Central Bank Communication that Works: Lessons from Lab Experiments*–

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Oleksiy Kryvtsov[†]
Bank of Canada

Luba Petersen[‡]
Simon Fraser University

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[†]Bank of Canada, 234 Wellington Street, Ottawa, Ontario K1A 0G9, Canada. Email: *okryvtsov@bankofcanada.ca*.

[‡]Department of Economics, Simon Fraser University. Email: *luba_petersen@sfu.ca* .

Contents

A Instructions

EXPERIMENTAL STUDY OF ECONOMIC DECISION MAKING

Welcome! You are participating in an economics experiment at ELVSE Lab. In this experiment you will participate in an 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 $10 for attending. Throughout this experiment you will also earn points based on the decisions you make. Every point you earn is worth $0.75.

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. Please also turn off your cell phone. 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 $10 for attending.

Your task in this experiment is to serve as private forecasters and provide real-time forecasts about the future over- or under-spending decisions of an assigned household, the pricing decisions of assigned firms, as well as the nominal interest rate that will be set by the economy's central bank.

In this experiment, your assigned 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 experiment 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.

These instructions will explain what these variables are and how they evolve in this economy, as well as how they depend on forecasts by yourself and other forecasters in this experiment. You will also have a chance to practice making forecasts for 4 periods in a practice demonstration. Below we will discuss the factors that influence your household's spending, your firm's pricing decisions, and the central bank's nominal interest rate.

Your screen and task

During the experiment, your 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 receive "News" about the current shock to the economy and its expected future value. Under "Next Period", you will enter your forecasts for the *subsequent* interest rate, your assigned household's excess spending, and your assigned firm's price change. On the right side of the screen, you will see four history plots. The top history plot displays past and the current period shock to the economy, as well as the past excess spending of the median households and past price changes of the median firms. The second plot displays past interest rates and your personal forecasts about the interest rate. The third plot displays your household's past spending and your forecasts of its spending. The fourth plot displays your firm's price changes and your forecast of its price changes.

The difference between your forecasts and the actual levels (realized with one-period delay) constitutes your forecast errors. Your forecasts will always be shown in pink while the realized value will be shown in blue. 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 75 seconds to submit new forecasts for the next period's interest rate, your household's excess spending, and your firm's price change. You may submit both negative and positive forecasts and there is no limit to the number that you may forecast. 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. You will earn zero points if you do not submit all three forecasts. After the first 9 periods, the amount of time available to make a decision will drop to 60 seconds per period. You will make around 70 forecasts.

Your forecasts

You will submit forecasts in a measurement called *basis points.* A basis point is 100th of a percent. For example,

1% = 100 basis points
3.25% = 325 basis points
-0.53% = -53 basis points
-4.81% = -481 basis points

These are just a handful of examples. You may submit any forecast you wish, positive or negative or zero. Please only submit integer values.

How the economy evolves

Every period (which you should think of as 3 months/one quarter), you and the other forecasters in your economy will submit personal forecasts about the excess spending decision of your assigned households, the price change of your assigned firms, and the excess interest rate that the central bank will set in the next period. Your assigned household and firm will, to some degree, use your forecasts to make their own decisions today.

The households' desire to spend will depend on, among other things, a random economy-wide disturbance which we call "shocks". All households experience the same shock to their spending. Over hundreds of rounds, the mean shock will equal zero. In practice, the shocks will be positive or negative (or very rarely, zero!) from round to round and will range approximately within [–134,134] roughly 2/3 of the time, and within [–268,268] 95% of the time. The shocks may exceed –268 or 268 in magnitude, but such events are relatively rare. The shocks will evolve according to the following process:

$$\text{Shock}_t = 0.45\ \text{Shock}_{t-1} + \text{Random Component}_t$$

Shocks dissipate to 45% of their value after each period. As a shock dissipates, new random events occur that increase or decrease the shock. On average, these random components are equal to zero.

Below we explain precisely how your household will choose to spend, how your firm will change its price, and how the central bank will set its interest rate relative to its steady state value of zero. In the equations below, variables related to your personal household and firm are shown in bold font while common variables that apply to all households and firms are shown in regular font.

$$\begin{aligned}\text{Excess spending of your household}_t = {} & 0.99\ \textbf{Forecast about your household's excess spending} \\ & \textbf{tomorrow}_t + 0.01\,\text{Median excess spending}_t \\ & + 0.48\,\text{Median price change}_t - 0.99\,\text{Interest rate}_t\end{aligned}$$

$$\begin{aligned}\text{Price change of your firm}_t = {} & 0.51\,\textbf{Forecast about your firm's price change tomorrow}_t \\ & + 0.4\,(\,\text{Median excess spending}_t + \text{Shock}_t) \\ & + 0.3\,\text{Median price change}_t\end{aligned}$$

- Your household will spend more this quarter if you predict that it will spend more next quarter. This is because it prefers to smooth its spending over time. It will spend less this quarter if the central bank raises its interest rate because it will have greater incentive to save and less incentive to borrow. Your household will also spend slightly more if the median household is spending more and if the median firm raises its price.

- Your firm will raise its price this quarter if you predict that it will raise its price next quarter. It will also raise its price if the median household is spending more and the median firm is raising its price.
- Larger positive shocks push the economy to boom causing households to increase their spending and, consequently, firms to raise their prices. Negative shocks have mirror effects, pushing the economy in recession, decreasing spending and prices.
- Interest rate (monetary) policy aims to stabilize the economy. Higher interest rates prevent the economy from overheating, dampens household spending, and consequently, lowers prices. Low interest rates stimulate spending and prices.

The central bank's objective is to keep aggregate price changes and excess spending as close to zero as possible.

- It will raise interest rates when the economy is booming (that is, there is a high median price change and median spending)
- It will decrease interest rate when the economy is in recession (that is, low median price change and excess spending)
- The interest rate will respond more aggressively to median price changes, and increase by more than 1% for a 1% increase in the median price.

COM-BACK

- The central bank will announce whether the interest rate changed last period and the direction it changed: "The interest rate decreased last period" or "The interest rate increased last period." Only changes greater than 25 basis points in magnitude will be announced.

COM-FWD

- The central bank will announce whether it is likely to increase or decrease interest rates in the next period: "The interest rate will likely decrease next period" or "The interest rate will likely increase next period." Only predicted changes greater than 25 basis points in magnitude will be announced. The central bank will rely on the expected future shock and the past interest rate to make their predicted change.
- Occasionally, the interest rate may stay unchanged between the last two periods. In this case the central bank will not make an announcement.

COMM-COMMIT

- Occasionally, the interest rate may stay unchanged, and during those periods, the the central bank will announce the number of periods before the next change. At the end of these periods of inaction, the central bank will announce that the interest rate will change in the current period.

Example: Suppose the interest rate in Period 9 is 40 basis points and you receive a message in Period 10 that "The interest rate will stay unchanged for 3 periods".

- This means that the interest rate in Periods 10, 11, and 12 will all equal 40. In Period 13, the interest rate will change.
- In Period 11 you will receive a message "The interest rate will stay unchanged for 2 periods."
- In Period 12 you will receive a message "The interest rate will change in the next period."
- In Period 13 you will receive a message "The interest rate will change this period."

ALL TREATMENTS:

- As you will submit forecasts for the household's excess spending, the firm's price change, and the central bank's interest rate in the *subsequent* period, you will need to take into consideration the *subsequent* period's median household and firm decisions, shocks, as well as your own and other forecasters' *subsequent* forecasts about the household and firm's decisions.

Your score

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

$$\text{Absolute Forecast Error}_t = |\text{Your Forecast}_t\text{-Actual Value}_{t+1}|$$

$$\begin{aligned}\text{Total Score}_t = \; & 0.33(2^{-0.01(\text{Absolute forecast error for interest rate}_{t+1})}) \\ & + 0.33(2^{-0.01(\text{Absolute forecast error for your household's excess spending}_{t+1})}) \\ & + 0.33(2^{-0.01(\text{Absolute forecast error for your firm's price change}_{t+1})})\end{aligned}$$

The maximum score you can earn each period is 1. Your score will decrease as your forecast error increases. Suppose your absolute error for each of your three forecasts is:

1. 0 : Your score will be 1
2. 50: Your score will be 0.71
3. 100: Your score will be 0.5
4. 200: Your score will be 0.25
5. 300: Your score will be 0.125
6. 500: Your score will be 0.06
7. 1000: Your score will be 0
8. 2000: Your score will be 0

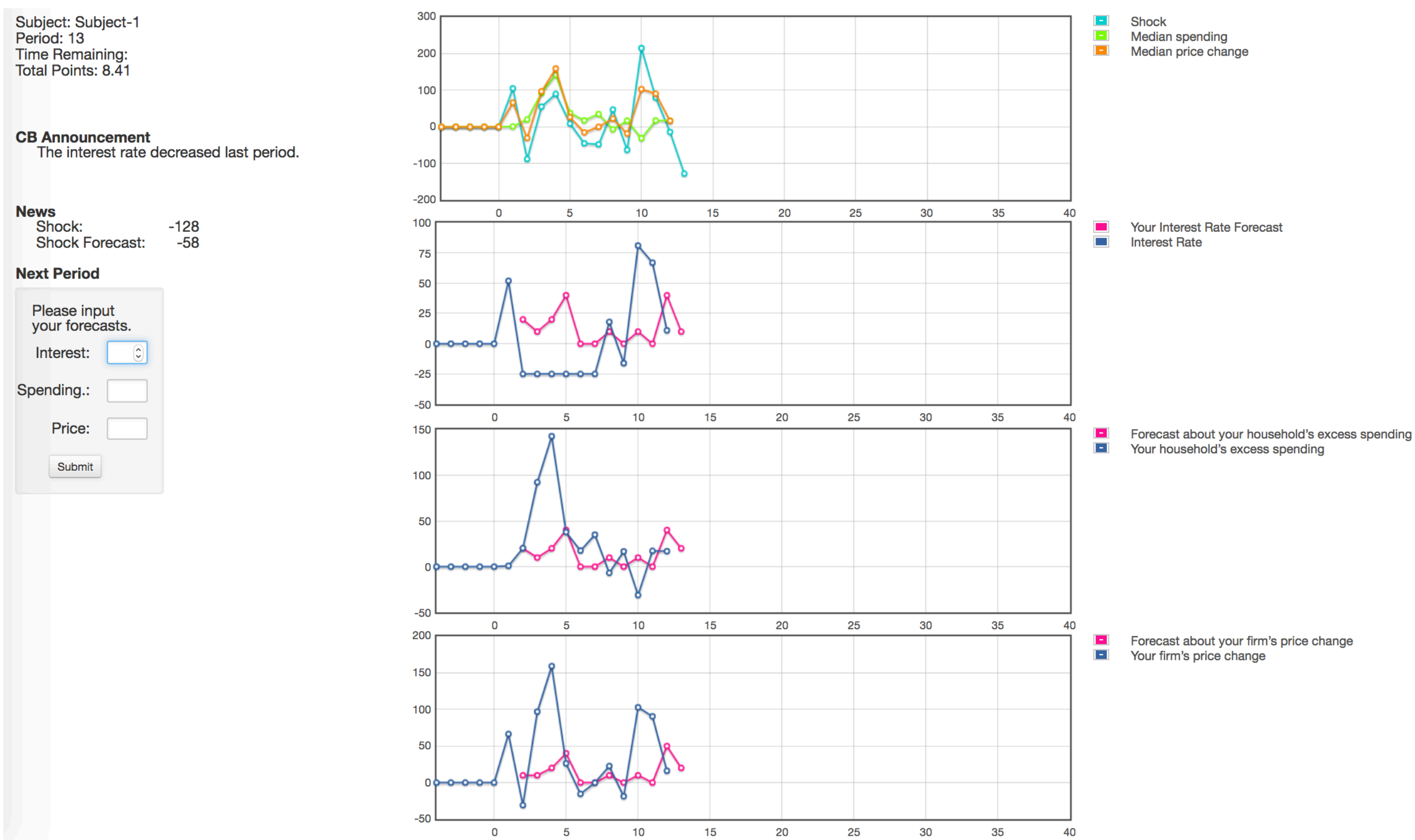
Your score, converted into Canadian dollars, plus the show up fee will be paid to you in cash at the end of the experiment.

B Experimental interface

The experiment was programmed in Redwood, an open-source software (Pettit, Hewitt, and Oprea, 2014). Throughout the experiment, subjects observe a single screen that contains various pieces of information. Figure B.1 shows a sample screenshot of participants' interface in the COM-BACK treatment. The right-hand side of the screen presents four panels of historical time series. The top history plot displays the observed history of demand shocks to the economy, and histories of aggregate household spending and aggregate firm price. The second plot displays past interest rates and the subject's individual interest-rate forecasts. The third plot shows the history of the subject's spending forecasts and the associated household spending. The fourth plot displays the subject's past price forecasts and associated price outcomes. Subjects were able to toggle over any point in the time series to observe the precise value. The vertical difference between their forecasts and the actual levels constituted the subject's forecast error.

At the top left of the screen, subjects observe their subject identification number, the current period, time remaining and the total number of points earned. Depending on the treatment, participants receive a "CB Announcement" in the form of a qualitative description about the past, current, or future nominal interest rate. Below, they receive "News" about the current shock to the economy and its expected future value. Under "Next Period," subjects enter their forecasts for the subsequent interest rate, their assigned household's spending, and their assigned firm's price change. Forecasts are submitted in basis points and rounded to the integer. After inputting their forecasts and pressing the SUBMIT button, participants need to wait until the other forecasters submit their expectations or until time runs out. While they wait, subjects continue to observe the same information. Instructions were kept at subjects' terminals for the duration of the experiment. Subjects were allowed to use a calculator and take notes.

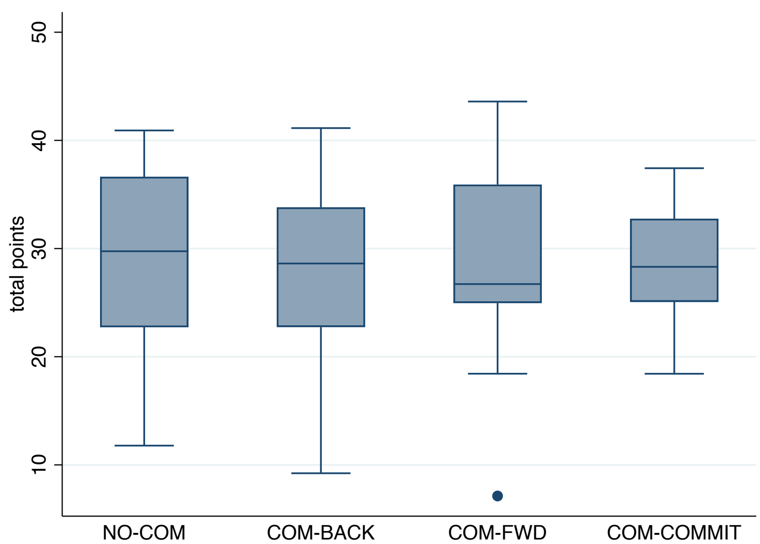
Figure B.1: Experimental interface



C Payoffs

Figure C.1 presents the distribution of final points by treatment. Total points range from 7.1 to 43.6, where the maximum that could be earned was 69. Median points are 26.7 in COM-FWD, 28.3 in COM-COMMIT, 28.6 in COM-BACK, and 29.7 in NO-COM. While we observe considerably lower total points in NO-COM and COM-BACK, the session-medians are not significantly different across treatments (Wilcoxon rank sum test, $N = 8$ per treatment, $p > 0.4$ in all cases). At other percentiles (15, 25, 50, 75, 85), the session-level differences remain statistically insignificant.

Figure C.1: Total points earned by treatment



Notes. This figure presents the distribution of final points earned by treatment. The box spans the quartile range and the whiskers extend to the highest and lowest observations. The horizontal line inside the box denotes the median observation. Values outside 1.5 times the interquartile range are indicated as dots.

D Calibration of model parameters

All data are at a quarterly frequency, spanning the inflation targeting period in Canada, from 1993Q1 to 2017Q4. The output gap and all trends are calculated by the Bank of Canada, and are available at https://www.bankofcanada.ca/rates/indicators/capacity-and-inflation-pressures/product-market-definitions/product-market-historical-data/. Inflation is based on Statistics Canada's v41690914 series: "Consumer price index (CPI) seasonally adjusted 2005 basket - Canada; All-items." Inflation deviations are computed relative to the Bank of Canada inflation-control target. The nominal interest rate is based on the Bank of Canada's v39078 series "Bank rate." The standard deviation of inflation is 0.54 per cent. Standard deviation of the output gap is 1.13 per cent, or 2.1 times the standard deviation of inflation. Standard deviations of the nominal interest rate and inflation are about the same of this period. The fraction of quarters with non-zero quarterly change in nominal interest rate is 0.56, which pins down the frequency of monetary policy action ι in the model. The persistence of the output gap in the data, 0.92, is much higher than the inflation persistence, 0.09. Since the model does not include mechanisms to account for differences in the persistence of inflation and the output gap, it predicts virtually the same persistence for the output gap and inflation. We therefore calibrate the model to match the persistence of inflation to 0.4, which is at the midpoint between inflation and output-gap persistence in the data. It is also close to inflation persistence over the longer historical time period, 1973:3-2017:4.

In the end, four model parameters (standard deviation and the serial correlation of the demand shock process, ρ_r and σ_r, the degree of real rigidities, ζ, and Taylor rule inflation parameter, ϕ_π), are jointly calibrated so that the model with adaptive expectations matches the following four calibration targets: standard deviation and the serial correlation of inflation deviations, 0.54 per cent and 0.4, the ratio of standard deviations of the output gap and inflation, 2.1, and the ratio of standard deviations of the nominal interest rate and inflation, 1. The adaptive expectations are such that forecast $E_{it}\left(X_{it+1}\right)$ at t of variable X_{it+1} :

$$E_{it}\left(X_{it+1}\right) = a_1 E_{it-2}\left(X_{it-1}\right) + a_1\left[X_{it-1} - E_{it-2}\left(X_{it-1}\right)\right]$$

We fix the Taylor rule output gap coefficient at $\phi_y = \phi_\pi/20$, which is consistent with the Taylor rule used by the Bank of Canada projection model, ToTEM II: https://www.banqueducanada.ca/wp-content/uploads/2013/10/technical_report_100.pdf. Table D.1 summarizes the calibrated parameters and calibration targets.

Table D.1: Parameters

A. Calibrated Parameters

σ_r	st dev of r^n_t innovations, %	1.20
ρ_r	ser corr of r^n_t	0.45
ζ	degree of real rigidities	0.80
ϕ_π	Taylor-rule coef, inflation	1.4

B. Targets

	Data	Model
st dev of π_t, %	0.54	0.54
ser corr of π_t	0.40	0.40
$std(x_t)/std(\pi_t)$	2.1	2.1
$std(i_t)/std(\pi_t)$	1.0	1.0

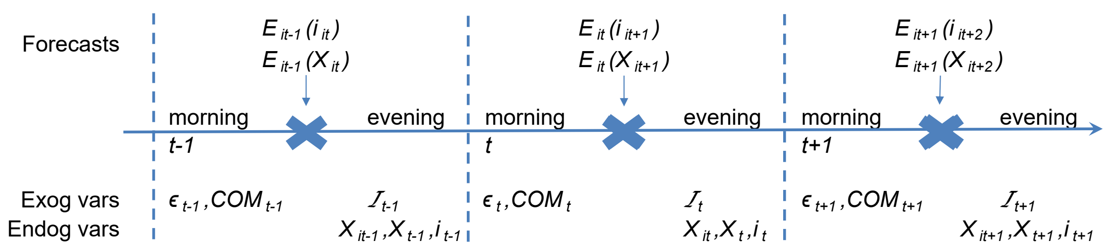
C. Assigned Parameters

	period	1 quarter
β	discount factor	$0.96^{1/4}$
σ	risk aversion	1
$1-\alpha$	prob of price changes	0.49
ϕ_x	Taylor-rule coef, output gap	$\phi_\pi/20 = 0.07$
ι	Fraction of periods with $i_t \neq 0$	0.56

E Timing of events in the experiments

Figure E.1 provides the timing of events in the experimental framework. Each period is divided in two sub-periods: before the forecasting decision ("morning") and after ("evening"). In the morning of period t, subject i observes realization of the demand impulse ϵ_t, central bank communication, if any, COM_t, realizations of monetary policy inaction in the evening of period $t-1$, $\mathcal{I}_{t-1}$, inflation and output in period $t-1$, denoted by X_{t-1}, associated nominal interest rate i_{t-1}, and individual price and expenditure variables, denoted by X_{it-1}. Subject i then submits her subjective forecasts for price and expenditure in period $t+1$, $E_{it}(X_{it+1})$, and interest rate in period $t+1$, $E_{it}(i_{t+1})$. After all forecasts are submitted, i.e., in the evening of period t, monetary policy inaction in period t is realized, $\mathcal{I}_t$, and output, inflation, and interest rate in period t are determined, using equations (1)–(5) in the text.

Figure E.1: Timing in the experiments



F Construction of impulse responses

The empirical law of motion for forecast $E_{it}X_{it+1}$ in the control experiment is estimated with equation (6) in the main text:

$$\begin{aligned} E_{it}X_{it+1} &= c_0 + c_{01}\mathcal{I}_{t-1} + (c_1 + c_{11}\mathcal{I}_{t-1})\, E_{it-1}X_{it} + (c_2 + c_{21}\mathcal{I}_{t-1})\, E_{it-2}X_{it-1} \\ &+ (c_3 + c_{31}\mathcal{I}_{t-1})\,\epsilon_t + (c_4 + c_{41}\mathcal{I}_{t-1})\,\epsilon_{t-1} + (c_5 + c_{51}\mathcal{I}_{t-1})\, r^n_{t-2} + \delta D_s + error_{it} \end{aligned} \tag{F.1}$$

where ϵ_t, ϵ_{t-1} are shock innovations, r^n_{t-2} is shock value at $t-2$, and D_s are session dummies. Variable $\mathcal{I}_{t-1}$ is the indicator of whether policy acted last period. It is equal to the realization of the i.i.d. Poisson random variable taking on values of 0 with arrival rate $1-\rho_i$, and 1 with probability ρ_i. Information on period t policy action $\mathcal{I}_t$ is not reflected on the value of $E_{it}X_{it+1}$.

The law of motion for variable X_{it} that is measurable with respect to information through the evening of period t is

$$\begin{aligned} X_{it} &= c_0 + c_{01}\mathcal{I}_t + (c_1 + c_{11}\mathcal{I}_t)\, X_{it-1} + (c_2 + c_{21}\mathcal{I}_t)\, X_{it-2} \\ &+ (c_3 + c_{31}\mathcal{I}_t)\,\epsilon_t + (c_4 + c_{41}\mathcal{I}_t)\,\epsilon_{t-1} + (c_5 + c_{51}\mathcal{I}_t)\, r^n_{t-2} + \delta D_s + error_{it} \end{aligned} \tag{F.2}$$

where the only change relative to (F.1) is that $\mathcal{I}_{t-1}$ is replaced with $\mathcal{I}_t$ to reflect the fact that period t policy action $\mathcal{I}_t$ is reflected in the value of X_{it}. We construct impulse responses for deviations of $E_{it}X_{it+1}$ and X_{it} (and aggregates X_t) from their respective estimated session-specific means $\hat{c}_0 + \hat{\delta}D_s$ (hats denote the estimated values).

Monetary policy surprises are associated with realization of monetary policy action or inaction in each period. Let $E^0_{it}(\cdot)$ denote expected value with respect to information available through the morning of period t. Monetary policy surprise in period t is defined as $\Delta\mathcal{I}_t = \mathcal{I}_t - E^0_{it}(\mathcal{I}_t) = \mathcal{I}_t - \rho_i$. Since $\mathcal{I}_t$ are i.i.d., monetary policy surprises are uncorrelated with ϵ_t at all leads and lags. Applying $E^0_{it}(\cdot)$ to the estimated law of motion (F.2) for deviation X_{it} gives (ignoring constant terms)

$$\begin{aligned} E^0_{it}(X_{it}) &= c_{01}\rho_i + (\hat{c}_1 + \hat{c}_{11}\rho_i)\, X_{it-1} + (\hat{c}_2 + \hat{c}_{21}\rho_i)\, X_{it-2} \\ &+ (\hat{c}_3 + \hat{c}_{31}\rho_i)\,\epsilon_t + (\hat{c}_4 + \hat{c}_{41}\rho_i)\,\epsilon_{t-1} + (\hat{c}_5 + \hat{c}_{51}\rho_i)\, r^n_{t-2} \end{aligned} \tag{F.3}$$

The conditional variation of X_{it} is

$$X_{it} - E^0_{it}(X_{it}) = \Delta\mathcal{I}_t \cdot \left[\hat{c}_{01} + \hat{c}_{11}X'_{t-1} + \hat{c}_{21}X'_{t-2} + \hat{c}_{31}\epsilon_t + \hat{c}_{41}\epsilon_{t-1} + \hat{c}_{51}r^n_{t-2}\right] \tag{F.4}$$

where $\Delta\mathcal{I}_t = \mathcal{I}_t - \rho_i$ is monetary policy surprise in period t. By construction, $X_{it} - E^0_{it}(X_{it})$ is variation in X_{it} due to $\Delta\mathcal{I}_t$. In general, IRFs for monetary surprises depend on the endogenous response of the economy to past demand shocks. This response is given by the factor in square brackets.

To construct impulse responses, let $\tau = 0, 1, ...$ denote period since the shock, with 0 corresponding to the period of the shock. Denote by $X^r_{i\tau}$ and $X^i_{i\tau}$ impulse responses of X_{it} deviations to demand and monetary shocks respectively. Initialize variables: $X^r_{i,-1} = X^r_{i,-2} = 0$, $\epsilon_{-1} = 0$, and $r^n_{-1} = r^n_{-2} = 0$.

Responses to a demand impulse $\epsilon_0 = 1$, $\epsilon_\tau = 0$, $\tau = 1, 2, ...$ are given by equation F.3:

$$\begin{aligned} X^r_{i\tau} &= (\hat{c}_1 + \hat{c}_{11}\rho_i)\, X^r_{i\tau-1} + (\hat{c}_2 + \hat{c}_{21}\rho_i)\, X^r_{i\tau-2} \\ &+ (\hat{c}_3 + \hat{c}_{31}\rho_i)\, \epsilon_\tau + (\hat{c}_4 + \hat{c}_{41}\rho_i)\, \epsilon_{\tau-1} + (\hat{c}_5 + \hat{c}_{51}\rho_i)\, r^n_{\tau-2},\ \tau = 0, 1, 2, ... \end{aligned}$$

where $r^n_\tau = \rho_r r^n_{\tau-1} + \epsilon_\tau$.

The contemporaneous response of X_{it} to a monetary policy surprise $\Delta\mathcal{I}_t$ is given by equation F.4. To control for the history leading up to the monetary surprise, we normalize these IRFs with the same history we used for IRFs to the demand impulse: $\epsilon_0 = 1$, $\epsilon_\tau = 0$, $\tau = 1, 2, ...$, which gives us $X^i_{i,0} = \rho_i \hat{c}_{31}$, $X^i_{i,-1} = X^i_{i,-2} = 0$ for and expansionary monetary surprise. The remaining values of this IRF are given by equation F.3:

$$X^i_{i\tau} = (\hat{c}_1 + \hat{c}_{11}\rho_i)\, X^i_{i\tau-1} + (\hat{c}_2 + \hat{c}_{21}\rho_i)\, X^i_{i\tau-2},\ \tau = 1, 2, ...$$

Intuitively, an IRF for an expansionary monetary surprise provides the additional response to a positive demand impulse that is due to a monetary policy inaction in the period of the impulse.

Similarly, we construct IRFs for aggregate variablesX_t. Demand shock IRFs are given by

$$\begin{aligned} X^r_{\tau} &= (\hat{c}_1 + \hat{c}_{11}\rho_i)\, X^r_{\tau-1} + (\hat{c}_2 + \hat{c}_{21}\rho_i)\, X^r_{\tau-2} \\ &+ (\hat{c}_3 + \hat{c}_{31}\rho_i)\, \epsilon_\tau + (\hat{c}_4 + \hat{c}_{41}\rho_i)\, \epsilon_{\tau-1} + (\hat{c}_5 + \hat{c}_{51}\rho_i)\, r^n_{\tau-2},\ \tau = 0, 1, 2, ... \end{aligned}$$

where hatted coefficients are estimated for specification F.1.

And monetary surprise IRF is given by $X^i_1 = \rho_i \hat{c}_{31}$, $X^i_0 = X^i_{-1} = 0$

$$X^i_{\tau} = (\hat{c}_1 + \hat{c}_{11}\rho_i)\, X^i_{\tau-1} + (\hat{c}_2 + \hat{c}_{21}\rho_i)\, X^i_{\tau-2},\ \tau = 2, 3...$$

G Accounting for countercyclical responses of monetary policy

The treatment effects on output and inflation are smaller than they would have been had interest rates not adjusted countercyclically, as prescribed by the Taylor rule. Indeed, in all experiments, interest rate increase is smaller after the demand shock in line with smaller output and inflation responses. For example, the COM-BACK treatment effect on interest rate response after ten periods is –118 bps, or two-thirds of the +172 bps response. To assess the full magnitude of communication effects on output and inflation, we estimate their counterfactual impulse responses by forcing treatment effect on interest rate to be zero. Effectively, we compensate the responses of the interest rate in COM treatments so that they exactly match the responses in the control experiment. The resulting additional responses in inflation and output depend on their respective elasticities with respect to exogenous interest rate variations. We approximate these elasticities using inflation and output responses in the control experiment.

Counterfactual responses are constructed as follows. Let $\pi_\tau^{*r}(k)$ and $\pi_\tau^{r}(k)$ ($\pi_\tau^{*i}(k)$ and $\pi_\tau^{i}(k)$) denote estimated inflation cumulative responses to the demand shock (monetary surprise) at horizon τ in control and treatment respectively; k denotes bootstrap simulation. Counterfactual inflation response$\pi_\tau^{+r}(k)$ is based on the factual response $\pi_\tau^{r}(k)$ and an additional response caused by the effect of counterfactual interest rate difference $i_\tau^{r}(k) - i_\tau^{*r}(k)$ on inflation. This additional effect is given by $\left(\frac{\partial\pi}{\partial i}(k)\right)_\tau (i_\tau^{r}(k) - i_\tau^{*r}(k))$, where $\left(\frac{\partial\pi}{\partial i}(k)\right)_\tau$ is the elasticity of inflation with respect to exogenous variations in interest rate at horizon τ. We approximate this elasticity by the elasticity of inflation response at horizon τ to a monetary surprise in the control experiment: $\left(\frac{\partial\pi}{\partial i}(k)\right)_\tau \approx \frac{\pi_\tau^{*i}(k)}{i_\tau^{*i}(k)}$. Hence, $\pi_\tau^{+r}(k) \approx \pi_\tau^{*r}(k) - \frac{\pi_\tau^{*i}(k)}{i_\tau^{*i}(k)} (i_\tau^{r}(k) - i_\tau^{*r}(k))$. Counterfactual effects for output are computed similarly.

H Aggregate dynamics in experimental sessions

Figures H.1–H.8 provide aggregate time series recorded in a particular session, across control and treatments. Row 1: Control experiment, Row 2: COM-BACK treatment, Row3: COM-FWD treatment, Row 4: COM-COMMIT treatment. Shaded areas mark explosive episodes defined as periods for which the absolute value of inflation or interest rate exceeds 10 times the standard deviation of the shock, or the absolute value of output gap exceeds 20 standard deviations of the shock.

Figure H.1: Session 1

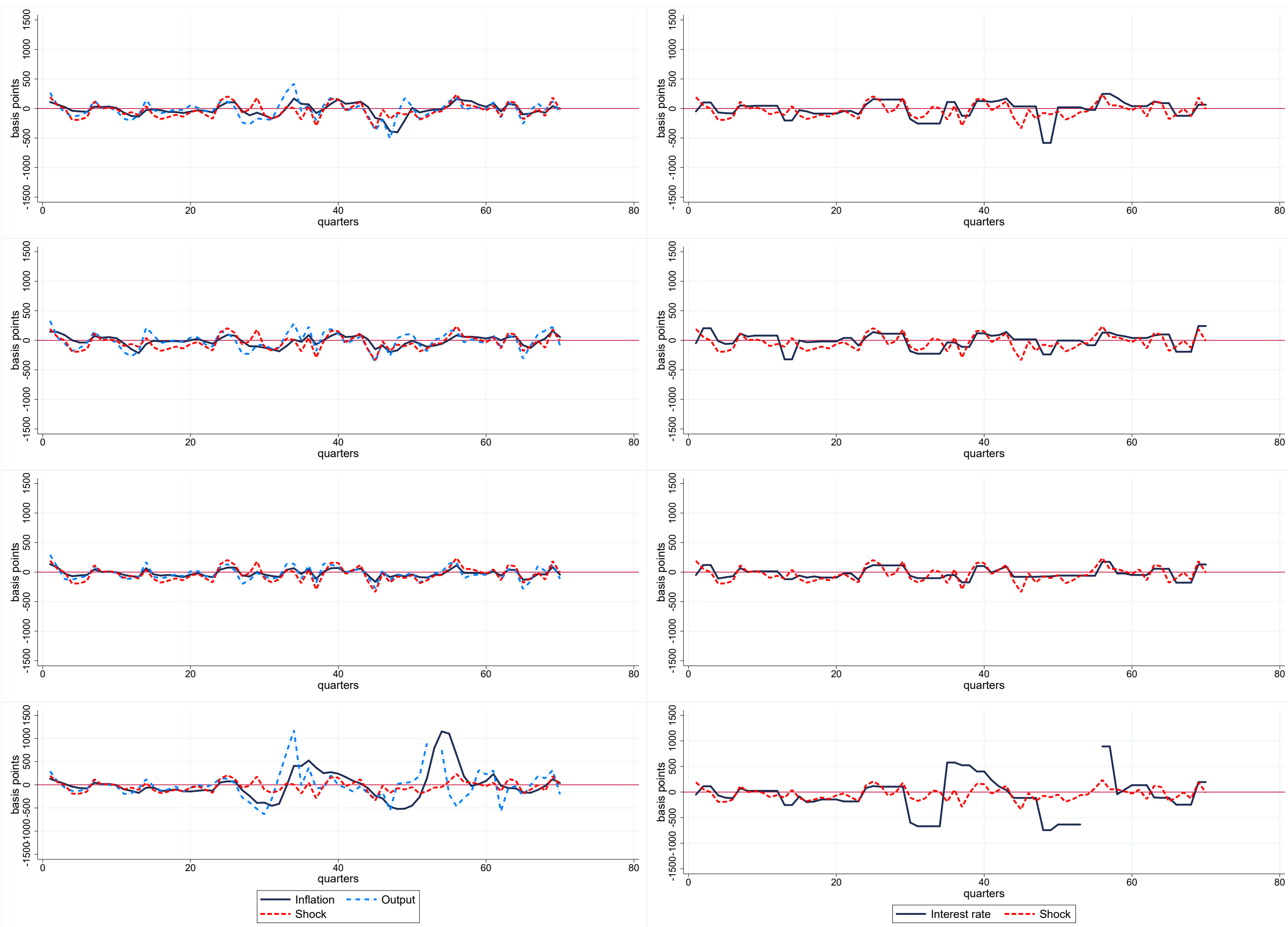


Figure H.2: Session 2

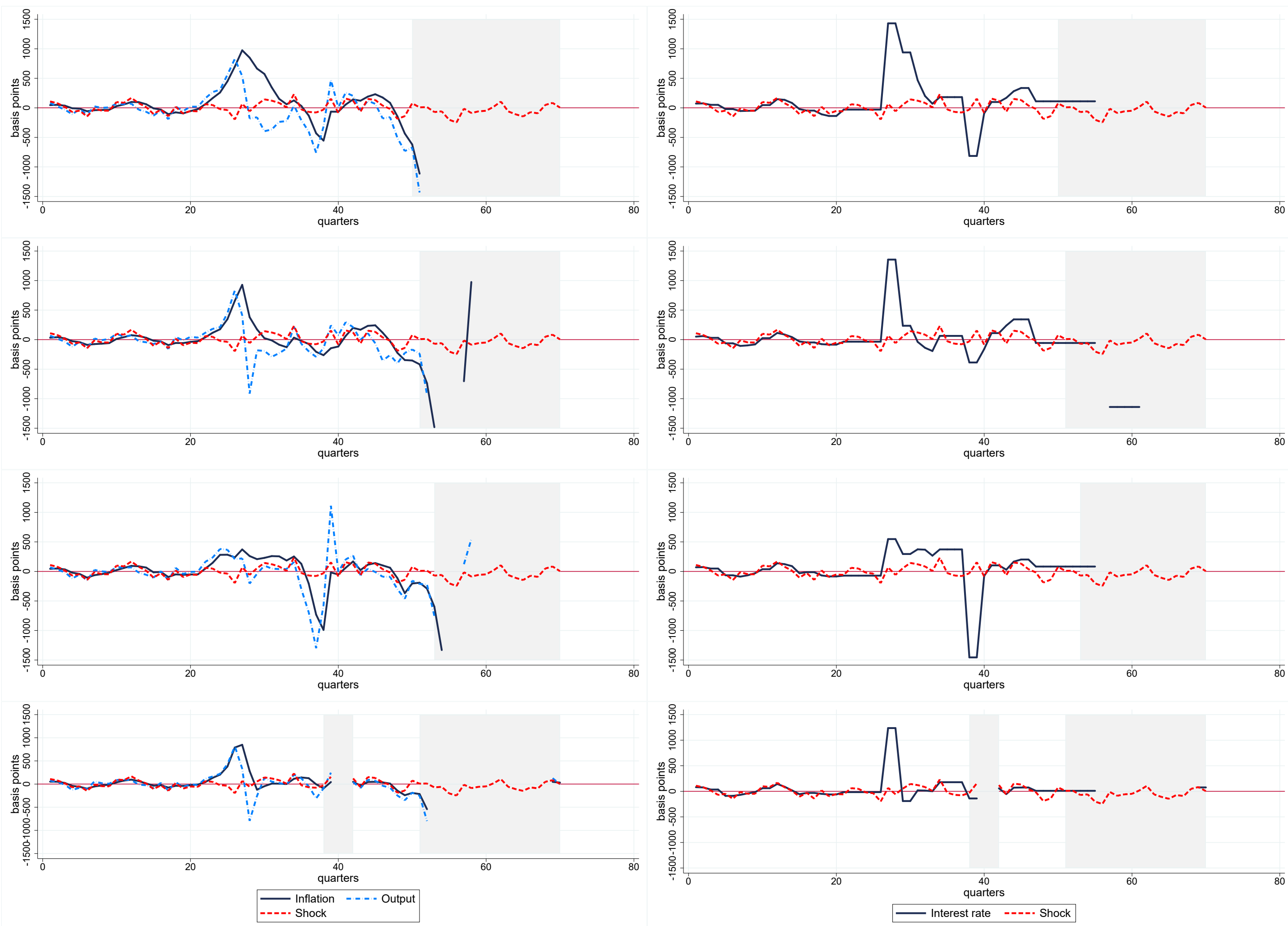


Figure H.3: Session 3

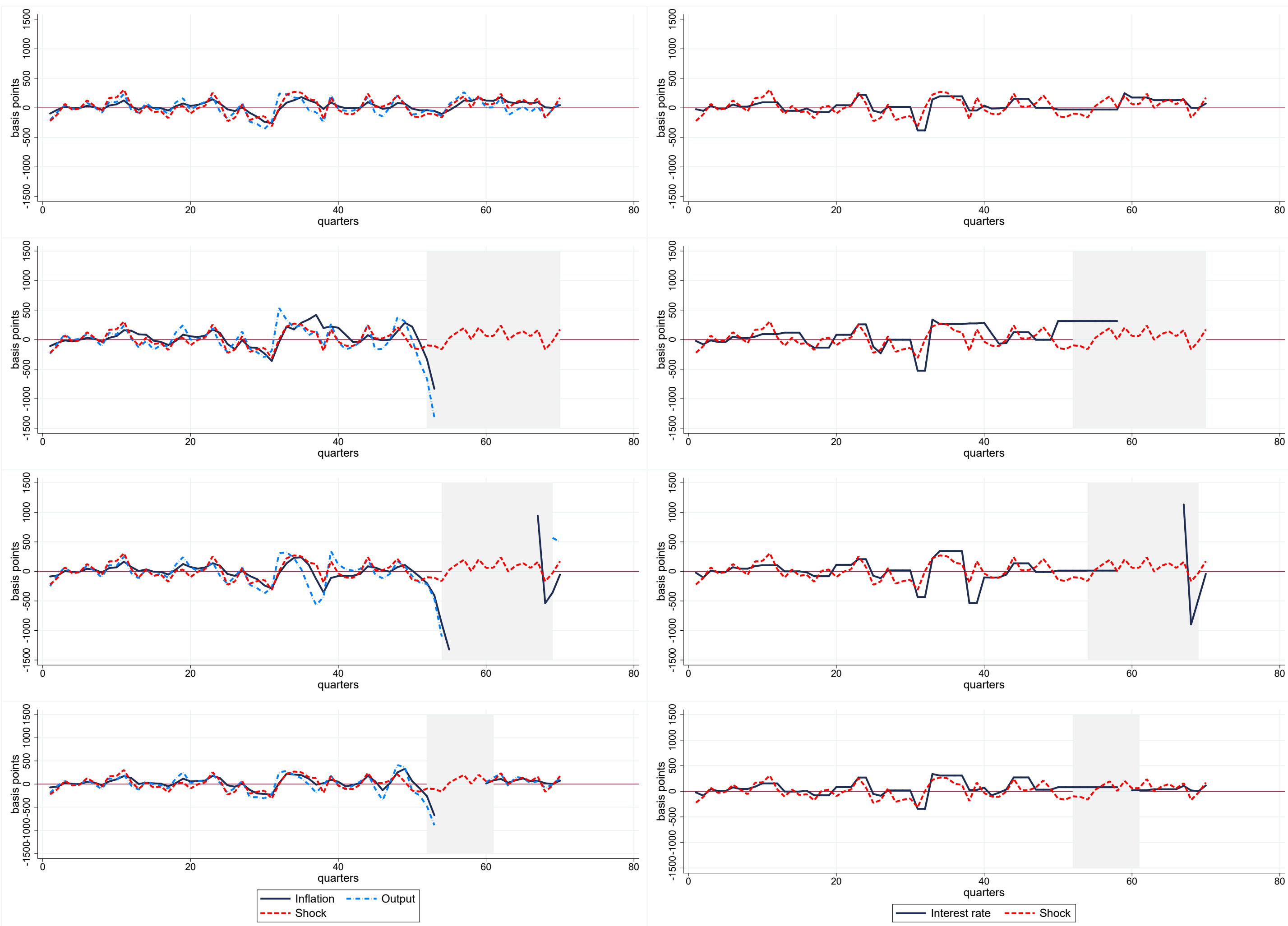


Figure H.4: Session 4

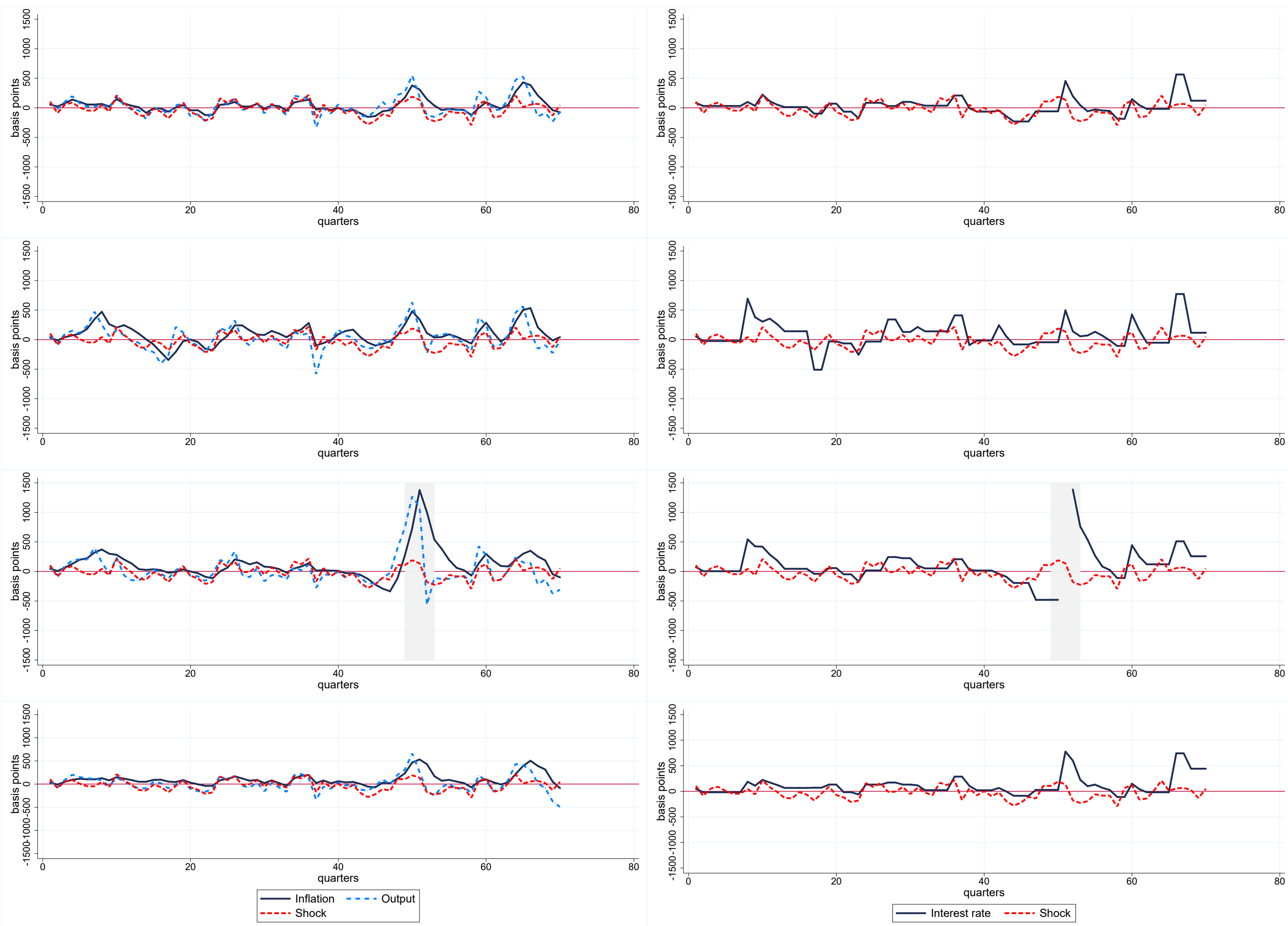


Figure H.5: Session 5

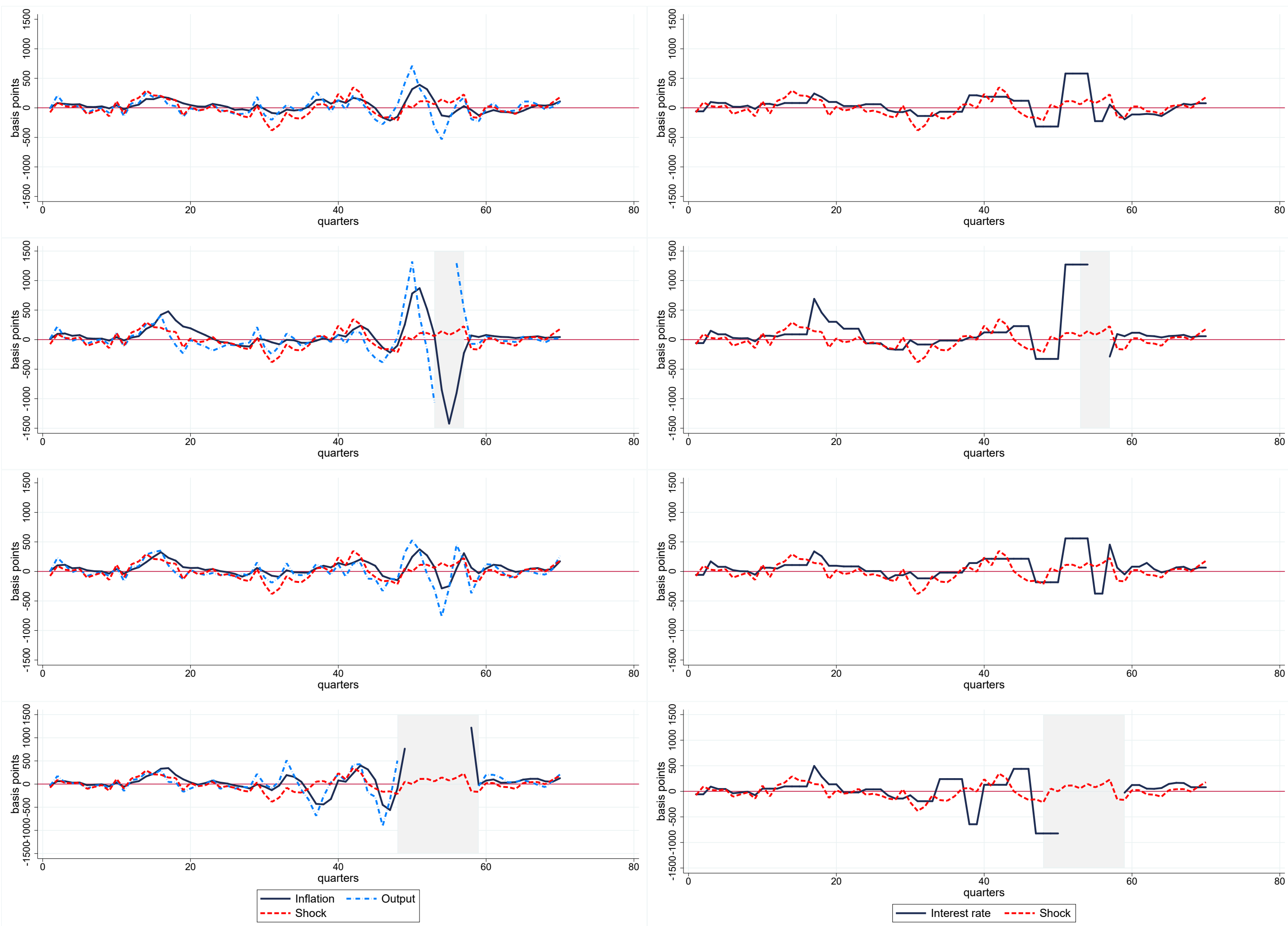


Figure H.6: Session 6

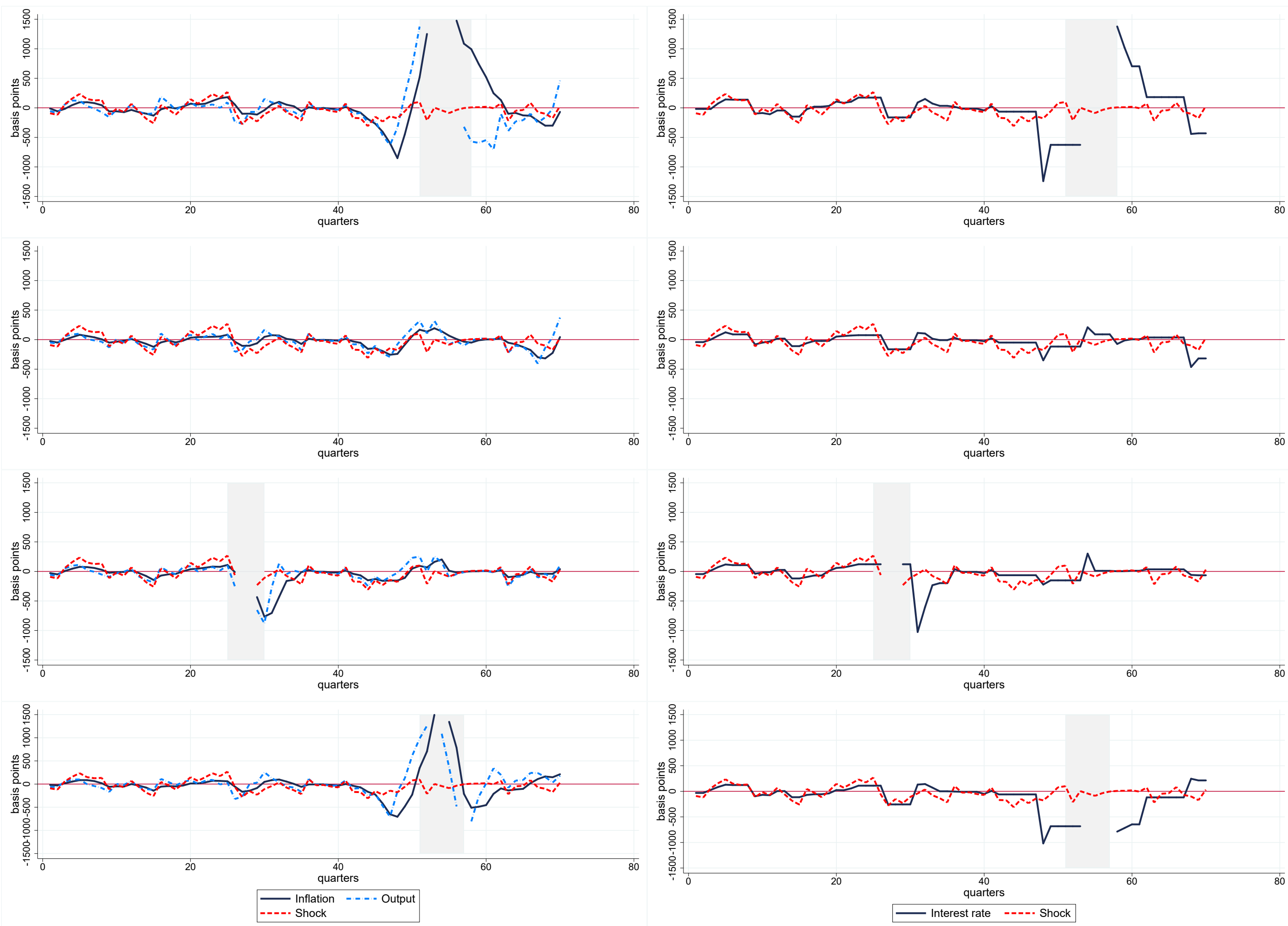


Figure H.7: Session 7

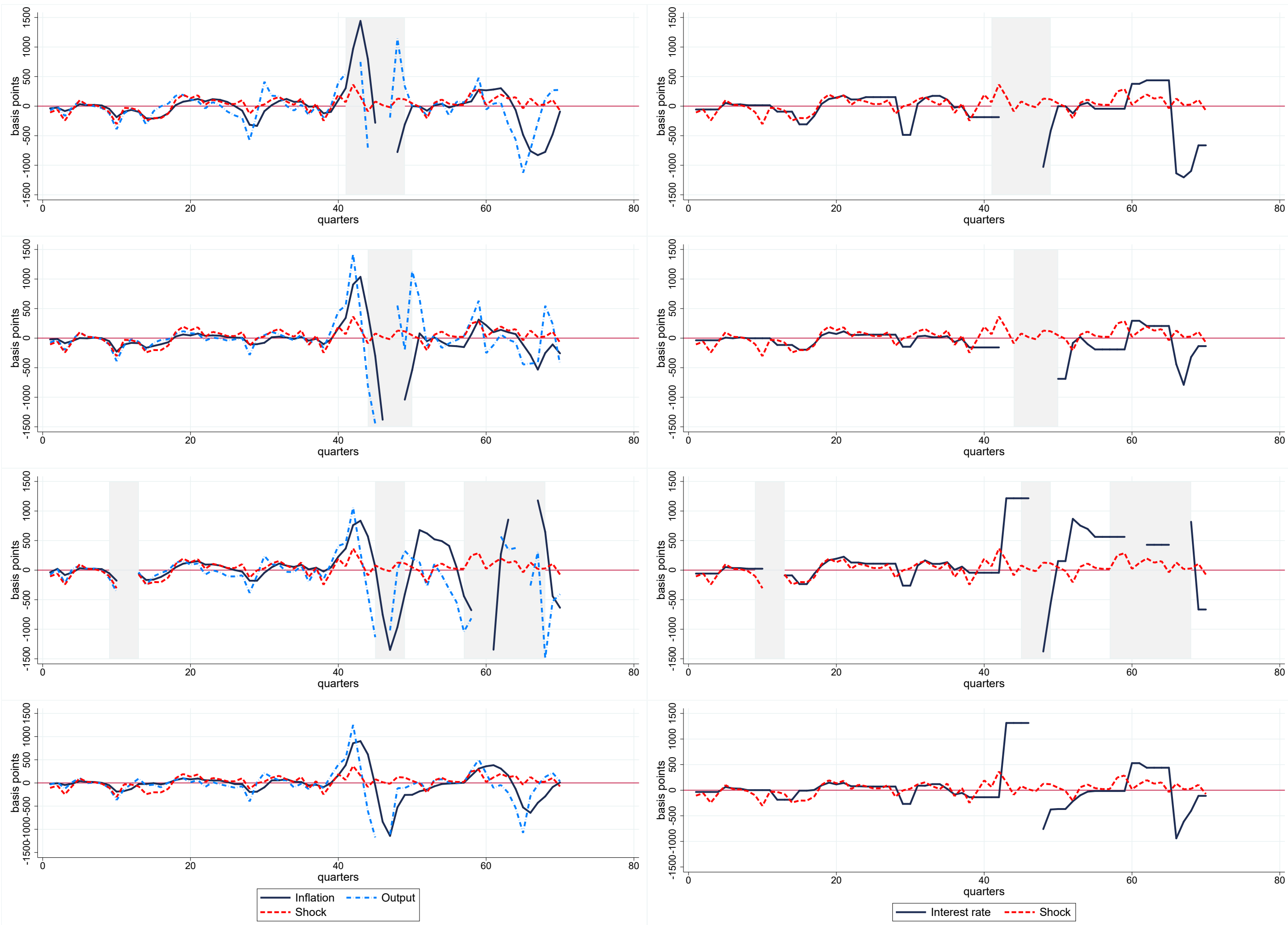
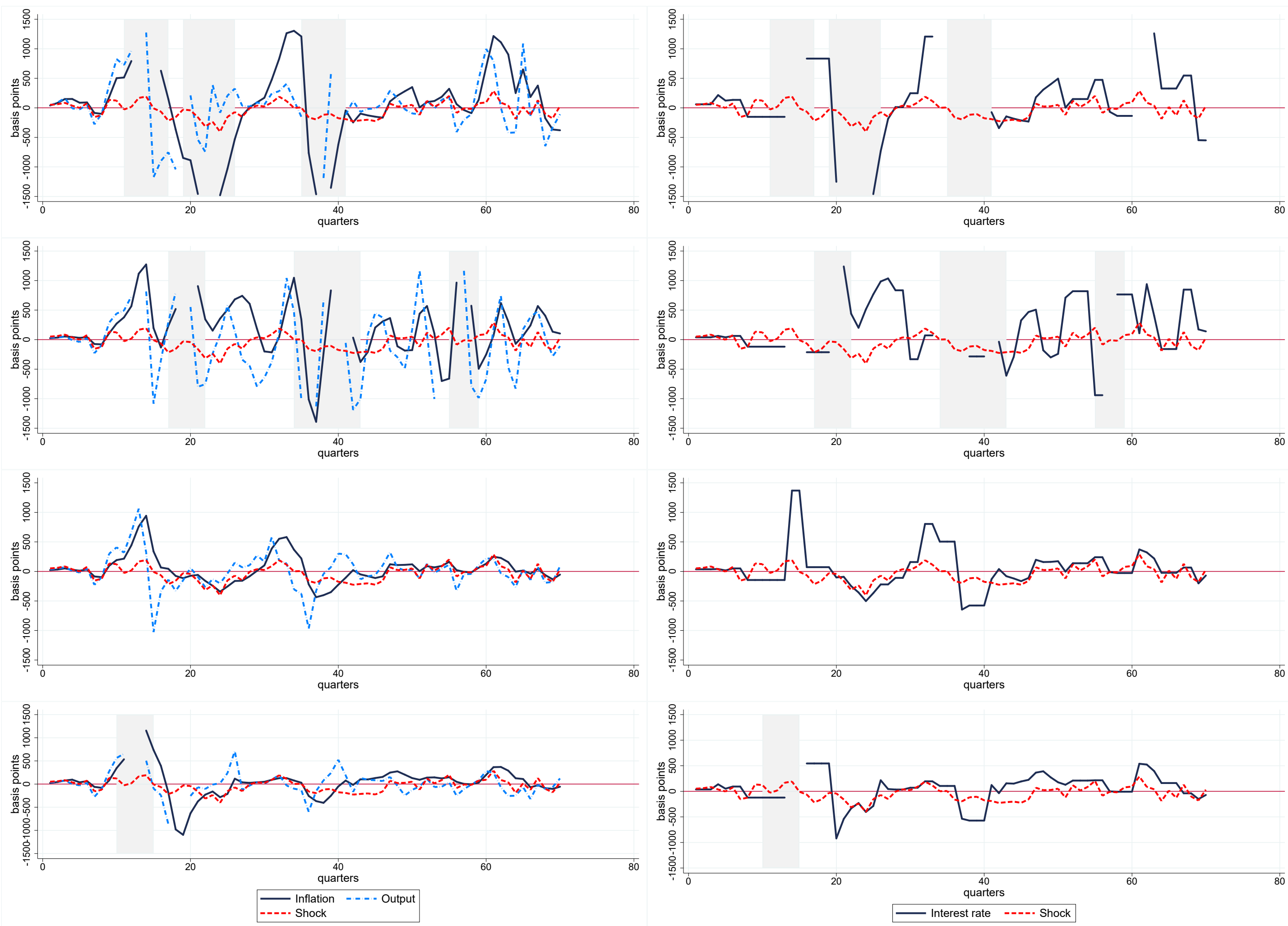


Figure H.8: Session 8



I Explosive episodes

Most sessions experience at least one event of extreme inflation and output. We denote an economy is in an "explosive episode" when either the output gap or inflation exceed 2688 bps or 1344 bps in magnitude. Such events are relatively rare, occurring in 6.4–7.6% of periods across four treatments, with no discernible difference in likelihood across treatments. The duration of explosive episodes ranges from 1 to 19 periods, with the median event lasting between 2 and 4.5 periods. Out of 27 episodes across all treatments, 24 ended before the end of the session. We find that duration of explosive episodes is positively correlated with the length of central bank inaction (Spearman's $\rho = 0.48$, $p = 0.011$) . The effect is especially pronounced in COM-BACK ($\rho = 0.75, p = 0.02$) and COM-FWD ($\rho = 0.71$, $p = 0.11$).[1]

We conduct a series of random-effect probit regressions to evaluate the determinants of explosive episodes. We consider the possibility that larger shocks, the number of periods since the last central bank action and the horizon of continued inaction contribute to increased likelihood of explosive episodes. We also add a dummy flagging an explosive episode in the previous period and a control for the cumulative number of periods in explosive episodes.

Across all treatments, the probability of an explosive episode is largely history-dependent (see Table I.1). Having been in an explosive episode in the previous period is the most quantitatively important factor affecting the likelihood of a current episode. Likewise, having spent more periods in explosive episodes leads to a significantly higher probability of experiencing another episode in the BACK and FWD treatments. Importantly, fundamentals in the form of demand shocks do not appear to be an important factor. In fact, larger demand shocks are associated with a lower likelihood of instability in COM-COMMIT.

More striking is the large role that monetary policy inaction plays in fueling inflationary expectations and increasing the likelihood of explosive events. The estimated coefficient on $NumPeriodsInactive_{t-1}$ ranges from 0.435 in the Control to 0.523 in COM-COMMIT, and is statistically significant at the 0.1% level. The announcement of a lengthy interest rate peg has been shown to generate explosive inflationary paths (Carlstrom, Fuerst, and Paustian, 2015). We find mixed evidence in COM-COMMIT to support the hypothesis that a longer forward guidance horizon increases the probability of being in an explosive episode. While the estimated coefficient on $F.G.Horizon_t$ is large (0.15), it is not statistically significant. Rather, COMMIT economies are more sensitive to the duration of concurrent inaction. This observation reinforces our earlier results that subjects are predominantly backward-looking, even in COM-COMMIT treatment.

Explosive episodes can arise when forecasts are very sensitive to changes in the economy or in response to individual specific variables, which is consistent with theories of diagnostic expectations (Gennaioli, Shleifer, and Vishny, 2015; Bordalo, Gennaioli, and Shleifer, 2018). Arifovic and Petersen (2017) find that forward guidance in the form of increased inflation

[1]Explosive inflation episodes occur both in OECD and non-OECD countries (2.2% and 1.8% of inflation observations, respectively, since 1950).

Table I.1: Explosive episodes

	Control	COM-BACK	COM-FWD	COM-COMMIT
$Pr(ExplosiveEpisode_t = 1 \mid X)$				
$ExplosiveEpisode_{t-1}$	2.910***	2.256***	2.719***	3.320***
	(0.40)	(0.41)	(0.52)	(0.58)
$\lvert r_t^n \rvert$	0.000	-0.003	0.001	-0.008**
	(0.00)	(0.00)	(0.00)	(0.00)
$NumPeriodsInactive_{t-1}$	0.435***	0.520***	0.508***	0.523***
	(0.12)	(0.12)	(0.13)	(0.15)
$CumulativeEpisodes_{t-1}$	0.004	0.017**	0.021**	0.003
	(0.01)	(0.01)	(0.01)	(0.01)
$F.G.Horizon_t$				0.150
				(0.13)
α	-7.174	-7.074	-7.794	-7.646
	(1449.28)	(1203.72)	(3632.83)	(6466.84)
Prop. Explosive Episodes	6.4%	7.7%	6.8%	6.4%
Session Fixed Effects	YES	YES	YES	YES
N	345	414	344	413
χ^2	65.91	69.65	55.19	53.39

Notes. Table presents results from a series of random effects probit regressions. ***, **, * denote significant values at 1%, 5% and 10% confidence levels. $ExplosiveEpisode_t$ is a dummy variable that takes the value of 1 when absolute inflation or output exceed 1345 and 2588 bps, respectively, and 0 otherwise. $|r_t^n|$ is the absolute value of the demand shock, $Inaction_t$ is a dummy variable that takes the value of 1 if the central bank is inactive in period t. $NumPeriodsInactive_{t-1}$ is a count of the number of periods of consecutive inaction up to period t, and $CumulativeEpisodes_{t-1}$ is a count of the number of periods the economy had been in an explosive episode. $F.G.Horizon_t$ is the communicated number of periods of current and future inaction in COM-COMMIT.

targets at the ZLB can in some cases worsen pessimistic expectations and reduce central bank credibility. Consistent with their findings, we observe that *less* communication is a better policy prescription during periods of lengthy inaction. Overall, COM does not appear to significantly reduce the likelihood of explosive episodes.

J Anchoring of expectations

The effectiveness of forward-looking communication is determined to a large degree by participants' perception of the likelihood that the central bank will adhere to its policy pronouncements. We refer to this perception as "anchoring" of expectations. We denote COM-FWD participants as anchoring on the central bank's announcement if they move their interest rate forecast in the same direction as the central bank's projected rate change, respectively. We denote a COM-COMMIT participant as anchoring on the central bank's commitment if she forecasts the observed interest rate to stay unchanged during periods of inaction. Because of the possibility of participants rounding their forecasts in COM-FWD, we denote anchoring as a forecast within 10 bps from the central bank's intended rate. Even in COM-BACK treatment, participants may anchor on announcements of past interest rate changes despite their irrelevance in the determination of future interest rates. Anchoring can either manifest itself as the participant forecasting the previous period's interest rate level or forecasting in the direction of the previous interest rate change.

We conduct a series of random effects probit regressions to evaluate the potential drivers of anchoring during periods of communication in Table J.1. Table presents results from a series of random effects probit regressions. ***, **, * denote significant values at 1%, 5% and 10% confidence levels. Columns (1) and (2) refer to COM-BACK anchoring based on lagged interest rates levels and changes, respectively, while columns (3) and (4) refer to anchoring in COM-FWD and COM-COMMIT. $Anchored_{i,t}$ is a dummy variable that takes the value of 1 if participant i in period t anchored their interest rate forecast on the central bank's announcement. $Period$ indicates the round and $Top3_i$ indicates whether participant i was in the Top3 forecasters of her session. $NumPeriodsInactive_{t-1}$ is a count of the number of periods of consecutive inaction up to and including period $t-1$. $ExplosiveEpisode_t$ is a dummy variable that takes the value of 1 when absolute inflation or output exceed 1345 and 2588 bps, respectively, and 0 otherwise. $F.G.Horizon_t$ is the communicated number of periods of current and future inaction in COM-COMMIT. α is a constant. Session controls included. Periods where there is no communication are excluded. Robust standard errors reported.

Anchoring is very strongly serially correlated in all three COM treatments. Experience has distinctly different effects across treatments. Anchoring declines over time in COM-FWD, from 77% of forecasts anchored in the first half to 68% in the second half of the sessions. By contrast, COM-BACK and COM-COMMIT anchoring improves with experience. In COM-BACK, anchoring on period $t-1$ interest rates increases from 19% to 27%, but there is no change in anchoring on past trends (41% of forecasts in both halves of the sessions). In COM-COMMIT, anchoring increases with experience from 40% to 45% .

Longer periods of recent monetary policy inaction significantly reduce participants' willingness to anchor on the central bank's communication in COM-FWD and COM-COMMIT (there are no announcements during inaction in COM-BACK treatment). With no observed

Table J.1: Anchoring on central bank information

	COM-BACK (1)	COM-BACK (2)	COM-FWD (3)	COM-COMMIT (4)
$P(Anchored_{i,t} = 1 \mid X)$				
$Anchored_{i,t-1}$	0.416***	0.399***	0.502***	2.152***
	(0.09)	(0.09)	(0.09)	(0.17)
$Period_t$	0.006**	0.002	-0.006**	0.004**
	(0.00)	(0.00)	(0.00)	(0.00)
$Top3_i$	0.048	-0.047	0.330**	-0.189
	(0.17)	(0.09)	(0.13)	(0.12)
$ExplosiveEpisode_{t-1}$	-0.130	-0.363**	0.086	-2.280***
	(0.19)	(0.16)	(0.19)	(0.65)
$NumPeriodsInactive_{t-1}$			-0.096***	-0.507***
			(0.03)	(0.05)
$NumPeriodsInactive_{t-1}$			0.024	0.444***
$\times ExplosiveEpisode_{t-1}$			(0.06)	(0.08)
$F.G.Horizon_t$				-0.091***
				(0.03)
$F.G.Horizon_t$				0.519***
$\times ExplosiveEpisode_{t-1}$				(0.18)
α	-1.035***	-0.374***	0.421**	-0.689***
	(0.24)	(0.14)	(0.19)	(0.25)
Perc. Anchoring				
Stable Periods	23.4%	41.3%	73.1%	41.9%
Explosive Episodes	13.3%	31.7%	63.7%	52.8%
N	1482	1482	2576	1182
χ^2	32.36	40.92	94.63	296.6

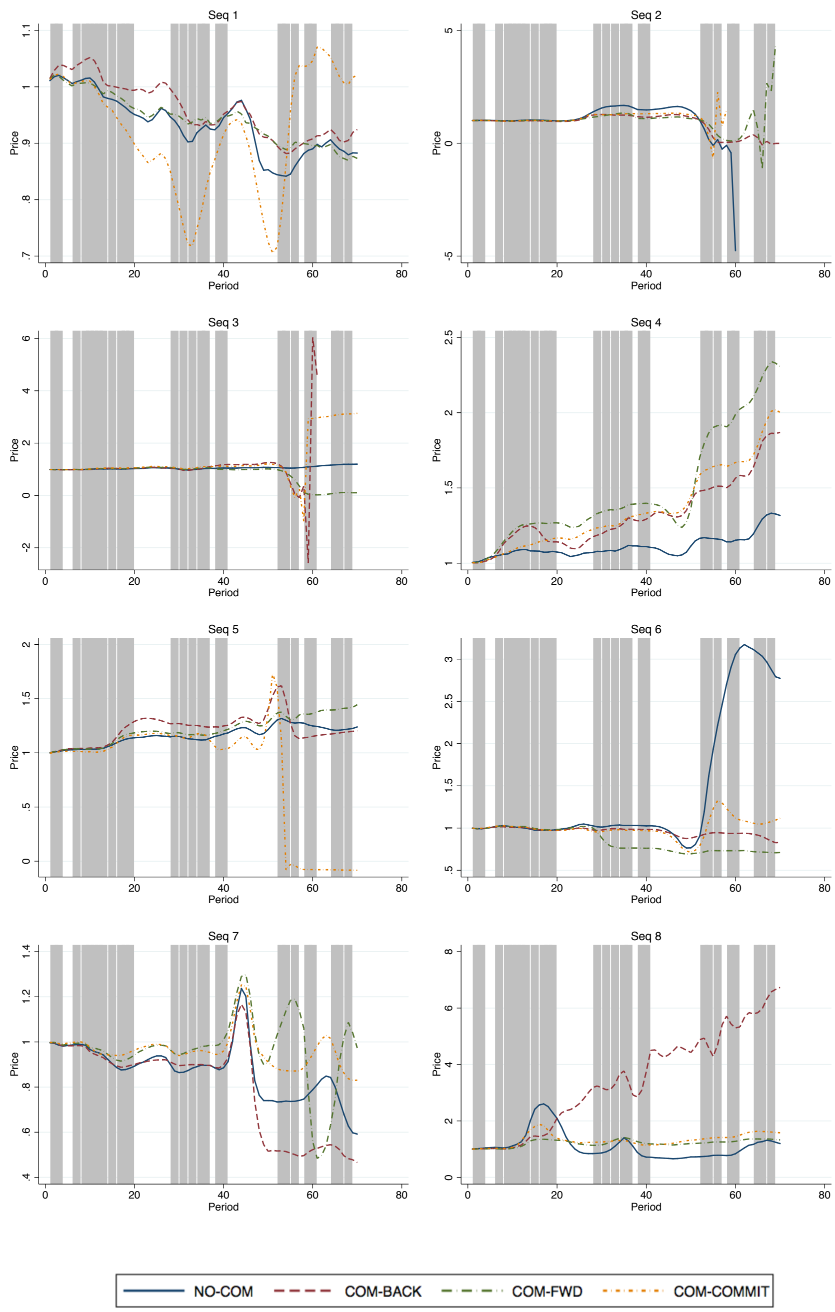
inaction in the previous period, 74% (51%) of COM-FWD (COMMIT) interest rate forecasts adjust in the intended direction. This number declines as observed inaction persists. After five periods of inaction, only 50% (33%) of COM-FWD (COMMIT) participants continue to update in the direction of the Bank's forecast. Explosive episodes tend to be associated with less anchored expectations, although in COM-COMMIT de-anchoring is not as severe as in COM-FWD.

Finally, expectations of the Bottom3 group are anchored as much as for the Top3 participants in COM-BACK treatment, and they are more anchored in COM-COMMIT treatment (46 vs 40%). By contrast, Bottom3 forecasts are less anchored in COM-FWD treatment (67 vs 78% for Top3). Hence, we see evidence of central bank communication providing focal points for participants' expectations, explicitly referencing the past (BACK) or future (COMMIT) interest rates. By contrast, qualitative guidance (FWD) is less effective for managing the expectations of the Bottom3, who would benefit most from communication, likely because it provides no explicit focal points.

K Price paths

Figure K.1 depicts the price paths in each session and treatment.

Figure K.1: Price level



L Forecast spread

Figures L.1–L.2 provide impulse responses (IRFs) of "spread" variable to a +100 bps demand impulse and an expansionary monetary surprise. The spread in forecasts between two groups is defined as the absolute difference between the mean Top3 forecast and the mean Bottom3 forecast. Shaded areas outline one-standard-deviation bands based on 1000 bootstrap simulations. Columns span treatment experiments: COM-BACK (left), COM-FWD (middle), and COM-COMMIT (right).

Figure L.1: Responses of forecast disagreement to +100 bps demand shock

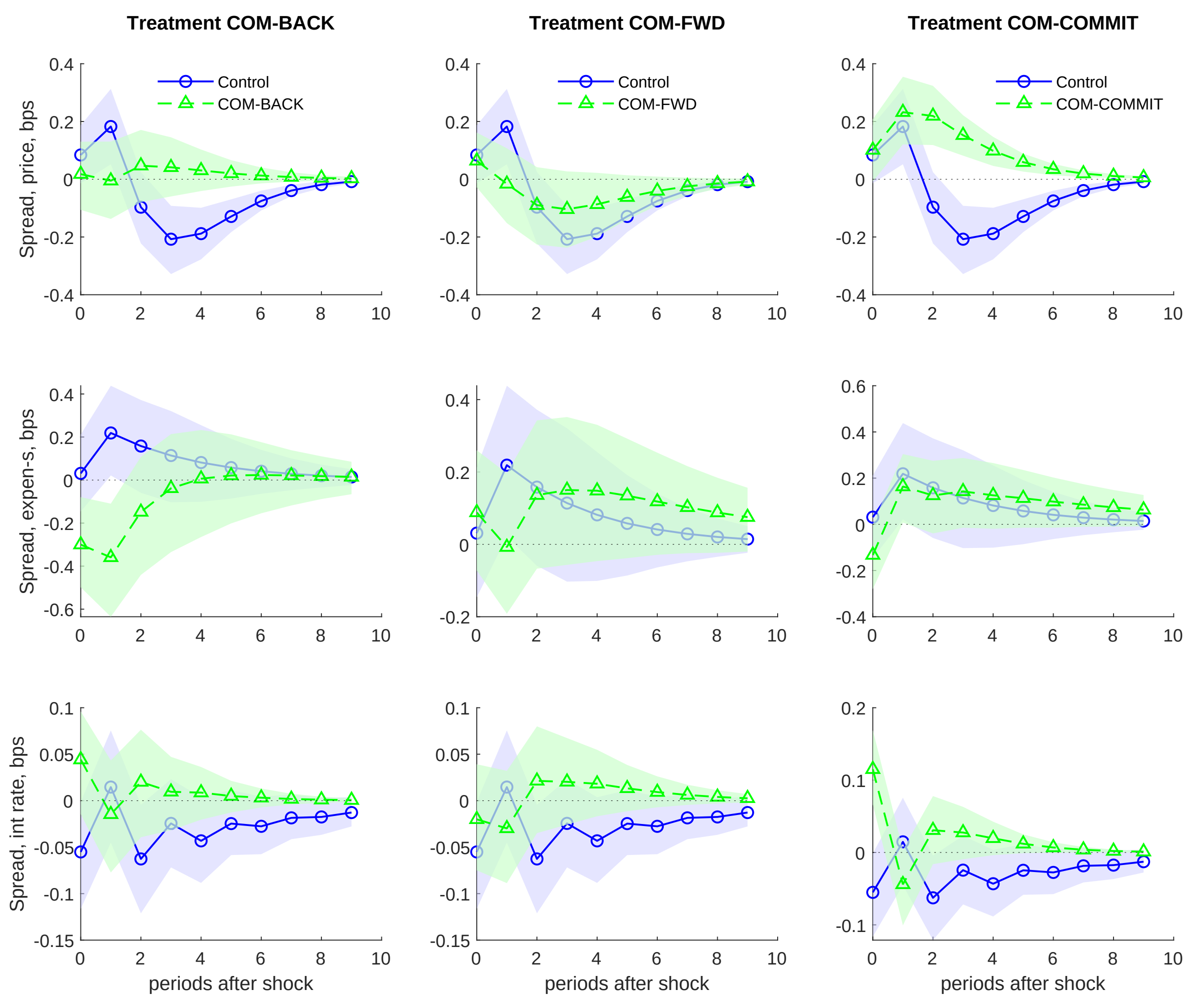
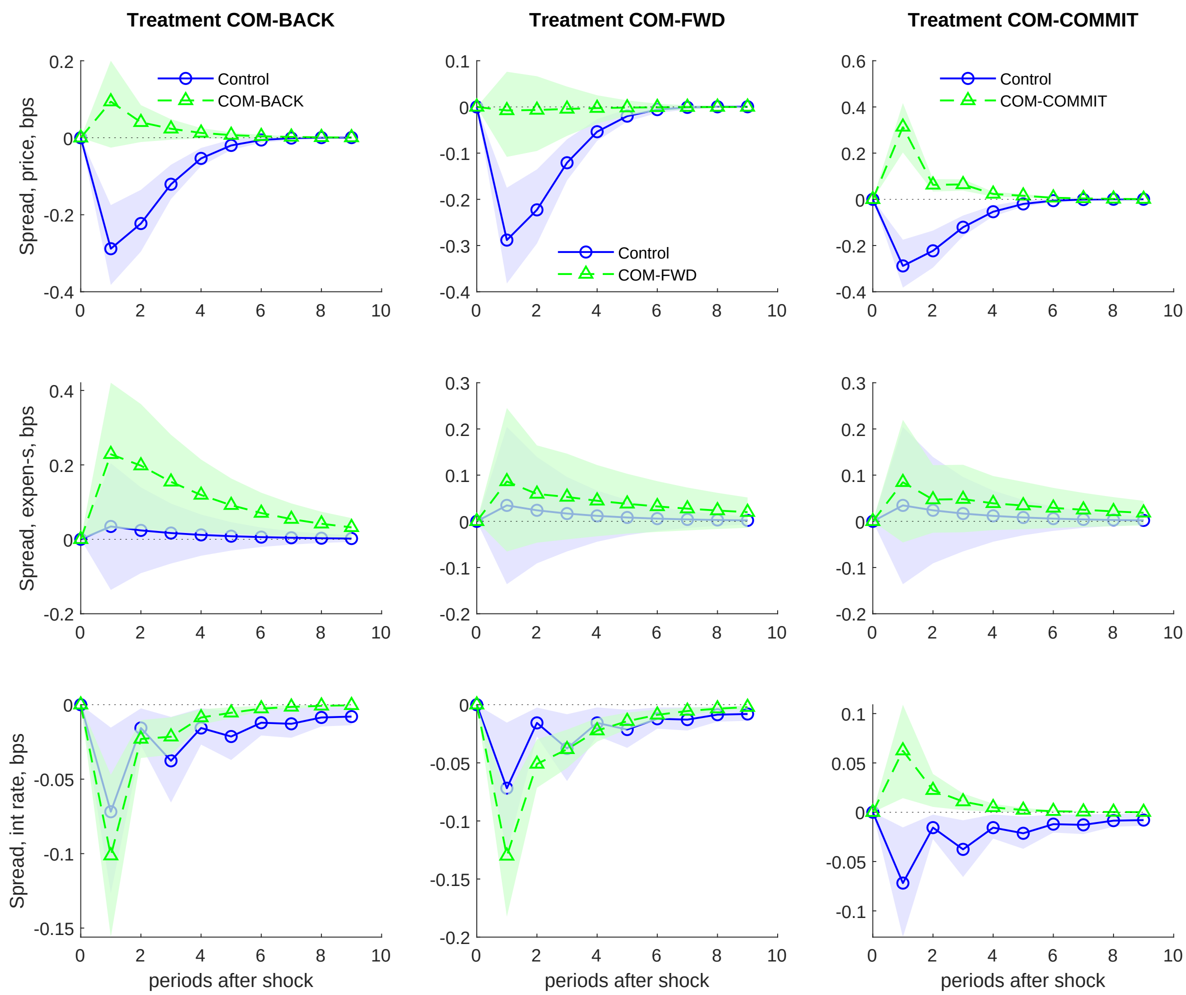


Figure L.2: Responses of forecast disagreement to an expansionary monetary surprise



M Forecast disagreement

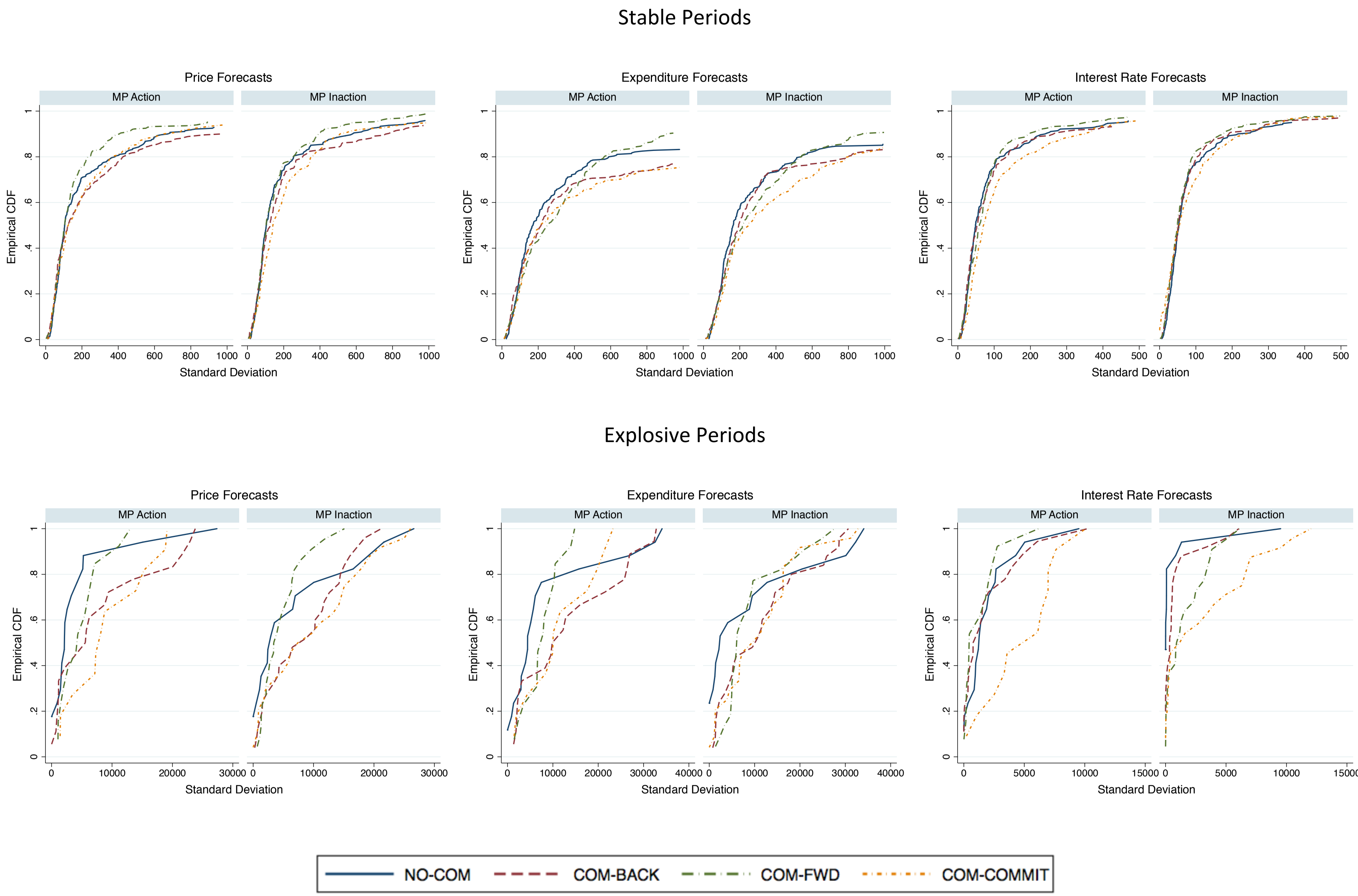
An alternative approach to measuring disagreement is to calculate, for each period in each session, the standard deviation of forecasts. We plot the distribution of disagreements, by treatment and monetary policy action, in Figure M.1. We consider stable and explosive periods seperately.

COM-COMMIT noticeably increases disagreement across most of our cuts of the data. During periods of action in stable periods, interest rate disagreement is significantly higher under COM-COMMIT, suggesting subjects become more confused when communication is turned off. COM-COMMIT subjects also exhibit more heterogeneity in their expenditure forecasts both with and without monetary policy action. During explosive episodes, interest rate expectations are significantly more disperse under COMMIT, even during periods of in-action. This suggests a lack of credibility or comprehension of the central bank's commitment to interest rates. We also observe increased dispersion in price and expenditure forecasts for the majority of the explosive periods in the COMMIT treatment.

COM-BACK also does not appear to reduce dispersion. In some cases, (e.g. interest rate forecasts during stable periods; MP action periods during explosive periods) interest rate dispersion is largely unaffected. Otherwise, we observe that dispersion increases with COM-BACK.

COM-FWD generates relatively more low-level disagreement, but considerably improves extreme disagreement. During explosive episodes with monetary policy action, disagreement reaches relatively less extreme levels; though it encourages more disagreement about nominal interest rates during periods of inaction when the communication appears to be contradict the persistently unchanging rates. The ability of qualitative communication to reduce extremely disperse expectations is also observed in Arifovic and Petersen (2017) who find qualitative communication of history-dependent inflation targets is relatively more effective at maintaining credibility in the target than quantitative communication at the ZLB.

Figure M.1: Distribution of forecast disagreement, by treatment, stable and explosive episodes



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