations involve making an ex-ante decision about the form of heterogeneity in expectations or they require a much more complicated generalized reduced form model that would be considerably more difficult for subjects to understand in a relatively short amount of time, and they increase the likelihood that subjects' behavior is driven by confusion. In making our decision to implement the homogeneous rational expectations version of the New Keynesian model, we opted to trade model precision for increased simplicity.

evolved according to the following system of equations:[8]

$$x_t = E_t^* x_{t+1} - \sigma^{-1}\left(i_t - i^* - E_t^* \pi_{t+1} - r_t^n\right) \ , \tag{1}$$

$$\pi_t = \beta E_t^* \pi_{t+1} + \kappa x_t \ , \tag{2}$$

$$i_t = \begin{cases} i^* + \phi_\pi(\pi_t - \pi_t^*) + \phi_x x_t & \text{if } i_t \geq 0 \\ 0, & \text{otherwise,} \end{cases} \tag{3}$$

$$r_t^n = \rho r_{t-1}^n + \epsilon_t \ . \tag{4}$$

Equation 1 refers to the investment-saving equation and describes the dynamics of aggregate demand relative to its flexible-price level or the output gap.[9] As aggregate expectations of future demand ($E_t^* x_{t+1}$) and inflation ($E_t^* \pi_{t+1}$) increase, current demand and output also increase. Exogenous increases in the natural rate of interest, r_t^n, has a positive effect on demand. Increases in the nominal interest rate, i_t, from its steady-state value, i^* will contract demand and vice versa. We parameterize $\sigma = 1$ and $i^* = 75$ basis points.[10]

Equation 2 describes the evolution of aggregate supply or inflation. Inflation depends primarily on aggregate expectations of future inflation ($E_t^* \pi_{t+1}$) and, to a lesser extent, on aggregate demand, x_t. The parameters are assigned values of $\beta = 0.995$ and $\kappa = 0.13$.

Equation 3 describes the central bank's response function and describes how nominal interest rates are set. The central bank aggressively responds to positive deviations of inflation from its steady state, $\pi_t - \pi_t^*$, and positive output gaps by adjusting nominal interest rates upward, and vice versa. We parameterize the coefficients of the nominal interest rate rule as $\phi_\pi = 1.5$ and $\phi_x = 0.5$. Monetary policy transmission operates by influencing the real interest

[8]See, for example, Woodford (2005) and Nakov (2008) for New Keynesian models with binding ZLBs. The European Central Bank has set a negative deposit rate since June 2014, and other central banks are considering the possibility of their own negative rates. One may ask whether our findings depend on zero being the actual lower bound. Kryvtsov and Petersen (2015) show that, when there is no ZLB, expectations are relatively stable and explosive dynamics never occur. So long as nominal interest rates can adjust downward sufficiently to offset pessimistic expectations, aggregate dynamics —and subsequently later expectations— will remain relatively stable. However, once the effective negative lower bound on interest rates is reached, monetary policy will no longer provide sufficient support to stabilize aggregate expectations and dynamics. The key advantage to setting a negative lower bound on interest rates is that it prolongs the time it takes for an economy to reach the lower bound and reduces the likelihood of deflationary dynamics.

[9]Throughout the paper, we refer to the output gap as simply *output*.

[10]Note that i^* is a transformation that we use in order to have mean zero output gap and inflation in the steady-state with a positive nominal interest rate. This is qualitatively similar to Nakov (2008) who assumes that deviations of its natural rate from its steady-state level follows an exogenous mean-reverting process.

rate by way of movements in the nominal interest rate. Monetary policy would generally be able to stabilize real output at its potential level for any fluctuation in r_t^n so long as it can adjust the policy rate such that $i_t - E_t\pi_{t+1} - r_t^n$ can be stabilized to zero. However, in this environment, the presence of a ZLB on nominal interest rates prevents the central bank from lowering the nominal interest rate sufficiently in response to very low inflation and output.

Finally, Equation 4 describes the evolution of the natural rate of interest or, as we will refer to it throughout the paper, the demand *shock* in the following sections. The shock follows an AR(1) process where $\rho = 0.8$, and ϵ_t is drawn randomly from a normal distribution with mean zero and standard deviation of 93 basis points. Equations 1–4 yield a steady state of $x^* = \pi^* = 0$ and $i^* = 75$.[11]

Treatments and Predictions

We conducted a total of four treatments. Our baseline treatment, *Constant Target (Constant)*, involved the central bank responding to deviations of inflation from a constant inflation target. Our second treatment, *State-Dependent Target (SD)*, has the central bank responding to deviations from an explicitly communicated quantitative state-dependent inflation target. In the third, the *Directional State Dependent Target (Dir. SD)* treatment, we kept the state-dependent inflation targeting rule, but communicated only the direction of the movement of the target to the subjects. Finally, in our fourth treatment, *Fiscal Policy (FP)*, we added a pre-announced expansionary fiscal policy to our baseline constant inflation targeting environment. In all treatments, the nominal interest rate generally took the form given in Equation 3. The key differences across treatments are outlined in Table 1.

Baseline Treatment

In our baseline treatment, an inflation target was set to a constant value, $\pi_t^* = 0$. In this *Constant Target (Constant)* treatment, we let the subjects know that the central bank's objective was to keep inflation and output as close to zero as possible.

Monetary Policy Treatments

In our state-dependent target treatments, the inflation target evolved based on past realized inflation and output. The time varying inflation non-optimal target is motivated in part by the

[11]We implemented the same parametrization as Kryvstov and Petersen (2015) except for a more persistent shock, $\rho = 0.8$ and the implementation of a steady state interest rate, $i^* = 75$.

optimal history-dependent price-level target developed in Eggertsson and Woodford (2003).[12] The inflation target we employed was computed as follows:

$$\pi^*_{t+1} = \frac{1}{\beta}\left(\pi^*_t - \pi_t\right) - \frac{\lambda}{\kappa\beta}\left(x_t - x_{t-1}\right) - \frac{\lambda\sigma}{\beta}x_t. \tag{5}$$

The state-dependent inflation targeting rule consisted of an inflation component and an output gap component. During a severe recession, the central bank may find it difficult to meet higher inflation targets due to the ZLB on nominal interest rates. In such cases, the first term of this rule implies that the central bank will increase its inflation target for the subsequent period.

When the economy exits the deflationary episode (either due to more optimistic expectations or improving fundamentals), the inflation target does not immediately return to zero. Instead, the central bank gradually decreases the inflation target to allow for higher inflation and output. The central bank accomplishes this by keeping nominal interest rates at zero even after the economy has returned to the steady state. This feature can be observed in the second term of the inflation targeting rule. The state-dependent inflation target implies that a credible central bank will accept higher future inflation, leading rational forecasters to form inflationary expectations of future inflation.

Simulations of the rational expectations equilibrium solution under constant and state-dependent inflation targets are presented in Figure 1. These simulations were conducted using OccBin developed by Guerrieri and Iacoviello (2015).[13] Simulations for the constant and state-dependent inflation target policies are shown as solid black and dashed blue lines respectively.

The simulations indicate that economic recovery is considerably faster and the severity of the crisis significantly lower under a state-dependent inflation target. When the central bank implements a state-dependent inflation target in the presence of a ZLB, output and inflation are nearly three and five times less reactive, respectively, with the impact of the negative demand shock. The amount of time spent at the ZLB is shortened with a state-dependent inflation target: interest rates are equal to zero for eight periods under a state-dependent

[12] We chose to implement an inflation target rather than a price-level target to avoid introducing an additional variable that subjects would have to consider when forming their forecasts. We reconfigured the optimal price-level target in Eggertsson and Woodford (2003) as an inflation target and implemented an approximation of it in our ad-hoc Taylor rule. The derivation can be found in the Online Appendix.

[13] OccBin solves dynamics models with occasionally binding constraints by solving for the piecewise linear non-explosive solution when a ZLB is present. The simulated dynamics are the impulse responses to a one-time negative natural rate of interest shock of 400 basis points that occurs in period 5. Note that if the economies were to experience positive shocks, the piecewise linear and the linear impulse responses would coincide.

target compared to 11 periods under a constant target. Moreover, output and inflation return to and exceed their steady-state levels by periods 10 and 8 under a state-dependent inflation target, while they converge asymptotically to the steady state under a constant inflation target. If our subjects behave in line with the rational expectations equilibrium solution — that is, utilizing only fundamental shocks and inflation targets to formulate their forecasts— we should expect to observe significantly faster recoveries and less severe recessions in the state-dependent target treatments. We formulate two hypotheses based on these treatments:

Hypothesis 1: Following a severe crisis shock, economies that follow a state-dependent inflation target will return to a steady state in fewer periods than those which follow a constant inflation target.

Hypothesis 2: Following a severe crisis shock, economies that follow a state-dependent inflation target will exhibit lower standard deviations of inflation and output than those which follow a constant inflation target.

The key assumption that underlines the success of state-dependent inflation targeting rules is that agents form rational expectations. However, we know from previous LTF experiments that initially subjects do not form rational expectations forecasts.[14] The question is whether they learn to form these expectations over time. If they do, and do so fast enough, the inflation targeting policies can be successful in mitigating the impact of a severe demand shock. However, if subjects do not learn to coordinate their expectations on fundamentals fast enough, these policies might prove ineffective in guiding economies out of liquidity traps.

We conduct an additional set of simulations involving semi-rational agents who condition a fraction $\omega = 0.75$ of their forecast on the ex-post rational forecast and $1 - \omega = 0.25$ on lagged output and inflation.[15] The simulations are presented in Figure 2. The state-dependent inflation target considerably reduces the deviations of output and inflation from the steady state at the cost of more time at the ZLB.

In our *State-Dependent Target (SD)* treatment, the central bank provided subjects a precise inflation target on which to coordinate their expectations. Rational agents who use the central bank's inflation target will be able to respond to the explicitly communicated forward guidance. However, if agents fail to coordinate on the target and fundamentals, the target will

[14]Heuristics such as naive, trend-chasing, and constant gain learning have been observed by Pfajfar and Žakelj (2014), Assenza et al. (2013), and Petersen (2014).

[15]This weighted average forecasting behavior is motivated by findings of Kryvtsov and Petersen (2015) who observe such adaptive forecasting heuristics in an environment with no ZLB.

continually rise and subjects may come to perceive the quantitative target as irrelevant. By communicating the target qualitatively in the form of a direction, subjects may better understand the central bank's intentions and more easily coordinate in the central bank's intended direction.

The possibility of perceived lack of central bank credibility motivated us to conduct a third treatment in which the central bank communicates a qualitative inflation target. In the *Directional State Dependent Target (Dir. SD)* treatment, the central bank set monetary policy to stabilize inflation around a state-dependent inflation target (as in the *SD* treatment), but only communicated to subjects the trajectory of the target which was presented as either "positive" or "negative." Therefore, we removed the time-series graph of the target.[16]

We did not set out with a preconception as to how expectations would respond to a qualitatively communicated target. If subjects formed expectations according to fundamentals, vaguely communicated targets would hinder coordination and economic recovery. If, on the other hand, subjects were reluctant to incorporate the explicit target in their forecast, or believed the central bank to be non-credible, qualitative targeting may better coordinate expectations. Thus, we form a set of conditional hypotheses as follows:

Hypothesis 3: Following a severe crisis shock, the communication of a state-dependent inflation target does not influence the number of periods it takes for economies to return to the steady state.

Hypothesis 4: Following a severe crisis shock, the communication of a state-dependent inflation target does not influence the standard deviation of output and inflation.

Fiscal Policy Treatment

We next consider whether economic crises can be effectively ameliorated by anticipated expansionary fiscal policy. As discussed in our review of the literature, much theoretical work has demonstrated that anticipated effective government spending should create more optimistic expectations about future demand and inflation. To determine whether this is the case, we conducted a fourth treatment that introduces fiscal spending into our baseline constant inflation targeting environment.

[16] Our communication variation is similar to Cornand and M'Baye (2014) who vary whether the inflation target is explicitly communicated in the form of a constant numerical target or implicitly by communicating the central bank's objective to stabilize inflation. By contrast, our target fluctuates and we communicate the direction of that fluctuation.

In the *Fiscal Policy (FP)* treatment, subjects were informed during the instruction phase that the government had the ability to engage in fiscal expenditures or taxation to influence aggregate demand. Subjects would be presented with the net impact of the government policy on aggregate demand, where the government was expected to balance its budget each period.[17] Government expenditures or taxation, denoted as g_t, had a direct effect on aggregate demand, resulting in a modified I-S curve:

$$x_t = E_t^* x_{t+1} - \sigma^{-1} \left(i_t - i^* - E_t^* \pi_{t+1} - r_t^n \right) + g_t. \tag{6}$$

The current and planned expenditures were provided to subjects in table form and presented on the overhead projector. During each of the two experimental repetitions, government expenditure was exogenously set to zero until the crisis occurred. On impact of the crisis shock, the government announced immediate fiscal spending equal to 200 basis points, or 50% of the size of the aggregate demand shock for the following period.[18] Subjects were also informed that, in each subsequent period, government spending would dissipate to 80% of its previous value, capturing a similar understanding of the economy's data-generating process. Government spending was small but positive in the final periods of Repetition 1 and 2, equalling 2 and 0 basis points, respectively.

Let t_c denote the period in which the economy experiences the crisis shock. Thus, the government spending rule implemented in the experiment was given by:

$$g_t = \begin{cases} 0 & \text{if } t < t_c \\ 200 & \text{if } t = t_c \\ 0.8 g_{t-1} & \text{if } t > t_c. \end{cases} \tag{7}$$

We compute the rational expectations equilibrium solution for the fiscal policy environment with constant inflation targeting and present the impulse responses associated with a -400 basis point natural rate of interest shock as a dotted green line in Figure 1. On impact of the negative demand shock in period 5, the government makes an announcement that it will increase government stimulus to 200 basis points in period 6. The government continues to announce and deliver in the following period 200 basis points of government stimulus for the rest of the 35-period horizon as the shock never fully returns to zero. The impulse responses are simulated under the assumption that agents fully anticipate the next period's government

[17]We follow Gali (2015)'s implementation of this fiscal policy.

[18]While our goal was to test whether fiscal policy would reduce the pessimistic reaction to the crisis, we did not want to offset the shock entirely.

stimulus but form no expectations of future spending thereafter.

Announced fiscal stimulus reduces the initial response to the shock in period 5. Under a constant inflation target, the output gap decreases 26.3% and inflation decreases 9.3%. By contrast, in the presence of announced fiscal stimulus to begin in period 6, output and inflation decrease 6.2% and 2%, respectively. Announced fiscal stimulus also reduces the amount of time the economy spends at the ZLB to 8 periods. These findings lead us to our key hypothesis for the fiscal policy treatment:

Hypothesis 5: Supplementing a constant inflation target with expansionary fiscal stimulus at the onset of the crisis reduces the duration and severity of recessions.

Our simulations of semi-rational agents in Figure 2 also show that fiscal policy can alleviate both the duration of the demand-induced recession and the deviations of the economy from the steady state. The simulations with semi-rational agents continue to suggest that recovery is best achieved by employing a state-dependent inflation target, followed by a combination of fiscal policy and constant inflation targeting and, last, by a constant inflation target. It is possible that subjects do not respond optimistically to the fiscal stimulus. The fiscal spending may be insufficient to stabilize pessimistic expectations. In that case, we would expect no significant differences in terms of macroeconomic dynamics between the *Constant Target* and *Fiscal Policy* treatments.

Hypothesis 6: Following a severe crisis shock, the coordination of expectations in the direction of the target is not influenced by the number of periods that it takes for fundamentals to return to the steady state.

Given our assumption that the central bank is credible and rational agents condition their expectations on the central bank's target, the speed of recovery of fundamentals does not influence the agents' usage of the target. In practice with subjects, if fundamentals recover slowly, then changes in inflation and the output gap will be primarily driven by changes in median expectations. Moreover, if subjects' expectations are formed adaptively, and subjects form initially pessimistic expectations following the crisis shock, slower recoveries of fundamentals have the potential to reduce the perceived credibility of the central bank's inflation target. In circumstances where the direction of the target does not induce a more optimistic outlook among agents, a spiral of progressively more pessimistic forecasts can persist indefinitely. Thus *Hypothesis 6* states that expectations are not influenced by the number of periods that it takes for fundamentals to return to the steady state. Pessimism will even predominate for a time after the fundamentals return to the steady state.

Experimental Implementation

The experiments were conducted in the CRABE Lab at Simon Fraser University where the subject pool consisted of undergraduate students recruited from a wide variety of disciplines. In each session, groups of nine inexperienced subjects (who had never played in a LTF experiment) played the role of professional forecasters and were given the task of submitting incentivized forecasts about the future state of the economy.

Subjects were required to repeatedly submit quarterly forecasts for future inflation and output. At the beginning of each session, subjects participated in 35 minutes of instruction and 10 minutes of practice. During the instruction period, we first introduced the data-generating process by providing a conceptual overview. We then provided subjects with a quantitative description of the model and explained in careful detail the shock process and monetary policy rule. We walked the subjects through the software they would interact with in four practice periods designed to familiarize them with the interface, and we provided them with the opportunity to ask questions. The computer interface was highly visual. All economic variables (output, inflation, personal forecasts, shocks, nominal interest rates, and the central bank's inflation target) were presented as evolving time series. In the *Directional SD* treatment, the central bank's inflation target announcement was presented in words on the left side of the screen. Subjects learned their forecast accuracy by observing changes in their points between rounds by visually comparing (and by mousing over) the distance between their forecast and the realized values. Instructions and screenshots of the computer interface can be found in the Online Appendix. During the experiment, subjects were not allowed to communicate with one another and, once play began, subjects were only allowed to direct their questions privately to the experimenter.

Subjects had access to the following information before submitting their forecast of the next period's inflation and output. They observed all historical information up to and including the previous period's realized inflation, output, and nominal interest rate, as well as their forecasts and their implied accuracy. Subjects also observed the current period's shock and any relevant policies or targets. Once the instruction and practice phases were complete, subjects submitted incentivized forecasts for an additional 75 minutes. Subjects had 80 seconds in the first 10 rounds and 65 seconds thereafter to submit forecasts (with 98.3% of forecasts submitted on time). Forecasts were submitted in basis point measurements (i.e., 1% was imputed as 100 basis points), and they could be positive or negative. Once all subjects submitted their forecasts or once time ran out, the median submitted forecasts for inflation and output were used as the aggregate forecast in the calculation of the current period's realized output, inflation, and nominal interest rate.[19]

Subjects' scores, and subsequently their earnings in the game, depended on the accuracy of their forecasts each period:

$$Score_{i,t} = 0.3(2^{-0.01|E_{i,t-1}\pi_t - \pi_t|} + 2^{-0.01|E_{i,t-1}x_t - x_t|}) \ , \tag{8}$$

where $E_{i,t-1}\pi_t - \pi_t$ and $E_{i,t-1}x_t - x_t$ were subject i's forecast errors associated with forecasts submitted in period $t-1$ for period t variables. The scoring rule incentivized subjects to form accurate forecasts.[20] This scoring rule was very similar to that used in the previous experimental literature in that scores decrease monotonically with the forecast errors and the minimum score a subject can earn in any period is zero.[21] Subjects' earnings, including a \$7 show-up fee, ranged from CAN \$20 to \$38.50, and averaged CAN \$26 for two hours of participation.

Every session consisted of two repetitions of 40 periods each. To reinforce the steady-state values, we initialized each sequence at the steady state and showed five pre-sequence periods where the economy was in the steady state. That is, output, inflation, and the shock were initialized at zero while the nominal interest rate was initialized at 75 basis points. There were no shocks in this initialization. We conducted two different repetitions on the same group of subjects to observe the effects of additional learning on their forecasting behaviour.

The experiment focused on the ability of monetary and fiscal policy to alleviate the duration and magnitude of recessions at the ZLB. As such, we implemented economies that would

[19] Median, rather than average, forecasts were employed to minimize the ability a single subject could have in manipulating aggregate expectations. This design decision is particularly useful when studying aggregate behavior with a limited number of participants.

[20] The underlying data-generating process assumes that households and firms form expectations in an effort to maximize their expected discounted utility and profits, respectively. We deviated from this assumption of the New Keynesian model and instead incentivized subjects based on the accuracy of their forecasts. Consistent with other LTF experiments, our goal was to focus on how individuals form beliefs about the economy. In order for subjects to take the task of forecasting seriously and for their decisions to be valuable to us, it is important to reward subjects based on the appropriate task —see Smith (1976) for a discussion of induced value theory. At the same time, we acknowledge the importance of studying expectation formation when subjects' forecasts play a critical role in influencing their consumption, labor and pricing decisions. See Duffy (2008) for a survey of this literature. For example, Marimon and Sunder (1993) use subjects' expectations to derive their optimal savings decisions. Hommes et al. (2007), and Bao et al. (2013) elicit subjects' expectations to determine firms' production decisions.

[21] In the scoring rules used by Assenza et al. (2013) and Pfajfar and Žakelj (2014), forecasts are no longer incentivized after a certain threshold. Under our rule, the per-period score reduces by 50% for every 100 basis point forecast error for both inflation and output, continually incentivizing subjects to make the most accurate forecasts possible.

experience and remain at the ZLB for a number of periods. To generate such an environment, we imposed a negative natural rate of interest shock of -400 basis points (±2 basis points) in periods 20 and 15 of the first and second repetitions, respectively. We chose to shock the economies in different periods so that subjects would not anticipate the shock in the second repetition. We selected approximately the same size shock (between -398 and -402) in both repetitions to make consistent comparisons.[22]

In order to control for variability of draws across treatments, we preselected a set of six shock sequences per repetition and implemented the same set in all treatments. We simulated six hundred randomly generated shock sequences using Equation 4, and we employed *social evolutionary learning (SEL)* (Arifovic et al., 2012) to explore behavioural responses at the ZLB and to select shock sequences that met the following criteria:[23] 1) The economies did not reach the ZLB prior to us imposing the liquidity trap shock, 2) the r_t^n shock remained negative for three to eight periods, and 3) the economies rebounded in the later periods with few if any returns to the ZLB.[24] We explicitly communicated to subjects that the randomly drawn shock sequences were preselected for experimental control.

Each treatment consisted of six independent sessions, where each session involved a different pair of shock sequences. Across treatments, the set of shock sequences was identical. Thus, for any given pair of shock sequences, we can observe how behaviour may differ across treatments. To avoid treatment contamination, we implemented a between-subject experimental design where subjects participated in only one treatment.

The different shock sequences implied that the number of periods it took for the fundamental shock to return to zero following a severe crisis shock varied across sessions within any given treatment. If subjects utilize only fundamentals and the inflation target to formulate their forecasts, then the number of periods that it takes for the fundamental shock to return to the steady state should have no bearing on whether subjects' forecasts are coordinated in the direction of the target. Varying the speed of recovery allows us to obtain a more robust

[22]Consistent with the theoretical literature, we study linear approximations to agents' optimal decisions. This implies that the only nonlinearity we consider is the one imposed by the ZLB. While we may face poor approximations of inflation and output in response to large shocks, the simplicity of the environment allows us to economize on the dimension of the state space, and avoid having to parametrize higher order terms of the nonlinear model (for further discussion, see Adam and Billi, 2007). Moreover, the linearized data generating process is considerably easier for subjects to understand. We chose the shock of this magnitude in order to ensure that experimental economies reached and remained at the ZLB for varied amounts of time.

[23]We chose *SEL* as it is a better behaved adaptive algorithm in simulations than some of the ones often used as a standard in the macroeconomic literature as it is more robust in these types of environments than other models of learning and expectations. It also performs well in capturing features of the experiments with human subjects as well as real-world data (Arifovic (2000).

[24]For robustness, in one sequence per treatment (Sequence 1 - Repetition 2) we set the crisis shock to -600 basis points.

understanding of how monetary and fiscal policy can stabilize expectations.

Our subjects can perfectly observe shocks while in the real world people must disentangle random drivers of the economy from the endogenous response of expectations and decisions to existing fundamentals. There is currently no New Keynesian LTF experiment that systematically compares behavior with and without information about stochastic shocks. We can only speculate that our experimental subjects are likely made more sensitive to the exogenous shocks than their less-informed counterparts in the real world. In the context of our experiment, this would suggest that our subjects would typically over-react to shocks, including the crisis shock, leading to a deeper initial recession and more successful recovery as fundamentals revert back to the steady state.

4 Aggregate Results

This section presents our findings for the aggregate economies. After 20 periods in Repetition 1 or 15 periods in Repetition 2, the experimental economies experienced a crisis shock of -400 basis points. Thereafter, the shock trended back and surpassed zero. Across different shock sequences we varied the number of periods it took for the shock to reach zero. We define *CrisisShockLength* as the number of periods, including the period of the initial shock, before the natural interest rate shock reaches zero.

On impact of the crisis shock, inflation and output expectations in all repetitions decreased significantly, driving the economies down to the ZLB. However, some economies escaped the ZLB and trended back up to the steady state, while others experienced persistent deflationary spirals. In all treatments, we observe liquidity traps where median expectations remain pessimistic in the presence of expansionary monetary policy. Importantly, the economic dynamics in our experiments are driven both by the exogenous process and the endogenous dynamics of participants' beliefs. Our sequences never reach the ZLB without the occurrence of a sufficiently large negative demand shock. Once at the ZLB, there is insufficient negative feedback from monetary policy that output and inflation respond almost entirely to expectations and the demand shock. At that point, the data-generating process yields a very large role for expectations to drive aggregate dynamics.

We present two examples of shock sequences where the economies, regardless of the treatment, either escaped or remained trapped at the ZLB.[25] In Figures 3 and 4, time series of output and inflation are presented as thin solid blue and dashed green lines, respectively. The

[25]All time series graphs of inflation, output, interest rates, and forecast distributions can be found in the Online Appendix.

nominal interest rate is presented as a short-dashed orange line, while the shock is presented as a thicker solid bold red line. Figure 3 presents the results from sequence 3 where the *CrisisShockLength* is three periods in Repetition 1 and five periods in Repetition 2. We find that across all treatments expectations track the path of the shock variable in the interval leading up to the crisis shock event (as do output and inflation). At the outset of the crisis shock, expectations drop and even trend downwards one period after the crisis shock. However, median expectations are quickly reversed and the economies all successfully returned back to the steady state relatively quickly in both repetitions. Sequence 4 presented in Figure 4 has a *CrisisShockLength* of eight periods in both repetitions. Again, median expectations fall significantly at the outset of the crisis shock. In all monetary policy treatments, expectations never return to the steady state, but instead experience severe deflationary episodes with output and inflation reaching very large negative levels. By contrast, in the *Fiscal Policy* treatment, we observe that expectations and the aggregate economy remain relatively stable and follow fundamentals as the shock trends back to the steady state.

Monetary Policy Results

We consider two measures of policy effectiveness. The first is related to the success of policy in reducing the duration of a liquidity trap, while the second addresses the policy's effectiveness in reducing the severity (or standard deviation) of output gap and inflation following the crisis shock. We begin with the duration of the liquidity trap. Because each shock sequence in a given treatment has a different *CrisisShockLength*, we normalize the number of periods before expectations are reversed by the *CrisisShockLength*. Specifically, we measure the duration of the liquidity trap at the session-repetition level using *Relative Trap Length*:

$$\textit{Relative Trap Length} = \frac{\text{Number of periods before expectations are reversed}}{\text{Number of periods before shock becomes nonnegative}}$$

The results are aggregated in dot plots in Figure 5. For inexperienced subjects in Repetition 1, the relative trap lengths are the shortest in the *Constant* treatment where it takes an average of 11.9 periods for subjects to reverse their expectations. By contrast, in treatments *SD* and *Dir. SD*, it takes an average of 17.1 and 14.1 periods, respectively. However, the differences across treatments are not statistically significant (*p-value*$>$ 0.126 for all pairwise two-sided Wilcoxon rank sum comparisons). For experienced subjects (Repetition 2), the average relative trap length increases in the *Constant* treatment with subjects taking an average of 17.3 periods to reverse their expectations. The average relative trap length worsens in the *SD* treatment (with an average of 19 periods to reverse the expectations) and decreases considerably in *Dir. SD* (with an average of 13 periods to reverse the expectations). Again, none of these are differences in the second repetition are statistically significant (with *p-value*> 0.20 in all cases).

Observation 1: The relative trap length does not differ significantly between the *Constant*, *SD* and *Dir. SD* treatments.

Figure 6 presents standard deviations of inflation across treatments and repetitions (log scale on the y-axis). During the first repetition, the standard deviation of inflation is significantly lower in the *Constant* treatment than in the *SD* treatment (*p-value*$= 0.055$). However, because of the considerable variability of inflation across sessions of *Dir. SD* treatment, we do not observe any statistically significant differences with respect to either the *Constant* or *SD* treatments. For experienced subjects, the standard deviation of inflation worsens in the *Constant* and *SD* treatments, and we fail to observe any statistically significant differences between the two (*p-value*$= 0.262$). However, the qualitative communication in the *Dir. SD* treatment is more effective at reducing inflation variability than quantitative communication in the *SD* treatment (p-value$= 0.109$). Turning to the output gap, we find qualitatively similar results, and a corresponding pattern of significance.

Observation 2: The severity of recessions, measured by the standard deviation of inflation and output, is significantly lower under a constant inflation target than under an explicitly communicated inflation target when subjects are inexperienced. With experience, state-dependent inflation targets communicated qualitatively result in less severe recessions than when communicated quantitatively. Neither form of state-dependent targets significantly reduces the standard deviation of inflation and output relative to a constant inflation target.

To quantify the central bank's ability to achieve its target, we calculate for each session, repetition, and phase the mean absolute deviation of inflation from the inflation target. The median value for each stratification is reported in Table 2. The median session deviations in the monetary policy treatments range from 71 to 78 basis points, and we observe no significant differences across any of the treatments ($p \geq 0.20$). Postshock, the deviations from target increase dramatically indicating that the central bank's target is no longer perceived as credible. A constant inflation targeting policy is significantly more effective than either of the state-dependent inflation targeting policies ($p = 0.016$ and $p = 0.078$, respectively).

In the preshock phase of the second repetition, deviations from target are higher. Wilcoxon signed-rank tests (not reported in the table) indicate that these deviations from target are only statistically significant in the *SD* treatment. This result suggests that the central bank is prone to losing credibility in achieving its state-dependent inflation target following a crisis. Preshock deviations from target are significantly higher in the *SD* than in the *Constant* ($p = 0.078$), but we observe no consistent differences between the *SD* and *Dir. SD* treatments.

With the onset of a second crisis, deviations from target increase again. We continue to observe that the deviations from target are significantly higher in the *SD* treatment than in the *Constant* treatment ($p = 0.078$). Compared to the *Constant* treatment, there are modest improvements in coordination of inflation on target in the *Dir. SD* treatment, but the effects are not statistically significant.

Observation 3: The central bank is significantly more effective at achieving its inflation target when it employs an explicit constant target than a quantitatively communicated state-dependent target. Constant targets also outperform qualitatively communicated state-dependent targets when subjects are inexperienced.

Does the *CrisisShockLength* influence the likelihood that an economy becomes unstable? To answer this question, we consider two measures of economic stability. Our first measure denotes a postshock economy as stable if expectations reverse direction before the conclusion of the sequence while our second measure applies a more stringent condition that both output and inflation return to the steady state.[26] Figure 6 categorizes each repetition of each session as unstable or stable according to both measures. Instability is strongly associated with increased *CrisisShockLength* in all inflation targeting treatments. With the exception of one session in the first repetition of the *Dir. SD* treatment, we observe that *CrisisShockLength* greater than five periods result in unstable dynamics. Pooling data across repetitions, we find that the ability for an economy to return to the steady state is significantly and positively correlated with the duration of the crisis in all but the *SD* treatment (Spearman correlation coefficient of $\rho > 0.48$ in all cases). Reversal of expectations is not significantly correlated with the *CrisisShockLength*.

We further conduct a series of probit regressions to identify the effects of the *CrisisShockLength* on the likelihood of coordinating expectations in the direction of the inflation target. We employ pooled data collected from both repetitions in the postshock phase. Specifically, we conduct the following random effects probit specification:

$$Pr(M_{i,t} = 1) = \alpha + \beta CrisisShockLength + u_i + \epsilon_{i,t} \tag{9}$$

[26] Note that there are 21 and 26 periods in the postshock phases of Repetition 1 and 2, respectively.

where $M_{i,t}$ takes the value of 1 if subject i forecasts trend away from the prior realized inflation toward the central bank's inflation target, u_i is a between-subject error and $e_{i,t}$ is the within-subject error. Robust standard errors are reported.

The estimation results for the monetary policy treatments are presented in the first three columns of Table 3. The longer is the *CrisisShockLength*, the lower is the probability that individuals will coordinate their expectation in the direction of the inflation target. In the *Constant* treatment, for every additional period it takes for fundamentals to return to zero, the likelihood a subject forms expectations in the direction of the target decreases by an average of 10.2%. The effect is similar in the *Dir. SD* treatment: the probability a subject forecasts in the direction of the target falls by 14% for each additional period the fundamentals take to return to the steady state. Both of these effects are highly significant at the 1% level. We observe a more muted response of expectations to the *CrisisShockLength* in the *SD* treatment. There, each additional period before the shock returns to the steady state results in only a 2% reduction in the likelihood of forecasting in the direction of the target.

We also consider the possibility that larger adjustments in the aggregate shock in the period immediately following the crisis shock may appear more focal and serve to effectively coordinate optimistic expectations in line with the target. We estimate the following random effects probit regression specification by treatment:

$$Pr(N_{i,t_c+1} = 1) = \alpha + \beta(r^n_{t_c+1} - r^n_{t_c}) + \epsilon_i \tag{10}$$

where N_{i,t_c+1} takes the value of 1 if subject i expects inflation to increase in period $t_c + 1$ relative to t_c. The results are presented in the second half of Table 3. In the *Constant* and *Dir. SD* treatments, a larger recovery of the shock immediately after the crisis occurs significantly increases the probability that subjects' expectations of inflation increase relative to past inflation. However, in the *SD* treatment, a larger initial recovery in fundamentals has no effect on the likelihood of forming optimistic inflation expectations.

Observation 4: A faster recovery of fundamentals increases the likelihood that subjects formulate forecasts in the direction of the central bank's constant inflation target.

Observation 5: Larger initial recoveries of the fundamental shock immediately following the initial crisis shock significantly increases the probability of forming optimistic expectations under constant and directional state-dependent inflation targets.

Fiscal Policy Results

We now turn our focus to aggregate results from the *FP* treatment. Combining a constant inflation targeting monetary policy with fiscal stimulus is often effective at stabilizing expectations during an economic crisis. The mean relative trap length under the *FP* treatment is 1.167 (SD 0.93) in the first repetition and 1.587 (SD 1.638) in the second repetition (see Figure 5). This is considerably smaller than the relative trap lengths observed in the *Constant* treatment, which have means of 1.652 (SD 0.977) and 2.713 (SD 2.872) in Repetitions 1 and 2, respectively. Two-sided Wilcoxon rank sum tests fail to reject the null hypothesis of equal distributions (p-$value > 0.26$) in both repetitions. The lack of statistical difference in these measures is driven by two *FP* sessions that experienced significant instability.

The standard deviations of inflation and output are also considerably reduced with the introduction of fiscal stimulus. Figure 6 presents a comparison of standard deviations at the session level in the *Constant* and *FP* treatments. Two-sided Wilcoxon rank sum tests indicate that macroeconomic variability is lower in the *FP* treatment ($p = 0.078$ for output in Repetition 1; $p = 0.109$ for inflation in both repetitions and output in Repetition 2).

Fiscal stimulus also improves the central bank's ability to achieve its targets during the postshock phases of Repetitions 1 and 2. Table 2 shows that the median postshock deviation from target is 116 and 155 basis points in the two repetitions, respectively. However, in both repetitions, the effect is not statistically significant ($p > 0.42$).

Observation 6: Supplementing a constant inflation target with expansionary fiscal policy has mixed success in reducing the duration and severity of recessions.

We report the results from a final series of probit regressions for the *FP* treatment in Table 3. We find a small, positive effect of *CrisisShockLength* on the likelihood of expectations moving in the direction of the central bank's inflation target. For each additional period necessary for fundamentals to return to the steady state, the probability of inflation expectations trending toward the zero falls modestly by 2.6%. Thus, fiscal policy is relatively effective at reducing the pessimism generated by a slow recovery of fundamentals. Second, we observe that subjects in the *FP* treatment are also more likely to adjust their expectations upward when fundamentals increase by a larger amount in the period immediately following the crisis shock.

Observation 7: Increasing the speed of recovery of fundamentals in the *FP* treatment has a small but significant positive effect on the likelihood that subjects will form expectations in the direction of the target. A larger initial upward adjustment in fundamentals significantly increases the likelihood that subjects will form optimistic expectations.

5 Heterogeneity in Forecasting Heuristics

In this section we consider how subjects form expectations during both stable times and immediately following the onset of the crisis. In particular, we seek to understand how different policies and communication strategies alter how subjects forecast before and after entering the ZLB.

We begin by focusing on a general specification for one period ahead forecast errors associated with subjects' forecasts $E_t^* x_{t+1}$ and $E_t^* \pi_{t+1}$ as:

$$E_t \left(E_t^* \begin{bmatrix} \pi_{t+1} \\ x_{t+1} \end{bmatrix} - \begin{bmatrix} \pi_{t+1} \\ x_{t+1} \end{bmatrix} \right) = \sigma^{-1} \rho_r \sum_{s=0}^{\infty} \begin{bmatrix} \kappa L_{s\pi} \\ L_{sx} \end{bmatrix} r_{t-s}^n \ , \tag{11}$$

where E_t denotes the mean conditional on state history through period t, and $L_{s\pi}$, L_{sx} are real numbers representing the elasticity of ex-ante forecast errors for inflation and the output gap with respect to shock realizations in periods $t, t-1, ...$ A standard assumption is that subjects form rational expectations; that is, ex ante forecast errors are always zero. This would imply that $L_{s\pi} = L_{sx} = 0$ for all s. According to (11), non-rational expectations imply that ex-ante forecast errors correlate with current or past shock realizations.[27]

We begin by constructing a series of specifications that consider the effects of current and lagged shocks on ex-ante one period ahead forecast errors:

$$E_{i,t} z_{t+1} = \alpha + \beta_1 \epsilon_{rt} + \beta_2 \epsilon_{rt-1} + \beta_3 \epsilon_{rt-2} ... \beta_7 \epsilon_{rt-4} + \gamma_i + \mu_{i,t} \ , \tag{12}$$

where $E_{i,t} z_{t+1}$ refers to either output or inflation ex-ante forecast errors, γ_i is the unobserved time-invariant individual effect, and $\mu_{i,t}$ is the error term. Under the null hypotheses of rational expectations, ex-ante forecast errors are predicted to be uncorrelated with shock innovations at any lag, ie., $\hat{\beta}_k = 0$ for all k and $\hat{\alpha} = 0$. In contrast, under an adaptive form of expectations where subjects significantly weight both current innovations and lagged output and inflation in their forecasts, ex-ante forecast errors would place significant weight

[27] Under non-rational expectations as defined above, the law of iterated expectations, in general, does not hold; e.g., $E_t^* E_{t+s}^* \pi_{t+1+s} \neq E_t^* \pi_{t+s+1}$ for a given $s = 1, 2, ...$

on lagged shock innovations, $\hat{\beta}_k \neq 0$ for some k. We estimate Equation 12 using pooled data from all subjects in both repetitions for each treatment. The results are presented for output and inflation forecast errors in Table 7 of the Appendix. We note that in all treatments, subjects either significantly over- or under-react to current and lagged innovations, or the weight placed on the constant, α, is significantly different from zero. We can confidently reject that the average subject in each treatment exhibits rational expectations.

We next construct a series of simple specifications that consider the effects of current innovations, lagged outcomes, inflation targets, and certain future fiscal stimulus on ex-ante one period ahead forecasts:

$$E_{i,t}z_{t+1} = \alpha + \beta_1 \epsilon_{rt} + \beta_2 z_{t-1} + \beta_3 \pi_t^* + \beta_4 g_{t+1} + \gamma_i + \mu_{i,t} \ , \tag{13}$$

where z_{t+1} refers to either output or inflation in period $t+1$, γ_i is the unobserved time invariant individual effect, and $\mu_{i,t}$ is the error term. We estimate Equation 13 using pooled data from all subjects in both repetitions for each treatment. The results are presented for output and inflation forecasts in Table 4. The first three columns of each table refer to results involving pre-shock forecasts. The following eight columns refer to postshock forecasts in the first five periods following the onset of the crisis, where we separate the analysis for sequences where the *CrisisShockLength* was less than or equal to five or greater than five.[28]

During the preshock phase, subjects in all treatments place a quantitatively large positive weight on both current innovations and lagged output and inflation when forming their forecasts. Lagged output and inflation are highly significant in preshock forecasts in all but the *SD* treatment where there is a high degree of heterogeneity across subjects. In the *SD* treatment, the central bank's inflation target has mixed success at coordinating expectations. While it increases average inflation expectations more than one for one, the effect is not statistically significant. In contrast, both output and inflation expectations in the *Dir. SD* treatment respond significantly to the qualitatively announced inflation target. The effect of π_t^* is marginal, raising output and inflation forecasts by roughly 0.09 and 0.08 basis points per 1 basis point increase in the target.

We next turn to the postshock phase. We find that the consistency in subjects' forecasting heuristics depends importantly on the *CrisisShockLength*. For quick-recovering fundamentals,

[28]We focus on the first ten periods of the postshock phase. Subjects' expectations become increasingly heterogeneous as recessions worsen. We exclude the period in which the crisis shock occurs to avoid including preshock historical information.We note that π_t^* is not independent of x_{t-1} and π_{t-1}, which may lead to some of our estimates to be deemed statistically insignificant due to multicollinearity. We include in the Online Appendix estimates of the effects of each of these covariates on forecasts individually before combining them in a final specification

we find that many of our explanatory variables play an important role in subjects' forecasting decisions. In the *Constant* treatment, current innovations and lagged outcomes continue to play a significant role in subjects' forecasts. Lagged inflation plays a very large role in subjects' forecasts. If inflation falls by 10 basis points in the prior period, inflation expectations significantly decrease by more than 150 basis points. The inflation target also significantly influences inflation forecasts in the *SD* treatment, raising forecasts nearly fivefold for every basis point increase in the target. In the *Dir. SD* treatment, expectations are relatively less reactive to lagged output and inflation and are not significantly influenced by the inflation target. Finally, in the *FP* treatment, we observe a similar positive reaction to current innovations and lagged outcomes. Future certain fiscal stimulus has only a modest and inconsistent effect on output expectations, and is negatively associated with inflation expectations. This result is consistent with inflation expectations rising as the stimulus gradually dissipates following the onset of the crisis.

For sequences with a longer *CrisisShockLength*, we obtain very noisy results. Heterogeneity across subjects becomes very large and, in most specifications, none of our explanatory variables are consistently effective at explaining forecasting behavior. Lagged output and inflation continue to play a large, albeit statistically insignificant, role in expectations.[29] Importantly, the central bank's inflation target does not have a consistent effect on inflation expectations in either the *SD* or *Dir. SD* treatments. Fiscal stimulus also proves ineffective at coordinating expectations out of the ZLB. In the *FP* treatment, fiscal stimulus has a negative but statistically insignificant effect on both sets of expectations.

We formally test whether subjects' forecast responses to current innovations, lagged outcomes, and inflation targets change significantly after the onset of the crisis. We interact each explanatory variable with a dummy *POST* that takes the value of 1 in the postshock phase. The results for output and inflation forecasts are presented in Table 5. In the quickly recovering *Constant* treatments, subjects usage of current innovations and lagged outcomes does not change significantly. For *Constant* sequences with a higher *CrisisShockLength*, we observe expectations becoming less responsive to current innovations and more responsive to lagged outcomes in the postshock phase. These effects are highly noisy and not statistically significant. In the *SD* and *Dir. SD* treatments, because of the high degree of heterogeneity in the postshock phase, we obtain very few consistent results. In in most of our specifications for the two state dependent inflation targeting treatments, subjects become increasingly reliant on lagged outcomes in the postshock phase. The central bank's inflation target is not con-

[29]When we exclude π_t^* from our state dependent inflation target treatment specifications, the effect of lagged output and inflation become statistically significant.

sistently used in either the pre or postshock phase according to our regression results. While the importance of the target in *SD* subjects' forecasts increases considerably in the postshock phase, the effect is highly variable across subjects. Finally, we do not observe any consistent changes in forecasting behavior in the *FP* treatment following the onset of the crisis.

Last, we investigate whether there are significant differences in how subjects' utilize information to formulate their forecasts across treatments. We interact innovations and lagged output and inflation with treatment-specific dummies and conduct a final set of regressions to identify the differential effect of our explanatory variables on subjects' expectations. The results are reported in Table 6, where we distinguish between preshock forecasts and postshock forecasts formed with either a slow or fast recovering sequence of shocks. All specifications include a set of treatment fixed effects.

In the postshock phase of both quick and slow recovering sequences, *SD* and *Dir. SD* subjects are significantly more reliant on lagged outcomes when forming their forecasts than their *Constant* counterparts. Their reaction to current innovations, however, does not appear to be consistently different. Only *Dir. SD* subjects appear to significantly under-react to innovations during quick-recovering crises. Comparing *SD* and *Dir. SD* treatments (results reported in the Online Appendix), we find that *Dir. SD* subjects' inflation expectations exhibit a significantly smaller positive association with past inflation and a significantly smaller negative correlation with the central bank's inflation target.

In the preshock phase of the *FP* treatment, we observe inflation and output gap expectations being significantly less responsive to innovations than in the *Constant* treatment. The observed difference between the *Constant* and *FP* treatments is puzzling given that, during this phase of the experiment, the treatments are nearly identical.[30] This difference in behavior persists into the postshock phase for sequences with a fast recovery of fundamentals. We also observe that inflation expectations are significantly less reliant on lagged inflation in the *FP* treatment. In the slow-recovery sequences, the heterogeneity across subjects is too great and we do not obtain any consistent treatment effects.

We attribute the increased usage but lack of coordination on historical information to the increased cognitive effort associated with the *SD* and *Dir. SD* treatments. In these treatments, subjects are presented with an additional piece of information, namely the evolving inflation target, on which they must decide how to condition their forecasts. Moreover, this information is only effective at influencing the economy so long as a sufficient number of subjects utilize it in their forecasts. This complicates the coordination process and contributes to the lack of

[30]The only difference is that the *FP* subjects may anticipate some form of government intervention during the experiment.

success of the state-dependent inflation target in the postshock phase.

Observation 8: In summary, subjects' expectations are highly heterogeneous and responsive to historical information. Introducing uncertain and evolving inflation targets in the *SD* treatment increases subjects' information sets and complicates their forecasting task. As a result, expectations formed in the *SD* treatment is considerably more heterogeneous than in the *Constant* treatment when fundamentals are slow to recover.

6 Discussion

We have demonstrated that severe, long-lasting expectations-driven liquidity traps can be generated in the laboratory. With a large unanticipated demand shock, subjects can form extremely pessimistic expectations, causing the economy to diverge into a deep recession. Recent theoretical research suggests that state-dependent inflation targeting by central banks can bring about greater economic stability and faster recoveries by committing to keep interest rates low following a recession even after inflation has returned to its target. We conduct a series of laboratory experiments to test whether such policies live up to these predictions, and if not, to identify why this is so.

We find that state-dependent inflation targets do not lead to significantly greater stability. In fact, in many instances, recession duration and severity are made considerably worse by continually raising the central bank's inflation target. This is particularly the case when fundamentals improve slowly. We attribute the relatively poorer performance of state-dependent inflation targets to a loss of confidence in the central bank's ability to stabilize the economy. During a slower recovery, the central bank's inflation target grows quite large as the economy fails to live up to the state-dependent target. The disparity between the inflation target and actual inflation — which is largely driven by non-rational expectations — grows rapidly. Such a policy is unlikely to be successful if agents' willingness to condition their expectations on the central bank's target is based on the central bank's efficacy in achieving past targets. However, the faster fundamentals improve, the greater is the likelihood the central bank achieves its inflation target and individuals coordinate their expectations in the direction of the target.

We emphasize that the central bank in our experimental economy is fully committed to its state-dependent policy to keep interest rates low even after the economy begins recovering. Unlike rational expectations' frameworks where credibility and commitment are synonymous, we have observed that agents may not perceive the central bank's intentions as credible despite the central bank's commitment to its policies. In short, our subjects need to *see it to believe* *it.*

Anticipated fiscal policy, by contrast, provides considerable support when fundamentals improve slowly. Compared to our baseline of a constant inflation target, introducing fiscal policy leads to significantly faster and more stable recoveries. Unlike state-dependent inflation targeting monetary policies that provide a promise of future recovery in the uncertain future, anticipated expansionary fiscal policy in our environment stimulates demand with certainty.

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Table 1: Summary of Treatments

Treatments	Inflation Target	Communication	g_t	# of Sessions	Subjects per Sess.
Constant	0	yes	0	6	9
SD	π_t^*	quantitative	0	6	9
Dir. SD	π_t^*	qualitative	0	6	9
FP	0	yes	yes	6	9

Table 2: Absolute Deviation of Inflation From Target by Treatment, Repetition, and Phase[I]

	Repetition 1		Repetition 2	
	Preshock	Postshock	Preshock	Postshock
Constant	71.84	156916	78.09	142960
	(43.03)	(13256.38)	(53.81)	(5.73e+07)
SD	70.98	1394853	162.66	7.82e+07
	(34.56)	(7.78e+07)	(566.09)	(7.50e+11)
Dir. SD	77.91	1442994	127.46	13866.32
	(59.13)	(2589327)	(68.28)	(5535459)
FP	46.92	115.69	84.46	154.59
	(39.87)	(613700.60)	(28.70)	(1910351)
Two-sided Wilcoxon rank sum tests:				
Constant vs. SD	0.749	0.016	0.078	0.078
Constant vs. Dir. SD	0.749	0.078	0.522	1.000
Constant vs. FP	0.522	0.872	0.749	0.423
SD vs. Dir. SD	1.000	0.522	0.522	0.055
SD vs. FP	0.200	0.016	0.016	0.025
Dir. SD vs. FP	0.749	0.025	0.262	0.109

(I) This table reports median session-level absolute deviations of inflation from the central bank's target. Standard deviations are reported in parentheses and p-values associated with two-sided Wilcoxon rank sum tests are calculated for pairwise treatment comparison. $N = 6$ for each cell.

Table 3: Probit Analysis of *CrisisShockLength* and Adjustment on Anchoring of Inflation Expectations [I]

Dep. Var	Pr(Forecast in Target Direction)=1				Pr(Increase Forecast Relative to Past Inflation)=1			
Treatment	*Constant*	*SD*	*Dir. SD*	*FP*	*Constant*	*SD*	*Dir. SD*	*FP*
CrisisShockLength	-0.102***	-0.040**	-0.140***	-0.026*				
	(0.01)	(0.02)	(0.02)	(0.01)				
$r_t^n - r_{t-1}^n$					0.006***	-0.003	0.007***	0.006***
					(0.00)	(0.01)	(0.00)	(0.00)
α	0.344***	-0.426***	0.552***	-0.155**	0.031	-0.464	-0.507**	-0.701***
	(0.09)	(0.12)	(0.16)	(0.08)	(0.22)	(0.76)	(0.22)	(0.22)
N	2503	2372	2503	2524	108	106	107	104
χ^2	60.32	5.829	37.03	3.151	10.11	0.221	14.16	14.36

(I) Random effects probit regressions involve data from the pooled postshock data from Repetitions 1 and 2. *CrisisShockLength* refers to the number of periods it takes for the natural rate of interest shock r_t^n to return to zero following the onstart of the crisis. α denotes the constant in each specification. Significance levels: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors are presented in parentheses.

Table 4: Forecasts Across Preshock and Postshock Phases [I]

Dep.Var.:	Preshock				Postshock - $CrisisShockLength \leq 5$				Postshock - $CrisisShockLength > 5$			
Output Forecast	*Constant*	*SD*	*Dir. SD*	*FP*	*Constant*	*SD*	*Dir. SD*	*FP*	*Constant*	*SD*	*Dir. SD*	*FP*
ϵ_t	0.408***	1.452**	0.228***	0.266***	0.829***	-26.572	-0.497	0.124**	-599.830	802.484	-473.737	22.238
	(0.03)	(0.72)	(0.03)	(0.03)	(0.17)	(43.64)	(1.36)	(0.05)	(1831.67)	(1232.53)	(513.70)	(31.30)
x_{t-1}	0.776***	-1.132	0.805***	0.810***	0.585***	33.303	1.168***	0.723***	31.580	4.856	-6.778	16.783
	(0.04)	(2.59)	(0.05)	(0.03)	(0.03)	(36.01)	(0.31)	(0.08)	(24.52)	(5.37)	(19.01)	(14.02)
π^*_t		-1.470	0.094**			16.566	0.030			2.796	-8.890	
		(1.32)	(0.04)			(23.93)	(0.15)			(3.77)	(17.66)	
g_{t+1}								0.154				-341.462
								(0.22)				(320.71)
α	17.823***	261.290	11.263***	6.500***	-20.235	119549.425	239.996	21.163	14470.408	-364427.915	31103.865	38377.076
	(2.74)	(196.78)	(3.27)	(2.19)	(13.52)	(388258.67)	(374.87)	(15.51)	(317924.19)	(405581.99)	(91934.27)	(46324.22)
N	1655	1660	1630	1656	482	480	476	485	460	475	482	471
F	195.1	19.53	123.3	306.7	185.1	0.874	38.24	73.73	1.188	3.839	13.85	0.633

Dep.Var.:	Preshock				Postshock - $CrisisShockLength \leq 5$				Postshock - $CrisisShockLength > 5$			
Inflation Forecast	*Constant*	*SD*	*Dir. SD*	*FP*	*Constant*	*SD*	*Dir. SD*	*FP*	*Constant*	*SD*	*Dir. SD*	*FP*
ϵ_t	0.235***	1.055	0.073***	0.104***	0.437***	-25.211*	0.172	0.039**	23.414	811.886	-207.957	-1.419
	(0.03)	(0.76)	(0.02)	(0.02)	(0.07)	(14.51)	(0.32)	(0.02)	(59.73)	(1536.10)	(183.95)	(1.69)
π_{-1}	0.815***	4.075	1.055***	0.914***	0.677***	15.225**	1.080***	0.790***	1.858	79.510	-56.354	2.378***
	(0.03)	(3.19)	(0.06)	(0.03)	(0.04)	(6.70)	(0.23)	(0.06)	(1.64)	(99.52)	(54.39)	(0.33)
π^*_t		1.066	0.076***			4.887*	-0.036			29.623	-26.842	
		(1.30)	(0.02)			(2.55)	(0.05)			(38.78)	(24.97)	
g_{t+1}								-0.171**				-4.294
								(0.08)				(3.88)
α	7.648***	594.865***	4.754***	2.973	-1.007	4011.462	41.870	32.991***	-25466.505**	380460.137	148958.913	434.738
	(2.46)	(46.79)	(1.12)	(2.18)	(4.56)	(15231.11)	(201.36)	(9.15)	(9902.70)	(1168111.85)	(326673.87)	(421.98)
N	1655	1660	1630	1656	482	480	476	485	460	475	482	471
F	402.5	8.351	143.5	354.9	195.2	4.364	24.22	79.40	1.500	4.973	0.863	34.33

(I) Fixed effects panel regressions involving data from the preshock phase and 10 periods following the crisis shock are included; α denotes the constant in each specification. Significance levels: $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors are presented in parentheses.

Table 5: Change in Forecasting Behavior After the Crisis [I]

Dep. Var.: Output Forecast	*Constant*		*SD*		*Dir. SD*		*FP*	
ϵ_t	0.585***	-81.427	290.774	-1.386	0.230	34.488	0.171***	114.394
	(0.04)	(351.20)	(214.06)	(4.04)	(0.35)	(34.53)	(0.04)	(133.46)
$\epsilon_t \times POST$	0.033	-512.579	41.065	-54.831	-0.080	-128.909	-0.005	-145.668
	(0.06)	(428.39)	(119.62)	(39.90)	(1.21)	(124.35)	(0.08)	(140.37)
x_{t-1}	0.782***	-213.716	22.173	16.894*	0.547	-52.724	0.732***	118.217
	(0.07)	(706.58)	(227.40)	(9.78)	(0.51)	(37.84)	(0.06)	(139.25)
$x_{t-1} \times POST$	-0.106	227.240	188.217	-5.714	0.550*	46.254**	0.009	-287.560
	(0.08)	(702.03)	(266.09)	(17.13)	(0.28)	(22.51)	(0.07)	(216.63)
π^*_{t-1}			-521.632	6.551	-0.145	-101.401		
			(473.90)	(5.28)	(1.16)	(77.75)		
$\pi^*_{t-1} \times POST$			710.729	0.367	0.140	92.770		
			(579.30)	(13.33)	(1.09)	(62.53)		
$g_{t+1} \times POST$							0.073**	2042.663
							(0.03)	(1372.02)
$POST$	10.264	-145496.940	-129738.075	-33023.344	143.137	26492.357	8.522	-400540.398
	(7.25)	(181066.58)	(231725.62)	(22032.16)	(231.77)	(29586.14)	(7.34)	(262121.77)
α	9.601	6316.168	-50471.892	3086.125	-0.997	-6557.661	14.630***	-33408.309
	(6.74)	(124797.61)	(162219.11)	(10823.16)	(286.02)	(16142.45)	(4.71)	(111326.83)
$CrisisShockLength$	Short	Long	Short	Long	Short	Long	Short	Long
N	1421	1389	1422	1147[I]	1409	1338[I]	1411	1400
F	166.6	0.703	1.077	16.66	20.40	22.15	53.38	0.416

Dep. Var.: Inflation Forecast	*Constant*		*SD*		*Dir. SD*		*FP*	
ϵ_t	0.397***	48.286	24.186	-2.214	0.562*	-39.797	0.072***	-41.415
	(0.04)	(39.28)	(36.58)	(4.94)	(0.30)	(54.07)	(0.02)	(66.08)
$\epsilon_t \times POST$	0.022	-52.778	517.159	-20.282	-0.715	230.460	-0.039*	114.948
	(0.04)	(62.49)	(495.21)	(15.78)	(0.71)	(219.32)	(0.02)	(120.99)
π_{t-1}	0.750***	170.732	-525.538	-24.536	-1.555	-497.345	0.864***	66.004
	(0.04)	(123.26)	(519.16)	(30.36)	(1.42)	(437.81)	(0.05)	(162.71)
$\pi_{t-1} \times POST$	0.025	-166.346	465.152	15.933	2.440**	442.376	-0.029	159.749
	(0.05)	(124.04)	(458.66)	(33.16)	(1.19)	(392.65)	(0.07)	(205.29)
π^*_{t-1}			-560.845	-6.564	-1.647	-226.155		
			(551.24)	(5.33)	(1.04)	(184.65)		
$\pi^*_{t-1} \times POST$			534.641	1.636	1.608	199.901		
			(526.74)	(7.01)	(1.03)	(163.62)		
$g_{t+1} \times POST$							-0.006	-1227.291
							(0.02)	(1094.96)
$POST$	6.938	7214.133	223244.496	-14868.667	-11.491	134361.809	11.812	232652.820
	(4.66)	(13702.04)	(208653.24)	(11324.89)	(105.25)	(120926.61)	(7.70)	(205890.82)
α	2.792	-15921.437	-48574.053	920.883	-97.996	-5225.834	7.056**	12483.312
	(3.51)	(10560.99)	(114853.59)	(4777.33)	(135.77)	(67260.07)	(3.15)	(86906.61)
$CrisisShockLength$	Short	Long	Short	Long	Short	Long	Short	Long
N	1421	1389	1422	1147[I]	1409	1338[I]	1411	1400
F	204.0	2.814	1.554	12.00	37.22	0.405	171.6	0.230

(I) Fixed effects panel regressions involving data from the preshock phase and 10 periods following the crisis shock. $POST$ is a dummy variable that takes the value of 1 in the postshock phase of each repetition and α denotes the constant in each specification. Significance levels: $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors are presented in parentheses.

(I) The number of periods following the crisis shock was reduced to 5 and 9 periods for the SD and Dir.SD treatments, respectively. These were the maximum number of periods in the postshock phase that would generate consistent estimates and an F-statistic could be calculated.

Table 6: Differences Across Treatments in Terms of Forecasting Heuristics[I]

	Output Forecasts			Inflation Forecasts		
	Preshock	Postshock	Postshock	Preshock	Postshock	Postshock
ϵ_t	0.420***	0.760***	-0.124	0.240***	0.417***	0.215**
	(0.03)	(0.10)	(0.38)	(0.03)	(0.05)	(0.11)
$\epsilon_t \times SD$	0.788*	0.510	-8.138	0.339	-0.157	-9.712
	(0.43)	(0.45)	(12.34)	(0.31)	(0.12)	(7.11)
$\epsilon_t \times Dir.SD$	-0.186***	-0.059	1.221*	-0.158***	-0.123*	0.160
	(0.05)	(0.14)	(0.70)	(0.03)	(0.07)	(0.20)
$\epsilon_t \times FP$	-0.162***	-0.595***	0.414	-0.143***	-0.427***	-0.149
	(0.05)	(0.16)	(0.38)	(0.03)	(0.06)	(0.11)
x_{t-1}	0.809***	0.811***	1.039***			
	(0.04)	(0.07)	(0.27)			
$x_{t-1} \times SD$	0.377	1.266***	0.905*			
	(0.42)	(0.43)	(0.47)			
$x_{t-1} \times Dir.SD$	-0.001	0.489***	0.912**			
	(0.06)	(0.14)	(0.39)			
$x_{t-1} \times FP$	-0.013	-0.024	-0.035			
	(0.05)	(0.20)	(0.31)			
π_{t-1}				0.855***	0.789***	1.053***
				(0.03)	(0.07)	(0.18)
$\pi_{t-1} \times SD$				0.305	1.106***	1.290***
				(0.51)	(0.42)	(0.32)
$\pi_{t-1} \times Dir.SD$				0.104*	0.436***	0.973***
				(0.06)	(0.12)	(0.31)
$\pi_{t-1} \times FP$				0.042	-0.276*	-0.075
				(0.04)	(0.14)	(0.18)
SD	419.465	466.728**	-21347.535	545.889	115.498**	-15946.674*
	(571.23)	(212.54)	(16800.42)	(589.20)	(57.01)	(9595.81)
$Dir.SD$	-10.087**	229.697***	892.511**	-3.891	47.196**	284.633***
	(4.38)	(73.97)	(381.89)	(2.81)	(21.98)	(106.18)
FP	-8.112*	-73.814**	159.070	-0.288	18.692	-16.313
	(4.15)	(35.02)	(181.28)	(2.85)	(16.90)	(26.56)
α	15.604***	109.399***	-77.830	4.405*	17.991	9.448
	(3.70)	(34.25)	(177.90)	(2.33)	(12.49)	(25.23)
$CrisisShockLength$		Short	Long		Short	Long
N	6601	1072	1052	6601	1072	1052
χ^2	1765.4	724.5	229.6	2982.4	1247.6	1039.9

(I) Random effects panel regression involving data from the preshock phase and five periods following the crisis shock; SD, $Dir.SD$ and FP are treatment-specific dummies and α denotes the constant in each specification. Significance levels: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors are presented in parentheses.

Figure 1: Simulation of Parametrized Environment with Different Inflation Targets and Fiscal Policy; Rational Expectations

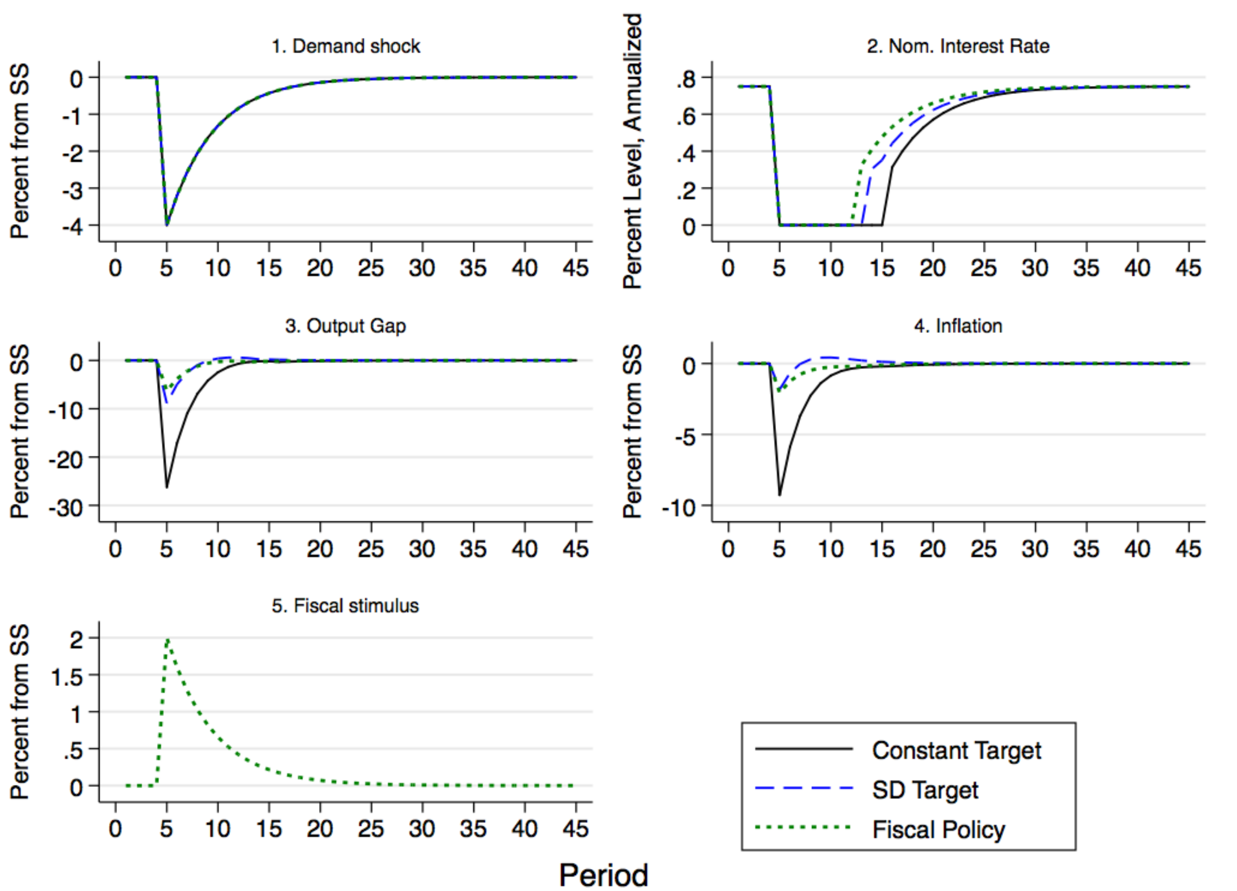
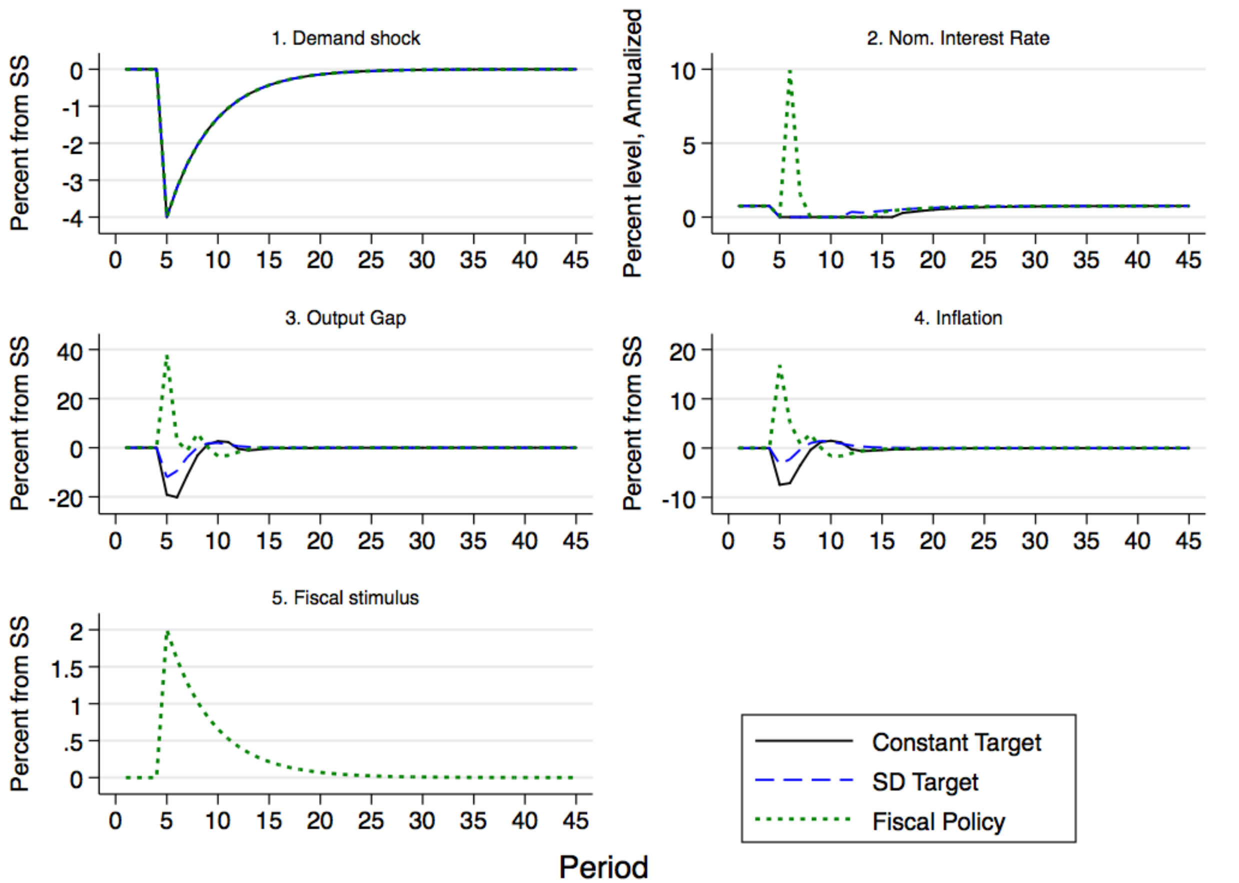


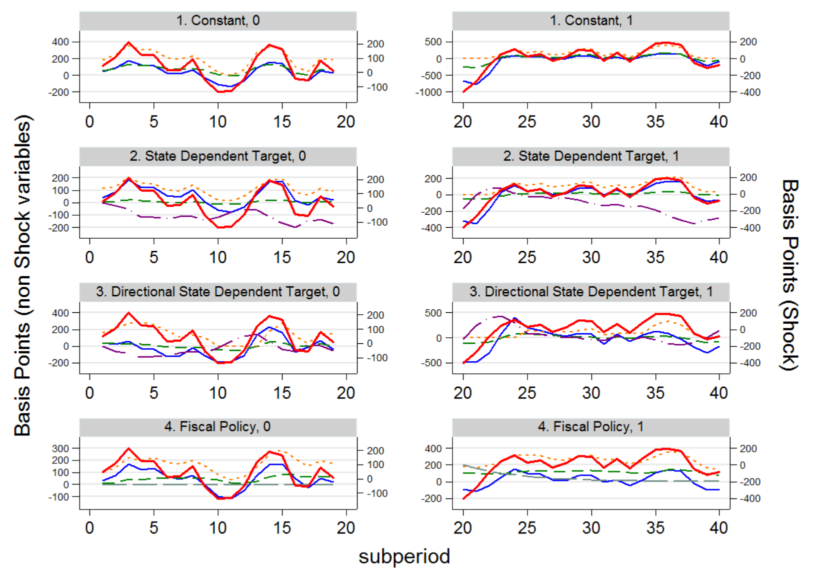
Figure 2: Simulation of Parametrized Environment with Different Inflation Targets and Fiscal Policy; Adaptive Expectations



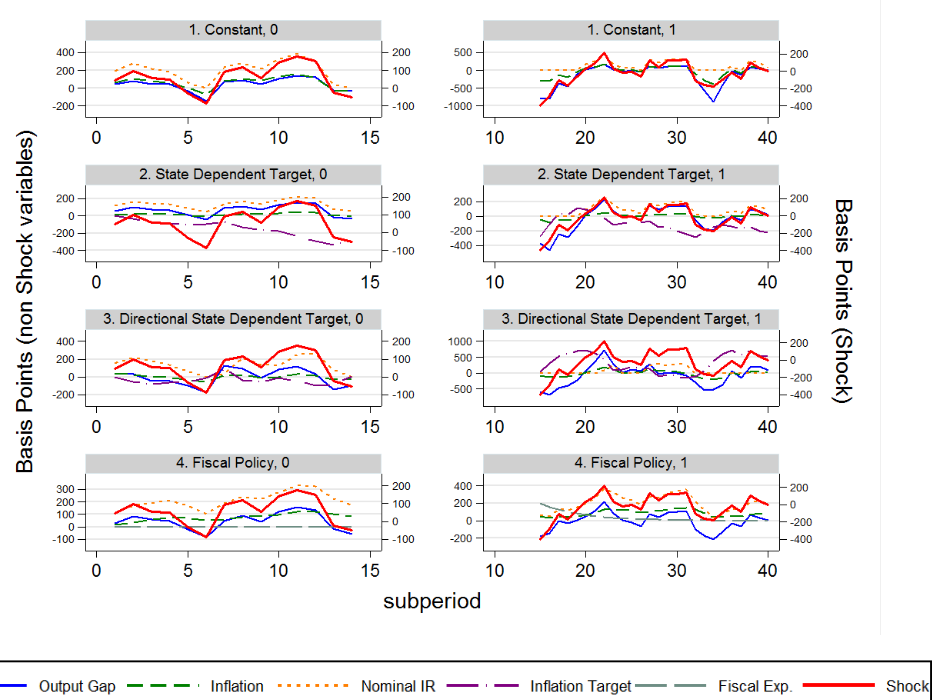
Expectations formed by placing 75% weight on rational expectations equilibrium solution and 25% weight on lagged inflation and output gap.

Figure 3: Example of a Stable Shock Sequence

Panel A: Sequence 3, Repetition 1

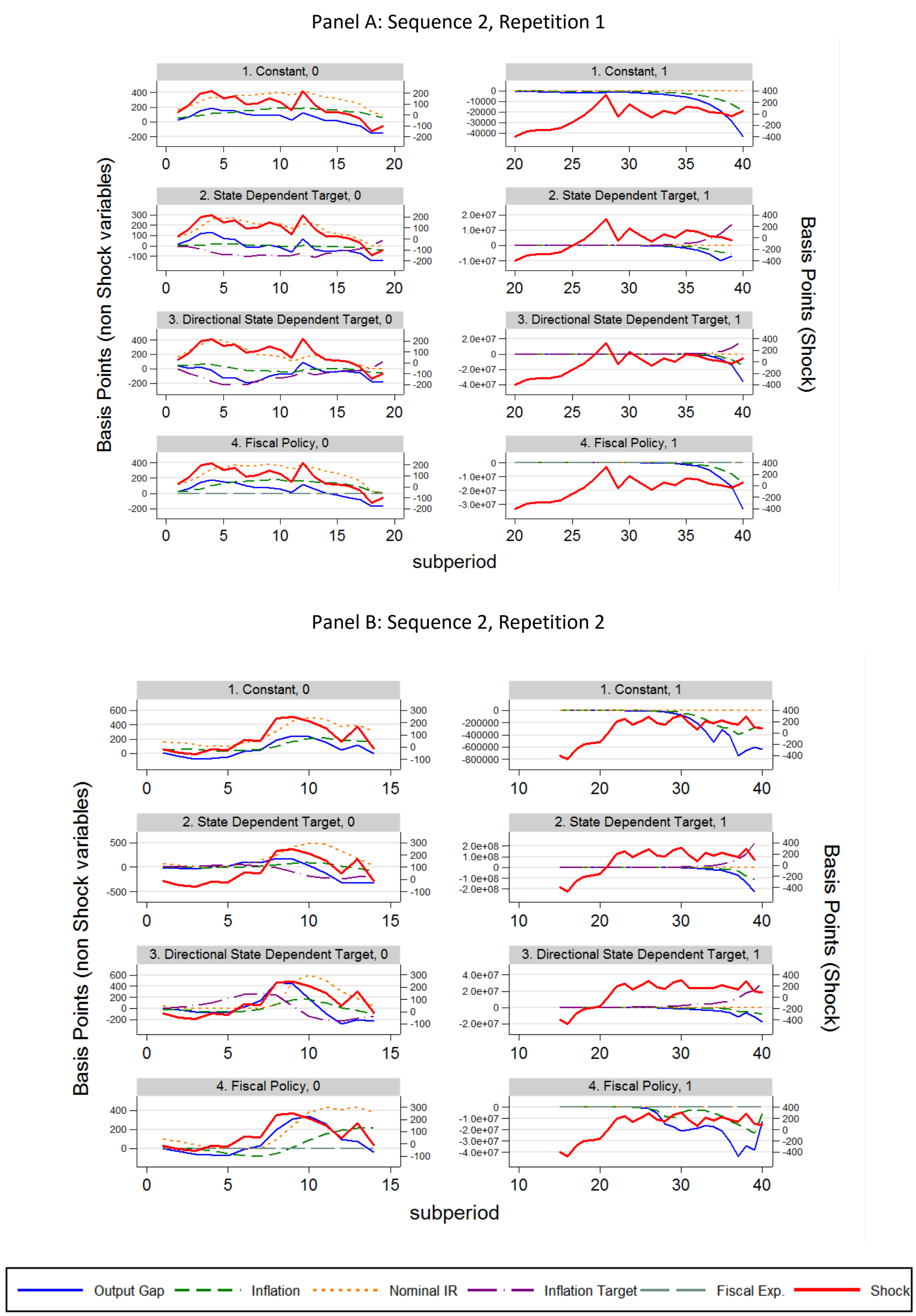


Panel B: Sequence 3, Repetition 2



Time series of aggregate variables by repetition. 0 refers to preshock outcomes and 1 refers to postshock outcomes.

Figure 4: Example of an Unstable Shock Sequences



Time series of aggregate variables by repetition. 0 refers to preshock outcomes and 1 refers to postshock outcomes.

Figure 5: Duration of Crisis by Treatment and Repetition

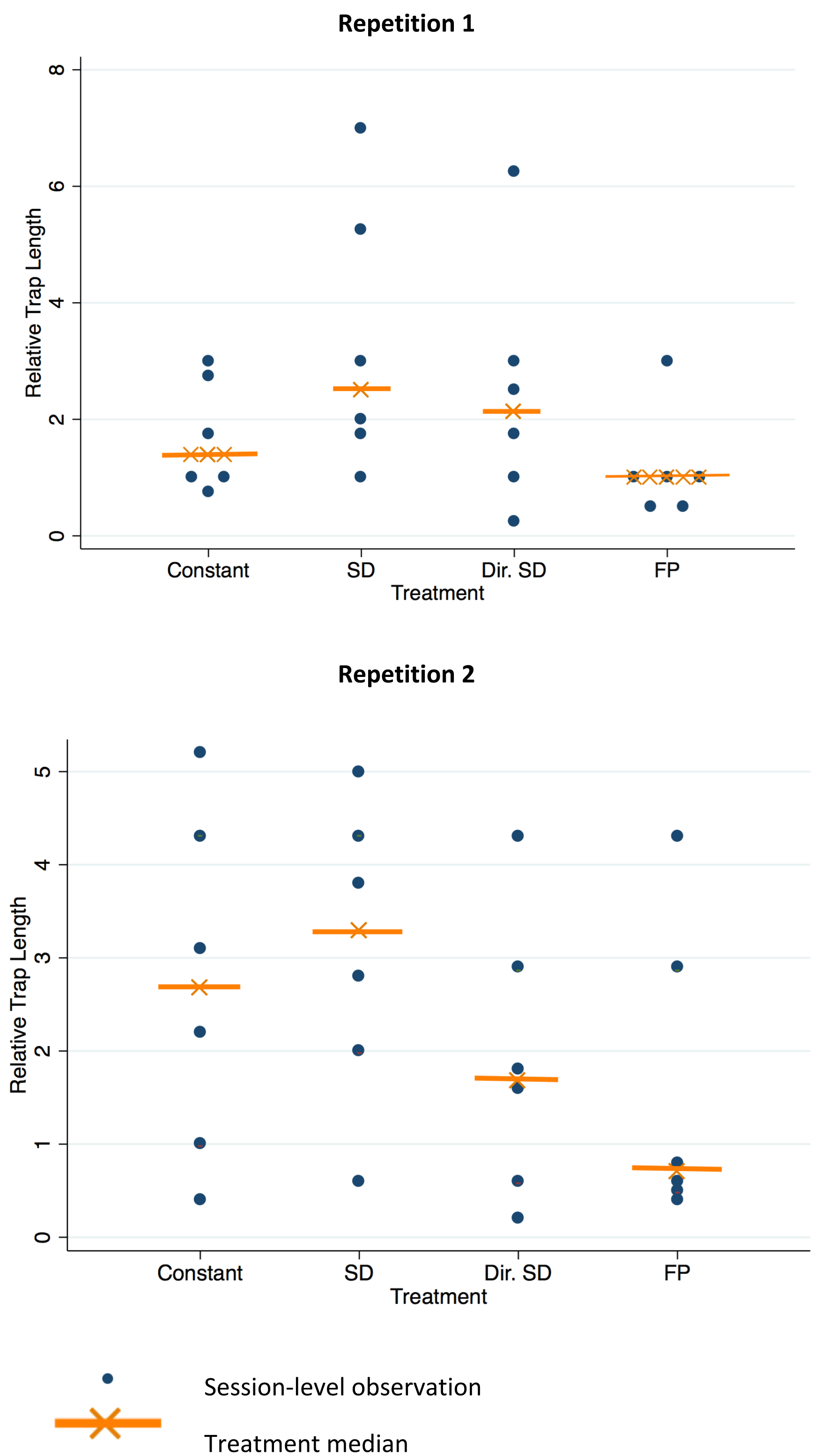


Figure 6: Inflation Variability by Treatment and Repetition

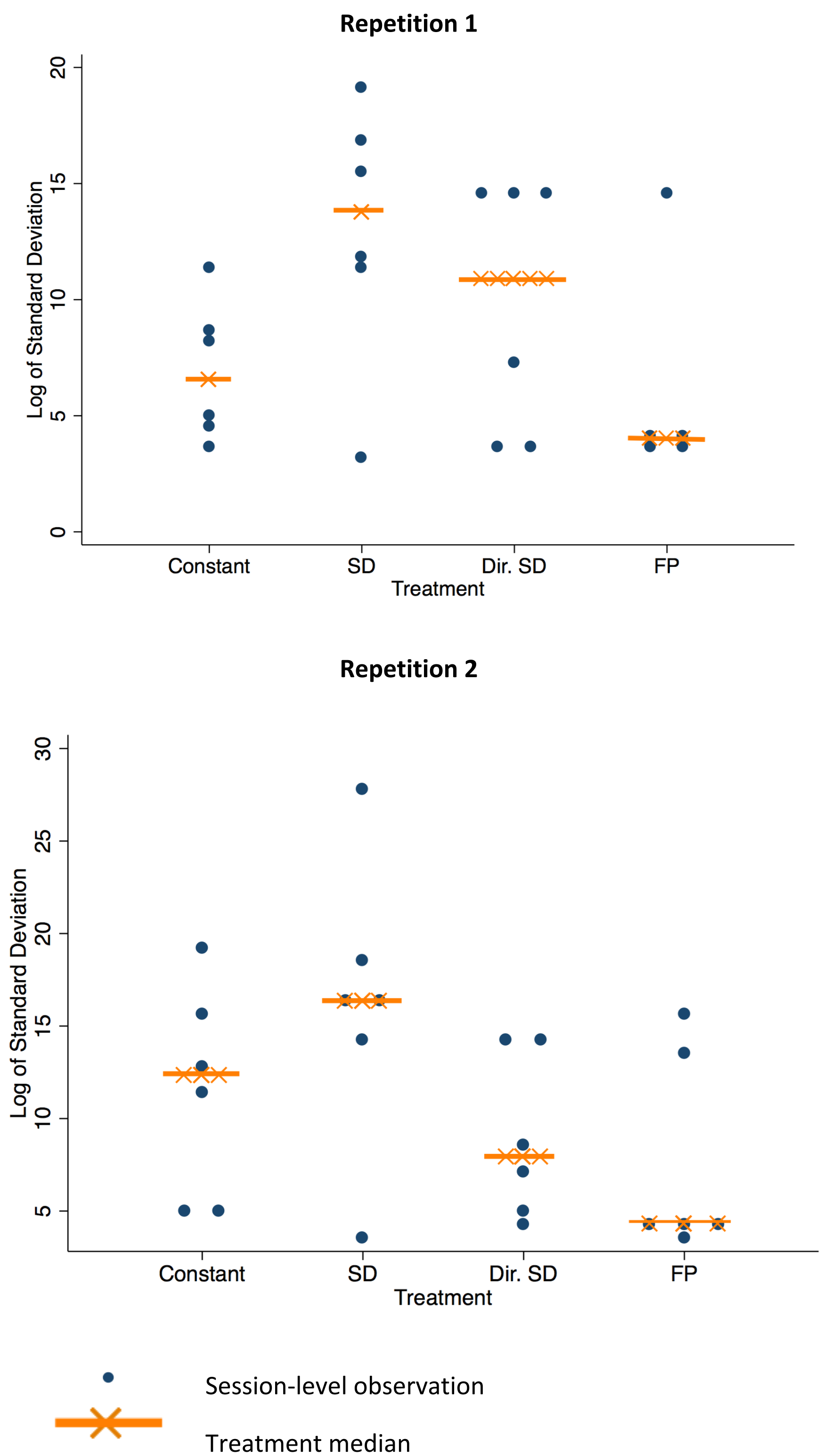


Figure 7: Stability of Economies by Length of Crisis Shock by Treatment and Repetition

7 Online Appendix - Not for Publication

Derivation of State-Dependent Inflation Targeting rule[31]

Below we discuss how we develop our non-optimal state-dependent inflation targeting rule. We are motivated by Eggertsson and Woodford's optimal price setting rule:

$$p_{t+1}^* = p_t^* + \frac{1}{\beta}(1+\kappa\sigma)\Delta_t - \frac{1}{\beta}\Delta_{t-1} \, (1)$$

where

$$\Delta_t \equiv p_t^* - \tilde{p}_t \, (2)$$

Here p_t^* denotes the price target and

$$\tilde{p} = p_t + \frac{\lambda}{\kappa}x_t \, (3)$$

refers to the output gap adjusted price level. Note that in the steady state, $\Delta_t = 0$.

We begin by defining the output gap adjusted inflation level as

$$\begin{aligned}
\tilde{\pi}_t &= \tilde{p}_t - \tilde{p}_{t-1} \Leftrightarrow \\
\tilde{\pi}_t &= (p_t - p_{t-1}) + \frac{\lambda}{\kappa}(x_t - x_{t-1}) \Leftrightarrow \\
\tilde{\pi}_t &= \pi_t + \frac{\lambda}{\kappa}(x_t - x_{t-1}) \ \ (4)
\end{aligned}$$

Equation (1) can be rewritten as

$$p_{t+1}^* = p_t^* + \frac{1}{\beta}(1+\kappa\sigma)\Delta_t - \frac{1}{\beta}\Delta_{t-1} \Leftrightarrow$$

$$p_{t+1}^* - p_t^* = \frac{1}{\beta}(1+\kappa\sigma)(p_t^* - \tilde{p}_t) - \frac{1}{\beta}\left(p_{t-1}^* - \tilde{p}_{t-1}\right) \Leftrightarrow$$

$$\pi_{t+1}^* = \frac{1}{\beta}\left(p_t^* - p_{t-1}^* - (\tilde{p}_t - \tilde{p}_{t-1})\right) + \frac{\kappa\sigma}{\beta}(p_t^* - \tilde{p}_t) \Leftrightarrow$$

$$\pi_{t+1}^* = \frac{1}{\beta}\left(p_t^* - p_{t-1}^*\right) - \frac{1}{\beta}(\tilde{p}_t - \tilde{p}_{t-1}) + \frac{\kappa\sigma}{\beta}(p_t^* - \tilde{p}_t) \Leftrightarrow$$

[31] We credit Andriy Barynskyy for this derivation.

$$\pi_{t+1}^* = \frac{1}{\beta}\pi_t^* - \frac{1}{\beta}\tilde{\pi}_t + \frac{\kappa\sigma}{\beta}\left(p_t^* - \tilde{p}_t\right) \Leftrightarrow$$

$$\pi_{t+1}^* = \frac{1}{\beta}\left(\pi_t^* - \pi_t\right) - \frac{\lambda}{\kappa\beta}\left(x_t - x_{t-1}\right) + \frac{\kappa\sigma}{\beta}\left(p_t^* - \tilde{p}_t\right) \ (5)$$

Now, the first two terms are straightforward and can be easily calculated. What about the term $\frac{\kappa\sigma}{\beta}\left(p_t^* - \tilde{p}_t\right)$?

Start with $\pi_t^* = p_t^* - p_{t-1}^*$. After rearranging, note that $p_t^* = \pi_t^* + p_{t-1}^* = \sum_{i=1}^{t}\pi_i^* + p_0^*$ (6). Similarly, $\tilde{p}_t = \sum_{i=1}^{t}\tilde{\pi}_i + \tilde{p}_0 = \sum_{i=1}^{t}\tilde{\pi}_i + p_0 + \frac{\lambda}{\kappa}x_0$ (7). If we assume that before period 1 $p_o = p_o^*$ and $x_0 = x^* = 0$, then these terms can be subtracted and we don't care about price level:

$$\begin{aligned}
\frac{\kappa\sigma}{\beta}\left(p_t^* - \tilde{p}_t\right) &= \frac{\kappa\sigma}{\beta}\left(\sum_{i=1}^{t}\pi_i^* + p_0^* - \sum_{i=1}^{t}\tilde{\pi}_i - p_0 - \frac{\lambda}{\kappa}x_0\right) \\
&= \frac{\kappa\sigma}{\beta}\left(\sum_{i=1}^{t}\pi_i^* - \sum_{i=1}^{t}\tilde{\pi}_i - \frac{\lambda}{\kappa}x_0\right) \\
&= \frac{\kappa\sigma}{\beta}\left(\sum_{i=1}^{t}\pi_i^* - \sum_{i=1}^{t}\tilde{\pi}_i\right) \ (8)
\end{aligned}$$

Now substitute (8) into (5):

$$\pi_{t+1}^* = \frac{1}{\beta}\pi_t^* - \frac{1}{\beta}\tilde{\pi}_t + \frac{\kappa\sigma}{\beta}\left(\sum_{i=1}^{t}\pi_i^* - \sum_{i=1}^{t}\tilde{\pi}_i\right) \Leftrightarrow$$

$$\pi_{t+1}^* = \frac{1}{\beta}\pi_t^* - \frac{1}{\beta}\pi_t - \frac{\lambda}{\kappa\beta}\left(x_t - x_{t-1}\right) + \frac{\kappa\sigma}{\beta}\left(\sum_{i=1}^{t}\pi_i^* - \sum_{i=1}^{t}\pi_i - \frac{\lambda}{\kappa}\sum_{i=1}^{t}\left(x_t - x_{t-1}\right)\right) \Leftrightarrow$$

$$\pi_{t+1}^* = \frac{1}{\beta}\left(\pi_t^* - \pi_t\right) - \frac{\lambda}{\kappa\beta}\left(x_t - x_{t-1}\right) + \frac{\kappa\sigma}{\beta}\left(\sum_{i=1}^{t}\pi_i^* - \sum_{i=1}^{t}\pi_i\right) - \frac{\lambda\sigma}{\beta}x_t \ (9)$$

We then use equation (9) as the central bank's inflation target when simulating the state-dependent inflation targeting rule. The inflation target is implemented in a non-optimal Taylor rule that has nominal interest rates responding to deviations of inflation from the target given by equation (9) and output gap from zero:

$$i_t = r^* + \phi_\pi(\pi_t - \pi_t^*) + \phi_x x_t$$

In designing our experiment and studying the space of parameters, we conducted simulations using social evolutionary learning agents to study dynamics in response to this state-dependent inflation targeting rule. We found in numerous simulations that the economies were highly unstable when the inflation target included the term $\frac{\kappa\sigma}{\beta}\left(\sum_{i=1}^{t}\pi_i^* - \sum_{i=1}^{t}\pi_i\right)$ due to the little weight agents placed on the target in early periods. In response to these initial simulations, we opted remove the term from equation (9) and instead implement the following which led to increased stability:

$$\pi_{t+1}^* = \frac{1}{\beta}\left(\pi_t^* - \pi_t\right) - \frac{\lambda}{\kappa\beta}\left(x_t - x_{t-1}\right) - \frac{\lambda\sigma}{\beta}x_t. \; (10)$$

Derivation of Fiscal Policy Environment[32]

In this example, we introduce government spending and taxation to the New Keynesian model. We assume that the household's log-linearized Euler equation is given by:

$$c_t = E_t c_{t+1} - \frac{1}{\sigma}(i_t - i^* - E_t \pi_{t+1} - \rho)$$

The household's log-linearized labour supply is given by

$$w_t - p_t = \sigma c_t + \eta n_t$$

where w_t and p_t are nominal wages and the price level, respectively, while n_t is employment.

Firms in this economy produce output using a contant returns to scale technology:

$$Y_t = Z_t N_t$$

Firms set prices a la Calvo, and have a fixed probability ω of being able to update their prices. Inflation is given by

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t$$

where $x_t = y_t - y_t^f$ is the output gap, defined as the log difference between the actual and flexible-price level of output.

Each period, the government makes purchases a fraction τ of the available output. Note that all output is purchased by either the household or government:

$$\begin{aligned} Y_t &= C_t + G_t \\ &= C_t + \tau Y_t \\ Y_t(1 - \tau_t) &= C_t \end{aligned}$$

Log-linearizing, we obtain

$$y_t + log(1 - \tau_t) = c_t$$

We make the assumption that all government spending is financed through lump-sum taxation:

$$g_t = -log(1 - \tau_t)$$

[32]This example comes from Galí(2015).

The government is essentially financing its expenditures by taking available output away from households.

Our next step is to construct the modified IS curve taking into consideration this government spending. This requires computing the marginal costs of the firm.

$$mc_t = w_t - p_t - mpn_t$$

The log of the marginal product of labour is z_t, so we have

$$\begin{aligned} mc_t &= w_t - p_t - z_t \\ &= \sigma c_t + \eta n_t - z_t \\ &= \sigma(y_t - g_t) + \eta(y_t - z_t) - z_t \\ &= y_t(\sigma + \eta) - \sigma g_t - z_t(1+\eta) \end{aligned}$$

We next need to compute the flexible price level of output to compute the output gap. Note that under flexible prices, this level of output occurs where marginal costs are equal to the equilibrium markup, $-\mu$:

$$\begin{aligned} -\mu &= mc_t \\ &= y_t^f(\sigma + \eta) - \sigma g_t - z_t(1+\eta) \\ y_t^f &= \frac{\sigma g_t + z_t(1+\eta)}{\sigma + \eta} \end{aligned}$$

Thus, the flexible price level of production depends positively on government spending. Increasing government spending implies the household will be able to consume less while still providing costly labour for production. As the marginal utility for consumption increases, labour supply also rises. This results in lower real wages, leading to even higher labour supply and production.

The output gap is defined as

$$\begin{aligned} x_t &= y_t - y_t^f \\ &= c_t + g_t - y_f^f \\ &= E_t c_{t+1} - \frac{1}{\sigma}(i_t - i^* - E_t \pi_{t+1} - \rho) + g_t - y_t^f \end{aligned}$$

We can write expected consumption as

$$E_t c_{t+1} = E_t x_{t+1} - E_t g_{t+1} + E_t y^f_{t+1}$$

Substituting the above equation into the output gap, we obtain:

$$\begin{aligned} x_t &= E_t x_{t+1} - E_t g_{t+1} + E_t y^f_{t+1} - \frac{1}{\sigma}(i_t - i^* - E_t \pi_{t+1} - \rho) + g_t - y^f_t \\ &= E_t x_{t+1} - \frac{1}{\sigma}(i_t - i^* - E_t \pi_{t+1} - \rho) + [g_t - E_t g_{t+1}] + \left[E_t y^f_{t+1} - y^f_t\right] \end{aligned}$$

Note that $E_t y^f_{t+1} = \frac{\sigma g_{t+1} + z_{t+1}(1+\eta)}{\sigma+\eta}$.

$$\begin{aligned} x_t &= E_t x_{t+1} - \frac{1}{\sigma}(i_t - i^* - E_t \pi_{t+1} - \rho) + [g_t - E_t g_{t+1}] + \\ &\quad \left[\frac{\sigma g_{t+1} + z_{t+1}(1+\eta)}{\sigma+\eta} - \frac{\sigma g_t + z_t(1+\eta)}{\sigma+\eta}\right] \\ &= E_t x_{t+1} - \frac{1}{\sigma}(i_t - i^* - E_t \pi_{t+1} - \rho) + [g_t - E_t g_{t+1}] \\ &\quad + \frac{\sigma}{\sigma+\eta}[E_t g_{t+1} - g_t] + \frac{1+\eta}{\sigma+\eta}[E_t z_{t+1} - z_t] \\ &= E_t x_{t+1} - \frac{1}{\sigma}(i_t - i^* - E_t \pi_{t+1} - \rho) + \frac{\eta}{\sigma+\eta}[g_t - E_t g_{t+1}] + \frac{1+\eta}{\sigma+\eta}[E_t z_{t+1} - z_t] \end{aligned}$$

Returning to our NKPC calibration, note that

$$\kappa = (\sigma + \eta)(1 - \omega)(1 - \beta\omega)/\omega$$

If $\beta = 0.995$, $\kappa = 0.13$, $\sigma = 1$, and $\omega = 0.853$, then $\eta = 3.99$. This implies that

$$\begin{aligned} x_t &= E_t x_{t+1} - (i_t - i^* - E_t \pi_{t+1} - \rho) + 0.799\,[g_t - E_t g_{t+1}] + [E_t z_{t+1} - z_t] \\ &= E_t x_{t+1} - (i_t - i^* - E_t \pi_{t+1} - \rho) + 0.799\,[1 - \rho_g]\, g_t + [E_t z_{t+1} - z_t] \end{aligned}$$

In our experiment, we assume that government spending behaves persistently, with $\rho_g = 0.8$. We begin with $g_t = 1250$ units of spending, which translates into a positive net effect on the output gap of 200 basis points. This government spending dissipates at a rates of ρ_g.

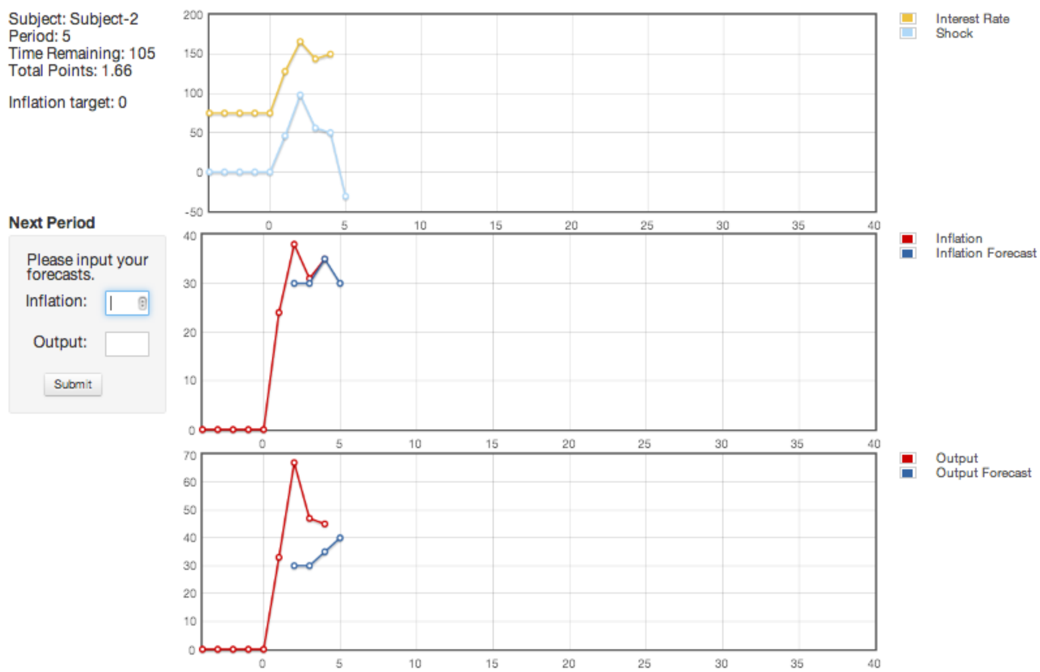


Figure 8: *Constant Target* and *Fiscal Policy* Treatment Screenshot

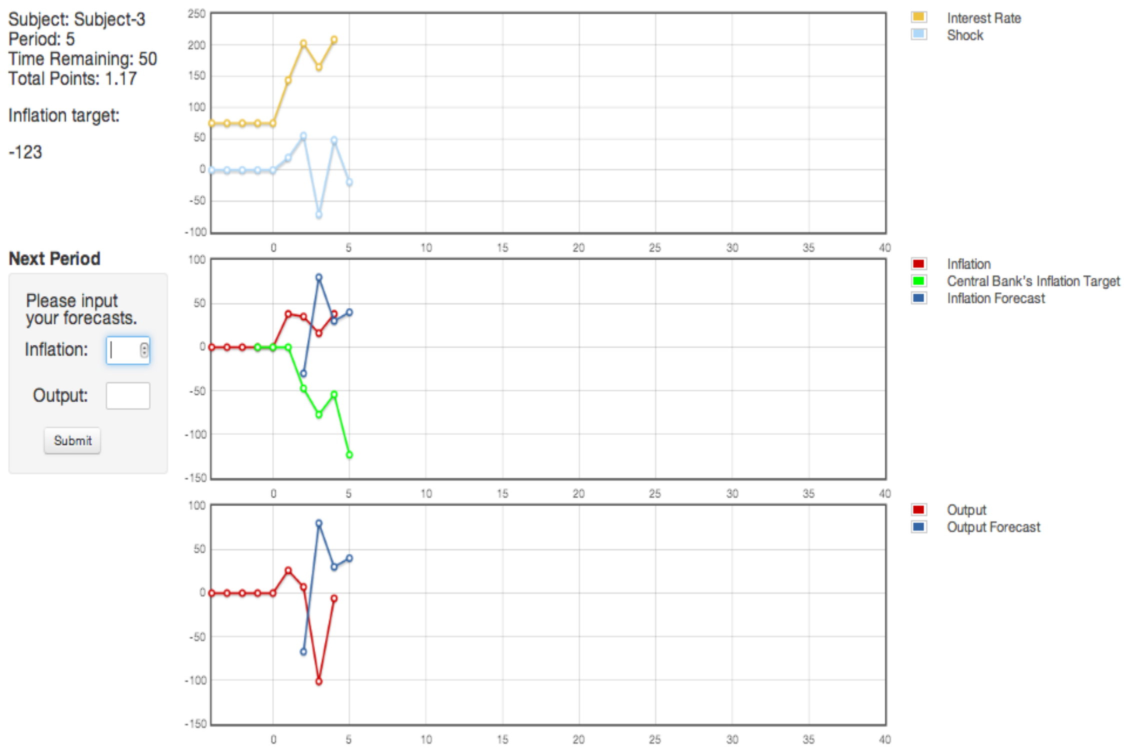


Figure 9: State Dependent Target Treatment Screenshot

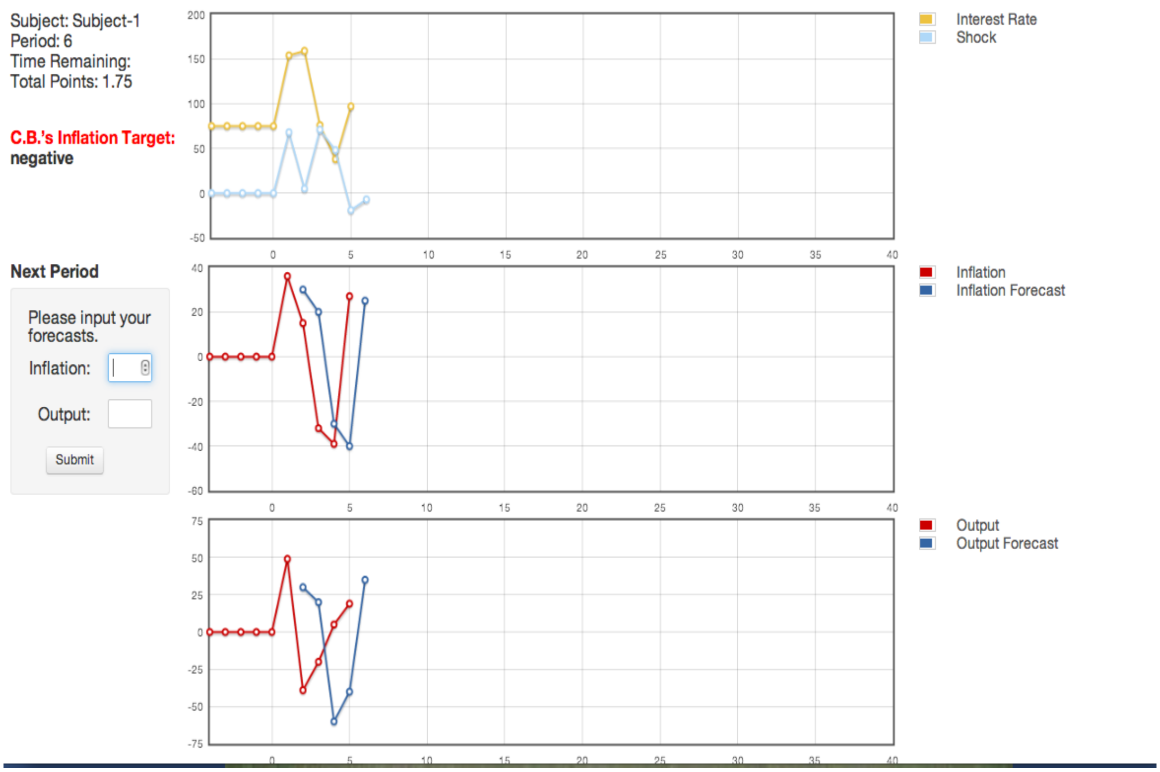


Figure 10: Directional State Dependent Target Treatment Screenshot

Experimental Instructions for Constant Target Treatment

Welcome! You are participating in an economics experiment at CRABE Lab. In this experiment you will participate in the experimental simulation of the economy. If you read these instructions carefully and make appropriate decisions, you may earn a considerable amount of money that will be immediately paid out to you in cash at the end of the experiment.

Each participant is paid CDN$7 for attending. Throughout this experiment you will also earn points based on the decisions you make. Every point you earn is worth $0.50. We reserve the right to improve this in your favour if average payoffs are lower than expected.

During the experiment you are not allowed to communicate with other participants. If you have any questions, the experimenter will be glad to answer them privately. If you do not comply with these instructions, you will be excluded from the experiment and deprived of all payments aside from the minimum payment of CDN $7 for attending.

The experiment is based on a simple simulation that approximates fluctuations in the real economy. Your task is to serve as private forecasters and provide real-time forecasts about future output and inflation in this simulated economy. The instructions will explain what output, inflation, and the interest rate are and how they move around in this economy, as well as how they depend on forecasts. You will also have a chance to try it out in a practice demonstration.

In this simulation, households and firms (whose decisions are automated by the computer) will form forecasts identically to yours. So to some degree, outcomes that you will see in the game will depend on the way in which all of you form your forecasts. Your earnings in this experiment will depend on the accuracy of your individual forecasts.

Below we will discuss what inflation and output are, and how to predict them. All values will be given in basis points, a measurement often used in descriptions of the economy. All values can be positive, negative, or zero at any point in time.

Score

Your score will depend on the accuracy of your inflation and output gap forecasts. The absolute difference between your forecasts and the actual values for output and inflation are your absolute forecast errors.

Absolute Forecast Error = absolute (Your Forecast – Actual Value)
Total Score = 0.30(2^-0.01(Forecast Error for Output)) + 0.30(2^-0.01 (Forecast Error for Inflation))

The maximum score you can earn each period is 0.6 points.
Your score will decrease as your forecast error increases. Suppose your forecast errors for each of output and inflation are:

0	-Your score will be 0.6	300	-Your score will be 0.075
50	-Your score will be 0.42	500	-Your score will be 0.02
100	-Your score will be 0.3	1000	-Your score will be 0
200	-Your score will be 0.15	2000	-Your score will be 0

Information about the Interface, Actions, and Payoffs

During the experiment, your main screen will display information that will help you make forecasts and earn more points.

At the top left of the screen, you will see your subject number, the current period, time remaining, and the total number of points earned. Below that you will see the interest rate for the current period. You will also see three history plots. The top history plot displays past interest rates and shocks. The second plot displays your past forecast of inflation and realized inflation levels. The final plot displays your past forecasts of inflation and realized inflation levels. The difference between your forecasts and the actual realized levels constitutes your forecast errors. Your forecasts will always be shown in blue while the realized value will be shown in red. You can see the exact value for each point on a graph by placing your mouse at that point.

When the first period begins, you will have 65 seconds to submit new forecasts for the next period's inflation and output levels. You may submit both negative and positive forecasts. Please review your forecasts before pressing the SUBMIT button. Once the SUBMIT button has been clicked, you will not be able to revise your forecasts until the next period. You will earn zero points if you do not submit all three forecasts. After the first 9 periods, the amount of time available to make a decision will drop to 50 seconds per period.

You will participate in two sequences of 40 periods, for a total of 80 periods of play. Your score, converted into Canadian dollars, plus the show up fee will be paid to you in cash at the end of the experiment.

INFORMATION SHARED WITH ALL PARTICIPANTS

Each period, you will receive the following information to help you make forecasts.

Interest Rate

The interest rate is the rate at which consumers and firms borrow and save in this experimental economy. The central bank's objective is to keep the economy stable. It responds to changes in the current level of output and inflation from the long run target of zero. The central bank aims to keep inflation at a level of 0 basis points per period by adjusting the interest rate. This will imply that, on average, the interest rate will be 75 basis points. The interest rate can be as low as zero and there is no limit on how high it can be.

Depends on: **Inflation in the current period (+)**

Example: If inflation increases today, the nominal interest rate will increase. If inflation decreases, the interest rate will be decrease.

Depends on: **Output in the current period (+)**

Example: If output increases in the current period, the nominal interest rate will increase. If it decreases, the interest rate will decrease.

Question: If inflation and output are -10 and -20, respectively, what sign will the interest rate be? __________.
What if inflation is -10 and output is 20?_________

Current Shock

A shock is a random "event" that affects output. E.g. A natural disaster can suddenly destroy crops, or a technological discovery immediately improves productivity.

Depends on: **Random Draw**

The central bank in the economy predicts that the shock will be relatively small most of the time. Two-thirds of the time it will fall between -93 and 93 basis points, and 95% of the time it will fall between -186 and 186 basis points. On average, it will be 0.

Every shock takes some time to dissipate. Suppose the shock in the current period is 100. Next period, that shock will now be 80% of 100, or 80 basis points. Assuming no new shocks were to occur, the value of the shock next period is 80 points. Some shock is likely to occur.

Shock Forecast

The shock forecast is a prediction of what the shock will be next period. It assumes that, on average, next period's shock is zero.

Example: If the current shock is -200 points, the forecasted value of the shock tomorrow is -200(0.80) = -160

HOW INFLATION AND OUTPUT ARE DETERMINED

You will be making forecasts about what you believe inflation and output will be tomorrow, as well as inflation four periods into the future.

1. ***Inflation***

Inflation is the rate at which overall prices change between two periods.

Depends on: **Forecasted inflation in the next period (+)**

Example: If the median subject forecasts future inflation to be positive, current inflation will be positive, and vice versa.

Question: Holding all else constant, will current inflation be positive or negative if the median forecast for future inflation is -20? __________________.

Current output (+)

Example: If current output is positive, current inflation will be positive. If current output is negative, current output will be negative.

Question: Holding all else constant, what sign is current inflation if current output is 50?______0?__________

2. ***Output***

Output refers to a measure of the quantity of goods produced in a given period.

Depends on: **Forecasted output in the next period (+)**

Example: If the median subject forecasts future output to be positive, current output will also be positive.

Question: Holding all else constant, will output be positive or negative if the median subject forecasts output to be -15 points next period?______________

Forecasted inflation in the next period (+)

Example: If the median subject forecasts inflation to be positive next period, current output will likely be positive.

Question: Holding all else constant, what sign will output be if the median subject forecasts inflation to be 250 points next period?______________. What sign will inflation have? ____________.

Current interest rate (-)

Example: If the current interest rate is positive, current output will be negative.

Question: Holding all else constant, what sign will output be if interest rates are 10? _______________ What sign will inflation have? ______________

Random Shocks (+)

Example: Positive shocks will have a positive effect on output. Negative shocks will have a negative effect on output.

Question: Holding all else constant, what sign will output be if the shock is -50?__________ . What sign will inflation have? _________________

How the economy evolves

You will submit forecasts for the next period's inflation and output, measured in basis points:
1% = 100 basis points
3.25% = 325 basis points
-0.5% = -50 basis points
-4.8% = -480 basis points

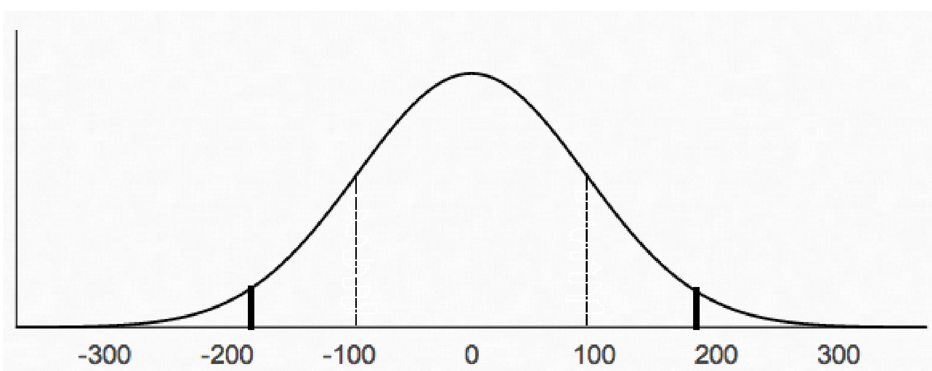
The economy consists of four main variables:

- Inflation, Output, Interest Rate, Shocks

At any time, t, the values of these variables will be calculated as follows:

$Shock_t = 0.8(Shock_{t-1}) + Random\ Component_t$

- The random component is 0 on average.
- Roughly two out of three times the shock will be between -93 and 93 basis points.
- 95% of the time the shock will be between -186 and 186 basis points.



E.g.

$$
\begin{aligned}
Shock_1 &= 30 \\
Shock_2 &= 30 \times 0.8 + New\ Draw \\
&= 24 + (30) \\
&= 54 \\
Shock_2 &= 24 + (-150) \\
&= -126
\end{aligned}
$$

How the economy evolves:

$Inflation_t = 0.995(\text{Median forecast of Inflation}_{t+1}) + 0.13(\text{ Output}_t)$

$Output_t = \text{Median forecast of Output}_{t+1} + \text{Median forecast of Inflation}_{t+1} - Interest\ Rate_t + Shock_t + 75$

$Interest\ Rate_t = 75 + 1.5(Inflation_t - Inflation\ Target_t) + 0.5(Output_t)$

$Inflation\ Target_t{=}0$

- The interest rate can never go below 0. If inflation or output become sufficiently negative, the interest rate will be zero.
- The Central Bank's inflation target will always be 0. Its goal is to keep inflation and output at 0.
- Expectations are self-fulfilling in this economy. If the median subject forecasts higher inflation and output in the future, both inflation and output will grow higher in the current period. Similarly, median forecasts of negative inflation and output will cause the economy to recede in the current period.

How the economy evolves

You will submit forecasts for the next period's inflation and output, measured in basis points:
1% = 100 basis points
3.25% = 325 basis points
-0.5% = -50 basis points
-4.8% = -480 basis points

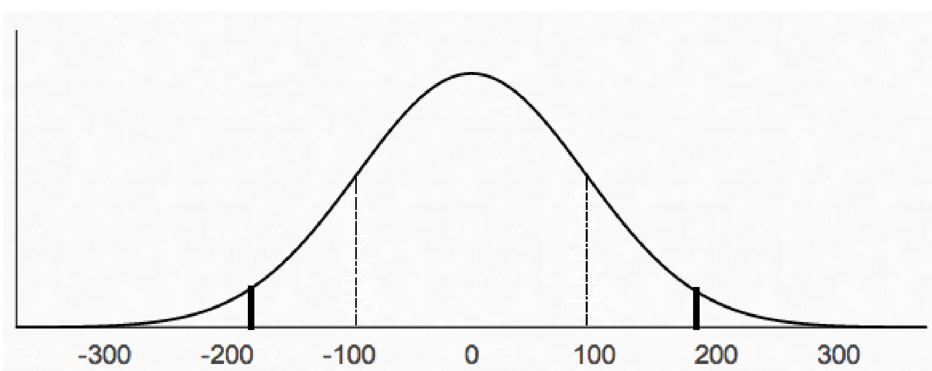
The economy consists of four main variables:

- Inflation, Output, Interest Rate, Shocks

At any time, t, the values of these variables will be calculated as follows:

$Shock_t = 0.8(Shock_{t-1}) + Random\ Component_t$

- The random component is 0 on average.
- Roughly two out of three times the shock will be between -93 and 93 basis points.
- 95% of the time the shock will be between -186 and 186 basis points.



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How the economy evolves:

$$Inflation_t = 0.995(\text{Median forecast of Inflation}_{t+1}) + 0.13(\text{ Output}_t)$$

$$Output_t = \text{Median forecast of Output}_{t+1} + \text{Median forecast of Inflation}_{t+1} - Interest\ Rate_t + Shock_t + 75$$

$$Interest\ Rate_t = 75 + 1.5(Inflation_t - Inflation\ Target_t) + 0.5(Output_t)$$

$$Inflation\ Target_t = (Inflation\ Target_{t-1} - Inflation_{t-1}) - 0.33(Output_{t-1} - Output_{t-2}) - 0.004 Output_{t-1}$$

- The interest rate can never go below 0. If inflation or output become sufficiently negative, the interest rate will be zero.
- The Central Bank's inflation target will always be changing in response to the economy. Its goal is to keep inflation and output at 0.
  - If the economy is in a recession and past inflation is lower than the Bank's target, the target will be raised. The Bank will promise to allow for higher inflation for at least a couple of periods after the economy comes out of a recession.
  - If the economy has been growing above the Bank's target and past inflation is higher than the Bank's target, the target will be lowered. The Bank will raise interest rates more aggressively to reduce inflation. This will also persist for at least a couple of periods after the economy returns to its steady state levels.

Experimental Instructions for Constant Target Treatment

Welcome! You are participating in an economics experiment at CRABE Lab. In this experiment you will participate in the experimental simulation of the economy. If you read these instructions carefully and make appropriate decisions, you may earn a considerable amount of money that will be immediately paid out to you in cash at the end of the experiment.

Each participant is paid CDN$7 for attending. Throughout this experiment you will also earn points based on the decisions you make. Every point you earn is worth $0.50. We reserve the right to improve this exchange rate in your favour if average payoffs are lower than expected.

During the experiment you are not allowed to communicate with other participants. If you have any questions, the experimenter will be glad to answer them privately. If you do not comply with these instructions, you will be excluded from the experiment and deprived of all payments aside from the minimum payment of CDN $7 for attending.

The experiment is based on a simple simulation that approximates fluctuations in the real economy. Your task is to serve as private forecasters and provide real-time forecasts about future output and inflation in this simulated economy. The instructions will explain what output, inflation, and the interest rate are and how they move around in this economy, as well as how they depend on forecasts. You will also have a chance to try it out in a practice demonstration.

In this simulation, households and firms (whose decisions are automated by the computer) will form forecasts identically to yours. So to some degree, outcomes that you will see in the game will depend on the way in which all of you form your forecasts. Your earnings in this experiment will depend on the accuracy of your individual forecasts.

Below we will discuss what inflation and output are, and how to predict them. All values will be given in basis points, a measurement often used in descriptions of the economy. All values can be positive, negative, or zero at any point in time.

Score

Your score will depend on the accuracy of your inflation and output gap forecasts. The absolute difference between your forecasts and the actual values for output and inflation are your absolute forecast errors.

Absolute Forecast Error = absolute (Your Forecast – Actual Value)
Total Score = 0.30(2^-0.01(Forecast Error for Output)) + 0.30(2^-0.01 (Forecast Error for Inflation))

The maximum score you can earn each period is 0.6 points.
Your score will decrease as your forecast error increases. Suppose your forecast errors for each of output and inflation are:

0	-Your score will be 0.6	300	-Your score will be 0.075
50	-Your score will be 0.42	500	-Your score will be 0.02
100	-Your score will be 0.3	1000	-Your score will be 0
200	-Your score will be 0.15	2000	-Your score will be 0

Information about the Interface, Actions, and Payoffs

During the experiment, your main screen will display information that will help you make forecasts and earn more points.

At the top left of the screen, you will see your subject number, the current period, time remaining, and the total number of points earned. Below that you will see the interest rate for the current period. You will also see three history plots. The top history plot displays past interest rates and shocks, as well as past, current, and next period's government spending or taxation. The second plot displays your past forecast of inflation and realized inflation levels. The final plot displays your past forecasts of inflation and realized inflation levels. The difference between your forecasts and the actual realized levels constitutes your forecast errors. Your forecasts will always be shown in blue while the realized value will be shown in red. You can see the exact value for each point on a graph by placing your mouse at that point.

When the first period begins, you will have 65 seconds to submit new forecasts for the next period's inflation and output levels. You may submit both negative and positive forecasts. Please review your forecasts before pressing the SUBMIT button. Once the SUBMIT button has been clicked, you will not be able to revise your forecasts until the next period. You will earn zero points if you do not submit all three forecasts. After the first 9 periods, the amount of time available to make a decision will drop to 50 seconds per period.

You will participate in two sequences of 40 periods, for a total of 80 periods of play. Your score, converted into Canadian dollars, plus the show up fee will be paid to you in cash at the end of the experiment.

INFORMATION SHARED WITH ALL PARTICIPANTS

Each period, you will receive the following information to help you make forecasts.

Interest Rate

The interest rate is the rate at which consumers and firms borrow and save in this experimental economy. The central bank's objective is to keep the economy stable. It responds to changes in the current level of output and inflation from the long run target of zero. The central bank aims to keep inflation at a level of 0 basis points per period by adjusting the interest rate. This will imply that, on average, the interest rate will be 75 basis points. The interest rate can be as low as zero and there is no limit on how high it can be.

Depends on: **Inflation in the current period (+)**

Example: If inflation increases today, the nominal interest rate will increase. If inflation decreases, the interest rate will be decrease.

Depends on: **Output in the current period (+)**

Example: If output increases in the current period, the nominal interest rate will increase. If it decreases, the interest rate will decrease.

Question: If inflation and output are -10 and -20, respectively, what sign will the interest rate be? __________. What if inflation is -10 and output is 20?________

Current Shock

A shock is a random "event" that affects output. E.g. A natural disaster can suddenly destroy crops, or a technological discovery immediately improves productivity.

Depends on: **Random Draw**

The central bank in the economy predicts that the shock will be relatively small most of the time. Two-thirds of the time it will fall between -93 and 93 basis points, and 95% of the time it will fall between -186 and 186 basis points. On average, it will be 0.

Every shock takes some time to dissipate. Suppose the shock in the current period is 100. Next period, that shock will now be 80% of 100, or 80 basis points. Assuming no new shocks were to occur, the value of the shock next period is 80 points. Some shock is likely to occur.

Shock Forecast

The shock forecast is a prediction of what the shock will be next period. It assumes that, on average, next period's shock is zero.

Example: If the current shock is -200 points, the forecasted value of the shock tomorrow is -200(0.80) = -160

Government Expenditures

Government expenditures indicate how much output will increase or decrease due to government spending or taxation. The government always balances its budget each period, meaning it does not carry debt or a surplus across periods.

HOW INFLATION AND OUTPUT ARE DETERMINED

You will be making forecasts about what you believe inflation and output will be tomorrow, as well as inflation four periods into the future.

1. ***Inflation***

Inflation is the rate at which overall prices change between two periods.

Depends on: **Forecasted inflation in the next period (+)**

Example: If the median subject forecasts future inflation to be positive, current inflation will be positive, and vice versa.

Question: Holding all else constant, will current inflation be positive or negative if the median forecast for future inflation is -20? _________________.

Current output (+)

Example: If current output is positive, current inflation will be positive. If current output is negative, current output will be negative.

Question: Holding all else constant, what sign is current inflation if current output is 50?______0?_________

2. ***Output***

Output refers to a measure of the quantity of goods produced in a given period.

Depends on: **Forecasted output in the next period (+)**

Example: If the median subject forecasts future output to be positive, current output will also be positive.

Question: Holding all else constant, will output be positive or negative if the median subject forecasts output to be -15 points next period?_____________

Forecasted inflation in the next period (+)

Example: If the median subject forecasts inflation to be positive next period, current output will likely be positive.

Question: Holding all else constant, what sign will output be if the median subject forecasts inflation to be 250 points next period?_____________. What sign will inflation have? ___________.

Current interest rate (-)

Example: If the current interest rate is positive, current output will be negative.

Question: Holding all else constant, what sign will output be if interest rates are 10? ______________ What sign will inflation have? _____________

Random Shocks (+)

Example: Positive shocks will have a positive effect on output. Negative shocks will have a negative effect on output.

Question: Holding all else constant, what sign will output be if the shock is -50?_________ . What sign will inflation have? ________________

Government Expenditures (+)

Example: Positive government expenditures will have a positive effect on output. Negative expenditures will have a negative effect on output.

Question: Holding all else constant, what sign will output be if government expenditures is 40?_________ . What sign will inflation have? ________________

How the economy evolves

You will submit forecasts for the next period's inflation and output, measured in basis points:
1% = 100 basis points
3.25% = 325 basis points
-0.5% = -50 basis points
-4.8% = -480 basis points

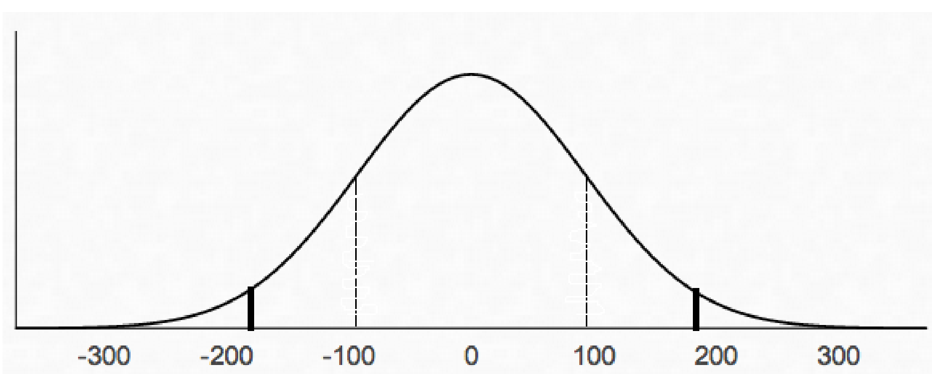
The economy consists of five main variables:

- Inflation, Output, Interest Rate, Government Spending, Shocks

At any time, t, the values of these variables will be calculated as follows:

$Shock_t = 0.8(Shock_{t-1}) + Random\ Component_t$

- The random component is 0 on average.
- Roughly two out of three times the shock will be between -93 and 93 basis points.
- 95% of the time the shock will be between -186 and 186 basis points.



E.g.

$$\begin{aligned} Shock_1 &= 30 \\ Shock_2 &= 30 \times 0.8 + New\ Draw \\ &= 24 + (30) \\ &= 54 \\ Shock_2 &= 24 + (-150) \\ &= -126 \end{aligned}$$

How the economy evolves:

$$Inflation_t = 0.995(Median\ forecast\ of\ Inflation_{t+1}) + 0.13(Output_t)$$

$$Output_t = Median\ forecast\ of\ Output_{t+1} + Median\ forecast\ of\ Inflation_{t+1} - Interest\ Rate_t + Effect\ of\ Government\ Expenditures_t + Shock_t + 75$$

$$Interest\ Rate_t = 75 + 1.5(Inflation_t - Inflation\ Target_t) + 0.5(Output_t)$$

where,

$Inflation\ Target_t$=0

- The government will occasionally spend money to stimulate demand or tax to reduce demand. At any point in time, you will see the overall effect of the government's planned expenditures or taxation for the next period on output. Note that the government balances its budget each period. That is, it does not carry a debt or a surplus into future periods. There is no uncertainty about the following period's government spending.
- The interest rate can never go below 0. If inflation or output become sufficiently negative, the interest rate will be zero.
- The Central Bank's inflation target will always be 0. Its goal is to keep inflation and output at 0.
- Expectations are self-fulfilling in this economy. If the median subject forecasts higher inflation and output in the future, both inflation and output will grow higher in the current period. Similarly, median forecasts of negative inflation and output will cause the economy to recede in the current period.

8 Heterogeneity

We next consider how expectations evolve under various forecasting heuristics: *rational*, where forecasts condition solely on the fundamental shock, *naive*, where forecasts condition solely on past realized output or inflation, and *trend-chasing* where forecasts condition on the change in output or inflation over the past two periods. For each phase of each repetition, we run the following OLS regressions for each individual i: $E_{i,t}x_{t+1} = \alpha + \beta r_t^n + \epsilon_t$, $E_{i,t}x_{t+1} = \alpha + \beta x_{t-1} + \epsilon_t$, and $E_{i,t}x_{t+1} = \alpha + \beta(x_{t-1} - x_{t-2}) + \epsilon_t$. For the state-dependent inflation targeting treatments, we also estimate each individual's responsiveness to the the central bank's evolving inflation target using the following regression equation: $E_{i,t}x_{t+1} = \alpha + \beta\pi_t^* + \epsilon_t$. Finally, for the *FP* treatments, we estimate subjects' responsiveness to fiscal policy: $E_{i,t}x_{t+1} = \alpha + \beta_1 r_t^n + \beta_2 g_t + \epsilon_t$.[33] These heuristics are motivated by extensive survey evidence of households and professional forecasts, as well as laboratory experimental studies that demonstrate significant evidence of backward-looking, rigid expectations (e.g. Pfajfar and Santoro (2010), Hommes (2011), Coibion and Gorodnichenko, (2012), Assenza et al. (2013), Andrade and Le Bihan (2013)). Individual subject estimation results are presented as cumulative distribution functions in Figures 11 to 15.

[33] All these variables are known to participants in period t when formulating their period $t+1$ forecasts.

Table 7: Rationality of Output and Inflation Forecasts, by Phase and Treatment [I]

Dep. Var.:	Preshock				Postshock - $CrisisShockLength \leq 5$				Postshock - $CrisisShockLength > 5$			
Output Forecast Error	*Constant*	*SD*	*Dir. SD*	*FP*	*Constant*	*SD*	*Dir. SD*	*FP*	*Constant*	*SD*	*Dir. SD*	*FP*
ϵ_t	-0.411***	-3.037	-0.474***	-0.484***	-0.374*	1769.803	7.124***	-0.408***	-1487.872	30433.760***	645.855	85.894
	(0.05)	(2.12)	(0.06)	(0.05)	(0.21)	(3146.93)	(1.80)	(0.05)	(1876.55)	(10142.89)	(750.18)	(106.49)
ϵ_{t-1}	-0.241***	-13.433	-0.014	-0.238***	-0.530***	-171.631	10.624***	-0.092***	-2240.641	18356.987***	1076.833***	-18.332
	(0.06)	(14.22)	(0.08)	(0.04)	(0.07)	(555.76)	(3.16)	(0.03)	(1807.08)	(6101.98)	(337.43)	(55.47)
ϵ_{t-2}	0.156***	-6.238	0.346***	0.181***	-0.100	-237.106	10.195***	0.046**	-1351.086	20703.079***	317.953*	-56.249
	(0.06)	(9.49)	(0.08)	(0.04)	(0.08)	(574.23)	(2.80)	(0.02)	(1421.29)	(7229.77)	(182.65)	(107.68)
ϵ_{t-3}	-0.052	-4.506	0.233***	0.118***	-0.111*	-82.791	14.198***	0.118***	-902.396	15519.755***	564.654**	-65.715
	(0.06)	(6.71)	(0.07)	(0.04)	(0.06)	(311.45)	(4.36)	(0.02)	(746.11)	(4534.84)	(217.82)	(109.14)
ϵ_{t-4}	-0.293***	-6.118	-0.017	-0.079*	0.314***	-370.362	13.556***	0.116***	-1821.159	16900.477***	851.143***	-31.321
	(0.06)	(6.74)	(0.06)	(0.04)	(0.07)	(1061.62)	(4.38)	(0.02)	(1459.84)	(5275.64)	(275.79)	(61.95)
α	73.465***	1426.753*	70.537***	27.191***	59.215***	-211776.222	4192.812***	4.831**	-650500.603***	7393252.412***	370672.121***	-13875.633
	(3.26)	(727.23)	(4.41)	(2.18)	(8.24)	(162030.14)	(147.72)	(2.08)	(219351.76)	(984989.73)	(35035.98)	(16733.39)
N	1303	1314	1230	1290	471	468	464	483	408	465	461	445
F	21.91	6.568	35.41	43.32	20.43	2.658	4.292	35.43	0.558	5.637	2.390	10.35

Dep. Var.:	Preshock				Postshock - $CrisisShockLength \leq 5$				Postshock - $CrisisShockLength > 5$			
Inflation Forecast Error	*Constant*	*SD*	*Dir. SD*	*FP*	*Constant*	*SD*	*Dir. SD*	*FP*	*Constant*	*SD*	*Dir. SD*	*FP*
ϵ_t	-0.134***	-2.579	-0.223***	-0.162***	-0.083	-673.195**	2.922***	-0.121***	62.969	3901.629	817.657	-18.068**
	(0.03)	(2.06)	(0.03)	(0.02)	(0.07)	(287.10)	(0.87)	(0.01)	(90.25)	(6854.81)	(612.95)	(7.12)
ϵ_{t-1}	-0.103***	-14.604	-0.164***	-0.188***	-0.125***	180.936***	4.494***	-0.111***	-0.370	1917.248	-1119.509	19.900***
	(0.03)	(14.15)	(0.03)	(0.01)	(0.03)	(53.64)	(1.27)	(0.01)	(72.05)	(3364.13)	(1738.48)	(5.38)
ϵ_{t-2}	-0.008	-8.651	-0.072***	-0.073***	-0.077**	155.342**	4.041***	-0.070***	-41.291	3459.280	194.880*	31.462***
	(0.02)	(9.44)	(0.02)	(0.02)	(0.03)	(63.78)	(1.16)	(0.01)	(66.30)	(4401.48)	(99.31)	(8.19)
ϵ_{t-3}	-0.103***	-6.270	-0.067***	-0.073***	-0.053*	93.045**	6.357***	-0.037***	-85.912	813.440	-130.332	28.607***
	(0.03)	(6.70)	(0.02)	(0.02)	(0.03)	(36.94)	(2.01)	(0.01)	(120.33)	(3535.68)	(441.08)	(7.39)
ϵ_{t-4}	-0.161***	-6.964	-0.022	-0.099***	0.068**	342.751***	4.798***	-0.000	2.560	2948.230	-240.801	18.099***
	(0.03)	(6.71)	(0.02)	(0.01)	(0.03)	(104.59)	(1.57)	(0.01)	(47.61)	(2879.15)	(691.39)	(5.22)
α	12.564***	1542.232**	31.811***	0.856	26.694***	124527.555***	1757.297***	-12.166***	-14196.402	982213.132*	-117126.031	8666.116***
	(1.63)	(725.12)	(1.47)	(0.88)	(2.82)	(14788.85)	(52.20)	(0.65)	(15965.16)	(528107.21)	(110755.69)	(1259.85)
N	1303	1314	1230	1290	471	468	464	483	408	465	461	445
F	15.66	2.475	18.53	68.49	5.030	3.088	4.146	41.52	4.927	0.454	1.645	11.15

(I) Data from the preshock phase and 10 periods following the Crisis Shock are included. α denotes the constant in each specification. Significance levels: $^{*}p < 0.10$ $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors are presented in parentheses.

Table 8: Forecasts - Across Pre- and Postshock Phases [I]

Dep. Var.:				Preshock						
Output Forecast	*Constant*	*SD*	*SD*	*SD*	*Dir. SD*	*Dir. SD*	*Dir. SD*	*FP*		
ϵ_t	0.420***	1.208***	1.087***	1.086***	0.234***	0.090***	0.220***	0.259***		
	(0.02)	(0.38)	(0.39)	(0.32)	(0.02)	(0.03)	(0.02)	(0.02)		
x_{t-1}	0.809***	1.186***		-0.001	0.808***		0.801***	0.796***		
	(0.04)	(0.39)		(1.10)	(0.04)		(0.04)	(0.02)		
π^*_t			-0.896***	-0.896		0.190***	0.086***			
			(0.19)	(0.57)		(0.04)	(0.03)			
α	15.604***	435.069	329.516	348.254	5.517**	-1.580	10.763***	7.492***		
	(2.34)	(578.16)	(566.07)	(523.98)	(2.15)	(3.66)	(2.59)	(1.44)		
N	1655	1660	1768	1660	1630	1738	1630	1656		
χ^2	552.2	59.63	86.32	95.63	496.1	28.30	600.0	1768.0		
Dep. Var.:				Postshock - $CrisisShockLength \leq 5$						
Output Forecast	*Constant*	*SD*	*SD*	*SD*	*Dir. SD*	*Dir. SD*	*Dir. SD*	*FP*	*FP*	*FP*
ϵ_t	1.009***	51.448	52.766	57.884	-0.900	-3.504***	-0.735	0.142***	0.127***	-0.096**
	(0.16)	(170.63)	(160.67)	(139.86)	(1.13)	(1.33)	(1.44)	(0.04)	(0.04)	(0.05)
x_{t-1}	0.714***	15.304		29.607	1.116***		1.187***	0.747***	0.691***	
	(0.03)	(10.61)		(81.33)	(0.11)		(0.28)	(0.05)	(0.03)	
π^*_t			-14.405	13.484		-0.716***	0.046			
			(10.03)	(81.43)		(0.07)	(0.15)			
g_{t+1}								0.220		-1.845***
								(0.17)		(0.12)
α	16.408*	117869.878	130945.372	104573.980	244.609	422.567**	230.649	15.889	31.104***	166.025***
	(9.08)	(126507.43)	(138094.13)	(195033.98)	(159.23)	(184.54)	(156.19)	(11.08)	(3.81)	(6.96)
N	482	480	480	480	476	476	476	485	486	485
χ^2	817.9	2.621	2.400	3.277	160.0	137.9	161.7	549.4	527.3	270.9
Dep. Var.:				Postshock - $CrisisShockLength > 5$						
Output Forecast	*Constant*	*SD*	*SD*	*SD*	*Dir. SD*	*Dir. SD*	*Dir. SD*	*FP*	*FP*	*FP*
ϵ_t	-771.949	544.358	398.911	936.896	-481.091	-450.565	-391.747	64.538	101.823	52.781
	(2102.97)	(1708.89)	(1720.77)	(1712.66)	(671.32)	(663.65)	(465.38)	(65.58)	(96.82)	(55.35)
x_{t-1}	30.540	0.958***		5.860	3.058***		-6.119	14.905		15.318
	(23.25)	(0.21)		(5.19)	(0.51)		(21.19)	(12.16)		(12.53)
π^*_t			-0.674***	3.475		-2.783***	-8.332			
			(0.15)	(3.71)		(0.47)	(19.43)			
g_{t+1}									527.299	-245.372
									(438.21)	(225.43)
α	2823.672	-442871.827**	-484218.974**	-273040.822**	10242.424	17962.665	31929.141	13531.594	-47772.391	29385.666
	(163325.44)	(216416.55)	(222630.89)	(128935.57)	(18991.79)	(17801.76)	(36567.39)	(12160.56)	(39159.88)	(26693.43)
N	460	475	475	475	482	482	482	474	471	471
χ^2	2.582	21.21	20.66	24.70	42.03	42.32	42.78	1.605	2.634	2.408

(I) Data from the preshock phase and 10 periods following the Crisis Shock are included. Mixed effect specification where α denotes the constant in each specification. Significance levels: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors are presented in parentheses.

Table 9: Forecasts - Across Pre- and Postshock Phases [I]

Dep.Var.:				Preshock						
$E_{i,t}\pi_{t+1}$	*Constant*	*SD*	*SD*	*SD*	*Dir. SD*	*Dir. SD*	*Dir. SD*	*FP*		
ϵ_t	0.240***	0.579*	0.591*	0.631*	0.082***	0.077***	0.075***	0.098***		
	(0.01)	(0.30)	(0.35)	(0.36)	(0.01)	(0.02)	(0.01)	(0.01)		
π_{t-1}	0.855***	1.160**		3.175	0.958***		1.036***	0.897***		
	(0.02)	(0.45)		(2.17)	(0.03)		(0.04)	(0.02)		
π_t^*			-0.308*	0.621		-0.186***	0.061***			
			(0.17)	(0.79)		(0.01)	(0.01)			
α	4.405**	550.294	500.757	584.065	0.514	-4.228***	3.929***	4.117***		
	(1.86)	(593.34)	(562.72)	(635.69)	(0.91)	(1.43)	(0.98)	(1.16)		
N	1655	1660	1768	1660	1630	1738	1630	1656		
χ^2	1528.5	32.78	28.63	44.25	913.5	199.1	1028.9	3018.2		
Dep.Var.:				Postshock - $CrisisShockLength \leq 5$						
$E_{i,t}\pi_{t+1}$	*Constant*	*SD*	*SD*	*SD*	*Dir. SD*	*Dir. SD*	*Dir. SD*	*FP*	*FP*	*FP*
ϵ_t	0.486***	-22.426	-20.029	-24.004	0.012	-1.319**	-0.066	0.041***	0.044***	-0.058***
	(0.06)	(58.81)	(58.97)	(58.47)	(0.56)	(0.64)	(0.53)	(0.02)	(0.02)	(0.02)
π_{t-1}	0.767***	3.854***		14.122	1.230***		1.158***	0.795***	0.866***	
	(0.03)	(1.07)		(10.89)	(0.14)		(0.18)	(0.04)	(0.04)	
π_t^*			-1.647***	4.400		-0.344***	-0.021			
			(0.45)	(4.30)		(0.04)	(0.05)			
g_{t+1}								-0.171***		-0.726***
								(0.06)		(0.07)
α	7.299**	12853.637	15432.698*	5307.458	65.627	205.509**	75.150	32.437***	14.893***	146.736**
	(3.61)	(8387.37)	(8774.87)	(4676.52)	(74.75)	(95.04)	(86.98)	(6.39)	(3.93)	(4.11)
N	482	480	480	480	476	476	476	485	486	485
χ^2	981.6	13.38	13.52	23.22	179.7	121.8	186.2	577.9	565.3	144.6
Dep.Var.:				Postshock - $CrisisShockLength > 5$						
$E_{i,t}\pi_{t+1}$	*Constant*	*SD*	*SD*	*SD*	*Dir. SD*	*Dir. SD*	*Dir. SD*	*FP*	*FP*	*FP*
ϵ_t	54.859	-600.252	-713.151	290.936	1191.452	982.236	-2.353	-1.306	2.204	-1.588
	(87.93)	(2303.28)	(2355.44)	(1805.82)	(1161.53)	(997.46)	(129.40)	(2.11)	(3.02)	(2.03)
π_{t-1}	2.866***	3.529***		67.614	12.473		-54.985	2.415***		2.439***
	(0.97)	(1.13)		(77.75)	(9.76)		(52.06)	(0.31)		(0.32)
π_t^*			-1.375***	25.047		-4.944	-26.234			
			(0.44)	(30.41)		(3.88)	(23.96)			
g_{t+1}									53.202***	-5.714*
									(11.63)	(3.18)
α	-20068.886	-224586.278	-254678.837	184232.716	121438.159	132482.908	140386.854	203.616*	-5019.028***	571.733*
	(21156.99)	(365811.39)	(372232.04)	(246395.08)	(107481.41)	(117164.78)	(124407.80)	(120.38)	(1056.68)	(322.31)
N	460	475	475	475	482	482	482	474	471	471
χ^2	8.911	9.896	9.834	11.40	1.727	1.768	2.562	61.25	21.53	83.51

(I) Data from the preshock phase and 10 periods following the Crisis Shock are included. Mixed effect specification where
denotes the constant in each specification. Significance levels: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard erro
are presented in parentheses.

Table 10: Forecasting Heuristics Across Treatments [I]

	All treatments			SD vs. Dir. SD								
$Dep.Var.:$		$CSL \leq 5$	$CSL > 5$				$CrisisShockLength \leq 5$			$CrisisShockLength > 5$		
$E_{i,t}\pi_{t+1}$	Preshock	Postshock	Postshock	Preshock	Preshock	Preshock	Postshock	Postshock	Postshock	Postshock	Postshock	Postshock
ϵ	0.240***	0.432***	0.217***	0.579*	0.591*	0.631*	0.274*	0.393**	-0.033	-7.089	-7.341	-10.543
	(0.01)	(0.04)	(0.08)	(0.30)	(0.35)	(0.36)	(0.16)	(0.19)	(0.18)	(25.49)	(25.45)	(22.82)
$\epsilon \times SD$	0.339	-0.158	-7.306									
	(0.30)	(0.16)	(25.48)									
$\epsilon \times Dir.SD$	-0.158***	-0.139*	0.160	-0.497*	-0.514	-0.556	0.019	-0.016	0.337*	7.467	8.197	10.317
	(0.02)	(0.08)	(0.22)	(0.30)	(0.35)	(0.36)	(0.17)	(0.20)	(0.19)	(25.49)	(25.45)	(22.82)
$\epsilon \times FP$	-0.143***	-0.427***	-0.162*									
	(0.02)	(0.05)	(0.09)									
π_{t-1}	0.855***	0.810***	1.044***	1.160**		3.175	1.874***		4.858***	2.429***		-15.890
	(0.02)	(0.05)	(0.14)	(0.45)		(2.17)	(0.38)		(1.87)	(0.31)		(18.26)
$\pi_{t-1} \times SD$	0.305	1.065***	1.386***									
	(0.45)	(0.38)	(0.34)									
$\pi_{t-1}D \times Dir.SD$	0.104***	0.429***	0.976***	-0.202		-2.138	-0.636*		-3.756**	-0.410		20.265
	(0.04)	(0.10)	(0.28)	(0.45)		(2.17)	(0.38)		(1.88)	(0.39)		(18.30)
$\pi_{t-1} \times FP$	0.042	-0.156	-0.103									
	(0.03)	(0.12)	(0.15)									
π_t^*					-0.308*	0.621		-0.627***	1.076*		-1.109***	-8.304
					(0.17)	(0.79)		(0.13)	(0.60)		(0.15)	(8.34)
$\pi_t^* \times Dir.SD$					0.123	-0.560		0.256*	-1.118*		0.331*	9.222
					(0.17)	(0.79)		(0.13)	(0.60)		(0.17)	(8.35)
SD	545.889	106.914	-13659.850**									
	(593.21)	(66.93)	(6268.50)									
$Dir.SD$	-3.891*	46.862***	283.019***	-549.780	-504.986	-580.136	-60.052	-4.466	-108.907	13942.869**	12765.399**	5782.963
	(2.07)	(16.57)	(109.07)	(593.26)	(562.65)	(635.60)	(67.52)	(57.20)	(83.23)	(6272.30)	(6159.12)	(8236.26)
FP	-0.288	5.338	-16.668									
	(2.19)	(13.28)	(19.65)									
α	4.405**	21.585**	8.014	550.294	500.757	584.065	128.498*	61.835	177.484**	-13651.836**	-12349.452**	-5660.525
	(1.86)	(9.99)	(18.86)	(593.26)	(562.65)	(635.60)	(66.22)	(55.10)	(82.15)	(6271.38)	(6157.93)	(8235.92)
N	6601	1072	1052	3290	3506	3290	537	537	537	533	533	533
χ^2	7764.8	1712.4	926.1	962.1	239.3	1073.6	327.3	295.4	395.1	218.0	215.3	206.8

(I) Data from the preshock phase and 4 periods following the Crisis Shock are included. Mixed effect specification where α denotes the constant in each specification. Significance levels: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Robust standard errors are presented in parentheses.

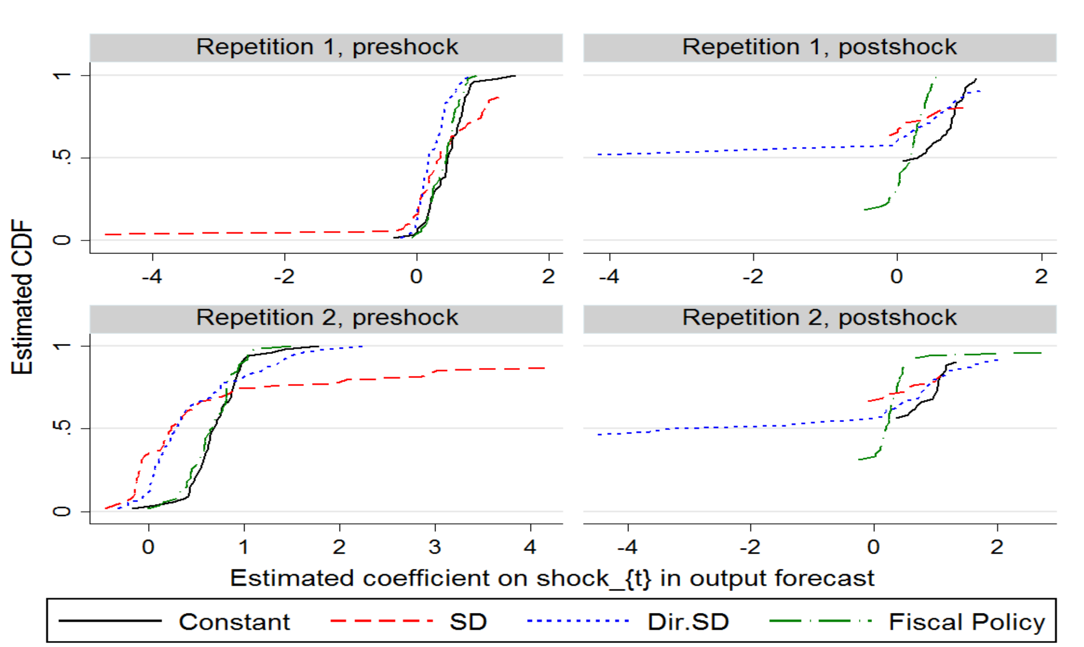
We consistently observe considerable heterogeneity in all treatments under all forecasting heuristics. One immediate takeaway from the estimated cumulative distribution functions is that heterogeneity across subjects increases – for all forecasting types – after the crisis shock occurs. Subjects' output and inflation forecast responses to aggregate shocks in the SD and DSD treatments become significantly more varied in the postshock phase (two-sided Wilcoxon rank sum tests, p-$value \leq 0.055$ in the SD treatment and p-$value \leq 0.016$ in the DSD treatment), while the differences in the C and FP treatments are not significantly different at the 10% level. SD subjects also become significantly more varied in their reaction to the central bank's evolving inflation target when forming both inflation and output forecasts in the postshock phase (two-sided Wilcoxon rank sum test: p-$value \leq 0.078$ for inflation forecasts in Repetition 1 and both p-$value \leq 0.025$ for both forecasts in Repetition 2). Likewise, they become significantly more varied in their response to lagged outcomes and trends following the crisis (two-sided Wilcoxon rank sum tests: p-$value < 0.05$ for both output and inflation forecasts in both repetitions with the exception of output forecast responses to lagged output being significant at the 10% level).

We compute a session-repetition-phase measure of the standard deviation of estimated coefficients from each forecasting model. Across sessions, the median pre- and postshock heterogeneity is tends to be the largest in the SD treatment for inflation and output forecasts. While the ordering of heterogeneity varies across forecasting heuristic and forecasted variable, we observe a consistent pattern that there is greater heterogeneity in how subjects utilize information about shocks, historical information, trends and inflation targets in the SD treatment than in the DSD treatment. Intriguingly, subjects in the state-dependent inflation target treatments are more homogenous in their reaction to the central bank's announced inflation target when it is announced qualitatively rather than quantitatively (two-sided Wilcoxon rank sum tests: p-$value = 0.055$ for Repetition 1 preshock inflation forecasts, p-$value = 0.109$ for Repetition 2 postshock inflation forecasts).

Turning to the *Constant* and *FP* treatments, we find that subjects are consistently more homogeneous in their response to aggregate demand shocks in the presence of fiscal policy. Inflation and output forecasts in the preshock phase of Repetition 1 and inflation forecasts in the postshock phase of Repetition 2 are significantly more homogeneous in the FP than in the C treatment (Two sided Wilcoxon rank sum test, p-$value < 0.10$ in all cases). Otherwise, we observe no consistent or significant difference in how subjects utilitze information between the C and FP treatments.

Finally, for each session-repetition-phase, we calculate the mean estimated coefficient in each group and compare these measures across treatments. Our most notable finding relates to

(a) Fundamentals-Driven Expectations - Output Forecasts



(b) Fundamentals-Driven Expectations - Inflation Forecasts

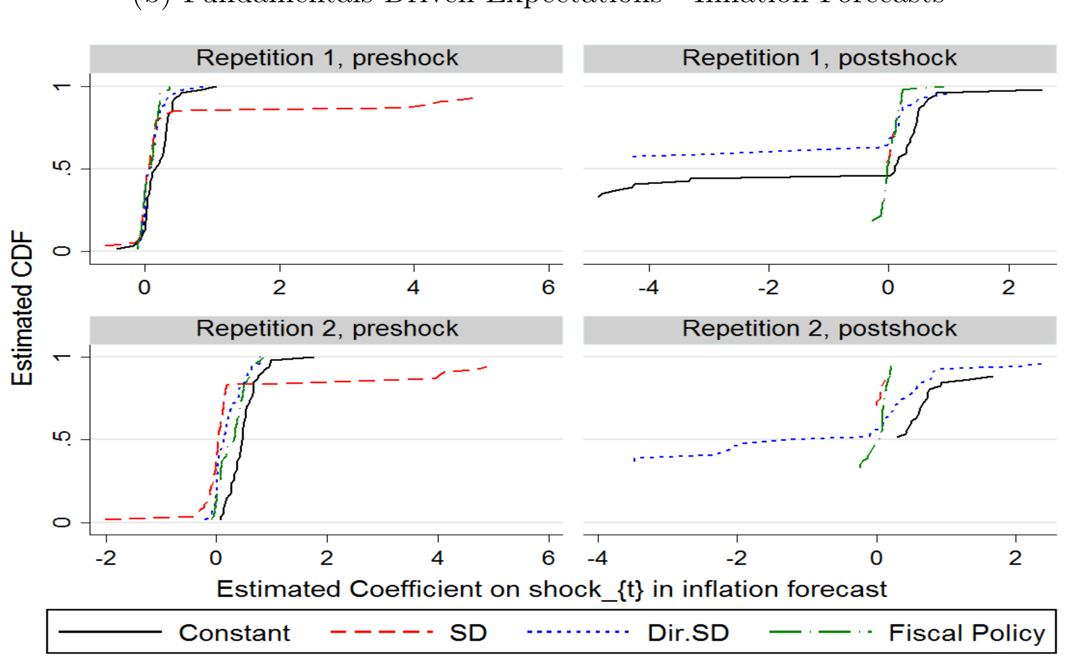
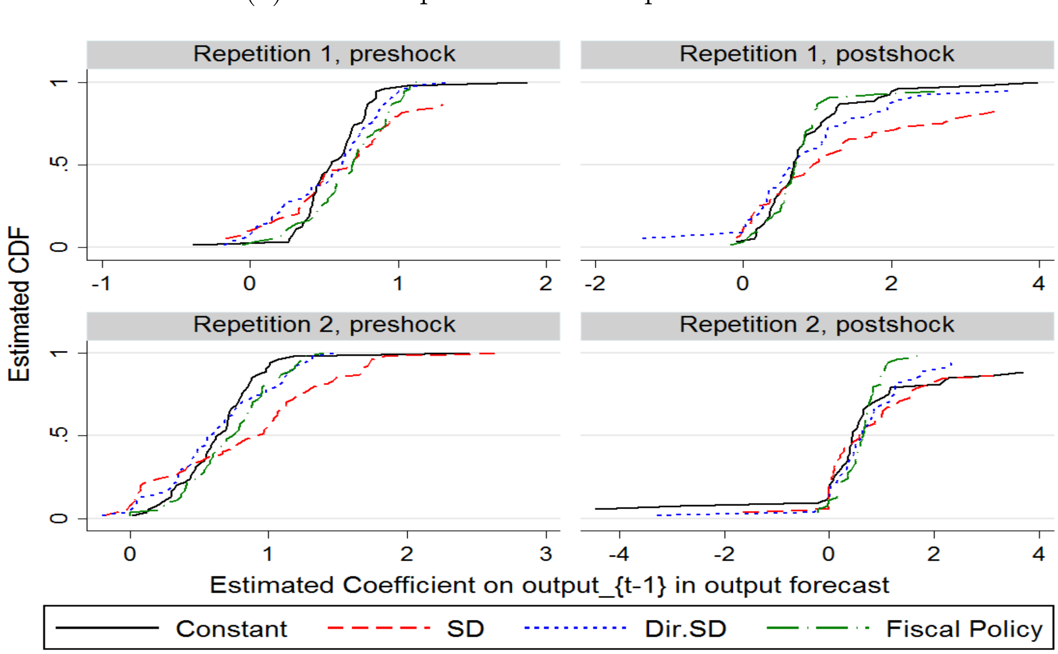


Figure 11: Distribution of Fundamental Types Across Treatments and Shock Phases - by Repetition and Phase

(a) Naive Expectations - Output Forecasts



(b) Naive Expectations - Inflation Forecasts

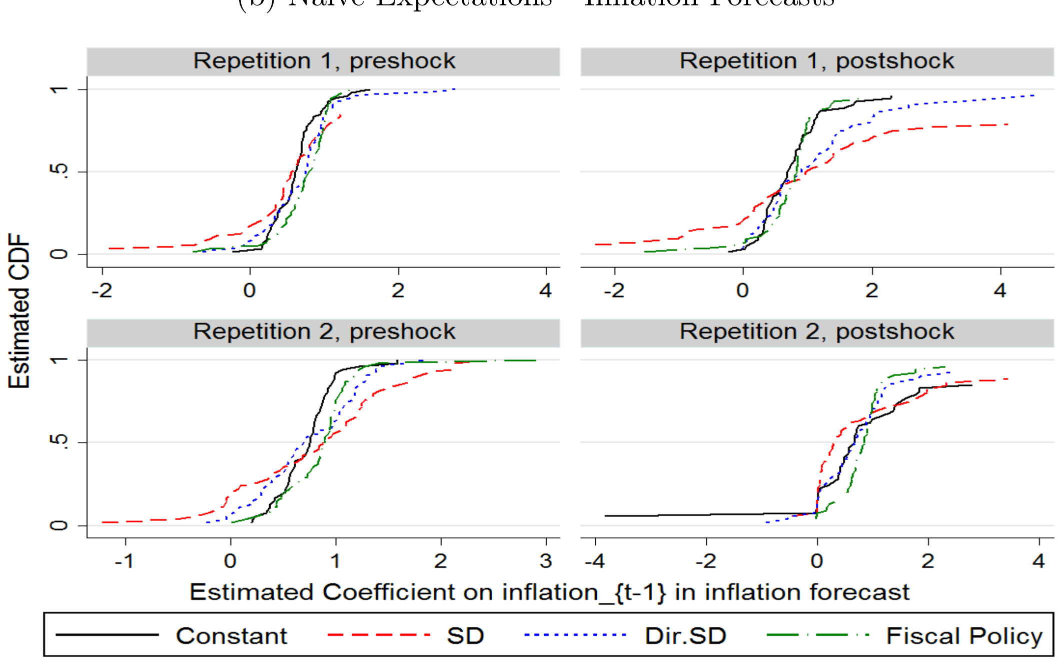
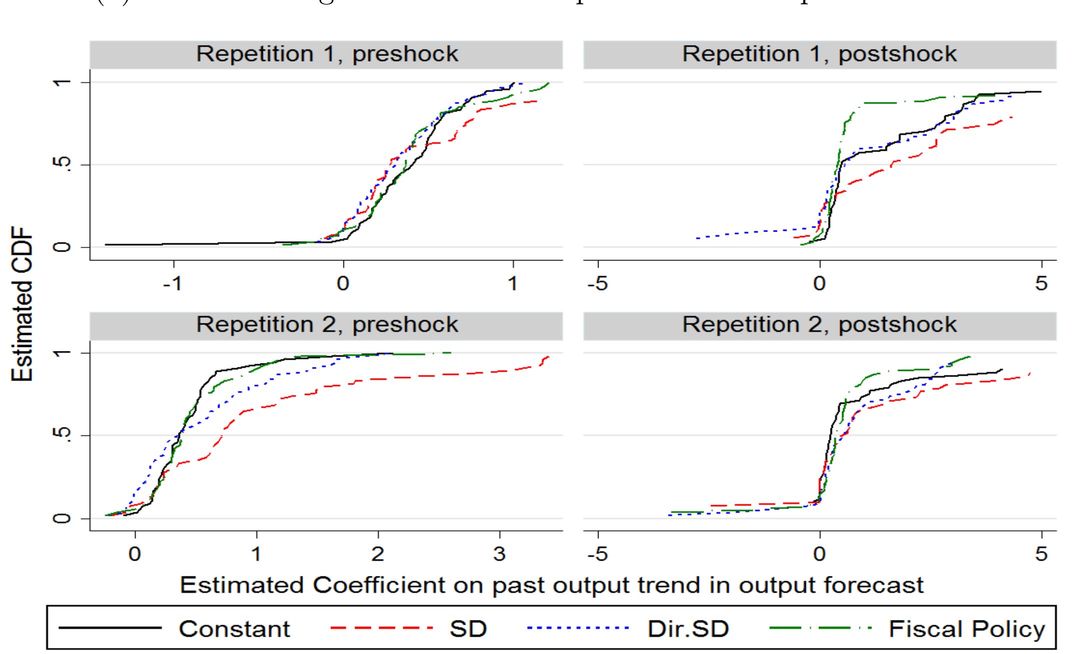


Figure 12: Distribution of Naive Types Across Treatments and Shock Phases - by Repetition and Phase

(a) Trend-chasing & Contrarian Expectations - Output Forecasts



(b) Trend-chasing & Contrarian - Inflation Forecasts

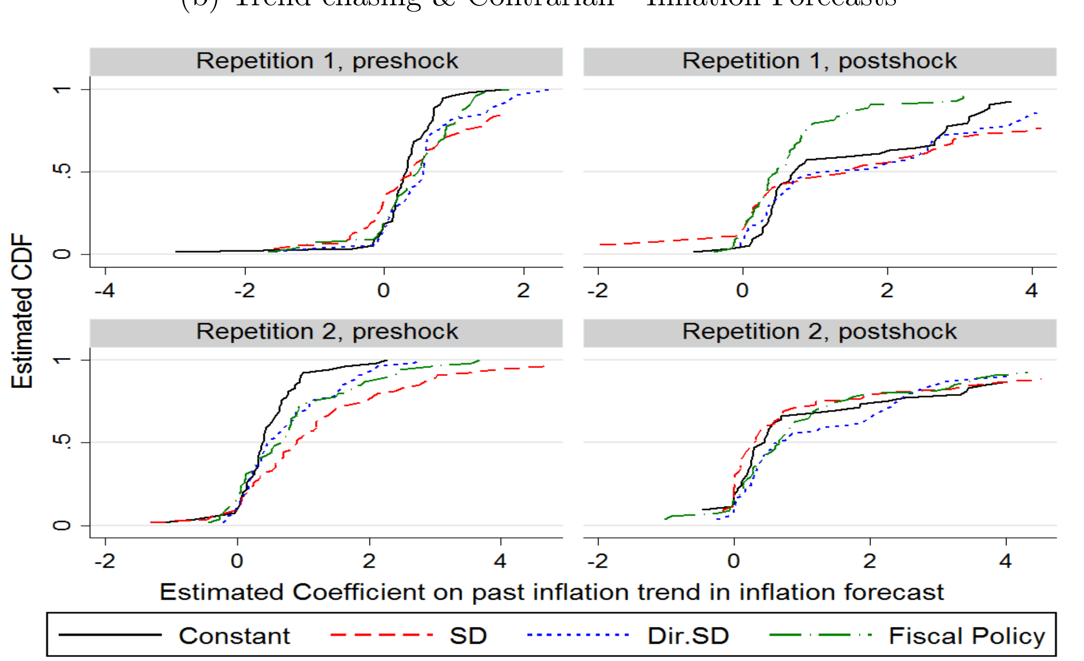
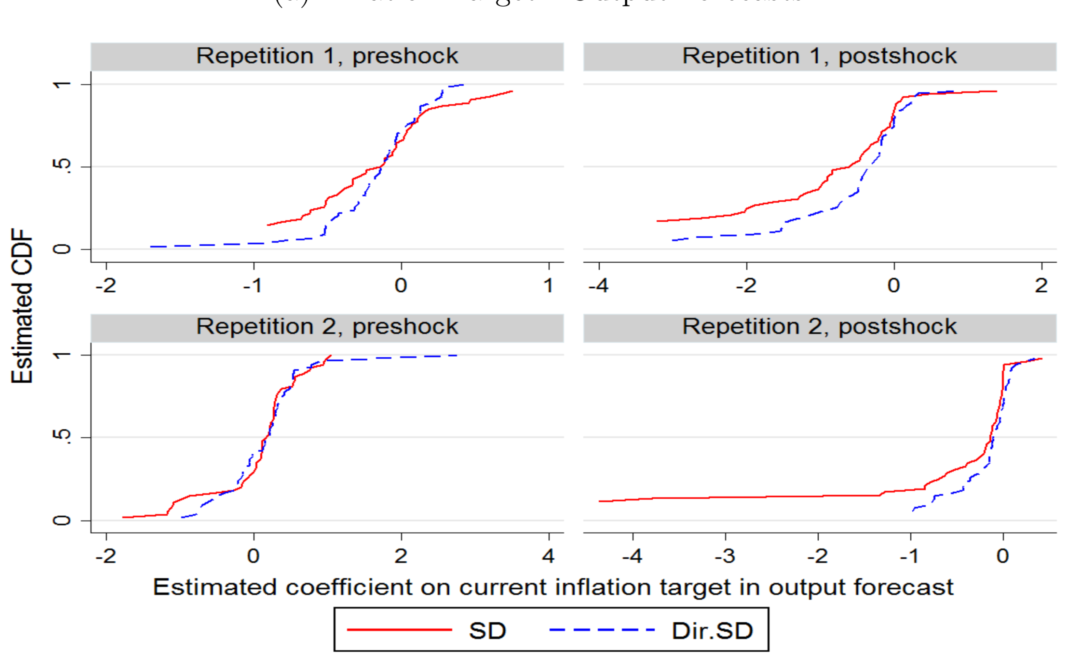


Figure 13: Distribution of Naive Types Across Treatments and Shock Phases - by Repetition and Phase

(a) Inflation Target - Output Forecasts



(b) Inflation Target - Inflation Forecasts

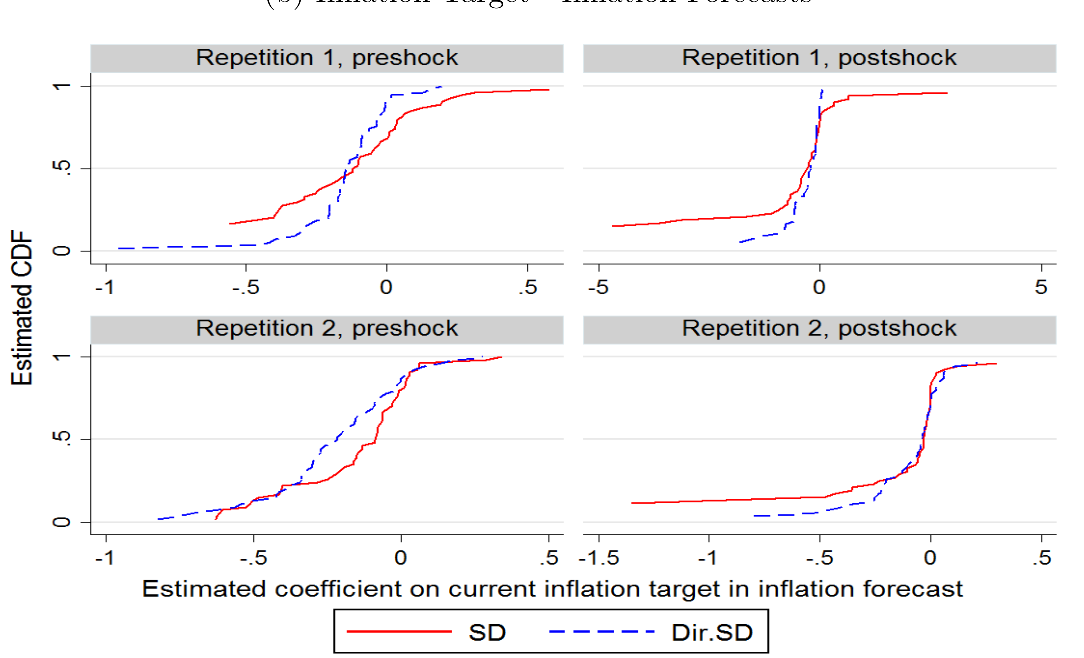
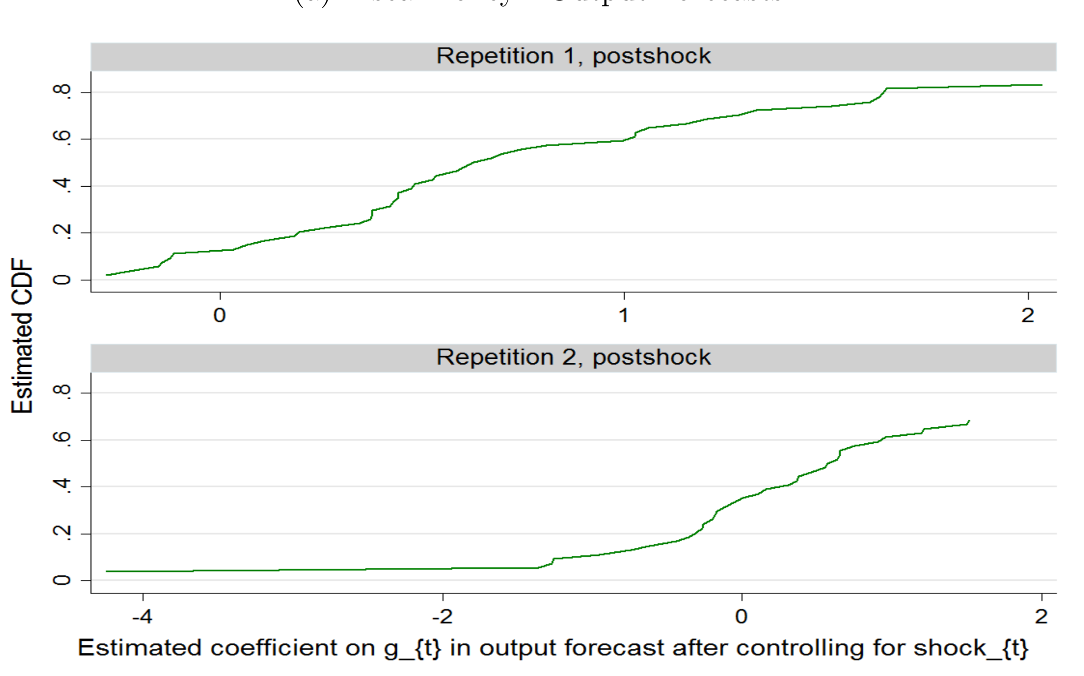


Figure 14: Distribution of Responses to State Dependent Inflation Target Across Treatments and Shock Phases - by Repetition and Phase

(a) Fiscal Policy - Output Forecasts



(b) Fiscal Policy - Inflation Forecasts

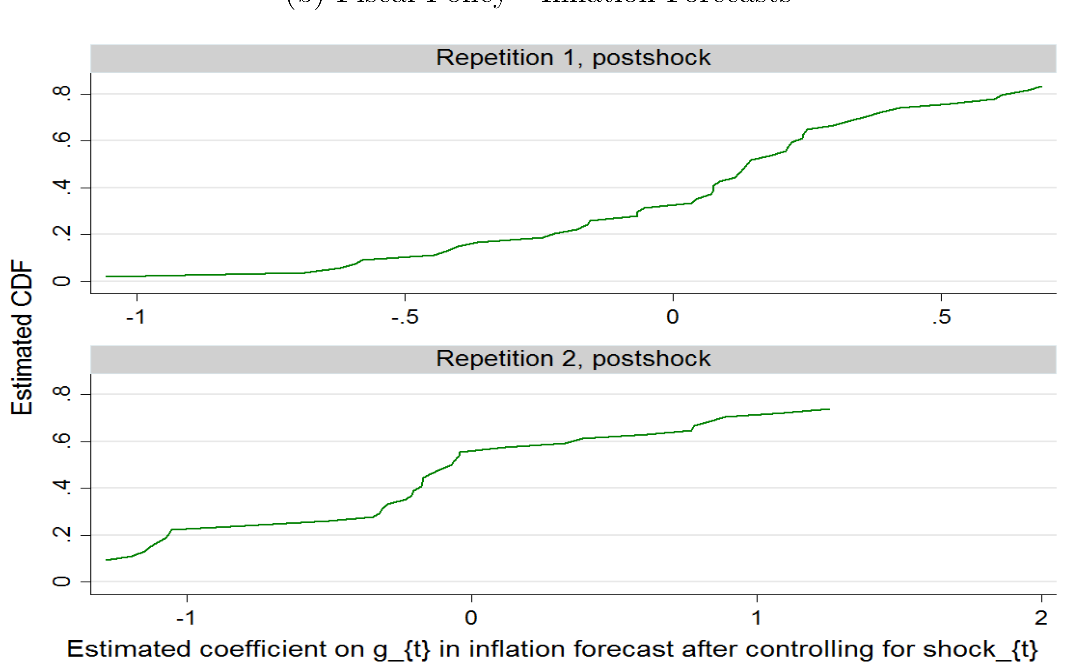


Figure 15: Distribution of Responses to Fiscal Policy Across Treatments and Shock Phases - by Repetition and Phase

		Inflation Forecasts			
		Preshock		Postshock	
Treatment		Repetition 1	Repetition 2	Repetition 1	Repetition 2
Constant	Shock	0.13	0.16	1.13	1.06E+06
	Lagged variable	0.27	0.20	0.31	1.48E+08
	Past trend	0.28	0.39	0.54	5.92E+07
State Dependent	Shock	0.10	0.07	2.35E+04	1.42E+10
	Lagged variable	0.43	0.46	11.62	2.11E+05
	Past trend	0.55	0.54	15.38	8.72E+04
	Inflation Target	0.19	0.09	4.53	4.39E+04
Directional State Dependent	Shock	0.08	0.18	2835.25	606.07
	Lagged variable	0.34	0.40	0.82	0.58
	Past trend	0.44	0.41	1.69	2.15
	Inflation Target	0.11	0.13	0.28	0.08
Fiscal Policy	Shock	0.08	0.14	0.09	0.08
	Lagged variable	0.28	0.21	0.31	0.39
	Past trend	0.45	0.49	0.37	0.68
	Government Expenditures			0.23	0.23

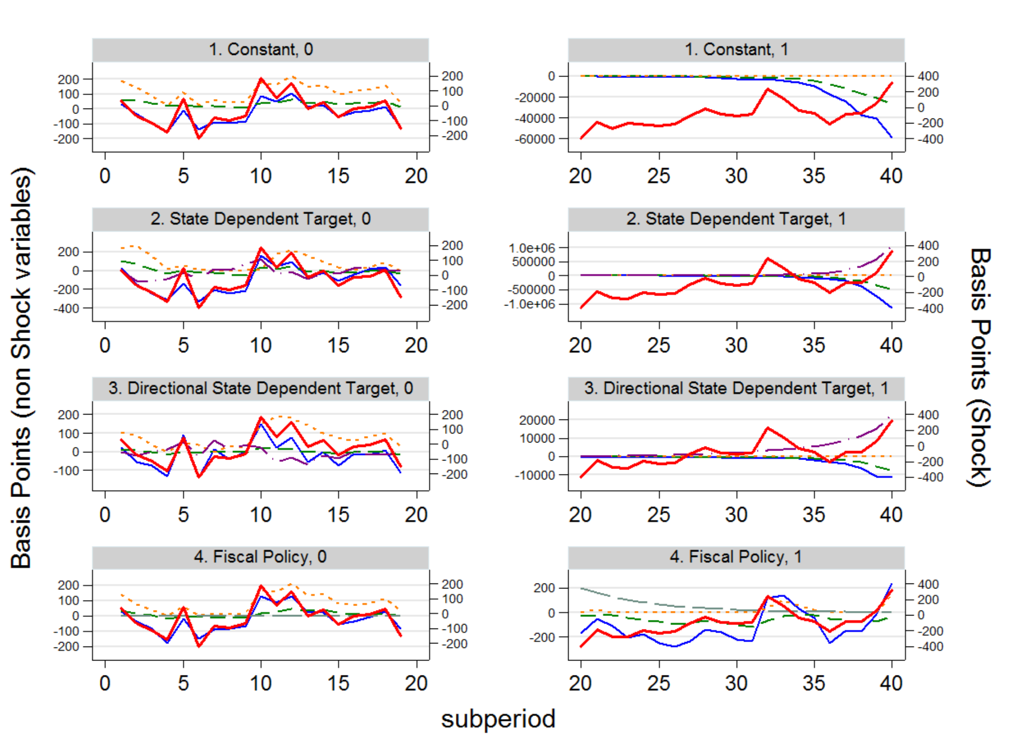
Figure 16: Median Standard Deviation of Estimated Forecasting Heuristic Types, Inflation Forecasts - by Treatment, Repetition, Phase

		Output Forecasts			
		Preshock		Postshock	
Treatment		**Repetition 1**	**Repetition 2**	**Repetition 1**	**Repetition 2**
Constant	**Shock**	0.24	0.26	2.27	2.22E+16
	Lagged variable	0.17	0.21	0.33	4.65E+13
	Past trend	0.15	0.21	0.71	8.64E+13
State Dependent	**Shock**	0.29	0.26	3390.82	1.09E+07
	Lagged variable	0.34	0.38	1.60	64.36
	Past trend	0.25	0.47	1.91	18.96
	Inflation Target	0.39	0.29	0.92	40.09
Directional State Dependent	**Shock**	0.17	0.28	1112.96	2200.58
	Lagged variable	0.29	0.28	0.67	0.55
	Past trend	0.19	0.37	1.42	1.38
	Inflation Target	0.24	0.29	0.41	0.20
Fiscal Policy	**Shock**	0.14	0.19	0.21	0.50
	Lagged variable	0.23	0.21	0.28	0.33
	Past trend	0.23	0.25	0.25	0.29
	Government Expenditures			0.45	0.98

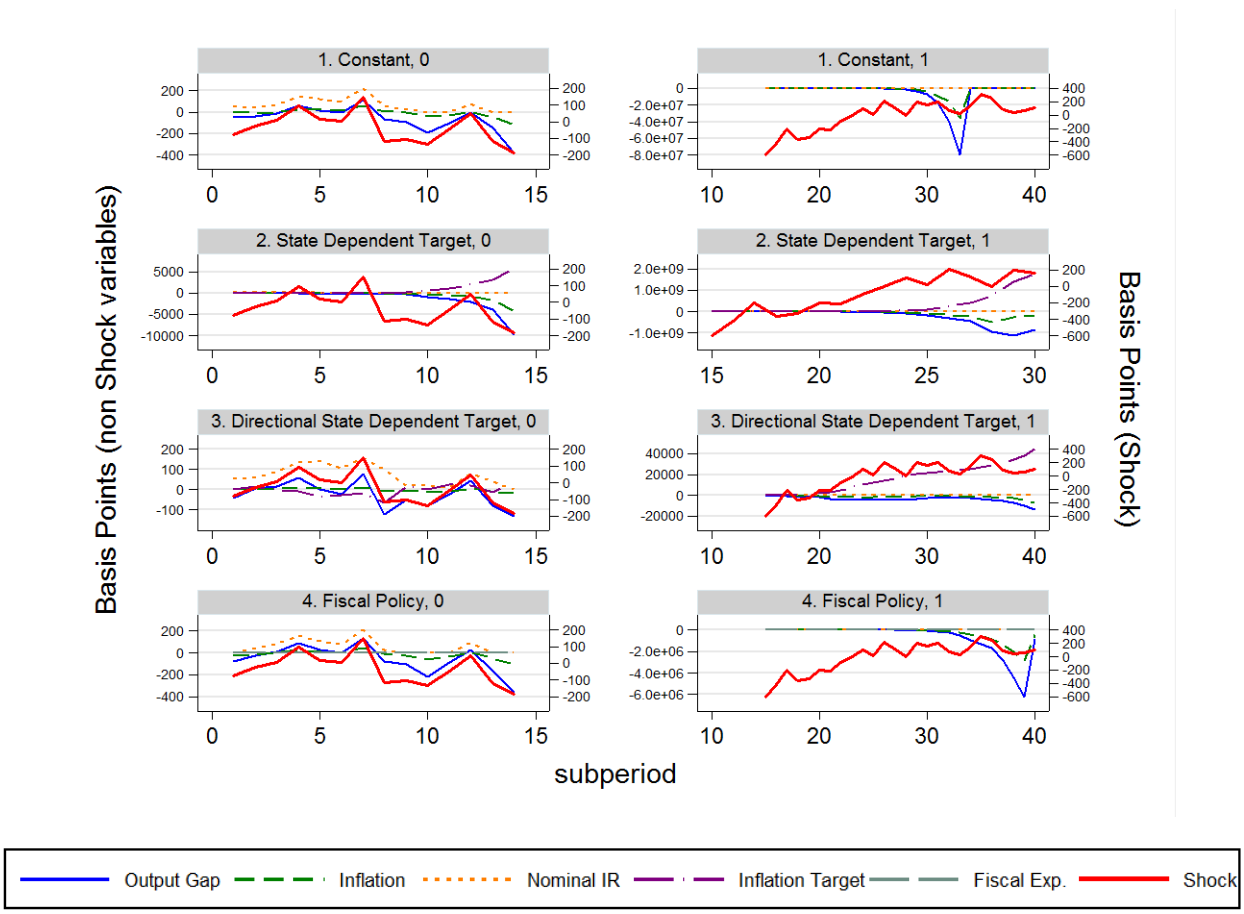
Figure 17: Median Standard Deviation of Estimated Forecasting Heuristic Types, Output Forecasts - by Treatment, Repetition, Phase

differences in forecasting heuristics between the *Constant* and (Directional) State Dependent Target treatments. Postshock C subjects are significantly more reactive to aggregate shocks when forecasting output than DSD subjects in the postshock phase (*p-value*< 0.10). Moreover, C subjects are significant less naive and trend-chasing when forecasting output postshock than their C counterparts (*p-value*< 0.05 for both estimates).

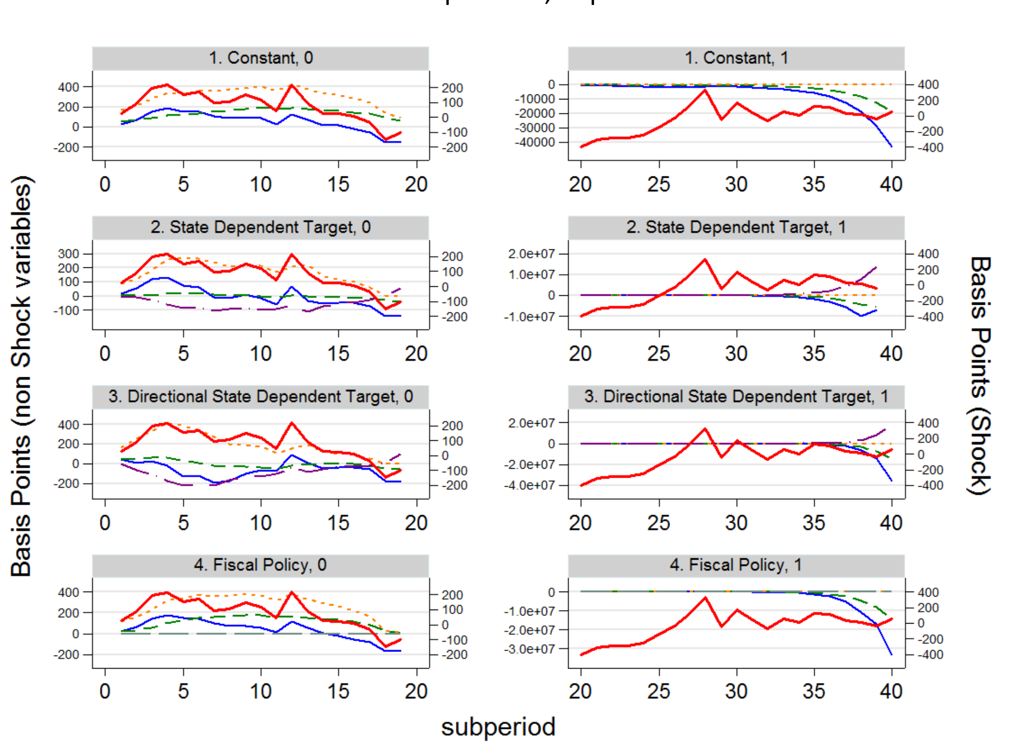
Panel A: Sequence 1, Repetition 1



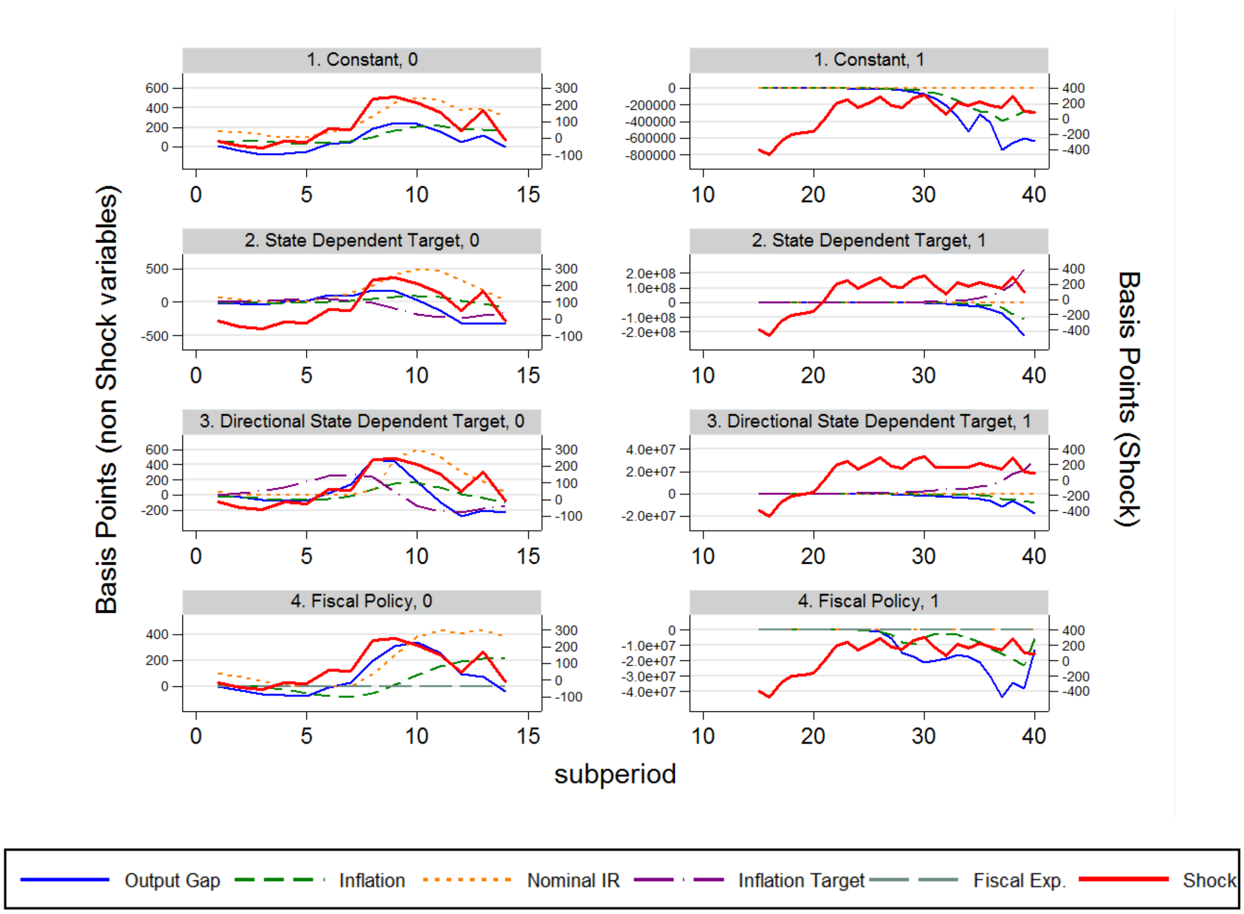
Panel B: Sequence 1, Repetition 2



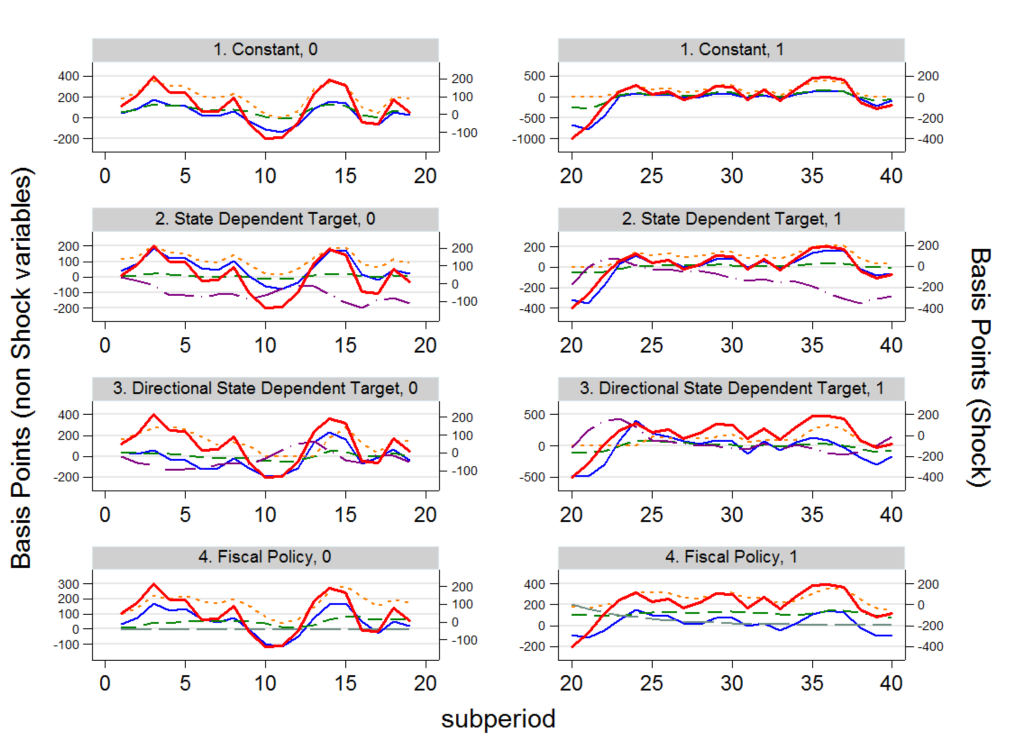
Panel A: Sequence 2, Repetition 1



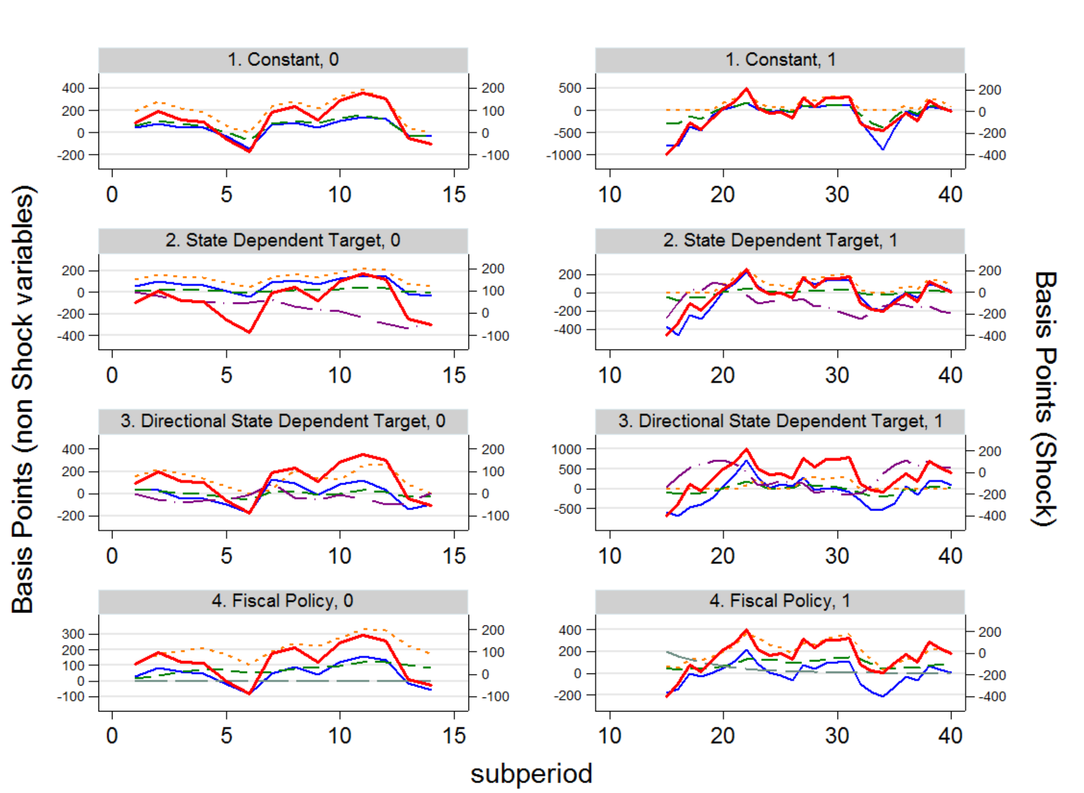
Panel B: Sequence 2, Repetition 2

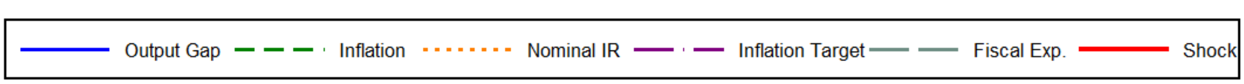


Panel A: Sequence 3, Repetition 1

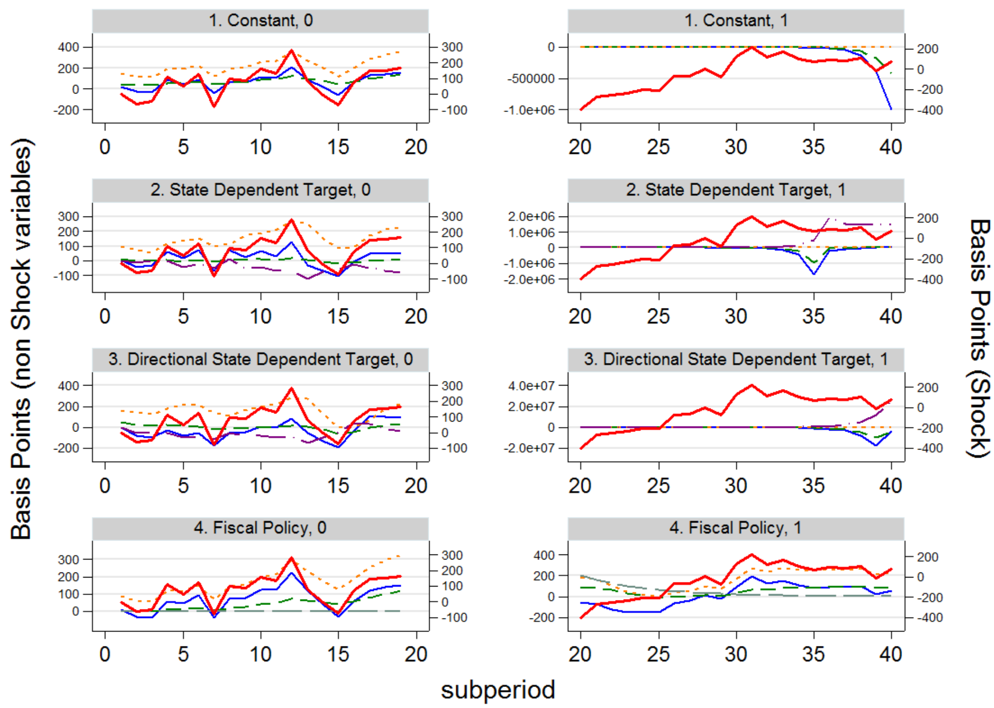


Panel B: Sequence 3, Repetition 2

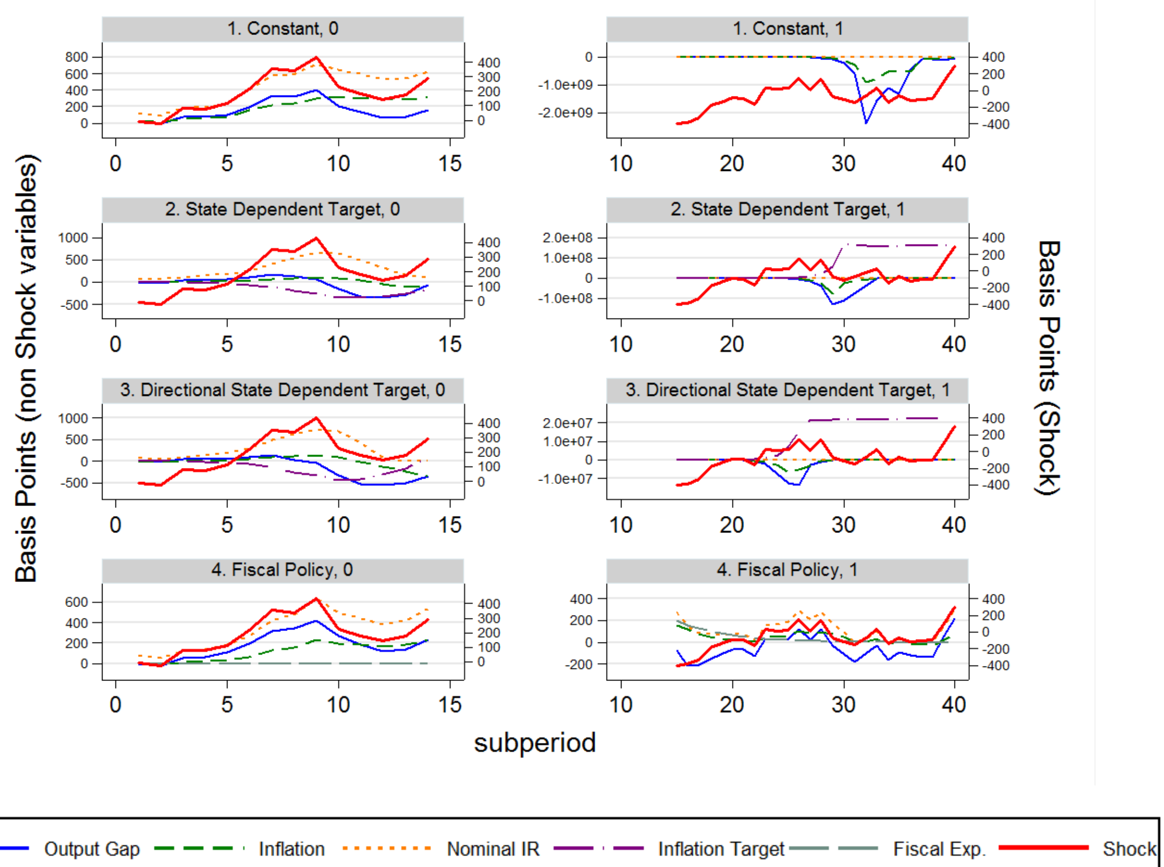




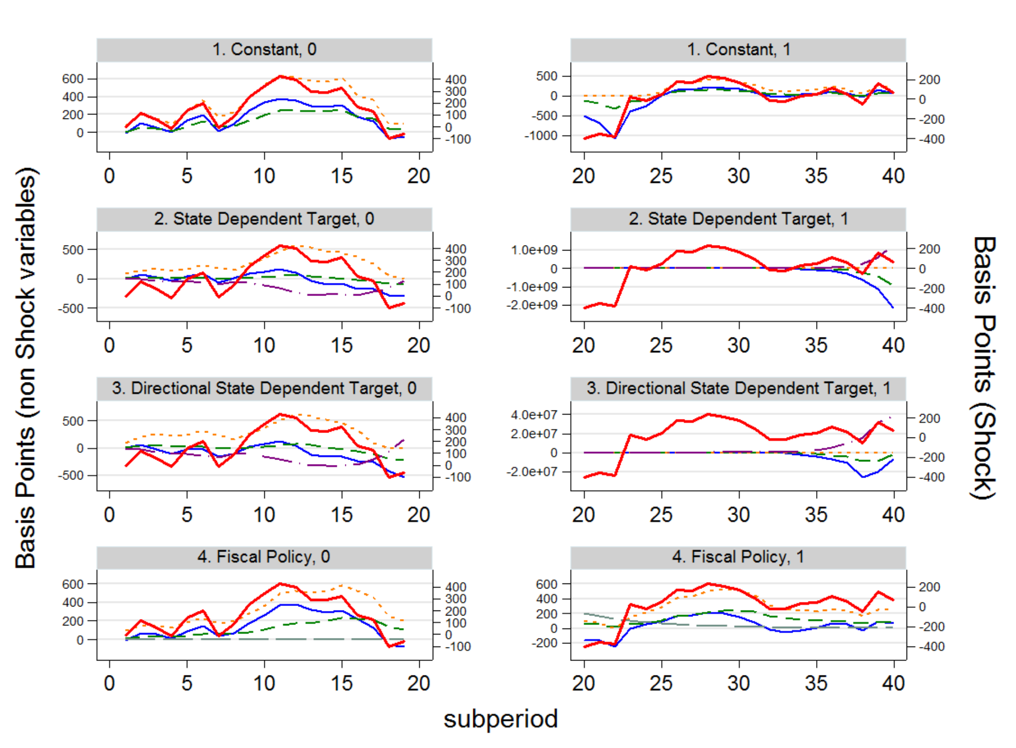
Panel A: Sequence 4, Repetition 1



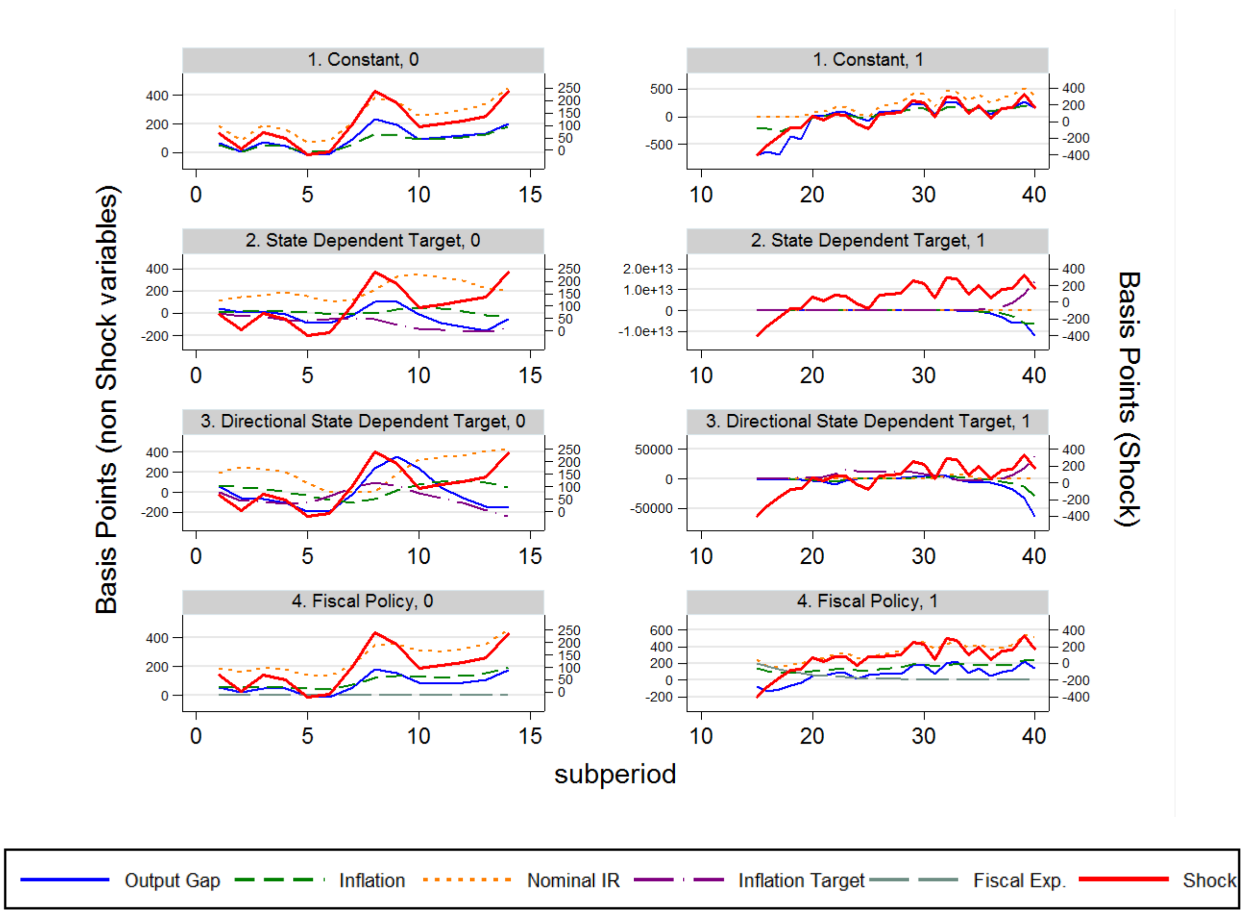
Panel B: Sequence 4, Repetition 2



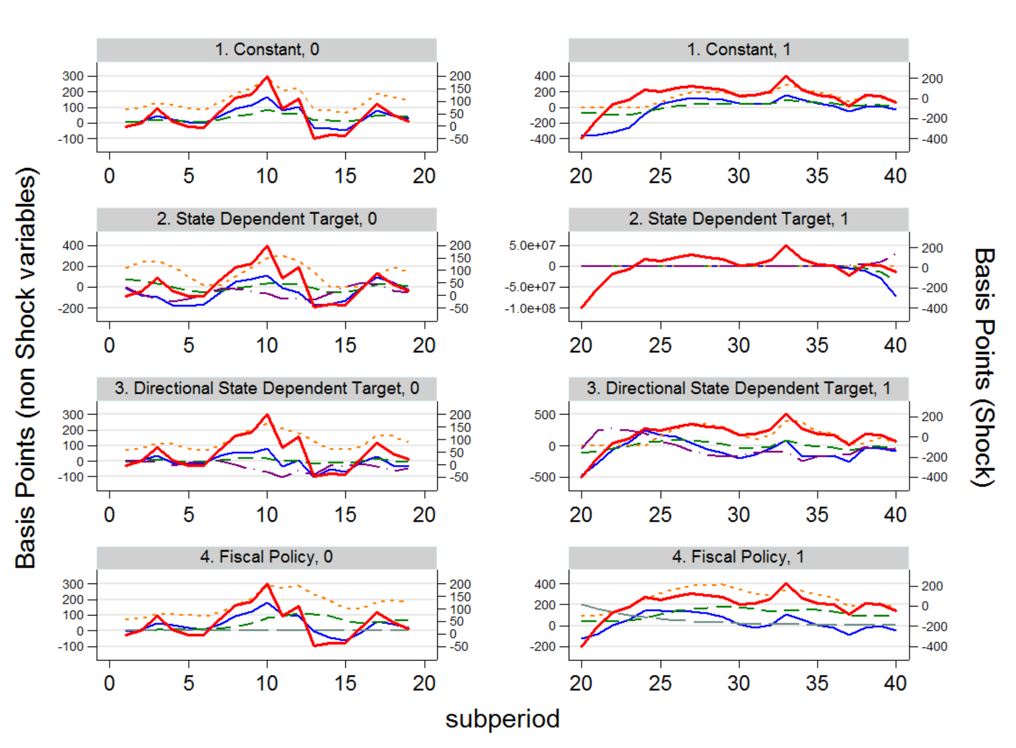
Panel A: Sequence 5, Repetition 1



Panel B: Sequence 5, Repetition 2



Panel A: Sequence 6, Repetition 1



Panel B: Sequence 6, Repetition 2