Coordinating expectations through central bank projections*

Fatemeh Mokhtarzadeh **Luba Petersen**†
University of Victoria Simon Fraser University

August 2016

Abstract

This paper explores how expectations of inflation and output are influenced by central bank forward guidance within a learning-to-forecast laboratory macroeconomy. Subjects are incentivized to forecast the output gap and inflation in a laboratory macroeconomy where their aggregated expectations directly influence macroeconomic dynamics. An automated central bank forms projections about the economy assuming subjects form expectations either following rational or adaptive expectations. Using a between-subject design, we vary whether the central bank communicates no information, rational nominal interest rate projections, or rational or adaptive dual projections of output and inflation. Communicating about future output and inflation generally reduces the degree to which subjects rely on lagged information and increase their reliance on the REE solution. The gains from dual projections are highly significant and more pronounced when the central bank assumes agents adaptive projections. Interest rate projections, by contrast, do not consistently alter subjects' forecast accuracy, disagreements, and heuristics used, due to the significant heterogeneity in how subjects utilize the information. Central bank credibility is only significantly lost when the central bank makes larger output forecast errors in high variability sessions. Our experimental findings suggest that expectations are best coordinated and stabilized by communicating adaptive output and inflation forecasts simultaneously.

JEL classifications: C9, D84, E52, E43, G12, G14
Keywords: expectations, monetary policy, forward guidance, communication, credibility, laboratory experiment, experimental macroeconomics

---

*Corresponding author: Luba Petersen (lubap@sfu.ca). We thank Camila Cordoba and Yang Li for outstanding research assistance and the Social Science and Humanities Research Council of Canada for generous financial support. We have benefited from useful comments and suggestions from Jasmina Arifovic, Camille Cornand, Geoff Dunbar, David Freeman, Lucas Herrenbrueck, Paul Hubert, John Knowles, Luminita Stevens, and Randall Wright, as well as seminar and conference participants at New York University, the Bank of Canada, Carleton University, Minneapolis Federal Reserve, Simon Fraser University, the 2015 North American Economic Science Association meetings, 2016 Spring Midwest Macroeconomic Meetings, the 2016 Canadian Experimental and Behavioural Economics Research Group Meetings, and the 2016 Computing in Economics and Finance Conference. All remaining errors are our own.

† Petersen: Department of Economics, Simon Fraser University, 8888 University Drive, Burnaby, BC, V5A 1S6, Canada, lubap@sfu.ca. Moktarhzadeh: Department of Economics, University of Victoria, Victoria, BC, V8P 5C2, Canada

1. Introduction

Expectations are an important driver of household and firm decisions, and thus the economy. In an effort to manage private agents' expectations, central banks have become increasingly transparent about their objectives, future policies and their outlook about the future. Many central banks publish a combination of projections about future GDP, GDP growth, CPI and/or their own policy rates.[1] What a central bank should communicate to effectively influence market expectations is still a very open question. One important challenge in answering this question comes from the difficulty in identifying the effects of central bank information on expectations as information on private agents' information sets is not readily available.

To circumvent such empirical challenges, we study forecasting behavior in a laboratory economy where the nature of central bank policy and communication can be systematically controlled and varied. This experimental variation provides us causal evidence on the effects of different forms of central bank projections on expectations and central bank credibility. We construct a laboratory testbed where subjects' incentivized inflation and output gap expectations are elicited, aggregated with other participants', and fed into a stochastic economy's data-generating process. Subjects' expectations are elicited under one of four treatments. In our benchmark environment, participants only observe current and historical information about the economy when forming their forecasts and historical outcomes. We compare our findings in the benchmark to treatments that involve communicating to subjects projected paths of nominal interest rate or dual projections of the output gap and inflation. The projections are rule-based and are derived from the rational-expectations equilibrium solution response to the current fundamentals. We also consider an adaptive dual projection whereby the central bank assumes agents forecast using a combination of historical and current information. Systematic variation of information across independent groups of subjects allows us to identify the effect of specific information on forecasting heuristics and aggregate dynamics.

We find that central bank projections can significantly stabilizes expectations and the aggregate experimental economy by 'nudging' naive forecasters towards fundamentally-driven rational expectations. Projections of future output gap and inflation results in consistently greater coordination of expectations and reduced forecast errors associated with the communicated variable. By contrast, forward guidance of nominal interest rates leads to mixed results. For relatively low variability in aggregate demand shocks, nominal interest rate projections are relatively accurate and result in significantly more 'rational' forecasts. However, as the variability of shocks increases, the benefits of such forward guidance weaken and subjects maintain an adaptive forecasting heuristic. Comparing

[1] The Reserve Bank of New Zealand (RBNZ), Norges Bank, Czech National Bank, Riksbank, and the Bank of Israel provide the public with a projected future path of nominal interest rates. The RBNZ and Norges Bank have gone even further to publish central bank projections of their economies' inflation rates and output gap. As interest rates have crept toward the zero lower bound since the start of the Great Recession, the Federal Reserve, ECB and Bank of England have experimented with a variety of forms of forward guidance about the direction of their future policy rates.

the two types of dual projections of output and inflation, we find that rational projections perform relatively better in stabilizing expectations in low variability sessions while adaptive projections are more effective at stabilizing expectations in high variability sessions.

Loss of credibility is an important concern central banks face when deciding whether to communicate their own projections. We find that this concern is valid only in highly volatile environments. As the central bank's forecast errors of the output gap grow large, the likelihood subjects utilize the projections decreases only when the variability of shocks is high. Credibility in the central bank's inflation forecasts, however, are not systematically affected by its past forecast inaccuracy. Likewise, in low variability sessions, subjects' trust in the central bank's projections is not consistently affected by past forecast errors.

The paper is organized as follows. The next section discusses related literature on central bank communication and expectations from theoretical, policy, and experimental viewpoints. Section 3 lays out our experimental design, hypotheses, and laboratory implementation. The experimental results are discussed in Section 4, namely how individuals form expectations and aggregate variables evolve under different forms of central bank communication, and Section 5 concludes.

2. Central Bank Communication and Expectations

The growing literature on central bank communication provides a strong body of theoretical and empirical work on the effectiveness of central bank communication on private agent's expectations. Central bank communication has evolved considerably over the last 30 years. The history of central bank communication policy can be roughly divided into three key periods.[2] For decades, central banks were uncommunicative and opaque about their operations to safeguard the central bank from political pressure, avoid credibility loss, and to achieve an element of surprise when they did change policy. However, in the early 1990's the Reserve Bank of New Zealand (RBNZ) began to adopt explicit inflation targeting and became more transparent about their inflation objective and mandate. Norway followed suit in 2001 and Sweden in 2007. Central banks' communication of inflation targets led to increased transparency and credibility and also allowed the markets to achieve low and stable inflation. Most recently, many central banks have moved toward explicitly communicating both their targets and forecasts about their future policy rates. Since 1997, the RBNZ has communicated not only their inflation target, but also inflation projections for the 90-day bank bill rate via Monetary Policy Statements (MPS). Norway in 2005, Sweden in 2007, Canada in 2009, and the U.S. in 2012 began to provide projections of key policy variables as a tool to manage market expectations (Woodford 2012). These types of forward guidance have been used to signal the likely future path of policy rates and the outlook of monetary policy in general.

Evidence on the effects of central bank projections on expectations is rather limited. Hubert

[2] See Kang et al. (2013) for a more detailed discussion and Blinder et al. (2008) for a survey of central bank communication strategies.

(2014) employs a linear regression approach to identify the effects of central bank inflation projections in Sweden, UK, Canada, Japan and Switzerland on private inflation forecasts collected by Consensus Forecasts' surveys. First, he finds no empirical support for the influence of private forecasts on central bank projections. Hubert finds a significant positive relationship between central bank projections and private expectations of inflation. Kool and Thornton (2012) find mixed evidence of the ability of forward guidance of future nominal interest rates to improve private agents's ability to forecast future short- and long-term rates. Forward guidance is associated with more accurate forecasting in Norway and Sweden, but not in the United States or New Zealand. Moreover, forward guidance appears to reduced the cross-sectional standard deviation of forecasts in New Zealand, Norway and Sweden, but not in the United States. McCaw and Ranchhod (2002) and Turner (2006) in different studies provide evidence that the RBNZ's interest rate projection path does not significantly improve short–term future expectations of the participants of three months horizon. Finally, Goodhart and Lim(2011) report that the projected future path of interest rate by the RBNZ is significant for 1–quarter ahead and slightly for 2–quarter ahead money market rate. While these findings speaks to how market forecasts react to central bank projections, there is no empirical work identifying the effects of central bank projections alter forecasting heuristics. Identifying forecasting heuristics at the individual-level is difficult due to the limited availability of long panel datasets of expectations.[3]

Central bank transparency is not without its own set of risks and challenges. Mishkin (2004) cautions that transparent central banks expose themselves to an "expectation trap" whereby a central bank may try to sustain a previously projected path for the economy to preserve its credibility when it be suboptimal to do so. The public may misperceive central bank targets or projections as promises. When the central bank fails to live up to its targets or projections, its credibility may be more critically lost (Woodford, 2005). Moreover, central bank communication can induce less clarity due to the limited ability of market agents to process additional information (Winkler, 2002; Kahneman, 2003). Confusion can be further compounded when the central bank does not have better information than private agents. For these reasons, Mishkin (2004), Goodhart (2005), Archer (2005) and Blinder (2009) assert that too much transparency can become counterproductive.

Empirical macroeconomists face significant hurdles when it comes to identifying the effects of exogenous disturbances, policy, or communication of expectations and must often make important identifying assumptions about the structure of the economy and the information sets of agents. As a consequence of these empirical challenges, laboratory experiments have increasing been conducted to study how monetary policy can influence the expectation formation process.[4] The advantage to

[3]Malmendier and Nagel (2015) identifying decreasing gain forecasting heuristics using cross-sectional data from the U.S. households in the Michigan Survey of Consumers. Andrade and LeBihan (2013) utilize the panel dimension of the European Survey of Professional Forecasters and find evidence of rational inattention a la sticky and noisy information models. Neither paper considers the effects of inflation projections on forecasting heuristics.

[4]See Duffy (2012) for a highly comprehensive survey of macroeconomic experiments, Cornand and Heinemann (2015) for a survey of experiments on central banking, and Amano et al. (2014) for a discussion of how laboratory

laboratory experimentation is that the researcher is able to carefully control for the many factors that might influence individuals' expectations in order to achieve more precise identification. The experimenter can control features of the data-generating process including important policy rules and communication strategies while systematically varying some feature of the economy.

Learning-to-forecast experiments (LTFEs) have been extensively used to study how expectations respond to information, policy, and structural features of the economy. In LTFEs, subjects play the roles of professional forecasters and are tasked with forming accurate forecasts for the following period(s) over a long multi-period horizon. Each period, aggregated forecasts are used by computerized households, firms, and banks to make decisions according to a prespecified data-generating process. In other words, subject-provided aggregate expectations have a direct effect on the macroeconomy. We discuss below LTFEs focused on the role of central bank communication in influencing expectations.[5]

There are three key LTFEs that study the effects of central bank communication on expectation formation. Kryvtsov and Petersen (2013) study the robustness of the strength of the expectations channel to variations in the aggressiveness of monetary policy to inflation, persistence of shocks, and central bank forward guidance of future policy rates. Different from other LTFEs, subjects are provided with the full data generating process to provide subjects with the best opportunity to formulate forecasts consistent with the rational expectations equilibrium solution. Among other things, Kryvtsov and Petersen find that providing focal central bank forecasts of the path of future interest rates leads to inconsistent forecasting behavior. Many inexperienced subjects incorporate the projections into their forecast and this leads to greater stability in some sessions. However, if only a few subjects initially employ the projections in their forecasts, the announcement creates more confusion and expectations become increasingly destabilized.

Arifovic and Petersen (2015) extend the aforementioned LTFE environment to study expectation formation at the zero lower bound. In a series of treatments, they consider the effects of history-dependent inflation targets that are communicated quantitatively or qualitatively on the coordination of expectations and economic stability. They find that qualitative communication of inflation targets tends to be more effective at stabilizing expectations because it minimizes the credibility loss when the central bank fails to meet its targets.

Cornand and M'Baye (2016) consider a more conventional LTFE where subjects only have a qualitative understanding of the economy's data generating process. They consider the effectiveness of announcing the central bank's constant inflation target when a central bank follows strict and

experiments can help inform monetary policy.

[5] The learning-to-forecast methodology originates with Marimon and Sunder (1993) who study price forecasting in an OLG experimental economy. Experiments studying inflation and output expectations in New Keynesian reduced form economies have been developed to study expectation formation and equilibria selection (Adam, 2007), the effects of different monetary policy rules on expectation formation Pfajfar and Zakelj (2014, 2016), Assenza et al. (2015), Hommes et al. (2015a)), expectation formation at the zero lower bound (Arifovic and Petersen (2015), Hommes et al. (2015b)), and central bank communication (Kryvtsov and Petersen (2013), Cornand and M'Baye (2016)).

flexible inflation targeting. They find that the gains from communicating the target depend on the nature of the central bank's policy rule. Under strict inflation targeting, subjects learn more quickly the central bank's target and additional communication does not have a significant effect on economic stability. By contrast, additional information about the inflation target when the central bank faces a dual mandate to stabilize inflation and output significantly reduces inflation variability.

3. Experimental Design, Hypotheses, and Implementation

Our experiment was designed to study how expectations are formed in the presence of central bank forward guidance and projections. The experiments were conducted at the CRABE Lab at Simon Fraser University where the subject pool consisted of undergraduate students from a variety of disciplines. The experiment closely follows the design of Kryvtsov and Petersen (2013). Each session involved groups of seven inexperienced subjects playing the role of forecasters who were tasked with submitting incentivized forecasts about the future state of the economy. The submitted forecasts were aggregated and used by computerized households and firms to form optimal decisions. The experimental economy's data-generating process was derived from a linearized version of a standard New Keynesian framework in which private expectations of future aggregate demand and inflation have a direct effect on current outcomes.[6] We focus on this general class of models because of its ubiquitous use by central banks over the last decade and for the important role expectations play in driving aggregate dynamics.

The aggregate economy implemented in our experiment is described by the following system of equations:

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

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

$$i_t = \phi_\pi \pi_t + \phi_x x_t, \tag{3}$$

$$r_t^n = \rho_r r_{t-1}^n + \epsilon_{rt}. \tag{4}$$

Equation (1) is the Investment-Saving curve and describes the evolution of the output gap or aggregate demand. It is derived from a log–linear approximation of households' intertemporal optimization around a deterministic zero inflation and output gap steady state. **??** describes how the current output gap, x_t depends positively on expectations of next period's output gap, $E_t x^*_{t+1}$.

[6] See Woodford (2003) for detailed assumptions and derivations in a model with rational expectations. We preferred to implement a linearized version of the New Keynesian model to simplify the environment for subjects. For a nonlinear implementation, see Hommes et al. (2015).

Output also depends on deviations of the real interest rate, $i_t - E_t\pi^*_{t+1}$ from the natural rate of interest, r^n_t, and the role this deviation plays depends on σ, the coefficient of risk aversion.[7]

Equation (2) is the New Keynesian Phillips curve which describes the evolution of inflation, π_t in response to changes in expected future inflation, $E_t\pi^*_{t+1}$ and current real activity, x_t. Importantly, the central bank faces a tradeoff when stabilizing inflation and output. The coefficient κ is a function of parameters associated with the frequency and size of firms' price changes, and governs how sensitive prices are to aggregate demand, while the coefficient β is the subjective discount rate.

Equation (3) is the central bank's response function and describes the evolution of nominal interest rates. Under this specification the central bank contemporaneously respond to deviations of output gap and inflation from their steady state values. In each period, the automated central bank increases the nominal interest rate in response to higher current inflation and the output gap. The coefficients ϕ_π and ϕ_x govern the central bank's reaction to inflation and output gap.[8] Importantly, subjects only know with certainty the previous period's interest rate when forming their forecasts. Note that the implemented environment studies deviations around a constant steady state, ignoring the presence of the zero lower bound. That is, negative nominal interest rates were possible in our experiment.[9]

Finally, Equation (4) describes how the natural rate of interest evolves in response to random perturbations. Throughout the paper, we will refer to r^n_t as a *shock* to the demand side of the economy. where ϵ_{rt} is $i.i.d$ with mean zero and $N(0, \sigma_r)$.[10]

The experimental economy's data-generating process was calibrated to match moments of the Canadian data following Kryvtsov and Petersen (2013). We set $\sigma = 1$, $\beta = 0.989$, $\kappa = 0.13$, $\phi_{pi} = 1.5$, $\phi_x = 0.5$, $\rho = 0.57$, and $\sigma_r = 1.13$. The environment had a unique steady state where $\pi^* = x^* = i^* = 0$.

Each session began with an instruction phase where we explained the data generating process both qualitatively and quantitatively. The instructions were followed a four round practice phase where we walked subjects through the software they would interact with in four practice periods. This also provided subjects an opportunity to ask questions about the data-generating process and the task they would be participating in.[11]

[7] The natural rate of interest is the equilibrium real rate of interest required to keep aggregate demand equal to the natural rate of output at all times.

[8] We differ from Kryvtsov and Petersen (2013) in that they implement a policy rule that responds to deviations of expected inflation and output, formed in the previous period, from the central bank's target.

[9] Two papers explicitly consider expectation formation at the zero lower bound. See Arifovic and Petersen (2015) for expectation formation in a linearized environment and Hommes et al. (2015b) for expectation formation in a nonlinear environment.

[10] Fluctuations in the natural rate of interest may originate from disturbances to government purchases, households? propensity to consume or willingness to work, and to firms' productivity. See Woodford (2003, Chapter 4) for details. We follow Kryvtsov and Petersen (2013), Arifovic and Petersen (2015), and Pfajfar and Zakelj (2013, 2016) in the implementation of a *AR(1)* shock process.

[11] At the beginning of the experiment, we requested that subjects not ask public questions related to strategy. We explained that such questions had the potential to bias other subjects' behavior, and if such questions should arise, we would have to immediately end the experiment and pay each subject their show-up fee. Consequently, no subject

Over two 30-period horizons, subjects were tasked with submitting forecasts of t the following period's output and inflation. The two distinct repetitions were employed to control for learning. When forming forecasts, subjects had access to the following common information (and all subjects understood that this was common information). They observed all historical information up to and including the previous period's realized inflation, output, nominal interest rate and shocks, as well as their own personal forecasts. They also observed the current period's shock, which allowed them to calculate the expected future shocks for the following periods. Subjects were provided 65 seconds for the first 10 rounds and 50 seconds thereafter to submit forecasts. Forecasts were submitted in basis point measurements and could be positive or negative. After all subjects submitted their forecasts or time elapsed, the median submitted forecasts for output and inflation were employed as the aggregate forecasts and implemented in the calculation of the current period's output, inflation, and nominal interest rate.[12]

We incentivize subjects to take seriously their forecasting decisions by rewarding them based on their forecast accuracy. Subject i's score in each period t was a function of her inflation and output forecast error determined in that period:

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

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 was intuitively easy to explain to subjects: for every 100 basis point error made for each of inflation and output, a subject's score would reduce by 50%. Another convenient feature of this payoff function was that it continued to incentivize subjects even as forecast errors grew large. At the end of the experiment, a subject's scores from all periods were converted into dollars and paid out to them in cash.

To ensure consistency across treatments, we preselected the shock sequences and employed them across all treatments. Two conditions were considered to generate a vector of the shock; two-third of the time the shock takes a value between -138 and $+138$ and 95 percent of the time it takes a value between -276 and $+276$.

Treatments and Hypotheses

To investigate the impact of central bank projections on economic stability and forecasting heuristics, we systematically varied the type of projections subjects received in a between-subject experimental design. Central bank projections were presented in the form of five–period ahead projection of the nominal interest rate or a dual projection of output gap and inflation, based on Equation (6) where the central bank assumes that agents form expectations according to the unique REE solution:

asked public questions about forecasting strategies.

[12]Forecasts were submitted on time in 99.7% of the rounds (10053 of 10080 opportunities).

$$i_t = 0.447157 \cdot r^n_{t-1} + 0.784487 \cdot \epsilon_t, \quad (6)$$
$$x_t = 0.472198 \cdot r^n_{t-1} + 0.82847 \cdot \epsilon_t,$$
$$\pi_t = 0.140706 \cdot r^n_{t-1} + 0.246852 \cdot \epsilon_t.$$

This implies that the central bank's $t+s$ forecasts of the following variables were given by:

$$E^{cb}_t x_{t+s} = \rho^{s-1} \cdot x_t, \quad (7)$$
$$E^{cb}_t \pi_{t+s} = \rho^{s-1} \cdot \pi_t,$$
$$E^{cb}_t i_{t+s} = \rho^{s-1} \cdot i_t$$

for $s = 1, ..5$.

We conducted three treatments that differed in terms of the forecasts communicated by the central bank.

- Treatment I: *No Communication (NoComm)*– There were no supplementary communication by the central bank.
- Treatment II: *Interest Rate Projection (IRProj)*–The central bank provided a five–period ahead projection of expected future nominal interest rates in each period.
- Treatment III: *Output and Inflation Projection (DualProj)*– The central bank provided a five–period ahead projection of expected future output and inflation in each period.

Subjects were informed that the central bank projections were simply forecasts formed by the central bank based on current and expected future shocks. We emphasized that the projections were not a promise but simply the central bank's best forecast of the future five periods. Subjects were also reminded that they were each receiving identical information from the central bank.

Our fourth treatment involved providing subjects with a combination of output gap and inflation projections, where the central bank instead assumes that subjects form output and inflation expectations as a weighted average of the REE solution and a one-period lag of output or inflation. This assumption is motivated by findings by Kryvtsov and Petersen (2013) that such an adaptive(1) forecasting heuristic well describes the median subject's forecasting heuristic. Under this heuristic, agents place 50% weight on period $t-1$ output (inflation) and 50% on the ex-post rational forecast of output (inflation) when forecasting period $t+1$ output (inflation). The projections were presented in the form of five–period ahead projections of output gap and inflation where the central bank assumes that agents form expectations according to the unique adaptive(1) solution:

$$
\begin{aligned}
i_t &= 0.267444 \cdot x_{t-1} + 0.857326 \cdot \pi_{t-1} + 0.446184 \cdot r^n_{t-1} + 0.782779 \cdot \epsilon_t, \\
x_t &= 0.305505 \cdot x_{t-1} - 0.284377 \cdot \pi_{t-1} + 0.388763 \cdot r^n_{t-1} + 0.682040 \cdot \epsilon_t, \\
\pi_t &= 0.076461 \cdot x_{t-1} + 0.666343 \cdot \pi_{t-1} + 0.167868 \cdot r^n_{t-1} + 0.294506 \cdot \epsilon_t.
\end{aligned} \tag{8}
$$

- Treatment IV: *Adaptive Output and Inflation Projection (AdaptiveDualProj)–* The central bank provided a five–period ahead projection of expected future output and inflation in each period assuming subjects form their expectations according to an Adaptive(1) heuristic.

The experimental design allows us to test a number of hypotheses regarding how subjects form expectations, both with and without forward guidance. Standard New Keynesian models make the simplifying assumption that agents form identically rational expectations about future output and inflation. If subjects form expectations consistent with the REE solution, they need only rely on parameters of the model and the current shock - both of which are common knowledge to them - to formulate their forecasts.

Hypothesis I: Subjects form expectations consistent with the REE solution.

Extensive survey and experimental evidence suggests that individuals do not form expectations rationally but instead weight historical information significantly in their forecasts. Thus, we test the alternative hypothesis that subjects place significant weight on historical information when formulating their forecasts.

Commonly observed forward guidance provides an important focal point for subjects to coordinate their forecasts on.[13] If a subject believes that the majority of participants will utilize the central bank's (rational) prediction in their forecast, their best response is to also utilize the forecast. In that case, we predict that the forward guidance will reduce subjects' usage of non-fundamental information in their forecasts in favor of the fundamentally-driven central bank projection. This in turn should reduce the heterogeneity in subjects' forecasts.

Hypothesis II: Forward guidance reduces subjects' reliance on historical information and increases their reliance on current fundamentals when forming expectations

Hypothesis III: Central bank projections reduce the heterogeneity in forecasts.

[13] Forecasting heuristics can be manipulated through focal information. Kryvtsov and Petersen (2013) provide nine-period ahead forecasts of future nominal interest rates where the automated central bank assumes agents form expectations according to the REE solution. They find that forecasting heuristics adjust from an adaptive(1) heuristic where agents place equal weight on lagged information from period $t-1$ and the REE solution to an Adaptive(2) heuristic for inflation forecasts where subjects weight $t-2$ inflation in their forecasts. Petersen (2014) extends the Kryvtsov and Petersen framework to allow for salient forecast error information presented centrally for subjects to observe. She finds that, with experience, subjects' forecasts of the future are significantly more responsive to forecast errors when presented with such focal auxiliary information.

The success of forward guidance depends on the central bank's credibility in achieving its projections. In our experiments, the automated central bank forms forecasts following an ad-hoc Taylor rule and assumes the median subject forms expectations according to either the REE or adaptive(1) solution. The central bank's projections will frequently be incorrect due to the fact that future innovations to the shock process may not be zero (as they are predicted to be) and subjects may use alternative heuristics to formulate their forecasts. As the projections become increasing incorrect, we expect that the central bank will lose credibility and subjects will reduce their willingness to utilize the central bank projection as their own forecast.

Hypothesis IV: The probability a subject utilizes the central bank's projections decreases with the central bank's past forecast errors.

Hypothesis V: Central bank projections reduce disagreement about future output and inflation and forecast errors.

Hypothesis VI: Central bank projections reduce the standard deviation of output and inflation.

While we expect Hypothesis VI to apply to our treatments where the central bank provides projections under the assumption agents form expectations according to current fundamentals only, we expect to reject this hypothesis for the AdaptiveDualProj treatment. Providing a projection that relies on historical information may encourage initially fundamentally-focused subjects to utilize past output and inflation in their forecasts. This, in turn, will generate greater volatility in both output and inflation.

Experimental Implementation

A total of 168 undergraduate students took part in the experiments at the CRABE lab located at Simon Fraser University from June 2015 to February 2016. Participants were invited randomly to participate in a single session from an inexperienced subject pool consisting of over 2000 subjects from a wide variety of disciplines. For each of our four treatments we collected data from 6 groups of 7 subjects each. Thus, we have a total of 24 independent observations. The experiments lasted for approximately 90 minutes including 35 minutes of instruction and four unpaid practice rounds to familiarize themselves with the software and task. No communication between subjects was allowed once they entered the laboratory. The average payment, including a CDN$7 show–up fee was CDN$25 and ranged from CDN$17 to $32. We used *Redwood*, an open source software (Pettit et al., 2013), to implement the experiment. The interface of the experiment displayed all information available to the participants throughout the session on a single screen. At the top left corner of the screen, the subject's number, the current period, time remaining, and the total number of points earned were presented. Three history panels were given in each period. The top history panel displayed past interest rates and shocks. The second panel displayed subject's past forecasts of inflation and the realized level of inflation. The final panel showed the subject's forecasts of output and the realized level of output. In treatments with central bank communication, an additional time series graph was added to the history plots to represent the central bank's projection. Figure 1 presents a representative screen–shot of the interface in the DualProj treatment with output and inflation projections. The central bank's projection of output, inflation, and nominal interest rates were presented as green lines which represented the expected future path of the respective variable. Around each projection was a confidence interval that increased as the projection went further into the future to reinforce the point that the central bank's projections were noisy predictions.

4. Experimental Results

This section summarizes our experimental findings. We first consider how central bank projections influences subjects' forecasting heuristics. We then turn to our aggregate-level data to identify the effects of forward guidance on economic stability and macroeconomic dynamics.

Individual-level Analysis

How do subjects form expectations about output and inflation? We can describe a general specification for ex ante one-period ahead forecast errors associated with forecasts $E_t^* x_{t+1}$ and $E_t^* \pi_{t+1}$ as:

$$E_t \left(E_t^* \begin{bmatrix} \pi_{t+1} \\ x_{t+1} \end{bmatrix} - \begin{bmatrix} \pi_{t+1} \\ x_{t+1} \end{bmatrix} \right) = \sigma^{-1} \rho_r \sum_{s=0}^{\infty} \begin{bmatrix} \kappa L_{s\pi} \\ L_{sx} \end{bmatrix} r_{t-s}^n \ , \tag{9}$$

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 $t, t-1, \ldots$. A standard assumption is that subjects form rational expectations, that is, ex ante forecast errors are always zero. This would imply that that $L_{s\pi} = L_{sx} = 0$ for all s. According to (Equation (9)), non-rational expectations imply that ex ante forecast errors correlate with current or past shock realizations.[14]

Experimental evidence from Kryvtsov and Petersen (2013) suggests that aggregate expectations are well described by a range of *adaptive(l) expectations* models where ex ante forecast errors display the following pattern:

$$E_t \left(E_t^* \begin{bmatrix} \pi_{t+1} \\ x_{t+1} \end{bmatrix} - \begin{bmatrix} \pi_{t+1} \\ x_{t+1} \end{bmatrix} \right) = -\omega \left(\begin{bmatrix} \pi_{t-l} \\ x_{t-l} \end{bmatrix} - E_t \begin{bmatrix} \pi_{t+1} \\ x_{t+1} \end{bmatrix} \right) \ . \tag{10}$$

According to this general adaptive framework, agents in period t use a period $t-l$ realization

[14]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 $s = 1, 2, \ldots$.

of inflation (the output gap) to form expectations of period-$(t+1)$ inflation (the output gap).[15] They are negative at the time of the shock and are positive thereafter since inflation forecasts are expected to persist while the forecasted variable slowly returns back to its steady state level.

We construct a series of specifications that consider the effects of projections on subjects' ex ante forecast errors. We estimate ex ante forecast errors as functions of the history of innovations to the r_t^n shocks, where we interact these innovations with treatment-specific dummies:

$$E_{i,t}z_{t+1} = \alpha + \beta_1 \epsilon_{rt} + \beta_2 \epsilon_{rt} \times IRProj + \beta_3 \epsilon_{rt} \times DualProj + \beta_4 \epsilon_{rt} \times ADProj + ...\beta_Z \epsilon_{rt-T} \times ADProj \ , \tag{11}$$

and where z refers to either output or inflation ex ante forecast errors, and T=4. Under the null hypotheses of rational expectations, ex ante forecast errors should 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 (l) expectations, ex ante forecast errors would place significant weight on lagged shock innovations, $\hat{\beta_k} \neq 0$ for some k. If central bank projections are effective at encouraging subjects to form more rational expectations, then we would expect to find that the weight subjects place on current and lagged shock innovations are significantly smaller in absolute terms than in the NoComm treatment. The results of these specifications are first presented by treatment and repetition in Table 1 and as a pooled set of regressions by repetition to identify treatment effects in Table 2. We separate our specifications by low and high standard deviation of shocks, r_t^n, where high variability shocks have a standard deviation greater than 140 basis points. This division conveniently splits our sessions equally between low and high shock variability. For reference, a comparison of the lowest and highest shock volatility sessions are presented in Table 3. The Appendix includes additional specifications run at the session-level.

First, we reject Hypothesis I that subjects form rational expectations. In Table 1 we see that in all treatments, repetitions, and shock variability levels, subjects' forecast errors significant weight either current or lagged innovations or the constant. We conclude that subjects' forecast errors are not only described by noise but rely significantly on historical information and are indicative of adaptive expectations.

In the NoComm treatment, inexperienced forecasters place significant negative weight on current innovations and positive weight on some lagged innovations. This is especially the case when shock variability is high. In this case, subjects exhibit a much stronger pattern of adaptive forecasting behavior. Inexperienced inflation forecasts are also highly insensitive to current shocks, and highly mean-reverting in response to lagged shocks. That is, subjects do respond to lagged innovations when forming their forecasts but appear to strongly predict inflation will revert to the steady state.

[15]Note that under adaptive(l) expectations, agents' forecast errors persist forever. Kryvtsov and Petersen assume that $\omega = 0.5$ and find that an adaptive(1) forecasting heuristic well describes the behaviour of subjects in their identically calibrated environment.

Experience does not alter forecasting heuristics considerably. Output forecast continue to under-react, albeit not significantly, to current innovations and over-react to lagged innovations, especially as the shocks become more variable. Inflation forecasts also continue to significantly under-react to current and one-period lagged innovations. When the shock process becomes more variable, subjects react more positively to three- and four-period lagged innovations.

We now turn to forecast errors under different forms of central bank projections. We begin first with nominal interest rate projections. Inexperienced output and inflation forecast errors in the IRProj treatment also respond negatively to current innovations, suggesting subjects are under-reacting to current innovations. As in the NoComm treatment, subjects in the IRProj treatment also place significant positive weight on lagged innovations when forming their output forecasts, especially when the standard deviation of the shock process is high. Referring to Table 2 in the left panel, we find that the response to current and lagged fundamentals is not significantly different for inexperienced subjects when forming their output and inflation forecasts under low variability shocks. However, when the standard deviation of shocks is high, subjects exposed to nominal interest rate projections are less under-responsive to current innovations and less responsive to lagged innovations than in the NoComm treatment. For experienced subjects, interest rate projections do not consistently refocus subjects' expectations to current innovations. Only inflation forecasts in the low shock variability environment appear to be significantly more responsive to current innovations. Responses to lagged fundamentals are also significantly altered in the low variability environment.

Dual projections of rational forecasts of output and inflation have mixed effects on subjects' forecasts. Inexperienced subjects in the DualProj treatment that face low variability in shocks do not significantly react to current and past innovations when forming either their output or inflation forecasts. This finding suggests that DualProj subjects facing low variability exhibit a highly rational forecasting heuristic. High variability, however, leads to significantly more pronounced adaptive forecasting heuristics whereby inexperienced subjects underreact to current innovations and overreact to lagged innovations. Compred to the NoComm treatment, we see that inexperienced DualProj subjects facing low variability respond significantly less to lagged innovations but do not alter their responses significantly in response to current innovations. The major gains from the DualProj treatment occur in the high variability sessions: inexperienced subjects facing highly variable shocks are significantly more responsive to current innovations and less responsive to lagged innovations. With experience, subjects that are presented with rational projections of output and inflation have a tendency to forecast positively to current innovations when forming their forecasts. This is likely due to the fact that the projections, themselves, suggest a positive response to the current innovation. For low variability shocks, subjects only place significant positive weight on current and two-period lags when forming their forecast, but are inconsistently reactive to other lags. In fact, subjects facing low variability shocks appear to over-react to innovations when presented with rational projections. When shock variability is high, output projections positively and significantly respond to one, three and four-period lagged innovations suggesting a still strong backward-looking heuristic. Inflation forecasts, however, are unresponsive to all innovations and are highly rational. Compared to the NoComm treatment, experienced forecasts for both output and inflation are significantly more responsive to current innovations and significantly less responsive to lagged innovations.

Last we consider how adaptive dual projections influence subjects' forecasting heuristics. When faced with low variability shocks, inexperienced subjects in the ADProj treatment place significant positive weight on current innovations (i.e. over-react to current fundamentals) and do not appear to respond to lagged innovations significantly. In contrast, subjects that face high variability in shocks exhibit a more adaptive forecasting heuristic: they place significant negative weight on current innovations and significant positive weight on lagged fundamentals. Compared to their NoComm counterparts, subjects who receive an adaptive projection of output and inflation react more positively to current innovations and less positively to lagged innovations when forming their forecasts This is especially the case for output forecasts in high variability sessions.

With experience, subjects in low variability sessions facing adaptive dual projections become increasingly overly sensitive to current and lagged innovations. Compared to NoComm subjects, these subjects place significantly less weight on lagged innovations and more weight on current innovations. Experienced ADProj subjects in high variability sessions no longer over-react to fundamentals but still continue to place positive weight on three- and four-period lags when forming their output and inflation forecasts. Output forecasts in the AdProj treatment with high variability are significantly less reliant on lagged innovations than in the NoComm treatment, but inflation forecasts are not significantly different.

Observation I: Expectations formed in the NoComm treatment under-react to current innovations and rely significantly on lagged innovations characteristic of adaptive expectations.

Observation II: With central bank projections of future output and inflation, subjects reduce the weight they place on lagged innovations and increase the weight they place on current innovations when forming their forecast. This response is significantly pronounced in inexperienced sessions with high shock variability and in all experienced sessions.

Observation III: Nominal interest rate projections do not lead to consistently different forecasting heuristics. Interest rate projections are only significantly effective at influencing inexperienced subjects to forecast rationally when the standard deviation of shocks is high. By contrast, experienced subjects' forecasts are only significantly

altered by interest rate projections when the variability of shocks is low.

Central bank projections provide a common focal piece of information for subjects' to coordinate their forecasts on. We quantify the degree of coordination by calculating the standard deviation of forecasts each period across subjects in a single group. We calculate the median disagreement at the session-repetition level. Summary statistics of median disagreement are reported in Table 4.[16] Central bank communication does not consistently lead to a statistically significant improvement in the coordination of expectations for inexperienced subjects. Rank-sum tests comparing session-repetition median disagreements across treatments fail to reject that the distributions of median disagreements are identical across most pairwise comparisons ($p > 0.20$). There are but a few key exceptions. Interest rate projections significantly increase disagreements about future inflation compared to the NoComm and AdaptiveDualProj treatments ($p = 0.025$ in both cases).

With experience, central bank projections considerably improve the coordination of output gap expectations. The average session-level disagreement in Repetition 2 falls from 175.15 bps in the NoComm treatment to under 50 bps when subjects receive some form of central bank forward guidance. The reduction in disagreement about future output is highly significant in the DualProj and ADProj treatments ($p = 0.055$ and $p = 0.025$ respectively), while less consistently effective in the IRProj ($p = 0.109$). Average disagreement about inflation increases insignificantly in the IRProj and DualProj treatments ($p > 0.26$) but is significantly decreased in the ADProj treatment ($p = 0.055$).

The extent to which subjects' forecasts deviate from the REE solution is depicted in Figure 4. The figure presents kernel densities of the absolute deviation of output and inflation forecasts from the REE solution's predicted forecasts. Compared to the NoComm baseline, a much larger mass of output (inflation) forecasts are exactly or very close to the REE forecast when subjects observe output (inflation) and dual projections. Moreover, the degree to which subjects coordinate their forecasts on these central bank projections increases with experience. While experienced output (inflation) forecasts are considerably better coordinated on the REE prediction with inflation (output) and interest rate projections than with no forward guidance, the differences are less stark. These findings provide support for Hypothesis IV.

Observation IV: Central bank projections generally have minimal effects on coordinating expectations for inexperienced subjects. Experienced subjects exhibit considerably less disagreement about future output when they observe any type of projection.

Central bank projections are meant, among other things, to help forecasters better anticipate the future. Thus, one measure of the success of a central bank's projection is its ability to reduce

[16] Normalizing median disagreement by the standard deviation of the shock does not alter the significance of our results.

forecast errors. We compute subjects' absolute forecast errors as the absolute difference between their forecasts and the realized outcome. Summary statistics on session-repetition median absolute forecast errors are presented in Table 5 and distributional plots of all absolute forecast errors by treatment are presented in Figure 2.

In the NoComm treatment, average absolute forecast errors for output and inflation in repetition 1 are 54.05 and 15.67 bps, respectively, and 48.50 and 15.75 bps in repetition 2. While output forecast errors become somewhat smaller with experience, inflation forecast errors hardly change. Interest rate projections reduce output forecast errors to 52.08 and 48.25 bps in repetitions 1 and 2, while increasing inflation forecast errors to 18.92 and 17.00 bps. The differences are not statistically significant at the 10% level.

Rational projections of output and inflation in the DualProj treatment considerably reduce output forecast errors but marginally decrease inflation forecast errors. In repetitions 1 and 2, output forecast errors decrease to 47.50 and 40.92 bps while inflation forecast errors decrease to 14.67 and 14.25 bps. These differences from the NoComm treatment, while sizeable for output gap forecast errors, are not statistically significant.

Adaptive projections of output and inflation in the ADProj treatment reduce both output and inflation forecast errors in both repetitions. Output forecast errors in repetition 1 and 2 decrease to 40.67 and 38.50 bps, respectively. Inflation forecast errors decrease to 13.75 and 12.75 bps. The adaptive projections of output and inflation significantly reduce inexperienced output forecast errors ($p = 0.037$) and experienced inflation forecast errors ($p = 0.042$). Forecast errors are not significantly different across rational and adaptive dual projections ($p > 0.20$ in all pairwise comparisons).

The kernel densities of absolute forecast errors provide a more complete understanding of the distributional differences across treatments. Output forecast errors in the DualProj and AdaptiveDualProj treatments are skewed downward compared to those observed in the NoComm and IRProj treatments. A similar pattern emerges for inflation forecast errors as well. These results suggest that forecast errors are considerably reduced when subjects are presented with a highly relevant projection.

Observation V: Rational and adaptive projections of output and inflation skew experienced forecast errors toward zero. Projections of future nominal interest rates do not significantly reduce forecast errors.

Finally, we consider how central bank forecast errors influence subjects' willingness to utilize the publicly announced projections as their own forecasts. We focus on subjects' likelihood of utilizing central bank projections in the DualProj and AdaptiveDualProj treatments where it is clearer whether subject are using the supplementary information.[17] Our dependent variables of interest are $UtilizedCBxForecast_t$ and $UtilizedCB\pi Forecast_t$ which take the value of 1 if a subject's period t forecast about $t+1$ was less than 2 basis points from the central bank's projection and 0 otherwise.[18] We employ a series of random effects probit models to understand how the probability subjects utilize the central bank's projections evolves. Our primary explanatory variables are the central bank's absolute forecast error about period $t-1$ output, $|FE^{cb}x_{t-1}| = |E^{cb}_{t-2}x_{t-1} - x_{t-1}|$ and $t-1$ inflation, $|FE^{cb}\pi_{t-1}| = |E^{cb}_{t-2}\pi_{t-1} - \pi_{t-1}|$. We additionally control for whether subjects previously utilized the central bank's forecast in period $t-2$ and subjects' own absolute forecast errors $|FEx_{i,t-1}|$ and $|FE\pi_{i,t-1}|$, and interactions of these two variables to observe whether past misguided trust in the central bank's projections resulted in a significant decrease in future willingness to trust. The results are presented, by treatment and repetition, in Table 6 and Table 7 for low and high shock variability sessions, respectively.

In low variability environments, the central bank's credibility is not consistently influenced by its past forecast errors. The estimated coefficients on lagged absolute forecast errors are small and generally statistically insignificant. Having utilized the central bank forecasts leads to a large likelihood of continuing to use the forecast, but again the effects are not consistent across subjects. ADProj subjects that make larger inflation forecast errors do tend to increase their likelihood of using the central bank's inflation projections when they are inexperienced. Likewise, with experience, they tend to rely on the central bank's forecast error more even if they made larger forecast errors when using the projections in the past.

In high variability environments, we find a more stark reaction to central bank forecast errors. Experienced subjects in both the DualProj and ADProj treatments significantly reduce their reliance on the central bank's output projections when the projections become increasingly incorrect. These subjects are also significantly more likely to utilize the output projections as the central bank's inflation projections become more inaccurate. As in the low variability environments, past usage of the projections tends to increase the average likelihood of using the projection in the following period, but this effect is highly heterogeneous across subjects. In general, we find inconsistent effects for most of explanatory variables. Experienced subjects do not consistently react negatively or strongly to the central bank's past inflation forecast errors.

[17] In the IRProj treatment, a subject may be using the projected interest rate to formulate their forecast, but may make calculation errors.

[18] According to this definition of utilization, subjects in the low variability sessions utilized output projections 37% of the time in both the DualProj and ADProj treatment while inflation projections were utilized 23% and 32% of the time in the DualProj and ADProj treatments, respectively. In the high variability sessions, output projections in the DualProj and ADProj treatment were employed for16% and 7.5% of decisions, while inflation projections were employed for 22% and 20% of decisions, respectively. In low variability sessions, subjects utilized both projections in the DualProj and ADProj 11% and 8% of the time. In high variability session, full utilization occurred 11% and 3.5% of the time in the DualProj and ADProj treatments. Kernel density and cumulative distribution functions of the central bank's absolute forecast errors can be found in the Appendix. We include IRPRoj forecast errors of the nominal interest rate for reference

Observation VI: In low variability sessions, credibility in the central bank's projections is not significantly influenced by its past forecast errors. In high variability sessions, credibility is only considerably and consistently lost among experienced subjects as the central bank's output forecast errors grow large in both the DualProj and ADProj treatments. Credibility in the inflation projections is not consistently lost as the central bank forms more inaccurate inflation forecasts.

Aggregate Analysis

We now consider the effects of central bank projections on aggregate macroeconomic variables. Our analysis begins by considering how the dynamics of output, inflation, and nominal interest rates respond to different forms of communication. We estimate the orthogonalized impulse responses of output, inflation, and nominal interest rates to a 1-standard deviation shock to aggregate demand. The results for Repetition 2 are presented in Figure 3 by shock sequence, ordered from least to most volatile sequences. The heavy solid lines indicate the estimated REE predictions, while the thin solid lines denote the estimated impulse response functions in the NoComm treatment. The initial response of output to the demand shock in the NoComm treatment is rather consistent with the REE prediction. In the periods that follow, however, we observe a consistently sluggish decline in output and by the fourth period following the initial shock, output gap becomes negative before returning to the steady state.

Inflation follows a noticeably different transition path from the REE prediction. On impact of the aggregate demand shock, inflation in the NoComm treatment exhibits a relatively muted response in most sessions. In those sessions, inflation then rises for 2 additional periods before beginning to trend back toward the steady state. The hump-shaped pattern of inflation is indicative of an Adaptive (2) forecasting model where the aggregate expectation of $t+1$ places significant positive weight on inflation from period $t-2$. Such inflation forecasting behavior is also observed in Kryvtsov and Petersen (2013).

Introducing central bank projections has varying effects on the transition paths of output and inflation. The estimated impulse response functions are presented for the IRProj as blue dashed lines, the DualProj as short red dashed lines, and the ADProj as green long dash-dot-long dash lines. Generally, all three types of projections have a similar effect on output dynamics for low variability shocks. As the shocks become more variable, nominal interest rate projections are associated with a greater contractionary overshooting effect of output, suggestive of a larger backward-looking nature of forecasts consistent with behavior in the NoComm treatment.

The effects of central bank communication are more stark when we consider the estimated responses of inflation. Rational and adaptive dual projections lead to a response of inflation that is considerably more in line with the REE prediction. Inflation is more consistently monotonically converging back to the steady state, and the hump-shaped pattern observed in the NoComm treatment is largely eliminated. We observe noticeable heterogeneity across sequences in the estimated impulse response functions of IRProj sessions. The impulse response functions tend to track the timing of the REE prediction better when the shock volatility is lower. However, for relatively more volatile shock sequences such as Sequences 4 and 6, the reactions of inflation under IRProj are more sluggish and exhibit timing similar to that of the NoComm treatment. In other words, for greater shock volatility, central bank projections of nominal interest rates do not considerably alter forecasting heuristics and inflation dynamics.

Summary statistics of the standard deviation of output and inflation, measured at the session-repetition level and normalized by their rational expectations equilibrium solution's respective standard deviations are presented in Table 8.[19] The results are also presented visually in Figure 5 with box plots of the standard deviation of output and inflation relative to the REE solution at the treatment–repetition level. Mean normalized standard deviations of output and inflation in the baseline NoComm treatment exceed 1 in both repetitions, implying the economies are, on average, more volatile than predicted by the rational expectations model. Wilcoxon signed–rank tests are conducted to determine whether the mean results are significantly different from the REE solution, ie. that the normalized standard deviations are equal to 1. In the first repetition of the NoComm treatment, we fail to reject the null hypothesis that the standard deviations are consistent with the REE solution. By the second repetition, output and inflation in the NoComm treatment are 6% and 50%, respectively, more volatile than predicted by the model and this difference is significant at the 5% level. Output and inflation variability are considerably lower in the presence of most forms of central bank communication than in the NoComm treatment, and with experience with the central bank projections, both output and inflation are not significantly different from the REE prediction at the 10% level.

The ability of central bank projections to enhance economic stability is mixed. While the projections lead to considerably lower variability in output and inflation, the differences are not statistically significant when subjects are inexperienced. However, by the second repetition, output variability is 9 percentage points lower in the DualProj treatment, a difference that is statistically significant at the 1% level. Inflation variability is also significantly reduced by 46 percentage points in the second repetition of the DualProj treatments (Wilcoxon rank sum tests reject the null hypothesis that the variability is identical across treatments: $p = 0.055$). Interest rate and adaptive dual projections lower output and inflation variability in experienced repetitions, but the effects are not consistent. The one exception is that adaptive dual projections do significantly reduce inflation volatility ($p = 0.078$).

Observation VII: With experience, output and inflation variability in the baseline

[19]The normalizing REE solution of output and inflation is calculated for each shock sequence.

NoComm treatment are significantly greater than predicted by the REE solution. Introducing central bank projections lowers macroeconomic variability to the REE predicted levels.

5. Conclusion

Forward guidance has become an increasingly important instrument that central banks use to influence aggregate expectations. Identifying the effects of forward guidance on expectations is especially challenging because the projections central banks make and the language they employ are a consequence of the effectiveness of past and expected future policies. To gain further insight into how central bank communications are used by ordinary individuals, we conduct a laboratory experiment where central bank projections are varied systematically across independent groups.

Our key finding is that central bank communication must be easy to understand for subjects to effectively utilize it in their forecast. Projections of output and inflation (which subjects are themselves forecasting) reduce subjects' backward-looking forecasting heuristics and refocus their expectations on current fundamentals. Such announcements lead to reduced heterogeneity in forecasts and forecast errors. By contrast, central bank projections of nominal interest rates are not consistently effective at coordinating expectations and improving forecast accuracy, especially when it comes to inflation forecasts. We speculate that the inconsistent ability of interest rate forward guidance to influence expectations comes from the additional cognitive challenge of how to employ such projections into one's own forecast. Subjects must consider about how nominal interest rates directly influence the output gap and, indirectly, inflation, and this is considerably more difficult.

References

1. Adam, K. (2007). "Experimental Evidence on the Persistence of Output and Inflation." Economic Journal 117 (520): 603–36.

2. Amano, R., O. Kryvtstov, and L. Petersen (2014). "Recent Developments in Experimental Macroeconomics.", Bank of Canada Review, Autumn, 1-11.

3. Assenza, T., P. Heemeijer, C. Hommes and D. Massaro. (2013). "Individual Expectations and Aggregate Macro Behavior.", Tinbergen Institute Discussion Paper No. 2013–016/II.

4. Arifovic, J. and L. Petersen. (2015). "Liquidity Traps and Central Bank Communication: Learning and Experiments." Manuscript. Simon Fraser University.

5. Archer, D. (2005). "Central bank communication and the publication of interest rate projections." Sveriges Riksbank Conference on Inflation Targeting. Stockholm: Bank for International Settlements (BIS).

6. Blinder, A. S. (2009). Talking about monetary policy: the virtues (and vice?) of central bank communication. Bank for International Settlements Working Paper No 274.

7. Blinder, A.S. and C. Wyplosz. (2005). "Central Bank Talk: Committee Structure and Communication Policy." Philadelphia: Paper Presented at the ASSA Meetings.

8. Blinder, A. S., Ehrmann, M., Fratzscher, M., De Haan, J., & Jansen, D. J. (2008). Central Bank Communication and Monetary Policy: A Survey of Theory and Evidence. Journal of Economic Literature, 46(4), 910-945.

9. Kang, Y., A. Koc, X., Luo, A. Muller, J. Pinho, and N. Zagaria (2013). " Central Bank Communication Policy A Comparative Study.," Report for Federal Reserve Bank of New York (FRBNY)

10. Cornand, C. and F. Heinemann. (2014). "Experiments on Monetary Policy and Central Banking." In Experiments in Macroeconomics, edited by J. Duffy. Research in Experimental Economics 17. Emerald Group Publishing Limited.

11. Cornand, C. and C.K. M'baye (2016). "Does Inflation Targeting Matter? An Experimental Investigation." Macroeconomic Dynamics. Forthcoming.

12. Duffy, J. (2012). "Macroeconomics: A Survey of Laboratory Research." University of Pittsburgh Working Paper No. 334.

13. Ehrmann, M. and M. Fratzscher. (2007): "Transparency, Disclosure and the Federal Reserve.", International Journal of Central Banking, 3(1): 179-225.

14. Eusepi, S. and B. Preston (2010). “Central Bank Communication and Expectations Stabilization.,” American Economic Journal: Macroeconomics, American Economic Association, vol. 2(3), pages 235-71.

15. Goodhart, C.., and W.B. Lim. (2011). “Interest Rate Forecasts: A Pathology.” Financial Markets Group, London School of Economics.

16. Holmsen, A., J. Qvigstad, and O. Roisland (2012). “Implementing and Communicating Optimal Monetary Policy.” Staff Memo of Norges Bank No.3.

17. Hommes, C., D. Massaro, M. Weber (2015). ”Monetary Policy under Behavioural Expectations: Theory and Experiment”, Discussion Paper 15-087//II, Timbergen Institute.

18. Hommes, C., D. Massaro, I. Salle (2015). ”Monetary and Fiscal Policy Design at the Zero Lower Bound: Evidence from the Lab”, CeNDEF Working Paper 15-11, University of Amsterdam.

19. Hubert, Paul. (2014). FOMC Forecasts as a Focal Point for Private Expectations. Journal of Money, Credit and Banking, 46, 13811420

20. Kahnemann, Daniel. (2003).“Maps of Bounded Rationality: Psychology for Behavioral Economics.” American Economic Review, 93(5): 1449-75.

21. King, M.. (2000).“Monetary Theory: Policy in Practice.” Address to the joint luncheon of the American Economic Association and the American Finance Association, Boston, available at http://www.bankofengland.co.uk/publications/speeches/2000/speech67.html.

22. Kool, C. J., and Thornton, D. L. (2012). How effective is central bank forward guidance?. FRB of St. Louis Working Paper No.

23. Kryvtsov, O. and L. Petersen. (2013). “Expectations and Monetary Policy: Experimental Evidence.” Bank of Canada Working Paper No. 2013-44

24. Marimon, R. and S. Sunder. (1993). “Indeterminacy of Equilibria in a Hyperinflationary World: Experimental Evidence.” Econometrica 61 (5): 1073–107.

25. McCaw, S. and Ranchhod, S. (2002). The Reserve Bank’s forecasting performance. Reserve Bank of New Zealand Bulletin, 65.

26. Mishkin, F. (2004).‘ Can Central Bank Transparency Go Too Far?” The National Bureau of Economic Research (NBER).

27. Petersen, L. (2014). Forecast Error Information and Heterogeneous Expectations in Learning-to-Forecast Macroeconomic Experiments. Experiments in Macroeconomics, Research in Experimental Economics, 17, 109-137.

28. Pfajfar, D. and B. Zakelj. (2014a). ‘ Experimental Evidence on Inflation Expectation Formation.” Journal of Economic Dynamics & Control 44: 147-68.

29. ——. (2016). “Inflation Expectations and Monetary Policy Design: Evidence from the Laboratory.” Macroeconomic Dynamics.

30. Ranchhod, S. (2002). Comparison of interest rate forecast errors: Reserve Bank, NZIER and the National Bank of New Zealand. Working Paper.

31. Rudebusch, G. and J. Williams, (2008). “Revealing the Secrets of the Temple: The Value of Publishing Central Bank Interest Rate Projections,” NBER Chapters, in: Asset Prices and Monetary Policy, pages 247-289 National Bureau of Economic Research, Inc.

32. Sugden, R. (1995). A theory of focal points. The Economic Journal, 533-550.

33. Svensson, Lars E.O. (2006). “The Instrument-Rate Projection under Inflation Targeting: The Norwegian Example.” Working Papers 75, Princeton University, Department of Economics, Center for Economic Policy Studies.

34. Svensson, Lars E.O. (2011). “Monetary policy after the crisis,” Proceedings, Federal Reserve Bank of San Francisco, issue Nov, pages 35-49.

35. Svensson, Lars E.O. (2012). “Assessment of Monetary Policy in Sweden in 2009.” Speech, March 18 2012.

36. Turner, J. (2006). ?An Assessment of Recent Reserve Bank Forecasts.? Reserve Bank of New Zealand Bulletin, 69, 38-43.

37. Tversky, A. and D. Kahneman (1974). Judgment under uncertainty: Heuristics and biases. Science, 185 (4157), 1124-1131.

38. Winkler, B. (2000). “Which kind of transparency? On the need for clarity in monetary policy-making”., European Central Bank Working Paper.

39. Woodford, M. (2005). “Central bank communication and policy effectiveness.” Proceedings– Economic Policy Symposium– Jackson Hole, Federal Reserve Bank of Kansas City, issue Aug, pages 399–474.

40. Woodford, M. (2013). “Macroeconomic analysis without the rational expectations hypothesis” (No. w19368). National Bureau of Economic Research.

6. Tables and Figures

Table 1: Effects of central bank projections on forecast errors[I]

	Panel A: Repetition 1							
	Low SD Shocks				High SD Shocks			
Output Forecast Errors	NoComm	IRProj	DualProj	ADProj	NoComm	IRProj	DualProj	ADProj
ϵ_t	-0.107**	-0.135***	0.028	0.162***	-0.649***	-0.330***	-0.255***	-0.116***
	(0.04)	(0.05)	(0.09)	(0.05)	(0.22)	(0.04)	(0.03)	(0.04)
ϵ_{t-1}	0.020	0.005	-0.101	-0.012	0.429**	0.313***	0.215***	0.269***
	(0.05)	(0.05)	(0.10)	(0.05)	(0.21)	(0.04)	(0.03)	(0.04)
ϵ_{t-2}	0.073	0.093*	-0.115	0.004	0.699***	0.282***	0.108***	0.154***
	(0.05)	(0.05)	(0.10)	(0.05)	(0.23)	(0.04)	(0.04)	(0.04)
ϵ_{t-3}	0.080*	0.119**	-0.061	0.029	0.742***	0.196***	0.121***	0.113***
	(0.04)	(0.05)	(0.09)	(0.05)	(0.22)	(0.04)	(0.04)	(0.04)
ϵ_{t-4}	0.072*	0.084*	-0.051	0.007	0.715***	0.084**	-0.025	-0.044
	(0.04)	(0.05)	(0.09)	(0.05)	(0.23)	(0.04)	(0.04)	(0.04)
α	12.790**	9.215	40.489***	18.280***	110.113***	25.898***	27.912***	27.131***
	(5.10)	(5.67)	(10.61)	(5.78)	(31.34)	(5.53)	(4.94)	(5.23)
N	349	350	346	350	699	697	697	698
χ^2	12.38	15.79	2.686	13.39	49.01	246.2	127.1	102.0

InflationForecast Errors	NoComm	IRProj	DualProj	ADProj	NoComm	IRProj	DualProj	ADProj
ϵ_t	-0.068***	-0.068**	0.035	0.050***	-0.141***	-0.079***	-0.052***	-0.046***
	(0.01)	(0.03)	(0.10)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
ϵ_{t-1}	-0.085***	-0.123***	-0.171	0.001	-0.074***	0.017	0.060***	0.062***
	(0.02)	(0.03)	(0.11)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)
ϵ_{t-2}	-0.049***	-0.092***	-0.096	-0.007	-0.043***	0.052**	0.024**	0.033**
	(0.02)	(0.03)	(0.11)	(0.02)	(0.01)	(0.03)	(0.01)	(0.01)
ϵ_{t-3}	-0.032**	-0.048*	-0.041	0.000	-0.002	0.020	0.027**	0.024*
	(0.02)	(0.03)	(0.10)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
ϵ_{t-4}	-0.024	-0.042	-0.001	-0.001	-0.009	0.026	-0.001	-0.002
	(0.01)	(0.03)	(0.10)	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)
α	5.225***	-6.772**	33.621***	5.034***	1.124	12.324***	6.297***	9.497***
	(1.71)	(3.19)	(11.46)	(1.69)	(1.50)	(3.47)	(1.61)	(1.78)
N	349	350	346	350	699	697	697	698
χ^2	50.34	29.38	3.802	12.80	261.5	20.45	64.95	54.09

	Panel B: Repetition 2							
	Low SD Shocks				High SD Shocks			
Output Forecast Errors	NoComm	IRProj	DualProj	ADProj	NoComm	IRProj	DualProj	ADProj
ϵ_t	-0.222	-0.011	0.118	0.380***	-0.064	-0.165***	0.086*	-0.012
	(0.23)	(0.04)	(0.08)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)
ϵ_{t-1}	0.160	-0.019	0.003	0.029	0.141***	0.162***	0.084*	0.027
	(0.25)	(0.04)	(0.08)	(0.05)	(0.04)	(0.04)	(0.05)	(0.05)
ϵ_{t-2}	0.586**	0.168***	0.224***	0.158***	0.201***	0.201***	0.068	0.035
	(0.25)	(0.04)	(0.08)	(0.05)	(0.04)	(0.04)	(0.05)	(0.05)
ϵ_{t-3}	0.785***	0.011	0.115	0.040	0.254***	0.300***	0.149***	0.149***
	(0.25)	(0.04)	(0.08)	(0.05)	(0.04)	(0.04)	(0.05)	(0.05)
ϵ_{t-4}	0.363	-0.029	0.059	-0.007	0.237***	0.283***	0.159***	0.108**
	(0.24)	(0.04)	(0.08)	(0.05)	(0.04)	(0.04)	(0.05)	(0.05)
α	115.356***	8.280*	16.850*	9.764*	1.210	-2.049	12.926**	4.021
	(28.93)	(4.58)	(9.67)	(5.37)	(5.45)	(5.21)	(6.17)	(6.22)
N	524	524	525	525	524	523	523	525
χ^2	14.10	21.94	12.13	104.3	102.4	169.7	25.80	16.06

InflationForecast Errors	NoComm	IRProj	DualProj	ADProj	NoComm	IRProj	DualProj	ADProj
ϵ_t	-0.128***	0.056***	0.071***	0.100***	-0.081***	-0.109***	0.040	-0.033
	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.03)	(0.03)
ϵ_{t-1}	-0.112***	0.016	0.011	-0.005	-0.049***	-0.079***	0.012	-0.023
	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.03)	(0.03)
ϵ_{t-2}	-0.041**	0.052***	0.050***	0.046***	-0.013	-0.046**	0.021	-0.005
	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.03)	(0.03)
ϵ_{t-3}	-0.022	0.014	0.015	0.013	0.025*	-0.004	0.038	0.060*
	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.03)
ϵ_{t-4}	0.000	-0.009	-0.002	-0.010	0.038***	0.037**	0.037	0.011
	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.03)
α	1.598	1.215	3.901**	2.866	2.688	1.748	9.761***	5.181
	(2.36)	(1.81)	(1.63)	(1.83)	(1.91)	(2.40)	(3.31)	(4.14)
N	524	524	525	525	524	523	523	525
χ^2	63.60	29.63	48.81	68.76	52.70	59.07	6.425	5.681

(I) This table presents results from a series of random effects panel regressions. α denotes the estimated constant in the random effects regressions. Robust standard errors are employed. $*p < 0.10$, $**p < 0.05$, and $***p < 0.01$.

Table 2: Effects of central bank projections on forecast errors - Treatment Effects[I]

	Repetition 1				Repetition 2			
	Output Gap Forecast Errors		Inflation Forecast Errors		Output Gap Forecast Errors		Inflation Forecast Errors	
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
ϵ_t	-0.098	-0.770***	-0.062	-0.129***	-0.255**	-0.066	-0.127***	-0.082***
	(0.06)	(0.11)	(0.05)	(0.02)	(0.13)	(0.05)	(0.02)	(0.02)
$\epsilon_t \times IRProj$	-0.023	0.482***	0.015	0.041*	0.257	-0.102	0.184***	-0.028
	(0.09)	(0.15)	(0.07)	(0.02)	(0.18)	(0.06)	(0.02)	(0.03)
$\epsilon_t \times DualProj$	0.099	0.553***	0.065	0.079***	0.382**	0.156**	0.198***	0.125***
	(0.09)	(0.16)	(0.07)	(0.02)	(0.18)	(0.06)	(0.02)	(0.03)
$\epsilon_t \times ADProj$	0.262***	0.693***	0.117	0.079***	0.647***	0.054	0.227***	0.049
	(0.09)	(0.15)	(0.07)	(0.02)	(0.18)	(0.06)	(0.02)	(0.03)
ϵ_{t-1}	0.032	0.343***	-0.078	-0.065***	0.150	0.140***	-0.112***	-0.050**
	(0.06)	(0.11)	(0.05)	(0.01)	(0.13)	(0.04)	(0.02)	(0.02)
$\epsilon_{t-1} \times IRProj$	-0.009	0.000	-0.019	0.076***	-0.166	0.020	0.128***	-0.029
	(0.09)	(0.15)	(0.08)	(0.02)	(0.19)	(0.06)	(0.02)	(0.03)
$\epsilon_{t-1} \times DualProj$	-0.170*	-0.100	-0.137*	0.127***	-0.144	-0.054	0.122***	0.063*
	(0.09)	(0.15)	(0.08)	(0.02)	(0.19)	(0.06)	(0.02)	(0.03)
$\epsilon_{t-1} \times ADProj$	-0.041	-0.044	0.086	0.125***	-0.118	-0.113*	0.107***	0.027
	(0.09)	(0.15)	(0.08)	(0.02)	(0.19)	(0.06)	(0.02)	(0.03)
ϵ_{t-2}	0.083	0.587***	-0.044	-0.032*	0.593***	0.201***	-0.041**	-0.014
	(0.07)	(0.12)	(0.06)	(0.02)	(0.14)	(0.04)	(0.02)	(0.02)
$\epsilon_{t-2} \times IRProj$	0.025	-0.265	-0.026	0.075***	-0.429**	-0.001	0.093***	-0.032
	(0.09)	(0.17)	(0.08)	(0.02)	(0.19)	(0.06)	(0.02)	(0.03)
$\epsilon_{t-2} \times DualProj$	-0.230**	-0.441***	-0.090	0.058**	-0.371*	-0.131**	0.092***	0.035
	(0.09)	(0.17)	(0.08)	(0.02)	(0.19)	(0.06)	(0.02)	(0.03)
$\epsilon_{t-2} \times ADProj$	-0.077	-0.396**	0.043	0.061***	-0.438**	-0.165***	0.087***	0.008
	(0.09)	(0.17)	(0.08)	(0.02)	(0.19)	(0.06)	(0.02)	(0.03)
ϵ_{t-3}	0.089	0.663***	-0.027	0.005	0.776***	0.253***	-0.022	0.025
	(0.06)	(0.12)	(0.05)	(0.02)	(0.14)	(0.04)	(0.02)	(0.02)
$\epsilon_{t-3} \times IRProj$	0.043	-0.440***	-0.001	0.008	-0.761***	0.046	0.036	-0.029
	(0.09)	(0.16)	(0.07)	(0.02)	(0.19)	(0.06)	(0.02)	(0.03)
$\epsilon_{t-3} \times DualProj$	-0.174**	-0.518***	-0.044	0.023	-0.658***	-0.103*	0.036	0.013
	(0.09)	(0.16)	(0.08)	(0.02)	(0.19)	(0.06)	(0.02)	(0.03)
$\epsilon_{t-3} \times ADProj$	-0.058	-0.525***	0.032	0.016	-0.732***	-0.104*	0.035	0.035
	(0.09)	(0.16)	(0.07)	(0.02)	(0.19)	(0.06)	(0.02)	(0.03)
ϵ_{t-4}	0.079	0.606***	-0.020	0.002	0.352***	0.237***	0.000	0.037
	(0.06)	(0.12)	(0.05)	(0.02)	(0.13)	(0.04)	(0.02)	(0.02)
$\epsilon_{t-4} \times IRProj$	0.015	-0.483***	-0.007	0.015	-0.378**	0.044	-0.009	-0.001
	(0.09)	(0.16)	(0.07)	(0.02)	(0.19)	(0.06)	(0.02)	(0.03)
$\epsilon_{t-4} \times DualProj$	-0.148*	-0.596***	-0.003	-0.002	-0.291	-0.075	-0.003	0.002
	(0.09)	(0.16)	(0.07)	(0.02)	(0.19)	(0.06)	(0.02)	(0.03)
$\epsilon_{t-4} \times ADProj$	-0.070	-0.614***	0.023	-0.008	-0.356*	-0.129**	-0.010	-0.026
	(0.09)	(0.16)	(0.07)	(0.02)	(0.19)	(0.06)	(0.02)	(0.03)
α	20.100***	47.783***	9.165***	7.309***	37.538***	4.025	2.396**	4.843***
	(3.57)	(8.20)	(3.03)	(1.12)	(7.88)	(2.89)	(0.96)	(1.53)
SD of shocks	Low	High	Low	High	Low	High	Low	High
N	1395	2791	1395	2791	2098	2095	2098	2095
χ^2	37.29	218.8	29.69	226.3	67.10	276.6	218.2	76.00

(I) This table presents results from a series of random effects panel regressions. α denotes the estimated constant in the random effects regressions. Robust standard errors are employed. $^*p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

Table 3: Effects of central bank projections on forecast errors, by shock sequence - Treatment Effects - Repetition 2 - Comparison[I]

	Low Variability Shocks		High Variability Shocks	
	fe_output	fe_inflation	fe_output	fe_inflation
	(1)	(2)	(3)	(4)
ϵ_t	-0.211***	-0.190***	-0.428***	-0.263***
	(0.07)	(0.03)	(0.08)	(0.04)
$\epsilon_t \times IRProj$	0.278***	0.249***	-0.097	0.057
	(0.10)	(0.04)	(0.12)	(0.06)
$\epsilon_t \times DualProj$	0.419***	0.295***	0.181	0.256***
	(0.10)	(0.04)	(0.12)	(0.06)
$\epsilon_t \times ADProj$	0.735***	0.336***	0.161	0.185***
	(0.10)	(0.04)	(0.12)	(0.06)
ϵ_{t-1}	0.187**	-0.176***	0.297***	-0.061
	(0.07)	(0.03)	(0.09)	(0.05)
$\epsilon_{t-1} \times IRProj$	-0.096	0.195***	-0.058	-0.092
	(0.11)	(0.05)	(0.13)	(0.07)
$\epsilon_{t-1} \times DualProj$	-0.059	0.231***	-0.171	0.060
	(0.11)	(0.05)	(0.12)	(0.07)
$\epsilon_{t-1} \times ADProj$	-0.019	0.231***	-0.149	0.107
	(0.11)	(0.05)	(0.12)	(0.07)
ϵ_{t-2}	0.403***	-0.129***	0.258***	-0.061
	(0.08)	(0.03)	(0.09)	(0.04)
$\epsilon_{t-2} \times IRProj$	-0.226**	0.169***	-0.079	-0.064
	(0.11)	(0.05)	(0.12)	(0.06)
$\epsilon_{t-2} \times DualProj$	-0.198*	0.219***	-0.400***	0.081
	(0.11)	(0.05)	(0.12)	(0.06)
$\epsilon_{t-2} \times ADProj$	-0.178*	0.202***	-0.295**	0.050
	(0.11)	(0.05)	(0.12)	(0.06)
ϵ_{t-3}	0.233***	-0.092***	0.427***	0.039
	(0.07)	(0.03)	(0.08)	(0.04)
$\epsilon_{t-3} \times IRProj$	-0.306***	0.092**	-0.016	-0.066
	(0.11)	(0.05)	(0.11)	(0.06)
$\epsilon_{t-3} \times DualProj$	-0.212**	0.118**	-0.327***	-0.033
	(0.11)	(0.05)	(0.11)	(0.06)
$\epsilon_{t-3} \times ADProj$	-0.219**	0.101**	-0.231**	0.030
	(0.11)	(0.05)	(0.11)	(0.06)
ϵ_{t-4}	0.095	-0.014	0.324***	0.020
	(0.07)	(0.03)	(0.08)	(0.04)
$\epsilon_{t-4} \times IRProj$	-0.184*	-0.022	0.022	-0.019
	(0.10)	(0.04)	(0.12)	(0.06)
$\epsilon_{t-4} \times DualProj$	-0.199**	-0.015	-0.129	0.025
	(0.10)	(0.04)	(0.12)	(0.06)
$\epsilon_{t-4} \times ADProj$	-0.176*	-0.008	-0.191*	0.009
	(0.10)	(0.04)	(0.12)	(0.06)
α	13.763***	4.133**	18.486***	11.339***
	(4.32)	(1.89)	(4.78)	(2.50)
SD r_t^n	125.60	125.60	155.82	155.82
N	699	699	698	698
χ^2	156.8	117.8	242.7	89.24

(I) This table presents results from a series of random effects panel regressions. α denotes the estimated constant in the random effects regressions. Robust standard errors are employed. $*p < 0.10$, $**p < 0.05$, and $***p < 0.01$.

Table 4: Forecast Disagreement By Treatment and Repetition - Session medians

Treatment		Repetition–1		Repetition–2	
		Output	Inflation	Output	Inflation
NoComm					
	Mean	196.98	19.31	175.15	19.59
	std.	375.47	3.27	280.30	3.03
IRProj					
	Mean	55.65	35.06	49.60	20.84
	std.	29.89	21.85	8.05	9.56
DualProj					
	Mean	50.37	29.75	47.71	22.36
	std.	24.85	24.41	32.90	15.07
AdaptiveDualProj					
	Mean	43.31	17.67	41.40	14.79
	std.	11.34	6.42	10.72	5.43
Rank–sum test:		p–value	p–value	p–value	p–value
NoComm–IRProj		0.873	0.025	0.109	0.749
NoComm–DualProj		0.522	0.631	0.055	0.262
NoComm–AdaptiveDualProj		0.749	0.423	0.025	0.055
IRProj–DualProj		0.522	0.262	0.078	0.522
IRProj–AdaptiveDualProj		0.631	0.025	0.109	0.037
DualProj–AdaptiveDualProj		0.873	0.337	0.631	0.037

The entries are the average and the standard deviation of the session-level median disagreement of output and inflation forecasts at the session-repetition level. Disagreement is measured as the within-period standard deviation of a particular forecasted variable. N=6 observations per treatment. Signed rank tests reject the null hypothesis that the session-level median disagreements are equal to zero for all treatments and repetitions ($p = 0.028$ in all cases).

Table 5: Absolute forecast errors of output and inflation, by treatment - Session Medians

Treatment		Repetition–1		Repetition–2	
		Output	Inflation	Output	Inflation
NoComm					
	Mean	54.08	15.67	48.50	15.75
	std.	11.93	2.66	11.33	3.13
IRProj					
	Mean	52.08	18.92	48.25	17.00
	std.	9.62	6.83	6.35	4.19
DualProj					
	Mean	47.50	14.67	40.92	14.25
	std.	8.83	3.20	9.67	2.40
AdaptiveDualProj					
	Mean	40.67	13.75	38.50	12.75
	std.	7.21	2.89	9.88	1.89
Rank–sum test:		p–value	p–value	p–value	p–value
NoComm–IRProj		0.630	0.267	1.000	0.506
NoComm–DualProj		0.261	0.519	0.197	0.195
NoComm–AdaptiveDualProj		0.037	0.147	0.200	0.042
IRProj–DualProj		0.574	0.260	0.149	0.105
IRProj–AdaptiveDualProj		0.045	0.078	0.065	0.029
DualProj–AdaptiveDualProj		0.173	0.746	0.873	0.516

The entries are the average and the standard deviation of session-repetition median absolute forecast errors. Rank sum tests are conducted on session-level median absolute forecast errors. N=6 observations per treatment. Signed rank tests reject the null hypothesis that the session-level median absolute forecast errors are equal to zero for all treatments and repetitions ($p = 0.028$ in all cases).

Table 6: Credibility of Central Bank Projections of Output and Inflation - By Repetition - Low Variability Shocks[I]

	Repetition 1				Repetition 2			
	DualProj		AdaptiveDualProj		DualProj		AdaptiveDualProj	
Dep.Var: Prob(Utilized CB Forecast=1)	$E_{i,t}x_{t+1}$	$E_{i,t}\pi_{t+1}$	$E_{i,t}x_{t+1}$	$E_{i,t}\pi_{t+1}$	$E_{i,t}x_{t+1}$	$E_{i,t}\pi_{t+1}$	$E_{i,t}x_{t+1}$	$E_{i,t}\pi_{t+1}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\lvert FE^{cb}x_{t-1}\rvert$	-0.013	-0.006	0.006	-0.018	0.008	-0.007	0.013	0.007
	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)	(0.00)	(0.01)	(0.01)
$(\lvert FE^{cb}x_{t-1}\rvert)^2$	0.000	0.000	-0.000	0.000	-0.000	0.000**	-0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$(\lvert FE^{cb}\pi_{t-1}\rvert)$	0.026	-0.006	0.008	0.059	-0.026	0.006	-0.027	-0.022
	(0.03)	(0.03)	(0.06)	(0.05)	(0.04)	(0.02)	(0.04)	(0.02)
$(\lvert FE^{cb}\pi_{t-1}\rvert)^2$	-0.001	-0.000	0.001	-0.001	0.001	-0.000	-0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$UtilizedCBxForecast_{t-2}$	0.146	0.265	0.241	0.238	0.268	0.206	-0.140	0.064
	(0.28)	(0.26)	(0.23)	(0.22)	(0.21)	(0.16)	(0.28)	(0.16)
$UtilizedCB\pi Forecast_{t-2}$	0.104	-0.065	0.230	0.189	0.051	0.124	0.238	0.169
	(0.25)	(0.23)	(0.21)	(0.19)	(0.20)	(0.14)	(0.23)	(0.11)
$\lvert FEx_{i,t-1}\rvert$	-0.002	-0.002	-0.000	-0.001	-0.004	-0.002	-0.004	0.002
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\lvert FE\pi_{i,t-1}\rvert$	-0.000	-0.010	0.002	0.011*	0.001	-0.002	0.001	-0.003
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)
$\lvert FEx_{i,t-1}\rvert \times UtilizedCBxForecast_{t-2}$	0.003	0.007***	0.000	-0.001	0.002	-0.000	0.004*	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\lvert FE\pi_{i,t-1}\rvert \times UtilizedCB\pi Forecast_{t-2}$	0.017	0.007	-0.006	0.015*	0.002	0.004	0.001	0.003
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)
α	-1.242***	-0.530*	-1.340***	-0.466*	-1.177***	-0.757***	-1.600***	-0.738***
	(0.29)	(0.28)	(0.22)	(0.24)	(0.25)	(0.20)	(0.27)	(0.17)
lnsig2u								
_cons	-1.038*	-0.854	-2.743**	-0.977*	-0.679	-0.051	-1.149*	-0.463
	(0.63)	(0.58)	(1.10)	(0.51)	(0.47)	(0.31)	(0.61)	(0.29)
N	388	388	392	392	588	1175	588	1176
χ^2	10.26	20.74	9.942	21.68	11.25	16.40	11.90	15.94

(I) This table presents results from a series of random effects probit regressions. $*p < 0.10$, $**p < 0.05$, and $***p < 0.01$. $UtilizedCBxForecast_t$ and $UtilizedCB\pi Forecast_t$ are dummy variables that takes the value of 1 if a subject's output and inflation forecast in period t about period $t+1$, respectively, were less than 2 basis points away from the central bank's projected forecast. $\lvert FE^{cb}x_{t-1}\rvert$ and $\lvert FE^{cb}\pi_{t-1}\rvert$ denote the absolute forecast errors the central bank made in period $t-2$ about period $t-1$ output and inflation, respectively. $\lvert FEx_{i,t-1}\rvert$ and $\lvert FE\pi_{i,t-1}\rvert$ denote subject i's forecast errors formed in period $t-2$ about period $t-1$ output and inflation, respectively.

Table 7: Credibility of Central Bank Projections of Output and Inflation - By Repetition - High Variability Shocks[I]

	Repetition 1				Repetition 2			
	DualProj		AdaptiveDualProj		DualProj		AdaptiveDualProj	
Dep.Var: Prob(Utilized CB Forecast=1)	$E_{i,t}x_{t+1}$	$E_{i,t}\pi_{t+1}$	$E_{i,t}x_{t+1}$	$E_{i,t}\pi_{t+1}$	$E_{i,t}x_{t+1}$	$E_{i,t}\pi_{t+1}$	$E_{i,t}x_{t+1}$	$E_{i,t}\pi_{t+1}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\lvert FE^{cb}x_{t-1}\rvert$	-0.006	0.001	-0.000	-0.007*	-0.021***	-0.007	-0.016*	0.007
	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)
$(\lvert FE^{cb}x_{t-1}\rvert)^2$	0.000	-0.000	-0.000	0.000	0.000**	0.000**	0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$(\lvert FE^{cb}\pi_{t-1}\rvert)$	0.018	0.001	0.011	0.024	0.060***	0.006	0.072**	-0.022
	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
$(\lvert FE^{cb}\pi_{t-1}\rvert)^2$	-0.000	-0.000	-0.000	-0.000	-0.000**	-0.000	-0.001*	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$UtilizedCBxForecast_{t-2}$	0.188	0.240	-0.273	0.330	0.137	0.206	-0.506*	0.064
	(0.19)	(0.19)	(0.34)	(0.24)	(0.25)	(0.16)	(0.29)	(0.16)
$UtilizedCB\pi Forecast_{t-2}$	0.190	0.343**	0.331	0.305*	0.299	0.124	-0.167	0.169
	(0.18)	(0.17)	(0.22)	(0.17)	(0.23)	(0.14)	(0.20)	(0.11)
$\lvert FEx_{i,t-1}\rvert$	-0.001	-0.002	0.002	0.002	0.001	-0.002	0.004	0.002
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\lvert FE\pi_{i,t-1}\rvert$	-0.002	-0.002	-0.010**	-0.005	-0.024***	-0.002	-0.008	-0.003
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
$\lvert FEx_{i,t-1}\rvert \times UtilizedCBxForecast_{t-2}$	0.000	0.001	-0.000	-0.000	0.002	-0.000	0.002	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\lvert FE\pi_{i,t-1}\rvert \times UtilizedCB\pi Forecast_{t-2}$	0.001	0.002	-0.009	0.002	0.008	0.004	-0.001	0.003
	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
α	-1.223***	-0.873***	-1.560***	-1.124***	-1.031***	-0.757***	-1.469***	-0.738***
	(0.22)	(0.24)	(0.22)	(0.17)	(0.31)	(0.20)	(0.22)	(0.17)
lnsig2u								
_cons	-0.506	-0.137	-2.049***	-1.387***	-0.043	-0.051	-1.924***	-0.463
	(0.41)	(0.38)	(0.75)	(0.42)	(0.49)	(0.31)	(0.66)	(0.29)
N	779	779	781	781	587	1175	588	1176
χ^2	10.21	25.85	12.19	19.50	20.89	16.40	12.24	15.94

(I) This table presents results from a series of random effects probit regressions. $*p < 0.10$, $**p < 0.05$, and $***p < 0.01$. $UtilizedCBxForecast_t$ and $UtilizedCB\pi Forecast_t$ are dummy variables that takes the value of 1 if a subject's output and inflation forecast in period t about period $t+1$, respectively, were less than 2 basis points away from the central bank's projected forecast. $|FE^{cb}x_{t-1}|$ and $|FE^{cb}\pi_{t-1}|$ denote the absolute forecast errors the central bank made in period $t-2$ about period $t-1$ output and inflation, respectively. $|FEx_{i,t-1}|$ and $|FE\pi_{i,t-1}|$ denote subject i's forecast errors formed in period $t-2$ about period $t-1$ output and inflation, respectively.

Table 8: Standard Deviations of Output and Inflation Normalized by the REE Solution

Treatment		Repetition–1		Repetition–2	
		std.Output	std.Inflation	std.Output	std.Inflation
NoComm					
	Mean	1.02	1.38	1.06**	1.50**
	std.	0.12	0.62	0.07	0.41
InterestRateProj					
	Mean	0.98	1.49	0.99	1.14
	std.	0.13	0.76	0.15	0.48
DualProj					
	Mean	0.96	1.06	0.97	1.04
	std.	0.04	0.20	0.04	0.12
AdaptiveDualProj					
	Mean	1.00	1.04	1.03	1.10
	std.	0.04	0.08	0.07	0.18
Rank–sum test:		p–value	p–value	p–value	p–value
NoComm–IRProj		0.522	0.749	0.262	0.200
NoComm–DualProj		0.109	0.262	0.010	0.055
NoComm–AdaptiveDualProj		0.337	0.262	0.337	0.078
IRProj–DualProj		1.000	0.522	0.522	0.749
DualProj–AdaptiveDualProj		0.149	0.631	0.109	0.631

We report summary statistics on the the standard deviation of output and inflation, measured at the session-repetition level, divided by the rational expectations equilibrium solution's respective standard deviations. 6 observations are computed per treatment-repetition. The top panel presents means and standard deviations of the variable of interest. Asterisks denote whether the mean result is significantly different from 1 using a Wilcoxon signed-rank test: $*p < 0.10$, $**p < 0.05$, and $***p < 0.01$. The bottom panel denotes the p-value results from a series of Wilcoxon rank-sum tests of identical distributions across treatments for different variables and repetitions.

Figure 1: Screenshot from DualProj Treatment

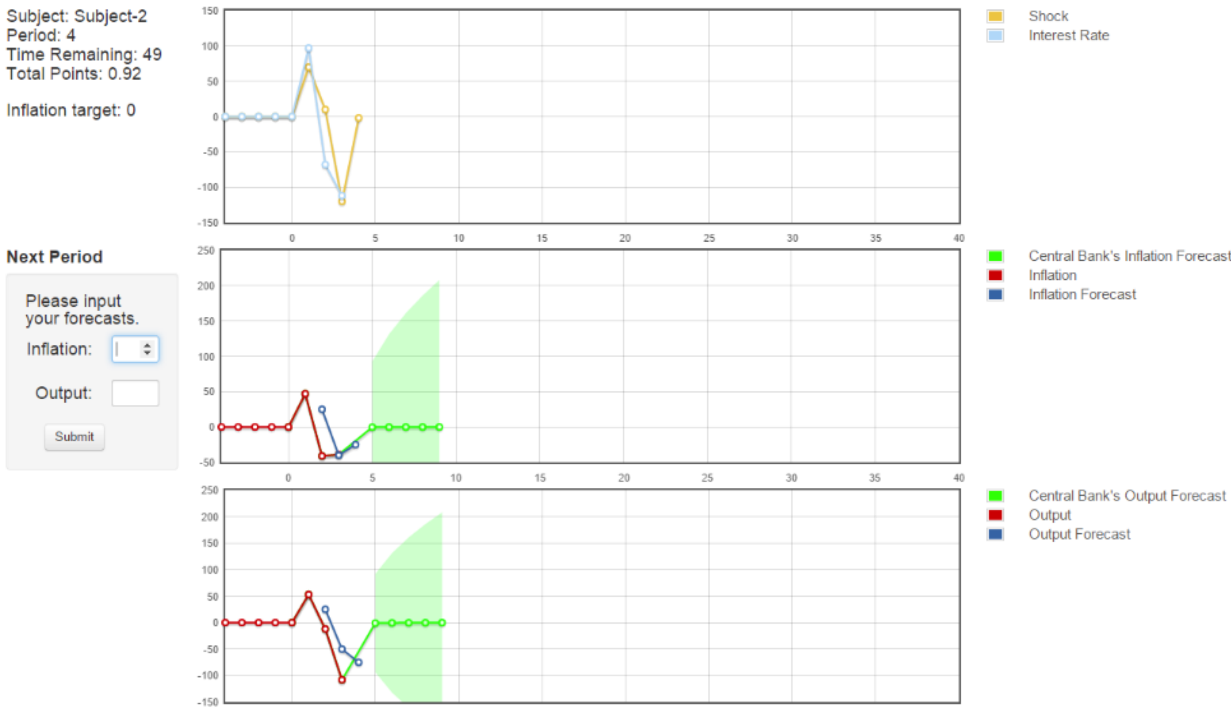


Figure 2: Kernel densities of absolute output and inflation forecast errors

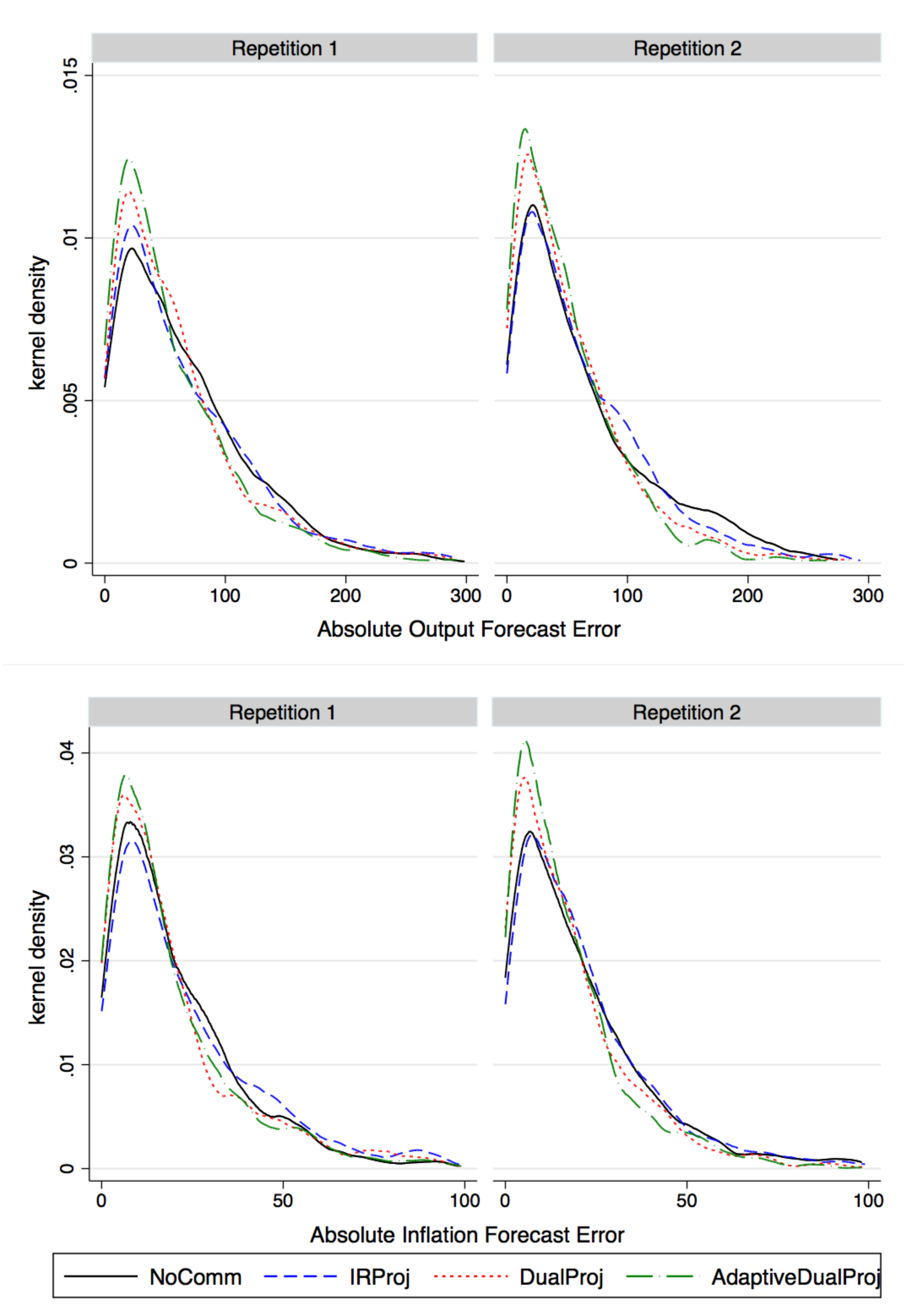


Figure 3: Estimated Impulse Responses of Endogenous Variables to 113 basis points shock

The figure shows the impulse responses of the variables to one standard deviation of the shock in basis points.

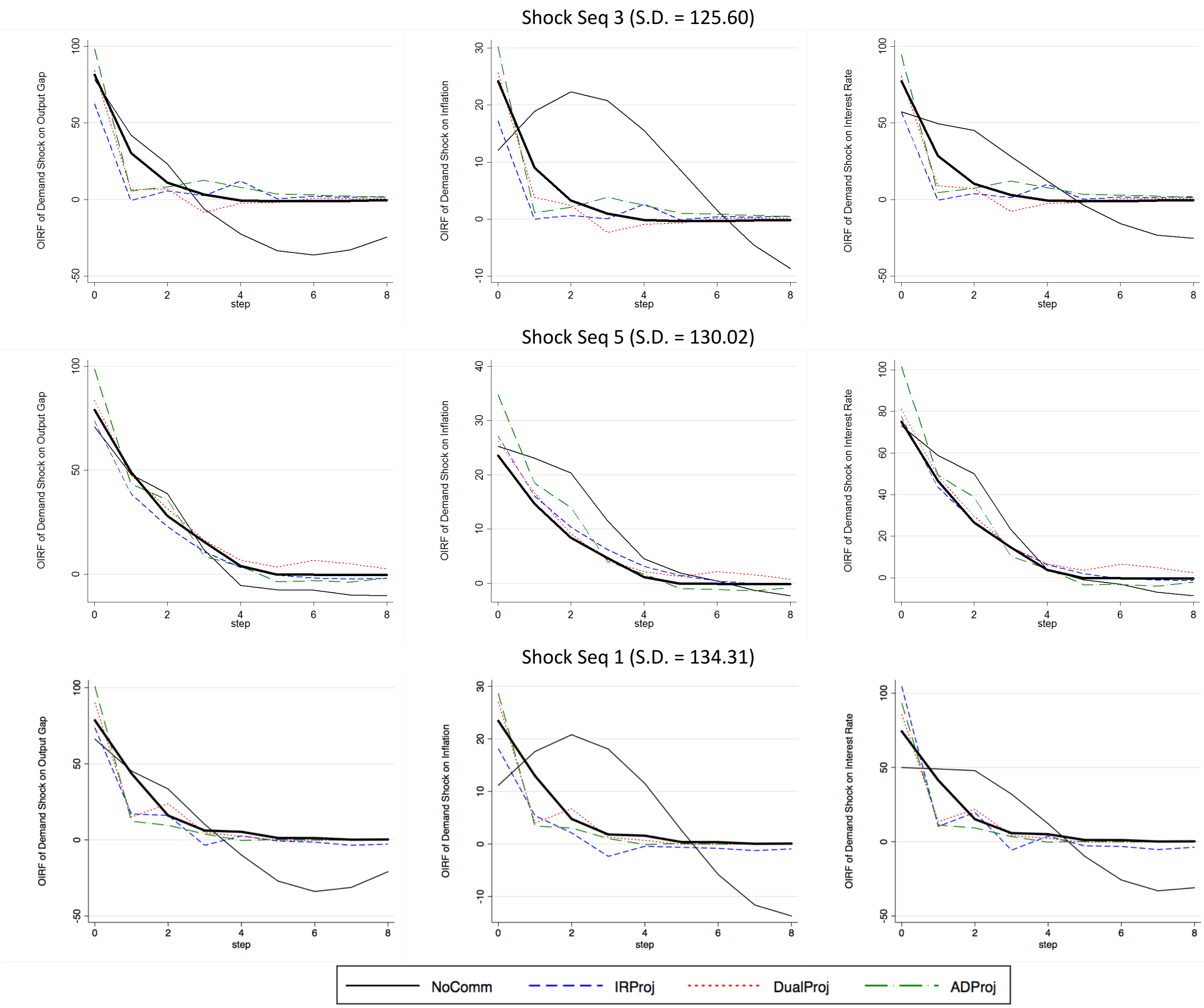


Figure 3: Estimated Impulse Responses of Endogenous Variables to 113 basis points shock

The figure shows the impulse responses of the variables to one standard deviation of the shock in basis points.

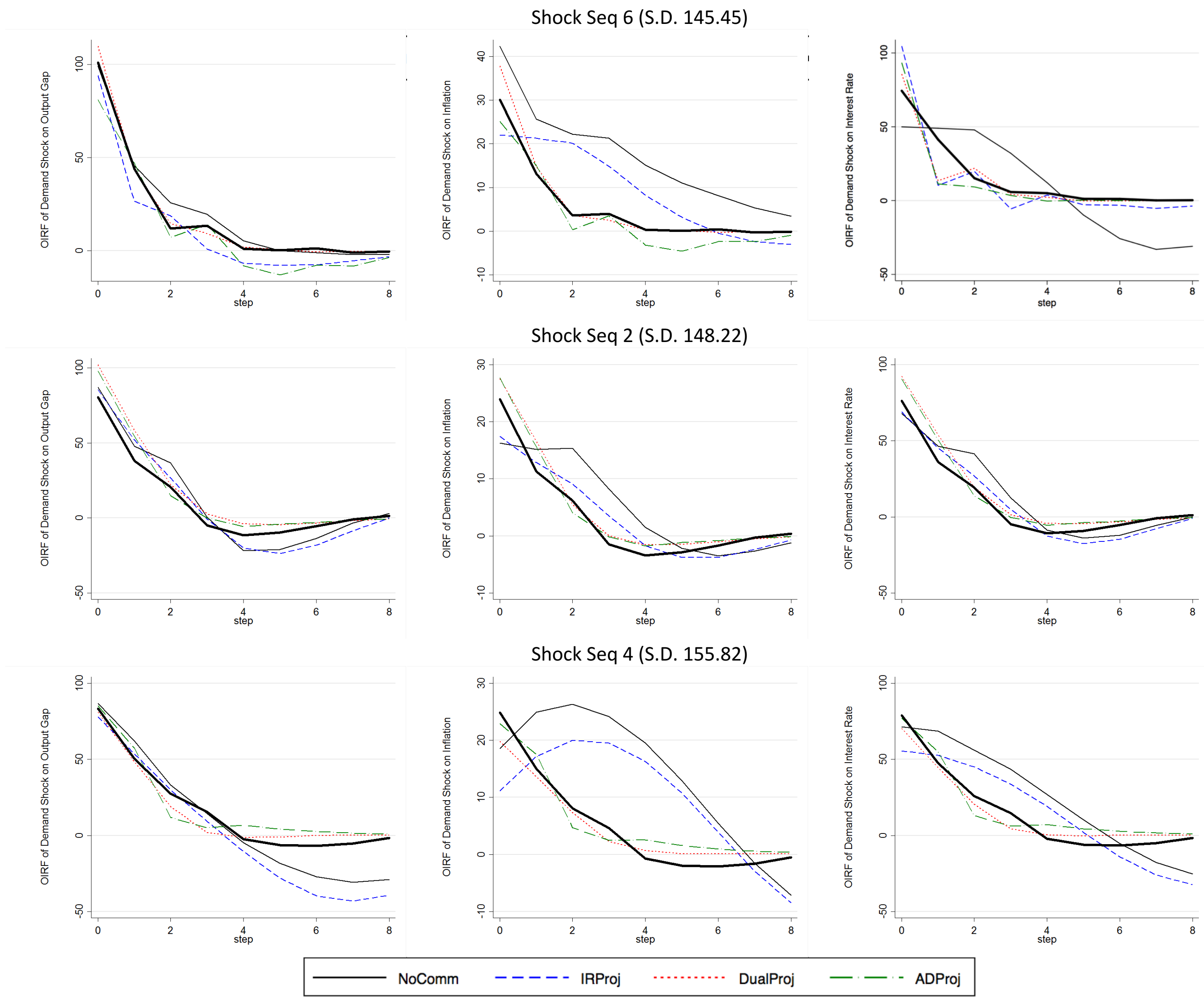


Figure 4: Kernel densities of absolute deviation of output and inflation forecasts from the REE prediction

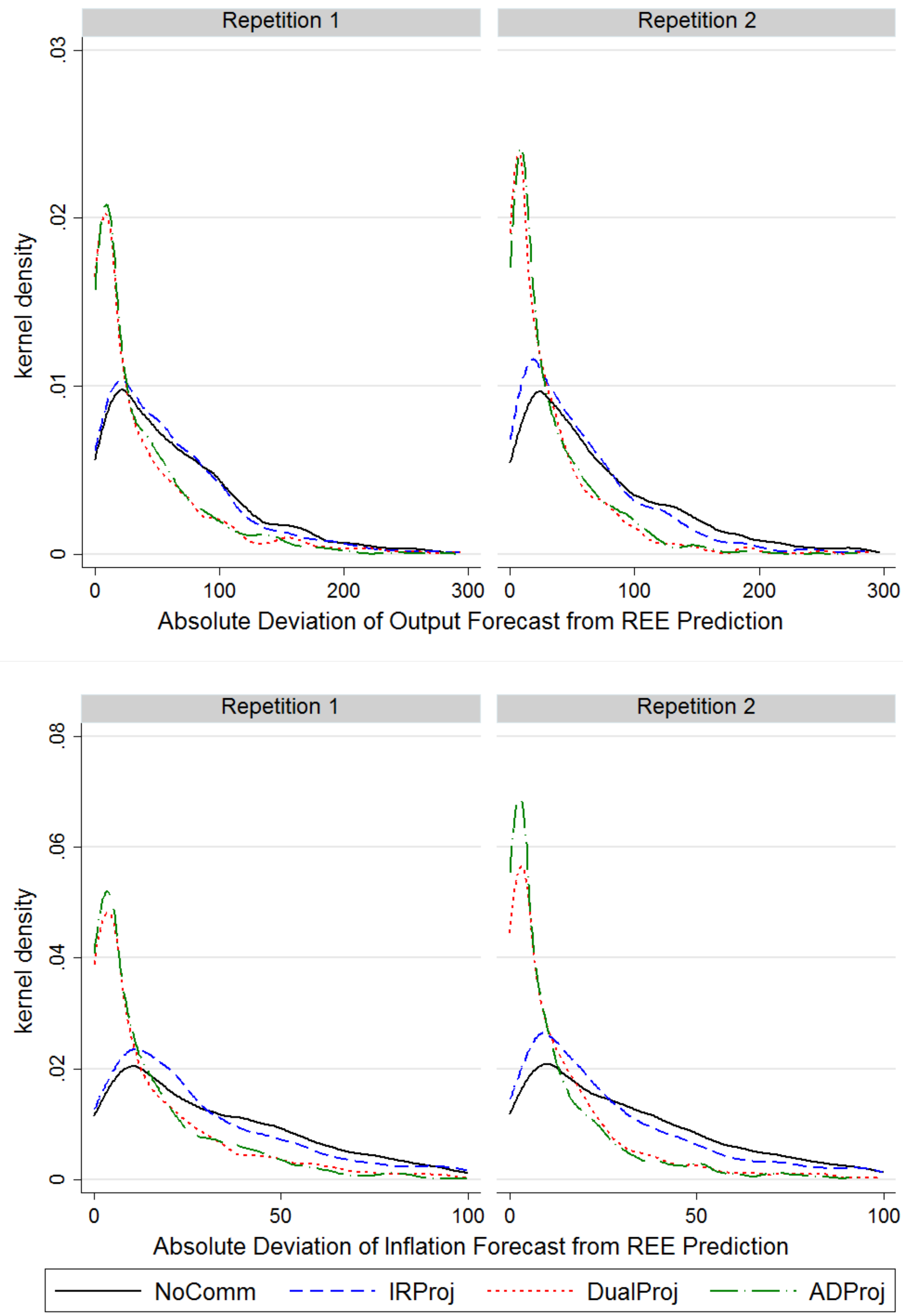
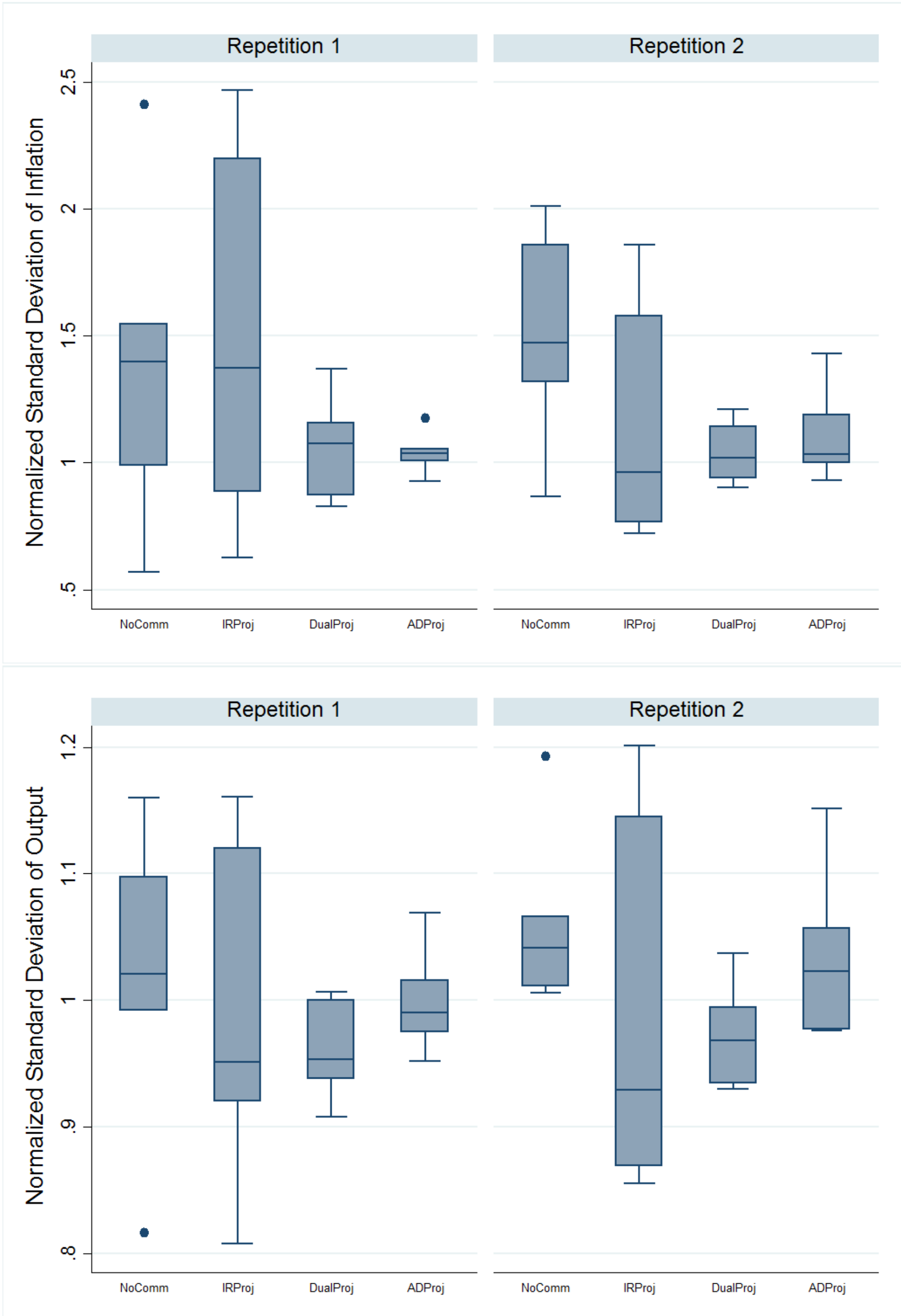


Figure 5: Standard Deviation of Output and Inflation Normalized by REE



The figure represents the standard deviation of output and inflation at the treatment–repetition level.

7. Appendix A–Solving the model under rational expectations

Replace equation (2) and (3) into (1):

$$x_t = E_t x_{t+1} - \sigma^{-1}\{\phi_\pi(\kappa x_t + \beta E_t \pi_{t+1}) + \phi_x x_t - E_t \pi_{t+1} - r_t^n\} \tag{12}$$

Rearrange the equation:

$$x_t = E_t x_{t+1} - \sigma^{-1}(\phi_\pi \kappa + \phi_x) x_t - \sigma^{-1}(\phi_\pi \beta - 1) E_t \pi_{t+1} + \sigma^{-1} r_t^n \tag{13}$$

$$[1 + \sigma^{-1}(\phi_\pi \kappa + \phi_x)] x_t = E_t x_{t+1} - \sigma^{-1}(\phi_\pi \beta - 1) E_t \pi_{t+1} + \sigma^{-1} r_t^n \tag{14}$$

We get:

$$x_t = \frac{1}{1 + \sigma^{-1}(\phi_\pi \kappa + \phi_x)} E_t x_{t+1} - \frac{\sigma^{-1}(\phi_\pi \beta - 1)}{1 + \sigma^{-1}(\phi_\pi \kappa + \phi_x)} E_t \pi_{t+1} + \frac{\sigma^{-1}}{1 + \sigma^{-1}(\phi_\pi \kappa + \phi_x)} r_t^n \tag{15}$$

Replace equation(8) into (2):

$$\pi_t = \kappa x_t + \beta E_t \pi_{t+1}, \tag{16}$$

$$\begin{aligned} \pi_t = \kappa\{ & \frac{1}{1 + \sigma^{-1}(\phi_\pi \kappa + \phi_x)} E_t x_{t+1} - \frac{\sigma^{-1}(\phi_\pi \beta - 1)}{1 + \sigma^{-1}(\phi_\pi \kappa + \phi_x)} E_t \pi_{t+1} + \\ & \frac{\sigma^{-1}}{1 + \sigma^{-1}(\phi_\pi \kappa + \phi_x)} r_t^n\} + \beta E_t \pi_{t+1} \end{aligned} \tag{17}$$

We get:

$$\begin{aligned} \pi_t = & \frac{\kappa}{1 + \sigma^{-1}(\phi_\pi \kappa + \phi_x)} E_t x_{t+1} + (\frac{\beta + \beta\sigma^{-1}\phi_x + \kappa\sigma^{-1}}{1 + \sigma^{-1}(\phi_\pi \kappa + \phi_x)}) E_t \pi_{t+1} \\ & + \frac{\kappa\sigma^{-1}}{1 + \sigma^{-1}(\phi_\pi \kappa + \phi_x)} r_t^n \end{aligned} \tag{18}$$

Solve for i_t:
Using equations 8 and 11 we get:

$$i_t = \frac{\phi_x + \phi_\pi \kappa}{1 + \sigma^{-1}(\phi_\pi \kappa + \phi_x)} E_t x_{t+1} + \frac{\phi_x \sigma^{-1} + \phi_\pi(\beta + \kappa\sigma^{-1})}{1 + \sigma^{-1}(\phi_\pi \kappa + \phi_x)} E_t \pi_{t+1} + \frac{\kappa\sigma^{-1}\phi_\pi + \sigma^{-1}\phi_x}{1 + \sigma^{-1}(\phi_\pi \kappa + \phi_x)} r_t^n \tag{19}$$

$$
\begin{aligned}
x_t &= \frac{1}{1+\sigma^{-1}(\phi_\pi\kappa+\phi_x)}E_t x_{t+1} - \frac{\sigma^{-1}(\phi_\pi\beta-1)}{1+\sigma^{-1}(\phi_\pi\kappa+\phi_x)}E_t\pi_{t+1} + \frac{\sigma^{-1}}{1+\sigma^{-1}(\phi_\pi\kappa+\phi_x)}r_t^n,\\
\pi_t &= \frac{\kappa}{1+\sigma^{-1}(\phi_\pi\kappa+\phi_x)}E_t x_{t+1} + \frac{\beta+\beta\sigma^{-1}\phi_x+\kappa\sigma^{-1}}{1+\sigma^{-1}(\phi_\pi\kappa+\phi_x)}E_t\pi_{t+1} + \frac{\kappa\sigma^{-1}}{1+\sigma^{-1}(\phi_\pi\kappa+\phi_x)}r_t^n,\\
i_t &= \frac{\phi_x+\phi_\pi\kappa}{1+\sigma^{-1}(\phi_\pi\kappa+\phi_x)}E_t x_{t+1} + \frac{\phi_x\sigma^{-1}+\phi_\pi(\beta+\kappa\sigma^{-1})}{1+\sigma^{-1}(\phi_\pi\kappa+\phi_x)}E_t\pi_{t+1} + \frac{\kappa\sigma^{-1}\phi_\pi+\sigma^{-1}\phi_x}{1+\sigma^{-1}(\phi_\pi\kappa+\phi_x)}r_t^n
\end{aligned}
$$

Results:

$$
\begin{aligned}
x_t &= 0.58997 \times E_t x_{t+1} - 0.28525 \times E_t\pi_{t+1} + 0.58997 \times r_t^n,\\
\pi_t &= 0.076696 \times E_t x_{t+1} + 0.95192 \times E_t\pi_{t+1} + 0.076696 \times r_t^n,\\
i_t &= 0.41004 \times E_t x_{t+1} + 1.2853 \times E_t\pi_{t+1} + 0.41003 \times r_t^n
\end{aligned}
$$

Under rational expectation, the transition path of interested variables are as the following:

$$
\begin{aligned}
x_t &= 0.472198 \times r_{t-1}^n + 0.82847 \times \epsilon_t,\\
\pi_t &= 0.140706 \times r_{t-1}^n + 0.246852 \times \epsilon_t,\\
i_t &= 0.447157 \times r_{t-1}^n + 0.784487 \times \epsilon_t,\\
E_{t-1}x_t &= 0.269153 \times r_{t-1}^n + 0.472198 \times \epsilon_t,\\
E_{t-1}\pi_t &= 0.080202 \times r_{t-1}^n + 0.140706 \times \epsilon_t
\end{aligned}
$$

8. Appendix B–Additional Results

Table 9: Effects of central bank projections on forecast errors, by shock sequence - Treatment Effects - Repetition 2[I]

	Panel A: Low variability shocks					
	fe_output	fe_inflation	fe_output	fe_inflation	fe_output	fe_inflation
	(1)	(2)	(3)	(4)	(5)	(6)
epsilon	-0.211***	-0.190***	-0.047	-0.041	-0.578*	-0.176***
	(0.07)	(0.03)	(0.13)	(0.03)	(0.35)	(0.02)
epsilonIRProj	0.278***	0.249***	-0.065	0.121***	0.572	0.215***
	(0.10)	(0.04)	(0.19)	(0.04)	(0.49)	(0.03)
epsilonDualProj	0.419***	0.295***	0.023	0.058	0.705	0.268***
	(0.10)	(0.04)	(0.19)	(0.04)	(0.49)	(0.03)
epsilonADProj	0.735***	0.336***	0.360*	0.135***	0.875*	0.258***
	(0.10)	(0.04)	(0.19)	(0.04)	(0.49)	(0.03)
L.epsilon	0.187**	-0.176***	0.112	-0.013	0.197	-0.187***
	(0.07)	(0.03)	(0.15)	(0.03)	(0.36)	(0.02)
L.epsilonIRProj	-0.096	0.195***	-0.208	0.030	-0.300	0.179***
	(0.11)	(0.05)	(0.21)	(0.05)	(0.51)	(0.03)
L.epsilonDualProj	-0.059	0.231***	-0.138	0.037	-0.385	0.169***
	(0.11)	(0.05)	(0.21)	(0.05)	(0.51)	(0.03)
L.epsilonADProj	-0.019	0.231***	-0.182	-0.060	-0.256	0.181***
	(0.11)	(0.05)	(0.21)	(0.05)	(0.51)	(0.03)
L2.epsilon	0.403***	-0.129***	0.214	0.059*	1.276***	-0.085***
	(0.08)	(0.03)	(0.15)	(0.03)	(0.37)	(0.02)
L2.epsilonIRProj	-0.226**	0.169***	-0.030	0.033	-1.156**	0.102***
	(0.11)	(0.05)	(0.21)	(0.05)	(0.53)	(0.03)
L2.epsilonDualProj	-0.198*	0.219***	0.187	-0.014	-1.232**	0.100***
	(0.11)	(0.05)	(0.21)	(0.05)	(0.53)	(0.03)
L2.epsilonADProj	-0.178*	0.202***	-0.064	-0.011	-1.186**	0.120***
	(0.11)	(0.05)	(0.21)	(0.05)	(0.53)	(0.03)
L3.epsilon	0.233***	-0.092***	0.170	0.037	1.956***	-0.035
	(0.07)	(0.03)	(0.15)	(0.03)	(0.36)	(0.02)
L3.epsilonIRProj	-0.306***	0.092**	-0.054	0.018	-1.914***	0.013
	(0.11)	(0.05)	(0.21)	(0.05)	(0.51)	(0.03)
L3.epsilonDualProj	-0.212**	0.118**	0.098	-0.021	-1.929***	0.035
	(0.11)	(0.05)	(0.21)	(0.05)	(0.51)	(0.03)
L3.epsilonADProj	-0.219**	0.101**	-0.007	0.015	-1.930***	0.036
	(0.11)	(0.05)	(0.21)	(0.05)	(0.51)	(0.03)
L4.epsilon	0.095	-0.014	-0.040	-0.036	1.092***	0.001
	(0.07)	(0.03)	(0.15)	(0.03)	(0.34)	(0.02)
L4.epsilonIRProj	-0.184*	-0.022	0.041	0.050	-1.081**	-0.014
	(0.10)	(0.04)	(0.21)	(0.05)	(0.48)	(0.03)
L4.epsilonDualProj	-0.199**	-0.015	0.285	0.062	-1.042**	-0.004
	(0.10)	(0.04)	(0.21)	(0.05)	(0.48)	(0.03)
L4.epsilonADProj	-0.176*	-0.008	0.044	0.018	-1.026**	0.000
	(0.10)	(0.04)	(0.21)	(0.05)	(0.48)	(0.03)
_cons	13.763***	4.133**	23.978***	4.719***	81.299***	-0.711
	(4.32)	(1.89)	(7.50)	(1.69)	(21.82)	(1.30)
SD r_t^n	125.60	125.60	130.02	130.02	134.31	134.31
N	699	699	700	700	699	699
chi2	156.8	117.8	29.87	50.79	39.64	192.9

(I) This table presents results from a series of random effects panel regressions. α denotes the estimated constant in the random effects regressions. Robust standard errors are employed. $^{*}p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

Table 9: Effects of central bank projections on forecast errors, by shock sequence - Treatment Effects - Repetition 2 - Continued[I]

	Panel A: High variability shocks					
	fe_output	fe_inflation	fe_output	fe_inflation	fe_output	fe_inflation
	(1)	(2)	(3)	(4)	(5)	(6)
epsilon	0.156**	0.065**	-0.081	-0.084*	-0.428***	-0.263***
	(0.07)	(0.03)	(0.08)	(0.05)	(0.08)	(0.04)
epsilonIRProj	-0.068	-0.147***	-0.075	0.031	-0.097	0.057
	(0.10)	(0.05)	(0.12)	(0.07)	(0.12)	(0.06)
epsilonDualProj	0.269***	0.077	0.093	0.085	0.181	0.256***
	(0.10)	(0.05)	(0.12)	(0.07)	(0.12)	(0.06)
epsilonADProj	0.113	0.028	-0.010	-0.024	0.161	0.185***
	(0.10)	(0.05)	(0.12)	(0.07)	(0.12)	(0.06)
L.epsilon	0.179***	0.011	0.045	-0.056	0.297***	-0.061
	(0.07)	(0.03)	(0.08)	(0.05)	(0.09)	(0.05)
L.epsilonIRProj	0.177*	-0.097**	-0.077	0.044	-0.058	-0.092
	(0.10)	(0.05)	(0.11)	(0.07)	(0.13)	(0.07)
L.epsilonDualProj	0.045	0.064	-0.071	0.038	-0.171	0.060
	(0.09)	(0.05)	(0.11)	(0.07)	(0.12)	(0.07)
L.epsilonADProj	0.037	0.066	-0.249**	-0.099	-0.149	0.107
	(0.09)	(0.05)	(0.11)	(0.07)	(0.12)	(0.07)
L2.epsilon	0.167**	0.010	0.230***	0.013	0.258***	-0.061
	(0.07)	(0.03)	(0.08)	(0.05)	(0.09)	(0.04)
L2.epsilonIRProj	0.152	-0.053	-0.057	-0.015	-0.079	-0.064
	(0.09)	(0.05)	(0.11)	(0.06)	(0.12)	(0.06)
L2.epsilonDualProj	-0.027	0.037	-0.018	0.018	-0.400***	0.081
	(0.09)	(0.05)	(0.11)	(0.06)	(0.12)	(0.06)
L2.epsilonADProj	-0.081	0.026	-0.130	-0.019	-0.295**	0.050
	(0.09)	(0.05)	(0.11)	(0.06)	(0.12)	(0.06)
L3.epsilon	0.272***	0.055*	0.152*	0.026	0.427***	0.039
	(0.06)	(0.03)	(0.08)	(0.05)	(0.08)	(0.04)
L3.epsilonIRProj	0.135	-0.027	0.055	-0.014	-0.016	-0.066
	(0.09)	(0.04)	(0.11)	(0.07)	(0.11)	(0.06)
L3.epsilonDualProj	-0.046	0.020	0.042	0.010	-0.327***	-0.033
	(0.09)	(0.04)	(0.11)	(0.07)	(0.11)	(0.06)
L3.epsilonADProj	-0.126	-0.018	0.047	0.081	-0.231**	0.030
	(0.09)	(0.04)	(0.11)	(0.07)	(0.11)	(0.06)
L4.epsilon	0.228***	0.077**	0.127	0.017	0.324***	0.020
	(0.06)	(0.03)	(0.08)	(0.05)	(0.08)	(0.04)
L4.epsilonIRProj	0.147	0.039	-0.038	-0.016	0.022	-0.019
	(0.09)	(0.04)	(0.11)	(0.07)	(0.12)	(0.06)
L4.epsilonDualProj	-0.018	-0.016	-0.075	-0.001	-0.129	0.025
	(0.09)	(0.04)	(0.11)	(0.07)	(0.12)	(0.06)
L4.epsilonADProj	-0.087	-0.054	-0.156	-0.084	-0.191*	0.009
	(0.09)	(0.04)	(0.11)	(0.07)	(0.12)	(0.06)
_cons	-13.276***	-3.140	5.594	4.372	18.486***	11.339***
	(4.50)	(2.18)	(5.36)	(3.18)	(4.78)	(2.50)
SD r_t^n	145.45	145.45	148.22	148.22	155.82	155.82
N	698	698	699	699	698	698
chi2	202.6	76.26	68.28	30.84	242.7	89.24

(I) This table presents results from a series of random effects panel regressions. α denotes the estimated constant in the random effects regressions. Robust standard errors are employed. $*p < 0.10$, $**p < 0.05$, and $***p < 0.01$.

Appendix C– Instruction

EXPERIMENTAL STUDY OF ECONOMIC DECISION MAKING

Welcome! You are participating in an economic 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 CAN $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 CAN $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 instruction 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 for 4 periods 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.

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:

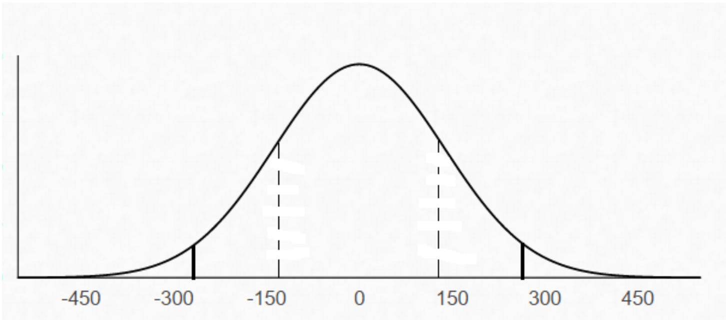
- Inflation, Output, Interest Rate, Shocks

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

$Shock_t = 0.57(Shock_{t-1}) + Random\ Component_t$

- The random component is 0 on average.

- Roughly two out of three times the shock will be between -138 and 138 basis points.
- 95% of the time the shock will be between -276 and 276 basis points.



E.g.

$$\begin{aligned} Shock_1 &= 30 \\ Shock_2 &= 30 \times 0.57 + New\ Draw \\ &= 17.1 + (30) \\ &= 47.1 \\ Shock_2 &= 17.1 + (-150) \\ &= -132.9 \end{aligned}$$

How the economy evolves:

$$Inflation_t = 0.989(Median\ forecast\ of\ Inflation_{t+1}) + 0.13(Output_t)$$

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

$$Interest\ Rate_t = 1.5(Inflation_t) + 0.5(Output_t)$$

- The Central Bank sets the target for output and inflation at zero. In order to achieve the target it will adjust the interest rate and in some cases this means the interest rate can become negative.
- 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.
- The Central Bank will make a five–period projection each period about the future levels of the inflation and output. It is important to remember that the projections are simply a forecast and not a promise. The Central Bank use the current and expected future shocks to form its projections. In particular, it predicts that the economy will return to zero levels of inflation and output in the near future.

Score

Your score will depend on the accuracy of your 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 $= 0.30(2^{-0.01(ForecastErrorforOutput)}) + 0.30(2^{-0.01(ForecastErrorforInflation)})$

The maximum score you can earn each period is 0.60. Your score will decrease as your forecast error increases. Suppose your forecast errors for each of output and inflation is:

1. 0 : Your score will be 0.6
2. 50: Your score will be 0.42
3. 100: Your score will be 0.30
4. 200: Your score will be 0.15
5. 300: Your score will be 0.075
6. 500: Your score will be 0.02
7. 1000: Your score will be 0
8. 2000: Your score will be 0

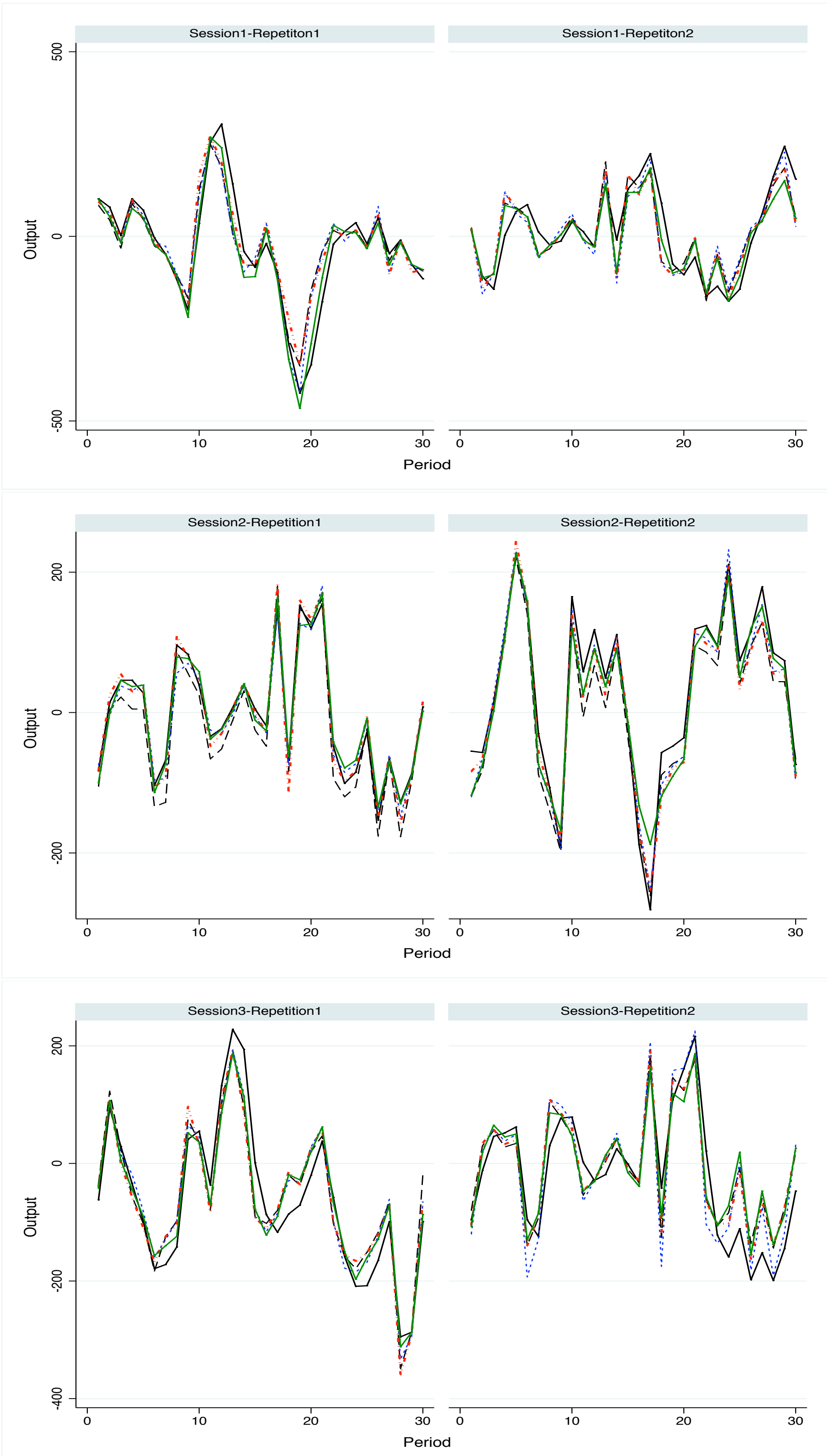
During the experiment, your main screen will display information that will help you make forecasts and earn more points.

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 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, and the Central Bank projection. The final plot displays your past forecasts of output and realized output levels, and the Central Bank projection .

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. The central bank forecast will be shown in green. You can see the exact value for each point on a graph by placing your mouse at that point.

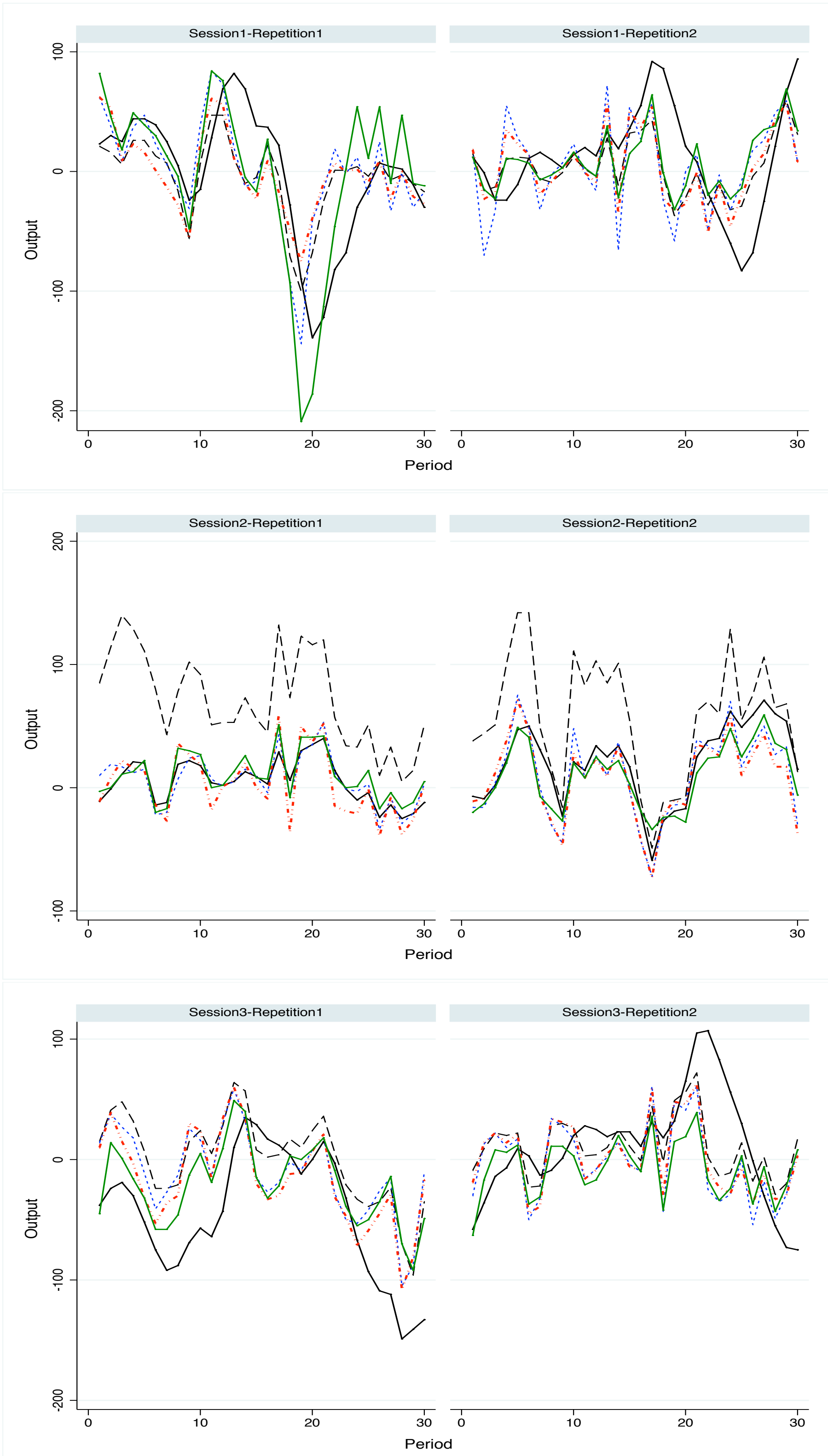
When the first period begins, you will have 65 seconds to submit new forecasts for the next period's inflation and output levels. You may submit both negative and positive forecasts. Please review your forecasts before pressing the SUBMIT button. Once the SUBMIT button has been clicked, you will not be able to revise your forecasts until the next period. You will earn zero points if you do not submit the two 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 30 periods, for a total of 60 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.

Figure 6: Time series of the output gap by session and repetition




Session4-Repetition1
Session4-Repetition2
Session5-Repetition1
Session5-Repetition2
Session6-Repetition1
Session6-Repetition2
Output
Period
NoComm
OutputProj
InflationProj
DualProj
InterestProj

Figure 7: Time series of the inflation by session and repetition



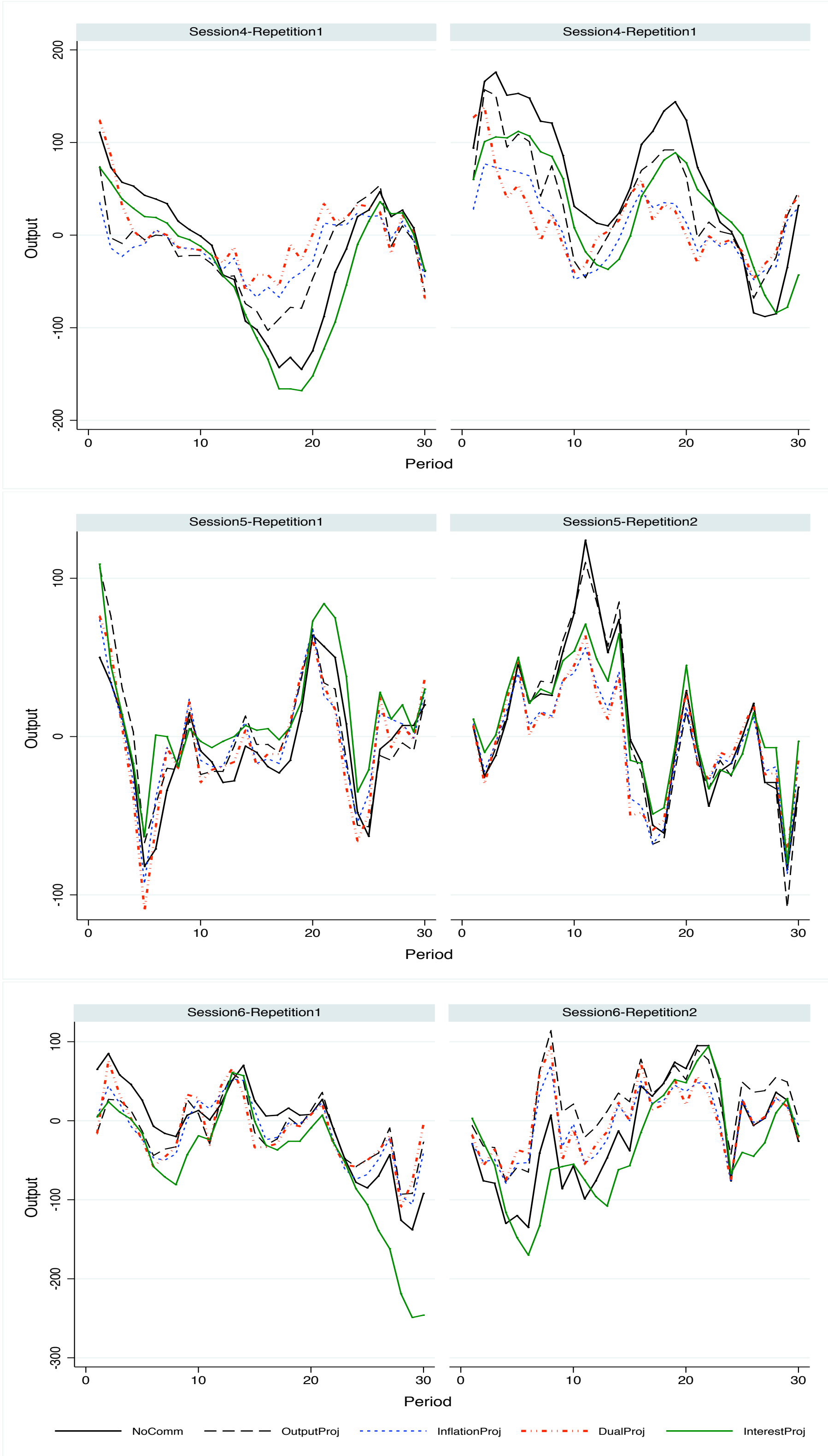

Session4-Repetition1
Session4-Repetition1
Session5-Repetition1
Session5-Repetition2
Session6-Repetition1
Session6-Repetition2
Output
Period
NoComm
OutputProj
InflationProj
DualProj
InterestProj

Figure 8: Central bank absolute forecast errors by repetition