“Escaping Expectations-Driven Liquidity Traps: Experimental Evidence”

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Abstract
Can monetary or fiscal policy stabilize expectations in a liquidity trap? We study expectation formation near the zero lower bound using a learning-to-forecast laboratory experiment. Monetary policy targets inflation around a constant or state-dependent target. Subjects’ expectations significantly over-react to stochastic aggregate demand shocks and historical information leading many economies to experience severe deflationary traps. Neither quantitative nor qualitative communication of inflation targets reduce the duration or severity of economic crises. A stronger initial recovery of fundamentals or supplementary anticipated fiscal stimulus stabilizes expectations and increases the speed of macroeconomic recovery.

JEL classifications: C92, E2, E52, D50, D91
Keywords: experimental macroeconomics, monetary policy, expectations, zero lower bound, learning to forecast, communication

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How should monetary policy be conducted when nominal interest rates are close to zero? This question is important as, once interest rates reach zero and cannot be reduced further (often referred to as the zero lower bound (ZLB)), the central bank loses an important tool for stimulating the economy. A negative demand shock could turn the situation dire because, close to the ZLB, the central bank may not be able to lower interest rates sufficiently to stimulate the economy during a recession. If the recession is persistent, households and firms will anticipate that the central bank will continue to fail to provide stimulus. Rationally, they form pessimistic expectations of the future that influence their decisions. Thus, the existence of the ZLB thus has the potential to generate a long, self-fulfilling macroeconomic crisis.

Macroeconomists and policy makers generally agree that policies that create inflationary expectations would alleviate the severity and duration of liquidity traps. In one of many proposals, Eggertson and Woodford (2003, 2004) show that creating inflationary expectations by promising to keep nominal interest rates low through increased inflation targets even after the economy has recovered can reduce the length of a liquidity trap. The state-dependent inflation target would be adjusted upward for each period the economy has failed to achieve past targets. This would reinforce the central bank’s commitment to higher future inflation. Such a policy would succeed if agents formed rational expectations and the central bank credibly committed to a long-run price level target. But, if agents are not rational, specifically constant gain learners (Evans, Guse and Honkapohja, 2005), accommodative monetary policy must be combined with significant fiscal stimulus to stabilize expectations and economic activity at the zero lower bound.

For policies to succeed, private agents must understand the intentions of the policy maker and that they are credible. However, central banks that have been perceived as credible in stable times have found it difficult to anchor expectations at the ZLB. Central bank forward guidance has evolved from a qualitative to quantitative nature since 2008, and has become progressively less effective at influencing market expectations (Filardo and Hofmann, 2014). Whether this is due to the nature of communication, different data generating
process or increasing pessimism is unclear.

Our overall goal is to examine the effectiveness of both the monetary policies and communication strategies of central banks near the ZLB. Is additional communication of a policy goal a necessary requirement for economic stability? Or is it sufficient to simply conduct policy without providing further explanation? What should a central bank communicate? Does the effectiveness of central bank announcements wear off with frequent communication?

We design a series of policy relevant learning-to-forecast laboratory experiments in order to gain insight into the relative effectiveness of state-dependent inflation targeting in alleviating crises at the zero lower bound. The laboratory provides us with a controlled environment in which we can clearly identify the effects of alternative policies and communication strategies on expectations, coordination and aggregate dynamics. In groups, subjects play the role of professional forecasters that submit forecasts for inflation and output. The forecasts are aggregated and used in the data-generating process driving the economic dynamics. We consider the effect of a state-dependent inflation target that is communicated either quantitatively as a numerical target or qualitatively in the form of a direction (e.g. "positive" vs. "negative") relative to the baseline where the central bank (CB) follows the conventional Taylor rule with a constant inflation target.

Compared to a constant inflation target, we find that neither form of state-dependent inflation targeting leads to a significant reduction in the severity or duration of liquidity traps. In fact, in many of our sessions we observe that the traps are considerably worsened by the central bank’s promise of future inflation. Expectations are significantly better anchored on the central bank’s inflation target when the target remains constant than when it is a time-varying quantitatively announced target. At the individual level, we find that there is significant heterogeneity in how subjects form their forecasts, making it difficult to identify a single forecasting heuristic. We observe mixed evidence that subjects condition sufficiently on the aggregate shocks and inflation targets when forming their forecast. Instead, they appear to consistently rely on historical values and trends. Such adaptive heuristics can be tempered, how-
ever, if the aggregate shocks are shorter-lived. Indeed, if the aggregate shocks generating the initial crisis quickly revert back to the steady state, adaptive behaviour is largely mitigated and the economies are more likely to recover.

We then consider whether anticipated fiscal policy would facilitate economic recovery. Positive government expenditures that create demand should provide a positive signal to forecasters that the economy is rebounding. Moreover, the expenditures, if done with minimal lag following the crisis, should work to minimize the trend-chasing behavior observed in our earlier experiments and more effectively reverse expectations toward the steady state. When we introduce fiscal expenditures following the economic crisis, we find that expectations are much less likely to become trend-chasing. Expectations become very focused on the aggregate shock and recovery of the economy.

I Relation to the existing literature

There are few theoretical models that explicitly discuss central bank communication (Eggertson and Woodford, 2003; Woodford, 2005; Baeriswyl and Cornand, 2010; Eusepi and Preston, 2010). These models typically assume rational agents that are, by construction, capable of incorporating whatever information is communicated to them into their beliefs about the future. Thus, the assumption in these models is that the central bank can control or alter expectations if the policy is appropriately communicated. Woodford (2005) shows how liquidity traps can be avoided at the ZLB through central bank communication. However, questions regarding how the communication is conducted by the central bank, how it is interpreted and understood by the public, and how it impacts their behaviour have not been addressed. This is a critical issue that then-Deputy Governor Jean Boivin (2011) addressed in a recent Bank of Canada speech.

The public’s understanding of the central bank’s objectives and policy rules in the future is a critical component of the effectiveness of monetary policy (Woodford, 2005; Eusepi and Preston, 2010). The most important channel through which central banks can influence spending decisions and pricing is
through market expectations regarding the future path of overnight interest rates. If agents form rational expectations, they should correctly infer the policy rule that the central bank is following. However, if agents have to adapt or learn, or if they possess imperfect information or understanding, a need for central bank communication arises.

But do central banks actually communicate effectively? The empirical results are mixed. In some cases, central bank announcements about their policy objectives have created more stability in financial markets and private sector forecasts (Connolly and Kohler, 2004; Fujiwara, 2005; Swanson, 2006) in countries that pursue inflation-targeting policies. Others find announcements generate significant and undesirable volatility in U.S. asset prices (Kohn and Sack, 2004; Ehrmann and Fratzscher, 2007). Importantly, communication may not be very effective once we control for the central bank’s pre-existing policies. Gurkaynak et al. (2006) show that long-term inflation expectations derived from index-linked bonds are significantly less responsive to central bank announcements in inflation-targeting (IT) countries like Sweden and the U.K. than they are in the U.S., which has no explicit inflation objective. Indeed, Siklos (2002), Johnson (2002) and Corbo et al. (2002) finds in a series of cross-country studies that the adoption of IT has led to lower forecast errors, suggesting greater macroeconomic stability without the need for communication.

Central banks face risks when they communicate to the public. As Woodford (2005) points out, communication of a central bank goal may be misperceived by the public as a promise. If a central bank fails to live up to its stated goals or promises, it will lose credibility and the public will stop conditioning their forecasts and behaviour on the announced goals. This is why many central banks, including the Federal Reserve, have historically communicated very little to the public. In December 2012, the Federal Reserve made an unusual announcement that it would keep interest rates low at least as long as the unemployment rate remains below 6.5 percent, the outlook for inflation one-to-two years ahead remains at or below 2.5%, and longer-term inflation expectations remain well anchored. This forward guidance was intended to
create long-run inflation expectations within an economy that is perceived to be stuck in a liquidity trap. The communication has yet to show any signs of influencing aggregate activity.

The success of central bank communication of monetary policy depends crucially on how it is perceived and understood by the public, and what kind of expectations they form. If there is no instantaneous adjustment of rational expectations, i.e. if agents need time to process and adapt their expectations, what is the appropriate model of aggregate expectations? In other words, what is a reasonable class of expectations that we can work with when analyzing the impact of central bank communication? Surveys of households and professional forecasters are widely used sources of direct evidence on expectation formation. Mankiw et al. (2004) and Coibion and Gorodnichenko (2012) discuss recent studies of expectations using survey for forecaster data. These studies lack the ability to control for agents’ information sets and the economy’s true underlying data generating process, and so are limited in their ability to tell us how individuals form their expectations. In the absence of empirical studies that would identify the process of expectation formation, experiments are an invaluable tool that we can use to identify a class of expectations. This identification will certainly have an impact on the types of communication (e.g. macroeconomic targets, forecasted paths of future interest rates, central bank outlooks) and the formulation of monetary policies a central bank would find optimal to pursue. Laboratory experiments benefit from more precise control of conditions under which subjects form their expectations (see for example, Arifovic and Sargent, 2003; Arifovic et al. 2013 a,b; Duffy, 2008, 2012; Adam, 2007; Hommes et al, 2008; Pfajfar and Zakelj, 2014; Hommes, 2011, 2013 reviews the literature on the evidence of heterogeneous expectations hypothesis in the experimental economies; Chakravarty et al., 2011, review the growing literature on experimental macroeconomics; and Cornand and Heinemann, 2014, survey experiments on monetary policy.)

Indeed, laboratory experiments have become an increasingly important tool in the macroeconomists toolbox. Amano et al. (2011) study the ability of subjects to make rational forecasts under a price-level targeting regime.
Kryvtsov and Petersen (2013) investigate the robustness of the expectations channel of monetary policy. They observe a relatively weak expectations channel that is strengthened with more aggressive monetary policy. Central bank forward guidance in the form of a multi-period forecast of future nominal interest rates initially works to coordinate expectations, but over time subjects stop conditioning on the information and expectations become more volatile. Expectation rules can be influenced significantly in the short-run by the presentation of information. Petersen (2014) finds that increasing the salience of forecast error information results in significantly greater usage of the information in forecasts and more pronounced constant-gain learning. In a similar learning-to-forecast experimental design, Cornand and M’Baye (2014) observe that communicating an explicit inflation target is not essential to maintain economic stability when the central bank has a strict inflation target. However, if the central bank has a dual mandate to stabilize inflation and output, communicating to private agents the central bank’s inflation target leads to significant improvements in stability and convergence to the target.

II Experimental Design and Implementation

We design a laboratory experiment to study expectation formation in the presence of the zero lower bound and alternative monetary policies. The experimental economy is based on a standard reduced-form version of the New Keynesian framework where the aggregate dynamics are driven by aggregate expectations, exogenous disturbances, and monetary policy. Specifically, the environment follows a data-generating process of the form

\[ x_t = E_t^* x_{t+1} - \sigma^{-1} \left( i_t - i^* - E_t^* \pi_{t+1} - r^*_n \right) , \]  

(1)

\[ \pi_t = \beta E_t^* \pi_{t+1} + \kappa x_t , \]  

(2)
\[ i_t = \begin{cases} 
    i^* + \phi_x (\pi_t - \pi_t^*) + \phi_x x_t & \text{if } i_t \geq 0 \\
    0, & \text{otherwise,}
\end{cases} \quad (3) \]

\[ r^n_t = \rho r^n_{t-1} + \epsilon_t. \quad (4) \]

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.\(^1\) As aggregate expectations of future output \((E_t^* x_{t+1})\) and inflation \((E_t^* \pi_{t+1})\) increase, current output will also increase. Exogenous changes in the natural rate of interest, \(r^n_t\), will have a positive effect on demand. When the nominal interest rate, \(i_t\), deviates from its steady state value, \(i^*\), it has a stabilizing effect on output so long as \(i_t \geq 0\) and will stimulate (contract) demand as interest rates fall (increase). We parameterize \(\sigma = 1\) and \(i^* = 75\) basis points.

Equation 2 describes the evolution of aggregate supply or inflation. Inflation depends primarily on 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 is the central bank’s response function and describes how nominal interest rates are set. The central bank 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. The central bank responds aggressively to deviations of inflation and output from its targets with a \(\phi_x = 1.5\) and \(\phi_x = 0.5\). The monetary transmission operates by influencing the real rate of interest through movements in the nominal interest rate. Monetary policy would generally be able to stabilize real output at its potential level for any fluctuation in \(r^n_t\) so long as it can adjust the policy rate such that \(i_t - E_t \pi_{t+1} - r^n_t\) can be stabilized to zero. However, in this environment, the presence of a zero lower bound on nominal interest rates prevents the central bank from lowering interest rates sufficiently in the presence of very low or negative inflation and

\(^1\)Throughout the paper, we refer to the output gap as simply “output”.
output. In other words, the central bank is unable to stabilize output at its steady state, and thus inflation, under sufficiently negative realizations of $r^n_t$.

Finally, Equation 4 describes the evolution of the natural rate of interest or, as we will refer to it throughout the paper, the shock. The shock follows an AR(1) process where $\rho = 0.8$, and $\epsilon_t$ is drawn randomly from a normal distribution with mean zero and standard deviation of 93 basis points.

Each session consisted of nine subjects. Subjects played the role of professional forecasters who submit quarterly forecasts for future inflation and output. At the beginning of each session, subjects participated in a 45 minute instruction and practice phase. During the instructions we first explained the data generating process qualitatively. 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 subjects through the software in four practice periods to familiarize them with the interface and provided them with an opportunity to ask questions. The computer interface was highly graphical. Subjects learned their forecast accuracy by observing changes in their points between rounds and by comparing visually (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.

Subjects had access to the following information before submitting their forecast of next period’s inflation and output. They observed all historical information including the previous period’s realized inflation, output, and nominal interest rate, as well as their forecast accuracy. Subjects also observed the current period’s shock and the central bank’s communicated inflation target. Subjects had 65 seconds to submit forecasts. Forecasts were submitted in basis point measurements (i.e. 1% is inputed as 100 basis points) and could be positive or negative. After all subjects submitted their forecasts or time ran out, the median 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. Subjects’ scores, and subsequently their earnings in the game, depended on the accuracy of their forecasts each period:


\[ Score_{i,t} = 0.3 \left( e^{-0.01|E^*_{i,t-1} \pi_t - \pi_t|} + e^{-0.01|E^*_{i,t-1} x_t - x_t|} \right), \tag{5} \]

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. This scoring rule is 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.\(^2\)

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. We conducted two sequences on the same group of subjects to observe the effects of additional learning on their forecasting behaviour. Our experiment consisted of three initial treatments in a between-subject design. Each subject participated in only one session.

This experiment focuses on policy’s ability to alleviate the duration and magnitude of liquidity traps. As such, we focused on economies that would experience and remain in a liquidity trap for some 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 chose approximately the same size shock (between -398 and -402) in both repetitions to make consistent comparisons.\(^3\)

\(^2\)In the scoring rules used by Assenza et al. (2013) and Pfajfar and Zakelj (2014), there is diminishing marginal loss from forecast errors. 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.

\(^3\)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 zero lower bound. 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
We employed social evolutionary learning, SEL (Arifovic and Karaivanov, 2010), to explore the parameter space when designing our experiment. Hundreds of shock sequences were drawn to observe the behaviour of our social evolutionary learning agents in those environments. We selected shock sequences that met the following criteria: 1) The economies did not reach the zero lower bound prior to us imposing the liquidity trap shock, 2) the shock remained negative for 3-8 periods, 3) the economies rebounded in the later periods with few if any returns to the zero lower bound.

II.A Treatments

We conducted three treatments relating to either the type of inflation targeting or the communication of the target. Each treatment consisted of six independent sessions, where each session involved a different pair of shock sequences. Across treatments, the set of shock sequences were identical. Thus, for any given pair of shock sequences, we can observe how behaviour may differ across treatments.

Monetary Policy Rules

Our nominal interest rate generally takes the form given in Equation 3. First, we consider an inflation target that is set to a constant value, $\pi^*_t = 0$. In this Constant Target (CT) treatment, we convey to subjects that the central bank’s objective is to keep inflation and output as close to zero as possible. Under this environment, when the crisis shock of -400 basis points occurs, forecasters should react by significantly reducing their output and inflation forecasts. Under rational expectations, subjects’ forecasts would solely track the fundamental shock.

As a comparison, we conduct a State-Dependent Target (SD) treatment 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 zero lower bound for varied amounts of time.
where the inflation target evolves based on the past realized inflation and output. The time-varying inflation target is computed as follows:

\[
\pi_{t+1}^* = \frac{1}{\beta} (\pi_t^* - \pi_t) - \frac{\lambda}{\kappa \beta} (x_t - x_{t-1}) - \frac{\lambda \sigma}{\beta} x_t
\]  

(6)

This inflation targeting rule consists of two components: the inflation and the output gap component. When the economy is in the liquidity trap, the central bank finds it difficult to meet higher inflation targets due to the zero lower bound on nominal interest rates. In such cases, the first component of this rule causes the central bank to increase its inflation target for the subsequent period.

When the economy exits the liquidity trap (either due to more optimistic expectations or due to the improving fundamentals), the inflation target does not immediately drop 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 reached the steady state.

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). OccBin solves dynamics models with occasionally binding constraints by solving for the piece-wise linear non-explosive solution. An analogous approach to simulating dynamics under the zero lower bound was used by Eggertson and Woodford (2003). The simulations presented show the linear solution that ignores the zero lower bound as a red dashed line. The solid blue line is the piece-wise linear solution that accounts for the zero lower bound. The first 30 periods refer to the dynamics associated with a negative natural rate of interest shock of 400 basis points while the following periods refer to dynamics under a positive shock. As the figures show, when the economy experiences positive shocks, the piecewise linear and the linear impulse responses coincide. The simulations indicate that economic recovery is considerably faster and the severity of the crisis significantly lower under
a state-dependent inflation target. Output and inflation are four and seven times more reactive to the negative shock when the central bank implements a constant inflation target.

The State-Dependent Target gives agents a precise inflation target to coordinate expectations on. 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 observe the target continually rising, 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.

Thus we 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 sets monetary policy to stabilize inflation around a state-dependent inflation target (as in the SD treatment), but only communicates to subjects the direction of the target. The direction is presented as either “positive” or “negative.” As such, we remove the time-series graph of the target.\(^4\)

The experiments were conducted at the CRABE Lab at Simon Fraser University. The subject pool consisted of undergraduate students recruited from a variety of disciplines. Subjects were invited to participate in sessions that involved 30 minutes of instructions and 90 minutes of game participation. Only one group participated in a given session. We have conducted six sessions of each treatment. For robustness, in one sequence per treatment (Sequence 1 - Repetition 2) we set the crisis shock to -600 basis points. Earnings, including a $7 show up fee, ranged from $20 to $38.50, and averaged $26 for two hours of participation.

\(^4\)Our communication variation is similar to Cornand and M’Baye (2014) who vary whether the inflation target is explicitly communicated in the form of 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.
III Results

After 20 periods in Repetition 1 or 15 periods in Repetition 2, the experimental economies experience a crisis shock of -400 basis points. Thereafter, the shock trends back to zero and surpasses zero. Across different shock sequences we vary the number of periods it takes for the shock to reach zero. We define BadShockLength as the number of periods, including the period of the initial shock, before the natural interest rate shock reaches zero.

On the impact of the crisis shock, expectations drop significantly and drive the economy down to the ZLB. All economies reach the ZLB on impact of the crisis shock in both repetitions. However, some economies escape the ZLB and trend back up to the steady state, while others experience persistent deflationary spirals. We define a liquidity trap as a situation where median expectations remain pessimistic in the presence of expansionary monetary policy. In all treatments, we observe liquidity traps that subjects are not able to escape from.

We present two representative examples of shock sequences where the economies, regardless of treatment, either escape or remain trapped at the ZLB. In Figures 2 and 3, times series of output and inflation in blue and green, respectively. The nominal interest rate is presented in orange, while the shock is presented in bold red. Figure 2 refers to sequence 3 where the BadShockLength is three periods in Repetition 1 and five periods in Repetition 2. PRE and POST refers to the preshock and postshock phases of each repetition, respectively. Across all treatments, expectations, and thus output and inflation, track the shock well. On the impact of the shock, expectations drop and even trend downwards one period after the crisis shock. However, median expectations are quickly reversed and the economies all successfully return back to the steady state relatively quickly in both repetitions. By contrast, sequence 2 presented in Figure 3 has a BadShockLength of 8 periods in both repetitions. Again, median expectations do fall significantly on the im-

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5 All time series graphs of inflation, output, interest rates, and forecast distributions can be found in the Online Appendix.
impact of the shock. However, in all treatments, they never return to the steady state, and instead, reach very large negative levels resulting in deep liquidity traps.

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

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

The results are aggregated in box plots in Figure 4 a. Among inexperienced subjects (Repetition 1), the relative traps are the lowest in the Constant treatment where it takes an average of 9.5 periods for subjects to reverse their expectations. By contrast, in treatments SD and Dir. SD, it takes an average of 15.2 and 13.8 periods, respectively. However, the differences across treatments are not statistically significant. Two-sided Wilcoxon rank sum tests failed to reject the null hypothesis that the distributions of the relative trap lengths across all pairwise treatment combinations (with \textit{p-value} 0.42 in all cases). With experienced subjects (Repetition 2), the average relative trap length increases in the Constant treatment with subjects taking an average of 12.9 periods to reverse their expectations, while the average relative trap length decreases only modestly in the SD treatments (with an average of 18 periods to reverse the expectations) and decreases considerably in Dir. SD (with an average of 11 periods to reverse the expectations. Again, none of these are statistically significant (with \textit{p-value} 0.173 in all cases).

Figure 4 b. presents standard deviations of inflation across treatments and repetitions (log scale on the y-axis). 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. As subjects become experienced, the standard deviation of inflation worsens in the Constant and SD treatments, and we do not observe any statistically significant differences between the two. However, the qualitative communication in the Dir. SD treatment is more effective at reducing inflation variability than quantitative communication is in the SD treatment (where the difference is statistically significant with $p$-value = 0.055). The results for the output gap follow an identical pattern.

We further conduct a series of probit regressions to identify the effects of the BadShockLength on the likelihood of coordinating expectations in the direction of the inflation target. The results for each treatment are presented in the first three columns of Table 1, where the data is pooled across repetitions and standard errors are clustered at the session level. The results indicate that the longer is the BadShockLength, the lower is the probability that individuals will coordinate their expectation in the direction of the inflation target. The estimate is large and statistically significant in the Constant treatment, but not precisely estimated in the two state-dependent treatments. We also consider the possibility that larger adjustments in the aggregate shock in the period after the crisis may appear more focal and serve to effectively coordinate expectations in line with the target. The results are presented in the second half of the table. Indeed, in the Constant and Dir. SD treatments, a larger recovery of the shock immediately after the crisis occurs significantly increases the probability that subjects coordinate their expectations toward the target in that period. In the SD treatment, a larger initial recovery in fundamentals has no effect on the likelihood of forming more optimistic inflation expectations.
IV Fiscal Policy

Our results in the previous sections suggest that when fundamentals recover faster, the probability and speed of recovery are increased and the severity of economic crises are reduced. We next consider whether economic crises can be effectively ameliorated by anticipated expansionary fiscal policy. Anticipated productive government spending should create more optimistic expectations about future demand and inflation. To determine whether this is the case, we conduct a fourth treatment that introduces fiscal spending into our baseline constant inflation targeting environment.

In the Fiscal Policy (FP) treatment, subjects are informed that the government is able to conduct discretionary expansionary and contractionary fiscal policy. The government does not follow a specified rule, nor is it required to balance its budget over the horizon of the game. Government expenditures or taxation, denoted as $g_t$, has a direct effect on aggregate demand, resulting in a modified I-S curve:

\[ x_t = E_t^* x_{t+1} - \sigma^{-1} (i_t - i^* - E_t^* \pi_{t+1} - \pi^*_t) + g_t, \tag{7} \]

Subjects were informed each period of the government’s planned expenditures in the following period and understood that the expenditures would occur with certainty. They were informed that the government’s spending was discretionary and was not required to be balanced. The planned expenditures were displayed to them on their screen in the form of a time series graph in the same panel as the nominal interest rate and the natural rate of interest shock. During the practice phase, subjects encountered both positive and negative government expenditures to ensure that they understood both were possible.

During the actual game, government spending was exogenously set to zero until the crisis occurred. On the impact of the crisis, the government announced fiscal spending equal to 200 basis points, or 50% of the size of the aggregate demand shock for the following period. Importantly, we do not try to offset the crisis shock entirely. We do, however, explore whether we can minimize the pessimistic reaction to the crisis by creating optimistic expectations...
through fiscal spending. To capture the fact that the fiscal authority often takes time to enact new expenditures, we only introduced the fiscal spending in the period following the initial crisis shock. The positive government spending announcements lasted for as long as the current natural rate of interest shock was trending back up to the steady state. Thus, the last period of positive government spending occurred in the period when the shock first became positive. The decision to keep spending positive until the shock returned to zero seemed to be a simple rule to follow and not overly generous, especially since in our previous treatments we found that expectations would take nearly twice as long to reverse and begin trending back to the steady state. Six sessions of the FP treatment were conducted following the same procedures and shock sequences as in the other treatments.

Combining a constant inflation-targeting monetary policy with fiscal stimulus is effective at stabilizing expectations during an economic crisis. The mean relative trap length under the fiscal policy treatment is 0.937 (s.d. 1.053) in the first repetition and 0.441 (s.d. 0.049) in the second repetition. This is considerably smaller than the relative trap lengths observed in the Constant Target treatment, which have means of 1.652 (s.d. 0.977) and 2.536 (s.d. 1.903) in Repetitions 1 and 2, respectively. Two-sided Wilcoxon rank sum tests reject the null hypothesis of equal distributions (p-value = 0.025) in the second repetition, but fail to in the first repetition (p-value = 0.126). Only one economy in the fiscal policy treatment experienced a severe liquidity trap (shock sequence 2, repetition 1). If we exclude that repetition from our analysis, we find that the differences between the constant and fiscal treatment are again highly significant (p-value = 0.028).

The standard deviations of inflation and output are also considerably reduced with the introduction of fiscal policy. Figure 5 b. presents a comparison of standard deviations at the session level in the Constant Target and Fiscal Policy treatments. The differences across treatments are visually dramatic. Two-sided Wilcoxon rank sum tests indicate that the differences across treatments are stark. In the first repetition, we obtain p-value = 0.078 for inflation and p-value = 0.109 for output, and when exclude the outlier ses-
sion, the significance increases considerably to $p\text{-value} = 0.011$ for inflation and $p\text{-value} = 0.018$ for output. With experience in the second repetition, the differences are more significant: $p\text{-value} = 0.010$ for inflation and $p\text{-value} = 0.004$ for output.

We report the results from a final series of probit regressions for the fiscal policy treatment in Table 1. We find a small, positive effect of BadShock-Length on the likelihood of expectations moving in the correct direction but the effect is not statistically significant. Thus, fiscal policy is effective at reducing the pessimism generated by slow recovery of fundamentals. Second, we observe that subjects in the Fiscal Policy treatment are also more likely to adjust their expectations upward when fundamentals improve by more in the period immediately following the crisis shock.

V Individual-Level Analysis

In this section, we consider how alternative forecasting strategies are influenced by the impact of the shock and the amount of time it takes for fundamentals to recover. Expectations are pooled across repetitions, differentiating between preshock and postshock forecasting behaviour.

We consider how expectations might evolve under five different 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. We regress forecasts on each of these pieces of information at the individual level, pre- and post-shock. Specifically, we run the following OLS regressions for each individual $i$: $E_{i,t}x_{t+1} = \beta r^n_t + \epsilon_t$, $E_{i,t}x_{t+1} = \beta x_{t-1} + \epsilon_t$, and $E_{i,t}x_{t+1} = \beta (x_{t-1} - x_{t-2}) + \epsilon_t$. For the state-dependent inflation targeting treatments, we estimate each individual’s responsiveness to the central bank’s evolving inflation target using the following regression equation: $E_{i,t}x_{t+1} = \beta \pi^*_t + \epsilon_t$. Finally, for the fiscal policy treatments, we estimate subjects’ responsiveness to fiscal policy: $E_{i,t}x_{t+1} = \beta g_t + \epsilon_t$. Inflation expectation regressions are similar. The cumulative distribution functions of
estimated $\beta$s are plotted in Figures 6 - 33. The solid blue and dashed red lines denote the pre- and postshock distributions, respectively.

Visual inspection of the distributions suggests that the postshock behavior - irrespective of forecasting type and treatment - is considerably more heterogeneous than the preshock behavior. The standard deviation in estimated coefficients increases dramatically in all but the Fiscal Policy treatment, where it increases the least.

Subjects reduce the aggregate shock’s weight in their postshock forecasts. In terms of output forecasts, median\(^6\) estimated $\beta_{r_t}$ falls from 0.72 to 0.49 in the CT treatment, from 0.26 to -267.63 in the SD treatment, from 0.08 to -1.06 in the DSD treatment, and from 0.65 to 0.47 in the FP treatment. A similar pattern occurs for inflation forecasts. The number of subjects whose expectations respond positively to the aggregate demand shock decreases after the crisis occurs.\(^7\)

In the CT treatment, the post-shock estimated coefficients are significantly negatively correlated with the bad shock length ($\rho_x = -0.38$ and $\rho_\pi = -0.30$, with the $p$-value $< 0.01$ in both cases).\(^8\) Similarly, subjects’ inflation forecasts respond more positively to aggregate demand shocks following the crisis in the DSD treatment ($\rho_\pi = -0.27$, $p$-value $< 0.01$) and FP treatment ($\rho_\pi = -0.43$, $p$-value $< 0.01$). In the SD treatment, the post-shock correlation is very small and not statistically significant.

The extent to which the median subject use lagged output in forming their output forecasts decreases in all treatments. Median estimated $\beta_{x_{t-1}}$ falls from 0.86 to 0.63 in CT, 0.70 to 0.61 in SD, 0.60 to 0.54 in DSD, and 0.83 to 0.67 in FP. Similarly, subjects’ inflation forecasts respond less to lagged inflation in the postshock phase of the CT, with the estimated median coefficient falling

---

\(^6\)When referring to median estimated values, we are referring to the median individual in the entire set of subjects for a given treatment and phase.

\(^7\)We have a total of 108 individual observations. The number of subjects responding positively to an increase in the aggregate demand shock in the pre and postshock phases changes as follows: CT Output, from 107 to 59; CT Inflation, from 100 to 59; SD Output, from 86 to 38; SD Inflation, from 78 to 40; DSD Output, from 67 to 51; DSD Inflation, from 85 to 46; FP Output, from 106 to 95; FP Inflation, from 104 to 88.

\(^8\)Spearman rank correlations are reported throughout.
from 0.88 to 0.7. While there is minimal change in how the median subjects utilizes past inflation in forming their inflation forecasts in the DSD and FP treatments, the median SD subject becomes increasingly naive in the postshock phase. In the SD treatment, the estimated weight on past inflation increases from 0.81 to 0.94. As the bad shock length increases, the weight subjects place on lagged inflation in the postshock phase increases in the CT treatment ($\rho_\pi = 0.30, \text{p-value} < 0.01$) and in the DSD treatment ($\rho_\pi = 0.21, \text{p-value} = 0.03$). FP subjects respond more strongly to lagged output information when forming their output gap forecasts ($\rho_x = 0.18, \text{p-value} = 0.05$).

The median subjects reduce their trend-chasing behavior when forming their output forecasts after the large shock occurs. The estimated weights placed on the past output trend decreases from 0.55 to 0.41 in CT, 0.62 to 0.41 in SD, 0.44 to 0.31 in DSD, and 0.53 to 0.45 in FP. Similarly, median inflation forecasts become less trend-chasing in the CT, where the estimated coefficient on trend inflation decreases from 0.79 to 0.57, and in FP where the coefficient decreases from 0.60 to 0.45. Median inflation forecasts become increasing trend-chasing in the SD and DSD treatments following the large shock. The estimated coefficients on trend inflation increase from 0.66 to 0.85 in SD and 0.52 to 0.88 in DSD. Postshock, trend-chasing behavior becomes more prevalent as the bad shock length increases, both for CT inflation forecasts ($\rho_\pi = 0.30, \text{p-value} < 0.01$) and for DSD inflation forecasts ($\rho_\pi = 0.34, \text{p-value} < 0.01$).

Subjects do not generally condition on the inflation target in the anticipated direction. The majority of subjects respond to higher inflation targets by decreasing their output and inflation forecasts. In the SD treatment, the estimated $\beta_{\pi t}$ decreases from -0.16 to -0.32 for output and from -0.11 to -0.14 for inflation, suggesting that the target becomes increasingly ineffective in the postshock phase. Preshock, 41% (44 out of 108) and 18.5% (20 out of 108) of subjects increased their output and inflation forecasts, respectively, in response to a higher inflation target. Postshock, only 7% (8 subjects) and 14% (15 subjects) continued to do so. Thus, on impact to the large shock, not only is the median subject responding less to the inflation target when forming
forecasts, but fewer subjects are forming inflation targets in the predicted direction. Reactions to the inflation target are not significantly correlated with the bad shock length (associated *p*-values > 0.27).

In the DSD treatment, we observe a different pattern where the qualitatively communicated inflation target has a small positive effect on output forecasts, with estimated $\beta_{p_i}^*$ of 0.09 preshock. However, postshock, the median reaction decreases to -0.17. Inflation forecasts respond negatively to higher inflation targets both pre- and postshock, with the estimate increasing from -0.13 to -0.07. Preshock, 61% (66 subjects) and 10% (11 subjects) increased their output and inflation forecasts in response to higher inflation targets. Postshock, 22% (24 subjects) and 19% (21 subjects) increase their output and inflation forecasts. Interestingly, the number of subjects who positively condition their output forecasts on the target is considerably higher - both pre- and postshock - in the DSD treatment compared to the SD treatment. Postshock, the number of subjects responding to the inflation target when forming output forecasts drops dramatically but increases modestly for inflation forecasts. Inflation forecasts also respond less to the inflation target as the bad shock length increases ($\rho_\pi = -0.23$, *p*-value = 0.02).

In response to an additional 100 basis points of government spending, median output and inflation forecasts decrease by 31 and 0.5 basis points, respectively. This alone would suggest that fiscal policy has a contractionary effect on expectations and the economy, which is inconsistent with what we have observed in our FP sessions. When we alternatively control for the effect of the aggregate shock on expectations$^9$, we find that expansionary fiscal policy creates more optimistic expectations in the majority of subjects. Median output and inflation forecasts increase by 41 and 37 basis points, respectively, in response to a 100 basis point increase in government spending. Postshock inflation forecasts also respond significantly less to fiscal policy as the bad shock length increases ($\rho_\pi = -0.28$, *p*-value < 0.01).

We also consider whether there are systematic differences in responses to

$^9$Specifically, we estimate the following regression: $E_{i,t,x_{t+1}} = \beta_0 r_t^n + \beta_1 g_t + \epsilon_t$. The associated cumulative density function is plotted in Figure 33b.
information across ‘stable’ and ‘unstable’ economies in the preshock phase of each session. This provides insight into an important source of heterogeneity that may explain why some economies are highly stable and others suffer deep recessions. We denote an economy as ‘stable’ if output or inflation stays above -1000 basis points in the postshock phase, and ‘unstable’ otherwise. CDFs are plotted for each heuristic and phase of the experiment. Two sample Kolmogorov-Smirnov tests are conducted on preshock behavior to test whether the distributions of stable and unstable economies are identical. The results and plots can be found in the Supplementary Appendix A1. Prior to the crisis, unstable economies tend to under-react to the shock relative to their stable economy counterparts and overreact to lagged output and inflation. Trend-chasing heuristics to form forecasts are also considerably more pronounced in the unstable economies. Participants in unstable State Dependent Target sessions exhibit considerably greater heterogeneity in how they respond to the announced inflation target, which may explain the limited effectiveness of the announced policy in the postshock phase.

VI 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, thus causing the economy to diverge into a deep recession. Recent research has suggested that state-dependent central banks can bring about greater economic stability and faster recoveries by promising to keep interest rates low following a recession even after inflation has returned to its target. We conduct a series of 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 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 policy to keep interest rates low even after the economy begins recovering. Unlike rational expectation 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 commitment to its policies. In short, our subjects need to "see it to believe it."

By contrast, anticipated fiscal policy 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 monetary policies that provide a promise of future recovery in the uncertain future, anticipated expansionary fiscal policy in our environment stimulates demand with certainty.

In our study of the individual-level data, we analyze how individuals’ expectations might evolve under five different forecasting heuristics: fundamental-driven, 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. Irrespective of forecasting type and treatment, the post-shock behaviour is substantially more heterogenous than in the pre-shock phase. The increase in heterogeneity post-shock is least pronounced when the economy receives anticipated fiscal stimulus following a crisis shock.
In general, subjects weight the aggregate shock less in their forecasts in the postshock phase. In addition, the number of subjects whose expectations respond positively to the aggregate demand shock decreases after the crisis occurs. Subjects reduce the weight they put on lagged output in all of the treatments in the postshock phase. Subjects’ use of lagged inflation in forecasting also decreases in the constant-target economies. There is a minimal change in its use in the state-dependent inflation targeting and fiscal policy treatments, while the median subject in the directional treatment becomes increasingly naive in the postshock phase. The median subject reduces his or her trend-chasing behaviour when forming their output forecasts after the large shock occurs. Median inflation forecasts become less trend-chasing in the constant target and fiscal policy treatments. However, median inflation forecasts become more trend-chasing in the directional and state-dependant treatments, following the large shock.

The key assumption that underlines the success of state-dependent inflation targeting rules is that agents form rational expectations. This is necessary for the inflation targeting policy to be credible and successful. However, we know that in experimental economies participants do not begin with rational expectations. The question is whether they learn to forecast as if they form rational expectations. If they do, and do so fast enough, the inflation targeting policies can be successful in mitigating the impact of a severe demand shocks. However, if agents do not learn to coordinate their expectations on fundamentals fast enough, these policies lose their power to guide economies out of liquidity traps.

In the state-dependent inflation targeting treatments, we find that qualitative directional communication leads to modest improvements in economic stability compared to explicit communication of a numerical target. Experienced subjects are better able to coordinate their expectations under a qualitatively communicated state-dependent inflation target leading to shorter average trap lengths and, subsequently, significantly lower volatility. Qualitatively communicated inflation targets are more effective coordination devices during recessions. As the quantitative target keeps rising during a deep recession,
it reinforces participants’ beliefs that the central bank is ineffective at anchoring expectations. Qualitative communication of the same target does not make it explicitly clear to participants whether it is coordinating expectations sufficiently in the correct direction.

Less is more when it comes to central bank communication during a liquidity trap. There are at least a couple of reasons why qualitative targets are more effective coordination devices. First, it may be easier for individuals and markets to coordinate on the inflation guidance that is unchanging during the liquidity trap. Second, under a qualitative target, the public simply observes an announcement that the central bank aims to achieve positive inflation. By contrast, under an explicitly communicated target in an ever-worsening liquidity trap, the public is continually reminded by the rising target that the economy is not achieving the central bank’s goal of higher inflation. This can generate increased pessimism and reduce the perceived credibility of the central bank, leading to a more severe and prolonged recession.
References


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<tr>
<th></th>
<th>Forecast in Target Direction</th>
<th></th>
<th>Increase Forecast Relative to Past Inflation</th>
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<td>SD</td>
<td>Dir. SD</td>
<td>Fiscal</td>
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<td>BadShockLength</td>
<td>-0.076***</td>
<td>-0.019</td>
<td>-0.006</td>
<td>0.035</td>
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<td></td>
<td>(0.03)</td>
<td>(0.06)</td>
<td>(0.05)</td>
<td>(0.04)</td>
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<tr>
<td>( r^n_t - r^n_{t-1} )</td>
<td>( \alpha )</td>
<td>0.651***</td>
<td>0.091</td>
<td>0.181</td>
</tr>
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<td></td>
<td>(0.17)</td>
<td>(0.48)</td>
<td>(0.38)</td>
<td>(0.25)</td>
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<td>7.67</td>
<td>0.12</td>
<td>0.01</td>
<td>0.53</td>
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(I) Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01. Standard errors are presented in parentheses and clustered at the session-level.
Figure 1: Simulations of parameterized environment with a constant and state-dependent inflation targets
Figure 2: An Example of a Stable Shock Sequence
Figure 3: An Example of an Unstable Shock Sequence
Figure 4: Duration and Severity of Crises in Constant Target, State-Dependent Target, and Directional State-Dependent Target treatments
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(a) Fundamentals-Driven Expectations - Output Forecasts

(b) Fundamentals-Driven Expectations - Inflation Forecasts
Figure 7: Distribution of Naive Types Across Treatments and Shock Phases
(a) Trend-chasing & Contrarian Expectations - Output Forecasts

(b) Trend-chasing & Contrarian - Inflation Forecasts

Figure 8: Distribution of Naive Types Across Treatments and Shock Phases
(a) Inflation Target - Output Forecasts

(b) Inflation Target - Inflation Forecasts

Figure 9: Distribution of Responses to State Dependent Inflation Target Across Treatments and Shock Phases
(a) Fiscal Policy - Output and Inflation Forecasts

(b) Fiscal Policy Controlling for Aggregate Shock - Output and Inflation Forecasts

Figure 10: Distribution of Responses to State Dependent Inflation Target Across Treatments and Shock Phases
Figure 11: Constant Target Treatment Screenshot
Figure 12: State Dependent Target Treatment Screenshot
Figure 13: Directional State Dependent Target Treatment Screenshot
Figure 14: Fiscal Policy 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:

<table>
<thead>
<tr>
<th>Error</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-Your score will be 0.6</td>
</tr>
<tr>
<td>50</td>
<td>-Your score will be 0.42</td>
</tr>
<tr>
<td>100</td>
<td>-Your score will be 0.3</td>
</tr>
<tr>
<td>200</td>
<td>-Your score will be 0.15</td>
</tr>
<tr>
<td>300</td>
<td>-Your score will be 0.075</td>
</tr>
<tr>
<td>500</td>
<td>-Your score will be 0.02</td>
</tr>
<tr>
<td>1000</td>
<td>-Your score will be 0</td>
</tr>
<tr>
<td>2000</td>
<td>-Your score will be 0</td>
</tr>
</tbody>
</table>

**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? ________________.

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.

\[ Begin{align*}
Shock_1 &= 30 \\
Shock_2 &= 30 \times 0.8 + New\ Draw \\
&= 24 + (30) \\
&= 54 \\
Shock_2 &= 24 + (-150) \\
&= -126 \end{align*} \]

E.g.
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:
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3.25% = 325 basis points
-0.5% = -50 basis points
-4.8% = -480 basis points

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\begin{align*}
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&= 54 \\
\text{Shock}_2 &= 24 + (-150) \\
&= -126
\end{align*}
\]
How the economy evolves:

\[
Inflation_t = 0.995(\text{Median forecast of } Inflation_{t+1}) + 0.13(\text{Output}_t)
\]

\[
Output_t = \text{Median forecast of } Output_{t+1} + \text{Median forecast of } Inflation_{t+1} - \text{Interest Rate}_t + \text{Shock}_t + 75
\]

\[
\text{Interest Rate}_t = 75 + 3(Inflation_t - \text{Inflation Target}_t) + (Output_t)
\]

\[
\text{Inflation Target}_t = (\text{Inflation Target}_{t-1} - \text{Inflation}_t - \text{Inflation Target}_t) - 0.33(\text{Output}_{t-1} - \text{Output}_{t-2}) - 0.004\text{Output}_{t-1}
\]

- 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.
  - 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.
- 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 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.

$Shock_1 = 30$

$Shock_2 = 30 \times 0.8 + New\ Draw$

$= 24 + (30)$

$= 54$

$Shock_2 = 24 + (-150)$

$= -126$
How the economy evolves:

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

\[ \text{Output}_t = \text{Median forecast of Output}_{t+1} + \text{Median forecast of Inflation}_{t+1} - \text{Interest Rate}_t + \text{Government Spending}_t + \text{Shock}_t + 75 \]

\[ \text{Interest Rate}_t = 75 + 1.5(\text{Inflation}_t - \text{Inflation Target}_t) + 0.5(\text{Output}_t) \]

where,

\[ \text{Inflation Target}_t = 0 \]

- The government will occasionally spend money to stimulate demand or tax to reduce demand. At any point in time, you will see the government’s planned spending or taxation for the next period. The government does not necessarily need to balance its budget. That is, if the government spends in one period, they are not required to tax in the future, and vice versa.

- 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.
Figure 15: Time series data, Pre and Post shock
Figure 16: Time series data, Pre and Post shock
Figure 17: Time series data, Pre and Post shock
Figure 18: Time series data, Pre and Post shock
Figure 19: Time series data, Pre and Post shock
Figure 20: Time series data, Pre and Post shock
Figure 21: Distribution of Inflation Forecasts (25th, 50th, and 75th percentile and standard deviation), Constant Rep 1
Figure 22: Distribution of Inflation Forecasts (25th, 50th, and 75th percentile and standard deviation), Constant Rep 2
Figure 23: Distribution of Inflation Forecasts (25th, 50th, and 75th percentile and standard deviation), SD Rep 1
Figure 24: Distribution of Inflation Forecasts (25th, 50th, and 75th percentile and standard deviation), SD Rep 2
Figure 25: Distribution of Inflation Forecasts (25th, 50th, and 75th percentile and standard deviation), Dir. SD Rep 1
Figure 26: Distribution of Inflation Forecasts (25th, 50th, and 75th percentile and standard deviation), Dir. SD Rep 1
Figure 27: Distribution of Inflation Forecasts (25th, 50th, and 75th percentile and standard deviation), Fiscal Rep 1
Figure 28: Distribution of Inflation Forecasts (25th, 50th, and 75th percentile and standard deviation), Fiscal Rep 2
Heterogeneous Behavior By Macroeconomic Volatility

In this section, we consider the heterogeneity in types across economic volatility. Economies that are highly volatile (i.e. output and inflation fall below -1000 basis points) are labeled "Unstable", while less volatile economies are labeled "Stable". In Figures 29-38, we plot the cumulative density functions of individual estimated responses to identify whether highly unstable economies exhibit considerable differences in how they respond to shocks, past information, etc. during stable times. For each treatment, we test whether the distributions of estimated coefficients are identical using two-sample Kolmogorov Smirnov tests. The corrected p-value results are presented in Table 2.

Table 2: Kolmogorov-Smirnov tests on preshock differences in distribution between stable and unstable economies\(^1\)

<table>
<thead>
<tr>
<th>Output Forecasts</th>
<th>shock</th>
<th>lagged output</th>
<th>trend output</th>
<th>inflation target</th>
<th>fiscal policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.106</td>
<td>0.001</td>
<td>0.184</td>
<td></td>
<td></td>
</tr>
<tr>
<td>State Dependent</td>
<td>0.004</td>
<td>0.556</td>
<td>0.001</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Directional S.D.</td>
<td>0</td>
<td>0</td>
<td>0.001</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fiscal + Constant</td>
<td>0.103</td>
<td>0.184</td>
<td>0.4</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inflation Forecasts</th>
<th>shock</th>
<th>lagged inflation</th>
<th>trend inflation</th>
<th>inflation target</th>
<th>fiscal policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.125</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>State Dependent</td>
<td>0.198</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Directional S.D.</td>
<td>0.811</td>
<td>0</td>
<td>0</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>Fiscal + Constant</td>
<td>0.001</td>
<td>0.028</td>
<td>0.195</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

(\(^1\)) Corrected p-value results from combined two-sample Kolmogorov Smirnov tests. Subject-level coefficients estimated with pooled data from both repetitions.
Figure 29: Distribution of Rational Types Across Treatments and Shock Phases
Figure 30: Distribution of Naive Types Across Treatments and Shock Phases
Figure 31: Distribution of Naive Types Across Treatments and Shock Phases
(a) Inflation Target - Output Forecasts - Preshock

Figure 32: Distribution of Responses to State Dependent Inflation Target Across Treatments and Shock Phases
Figure 33: Distribution of Responses to State Dependent Inflation Target Across Treatments and Shock Phases
Figure 34: Distribution of Rational Types Across Treatments and Shock Phases
Figure 35: Distribution of Naive Types Across Treatments and Shock Phases
(a) Trend-chasing & Contrarian Expectations - Inflation Forecasts - Preshock

(b) Trend-chasing & Contrarian - Output Forecasts - Postshock

Figure 36: Distribution of Naive Types Across Treatments and Shock Phases
Figure 37: Distribution of Responses to State Dependent Inflation Target Across Treatments and Shock Phases
Figure 38: Distribution of Responses to State Dependent Inflation Target Across Treatments and Shock Phases