The Stabilizing Effects of Publishing Strategic Central Bank Projections

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Abstract

Expectations are among the main driving forces for economic dynamics. Therefore, managing expectations has become a primary objective for monetary policy seeking to stabilize the business cycle. In this paper, we study whether central banks can manage private-sector expectations by means of publishing one-period ahead inflation projections in a New Keynesian learning-to-forecast experiment. Subjects in the experiment observe these projections along with the historic development of the economy and subsequently submit their own one-period ahead inflation forecasts. In this context, we find that the central bank can significantly manage private-sector expectations and that this management strongly supports monetary policy in stabilizing the economy. Moreover, published central bank inflation projections drastically reduce the probability of a deflationary spiral after strong negative shocks to the economy.

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1 Introduction

Private-sector expectations determine the effectiveness of the main conventional monetary policy instrument, i.e. the short-term nominal interest rate, in normal times. Moreover, they are key to the transmission of unconventional monetary policy, e.g. quantitative easing and forward guidance, when the short-term nominal interest rate is restricted by the zero lower bound. Therefore, managing private-sector expectations has become a primary objective for monetary policy makers.

To influence private-sector expectations, nowadays, central banks provide the public with detailed information about their views of monetary policy and the fundamental factors driving their monetary policy decisions (Blinder et al., 2008). A pivotal aspect in this regard is the central bank practice to publish inflation projections. This practice, which qualifies as a tool of "Delphic forward guidance",[1] intends to provide superior information about future macroeconomic developments to the private sector and thereby to reduce private-sector uncertainty (Campbell et al., 2012). But central banks may also use this tool to strategically influence private-sector expectations by intentionally over- or underreporting the projected level of inflation (Gomez-Barrero and Parra-Polania, 2014; Charemza and Ladley, 2016; Jensen, 2016).

While the publication of central bank inflation projections might be a powerful tool for private-sector expectations management, the central bank must consider its effects on the (endogenous) credibility[2] of its future projections (Blinder, 2000). Publishing accurate inflation projections strengthens the central bank's reputation as a credible forecaster, but it prevents the central bank from strategically managing private-sector expectations. Conversely, publishing intentionally biased inflation projections may allow the central bank to steer private-sector expectations in the direction necessary to drive inflation closer to the central bank's inflation target, but it may be damaging to credibility if the published projections result in large forecast errors. This trade-off between short term gains and potential long term losses raises the question how the central bank's ability to manage expectations via inflation projections depends on their credibility and how in turn credibility depends on their past forecasting performance.

Against this background, in this paper we study (i) whether central banks can influence or even manage private-sector expectations via the publication of strategic inflation projections.[3] If so, (ii) whether such expectations manage-

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[1]Delphic forward guidance means that the central bank publicly states a forecast of macroeconomic fundamentals and the likely future course of monetary policy (Campbell et al., 2012). In our experiment, inflation projections by the central bank convey information about the expected future interest rate policy via a fixed Taylor rule. The counterpart of Delphic forward guidance is Odyssean forward guidance, which refers to the commitment to a specific announced future monetary policy.

[2]Throughout this paper, the term credibility refers exclusively to the central bank's inflation projections, and not to the central bank as the monetary authority.

[3]The focus on the publication of inflation projections rather than interest rate projections is motivated by the work of Ferrero and Secchi (2010), who study the effect of different central bank communication strategies in a standard New Keynesian model when agents are learning. They find that the communication of interest rate projections can be destabilizing, while the communication of inflation projections is stabilizing. Although, the model attributes a stabilizing role also to output gap projections, we choose to abstract from output gap projections entirely based on institutional and empirical grounds. Institutionally, it is inflation stabiliza-

ment can be used as an instrument to stabilize inflation and output in normal times and in times of severe economic stress (i.e., periods where there is a high probability of the zero lower bound on the nominal interest rate becoming binding) and (iii) how the effectiveness of such instrument depend on the endogenous degree of the central bank's credibility as an accurate forecaster.

The analysis is conducted by means of a laboratory experiment.[4] The great advantage of a laboratory experiment for the questions at hand, is that we can control the economic environment in which real human subjects form their expectations. This allows us to clearly identify the impact of publishing strategic central bank inflation projections on the subjects' expectation formation process and on the resulting dynamic evolution of the underlying theoretical economy. Moreover, studying such policy intervention directly in the field is not possible, since no central bank would risk its reputation by experimenting with untested forms of strategic deception.

The underlying economic environment of the experiment is given by a standard forward-looking New Keynesian model with zero lower bound on the nominal interest rate. The experimental task for the subjects is a learning-to-forecast experiment as pioneered by Marimon and Sunder (1993). Acting in the role of "professional forecasters" in the private sector subjects are asked repeatedly to form expectations about inflation one period ahead. Prior to submitting their forecast, they are presented with a one-period ahead inflation projection that is published by the central bank.

We find that the publication of strategic inflation projections strongly affects private-sector expectations. Subjects put a large weight on the public inflation projection when forming their expectations about future inflation. Strategic inflation projections act as a focal point, anchoring expectation and thereby decreasing the dispersion among individual forecasts. Moreover, they help stabilize the economy; they bring inflation and output faster and closer towards the central bank's target and reduce their volatility over the business cycle. At the zero lower bound, the publication of overly optimistic strategic projections greatly reduce the risk of deflationary spirals. We show that these results do not solely come from the role of projections as a focal point, but also depends on the reasonability of the projections. For instance, if inflation projections are pure noise, they remain without effect for macroeconomic stability. Finally, we show that credibility is an important factor for the stabilizing role of central bank inflation projections. Nevertheless, achieving full credibility on expense of all strategic behavior is not optimal.

Albeit publishing inflation projections is common practice for central banks, it has yet received very little attention in the context of learning-to-forecast experiments. To the best of our knowledge, the only exception is Mokhtarzadeh and Petersen (2017), who study the effects of central bank projections of inflation, the output gap, and the interest rate on expectation formation and economic stability. In contrast to this paper projections abstract from any

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tion which has traditionally been the core mandate of many central banks. Empirically, the relationship between output gap predictions and private-sector expectations is rather vague. E.g., in the United States, the FOMC's central bank output gap projections neither have an informational advantage over private-sector output gap forecasts (Romer and Romer, 2000), nor do they significantly influence private-sector output gap expectations (Hubert, 2014).

[4]For a thorough discussion about the potential advantages of laboratory experiments for the conduct of monetary policy analysis, see Cornand and Heinemann (2014) and Duffy (2016).

strategic motive, i.e. they are unbiased. Furthermore, Mokhtarzadeh and Petersen (2017) do not study situations when the zero lower bound of the nominal interest rate is binding.

The paper is organized as follows. Section 2 reviews the relevant literature. Section 3 describes our experimental design. Section 4 analyzes the expectation formation processes of the subjects. In Section 5 we study the influence of published central bank inflation projections on economic stability. Section 6 analyses the interaction of strategic published inflation projections and credibility, and discusses how this interaction affects the stabilizing role of published inflation projections. Finally, Section 7 concludes.

2   Related Literature

Laboratory experiments on monetary policy have become increasingly popular in recent years (see Cornand and Heinemann (2014) and Duffy (2016) for extensive surveys). A considerable fraction of this literature deals with learning-to-forecast experiments in New Keynesian models. Adam (2007) shows that in such an environment subjects' expectation formation processes generally fail to be rational, but can be rather described by simple forecasting rules based on lagged inflation. Assenza et al. (2019) and Pfajfar and Zakelj (2014, 2016) study the expectation formation process of the subjects and its interaction with conventional monetary policy rules. They find a stronger mandate for price stability advances the coordination of private-sector expectations and reduces the volatility of economic fundamentals. Kryvtsov and Petersen (2015) show that much of the stabilizing power of monetary policy is through its effect on private-sector expectations. Close to the zero lower bound, however, Hommes et al. (2019) find that conventional monetary policy is generally not very effective in stabilizing the economy and cannot reduce the risk of falling into an expectations-driven liquidity trap.

The effects of central bank communication on economic stability in New Keynesian learning-to-forecast experiments are mixed. While Cornand and M'Baye (2016a,b) find that the communication of the central bank's inflation target can reduce the volatility of the economy in normal times, Arifovic and Petersen (2017) find that it does not provide a stabilizing anchor in crisis times, e.g. in a liquidity trap. Mokhtarzadeh and Petersen (2017) find that providing the economy with central bank projections for inflation and the output gap stabilizes the economy, while Kryvtsov and Petersen (2015) find that providing the expected future interest rate path diminishes the effectiveness of monetary policy in stabilizing the economy.

3   Experimental Design

The experimental design heavily borrows from Assenza et al. (2019). Subjects interact with the economy through expectations of inflation, which affect the contemporaneous outcome of the economy through positive feedback[5] of the

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[5]Positive feedback means that the derivative of the function $f(\cdot)$ is positive. Note that although the nominal interest rate rule (4) adds some negative feedback to the economy, the overall feedback of inflation expectations on current inflation remains positive, independent of the coefficients in this interest rate rule.

form:

$$\pi_t = f\left(\bar{E}_t \pi_{t+1}\right), \tag{1}$$

where π_t and $\bar{E}_t \pi_{t+1}$ denote inflation and aggregate private-sector expected future inflation, respectively, and f is a functional form, which is specified below. Note that subjects do not yet know the realization of π_t when they form their expectation about π_{t+1}, but have information about the economy only up to period $t-1$. We follow Kryvtsov and Petersen (2015) and Arifovic and Petersen (2017) and define aggregate private-sector inflation expectations as the median[6] of the individual subjects inflation expectations, i.e. $\bar{E}_t \pi_{t+1} = median(\mathbf{E_t \pi_{t+1}})$, where $\mathbf{E_t \pi_{t+1}}$ is a vector collecting all $j = 1, ...J$ subjects' individual inflation expectations $E_t^{fc,j} \pi_{t+1}$ of period t for period $t+1$.

3.1 The New Keynesian Economy

The underlying economy evolves according to a New-Keynesian model under heterogeneous expectations.[7]

$$y_t = \tilde{E}_t y_{t+1} - \frac{1}{\sigma}\left(r_t - \bar{E}_t \pi_{t+1} - \bar{r}\right) + e_t, \tag{2}$$

$$\pi_t = \beta \bar{E}_t \pi_{t+1} + \kappa y_t + u_t, \tag{3}$$

$$r_t = max\left[0, \bar{r} + \pi^T + \phi_\pi\left(\pi_t - \pi^T\right) + \phi_y y_t\right], \tag{4}$$

where y_t is the aggregate output gap, r_t is the nominal interest rate, $\bar{r} = \frac{1}{\beta} - 1$ is the steady state interest rate, and $\tilde{E}_t y_{t+1}$ is the aggregate expected future output gap. The parameter π^T denotes the central bank's target value for inflation. Following Assenza et al. (2019) and others, the economy is perturbed by stochastic i.i.d demand and supply shocks with small standard deviation, denoted by e_t and u_t, respectively.[8] This is done to let experimental results reflect endogenous dynamics and the expectation formation of subjects rather than external shocks (large highly persistent positive or negative shocks could hinder or facilitate convergence to the target in a - for this study - non-meaningful way). Moreover, e.g. Milani (2011) shows that bounded rationality in expectations amplifies persistence endogenously and removes the need for highly persistent fundamental shocks to fit the data.

The calibration of the constant model parameters follows Clarida et al. (2000). We set the quarterly discount factor $\beta = 0.99$, implying an annual risk-free interest rate of four percent. The coefficient of relative risk aversion is set to $\sigma = 1$ and the output elasticity of inflation is $\kappa = 0.3$. The quarterly inflation target is set to $\pi^T = 0.00045$, implying an annual inflation rate of

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[6]When the aggregate is determined as the mean of all forecasts, an individual could cast an extreme forecast, in order to obtain an extreme aggregate, which would then feed back into the economy. Such individual strategic power that does not reflect the real world is eliminated when the aggregate is instead determined by the median of all forecasts.

[7]Microfoundations for this model under heterogeneous expectations can be found, for instance, in Branch and McGough (2009), Kurz et al. (2013), and Hommes and Lustenhouwer (2015).

[8]There are six economies (groups) in each treatment. Therefore, there are six random shock processes each for $u_t \sim N(0, \sigma_u^2)$ and $e_t \sim N(0, \sigma_e^2)$ with $\sigma_u = \sigma_e = 0.00075$. These are applied to all treatments so that each shock sequence is applied once in each treatment. In particular, the following pairings arise: E1-E7-E13-E19, E2-E8-E14-E20, E3-E9-E15-E21, E4-E10-E16-E22, E5-E11-E17-E23, E6-E12-E18-E24.

0.18 per cent.[9] The Taylor rule coefficients are chosen to be $\phi_\pi = 1.25$ and $\phi_y = 0.3$, which is well within the range of values that are common in related experiments.[10]

Equation (2) refers to an optimized IS curve, equation (3) is the New Keynesian Phillips curve and equation (4) is the rule for the nominal interest rate set by the central bank. We assume the central bank follows a Taylor (1993) type interest rate rule, where it adjusts the interest rate in response to inflation and output gap. Furthermore, equation (4) also shows that the nominal interest rate is subject to a zero lower bound.[11] Under rational expectations this model has two steady states. A locally determinate steady state that has values of inflation and output (close to) $\pi_t = y_t = 0$ given that π^T is (close to) zero, and a locally indeterminate steady state where the zero lower bound on the nominal interest rate is binding and $(\pi_t, y_t) = (-\bar{r}, -\frac{1-\beta}{\kappa}\bar{r})$ (Benhabib et al., 2001). Under adaptive learning and other backward-looking expectation formation processes the target steady state is locally stable (if the Taylor principle is satisfied), while the zero lower bound steady state is an unstable saddle-point (see e.g. Evans et al. (2008) and Hommes and Lustenhouwer (2015)). Therefore, depending on initial conditions, either convergence to the target steady state occurs or the economy falls into a deflationary spiral (Evans et al., 2008).

Finally, aggregate output gap expectations $\tilde{E}_t y_{t+1}$ are endogenously determined by the model. $\tilde{E}(y)$ follows a Heuristic Switching Model (Brock and Hommes, 1997), that was originally developed to fit a learning-to-forecast experiment in an asset price setting (Anufriev and Hommes, 2012), but has proven its robustness to fit also learning-to-forecast experiments in New Keynesian frameworks (e.g. Assenza et al., 2019). The Heuristic Switching Model can be summarized by the following equations:

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\begin{cases}
\text{Adaptive Rule} & \rightarrow \quad E_t^{ada} y_{t+1} = 0.65 y_{t-1} + 0.35 E_{t-1}^{ada} y_t \\
\text{Weak Trend} & \rightarrow \quad E_t^{wtr} y_{t+1} = y_{t-1} + 0.4 \left(y_{t-1} - y_{t-2} \right) \\
\text{Strong Trend} & \rightarrow \quad E_t^{str} y_{t+1} = y_{t-1} + 1.3 \left(y_{t-1} - y_{t-2} \right) \\
\text{Learn and Anchor} & \rightarrow \quad E_t^{laa} y_{t+1} = \frac{\left(y_{t-1}^{av} + y_{t-1} \right)}{2} + \left(y_{t-1} - y_{t-2} \right)
\end{cases}
\tag{5}
$$

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U_{t-1}^h = \frac{100}{1 + |y_{t-1} - E_{t-2}^h y_{t-1}|} + \eta U_{t-2}^h
\tag{6}
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[9]We choose a value of the inflation target near zero to be in line with the zero inflation steady state that is assumed when log-linearizing the macro economic model to obtain equations (2) and (3). We choose however a value slightly different from zero in order not to present subjects with a round number on which they can easily coordinate.

[10]Standard values for comparable experiments range from $\phi_\pi \in (1, 2)$ and $\phi_y \in (0, 0.5)$, e.g., Cornand and M'Baye (2016b) and Arifovic and Petersen (2017) among others.

[11]Note that under commitment to a Taylor rule, setting the nominal interest rate is not part of the task attributed to the subject with the role as central bank forecaster. Rather, the nominal interest rate is influenced implicitly, through the effects of published inflation projections on private-sector expectations and their feedback on the economy. Information about likely feedback effects and the corresponding prescribed reaction of future interest rates are provided to the central bank (described in detail in Section 3.4.2) as input for the inflation projection. Thereby, the published inflation projections and the nominal interest rate are in practice not chosen independently of each other.

$$n_t^h = \delta n_{t-1}^h + (1 - \delta) \frac{exp\left(\gamma U_{t-1}^h\right)}{\sum_{j=1}^4 exp\left(\gamma U_{t-1}^j\right)} \tag{7}$$

$$\tilde{E}_t y_{t+1} = E_t^{ada} y_{t+1} n_t^{ada} + E_t^{wtr} y_{t+1} n_t^{wtr} + E_t^{str} y_{t+1} n_t^{str} + E_t^{laa} y_{t+1} n_t^{laa} \tag{8}$$

Equation (5) lists the set of forecast heuristics. The variable y_{t-1}^{av} denotes the average past output gap. Once heuristics are used, the agents weight their past performance following equation (6), with η denoting the parameter describing the preference for the past. Equation (7) updates the probability of using heuristic h when forecasting for period $t + 1$. Notice that γ captures the sensitivity of agents to heuristic performances and δ denotes the fraction of agents that in period t stick to the heuristic they used in period $t - 1$. Then, using, (8) the expectation are aggregated and $\tilde{E}_t y_{t+1}$ is determined. The calibration of the Heuristic Switching Model follows Assenza et al. (2019), i.e., we set $\eta = 0.7$, $\delta = 0.9$, and $\gamma = \left(0.4 \cdot 4^2\right) = 6.4$.[12]

3.2 The Experiment

We apply a learning-to-forecast experiment following the approach of Assenza et al. (2019). The general setup is as follows: subjects in the laboratory are randomly divided in groups of 7. Subjects either take the role as a professional forecaster or as a central bank forecaster. Professional forecasters are employed at the forecasting department of a company which needs predictions about future inflation as input for the management's operative decisions. Professional forecasters' job is to generate these inflation forecasts and to communicate them to the management. Professional forecasters are provided with some qualitative knowledge of the economy,[13] the direction of the feedback on their expectations (i.e. positive feedback), and a public central bank projection. The professional forecasters' payoffs are determined according to their forecasting performance, measured by the following payoff function from Assenza et al. (2019):

$$\Pi_{fc,j} = \frac{100}{1 + |\pi_{t+1} - E_t^{fc,j} \pi_{t+1}|}. \tag{9}$$

The central bank forecaster is employed at the forecasting department of the central bank and the central bank forecaster's job, too, is to generate inflation forecasts, which we denote $E_t^{cbf} \pi_{t+1}$. However, this forecast does not enter the vector $\mathbf{E_t} \pi_{t+1}$ from which the aggregate inflation expectation is determined. The incentives for the central bank forecaster in determining her inflation forecasts, therefore, are different from the incentives of professional forecasters and also differ strongly between treatments. These differences will be explained in Section 3.4. Ideally, we would like to employ professional central bankers in the role of the central bank forecaster. Yet, previous experimental evidence by

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[12]We multiply γ by 4^2 relative to the calibration of Assenza et al. (2019) because we use a Heuristic Switching Model with quarterly rather than annualized data.

[13]This is a common assumption in much of the relevant literature, that tries to be consistent with the fact that in the real wold people have some qualitative knowledge of how the economy works, but do not know the exact data generating process. Exceptions to this assumption are Adam (2007), who does not provide any information about the working of the economy, and Kryvtsov and Petersen (2015), Arifovic and Petersen (2017), and Mokhtarzadeh and Petersen (2017), who provide the subjects with the fully quantified set of equations.

Arifovic and Sargent (2003), Engle-Warnick (2010), and Duffy and Heinemann (2018) makes us believe that our results derived from inexperienced student subjects remain externally valid and relevant to discussion about the conduct of monetary policy. All these papers put student subjects in the role of central bankers and show that they perform reasonably well, even in such complex and uncommon decision making processes.[14]

Whether a subject is assigned the role of a professional forecaster or a central bank forecaster is the outcome of a preliminary stage (henceforth: Stage I). In Stage I, all subjects of a group play 8 initial rounds of the experiment as professional forecasters in the absence of any public central bank inflation projection. To level the playing field, all participating subjects are presented with an identical three-period history (for periods $t = -2$, $t = -1$, and $t = 0$) for inflation, the output gap and the interest rate, which initializes the economy off the central bank's target values.[15] Subjects are ranked according to their relative forecasting performance. The role of the central bank forecaster for the remaining rounds of the experiment (period 9-37) is assigned to the best ranked subject. This is common knowledge.

Since we are interested in the expectations channel of monetary policy both in normal times and in times when the zero lower bound on the nominal interest rate may become binding, in the spirit of Arifovic and Petersen (2017), starting in period 29 there is a series of four consecutive negative demand shocks. The shocks are chosen such that the forced recession is likely to drive the economy into the liquidity trap and therewith the possibility of a deflationary spiral. With this subdivision, the economy is fairly stable in the first part of the actual experiment (periods 9-28; henceforth: Stage II). Here it is investigated whether published central bank inflation projections can influence private-sector expectations and actively stabilize the economy. In the latter part of the experiment (periods 29-37; henceforth: Stage III), on the other hand, it is investigated whether the central bank can prevent or reverse a deflationary spiral with its published inflation projections.

The timing of the experiment is as follows: In $t = 1, ..., 8$ (Stage I), all subjects submit their inflation forecast $E_t^{fc,j} \pi_{t+1}$ simultaneously. In $t = 9, ..., 37$ (Stages II and III), first the central bank forecaster submits her forecast $E_t^{cbf} \pi_{t+1}$. Professional forecasters observe the public projection $E_t^{pub} \pi_{t+1}$ and subsequently submit their own forecasts $E_t^{fc} \pi_{t+1}$. After all professional forecasters have submit their forecast, the aggregate inflation forecast $\bar{E}_t \pi_{t+1}$ is determined and the values for the variables in period t are computed. The economy proceeds to the next round.

3.3 The Central Bank Inflation Projection

In each period, the central bank forecasting department generates an inflation projection. To do so, it is provided with superior information about the experimental economy.

First, the central bank is provided with a data-driven forecast $E_t^{ddf} \pi_{t+1}$. The data-driven forecast predicts what level of inflation is likely to prevail in

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[14]For a detailed survey on student subjects as central bankers in experiments and a discussion about their external validity, refer to Cornand and Heinemann (2014).

[15]The history is displayed in Figure 4 in Appendix C. It comprises the first three observations.

period $t + 1$. For this it uses the New Keynesian model equations (2) to (4); the Heuristic Switching model that describe output gap expectations in the economy (equations (5) to (8)); and an analogue heuristic switching model to predict private-sector inflation expectations; and data up to period $t - 1$. To account for the potential self-fulfilling properties that a published central bank projection can have on the economy[16] the heuristic switching model for inflation is extended with a fifth heuristic which is termed "Follow the Published Projection" and which is defined by $E_t^{fpp} \pi_{t+1} = E_t^{pub} \pi_{t+1}$. The data-driven forecast then performs a grid search to choose the forecast that is most likely to be accurate, taking account of the effects that such a forecast is likely to have on private-sector expectations.[17]

Second, the central bank is provided with information about which aggregate inflation expectations for the following period would need to prevail for inflation to jump (in expectations) immediately to the target level π^T. This specific aggregate inflation expectation is calculated by performing a grid search on $\bar{E}_t \pi_{t+1}$ in the model defined by equations (2) to (8). This information tells the central bank in what direction it should steer aggregate expectations about $t+1$ to get closer to its inflation target in period t. We label this piece of information "required for target" and denote it by $E_t^{rft} \pi_{t+1}$.

Third, the central bank is presented with a "credibility index" measuring aggregate credibility given to the central bank projections by the individual professional forecasters from the recent past. In the spirit of Cecchetti and Krause (2002), we base our measure of the central bank's credibility towards a professional forecaster j by the distance between the central bank's inflation projection and j's inflation forecast. We normalize this distance such that $Cred_t^j$ takes values between 0 (projection is not credible at all) and 1 (projection fully credible). Hence, individual credibility is given by

$$Cred_t^j = exp\left(-3 \cdot \left(E_t^{pub} \pi_{t+1} - E_t^{fc,j} \pi_{t+1}\right)^2\right). \tag{10}$$

The scale parameter 3 is calibrated based on pilot data such that deviations from mean credibility of more than one standard deviation result in a zero payoff. The "credibility index" provided to the central bank forecaster is defined as the average credibility given to the central bank by all professional forecasters in the last four periods, i.e. $I_t^{cred} = \frac{1}{24} \sum_{j=1}^{6} \sum_{i=1}^{4} Cred_{t-i}^j$. $I_t^{cred} = 1$ if all individual forecasts from the last four periods met the central bank projection, and I_t^{cred} goes to 0 if all forecasts moved infinitely far away from it.

The the data-driven forecast and the "required for target" define an interval

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[16]This works as follows: When the central bank publishes a projection, this is likely to affect, to some extent, the inflation expectations of the professional forecasters. Since the main determinant of current inflation is expected inflation, aggregate expectations of professional forecasters in turn affect realized inflation. This implies that when the published projection is high, this is likely to also lead to somewhat higher aggregate inflation expectation, and therefore to a higher inflation realization.

[17]Since the published projections about $t + 1$ affects realizations in period t, and the published projections cast about $t + 2$ affects realizations in $t + 1$, an assumption needs to be made about what the published projections about $t + 2$ will be, in order to evaluate whether the forecast made about $t + 1$ is likely to come true. The data driven forecast simply assumes here that the published projections about $t + 2$ will be the same as the published projections about $t+1$. Since both inflation and the published projection turn out to be highly persistent, also in our experimental sessions, this is arguably not a very restrictive assumption.

of generally sensible inflation projections. If the central bank wants to build up credibility, it follows the data-driven forecast and provides a "non-strategic" inflation projection. If the central bank intends to steer the economy, it provides a "strategic" projection which lies between the data-driven forecast and the "required for target" criterion. The extend to which the inflation projections are biased away from the data-driven forecast and towards the "required for target" criterion determines the degree of strategic-ness.[18] Inflation projections outside of this interval are not sensible. We term the latter "random" projections.

To sum up, when generating the inflation projection, the central bank must decide whether it follows the data-driven forecast or to what extent it publishes a projection which is biased towards the "required for target" criterion, taking into account its credibility.

3.4 Treatments

We consider four treatments in this experiment.

3.4.1 Treatment 1: No Published Central Bank Inflation Projections (Control Treatment)

In this treatment, the control treatment, no central bank projections are published. The central bank forecaster produces forecasts, but these forecasts are not revealed. For her predictions, she is paid according to equation (9).

3.4.2 Treatment 2: Inflation Projections from a Human Central Bank Forecaster

In this treatment, the central bank publishes official central bank inflation projections (i.e., $E_t^{pub}\pi_{t+1} = E_t^{cbf}\pi_{t+1}$) which are generated by the central bank forecaster subject. The other subjects of her group are informed (i) that there is a central bank forecaster publishing official central bank inflation projections in this economy, (ii) that the central bank forecaster is the subject that predicted inflation best in Stage I, (iii) that the central bank forecaster has additional information about the economy without specifying this any further, and (iv) that the central bank has an inflation target without quantifying this target.[19] Note that it is not a priori clear whether it is optimal for professional forecasters to use the published projection when forming their own forecasts or to ignore it. This depends on what a subject believes about how the central bank forms its projection and about how other subjects form their expectations.[20]

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[18]We formalize the concept of strategic-ness for our numerical analysis in Section 6.2.

[19]Providing professional forecasters with the value of the inflation target of the central bank would give them an extra focal point to coordinate on, that is correlated with the published central bank projections. This would make it harder to identify to what extend forecasters and the economy are affected by the published forecasts. Since our research questions focus on the consequences of providing published forecasts and not on an inflation targeting scheme as a whole, we therefore choose not to provide this additional information.

[20]For example, it is optimal for a subject to predict exactly the published projection when she thinks that the central bank is able to foresee what the median forecast will be and that the central bank will use all its information to publish a truthful forecast. If, on the other hand, the subject believes that the central bank is not good in predicting the median forecast of the professional forecasters or if she believes that the central bank is more concerned with strategically trying to steer the economy rather then publishing accurate projections, then the subject is better of ignoring the published projection.

The central bank forecaster's objective, in this treatment, is twofold: On the one hand she has to stabilize inflation, i.e., minimize the deviations of inflation from her target values, while on the other hand her inflation projections have to remain maximally credible, as measured by the credibility index. We consider central bank credibility explicitly, as it is of utmost importance for the functioning of monetary policy and thereby enjoys a lot of attention of monetary policy makers (Blinder, 2000; Bordo and Siklos, 2014). In line with this strategy, Gomez-Barrero and Parra-Polania (2014) present a theoretical model of strategic central bank forecasting which explicitly considers reputational concerns of central bank credibility in the central bank's loss function. The payoff functions of the central bank forecaster have the following form:

$$
\begin{array}{lll}
\Pi_{cbf}^{stability} & = & \max\left(0, 100 - 44.4\left(\pi_t - \pi^T\right)^2\right) \\
\Pi_{cbf}^{credibility} & = & \max\left(0, 100 - 400\left(1 - I_t^{cred}\right)^2\right)
\end{array} \quad . \tag{11}
$$

Equation (11) is calibrated such that in each period the central bank forecaster receives a payoff of zero for stability if inflation deviates from target by more than 1.5 percentage points and receives a payoff of zero for credibility of the projection if the credibility index is below 0.5. To prevent hedging between the two goals, at the end of the experiment, only one of them is chosen randomly by the computer for payoff (Blanco et al., 2010).

3.4.3 Treatment 3: "Algorithmic" Inflation Projections

In this treatment, we follow Mokhtarzadeh and Petersen (2017) and provide a published central bank projection that comes from a computer algorithm. Analogous to the previous treatment, the subjects are informed (i) that there is a computer algorithm publishing official central bank inflation projections in this economy, (ii) that the central bank forecaster has additional information about the economy without specifying this any further, (iii) that it may or may not exploit this superior information and (iv) that the central bank has an inflation target without quantifying this target.

In contrast to the algorithm proposed by Mokhtarzadeh and Petersen (2017), our computer algorithm makes strategic inflation projections. The extent to which the projections are strategic depends primarily on the current state of the economy (in particular, whether previous inflation was (i) close to, (ii) above, or (iii) below its target value) and secondarily on the credibility of recent central bank inflation projections.

The computer algorithm works as follows: (i) If previous inflation was *close to target* (within ±0.5 percentage points), the central bank tries to initiate long term coordination on its inflation target through projections equal to the inflation target. (ii) If previous inflation was *sufficiently above target* (for more than 0.5 percentage points), the algorithm solves a trade-off between building credibility and steering the economy. If past projections have been little credible, the algorithm aims at building credibility through accurate inflation projections based primarily on the data driven forecast (which is calculated in the same way as in Treatment 2). If projections have been credible, the algorithm leans more towards the "required-for-target" information. (iii) If previous inflation was *sufficiently below target* (for more than 0.5 percentage points) the economy faces

the risk of a binding zero lower bound and a deflationary spiral. Now, building up credibility by following the data-driven forecast becomes dangerous as the data-driven forecast may predict a deflationary spiral. Therefore, the algorithm balances forecasting the target with forecasting the last observed inflation level, where the latter can improve on credibility without amplifying the downturn in inflation. The weight on the last observed value is relatively high when there is a downward trend in inflation, because then it might not be credible that inflation will suddenly go up by much. On the other hand, if there is an upward trend in inflation it might be more credible that inflation will go up more, so the computer algorithm can put more weight on the target.

The explicit algorithm is spelled out below:

"close to target": $E_t^{pub} \pi_{t+1} = \pi^T$

"sufficiently above target": $E_t^{pub} \pi_{t+1} = I_t^{cred} * E_t^{rft} \pi_{t+1} + (1 - I_t^{cred}) E_t^{ddf} \pi_{t+1}$

"sufficiently below target": if $\pi_{t-1} < \pi_{t-2} : E_t^{pub} \pi_{t+1} = 0.5\pi^T + 0.5\pi_{t-1}$
$\qquad\qquad\qquad\qquad\quad$ if $\pi_{t-1} > \pi_{t-2} : E_t^{pub} \pi_{t+1} = 0.8\pi^T + 0.2\pi_{t-1}$

For reasons of comparability, in this treatment, the central bank forecaster subject takes the same role as in Treatment 1 and is, again, paid for her prediction accuracy according to equation (9).

3.4.4 Treatment 4: "Random" Inflation Projections

In Stage II of this treatment, the published inflation projections are randomly drawn from a uniform distribution with support from -5 to 5, i.e., $E_t^{pub} \pi_{t+1} \sim Unif(-5,5)$. The support is chosen according to realized inflation throughout the first three treatments of this experiment.

In Stage III of this treatment, the algorithmic forecast from Treatment 3 is applied. This twist after Stage II allows us to draw conclusions about the persistence of central bank credibility in the light of drastic changes in the economic environment.

3.5 Hypotheses

Our experimental design allows us to address several hypothesis, following the distinction between "strategic" and "random" projections defined in Section 3.3. We consider central bank inflation projections to be strategic, if they lie systematically (i.e. most of the time) inside the interval between the data-driven forecast and the "required for target" information. Analogously, central bank projections ar considered "random," if they lie systematically (i.e. most of the time) outside the interval between the data-driven forecast and the "required for target" information. According to this criterion, projections from a human central bank forecaster and the algorithmic projections are considered "strategic", while the random projections are indeed considered "random".[21]

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[21]For the central bank forecaster subjects, more than 85% of all public central bank projections lie within the required interval; algorithmic projections lie in the interval more than 80% (and above 90% if the predictions of the target inflation rate when the economy is "close to target" are considered as well). Less than 4% of all random projections from Treatment 4 lie within the required interval.

Hypothesis 1: Strategic projections anchor private-sector inflation expectations; random projections do not.

In their seminal theoretical contribution, Morris and Shin (2002) show that public central bank information can act as a coordination device by anchoring private-sector expectations and thereby reduce the dispersion of private-sector expectations. Empirical support for such an anchoring effects for expectations (especially in the context of public central bank projections) is given by Hubert (2014) for the Federal Reserve, by Fujiwara (2005) for the Bank of Japan, and by Ehrmann et al. (2012) for 12 advanced economies (including the former two).

Hypothesis 2: Strategic projections stabilize the economy (a) in normal times and (b) in times of severe economic stress; random projections do not.

Although from an empirical point of view published central bank inflation projections seem beneficial for macroeconomic stability (Chortareas et al., 2002), from a theoretical point of view, the effects of published central bank inflation projections on macroeconomic stability are generally ambiguous and depend on the quality of the projections. Having superior information, central bank projections can be stabilizing through an anchoring effect on private-sector inflation expectations in normal times (Eusepi and Preston, 2010; Ferrero and Secchi, 2010) and at the zero lower bound (Goy et al., 2017). This anchoring effect can, by contrast, be destabilizing if potentially noisy projections crowd out more accurate private information (Geraats, 2002; Amato and Shin, 2006; Walsh, 2007).

Hypothesis 3: The ability of the central bank to stabilize the economy by means of its projections depends positively on the credibility of the central bank projections.

Svensson (2015) shows for Sweden that credible interest rate projections remarkably influenced market behavior towards stabilization in 2009, whereas in 2011 non-credible projections left the market unimpressed and without any response in market behavior.

Hypothesis 4: The credibility of the central bank projections depends positively on their past performance

In a survey among 84 central bank presidents worldwide, Blinder (2000) finds that the most important matter for credibility is believed to be a consistent track record. With respect to inflation projections and projection of inflation in particular, such a consistent track record is established primarily by a sustained projection accuracy. Loss in credibility of the central bank's projections can therefore be attributed to a (systematic) failure to produce accurate projections (Mishkin, 2004). Following this line of reasoning, also Mokhtarzadeh and Petersen (2017) determine central bank credibility by looking at past central bank forecasting performance.

3.6 Experimental Procedure

Each treatment of this experiment consists of six economies with seven subjects each. Thus, the experiment has a total of $4 * 6 * 7 = 168$ subjects. Subjects were recruited from a variety of academic backgrounds using ORSEE (Greiner, 2015). The subject population comprised undergraduate students (64%), graduate students (34%), and non students (2%). Subjects were mostly from the natural sciences (61%) and the social sciences (16%). Around two thirds of the subjects were male (62%) and one third were female (38%). During the experiment, subjects earned experimental currency units (ECU) according to their respective payoff functions. At the end of the experiment, subjects were paid €1 for every 85 ECU; that is, each ECU paid approximately €0.012. The average payment was €31.66. The experimental software was programmed in oTree (Chen et al., 2016). The experiment was conducted in May and June 2016 at the experimental lab of the Technische Universität Berlin.

4 Expectation Formation of Professional Forecasters

For central bank projections to be an effective tool of monetary policy, they must influence the expectation formation process of the professional forecasters. Therefore, in this section we investigate if professional forecasters form expectations differently when presented with central bank projections and if so, how this depends on the quality of the projections. Since Stage I is a learning stage in all treatments and Stage III presents subjects with an inherently unstable environment, we focus this analysis on Stage II only.

We follow Assenza et al. (2019) and Pfajfar and Zakelj (2014) and estimate for each subject's inflation forecast a general linear forecasting rule of the form

$$E_t^{fc,j}\pi_{t+1} = c^j + \sum_{i=1}^{2}\alpha_i^j E_{t-i}^{fc,j}\pi_{t+1-i} + \sum_{i=1}^{2}\beta_i^j\pi_{t-i} + \gamma^j y_{t-1} + \delta^j E_t^{pub}\pi_{t+1} + \varepsilon_t^j, \quad (12)$$

where ε^j is the error term of each individual regression, using non-linear least squares. For Treatment 1, δ^j is set equal to zero. The results are summarized in Table 1. The table shows the percentage of individually significant regressors at the 10%-significance level and the median estimated parameter values for each treatment, respectively.[22] First, we consider all professional forecasters who did not see a central bank projection before making their forecasts. This group consists of all professional forecasters in Treatment 1 (the control treatment). The Column [1] of Table 1 shows that 92% of subjects consider the first lag of inflation when forming their expectation about future inflation. 36% of subjects consider the second lag of inflation. Given that the sign of the coefficient on the first lag is generally positive with a median of 1.11, while the sign on the second lag of inflation is generally negative with median of -1.14 it appears that many professional forecasters engaged either in naive adaptive or in trend following behavior when forecasting inflation. In line with early evidence from Adam

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[22]In the estimation we follow Massaro (2012) by iteratively eliminating all insignificant regressors. The details of the procedure are presented in Appendix A.

Treatment	[1]	[2]	[3]	[4]
constant	39%	36%	56%	50%
	(0.431)	(0.381)	(0.162)	(0.807)
$E_{t-1}^{fc,j}\pi_t$	14%	19%	14%	19%
	(0.429)	(0.140)	(0.395)	(0.550)
$E_{t-2}^{fc,j}\pi_{t-1}$	3%	11%	17%	8%
	(-0.734)	(-0.479)	(-0.385)	(-0.369)
π_{t-1}	92%	47%	56%	42%
	(1.105)	(0.617)	(0.744)	(0.813)
π_{t-2}	36%	25%	17%	11%
	(-1.140)	(-0.553)	(-0.006)	(-0.586)
y_{t-1}	14%	11%	14%	25%
	(-1.055)	(0.971)	(0.348)	(1.350)
$E_t^{pub}\pi_{t+1}$		69%	31%	31%
		(0.818)	(1.441)	(0.216)
avg. R^2	0.76	0.72	0.66	0.46
#Sign.Coeff	1.97	2.19	2.03	1.86

Table 1: Percentages of regressors that are significant at the 10%-level and the median regression coefficients (in parentheses) from estimation of equation (12) for all professional forecasters per treatment. Additionally, the table shows the average R^2 and the average number of significant coefficients per forecaster for each treatment.

(2007) only few subjects consider past realizations of the output gap to predict future inflation.

Next, we consider all subjects which were shown a public central bank projection prior to submitting their own forecast. This group consists of all subjects in Treatment 2, 3, and 4. Column [2] of Table 1 shows the results of the regression on the subjects with a published projection provided by a human central banker. It can be seen that for 69% of the subjects the published projection has a statistically significant effect on their expectations. This is more than for the first lag of inflation which is now statistically significant for less than half of the subjects. The influence of the second lag of inflation is also reduced considerably. Algorithmic projections are statistically significant for 31% of the subjects (Column [3]).[23] The first and second lag of past inflation lose significance compared to the control treatment. A similar result is obtained for random projections (Column 4). Note, however, that although 31% of subjects consider random projections informative, the average coefficient of 0.216 implies that their forecast is only marginally influenced by it. From this evidence, we conclude that public projections significantly affect subjects' own forecasts.

The bottom row of Table 1 presents the average number of significant regressors used in the expectation formation process in each of the four treatments. Interestingly, this number is around two for all of the four treatments. This leads to the conclusion that subjects rather substitute the public central bank

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[23]This low number is the result of the design of the computer algorithm for the algorithmic projections. Note that the computer algorithm publishes the target value whenever the economy is close to the target, thereby resulting in very little variation of the projection. Since individual forecasts vary slightly around the prediction, they are not picked up by the econometric procedure as following the prediction. However, in Section 5 we will present further results, which support the notion that the computerized forecasts from Treatment 3 significantly influence the forecasters expectations.

	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Stage II	0.351	0.293	0.248	0.670
	(0.155)	(0.148)	(0.116)	(0.342)
p-value	—	0.589	0.485	0.065
Stage III	2.371	0.528	0.512	0.781
	(2.705)	(0.360)	(0.134)	(0.495)
p-value	—	0.093	0.093	0.240

Table 2: Average median dispersion of professional forecasts in economies of treatment j (standard deviation in parentheses) for $j = 1, ..., 4$. The p-values result from two-sided Wilcoxon rank sum tests for pairwise comparisons with $N = 6$ observation of treatment 1 with treatments 2, 3, and 4.

inflation projection for another source of information than complement their information set in the expectation formation process.

5 Macroeconomic Results

Having established that central bank projections influence private-sector expectations, we now turn to the ramifications of this influence for the macroeconomy.

5.1 Anchoring Effect of Central Bank Projections

Central bank projections are common to all professional forecasters and thereby provide public information. Such public information can act as a focal point, coordinating private-sector expectations (Morris and Shin, 2002), and thereby giving rise to potential expectations management.

According to Hubert (2014), anchoring of expectations manifests itself in two dimensions; either in coordination around a particular level of inflation or in a lower cross-sectional dispersion of individual professional forecasts in each period t. In this paper, we focus on the role of anchoring as reduction in the cross-sectional dispersion of individual expectations. Following Ehrmann et al. (2012) and Hubert (2014), we measure dispersion by the the inter-quartile range of professional forecasts in any given period. Table 2 presents the average median dispersion of professional forecasts per treatment.[24] The p-values are derived from a series of non-parametric two-sided Wilcoxon rank sum tests. The table shows that although strategic projections (Treatments 2 and 3) reduce the average dispersion roughly by one third the differences are not statistically significant. Random projections (Treatment 4), by contrast, significantly increase average dispersion, almost doubling it.

Kernel density estimates of per-period dispersion in Treatments 1-4 are depicted in Figure 1. The more right-skewed is a Kernel density estimate, the less disperse are the elicited individual professional forecasts. To test for significance of statistical differences, a permutation test is applied. Relative to Treatment 1, density estimates are significantly more right-skewed under strategic projections ($p < 0.05$) and significantly less right-skewed under random projections

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[24]The results are similar if dispersion is measured via the standard deviation and the range as well as for the means instead of the medians of the dispersion measures.
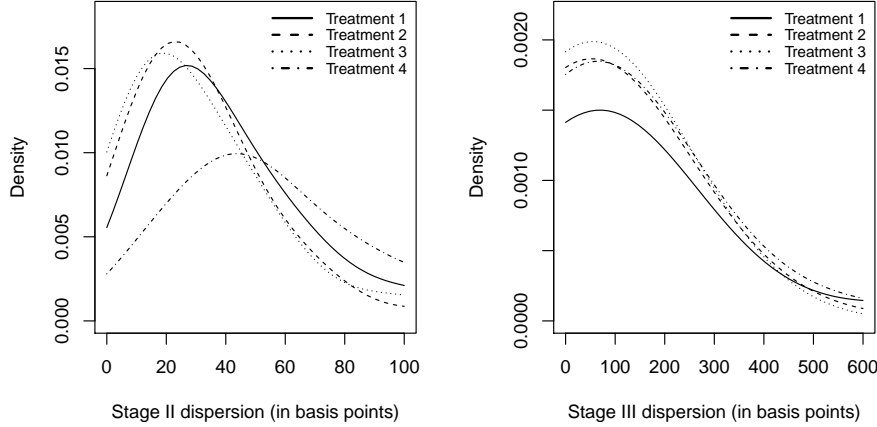
Figure 1: Kernel density estimates of per period dispersion in Stage II (left panel) and Stage III (right panel) per treatment.

($p < 0.001$). These results hint towards an important (de-)anchoring effect of (random) strategic projections.

To quantify the anchoring effect of public inflation projections, in the spirit of Ehrmann et al. (2012) and Hubert (2014), we resort to a simple regression analysis of the form

$$\sigma_{fc,t} = constant + \beta_1 PP_t + \beta_2 \sigma_{fc,t-1} + \beta_3 X_{t-1} + \varepsilon_t, \qquad (13)$$

where $\sigma_{fc,t}$ is the cross-sectional dispersion of the professional forecasters in period t, PP_t is a dummy variable which takes value 1 when a public inflation projection is present and X_t is a vector of macroeconomic controls. The macroeconomic controls X_{t-1} comprise the lagged inflation rate, the lagged output gap, and lagged inflation uncertainty defined by $IU_{t-1} = |\pi_{t-1} - \pi_{t-2}|$, which is the absolute error of a random walk forecast (Ahrens and Hartmann, 2015). We expect a positive relationship between lagged inflation uncertainty and the dispersion across individuals. The higher lagged inflation uncertainty, the harder the prediction of inflation and thereby the greater the dispersion across individuals (Capistrán and Timmermann, 2009; Dovern and Hartmann, 2016). Concerning the remaining control variables, first, we expect dispersion to be positively influenced by lagged inflation. Mankiw et al. (2004) show that a higher level of inflation yields more disagreement in inflation expectations. For the lagged output gap we expect a negative relationship, since Dovern et al. (2012) and Hubert (2014) document a higher disagreement in recessions. We estimate equation (13) with ordinary least spuares (OLS) and heteroskedasticity- and autocorrelation-robust Newey-West standard errors.

The estimation results are summarized in Table 3. Column [1] in Table 3 shows the results when all four treatments are considered. In this case, the publication of inflation projections per se has no anchoring effect, i.e., PP_t is close to zero and statistically insignificant. Similar results hold for the interest rate

	[1]	[2]	[3]	[4]
constant	−0.126**	0.226***	0.201***	0.184**
	[0.057]	[0.045]	[0.042]	[0.075]
PP_t	0.044	−0.126***	−0.084**	0.285***
	[0.053]	[0.043]	[0.034]	[0.089]
$\sigma_{fc,t-1}$	0.227***	0.136**	0.125	0.137*
	[0.055]	[0.069]	[0.076]	[0.079]
π_{t-1}	0.113***	0.015	0.038	0.138***
	[0.037]	[0.019]	[0.026]	[0.048]
y_{t-1}	−0.001	0.007	−0.009	0.078
	[0.037]	[0.038]	[0.037]	[0.073]
IU_{t-1}	0.300***	0.371***	0.382***	0.292***
	[0.069]	[0.085]	[0.092]	[0.100]

Table 3: Anchoring effect of published projections. The table shows the results from estimating equation (13) with OLS and heteroskedasticity- and autocorrelation-robust Newey-West standard errors for different subsamples of the experimental data. The respective samples are: [1] T1-T4; [2] T1 vs T2; [3] T1 vs T3; [4] T1 vs T4

and output gap coefficients. For the complete set of data, cross-sectional dispersion is a persistent phenomenon which is mainly driven by inflation uncertainty. In Columns [2]-[4] we distinguish between strategic and random projections. While Columns [2] and [3] show variants which abstract from random projections (Treatment 4), Column [4] abstracts from strategic projections. Consider Columns [2] and [3] first. Column [2] shows the parameter estimates of (13) using data from Treatments 1 and 2 and Column [3] using data from Treatments 1 and 3. First, the table shows that parameter values generally have the expected sign. Strategic projections unambiguously reduce the dispersion of individual expectations. The reduction is statistically significant. The influence of inflation uncertainty on the dispersion remains statistically significant. The interest rate and the output gap coefficients again are negligible and statistically insignificant. Finally, Column [4] shows the parameter estimates of (13) using data from Treatments 1 and 4 only. Now, the effect of publishing inflation projections is positive and statistically significant. Random projections increase the cross-sectional dispersion by approximately 29%. The results are similar if we consider contemporaneous macroeconomic controls X_t, as applied in the original studies by Ehrmann et al. (2012) and Hubert (2014).

Taken together, the above results give rise to the notion that strategic projections act as an anchor for private-sector inflation expectations, while random projections unleash disturbing forces driving private-sector expectations apart. Therefore, the evidence supports Hypothesis 1.

From a policy maker's point of view, this anchoring effect can be a useful monetary policy instrument. Eusepi and Preston (2010) point out that in economies with potentially self-fulfilling expectations and learning, expectation may be unanchored and inconsistent with monetary policy. Therefore, unlike under rational expectations, the Taylor principle alone does not guarantee macroeconomic stability. Central bank projections, by contrast, can generate macroeconomic stabilization through anchoring of private-sector expectations

on a path consistent with monetary policy. In the following section, we have a closer look at the role of central bank projections for macroeconomic stability.

5.2 Macroeconomic Stability

In this Section, we analyze to what extent strategic projections stabilize the economy. To fix ideas, first we juxtapose the median economic dynamics arising from the actual experiment in each of the four treatments and their statistical properties.

Figure 2 shows the median evolution of inflation, the output gap, and the interest rate for all four treatments; Treatment 1 is depicted by the solid lines, Treatment 2 by the dashed lines, Treatment 3 by the dotted lines, and Treatment 4 by the dashed-dotted lines.[25] The figure shows that all four treatments share a common pattern for the evolution of the macroeconomy over much of the 37 rounds of the experiment. First, there is convergence towards the central bank's target levels (horizontal gray line). Second, starting in period 29 (the second vertical, gray line), a deep recession takes place which drives the economy towards the zero lower bound. While median economies recover from the recession under strategic projections (Treatments 2-4 in Stage III), the median economy falls into a deflationary spiral in the absence of published projections (Treatment 1).

Although, all four treatments share a common pattern (with the exception of Stage III), there are considerable quantitative effects of published projections on macroeconomic stability. In the following, we analyze these effects separately for normal times and for times of severe economic stress.

5.2.1 Macroeconomic Stability in Normal Times

First we analyze the stabilizing role of published central bank inflation projections for the economy in normal times, i.e., we focus entirely on Stage II. We evaluate macroeconomic stability by the mean squared deviations of inflation and the output gap from their respective target values.

$$S_{i,j}^{\pi} \quad = \quad \frac{1}{20} \sum_{t=9}^{28} \left(\pi_t - \pi^T \right)^2, \tag{14}$$

$$S_{i,j}^{y} \quad = \quad \frac{1}{20} \sum_{t=9}^{28} y_t^2. \tag{15}$$

The lower $S_{i,j}^{\pi}$ and $S_{i,j}^{y}$ the more stable the economy. Columns [1] to [4] of Table 4 summarize the treatment-average mean squared deviation from target for inflation ($\bar{S}_j^{\pi} = \frac{1}{6} \sum_{i=1}^{6} S_{i,j}^{\pi}$) and the output gap ($\bar{S}_j^{y} = \frac{1}{6} \sum_{i=1}^{6} S_{i,j}^{y}$). The p-values in Table 4 are derived from a series of non-parametric two-sided Wilcoxon rank sum tests. Strategic projections (Treatments 2 and 3) reduce $\bar{S}_j^{\pi}$ by approximately two thirds and $\bar{S}_j^{y}$ by approximately one third. These differences are statistically significant. Random projections, by contrast, have no statistically significant effect on macroeconomic stability.

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[25]Figures 5 to 8 in Appendix C show all 6 individual economies for each treatment, respectively.
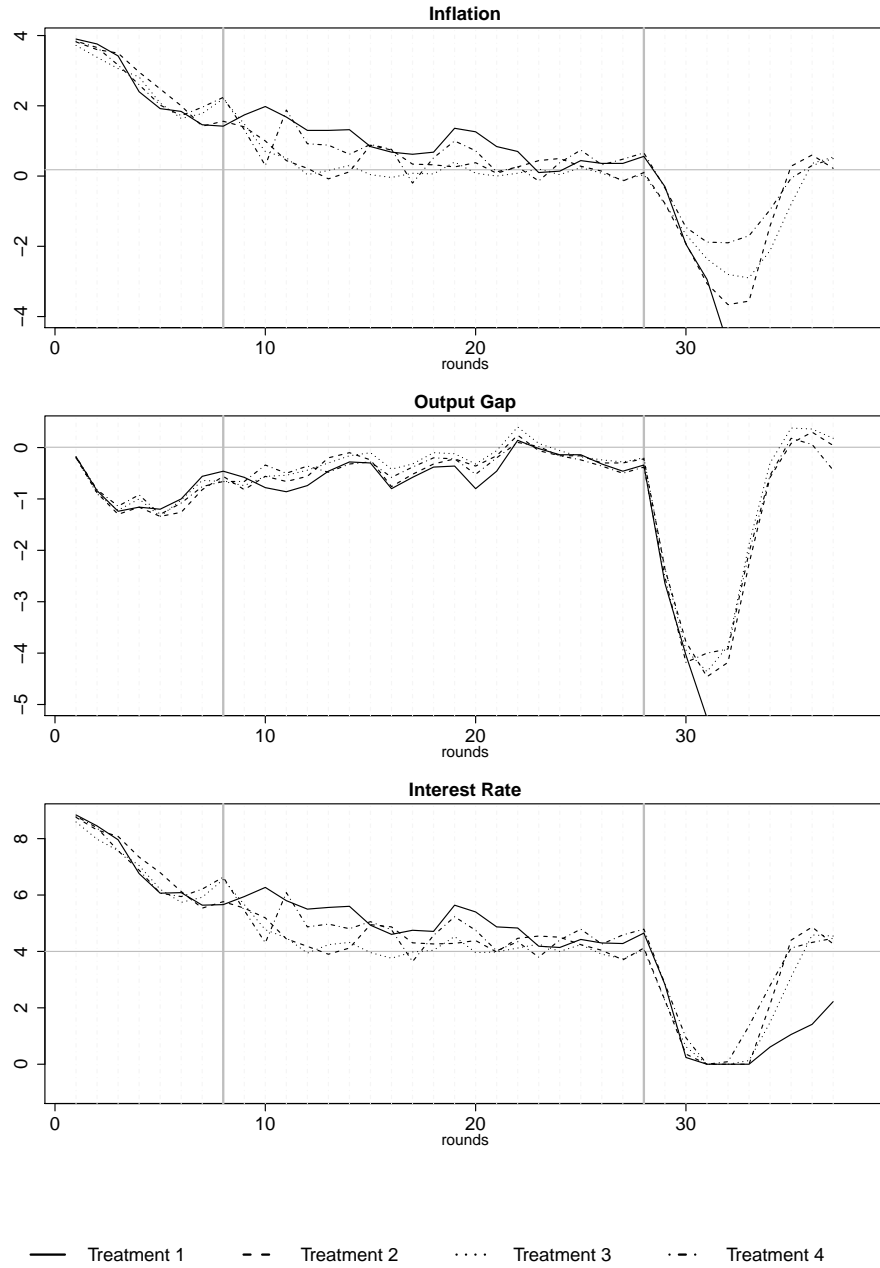
Figure 2: Median responses of inflation (upper panel), the output gap (middle panel), and the interest rate (lower panel) for all four treatments. For each treatment, median responses are generated by taking the median of each inflation, the output gap, and the interest rate from all six economies at each period $t = 1, ..., 37$.

Note that for Treatment 1 the median interest rate leaves the zero lower bound despite a deflationary recession. This abnormal artifact is a result from the aggregation procedure (median) as three economies of Treatment 1 remain at the zero lower bound, while three economies leave the zero lower bound (see Figure 5 in Appendix C.)

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	[1] Treatment 1	[2] Treatment 2	[3] Treatment 3	[4] Treatment 4	[5] CF1	[6] CF2
$\bar{S}_j^\pi$	1.605	0.532	0.411	1.130	0.736	0.163
	(0.991)	(0.367)	(0.425)	(0.923)	(0.379)	(0.071)
p-value	—	0.026	0.009	0.310	0.041	0.002
$\bar{S}_j^y$	0.378	0.233	0.231	0.285	0.236	0.182
	(0.137)	(0.046)	(0.080)	(0.160)	(0.035)	(0.065)
p-value	—	0.093	0.065	0.310	0.041	0.009

Table 4: Average mean-squared-deviation of Stage II inflation and the output gap from their respective targets in economies of treatment j (standard deviation in parentheses) for $j = 1, ..., 4$, and of the counterfactual simulations. The p-values in column [2]-[6] result from two-sided Wilcoxon rank sum tests for pairwise comparisons to Treatment 1 with $N = 6$ observation.

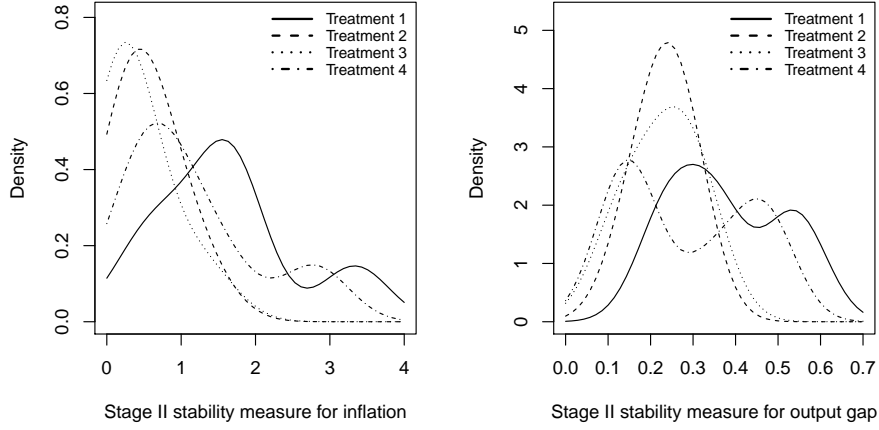**Figure 3:** Kernel density estimates of economy-average mean squared deviations of inflation (left panel) and output gap (right panel) from their respective targets per treatment.

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	T1	T2	T3	T4
Periods at zero lower bound	5	3	2.5	1.5
Length of recession	7.5	4.5	4	3
Depth of recession	-239.76	-4.28	-4.18	-4.22
Periods of deflation	8	6	7	6.5
Deflationary spirals	3	1	0	1
Credibility Index in $t = 28$	—	0.88	0.89	0.13

Table 5: Important key indicators for Stage III. The table shows treatment medians of key indicators describing the severity of the recession and the accompanying liquidity trap in Stage III.

To asses distributional differences in economic stability, Figure 3 presents Kernel density estimates for $S_{i,j}^{\pi}$ and $S_{i,j}^{y}$ per treatment. Significance is again testet, by applying a permutation test. Compared to Treatment 1, inflation and output gap are considerably right-skewed (i.e. more stable) in Treatments 2 and 3. These distributional differences are statistically significant for Treatment 2 and 3 inflation ($p < 0.05$) and for the Treatment 2 output gap ($p < 0.1$). Distributional differences between Treatments 1 and 4 are never statistically significant.

The stabilizing role of strategic projections manifests through a much faster convergence of inflation towards its target. In Treatments 2 and 3, inflation reaches the close neighborhood of the inflation target, say an interval of ± 25 basis points around the target, on average within 5 periods. In Treatments 1 and 4, time to convergence triples, with a third of the economies not reaching convergence at all during Stage II.

The analysis implies that strategic projections are an effective instrument to increase welfare through its stabilizing role in the economy. Random projections, by contrast, remain without statistically significant effects on stabilization. As a result, the above analysis supports Hypothesis 2(a).

5.2.2 Published Central Bank Projections at the Zero Lower Bound

Next we analyze the impact of strategic inflation projections in times of severe economic stress. To do so, we look at Stage III (periods 29-37) of the experiment.[26] Between periods 29 and 32, a series of four consecutive negative demand shocks of -2.5% annually in periods $t = 29, ..., 32$ hits all 24 economies alike. Figure 2 and Figures 5 to 8 in Appendix C show the reaction of the macroeconomies to these shocks. In each case, a deflationary recession takes place, which drives the economy to the zero lower bound on the nominal interest rate. The severity of the economic downturn, however, can be mitigated when the central bank publishes strategic inflation projections. This can be seen from Table 5 where we summarize important key indicators describing the median severity of the economic downturn in each of the four treatments. In the results description below, p-values of the two-sided Wilcoxon rank sum tests are reported only if differences in medians are statistically significant.

Table 5 shows that strategic projections on average halve the median time

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[26]Be reminded that in Stage III of Treatment 4 the public inflation projection is produced by the "good" computer algorithm instead of the random number generator.

spent at the zero lower bound, from 5 periods in Treatment 1 to less than 2.5 periods on average in Treatments 2-4. Secondly, the length of the recession[27] is significantly ($p_{(T1,T2:T4)} = 0.090$) reduced from 8 periods in Treatment 1 to less than 4 periods on average in Treatments 2-4. Also, the depth of the recession radically reduces in the presence of strategic projections. We measure the depth of the recession by comparing the latest pre-crisis output gap with the largest negative output gap during the crisis. In Treatment 1, the median depth is a loss in output gap of approximately -240 percent, whereas this loss is around -4 percent on average for Treatments 2-4. Prices, in all economies, fall, i.e., there is deflation. However, with 6.5 periods on average in Treatments 2-4 median deflation episodes are reduced by 1.5 periods relative to Treatment 1. All qualitative results carry over for pairwise comparisons of Treatment 1 to Treatments 2, 3, and 4.

Despite binding zero lower bounds and prolonged deflationary episodes, deflationary spirals are rare. However, they occur much more often in the absence of strategic projections than in the presence of strategic projections. In Treatment 1 three out of six economies result in a deflationary spiral after a series of severe fundamental shocks. While deflationary spirals can be avoided successfully in all six economies of Treatment 3, in both Treatments 2 and 4 one out of six economies result in a deflationary spiral. Therefore, published inflation projections significantly ($p_{(T1,T2:T4)} = 0.060$) reduce the occurrence of deflationary spirals.

The stabilizing role of published central bank inflation projections at the zero lower bound is particularly surprising, since at the zero lower bound an overoptimistic (or strategic) inflation projection can by no means be supported with movements of the interest rate. We believe that the evidence presented in this section supports Hypothesis 2(b).

6   Discussion

In this section we analyze the relationship between anchoring, credibility, and strategic-ness and its implications for the stabilizing role of published central bank inflation projections. This way, we shed light on the transmission channel through which published inflation projections affect the economy. We argue that the stabilizing effect of published projections functions through the anchoring of expectations around the public projection, i.e. credibility.[28] A high degree of strategic-ness helps to stabilize the economy only if the projections are credible. In case projection are not credible at all, they are without any effect on the macroeconomy.

As the influences of credibility and strategic-ness are generally interdependent in our experimental setup, we make use of two counterfactual simulations, which allow us to study each channel separately. In these counterfactuals, we assume that central bank projections are fully credible. Under this assumption,

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[27]According to the NBER, a recession is a drop in economic activity between peak and trough.

[28]Note that by definition credibility implies anchoring (around the projection), but that anchoring not necessarily implies credibility (e.g. if it takes place far away from the projection). In our experiment, however, there is a strong negative correlation between anchoring and credibility, suggesting that we can use these terms interchangably in the following analysis.

all professional forecasters strictly adopt the central bank projection in each period. In the first counterfactual (henceforth: CF1), the central bank publishes the non-strategic data-driven forecast as projection. This counterfactual allows us to isolate the role of credibility. By contrast, in the second counterfactual (henceforth: CF2), the projections are generated by the computer algorithm from Treatment 3. This counterfactual highlights the power of strategic-ness of a credible central bank.

6.1 The Effect of Credibility on Economic Stability

Now, we study in isolation the influence of credibility for the stabilizing role of published central bank inflation projections, i.e. we abstract from strategic behavior of the central bank. To do so, we compare CF1 to Treatments 1, i.e. Columns [1] and [5] of Table 4. Column [5] of Table 4 shows the average stability measures for inflation and output gap of the 6 counterfactual economies of CF1, where a fully credible non-strategic projection was available. The average stability measures from CF1 is significantly lower ($p < 0.05$) than the stability measures of Treatment 1, where no projection was available.[29] Thus, anchoring of expectations around the path implied by the data-driven forecast increases economic stability, even though these forecasts are non-strategic.

6.2 The Effect of Strategic-ness on Economic Stability

Next, we study the influence of strategic-ness for the stabilizing role of published central bank inflation projections. We measure the degree of strategic-ness in any period t by the deviation of the published inflation projection from the data-driven forecast, normalized by the necessary deviation from the data-driven forecast to reach the central bank's target values. This measure is given by

$$SP_t = \frac{E_t^{pub}\pi_{t+1} - E_t^{ddf}\pi_{t+1}}{E_t^{rft}\pi_{t+1} - E_t^{ddf}\pi_{t+1}}. \tag{16}$$

If $SP_t = 0$ the published projection coincides with the data-driven forecast. This is the case of purely informational behavior. A value $0 < SP_t < 1$ imply a positive degree of strategic behavior. If $SP_t = 1$ the published projection coincides with the "required for target." This is the case of perfectly strategic behavior.[30]

Table 6 summarizes the average session-median strategic-ness for Treatments 2 to 4 and the two counterfactuals. One-sample Wilcoxon tests show that in Treatments 2 and 3 the average session-median "strategic-ness" measures significantly exceed zero in all of the cases, indicating an overall strategic behavior of the central bank forecaster. Second, the two-sided Wilcoxon signed ranked

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[29]Note that the absence of a projection is observationally equivalent to the presence of a projection which is fully ignored, i.e. fully non-credible.

[30]The index can also take values above unity and below zero. If $SP_t > 1$ the published projection lies outside the interval of the data driven forecast and the "required for target" information, on the side of the "required for target". This implies that the central bank is trying to steer more than necessary to achieve the target. If $SP_t < 0$, the published projection lies outside the band of the data driven forecast and the "required for target" information, on the side of the data driven forecast. This implies that the central bank CB tries to drive expectations "away" from target. A proof of these claims is presented in Appendix B.

	[1] Treatment 2	[2] Treatment 3	[3] Treatment 4	[4] CF1	[5] CF2
Stage II	0.347 (0.177)	0.808 (0.102)	2.788 (1.259)	0.000 (0.000)	0.900 (0.047)
Stage III	0.505 (0.303)	0.553 (0.132)	0.512 (0.134)	0.000 (0.000)	0.683 (0.073)

Table 6: Average session-median strategic-ness for Treatments 2 to 4 and the two counterfactuals. Standard deviations in parentheses.

test finds that the median strategic-ness in Treatment 3 is significantly higher than in Treatment 2 (p-value=0.004).

In order to study in isolation (i.e. keeping credibility fixed) the influence of strategic-ness for the stabilizing role of published central bank inflation projections, we compare CF1, where the published projection equals the non-strategic data driven forecast to CF2, where the published projection follows the strategic algorithm of Treatment 3. In particular, we compare Columns [5] and [6] of Table 4. Column [6] of Table 4 shows the average stability measures for inflation and output gap from the 6 counterfactual economies of CF2. The results show that inflation in CF2 is significantly more stable ($p < 0.01$) compared to inflation in CF1. By contrast, for the output gap this difference is only marginally significant ($p < 0.1$). Thus, anchoring of expectations around a strategic path implied by the algorithm of Treatment 3, under full credibility, increases further economic stability.

CF1 and CF2 also provide insights into the role of strategic-ness at the zero lower bound (i.e. Stage III). In particular, we find that when the central bank publishes the data-driven forecast (CF1) all forced recessions result in a deflationary spiral. By contrast, when the central bank acts strategically (CF2), none of the forced recessions results in a deflationary spiral.

Another particularly illustrative example for the importance of strategic-ness to prevent deflationary spirals can be found when looking at the single economies from Treatment 2. Table 7 summarizes the median strategic-ness measures for the single economies in Stage III. First note the central bank forecaster in economy E11. The median "strategic-ness" measure (-0.0050) implies that this central bank forecaster does not act strategically at the zero lower bound, but instead resorts fully to the data-driven forecast, which predicts a deflationary spiral. Since projections act as a focal point for private-sector expectations, the economy falls into an expectation-driven deflationary spiral. The central bank forecasters of the other five economies, by contrast, do not publicly predict a deflationary spiral, but resort to strategic (in this case over-optimistic) inflation projections. None of their economies experiences a deflationary spiral.[31]

From the above analysis, we conclude that credibility is the catalyst by

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[31] Figure 9 in the appendix presents the Stage III time series for the inflation projection, the data-driven forecast, the "required for target," and the individual private-sector forecasts. The figure shows that the central bank forecaster in economy E11 tracks almost perfectly the data-driven forecast. Private forecasts are highly anchored on these predictions and consequently too follow the data-driven forecast. In the other five economies, the central bank forecaster substantially deviates upwards from the data-driven forecast, pulling expectations out of the slump.

	E7	E8	E9	E10	E11	E12
Median SP_t	0.7273	0.8061	0.4106	0.6970	-0.0050	0.3929

Table 7: Median "strategic-ness" measures (equation (16)) for the human central bank forecasters of Treatment 2.

which strategic projections translate into the economy, i.e. credibility is necessary for strategic projections to work. However, excessive strategic-ness of published projections may hamper credibility through systematic positive or negative forecast errors. The relationship between forecast performance and credibility is subject of the next section.

6.3 The Determinants of Credibility

To analyze the determinants of credibility, we follow Mokhtarzadeh and Petersen (2017) and estimate a series of probit models, where the dependent variable U_t is binary taking value 1 if individual professional forecasters utilized the central bank projection and 0 if not. A central bank projection is said to be *utilized* if an individual professional forecasters forecast is within 5 basis points of the respective central bank projection.[32] This measure acts as a proxy for our credibility measure from above, as it gives us the increase in the likelihood that a projection is closely followed. In accordance with Mokhtarzadeh and Petersen (2017), our explanatory variable is past forecasting performance of the central bank projections, measured by the absolute[33] forecast error from the previous period. As controls we employ the absolute deviation of previous inflation from the central bank's inflation target, the professional forecasters previous absolute forecast error, period $t-2$ utilization of the central bank projection, and the interaction of the latter two. The interaction term measures the degree to which past shaken confidence in the central bank projection influences the willingness to utilize the central bank projection in the future. Additionally, we control for past aggregate credibility of the central bank projection measured by the period $t-1$ credibility index, and the subjects cognitive ability measured by the three-item "cognitive reflection test" of Frederick (2005). The estimation results for Stage II from Treatments 2, 3, and 4 are presented in Table 8.[34]

The tables show that central bank projections are more likely to be adopted in the future, if they were accurate in the past, independent of whether the economy functions in normal times or in times of severe economic stress. Consequently, credibility increases in past forecasting performance, confirming Hypothesis 4. Additionally, credibility is a persistent phenomenon. If a professional forecaster adopted the central bank projection in the past or if it was credible

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[32]Mokhtarzadeh and Petersen (2017) choose a band of 2 basis points to identify utilization of the central bank projection, which yields approximately 20% of private forecasts to utilize the central bank projection in their experiment. In our experiment, a 2-basis-point band yields a utilization of only around 7.5%, whereas a 5-basis-point band yields around 17.5% utilization. The increased number of observations in the 5-basis-point case does not change the qualitative results of the estimation, but results in stronger statistical significance.

[33]Results do not change if forecast errors are squared. Only exception is that the interaction term gains significance. Results are available from the authors on request.

[34]The estimation results for Stage III can be found in Table 13 in Appendix C.

	[1]	[2]	[3]	[4]	[5]
constant	−0.712***	−0.559***	−1.495***	−1.700***	−1.697***
	[0.063]	[0.066]	[0.162]	[0.175]	[0.175]
$\|E^{pub}_{t-2}\pi_{t-1} - \pi_{t-1}\|$	−0.383***	−0.331***	−0.131**	−0.133**	−0.144**
	[0.051]	[0.047]	[0.055]	[0.055]	[0.056]
U_{t-2}	0.693***	0.666***	0.518***	0.491***	0.361***
	[0.126]	[0.121]	[0.124]	[0.125]	[0.088]
$\|E^{fc,j}_{t-2}\pi_{t-1} - \pi_{t-1}\|$	−0.054	−0.013	−0.017	−0.014	
	[0.073]	[0.027]	[0.030]	[0.028]	
$\|E^{fc,j}_{t-2}\pi_{t-1} - \pi_{t-1}\| * U_{t-2}$	−0.317	−0.292	−0.299	−0.279	
	[0.196]	[0.184]	[0.190]	[0.190]	
$\|\pi_{t-1} - \pi^T\|$		−0.440***	−0.319***	−0.319***	−0.333***
		[0.098]	[0.100]	[0.100]	[0.100]
I^{cred}_{t-1}			1.208***	1.185***	1.179***
			[0.190]	[0.191]	[0.191]
CRT				0.110***	0.113***
				[0.035]	[0.035]

Table 8: Determinants of the utilization of central bank projections in Stage II. This table summarizes the results of a series of probit models from Section 6.3, where the dependent variable U_t is binary taking value 1 if individual professional forecasters utilized the central bank projection and 0 if not. A central bank projection is said to be utilized if an individual professional forecasters forecast is within 5 basis points of the respective central bank projection. The data used for estimation of the series of probit models stems from Stage II of Treatments 2, 3, and 4.

in the past, the professional forecasters are more likely to adopt the central bank projection in the future. Even if the adoption of a past projection ex-post turns out to be a disappointment, i.e., it resulted in an own large forecast error, the willingness of the professional forecaster to adopt future central bank projections remains unchanged, which can be read from the insignificance of the interaction term in Tables 8 and 13. Subjects seem to pay more attention to the performance of the central bank projections than to reflect on their past behavior and its outcomes. Finally, the probit regressions shows that cognitive ability increases the likelihood to adopt central bank projection.

Finally, we would like to raise a note of caution; although credibility, be it high or low, is a very persistent phenomenon, it can change quickly in response to extreme changes in the economic environment. An illustrative example can be found comparing the severe recessions of Treatments 3 and 4. Whereas the central bank's average Treatment 3 credibility reduces dramatically when entering the recession in Stage III (from 0.9 in Stage II to 0.5 in Stage III), the average Treatment 4 credibility increases massively (from 0.0 to 0.4) by switching from the random projections in Stage II to the algorithmic projection in Stage III, despite the challenges put forth to the algorithm by the recession.

7   Conclusion

In this paper, we study the stabilizing role of published central bank inflation projections in a standard New Keynesian learning-to-forecast laboratory experiment. Subjects take the role of "professional forecasters" in the private sector who form one-period ahead inflation forecasts. Subjects are provided with a limited understanding of the true data generating process and a public central bank inflation projection. We show that central banks can manage private-sector expectations via the publication of strategic central bank inflation projections and that such expectations management can successfully be applied as an additional monetary policy instrument to stabilize the economy.

In particular, we show that published central bank inflation projections considerably influences the subjects' expectations formation process. In the absence of published inflation projections, subjects expectation formation process is well characterized as mostly backward-looking with simple trend following. In the presence of published central bank projections, by contrast, the public inflation projection becomes an influential piece of information which starkly diminishes the prevalence of backward-looking expectation formation. Consequently, strategic inflation projections act as a focal point, anchoring expectation and thereby decreasing the dispersion among individual forecasts.

This influence on expectations allows the central bank to stabilize the economy; i.e. to bring inflation and output faster and closer towards their respective target values and reduce their volatility over the business cycle. At the zero lower bound, the publication of overly optimistic (i.e. strategic) projections greatly reduce the risk of deflationary spirals. Random inflation projections, by contrast, are generally harmful to the economy as they unleash disturbing forces which give rise to large fluctuations of the economy. Finally, we show that credibility is an important precondition for the stabilizing role of published central bank inflation projections, but that achieving full credibility on the expense of all strategic behavior is not optimal either.

Our results have important implications for central bank practice. We show that published central bank inflation projections are a powerful tool expectations management and for stabilization policy in normal times and at the zero lower bound. However, while a good track record of accurate forecasts is important for credibility, we find that some strategic-ness in the published projection greatly enhances the stabilizing power of central bank inflation projections. Especially in times of severe economic stress, fully truthful projections may be harmful rather than beneficial.

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A Estimation procedure for equation (12)

First Formula (12) is estimated with OLS. Then the joint significance of all the coefficients that where found to be individually insignificant in the above regression is tested. If these coefficients are jointly insignificant, all of them are removed. If they are jointly significant, exactly 1 coefficient is removed. The coefficient that is removed is then the individually insignificant coefficient that ranks first in the following order of removal list: $\alpha_2, \gamma_1, \beta_2, \delta, \beta_1, \alpha_1, c$.

After one or more coefficients are removed, Equation (12) is reestimated without this (these) coefficient(s). Then the joint significance of the coefficients found to be individually insignificant in the new regression is tested and coefficient(s) are removed according to the same procedure as above. This process is repeated until either a regression is performed where all remaining coefficients are individually significant, or until all coefficients are removed.

B Proof of "strategic-ness" index

Below we proof the following three claims about the "strategic-ness" index, SP_t, of equation (16):
(a) $0 < SP_t < 1$ implies that the published projection lies in the band between the data driven forecast and the "required for target" information:
$E_t^{rft}\pi_{t+1} < E_t^{pub}\pi_{t+1} < E_t^{ddf}\pi_{t+1}$ or $E_t^{ddf}\pi_{t+1} < E_t^{pub}\pi_{t+1} < E_t^{rft}\pi_{t+1}$
(b) $SP_t > 1$ implies that the published projection lies outside the band of the data driven forecast and the "required for target" information, on the side of the "required for target":
$E_t^{pub}\pi_{t+1} < E_t^{rft}\pi_{t+1} < E_t^{ddf}\pi_{t+1}$ or $E_t^{ddf}\pi_{t+1} < E_t^{rft}\pi_{t+1} < E_t^{pub}\pi_{t+1}$
(c) $SP_t < 0$ implies that the published projection lies outside the band of the data driven forecast and the "required for target" information, on the side of the data driven forecast:
$E_t^{pub}\pi_{t+1} < E_t^{ddf}\pi_{t+1} < E_t^{rft}\pi_{t+1}$ or $E_t^{rft}\pi_{t+1} < E_t^{ddf}\pi_{t+1} < E_t^{pub}\pi_{t+1}$
Proof: (1) When $0 < SP_t$ either both numerator and denominator in Equation (16) are negative or both are positive:

(i) Consider that both numerator and denominator are negative. It must be that $E_t^{pub}\pi_{t+1} < E_t^{ddf}\pi_{t+1}$ and $E_t^{rft}\pi_{t+1} < E_t^{ddf}\pi_{t+1}$. Since the denominator is negative $SP_t < 1$ further implies that $E_t^{pub}\pi_{t+1} - E_t^{ddf}\pi_{t+1} > E_t^{rft}\pi_{t+1} - E_t^{ddf}\pi_{t+1}$ so that $E_t^{rft}\pi_{t+1} < E_t^{pub}\pi_{t+1}$ and hence $E_t^{rft}\pi_{t+1} < E_t^{pub}\pi_{t+1} < E_t^{ddf}\pi_{t+1}$. $SP_t > 1$, on the other hand, implies that $E_t^{rft}\pi_{t+1} > E_t^{pub}\pi_{t+1}$ and hence $E_t^{pub}\pi_{t+1} < E_t^{rft}\pi_{t+1} < E_t^{ddf}\pi_{t+1}$.

(ii) Consider that both numerator and denominator are positive. $0 < SP_t$ implies $E_t^{pub}\pi_{t+1} > E_t^{ddf}\pi_{t+1}$ and $E_t^{rft}\pi_{t+1} > E_t^{ddf}\pi_{t+1}$. $SP_t < 1$ then implies $E_t^{pub}\pi_{t+1} - E_t^{ddf}\pi_{t+1} < E_t^{rft}\pi_{t+1} - E_t^{ddf}\pi_{t+1}$ so that $E_t^{ddf}\pi_{t+1} < E_t^{pub}\pi_{t+1} < E_t^{rft}\pi_{t+1}$, while $SP_t > 1$ implies $E_t^{ddf}\pi_{t+1} < E_t^{rft}\pi_{t+1} < E_t^{pub}\pi_{t+1}$. This completes the proof of (a) and (b).
(2) When $SP_t < 0$, either the numerator of Equation (16) is negative while the denominator is positive, or the numerator is positive while the denominator is negative: In the first case, it must hold that $E_t^{pub}\pi_{t+1} < E_t^{ddf}\pi_{t+1}$ while $E_t^{rft}\pi_{t+1} > E_t^{ddf}\pi_{t+1}$. In the second case, it must hold that $E_t^{pub}\pi_{t+1} > E_t^{ddf}\pi_{t+1}$ while $E_t^{rft}\pi_{t+1} < E_t^{ddf}\pi_{t+1}$. This proves (c).

C   Additional tables and figures

Statistic/Economy	E1	E2	E3	E4	E5	E6	Avg
			Periods 1-8 (Stage I)				
			Inflation				
Mean	3.0	2.6	2.8	2.6	2.0	1.9	2.5
Median	2.6	3.2	2.4	2.5	2.1	1.6	2.4
Variance	0.4	1.6	1.0	0.4	2.5	2.6	1.4
			Output gap				
Mean	-1.2	-0.9	-0.7	-0.9	-0.8	-0.7	-0.9
Median	-1.2	-0.9	-0.7	-0.8	-0.9	-0.8	-0.9
Variance	0.1	0.2	0.3	0.3	0.2	0.4	0.2
			Interest rate				
Mean	7.4	7.0	7.3	7.1	6.2	6.2	6.9
Median	6.9	7.7	6.8	6.8	6.3	5.6	6.7
Variance	0.8	2.5	1.6	0.8	3.7	4.2	2.3
			Periods 9-28 (Stage II)				
			Inflation				
Mean	1.2	0.5	1.4	0.8	-0.3	1.1	0.8
Median	1.1	0.5	1.4	0.5	-1.0	1.0	0.6
Variance	0.4	0.3	0.2	0.5	3.2	1.0	1.0
			Output gap				
Mean	-0.7	-0.3	-0.5	-0.3	-0.2	-0.4	-0.4
Median	-0.7	-0.3	-0.4	-0.3	0.0	-0.4	-0.4
Variance	0.1	0.2	0.2	0.2	0.3	0.2	0.2
			Interest rate				
Mean	5.3	4.6	5.6	4.9	3.5	5.2	4.9
Median	5.2	4.3	5.7	4.6	2.7	5.1	4.6
Variance	0.7	0.5	0.4	0.7	4.7	1.3	1.4
			Periods 29-37 (Stage III)				
			Inflation				
Mean	-1.6	-1.0	-0.2	-65.9	-73.7	-128.4	-45.1
Median	-1.9	-1.6	-0.4	-14.6	-11.5	-21.8	-8.6
Variance	1.0	1.9	1.0	$1.1{*}10^4$	$1.9{*}10^4$	$6.2{*}10^4$	$1.5{*}10^4$
			Output gap				
Mean	-1.5	-1.2	-1.9	-92.5	-90.6	-156.6	-57.4
Median	-2.1	-1.1	-1.5	-14.7	-12.4	-26.3	-9.7
Variance	3.1	2.1	4.2	$2.5{*}10^4$	$2.8{*}10^4$	$8.7{*}10^4$	$2.3{*}10^4$
			Interest rate				
Mean	1.5	2.3	3.1	0.3	0.7	0.2	1.3
Median	1.2	1.8	3.2	0.0	0.0	0.0	1.0
Variance	2.5	4.7	3.8	0.5	2.5	0.4	2.4

Table 9: Descriptive Statistics of Treatment 1 (Control). The table summarizes mean, median, and variance in each of the three stages for each of the six economies of Treatment 1 as well as their corresponding averages over all six economies of Treatment 1.

Statistic/Economy	E7	E8	E9	E10	E11	E12	Avg
				Periods 1-8 (Stage I)			
				Inflation			
Mean	3.1	2.5	2.9	3.4	2.2	1.6	2.6
Median	3.2	3.0	2.7	3.4	2.3	1.5	2.7
Variance	1.3	1.8	0.5	0.1	1.2	0.9	1.0
				Output gap			
Mean	-1.3	-0.9	-0.7	-1.2	-0.9	-0.5	-0.9
Median	-1.4	-0.9	-0.8	-1.1	-1.0	-0.6	-1.0
Variance	0.1	0.2	0.2	0.5	0.2	0.2	0.2
				Interest rate			
Mean	7.5	6.9	7.5	8.0	6.5	5.9	7.0
Median	7.7	7.4	7.1	7.9	6.7	5.7	7.1
Variance	2.2	2.8	0.8	0.2	1.9	1.7	1.6
				Periods 9-28 (Stage II)			
				Inflation			
Mean	0.5	0.2	0.3	0.9	0.1	0.5	0.4
Median	0.4	0.3	0.4	0.8	0.2	0.5	0.4
Variance	0.3	0.2	0.3	0.8	0.5	0.5	0.4
				Output gap			
Mean	-0.4	-0.2	-0.2	-0.3	-0.4	-0.2	-0.3
Median	-0.5	-0.2	0.0	-0.3	-0.3	-0.2	-0.3
Variance	0.1	0.2	0.2	0.2	0.1	0.1	0.2
				Interest rate			
Mean	4.5	4.2	4.4	5.0	4.0	4.6	4.4
Median	4.4	4.3	4.5	5.0	4.1	4.6	4.5
Variance	0.4	0.3	0.6	1.1	0.9	0.8	0.7
				Periods 29-37 (Stage III)			
				Inflation			
Mean	-0.9	-1.2	-1.7	-1.3	-23.1	-0.9	-4.9
Median	-1.0	-0.6	-2.0	-1.6	-8.9	-0.7	-2.5
Variance	1.0	2.7	6.7	3.5	1155.5	2.5	195.3
				Output gap			
Mean	-2.0	-1.5	-2.4	-1.8	-29.6	-1.6	-6.5
Median	-2.3	-1.7	-2.3	-2.2	-10.4	-1.3	-3.4
Variance	4.7	3.0	4.6	4.7	1898.8	2.9	319.8
				Interest rate			
Mean	2.3	2.3	2.1	2.2	0.2	2.5	1.9
Median	2.0	3.0	0.4	1.3	0.0	2.3	1.5
Variance	3.7	4.4	7.6	4.9	0.4	4.8	4.3

Table 10: Descriptive Statistics of Treatment 2. The table summarizes mean, median, and variance in each of the three stages for each of the six economies of Treatment 2 as well as their corresponding averages over all six economies of Treatment 2.

Statistic/Economy	E13	E14	E15	E16	E17	E18	Avg
				Periods 1-8 (Stage I)			
				Inflation			
Mean	2.4	2.2	2.4	2.8	2.6	3.0	2.6
Median	1.8	2.6	2.5	2.9	2.7	2.8	2.5
Variance	0.7	1.7	0.0	1.5	0.4	1.4	1.0
				Output gap			
Mean	-1.0	-0.8	-0.5	-0.9	-1.0	-1.0	-0.9
Median	-1.0	-0.8	-0.6	-0.8	-1.1	-1.1	-0.9
Variance	0.1	0.1	0.2	0.5	0.1	0.4	0.2
				Interest rate			
Mean	6.7	6.5	6.8	7.3	7.0	7.5	7.0
Median	6.0	6.9	6.9	7.3	7.0	7.1	6.9
Variance	1.2	2.8	0.1	2.6	0.7	2.5	1.7
				Periods 9-28 (Stage II)			
				Inflation			
Mean	0.4	0.0	0.2	0.3	0.0	0.8	0.3
Median	0.4	0.0	0.2	0.2	-0.1	0.6	0.2
Variance	0.2	0.2	0.2	0.3	0.4	1.0	0.4
				Output gap			
Mean	-0.4	-0.1	-0.1	-0.1	-0.4	-0.4	-0.2
Median	-0.4	-0.2	0.0	-0.1	-0.2	-0.4	-0.2
Variance	0.1	0.1	0.2	0.1	0.2	0.2	0.2
				Interest rate			
Mean	4.4	4.0	4.2	4.3	3.9	4.9	4.3
Median	4.4	4.0	4.3	4.3	3.7	4.6	4.2
Variance	0.3	0.3	0.3	0.4	0.6	1.4	0.6
				Periods 29-37 (Stage III)			
				Inflation			
Mean	-0.8	-1.8	-0.9	-1.0	-1.7	-2.0	-1.4
Median	-0.8	-2.3	-0.9	-1.6	-1.7	-1.8	-1.5
Variance	0.9	1.0	1.1	3.1	1.5	3.5	1.9
				Output gap			
Mean	-1.9	-1.2	-1.7	-1.5	-1.9	-1.8	-1.7
Median	-2.1	-1.4	-1.7	-1.0	-2.0	-2.6	-1.8
Variance	4.4	3.2	4.4	5.4	3.2	2.7	3.9
				Interest rate			
Mean	2.3	1.4	2.3	2.4	1.5	1.5	1.9
Median	2.1	1.3	2.2	2.3	0.7	0.0	1.4
Variance	3.6	1.9	3.4	6.2	2.8	4.4	3.7

Table 11: Descriptive Statistics of Treatment 3. The table summarizes mean, median, and variance in each of the three stages for each of the six economies of Treatment 3 as well as their corresponding averages over all six economies of Treatment 3.

Statistic/Economy	E19	E20	E21	E22	E23	E24	Avg
			Periods 1-8 (Stage I)				
			Inflation				
Mean	1.6	2.3	2.2	3.0	2.6	2.9	2.5
Median	1.2	2.7	2.3	3.0	2.4	2.6	2.4
Variance	0.7	1.7	0.6	0.5	1.1	0.6	0.9
			Output gap				
Mean	-0.7	-0.8	-0.5	-1.0	-1.0	-1.0	-0.8
Median	-0.7	-0.9	-0.5	-0.9	-1.1	-1.0	-0.8
Variance	0.0	0.1	0.2	0.4	0.1	0.3	0.2
			Interest rate				
Mean	5.8	6.7	6.7	7.5	7.0	7.4	6.8
Median	5.3	7.1	6.7	7.5	6.7	7.0	6.7
Variance	1.1	2.8	1.0	1.0	1.8	1.2	1.5
			Periods 9-28 (Stage II)				
			Inflation				
Mean	0.2	-0.1	1.1	0.9	0.6	0.9	0.6
Median	0.2	-0.1	1.0	1.1	0.6	1.1	0.7
Variance	0.6	0.2	0.2	1.0	0.6	2.5	0.8
			Output gap				
Mean	-0.2	-0.1	-0.4	-0.3	-0.6	-0.4	-0.3
Median	-0.3	-0.1	-0.3	-0.2	-0.5	-0.4	-0.3
Variance	0.1	0.2	0.3	0.0	0.2	0.2	0.2
			Interest rate				
Mean	4.1	3.9	5.2	5.1	4.5	5.0	4.6
Median	4.2	3.8	5.2	5.4	4.5	5.2	4.7
Variance	0.9	0.3	0.2	1.7	1.0	3.4	1.2
			Periods 29-37 (Stage III)				
			Inflation				
Mean	-0.7	-1.5	-13.6	-1.1	-0.6	0.3	-2.9
Median	-1.0	-1.9	-6.0	-1.4	-0.5	0.4	-1.7
Variance	1.1	0.8	409.4	1.0	0.9	2.9	69.4
			Output gap				
Mean	-1.9	-1.0	-15.2	-1.4	-2.2	-2.2	-4.0
Median	-2.0	-0.9	-5.2	-0.8	-2.4	-2.1	-2.2
Variance	4.4	2.7	482.0	4.4	2.4	4.2	83.3
			Interest rate				
Mean	2.5	1.6	0.5	2.1	2.5	3.7	2.1
Median	2.2	1.1	0.0	2.2	2.5	3.6	1.9
Variance	4.3	2.1	1.1	3.3	3.2	7.7	3.6

Table 12: Descriptive Statistics of Treatment 4. The table summarizes mean, median, and variance in each of the three stages for each of the six economies of Treatment 4 as well as their corresponding averages over all six economies of Treatment 4.

	[1]	[2]	[3]	[4]	[5]
constant	−0.798***	−0.481***	−0.923***	−0.983***	−0.892***
	[0.070]	[0.082]	[0.141]	[0.152]	[0.136]
$\|E_{t-2}^{pub}\pi_{t-1} - \pi_{t-1}\|$	−0.314***	−0.258***	−0.273***	−0.277***	−0.281***
	[0.052]	[0.058]	[0.061]	[0.061]	[0.061]
U_{t-2}	0.826***	0.616***	0.521***	0.509***	0.411***
	[0.160]	[0.167]	[0.169]	[0.170]	[0.098]
$\|E_{t-2}^{fc,j}\pi_{t-1} - \pi_{t-1}\|$	0.059	0.114**	0.136**	0.139**	0.126**
	[0.050]	[0.055]	[0.057]	[0.057]	[0.056]
$\|E_{t-2}^{fc,j}\pi_{t-1} - \pi_{t-1}\| * U_{t-2}$	−0.171*	−0.057	−0.085	−0.082	
	[0.102]	[0.107]	[0.107]	[0.107]	
$\|\pi_{t-1} - \pi^{T}\|$		−0.334***	−0.310***	−0.310***	−0.314***
		[0.040]	[0.040]	[0.040]	[0.040]
I_{t-1}^{cred}			0.703***	0.698***	0.694***
			[0.182]	[0.182]	[0.694]
CRT				0.034	
				[0.034]	

Table 13: Determinants of the utilization of central bank projections in Stage III. This table summarizes the results of a series of probit models from Section 6.3, where the dependent variable U_t is binary taking value 1 if individual professional forecasters utilized the central bank projection and 0 if not. A central bank projection is said to be utilized if an individual professional forecasters forecast is within 5 basis points of the respective central bank projection. The data used for estimation of the series of probit models stems from Stage II of Treatments 2, 3, and 4.
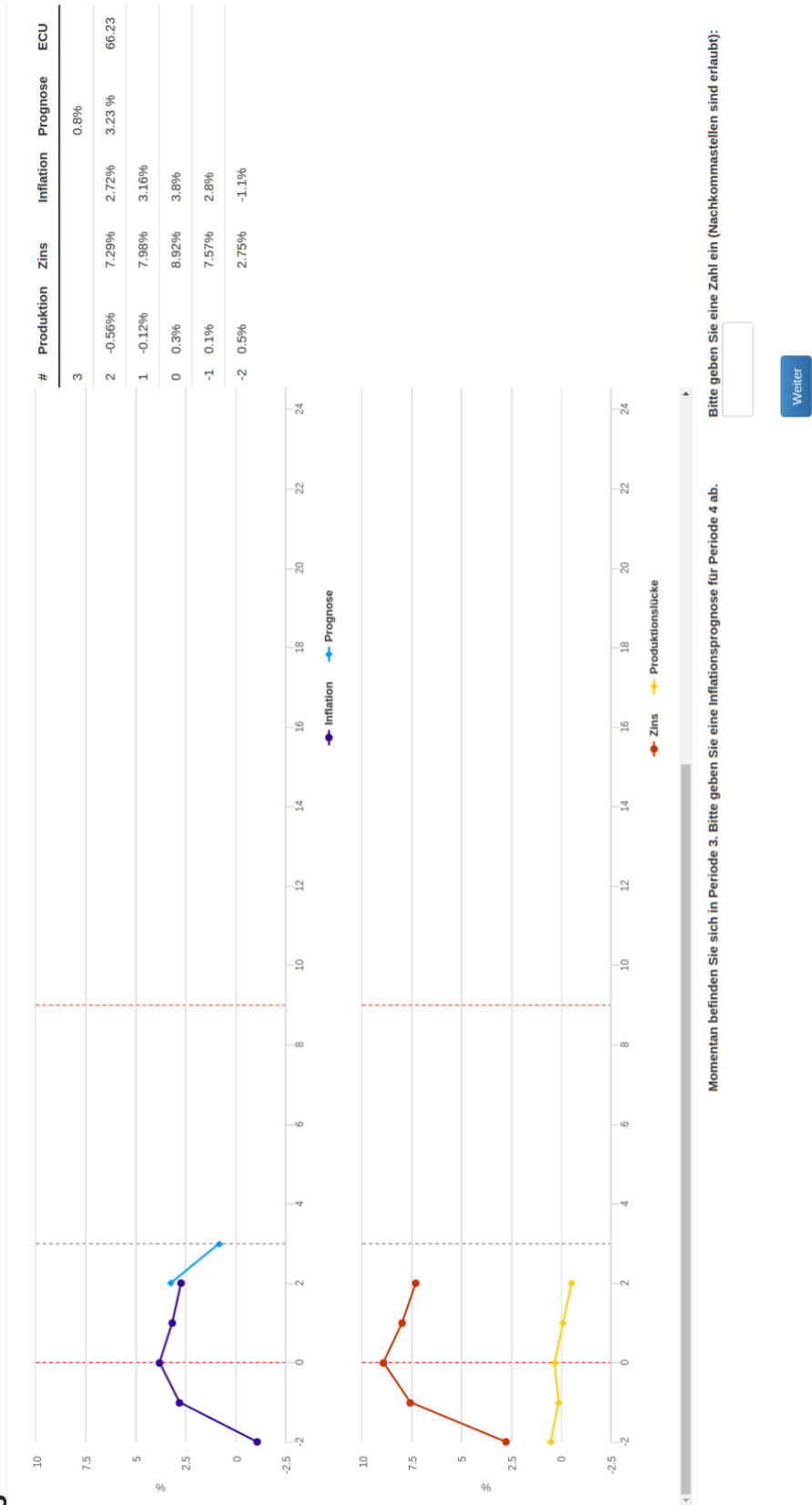
Figure 4: Computer interface as seen by the subjects. The figure shows the graphical and tabular representation of the complete history of the economy as well as the timer and the input box. The exemplary subject is currently in period 3 and she is asked to provide a forecast for period 4.
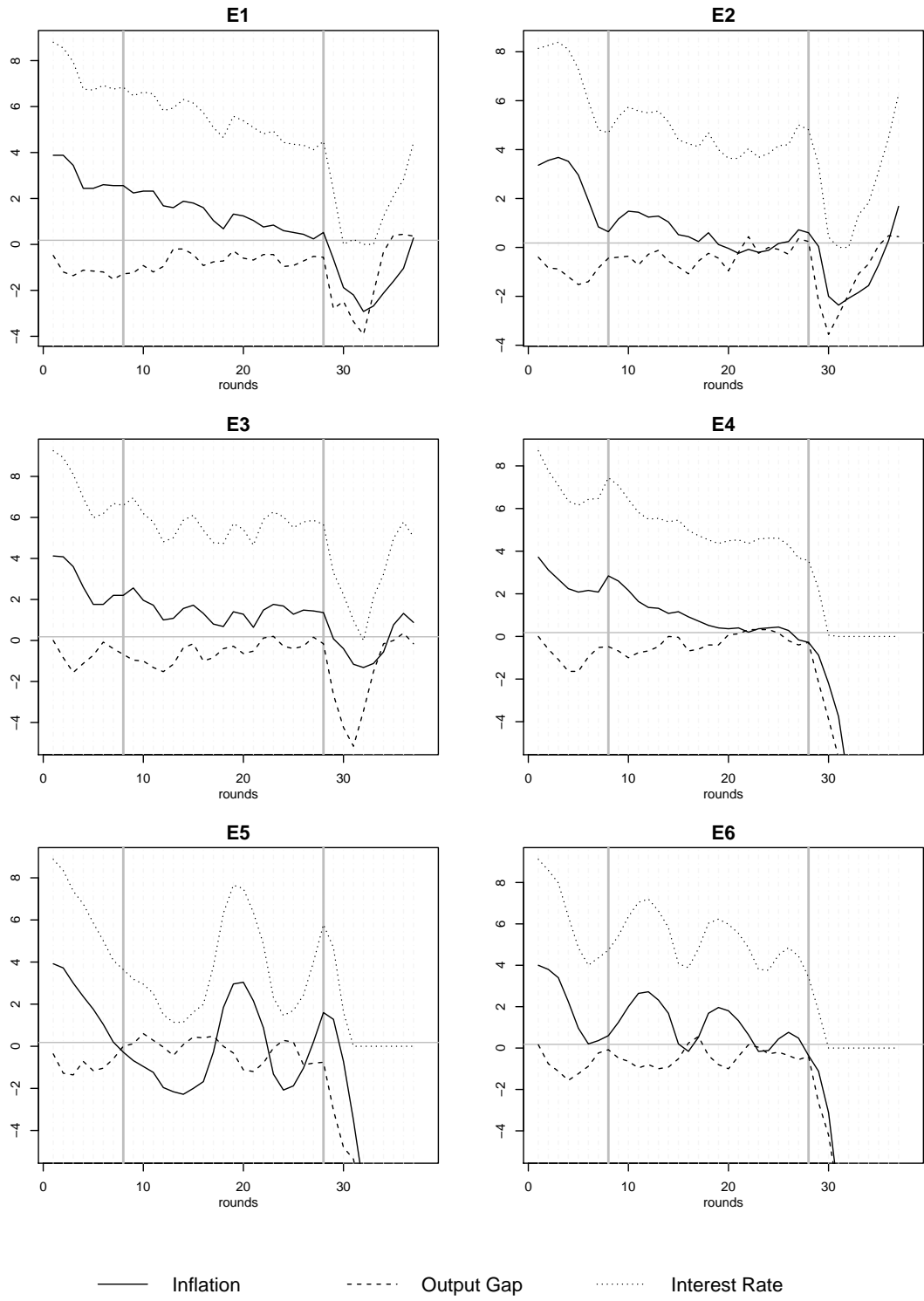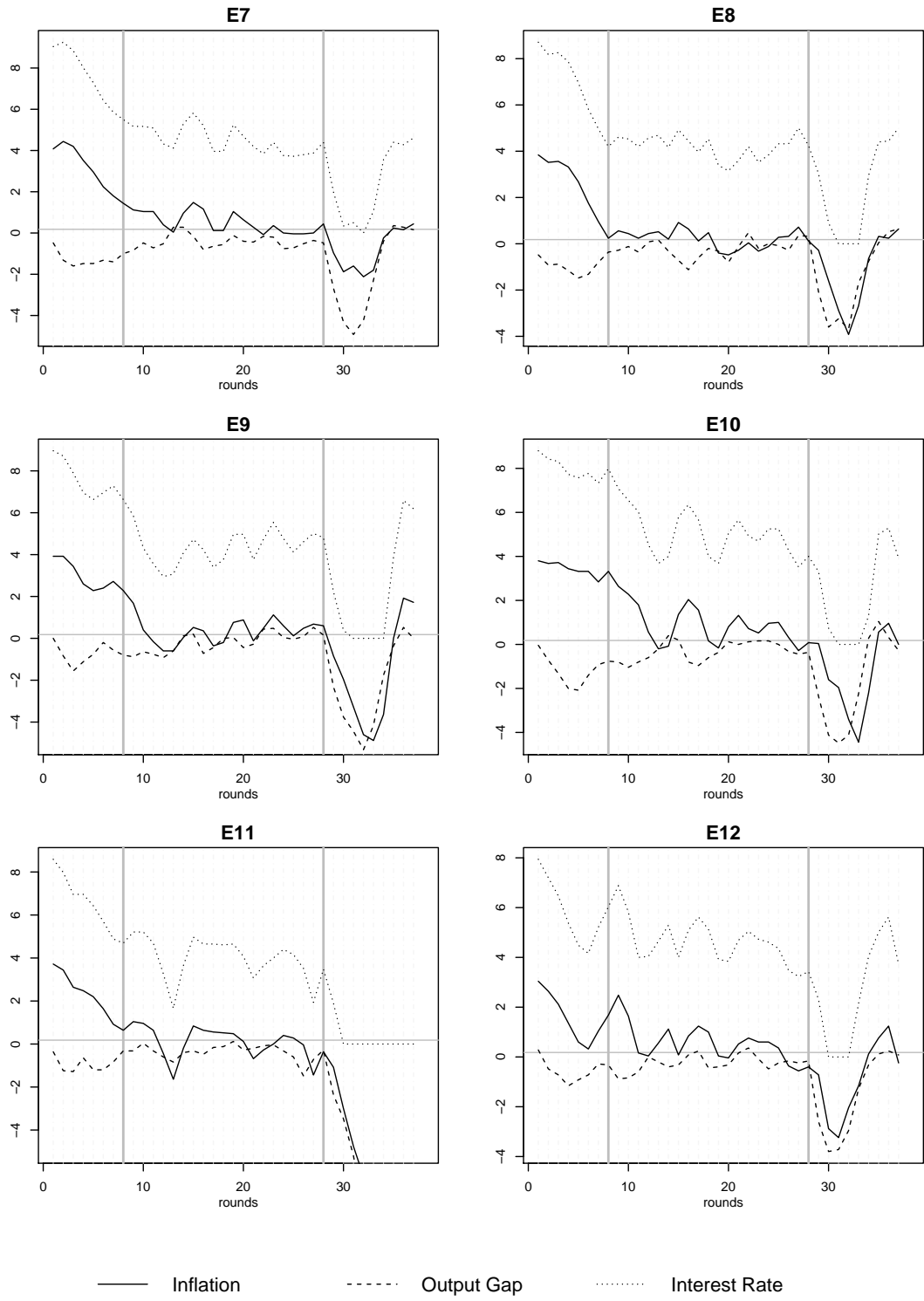
Figure 5: Resulting aggregate time series for inflation (solid line), the output gap (dashed line), and the interest rate (dotted line) for all six experimental economies of Treatment 1 (control treatment).
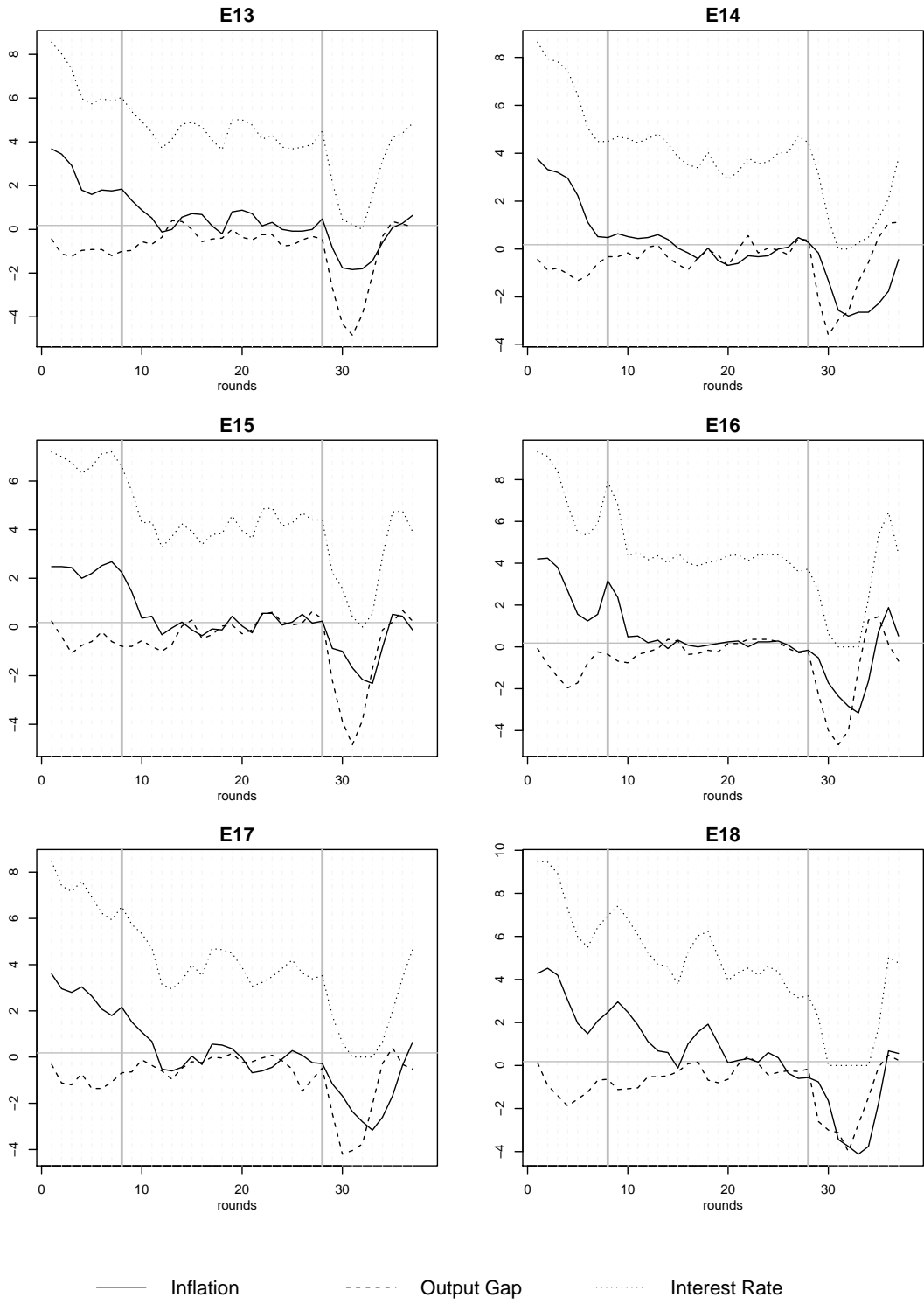
Figure 6: Resulting aggregate time series for inflation (solid line), the output gap (dashed line), and the interest rate (dotted line) for all six experimental economies of Treatment 2.
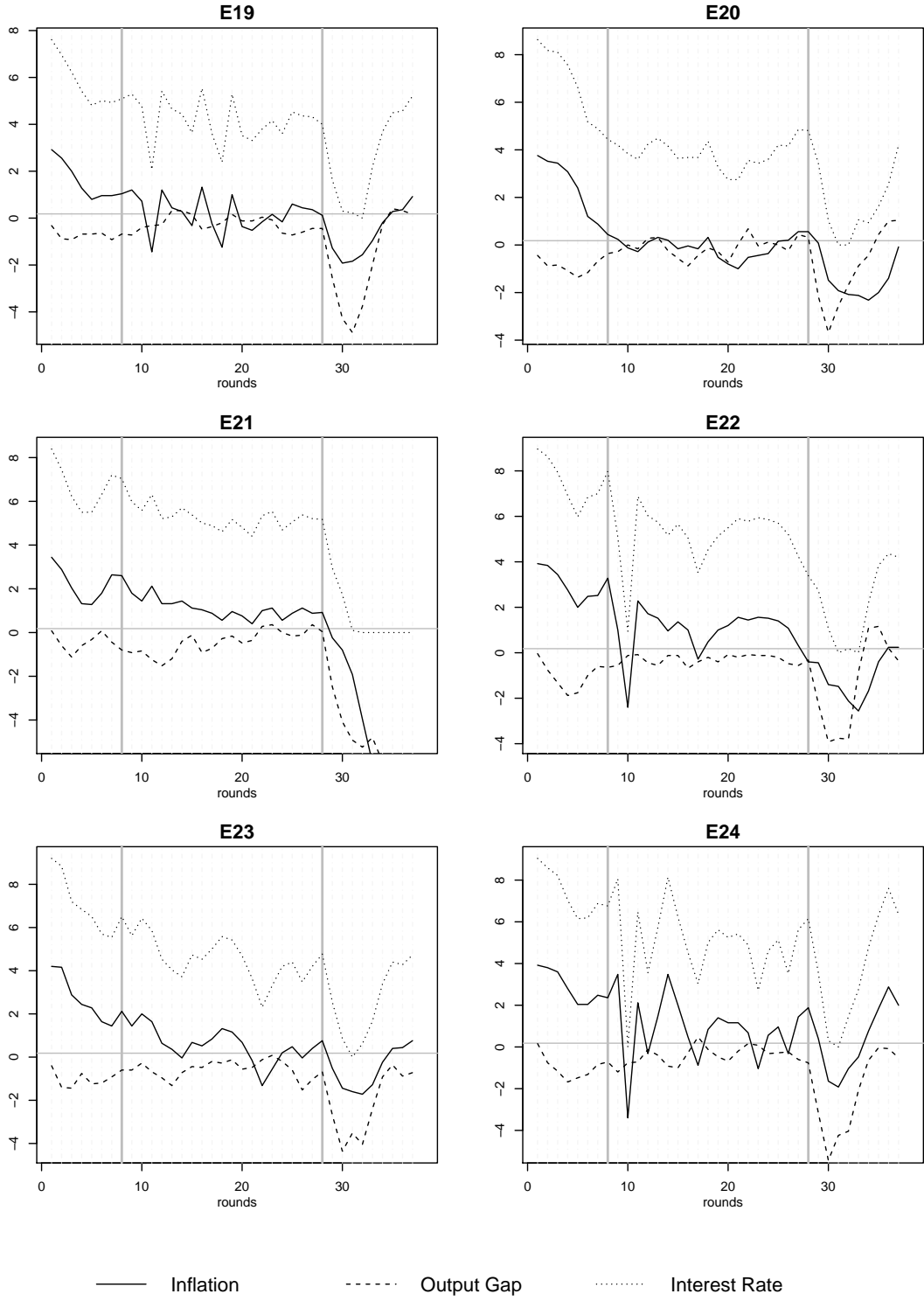
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Figure 7: Resulting aggregate time series for inflation (solid line), the output gap (dashed line), and the interest rate (dotted line) for all six experimental economies of Treatment 3.

Figure 8: Resulting aggregate time series for inflation (solid line), the output gap (dashed line), and the interest rate (dotted line) for all six experimental economies of Treatment 4.
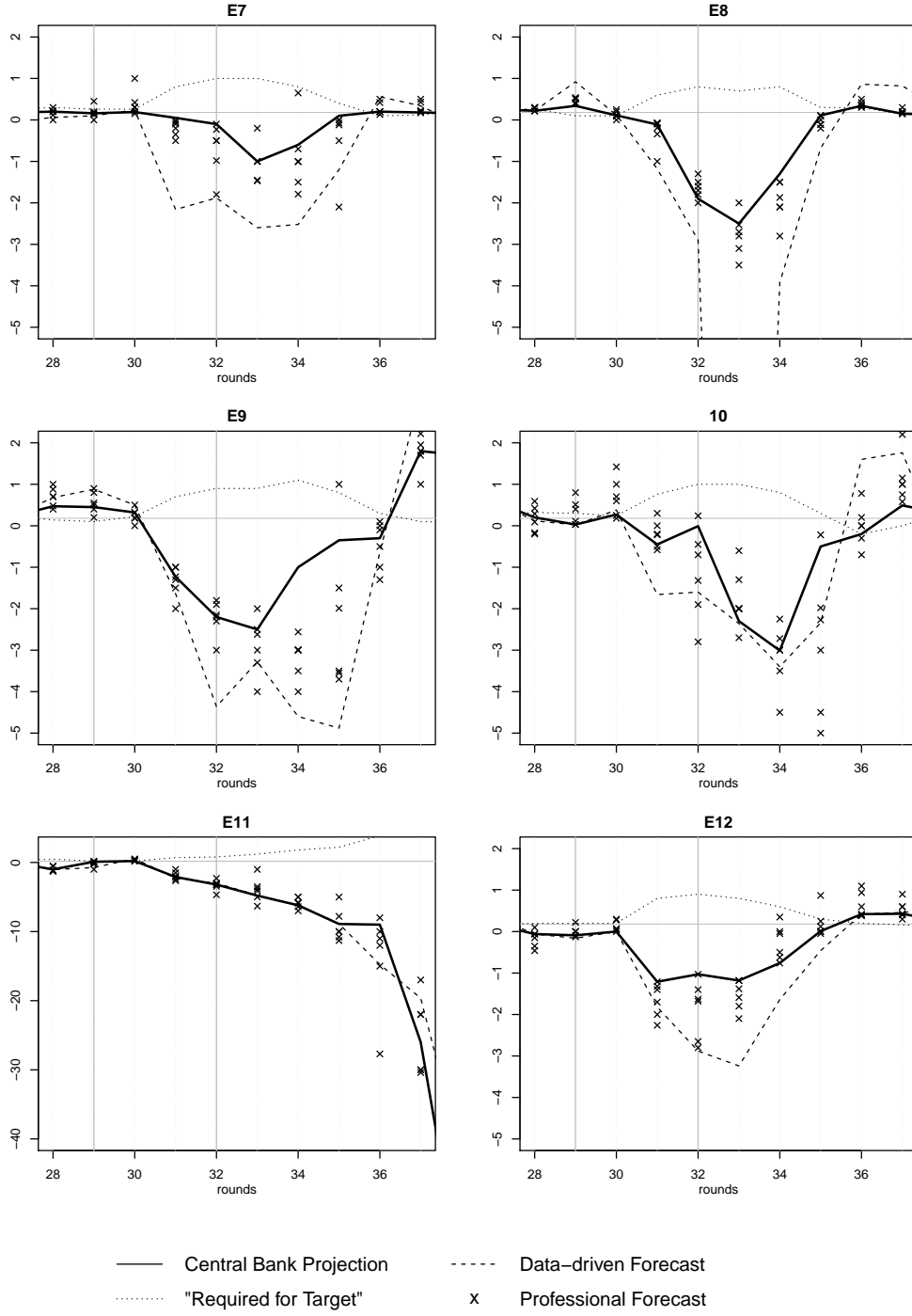
Figure 9: Stage III time series for the public central bank inflation projection (solid line), the data-driven forecast (dashed line), the "required for target" (dotted line), and the individual private-sector forecasts (x) for all six experimental economies of Treatment 2. Vertical gray lines denote the four-period fundamental shock sequence.

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