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DOES INFLATION TARGETING MATTER? AN EXPERIMENTAL INVESTIGATION

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We use laboratory experiments with human subjects to test the relevance of different inflation-targeting regimes. In particular and within the standard New Keynesian model, we evaluate to what extent communication of the inflation target is relevant to the success of inflation targeting. We find that if the central bank cares only about inflation stabilization, announcing the inflation target does not make a difference in terms of macroeconomic performance compared with a standard active monetary policy. However, if the central bank also cares about the stabilization of economic activity, communicating the target helps to reduce the volatility of inflation, interest rate, and output gap, although their average levels are not affected. This finding is consistent with the theoretical literature and provides a rationale for the adoption of a flexible inflation-targeting regime.

Keywords: Inflation Targeting, Inflation Expectations, Central Bank Communication, Monetary Policy, New Keynesian Model, Laboratory Experiments

1. INTRODUCTION

Inflation targeting (IT) is a monetary policy strategy mainly characterized by (a) an explicit announcement of a numerical or band target for inflation to the public, (b) a clear central bank mandate to pursue inflation stabilization as the primary objective of monetary policy, and (c) a high degree of transparency and accountability. Empirically, there are a wide variety of IT regimes, depending

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on the degree to which these criteria are applied. As the benefits of explicitly adopting an IT regime are still debated in the literature, this paper experimentally investigates to what extent (a) and (b) matter in terms of macroeconomic outcomes.

Although a large part of the literature suggests that explicit IT regimes are generally associated with higher macroeconomic performance [Levin et al. (2004); Roger and Stone (2005); Roger (2009)], some studies, including Ball and Sheridan (2005), Lin and Ye (2007), Angeriz and Arestis (2008), and Willard (2012), find that there is no evidence that these performances are attributable to IT in OECD countries: Both targeting and nontargeting economies have been successful in achieving and maintaining low inflation, suggesting that a central bank does not need to implement an explicit IT regime to achieve higher macroeconomic performance. To explain these findings, Svensson (2010) argues that many non-IT developed countries have adopted a monetary policy framework that is very similar to IT, which makes the real role of the latter hardly interpretable. Although there seems to be consensus on the relevance of IT in emerging countries [Fraga et al. (2003), Lin and Ye (2009)], Brito and Bystedt (2010), among others, find that this regime has no significant impact on macroeconomic outcomes in these countries. The empirical literature thus questions the relevance of IT regimes to economic performance.

Regarding the importance of communication for IT to be effective, the empirical evidence is scarce. Chadha and Nolan (2001) and Swanson (2006) find that central bank announcements about their policy objectives in IT countries did not create more financial instability. Nevertheless, in terms of inflation expectations management, although Johnson (2002) finds evidence that expected inflation falls after the announcement of an inflation target, he shows that IT does not lead to lower forecast errors for disinflation in IT countries than in non-IT countries. In the same spirit, Gurkaynak et al. (2010) emphasize that long-term inflation expectations respond less to central bank announcements in Sweden and the United Kingdom than they do in the United States, suggesting that communication may be more effective in non-IT countries.

Although survey data offer the advantage of dealing with natural expectations, they do not make it possible to perfectly disentangle the effect of announcing the target and that of the central bank's objectives. Turning to a laboratory experiment as a complementary tool offers a controlled environment in which the experimenter can observe how subjects form inflation expectations and their impact on aggregate outcomes in different informational and institutional contexts.

Built on a standard New Keynesian framework, this paper aims precisely at restating the macroeconomic performance (in terms of inflation, output gap, and interest rate stabilization and volatility) of a variety of IT regimes through a laboratory experiment with human subjects. More precisely, we evaluate the following:

- The role of announcing the target
  To highlight the role of the target, we compare two monetary policy rules that are the same in their specifications, except for the public nature or not of

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the target. The first policy rule is implemented by an *explicit IT* central bank, in the sense that it clearly announces its target for inflation to the public. The second policy configuration is pursued by an *implicit IT* central bank, in the sense that it does not communicate its target to the public. This comparison is motivated by the fact that, in practice, all central banks acknowledge the importance of price stability for promoting economic activity, although some of them make the choice not to communicate their numerical inflation objectives clearly.

- The role of central bank objectives
  Following the literature, we also distinguish two different IT regimes: the *strict IT* regime, where the monetary authorities care only about inflation stabilization, without considering the stability of the real economy, and the *flexible IT* regime, in which the central bank targets inflation, but also gives some weight to the stabilization of the output gap.[1]

Our results suggest some interesting insights. Indeed, we find that if the central bank only cares about inflation stabilization, announcing the inflation target does not make a difference in terms of macroeconomic performance from a monetary policy that simply follows the Taylor principle. This suggests that a central bank that has the sole objective of stabilizing inflation does not need to implement an inflation-targeting framework to achieve higher macroeconomic performance. A standard active monetary policy is sufficient to achieve the same economic performances. However, if the central bank also cares about the stabilization of economic activity, communicating the target helps to reduce the volatility of inflation, interest rate, and output gap, although their average levels are not affected. The relevance of announcing the target in this context is mainly due to the target's ability to reduce uncertainty about policy objectives faced by agents.

Our paper is closely related to a recent experiment by Arifovic and Petersen (2015), focusing on the role of communication in escaping liquidity traps. The authors observe that explicit communication can worsen the anchoring of expectations on inflation targets, which stands in contrast to the findings of our paper. Some differences in the experimental setup may explain these contrasting results. First, whereas we implement a constant target, in Arifovic and Petersen the target is mainly state-contingent, and so the central bank communicates the direction of the target, which fluctuates. This is a major difference, as it is probably easier for subjects to coordinate on a constant rather than on a changing target. Second, like Kryvtsov and Petersen (2013), Arifovic and Petersen use an experimental NK model in which subjects provide forecasts for both inflation and the output gap. Although our setup has the drawback of being less exhaustive in this respect (as we ask only for inflation expectations), it has the advantage of providing an easier task for subjects and making it possible to directly assess the relevance of the announcement of the inflation target, and may contribute to easing coordination. Third, as Arifovic and Petersen deal with the question of the liquidity trap, their experiment typically raises credibility issues when the central bank is unable to

achieve its goals. In contrast, our experiment does not raise credibility problems to a great extent.[2]

The rest of the paper is organized in the following way. Section 2 describes the simplified New Keynesian model underlying our experimental economy. Section 3 presents the methodology and the design of our experiment. Section 4 presents the results of the experiment in terms of macroeconomic outcomes. Finally, Section 5 concludes the paper.

2. THE MODEL

We present the simplified New Keynesian underlying theoretical model of the economy that is used for the purpose of our experiment. The model is based on three main equations: (1) an aggregate demand equation (IS curve), (2) a supply function (New Keynesian Phillips curve), and (3) a reaction function of the central bank (the interest rate rule):[3]

$$y_t = \bar{y}^e_{t+1} - \alpha(i_t - \bar{\pi}^e_{t+1}) + g_t, \tag{1}$$

$$\pi_t = \beta\bar{\pi}^e_{t+1} + \lambda y_t + u_t, \tag{2}$$

$$i_t = \pi^T + \phi_\pi(\pi_t - \pi^T) + \phi_y y_t, \tag{3}$$

where y_t and $\bar{y}^e_{t+1}$, respectively, represent the current and average expected output gap, π_t and $\bar{\pi}^e_{t+1}$, respectively, represent the current and average expected inflation, i_t is the short-term nominal interest rate, and π^T is the central bank's inflation target. The parameters α, β, λ, ϕ_π, and ϕ_y are positive; g_t and u_t, respectively, represent white noise exogenous demand and supply shocks.[4] The coefficients ϕ_π and ϕ_y, respectively, measure the response of the central bank to deviations of actual inflation from its target π^T, and to deviations of current output from its potential level. We also realistically assume that the reaction function of the central bank respects the Taylor principle, that is, reacts more strongly ($\phi_\pi > 1$) to deviations of actual inflation from the target value.

One of the main implications of the New Keynesian framework is that agents have to forecast both inflation and the output gap. Following the literature [Pfajfar and Zakelj (2013, 2014) and Assenza et al. (2013)], we consider only inflation forecasts and make an assumption about the output gap expectations. We assume naive expectations on the output gap; that is, the expected output gap is equal to the lagged output gap ($\bar{y}^e_{t+1} = y_{t-1}$). Although such an assumption may reinforce inertial expectations, there is significant survey and experimental evidence pointing to strongly naive expectations.[5] Considering expectations on the output gap as given, subjects only have to forecast inflation. Substituting equation (3) into (1), the system is transformed as follows:

$$y_t = \frac{1}{1+\alpha\phi_y}y_{t-1} - \frac{\alpha\phi_\pi}{1+\alpha\phi_y}\pi_t + \frac{\alpha}{1+\alpha\phi_y}\bar{\pi}^e_{t+1} + \frac{\alpha(\phi_\pi - 1)}{1+\alpha\phi_y}\pi^T + \frac{1}{1+\alpha\phi_y}g_t, \tag{4}$$

$$\pi_t = \beta\bar{\pi}^e_{t+1} + \lambda y_t + u_t. \tag{5}$$

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Manipulating this system yields the following inflation equation:

$$\pi_t = A + \frac{\alpha\lambda + \beta(1+\alpha\phi_y)}{1+\alpha(\phi_y+\lambda\phi_\pi)}\bar{\pi}^e_{t+1} + \frac{\lambda}{1+\alpha(\phi_y+\lambda\phi_\pi)}y_{t-1} + \varepsilon_t, \qquad (6)$$

where $A = \frac{\alpha\lambda\pi^T(\phi_\pi-1)}{1+\alpha(\phi_y+\lambda\phi_\pi)}$ is a constant, and $\varepsilon_t = \frac{\lambda}{1+\alpha(\phi_y+\lambda\phi_\pi)}g_t + \frac{1+\alpha\phi_y}{1+\alpha(\phi_y+\lambda\phi_\pi)}u_t$ is the set of exogenous shocks.

Hence, actual inflation depends on a constant including the inflation target, agents' average inflation forecasts, the lagged output gap, and the shocks affecting the economy.

The experiment consists in asking subjects for inflation expectations, which will be put back into the model, yielding economic outcomes.

3. THE EXPERIMENT

Although a large empirical literature on inflation expectations and monetary policy is based on survey data,[6] part of the literature explains agents' inflation expectations formation process and its relation with monetary policy using laboratory experiments with human subjects. These studies refer to so-called learning to forecast experiments (LtFEs).[7]

Our experimental study is close to those of Assenza et al. (2013) and Pfajfar and Zakelj (2013, 2014), in the sense that we use the same model and the results come from agents' inflation expectations.[8] However, first, whereas these papers focus on the agents' inflation expectations formation process and its interplay with monetary policy in stabilizing inflation, our analysis focuses on the effect of the announced inflation target on agents' inflation expectations and on macroeconomic outcomes. Second, the reaction function of the central bank is also different. Whereas Assenza et al. (2013) and Pfajfar and Zakelj (2013, 2014) assume that the central bank cares only about inflation stabilization, we more realistically allow for the possibility of having a central bank which takes into account, in addition (but with less weight), output gap stabilization.

For experimental purposes, we calibrate the model parameters as in Clarida (2000) and Assenza et al. (2013): $\beta = 0.99$, $\alpha = 1$, and $\lambda = 0.3$, and we set the central bank's target value at $\pi^T = 5$.[9] The variance of shocks is set to 0.25.

This section presents the methodology and the procedure of our experiment.

3.1. Methodology

The experiment consists in retrieving subjects' inflation expectations in the lab and introducing them into the theoretical model in order to derive the current values of inflation, output gap, and interest rate. For instance, to determine the actual inflation in the next period, we average subjects' inflation forecasts for this next period and introduce them into the New Keynesian theoretical model of our computer program. Given the model parameters, the program computes the

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TABLE 1. Summary of sessions

Treatment	ϕ_π	ϕ_y	Nb. of sessions (obs.)	Target
Implicit strict IT	1.5	0	4	Not announced
Explicit strict IT	1.5	0	4	Announced
Implicit flexible IT	1.5	0.5	4	Not announced
Explicit flexible IT	1.5	0.5	4	Announced

current values of the main macroeconomic variables (inflation, output gap, and interest rate). Period after period, we obtain time series of the main variables.

As mentioned earlier, the main objectives of this study are first to assess the relevance of the target announcement and second to evaluate how the objectives of the central bank matter for economic performances.[10] To pursue these aims, we consider four different treatments in which subjects' task is to forecast next-period inflation in each of the 60 periods of the session:[11]

- Treatment 1—implicit strict IT: The central bank does not announce its inflation target to the public and its sole objective is to stabilize inflation.
- Treatment 2—explicit strict IT: The central bank explicitly communicates its 5% inflation target (which it commits to reach within two periods), and its unique objective is to stabilize inflation (as in Treatment 1).[12]
- Treatment 3—implicit flexible IT: The central bank does not announce its target for inflation to the public (as in Treatment 1) and the central bank has both inflation and output gap stabilization objectives.
- Treatment 4—explicit flexible IT: The central bank explicitly communicates its target for inflation (as in Treatment 2) and it has both inflation and output gap stabilization objectives (as in Treatment 3).

For each treatment, we conducted four sessions with six subjects each, yielding four independent observations per treatment, as stated in Table 1.

3.2. Procedure

The experiment was run at the GATE-LSE laboratory (University of Lyon). Most subjects were undergraduate students in economics and business administration. Participants earned about €16 on the average, depending on the accuracy of their forecasts. Sessions lasted 3/4 of an hour on the average. The program was written using z-Tree experimental software [Fischbacher (2007)].

At the beginning of each session, subject were given written instructions[13] providing some general information about the variables that composed the economy. Participants were instructed about their roles as forecasters in the economy. The economy was described by four main macroeconomic variables: inflation, output gap, interest rate, and the central bank's inflation target (in explicit IT treatments). We restrict the economy to positive values and high initial levels of

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inflation because our goal is to study how IT may contribute to the success of the disinflation process (for instance, as in emerging market economies). Indeed, an inflation-targeting framework may be implemented in a context of high inflation in an economy, and aims at reducing this high level of inflation. In all treatments, the economy begins with the five previous time series of inflation, output gap, and interest rate up to period 0. These five previous series were computed with the same initial values for all treatments, to ease comparison between them. Participants could then observe on their screens time series of these variables up to the current period. In addition, subjects were informed about the fact that an inflation-targeting regime is implemented by the central bank in a context of high inflation in the economy in order to reduce it. Subjects also knew that the actual values of inflation and output gap depended mainly on their own predictions, as well as other subjects' inflation forecasts. They were aware that these macroeconomic outcomes depended on the lagged output gap, on small random shocks that affected the economy, and on the central bank's inflation target. However, participants were not informed about the true model underlying the economy, nor did they observe other subjects' inflation forecasts. Moreover, in implicit IT treatments (Treatments 1 and 3), agents did not know the central bank's inflation target. For comparison purposes, all treatments had exactly the same random shocks.

Participants' payoff function was described as follows:

$$\max\left\{\frac{160}{1+f}-40,0\right\},$$

where $f = \mid \pi_t - \pi^i_{t/t-1} \mid$ denoted the absolute value of the forecasting errors made by subject i, and was expressed in percentage points. This payoff function implies that a subject i gets some points whenever its forecasting error is less than 3%. The smaller this forecasting error, the higher the payoff.

3.3. Theoretical Predictions

As we consider two different calibrations of the Taylor rule,[14] we now present how these variations in rules influence economic dynamics when subjects follow alternative forecasting heuristics. More precisely, we present simulation results for output gap, inflation, and interest rate for a selection of starting points under rational (Figure 1) and nonrational [adaptive (Figure 2), trend-extrapolative (Figure 3), and naive (Figure 4)] inflation expectations. Indeed, although rational expectations provide a useful benchmark, in a LtFE, subjects do not know the model but only have a qualitative description of how the economy works. Therefore—and as explained in the preceding—subjects may not form rational expectations. We thus provide alternative theoretical benchmarks based on nonrational homogenous expectations.[15]

Simulations are provided under strict (dotted lines) and flexible (solid lines) IT. For simulation purposes, the specific form given to adaptive expectations is

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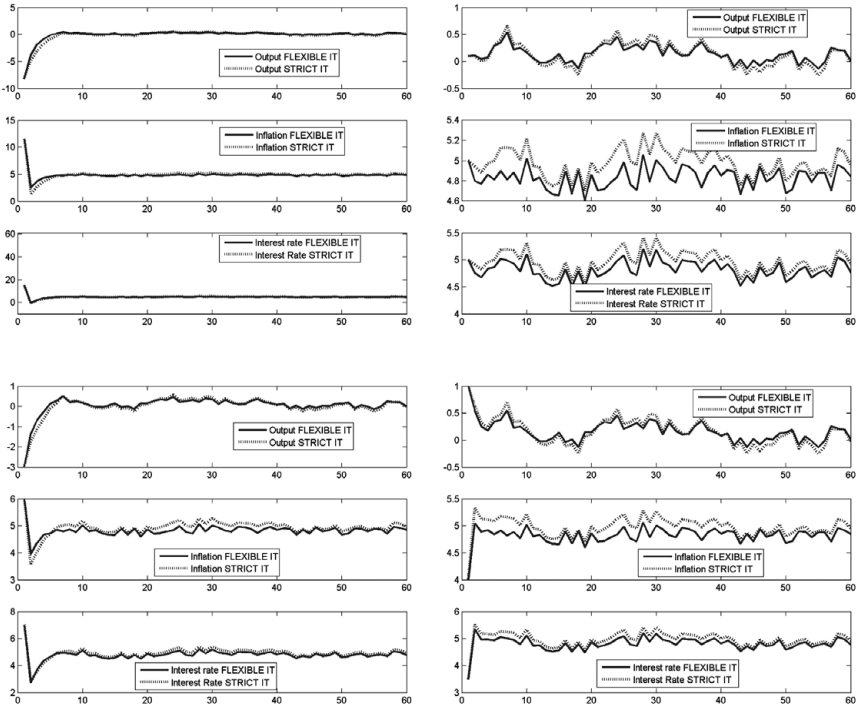

FIGURE 1. Theoretical predictions under rational expectations for various initial parameter values. Top panel: $y_1 = -8.2$, $\pi_1 = 11.5$, $i_1 = 14.8$; second panel: $y_1 = 0.1$, $\pi_1 = 5$, $i_1 = 5$; third panel: $y_1 = -3$, $\pi_1 = 6$, $i_1 = 7$; bottom panel: $y_1 = 1$, $\pi_1 = 4$, $i_1 = 3.5$.

$\pi^i_{t+1/t} = \pi^i_{t-1/t-2} + 0.5(\pi_{t-1} - \pi^i_{t-1/t-2})$, that given to trend extrapolative expectations is $\pi^i_{t+1/t} = \pi_{t-1} + 0.5(\pi_{t-1} - \pi_{t-2})$, and that given to naive expectations is $\pi^i_{t+1/t} = \pi_{t-1}$.[16] The selection of starting points includes values for output gap, inflation, and interest rate that are close or equal to experimental values ($y_1 = -8.2, \pi_1 = 11.5, i_1 = 14.8$), values that are close or equal to steady state values ($y_1 = 0.1, \pi_1 = 5, i_1 = 5$), and values that are close to a potential experimental situation after some rounds ($y_1 = -3, \pi_1 = 6, i_1 = 7$ and $y_1 = 1$, $\pi_1 = 4$, $i_1 = 3.5$).[17] The shocks are those implemented in the experiment. We assume here that agents are not heterogeneous (i.e., use the same forecasting heuristics).[18]

The main predictions that we can address are the following. Under rational expectations, output gap evolves closely under strict and flexible IT. Inflation and interest rates are slightly lower under flexible IT;[19] however, trends are similar. Under nonrational expectations, under flexible IT, the output gap converges faster around its steady state value, whereas inflation converges faster around the target under strict IT. As emphasized in the preceding, following the literature pointing to

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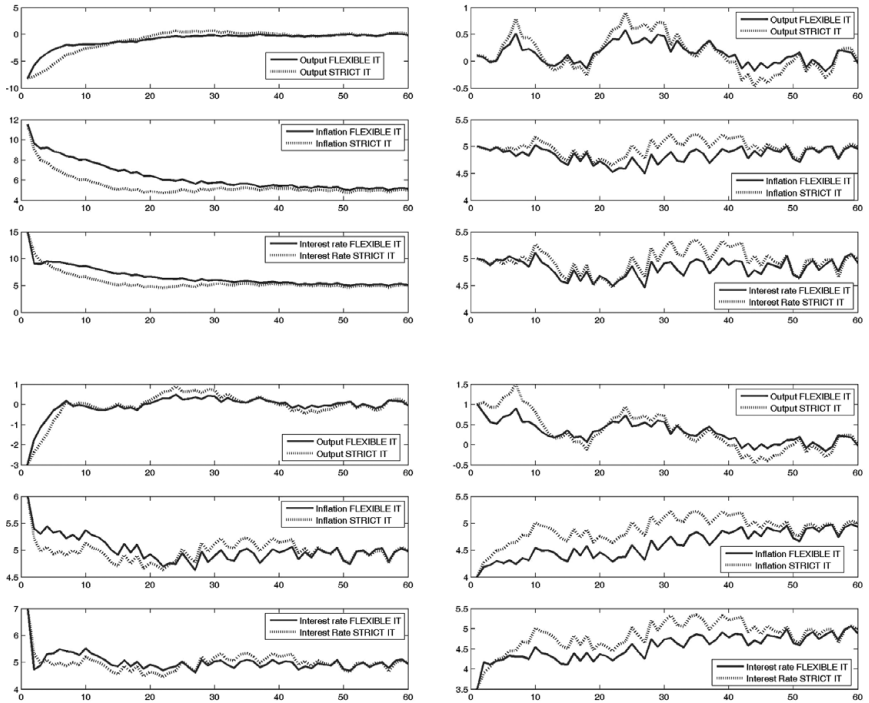

FIGURE 2. Theoretical predictions under adaptive expectations for various initial parameter values. Top left panel: $y_1 = -8.2$, $\pi_1 = 11.5$, $i_1 = 14.8$; top right panel: $y_1 = 0.1$, $\pi_1 = 5$, $i_1 = 5$; bottom left panel: $y_1 = -3$, $\pi_1 = 6$, $i_1 = 7$; bottom right panel: $y_1 = 1$, $\pi_1 = 4$, $i_1 = 3.5$.

heterogeneous expectations [Hommes (2011)], we do not expect subjects to behave rationally. Focusing on nonrational expectations, Appendix A provides descriptive statistics comparing average levels of macroeconomic variables over 60 periods and their variance for our different starting points and forecasting heuristics. In general, the level of macroeconomic variables is very similar under strict and flexible IT for a specific forecasting heuristic, although this depends crucially on starting points. However, variances are larger under strict IT, especially in terms of output gap.

We now discuss how communication should influence behavior for our alternative forecasting heuristics based on nonrational expectations. Figure 5 presents simulations results for a rule that includes the target, for the same initial starting points as in the preceding to provide an example of how the disclosure of the target may affect the results in comparison with a rule that would not include it. We call this rule the "communication" rule:[20] $\pi^i_{t+2/t} = 0.5\pi^T + 0.5\pi_{t-1}$. It can be compared with the naive rule for each IT regime (strict and flexible), as the components other than the target correspond to the naive expectations.[21]

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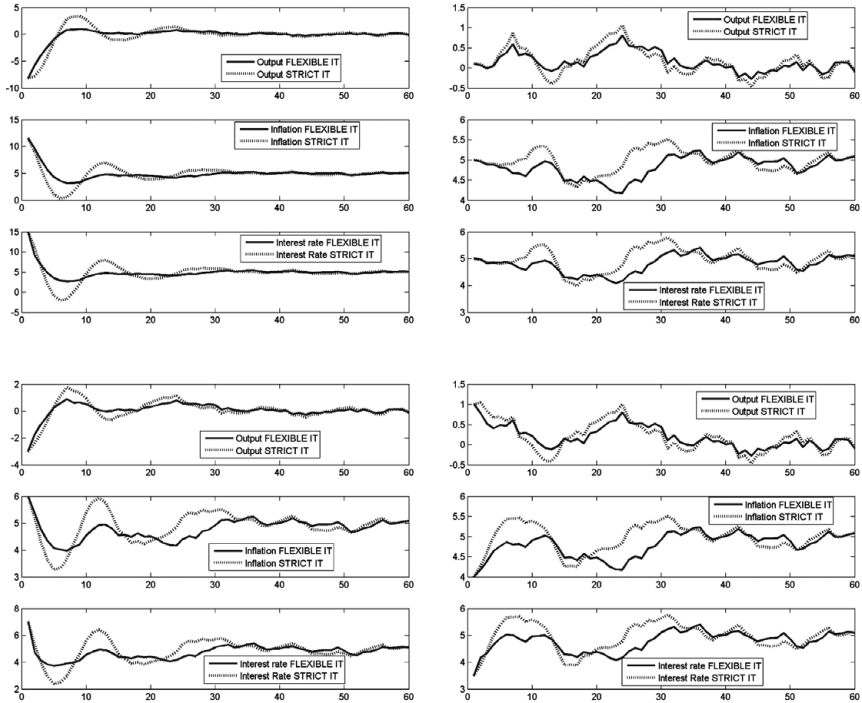

FIGURE 3. Theoretical predictions under trend extrapolative expectations for various initial parameter values. Top panel: $y_1 = -8.2$, $\pi_1 = 11.5$, $i_1 = 14.8$; second panel: $y_1 = 0.1$, $\pi_1 = 5$, $i_1 = 5$; third panel: $y_1 = -3$, $\pi_1 = 6$, $i_1 = 7$; bottom panel: $y_1 = 1$, $\pi_1 = 4$, $i_1 = 3.5$.

The comparison between the economic outcomes obtained with this rule and the naive inflation expectation forecasting heuristic shows that macroeconomic variables reach values that are close to the steady state within fewer periods. Moreover, Appendix A shows that although average levels of macroeconomic variables are similar under the two forecasting heuristics, the variance is much lower with the "communication" rule. So we conclude that, in principle, in particular if it is credible, the announcement of the target should not affect average levels, but should reduce the variance of macroeconomic variables under both strict and flexible IT regimes.

4. EXPERIMENTAL ECONOMIC OUTCOMES

This section analyzes the macroeconomic outcomes in our experimental economy.[22] Figure 6 presents the evolution of average inflation and inflation expectations across treatments.

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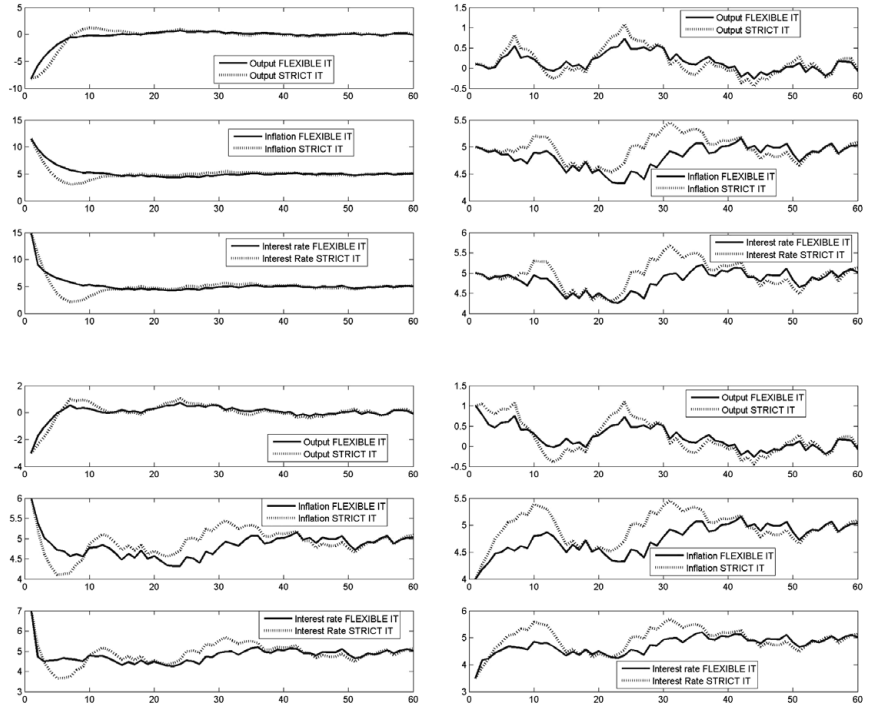

FIGURE 4. Theoretical predictions under naive expectations for various initial parameter values. Top panel: $y_1 = -8.2$, $\pi_1 = 11.5$, $i_1 = 14.8$; second panel: $y_1 = 0.1$, $\pi_1 = 5$, $i_1 = 5$; third panel: $y_1 = -3$, $\pi_1 = 6$, $i_1 = 7$; bottom panel: $y_1 = 1$, $\pi_1 = 4$, $i_1 = 3.5$.

All four treatments exhibit similar patterns as both inflation and inflation expectations converge toward the target. Also note that both variables never go out of the inflation range of 4–6% from the 7th period (in strict IT treatments), and from the 20th period (in flexible IT treatments). In this section, we perform a pairwise comparison of treatments in terms of macroeconomic outcomes (inflation, interest rate, and the output gap) using nonparametric statistical tests to evaluate the best targeting strategy. More specifically, we analyze whether explicitly announcing the target is relevant in terms of macroeconomic performance. Before analyzing the role of the target announcement in both strict and flexible IT regimes, we first compare the effectiveness of these regimes in terms of macroeconomic performance.

4.1. Strict versus Flexible IT Regimes

Figure 7 presents the evolution of average inflation and output gap series[23] for both implicit IT treatments, on one hand, and both explicit IT treatments, on the other hand (over four independent sessions for each treatment).

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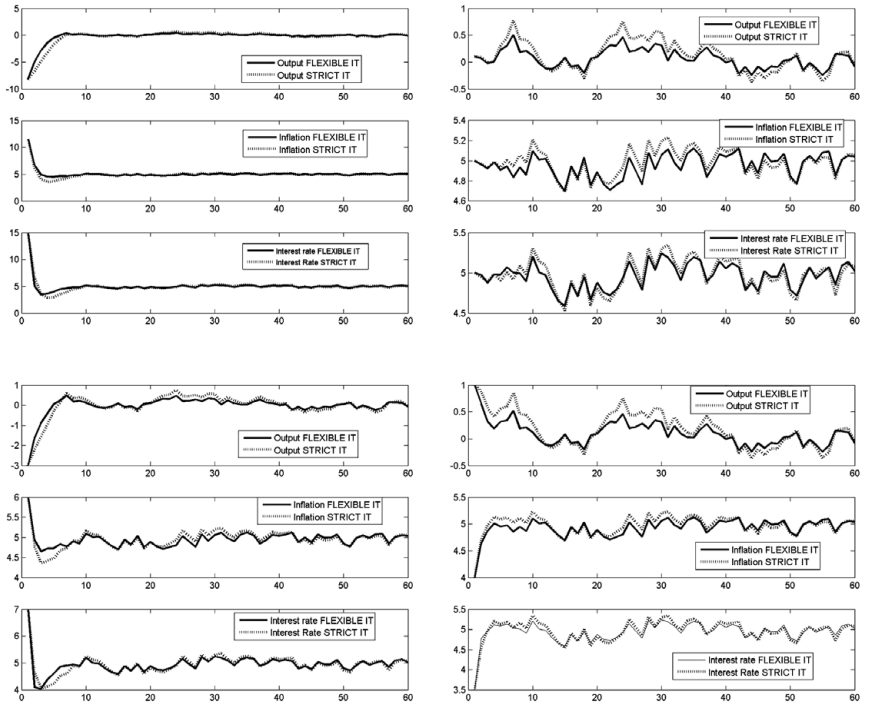

FIGURE 5. Theoretical predictions using the "communication" rule for various initial parameter values. Top panel: $y_1 = -8.2$, $\pi_1 = 11.5$, $i_1 = 14.8$; second panel: $y_1 = 0.1$, $\pi_1 = 5$, $i_1 = 5$; third panel: $y_1 = -3$, $\pi_1 = 6$, $i_1 = 7$; bottom panel: $y_1 = 1$, $\pi_1 = 4$, $i_1 = 3.5$.

In line with theoretical predictions under nonrational expectations, inflation series in both cases show quite similar trend convergence, although there is faster convergence toward the target in the strict IT regimes. Output gap series also exhibit similar trends.

To distinguish differences between treatments, we present in Appendix C statistical tests regarding comparisons in macroeconomic outcomes series. The Mann–Whitney–Wilcoxon procedure is used to test for equality of medians between macroeconomic series of treatments, whereas the Siegel–Tukey test is used to assess whether there is a difference in terms of variances between series.[24] The null hypothesis is that there is equality between series of interest in terms of medians or variances. The statistical tests (over four independent sessions for each treatment) indicate that the average inflation is significantly lower in a strict IT regime than in a flexible IT framework. This could be explained by the fact that there is a single objective in the former regime. However, there is no significant difference between the two regimes in terms of volatility of inflation.[25] Moreover, although there is no significant difference between strict and flexible IT regimes

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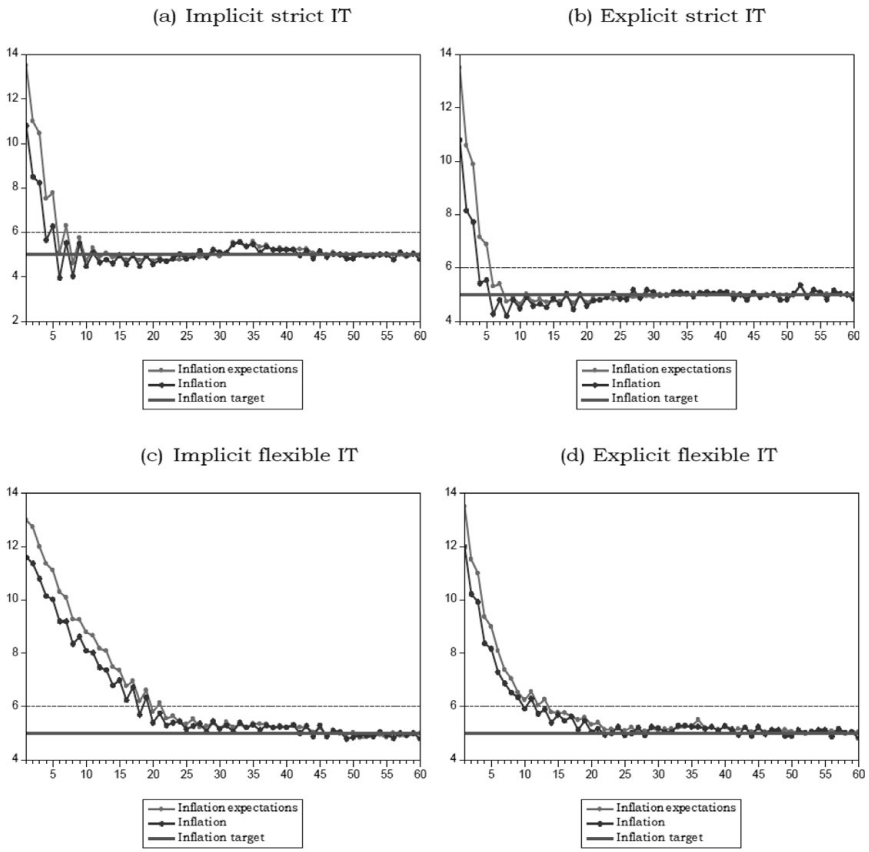

FIGURE 6. Average inflation and inflation expectations across treatments.

in the volatility of interest rates, the average level of interest rates is, in contrast, significantly lower in a strict IT regime. We also find ambiguous results concerning the output gap. Indeed, although there is no clear-cut result regarding its average level, its volatility is significantly lower in a flexible IT regime.

To summarize, the advantages of one IT regime over the others are not obvious. This result is in line with the theoretical predictions of Section 3.3 and with the constant debate in the literature about the trade-off between credibility and flexibility faced by central banks. On one hand, in a strict IT regime, monetary authorities can gain high credibility (because of faster disinflation), but at the cost of a wider output gap. On the other hand, in a flexible IT regime, the central bank can close the output gap, but at the expense of a higher inflation rate. In terms of policy implications, we argue that both IT regimes could subsequently be applied as a framework for monetary policy, particularly for central banks that lack credibility. A strict IT regime could first be applied to establish credibility

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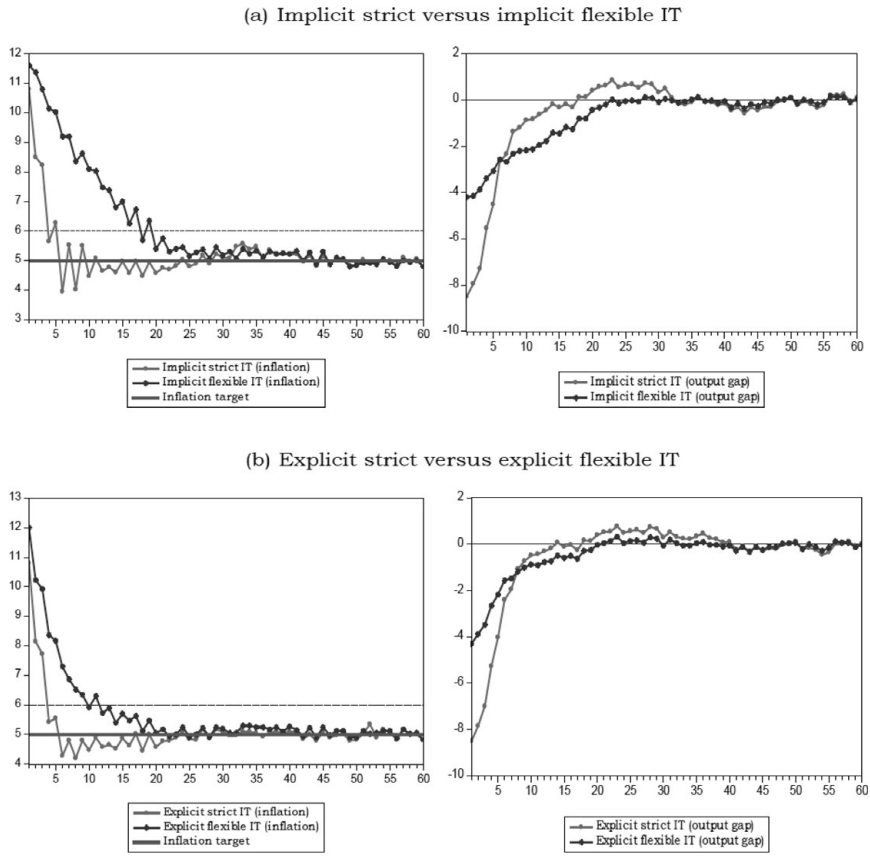

FIGURE 7. Average inflation and output gap series for strict versus flexible IT regimes.

of the regime, and then a flexible IT regime should follow the former regime to reduce adjustment costs and stabilize the economic environment.

We now investigate the role of the target announcement in each IT regime.

4.2. Implicit versus Explicit Strict IT

Figure 8 presents the evolution of average inflation and output gap series for implicit and explicit strict IT treatments.

Regarding inflation, we can observe that these series show quite similar trend convergence, although there is faster convergence toward the target in the explicit strict IT case. We use statistical tests similar to the earlier ones to check whether there are differences between the two treatments in terms of macroeconomic outcome series. Tests indicate that there are no significant differences between

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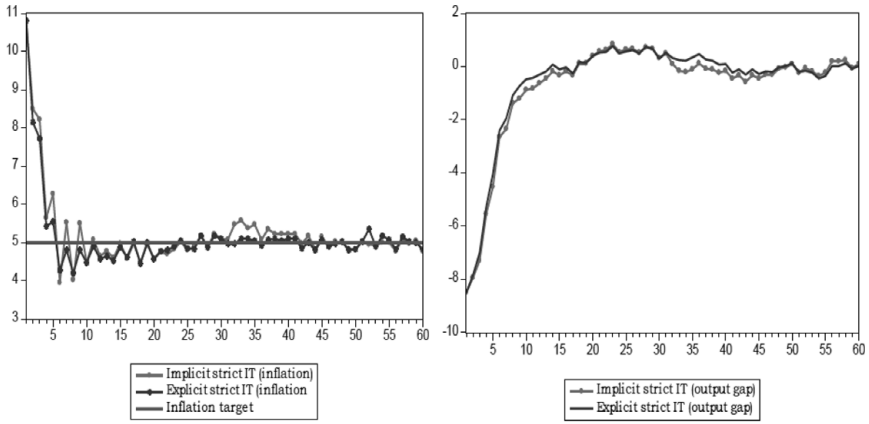

FIGURE 8. Average inflation and output gap series for implicit versus explicit strict IT.

the two treatments at any conventional levels in terms of medians (or means) and variances of macroeconomic outcomes.

Our analysis implies that a central bank that cares only about inflation stabilization does not need to implement an explicit IT announcement to gain higher macroeconomic performance. Instead, it is sufficient for it to respect the Taylor principle.

Although the insignificant difference between the two treatments in level of macroeconomic variables is in line with theoretical predictions (based on nonrational expectations) of Section 3.3, that in terms of variance is not. A possible explanation can be found in the policy reaction function. As the central bank's objective is unique and clear in this regime, whether it announces its target for inflation or not, the strong policy reaction to inflation ($\phi_\pi = 1.5$) allows subjects to understand the target quickly and thus to coordinate their expectations on it. Hence, the role of the announced target in this context is rather insignificant.

Finally, our finding questions some results of the literature [Friedman and Kuttner (1996)], as we find that there is no evidence that adopting an explicit IT regime leads to higher output gap volatility.[26] We can summarize our findings as follows.

Result 1. If the central bank cares only about inflation stabilization, inflation targeting does not make a difference, in terms of macroeconomic outcomes, from a standard monetary policy that respects only the Taylor principle.

4.3. Implicit versus Explicit Flexible IT

We now investigate the potential differences between implicit and explicit flexible IT treatments in terms of macroeconomic outcomes. Figure 9 presents the evolution of average inflation series for both implicit and explicit flexible IT treatments.

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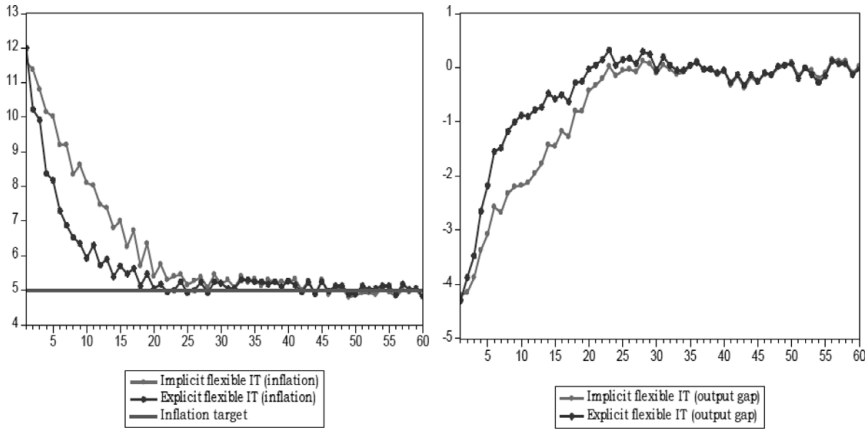

FIGURE 9. Average inflation series for implicit versus explicit flexible IT.

As in the previous analysis, we observe that the two inflation series show quite similar trend convergence, although there is faster convergence toward the target in the explicit flexible IT case.[27]

Tests indicate that there are significant differences between the two treatments in terms of volatility of macroeconomic outcomes, but not in terms of their average levels, which is in line with the theoretical predictions (based on nonrational expectations) of Section 3.3. More precisely, we find that the average standard deviations of inflation, interest rate, and output gap are significantly lower in the explicit flexible IT treatment than in the implicit flexible IT treatment. This finding is also in line with the theoretical result of Demertzis and Hughes-Hallett (2007), who find that when agents are uncertain about the central bank's objectives and especially its output gap objective, greater transparency negatively affects the variability of inflation and output gap, but not their average levels.

Three reasons can be put forward to explain the relevance of announcing the target in the flexible IT regime. The first explanation can be found in the policy objectives of the central bank. Indeed, as the objectives of the central bank are to stabilize both inflation and the output gap, agents may find it more difficult to understand these goals than a single objective. In this context, the announcement of the target is important, as it helps to clarify these objectives. The second reason may be that a flexible IT regime seems more sensitive to fluctuations in inflation forecasts than a strict IT regime.[28] This should make it more difficult to stabilize the economy, because subjects take much longer to reach the target. Hence, the announcement of the target for inflation is more helpful in reducing forecast errors. Finally, the third explanation, which is closely related to the second one, is the role of the forecasting rules used by subjects. Appendix E provides an analysis of individual inflation expectations formation. As explained there, the trend extrapolation rule [agents expect that upward (downward) movements in

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inflation will be followed by downward (upward) movements in the next period] better explains the evolution of average inflation expectations in the implicit flexible IT treatment than in the explicit flexible IT treatment. Following this rule requires more frequent and aggressive adjustments in the policy reaction function to mitigate the high volatility in inflation and output gap in the case of implicit flexible IT than in the case of explicit flexible IT. As Orphanides and Williams (2005, 2007) argue, the communication of the target reduces the uncertainty faced by agents in their estimating rules and consequently helps them learn about the true economic model. We can thus summarize our findings in the following way.

Result 2. If the central bank cares about the stabilization of both inflation and output gap, communicating the target helps to reduce the volatility of inflation, interest rate, and the output gap, although their average levels are not affected. The announcement of the inflation target reduces the uncertainty faced by agents in their expectation formation rules.

5. CONCLUSION

Using laboratory experiments with human subjects, we analyze to what extent communication of the inflation target is relevant in an inflation-targeting framework. To be able to interpret the role of the announced target—which has been difficult to highlight in the empirical literature with real data—we compare two monetary policy rules which differ only with respect to whether the target is announced (explicit IT treatments) or not (implicit IT treatments).

First, we find that when the central bank only cares about inflation stabilization, announcing the inflation target does not make a difference, in terms of stabilizing macroeconomic outcomes, from a standard active monetary policy. This suggests that a central bank caring only for inflation stabilization does not need to implement an inflation-targeting framework to achieve higher macroeconomic performance. A simple monetary policy that respects the Taylor principle is sufficient to achieve the same economic performance. Second, we find that if the central bank also cares about the stabilization of the output gap, communicating the target helps to reduce the volatility of inflation, interest rate, and output gap, although their average levels are not affected.

Although our experimental study has been conducted in a controlled environment and the applicability of our results should be handled carefully, we argue that the irrelevance of explicit inflation targeting when the central bank is an inflation targeter does not mean that opponents of inflation targeting [Ball and Sheridan (2005), Angeris and Arestis (2008), among others] are right. As noted by Svensson (2010), in practice inflation targeting is never strict but always flexible, as central banks also care about the stabilization of the real economy or of the financial system. The relevance of explicitly announcing the inflation target in our second result provides a rationale for the adoption of flexible inflation targeting by all inflation-targeting countries.

NOTES

1. For an analysis of how IT may have changed the preferences of central banks, see Creel and Hubert (2015).

2. Moreover, whereas Arifovic and Petersen focus on the anchoring role of the target announcement in the context of a liquidity trap, the anchoring role of the target in our paper is evaluated in a context of disinflation, starting from high inflation levels.

3. Although IT usually refers to optimal monetary policy rather than instrumental rules, we nevertheless focus on a reduced form of the New Keynesian model, following Pfajfar and Zakelj (2014), as forecasts can be directly elicited.

4. The fundamental shocks considered here are i.i.d. white noises, as in Assenza et al. (2013), instead of assuming an AR(1) noise process, as in Pfajfar and Zakelj (2013, 2014), so that potential fluctuations in inflation must be endogenously driven by agents' expectations.

5. The LtFE literature shows that subjects' inflation expectations fail to be captured by rational expectations, but instead are well described by simple strategies, such as naive expectations, trend-chasing, and constant-gain learning heuristics [see, e.g., Hommes et al. (2005), Assenza et al. (2013), Pfajfar and Zakelj (2014), and Petersen (2014)]. Regarding survey papers, Pesaran and Weale (2006), Andolfatto et al. (2008), Lanne et al. (2009), and Coibion and Gorodnichenko (2015), to mention but a few, question rational expectations. More particularly, on the beef market, Chavas (2000) estimates that almost half of beef producers behave naively.

6. See, e.g., Branch (2004), and Capistran and Timmermann (2009).

7. See Hommes (2011) for an overview on LtFEs. Some experimental studies including Marimon and Sunder (1995), and Bernasconi and Kirchkamp (2000) analyze agents' expectations formation process within overlapping generation models and compare the effectiveness of different monetary rules.

8. Adam (2007), Assenza et al. (2013), and Pfajfar and Zakelj (2013, 2014) analyze the formation of inflation expectations within the standard New Keynesian framework. Assenza et al. (2013) and Pfajfar and Zakelj (2013, 2014) also analyze how monetary policy should be conducted to better stabilize inflation volatility using different versions of the Taylor rule.

9. We opted for this arbitrary value of the target instead of $\pi^T = 2$ because we feared that subjects naturally coordinated their expectations toward 2, as it may be well-known to participants that the European Central Bank aims at stabilizing inflation below but close to 2 %.

10. More precisely, we analyze how the central bank may stabilize agents' inflation expectations in an environment characterized by high inflation, as in emerging and developing economies. This is why, in the experiment, first periods start with a high level of inflation.

11. This forecasting process is simpler for subjects than forecasting inflation two periods ahead, as suggested by the New Keynesian framework. This specification is also used by Pfajfar and Zakelj (2013, 2014).

12. In both explicit treatments (2 and 4), in order to avoid credibility issues and given the various random shocks affecting the economy, subjects were told in the instructions that the central bank allowed itself a margin error of $\pm 1\%$ around its target. This statement does not mean that the central bank does not intervene in this case, but is intended to make clear to subjects that the central bank could sometimes not exactly reach its target.

13. Appendix F provides a translation from French to English of instructions for Treatment 4. Appendix G shows some examples of the screens.

14. Under the standard calibration parameters that we consider, following the literature, under strict IT, the steady state is $\bar{y} = 0.1, \bar{\pi} = 5, \bar{i} = 5$, and under flexible IT, the steady state is $\bar{y} = 0.1, \bar{\pi} = 4.8$, $\bar{i} = 4.8$, which are close to target values.

15. For a theoretical analysis of how alternative interest rate rules influence inflation dynamics when agents have heterogeneous expectations, see Anufriev et al. (2013).

16. In the simulations, output gap is assumed to follow the same process as in the experiment.

17. When necessary, π_0 is taken equal to π_1.

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18. Appendix E instead looks at subjects' heterogeneous expectation formation in the experiment.

19. This is because the steady state value is slightly lower.

20. This is inspired by Bomfin and Rudebusch (2000).

21. This is only one example, but one could do the same exercise with a rule including the target and adaptive or trend-extrapolative inflation expectations.

22. Providing a theoretical model with heterogeneous interacting agents to explain experimental aggregate outcomes is beyond the scope of this paper. See, e.g., Hommes and Lux (2013) for genetic algorithms explaining aggregate price fluctuations and individual forecasting behaviour in learning to forecast experiments.

23. Appendix D provides figures showing the evolution of inflation and average inflation expectations for each session of each treatment.

24. The Mann–Whitney–Wilcoxon test is equivalent to the test of differences of means in parametric tests, whereas the Siegel–Tukey test is equivalent to the analysis of variances (ANOVA) in parametric tests.

25. See also Appendix B for the descriptive statistics for all treatments.

26. We instead find that the average standard deviation in explicit strict IT treatment is lower (1.96) than the one in implicit strict IT (2.02), although this difference does not appear to be statistically significant.

27. The backward-looking component that is induced by our assumption of naive output gap expectations may in principle render communication less effective. It is thus possible that the difference in terms of speed of convergence that we observe between explicit and implicit IT might be more pronounced if we had not imposed naive expectations for the output gap.

28. This can be seen from equation (6). Recalling this equation:

$$\pi_t = A + \frac{\alpha\lambda + \beta(1+\alpha\phi_y)}{1+\alpha(\phi_y+\lambda\phi_\pi)}\bar{\pi}^e_{t+1} + \frac{\lambda}{1+\alpha(\phi_y+\lambda\phi_\pi)}y_{t-1} + \varepsilon_t,$$

let $\Gamma = \frac{\alpha\lambda+\beta(1+\alpha\phi_y)}{1+\alpha(\phi_y+\lambda\phi_\pi)}$ be the coefficient of average inflation forecasts. By replacing all the parameters with their given values, one obtains for a strict IT regime $\Gamma = 0.89$, and for a flexible IT regime $\Gamma = 0.92$. Note that Γ is larger for the flexible IT regime. Consequently, flexible IT seems more sensitive to fluctuations in inflation expectations.

29. It is widely accepted in modern macroeconomic theory that maintaining a stable monetary policy largely depends on the ability of the monetary authorities to control agents' expectations [see, e.g., Woodford (2005)].

30. Since the influential contribution of Muth (1961), the rational expectations (RE) hypothesis has become the foremost theory explaining agents' expectations formation and has been widely used in policy models. According to the RE hypothesis, all agents form expectations that match economic outcomes on the average, without systematic forecasting errors, by using all available information. However, given the strong assumptions implied by RE theory, a recent literature on learning to forecast [Evans and Honkapohja (2001), Bullard and Mitra (2002), Orphanides and Williams (2005, 2007)], which suggests that agents form expectations that are model-inconsistent, has explored models of expectations formation that rely on learning dynamics. Agents are subjected to perpetual learning from their economic environment in order to improve their expectations of macroeconomic outcomes. This literature stipulates that agents have imperfect knowledge and heterogeneous information about the true economic model and need to constantly learn from the economic environment in forming their expectations. These expectations are updated each period based on incoming economic data.

31. Assenza et al. (2013) and Pfajfar and Zakelj (2013, 2014) show that instead of using only one forecasting rule, agents switch between different rules during the cycle. We observe the same patterns in our experiment.

32. The methodology adopted is the same as in Pfajfar and Zakelj (2013, 2014).

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APPENDIX A: DESCRIPTIVE STATISTICS: THEORY

A.1. ADAPTIVE FORECASTING RULE

TABLE A.1. Descriptive statistics: Adaptive forecasting rule

		$y_1 = -8.2, \pi_1 = 11.5, i_1 = 14.8$		$y_1 = 0.1, \pi_1 = 5, i_1 = 5$	
		Strict IT	Flex. IT	Strict IT	Flex. IT
Mean	Inflation	5.44	6.28	4.97	4.84
	Output	−1.04	−0.98	0.14	0.13
	Interest rate	5.66	6.49	4.95	4.82
Variance	Inflation	1.33	2.03	0.02	0.02
	Output	4.73	2.16	0.11	0.04
	Interest rate	3.00	3.03	0.05	0.03
		$y_1 = -3, \pi_1 = 6, i_1 = 7$		$y_1 = 1, \pi_1 = 4, i_1 = 3.5$	
		Strict IT	Flex. IT	Strict IT	Flex. IT
Mean	Inflation	4.98	5.00	4.88	4.60
	Output	−0.07	−0.07	0.32	0.30
	Interest rate	4.98	5.00	4.82	4.55
Variance	Inflation	0.04	0.05	0.06	0.06
	Output	0.46	0.27	0.22	0.07
	Interest rate	0.12	0.11	0.13	0.09

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A.2. TREND EXTRAPOLATIVE FORECASTING RULE

TABLE A.2. Descriptive statistics: Trend extrapolative forecasting rule

		$y_1 = -8.2, \pi_1 = 11.5, i_1 = 14.8$		$y_1 = 0.1, \pi_1 = 5, i_1 = 5$	
		Strict IT	Flex. IT	Strict IT	Flex. IT
Mean	Inflation	4.91	4.94	4.97	4.82
	Output	−0.17	−0.17	0.15	0.14
	Interest rate	4.86	4.89	4.95	4.81
Variance	Inflation	2.60	1.48	0.08	0.07
	Output	4.03	2.14	0.11	0.05
	Interest rate	5.88	2.42	0.17	0.10
		$y_1 = -3, \pi_1 = 6, i_1 = 7$		$y_1 = 1, \pi_1 = 4, i_1 = 3.5$	
		Strict IT	Flex. IT	Strict IT	Flex. IT
Mean	Inflation	4.91	4.83	4.96	4.79
	Output	0.04	0.04	0.19	0.19
	Interest rate	4.88	4.79	4.94	4.77
Variance	Inflation	0.27	0.13	0.12	0.09
	Output	0.61	0.32	0.14	0.08
	Interest rate	0.64	0.22	0.27	0.14

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A.3. NAIVE FORECASTING RULE

TABLE A.3. Descriptive statistics: Naive forecasting rule

		$y_1 = -8.2, \pi_1 = 11.5, i_1 = 14.8$		$y_1 = 0.1, \pi_1 = 5, i_1 = 5$	
		Strict IT	Flex. IT	Strict IT	Flex. IT
Mean	Inflation	5.01	5.21	4.96	4.82
	Output	−0.34	−0.34	0.15	0.14
	Interest rate	5.02	5.22	4.94	4.81
Variance	Inflation	1.33	1.43	0.05	0.04
	Output	3.72	2.16	0.11	0.05
	Interest rate	3.02	2.19	0.11	0.06
		$y_1 = -3, \pi_1 = 6, i_1 = 7$		$y_1 = 1, \pi_1 = 4, i_1 = 3.5$	
		Strict IT	Flex. IT	Strict IT	Flex. IT
Mean	Inflation	4.91	4.83	4.94	4.75
	Output	0.04	0.04	0.22	0.21
	Interest rate	4.87	4.79	4.91	4.72
Variance	Inflation	0.11	0.08	0.09	0.07
	Output	0.48	0.30	0.18	0.08
	Interest rate	0.28	0.15	0.19	0.10

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A.4. "COMMUNICATION" RULE

TABLE A.4. Descriptive statistics: "Communication" rule

		$y_1 = -8.2, \pi_1 = 11.5, i_1 = 14.8$		$y_1 = 0.1, \pi_1 = 5, i_1 = 5$	
		Strict IT	Flex. IT	Strict IT	Flex. IT
Mean	Inflation	5.00	5.06	4.98	4.95
	Output	−0.33	−0.24	0.12	0.07
	Interest rate	5.01	5.03	4.97	4.96
Variance	Inflation	0.85	0.77	0.02	0.01
	Output	2.46	1.68	0.08	0.03
	Interest rate	1.93	1.72	0.04	0.02
		$y_1 = -3, \pi_1 = 6, i_1 = 7$		$y_1 = 1, \pi_1 = 4, i_1 = 3.5$	
		Strict IT	Flex. IT	Strict IT	Flex. IT
Mean	Inflation	4.95	4.95	4.97	4.93
	Output	−0.03	−0.04	0.17	0.10
	Interest rate	4.94	4.94	4.96	4.94
Variance	Inflation	0.05	0.04	0.03	0.03
	Output	0.37	0.24	0.11	0.05
	Interest rate	0.15	0.13	0.08	0.06

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APPENDIX B: DESCRIPTIVE STATISTICS: EXPERIMENT

B.1. STRICT INFLATION TARGETING

TABLE B.1. Descriptive statistics: Strict IT

	Inflation expectations									
	Implicit strict IT					Explicit strict IT				
Stat. by session (S)	S1	S2	S3	S4	Avg	S1	S2	S3	S4	Avg
Mean	4.97	5.06	5.00	5.02	5.01	4.96	4.97	5.02	4.97	4.98
Median	5.36	5.57	5.40	5.57	5.48	5.40	5.23	5.46	5.26	5.34
StdDev	1.67	1.53	1.56	1.62	1.60	1.66	1.42	1.52	1.42	1.51
					Inflation					
Mean	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	4.95	4.99
Median	5.13	5.27	5.16	5.27	5.21	5.16	5.04	5.20	5.07	5.12
StdDev	1.11	0.98	1.05	1.09	1.06	1.06	0.95	0.99	0.91	0.98
					Output gap					
Mean	0.00	−0.10	0.00	−0.40	−0.13	0.00	0.00	−0.10	0.10	0.00
Median	−0.55	−0.81	−0.60	−0.83	−0.70	−0.62	−0.47	−0.72	−0.44	−0.56
StdDev	2.07	1.97	2.00	2.02	2.02	2.09	1.88	1.98	1.89	1.96
					Interest rate					
Mean	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	4.95	4.99
Median	5.22	5.44	5.26	5.43	5.34	5.26	5.09	5.33	5.13	5.34
StdDev	1.66	1.46	1.56	1.63	1.58	1.60	1.43	1.48	1.37	1.47

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B.2. FLEXIBLE INFLATION TARGETING

TABLE B.2. Descriptive statistics: Flexible IT

	Inflation expectations									
	Implicit flexible IT					Explicit flexible IT				
Stat. by session (S)	S1	S2	S3	S4	Avg	S1	S2	S3	S4	Avg
Mean	6.36	6.10	7.04	6.36	6.46	7.01	5.62	5.95	5.98	5.89
Median	5.30	5.18	6.28	4.95	5.34	5.10	5	5.07	5.53	5.18
StdDev	2.26	2.19	2.11	2.49	2.21	1.96	1.65	1.89	1.45	1.70
					Inflation					
Mean	6.08	5.87	6.64	6.08	6.17	5.79	5.46	5.74	5.76	5.69
Median	5.20	5.20	6.10	5	5.30	5.10	5	5.10	5.40	5.19
StdDev	1.86	1.81	1.74	2.06	1.82	1.60	1.35	1.55	1.19	1.38
					Output gap					
Mean	−0.72	−0.59	−1.07	−0.72	−0.77	−0.53	−0.33	−0.50	−0.50	−0.47
Median	−0.10	−0.10	−0.60	0	−0.15	−0.10	0	−0.05	−0.30	−0.11
StdDev	1.21	1.22	1.12	1.33	1.20	1.09	0.95	1.07	0.86	0.98
					Interest rate					
Mean	6.28	6.04	6.95	6.28	6.39	5.94	5.55	5.87	5.91	5.82
Median	5.30	5.20	6.40	5	5.40	5.20	5	5.10	5.60	5.31
StdDev	2.18	2.10	2.06	2.42	2.13	1.87	1.58	1.80	1.38	1.60

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APPENDIX C: STATISTICAL TEST RESULTS

In the following tables, p-values are reported in brackets. ***, **, and *, respectively, indicate significance at conventional 1%, 5%, and 10% levels.

C.1. PAIRWISE COMPARISON: IMPLICIT STRICT VERSUS IMPLICIT FLEXIBLE IT

TABLE C.1. Statistical tests: Implicit strict versus implicit flexible IT

Macroeconomic outcomes	Mann–Whitney–Wilcoxon test Statistical equality of medians?	Siegel–Tukey test Statistical equality of variances?
Inflation	No*** (0.0000)	Yes (0.9594)
Output gap	Yes (0.1467)	No* (0.0918)
Interest rate	No*** (0.0001)	Yes (0.7401)

C.2. PAIRWISE COMPARISON: EXPLICIT STRICT VERSUS EXPLICIT FLEXIBLE IT

TABLE C.2. Descriptive statistics: Explicit strict versus explicit flexible IT

Macroeconomic outcomes	Mann–Whitney–Wilcoxon test Statistical equality of medians?	Siegel–Tukey test Statistical equality of variances?
Inflation	No*** (0.0000)	Yes (0.6973)
Output gap	No** (0.0349)	No** (0.0124)
Interest rate	No*** (0.0000)	Yes (0.3106)

C.3. PAIRWISE COMPARISON: IMPLICIT VERSUS EXPLICIT STRICT IT

TABLE C.3. Descriptive statistics: Implicit versus explicit strict IT

Macroeconomic outcomes	Mann–Whitney–Wilcoxon test Statistical equality of medians?	Siegel–Tukey test Statistical equality of variances?
Inflation	Yes (0.2558)	Yes (0.2481)
Output gap	Yes (0.2493)	Yes (0.6963)
Interest rate	Yes (0.2761)	Yes (0.2948)

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C.4. PAIRWISE COMPARISON: IMPLICIT VERSUS EXPLICIT FLEXIBLE IT

TABLE C.4. Descriptive statistics: Implicit versus explicit flexible IT

Macroeconomic outcomes	Mann–Whitney–Wilcoxon test Statistical equality of medians?	Siegel–Tukey test Statistical equality of variances?
Inflation	Yes (0.2001)	No** (0.0489)
Output gap	Yes (0.1272)	No* (0.0931)
Interest rate	Yes (0.2293)	No** (0.0444)

APPENDIX D: INFLATION AND AVERAGE INFLATION EXPECTATIONS SERIES ACROSS SESSIONS BY TREATMENT

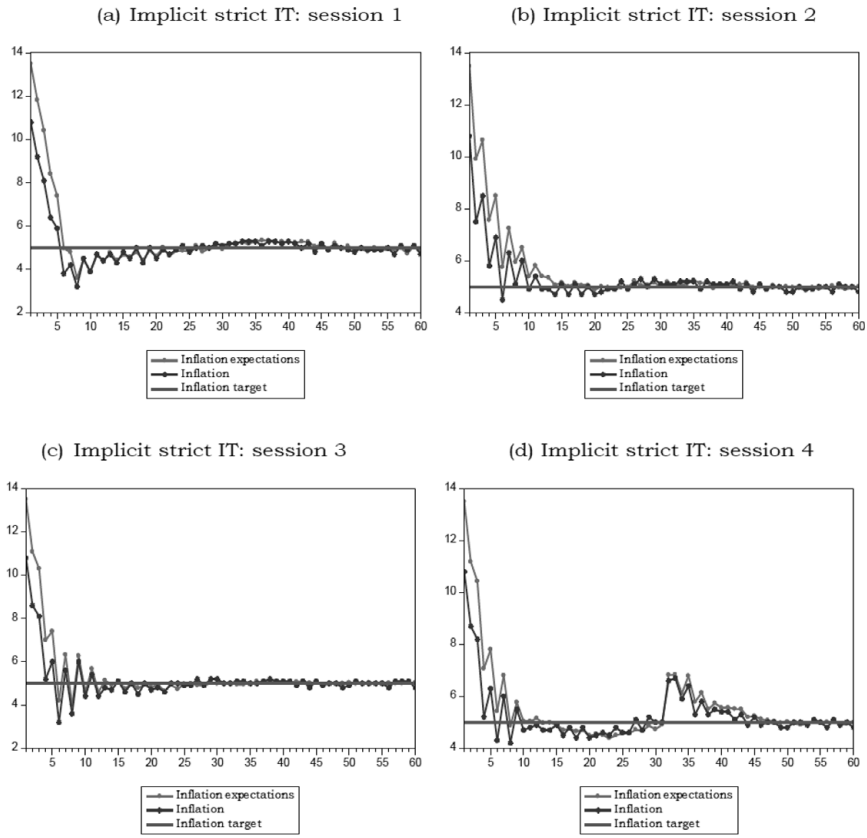

FIGURE D.1. Implicit strict IT: Sessions 1–4.

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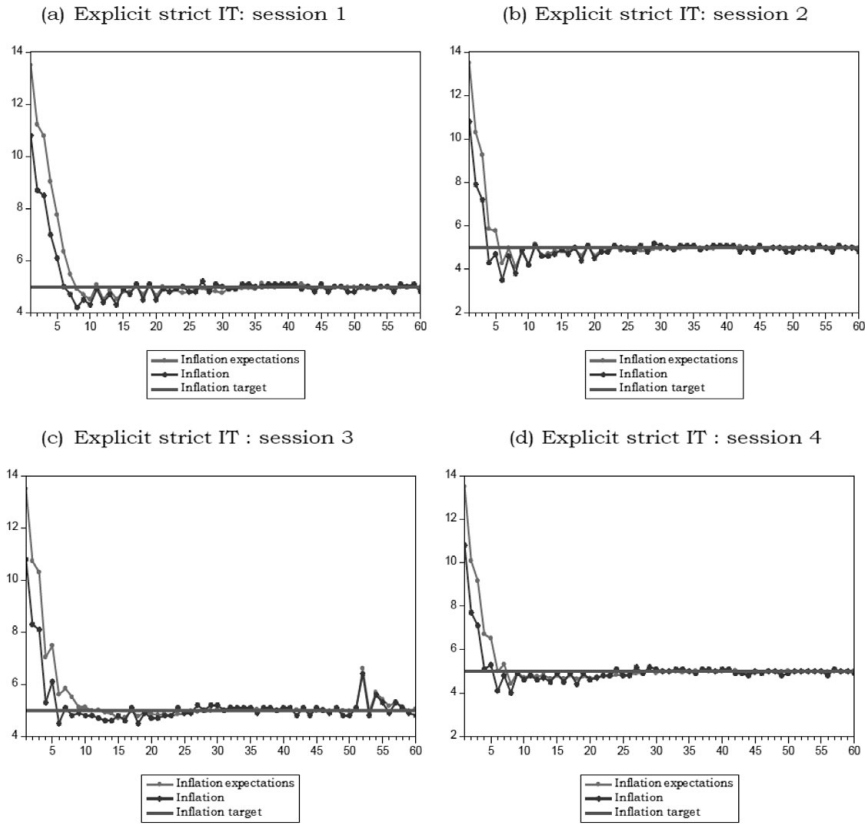

FIGURE D.2. Explicit strict IT: Sessions 1–4.

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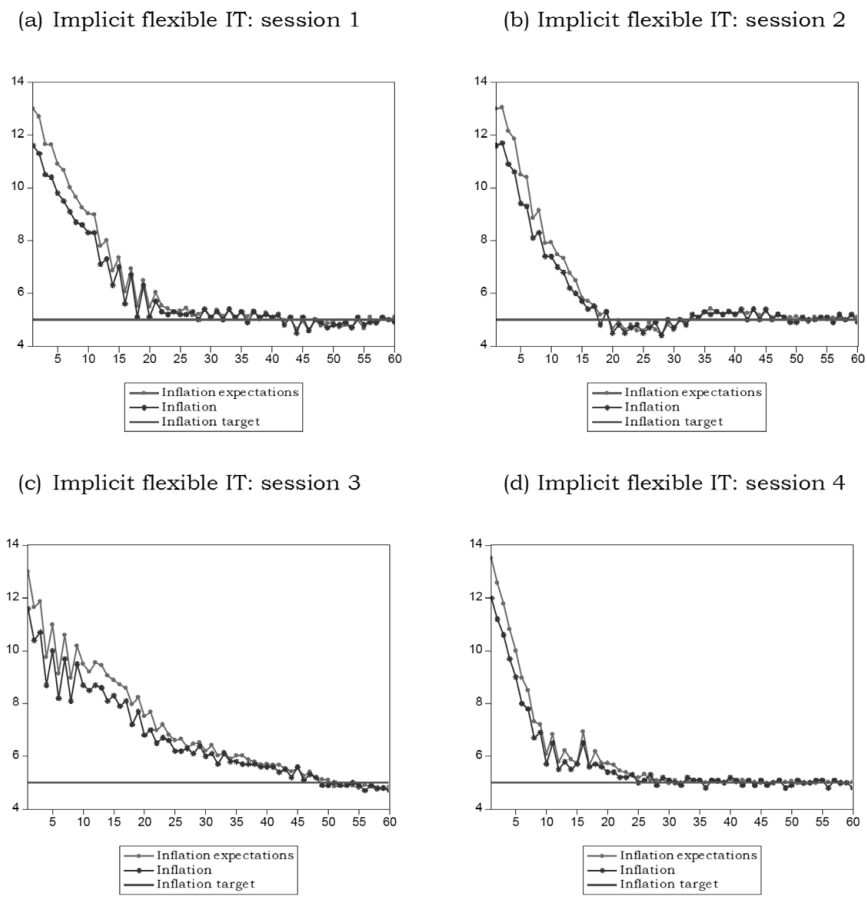

FIGURE D.3. Implicit flexible IT: Sessions 1–4.

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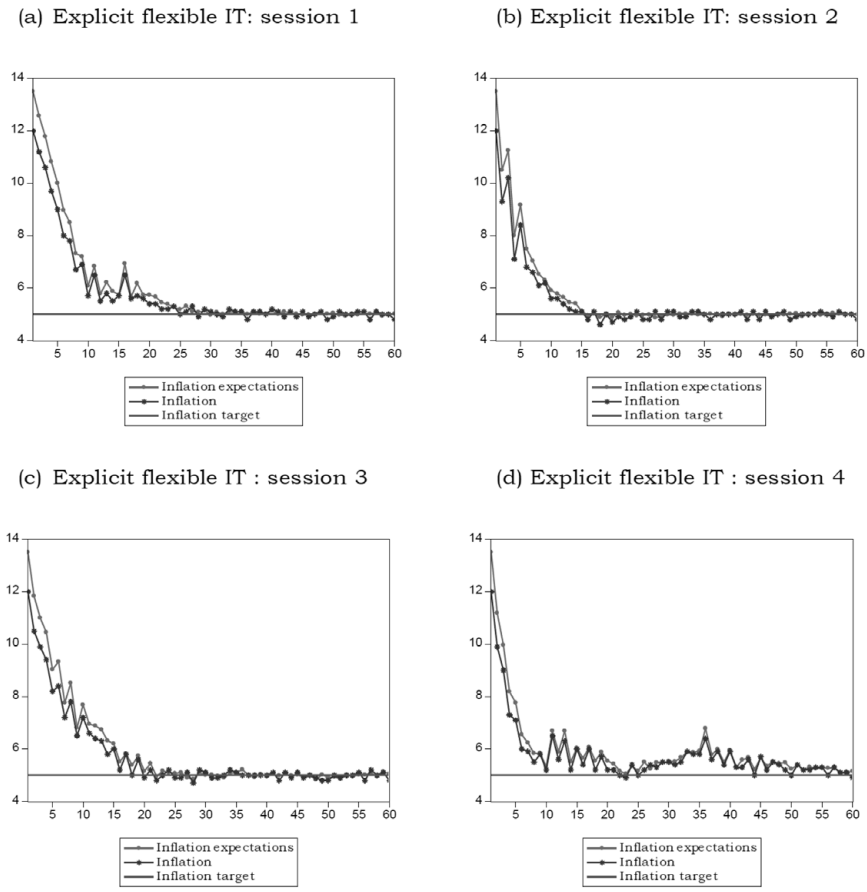

FIGURE D.4. Explicit flexible IT: Sessions 1–4.

APPENDIX E: FORMATION OF INDIVIDUAL INFLATION EXPECTATIONS

In this Appendix, following the LtFE literature, which emphasizes expectations heterogeneity, we analyze the formation of individual inflation expectations owing to time series data that the experiment made it possible to collect for all subjects. This exercise is important for at least two reasons. First, as agents' expectations mainly influence macroeconomic outcomes,[29] analyzing how these expectations are formed enables us to understand and interpret the resulting macroeconomic outcomes (in Section 4). Second, it makes it possible to evaluate the impact of implicit and explicit inflation-targeting rules on the agents' expectations formation.

We consider the main expectations formation models supported in the literature by following Assenza et al. (2013) and Pfajfar and Zakelj (2013, 2014).[30] Subjects behave like

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econometricians and select both the given rule and its parameters to forecast inflation. As exogenous shocks were not directly observable in our experiment, we do not include them in the given expectation models. As in Assenza et al. (2013), we assume that subjects need to have a learning step before completely forming their forecasting rules. Therefore, we drop the first 10 periods of the experiment out of our regression samples. The methodology we apply here is the following. For each subject of each session (each including four treatments), we estimate the coefficient(s) of interest of the given expectation model (OLS estimation). Then and conditional on the significance of the estimated parameter(s), we compute for each treatment the percentage of subjects using such a forecasting rule.

E.1. PREDICTION MODELS

Naive expectations model: This forecasting model can be described as follows:

$$\pi^i_{t+1/t} = \alpha_0 + \alpha_1 \pi_{t-1}, \tag{M1}$$

where $\pi^i_{t+1/t}$ denotes subject i's (where $i = 1, 2, \ldots, 96$) inflation expectation at time t for $t + 1$, π_{t-1} represents the past period inflation rate, and α_0 and α_1 are the estimating parameters. According to this forecasting rule, agents simply form their expectations for the next period conditional on the past period inflation rate.

AR(1) expectations model: This expectations model can be defined as follows:

$$\pi^i_{t+1/t} = \beta_0 + \beta_1 \pi^i_{t/t-1}, \tag{M2}$$

where $\pi^i_{t+1/t}$ denotes subject i's inflation expectation at time t for $t + 1$, $\pi^i_{t/t-1}$ represents its past period forecast, and β_0 and β_1 are the estimating parameters. This forecasting rule suggests that agents form their next-period expectations taking into account only their last inflation forecasts.

Trend extrapolation model: This forecasting rule can be presented as follows:

$$\pi^i_{t+1/t} = \gamma_0 + \pi_{t-1} + \gamma_1(\pi_{t-1} - \pi_{t-2}), \tag{M3}$$

where γ_0 and γ_1 are the estimating parameters. According to this prediction rule, agents form their inflation forecasts based on past inflation, but also on the trend of past inflation. In other words, if $\gamma_1 \geq 0$, agents expect that the upward or downward movements in inflation will continue in the next period. Conversely, if $\gamma_1 > 0$, agents expect that the upward (downward) movements in inflation will be followed by downward (upward) movements in the next period. This type of forecasting rule is found to be important for expectations formation processes in the experimental literature.

Adaptive expectations model: This model can be defined in the following way:

$$\pi^i_{t+1/t} = \pi^i_{t-1/t-2} + \eta(\pi_{t-1} - \pi^i_{t-1/t-2}), \tag{M4}$$

where $\eta \geq 0$ is the constant gain parameter. In this version of adaptive learning rule, agents revise their expectations based on their last observed errors. The revision concerns the previous period forecast (for time $t - 1$, which is made at $t - 2$).

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TABLE E.1. Percentage of subjects using M1, M2, M3, and M4 expectation models for each treatment

Model	Implicit strict IT	Explicit strict IT	Implicit flexible IT	Explicit flexible IT
M1	75.00	70.83	50.00	66.67
M2	41.67	29.17	45.83	20.83
M3	62.50	79.17	37.50	44.83
M4	95.83	91.67	91.67	69.67

E.2. ECONOMETRIC RESULTS AND SWITCHING BEHAVIOR

Table E.1 presents for each treatment the percentage of subjects using the given expectations model.

We observe some differences across treatments as to which forecasting rule is more relevant. Indeed, we find that the implicit strict IT treatment is the one that has the highest proportion (75.00%) of subjects who use the naive expectations model (M1) to forecast inflation, whereas the implicit flexible IT treatment is associated with the lowest proportion (50.00%) of subjects who use this forecasting rule to form their expectations. We also explore whether the behavior of individual inflation expectations among treatments is consistent with the AR(1) model. We find that in general, (M2) is the least used forecasting rule over all treatments: subjects do not really use this forecasting rule to predict inflation.

Of particular interest are the remaining two forecasting models, i.e., trend extrapolation (M3) and adaptive expectations (M4) models. We find that both prediction rules play an important role in the dynamics of inflation expectations formation, as all subjects in each treatment use these models on average to forecast inflation. The strict IT treatments (implicit and explicit) are associated with the highest proportion (62.50% and 79.17%, respectively) of subjects using M3, whereas both implicit IT treatments (Treatments 1 and 3) are associated with the highest proportion of subjects using the adaptive learning rule to predict inflation. These results are consistent with those of Assenza et al. (2013) and Pfajfar and Zakelj (2014), who find in their implicit strict IT treatments that subjects use M3 and M4 most to form their expectations. Moreover, we find that for the trend extrapolation model, the significant coefficient γ_1 is below 0 for a large proportion of subjects in all treatments. This suggests that on the average and in all treatments, subjects using this rule expect that upward (downward) movements in inflation in the current period will be followed by downward (upward) movements in the next period.

An additional observation stemming from Table E.1 is that the shares of each treatment do not add up to 100%. This is explained by the fact that subjects switch between different rules during the experiment, as supported by the literature.[31] To analyze this switching behavior more deeply, we recursively compute the root mean squared error (RMSE) up to period t for models M1, M2, M3, and M4 and then compare them for each subject in each period of the cycle.[32] The best model in each period is the one that produces the lowest RMSE. Switching occurs whenever the model that best performs in the previous period is outperformed in the current period. The general results are given in Table E.2.

Two main observations emerge from Table E.2. First, it appears that on the average, switching behavior occurs more frequently in implicit IT treatments (1 and 3) than in explicit IT treatments (2 and 4). Second, in pairwise comparisons, the frequency of switching is more

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TABLE E.2. Average number of switching periods by treatment

Treatment	No.
Implicit strict IT	3
Explicit strict IT	7
Implicit flexible IT	3
Explicit flexible IT	6

important in an explicit flexible IT treatment than in an explicit strict IT treatment, whereas we observe the same frequency of switching in both implicit IT treatments (1 and 3). Indeed, switching occurs every three periods on the average in both implicit IT treatments. In the explicit flexible IT treatment, subjects switch every six periods on the average, whereas in the explicit strict IT treatment, they switch every seven periods on the average. As we said earlier, the first observation can be explained by the fact that the announcement of the inflation target serves as guidance for agents' expectations formation, in contrast to a case where subjects do not have any information about the objectives of the central bank. The second observation can be explained by the nature of the central bank's objective. Indeed, as the central bank has only a single goal in the strict IT treatments, subjects understand the preference of the central bank more quickly and form their expectations accordingly, compared with the flexible IT treatments, in which the double objective of the central bank renders subjects' expectation formation more complicated.

After having established the role played by forecasting rules in the dynamics of individual inflation expectations in each treatment, we now look for the prediction model that best explains the formation of average inflation expectations within each treatment. To do so, for each session of each treatment, we consider average inflation expectations and look at all prediction models to select the one that yields the highest adjusted R^2. After doing this, we select the most relevant forecasting rule for a whole treatment. We find that the trend extrapolation rule appears to be the forecasting model that best explains the formation of average inflation expectations in all treatments except explicit flexible IT. In particular, we find that in three out of four sessions in both implicit and explicit strict IT treatments M3 is the most used model on average, and in two out of four sessions in the implicit flexible IT treatment M3 is the most used model on average, whereas in explicit flexible IT treatment M3 is the most used model in only one out of four sessions. For the last treatment, M1 is best representative of inflation expectations in two out of four sessions on the average, suggesting that in these two sessions, agents use the naive expectations model when oscillations decrease and actual inflation converges toward the inflation target.

APPENDIX F: INSTRUCTIONS

We present a translation from French to English of the instructions for Treatment 4 (explicit flexible inflation targeting). Instructions for other treatments are available from the authors upon request.

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General information

Thank you for your participation in this economic experiment, in which you can earn money. Your earnings will depend on both your actions and those of the other participants and will be paid in cash at the end of the experiment. From now until the end of the experiment, you are not allowed to communicate with each other. If you have any question, please raise your hand and we will come to you.

You are a group of six participants. The rules are the same for all participants. The experiment consists of 60 periods. Your role is to predict future values of a given economic variable. Your earnings will depend on the accuracy of your predictions. In each of the 60 periods, the economy will be characterized by the following variables: the inflation rate, the output gap, the interest rate, and the inflation target of the central bank.

Information about economic variables

To better understand the economic variables that you will use to make your decisions, we explain these variables as follows.

Inflation: Is defined as the generalized rise in prices in the economy. Inflation will depend in each period on agents' average inflation forecasts in the economy (that is, both your forecast and the forecasts of the five other participants), on the output gap, and on a random shock affecting the economy.

The output gap: Describes the gap between the current output and the potential output (that is, the level of output the economy can achieve by using the maximum of its productive capacity). If the output gap is positive, the economy is producing beyond its potential level. Conversely, if the output gap is negative, the economy is producing below its potential level. The output gap also depends in each period on the agents' average inflation forecasts (your prediction and the predictions of the five other participants), the lagged output gap, the interest rate, and a random shock affecting the economy.

The interest rate: Is defined as the price of borrowing money for a period, and is set by the central bank of the economy. The interest rate mainly depends on inflation (and therefore indirectly on inflation forecasts), the output gap, and the inflation target of the central bank.

The inflation target: Is clearly announced to all participants by the central bank in the form of a numerical target of 5% with a tolerance interval of $\pm 1\%$ around the target. The inflation target is announced in a context of high inflation in the economy, and reflects the central bank's determination to reduce this high inflation. So the central bank commits to reach its inflation target of 5%. However, given the various random shocks affecting the economy, the central bank allows itself a margin of error of $\pm 1\%$ around its target. The inflation target then corresponds to a commitment of the central bank, which has to ensure (via the interest rate) that inflation in the economy will converge toward this target.

The central bank has two goals: one primary, and the other secondary.

The primary goal, the more important, is for the central bank to stabilize inflation, that is, to make as quickly as possible actual inflation converge toward its inflation target. The central bank uses the interest rate to stabilize inflation. Positive and significant deviations

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of actual inflation from the target (that is, actual inflation is not equal to the numerical target of 5%, and is above the upper band of the tolerance interval of 6%) force the central bank to increase the interest rate in order to lead actual inflation toward its target. In contrast, when the central bank notes that inflation is too low compared with its inflation target (that is, actual inflation is not equal to the numerical target of 5%, and is below the lower band of the tolerance interval of 4%) and penalizes the economic activity, it reduces the interest rate.

The secondary goal for the central bank consists in stabilizing the output gap, that is, the gap between the current and potential output of the economy, by also using the interest rate. When the output gap is positive, the central bank tends to increase the interest rate, and when it is negative, the central bank tends to reduce the interest rate.

All these variables can be relevant for your inflation forecasts, but it is up to you to use them at your convenience to decide on your inflation expectations. The actual values of the different variables largely depend on your inflation forecasts and those of the others, but also on random shocks affecting the economy.

At the beginning of the experiment and before entering your inflation forecast for the first period in the computer, you observe on the screen the past values of the main economic variables (inflation, output gap, and interest rate) of the five previous periods. Given the high values of inflation in the economy, the central bank implements an inflation-targeting strategy by announcing to all participants its numerical target of 5% with tolerance interval $\pm 1\%$. By this announcement, the central bank commits to lead actual inflation toward its inflation target within a maximum of two periods. So you observe the central bank's target within its tolerance interval. This target remains unchanged throughout the duration of the experiment. Based on these variables, you have to forecast inflation for the next period.

Once you have made your decision, a period ends and a new period starts where you observe the past and actual values of inflation, the output gap, the interest rate, and your inflation forecast in the previous period. However, you do not observe the expectations of other participants in your group (you just indirectly observe them through actual inflation). All you observe in terms of expectations is your own time series forecasts. As time goes on, you get a large number of observations that allow you to evaluate the accuracy of your forecasts compared with actual values of inflation, as well as the inflation target of the central bank.

Information about your role in the economy

Throughout the 60 periods of the experiment, your role as an agent of the economy is simple. You have to forecast the actual value of future inflation. In other words, you have to predict in each period the inflation that will prevail in the next period, based on all information available to you when making your decision. You must then enter into the computer your inflation forecast. Suppose that on your computer screen, you observe at period 2 actual inflation. This observed inflation is not based on the forecasts that you and the other participants of your group have made at period 2, but the predictions you made in the previous period, that is, those made in period 1 for period 2.

By choosing your inflation forecast, you seek to maximize your earnings. Your gain in each period depends on the accuracy of your inflation forecast relative to actual (realized)

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inflation. More specifically, your gain is given by

$$\text{Your profit in ECU} = \max\left\{\frac{160}{1+f} - 40, 0\right\},$$

where f =| Inflation−Your forecast |. "Inflation" indicates actual inflation, "Your forecast" defines your inflation forecast made in the previous period for the next, f indicates in absolute value your forecasting error, and finally "ECU" indicates the Experimental Currency Unit. The profit function above means that you get money every time your forecasting error is less than 3%. The smaller your forecasting error, the higher your payoff. For instance, if f = 0, you receive the maximum payoff of 120 units (160/(1+0)–40). If your forecasting error is 1.5%, you receive 24 units (160/(1+1.5)–40). Otherwise, if your forecasting error is 3% or higher, then you receive 0 units (160/ (1+3) – 40). You can only choose your inflation forecasts within the interval [3, 16]. You can only choose whole numbers or numbers with one decimal digit (for instance, 5, 8.5, 4.6, etc.). In addition, when making your decisions, you have to enter only numbers without the "%" symbol.

Once you have entered your decision into the computer, click on the "Submit" button. Once all participants have done the same, the period ends and the profit for this period is written on the computer screen. Then the next period starts. Once all 60 periods are completed, the experiment ends. In each of the 60 periods of the experiment, at the top of each screen and on a graph, you can observe the entire history of economic variables, as well as your earnings. You can then check in each period if your inflation forecast made in the previous period corresponds to actual inflation, and also whether it corresponds or converges toward the inflation target of the central bank. You will be informed about your gains period by period, and at the end of the experiment, your earnings will be added and will be paid in cash converted at the exchange rate of €1=520 ECU. Note that you do not get money in the first period of the experiment because you will not have made any forecast for period 1. So your potential gains start in period 2 of the experiment, because you will have made forecasts in period 1 for period 2.

Questionnaire

At the beginning of the experiment, we ask you to fill out a questionnaire to make sure that you understand the instructions. When all participants have correctly answered the questionnaire, the experiment will begin. At the end of the experiment, we ask you to complete a personal questionnaire on the computer. All requested information will remain strictly confidential and is used for the sole purpose of research.

If you have any questions, please ask them now!

Thank you for your participation!

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APPENDIX G: EXAMPLES OF SCREENS

We provide examples of screens (first screen: implicit inflation targeting; second screen: explicit inflation targeting).

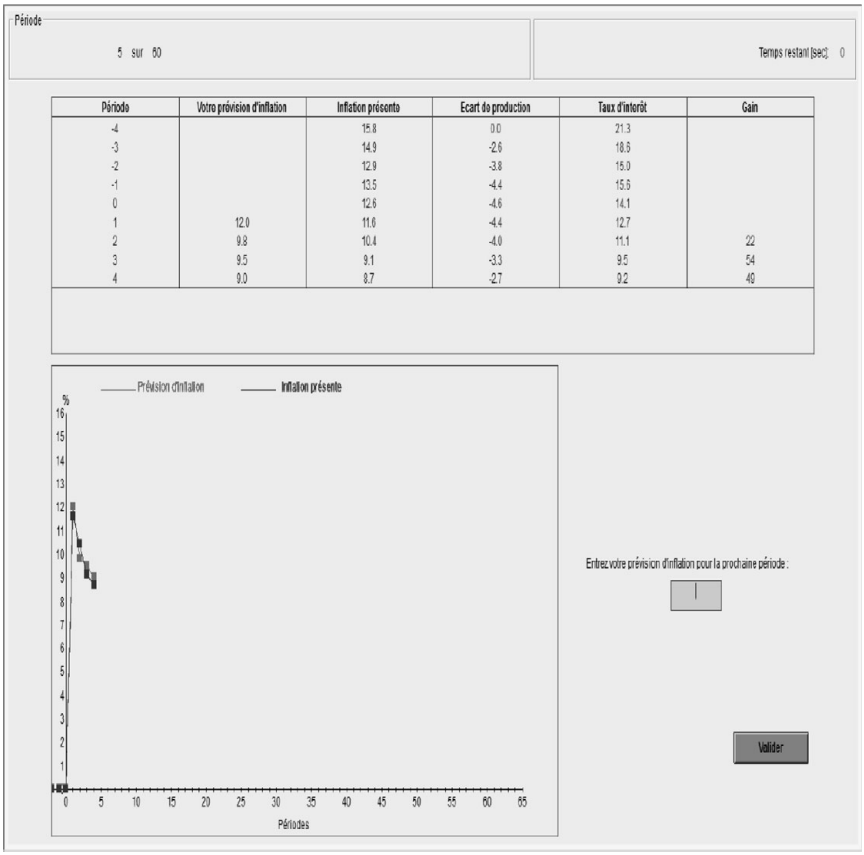

FIGURE G.1. Implicit IT: Example of screen.

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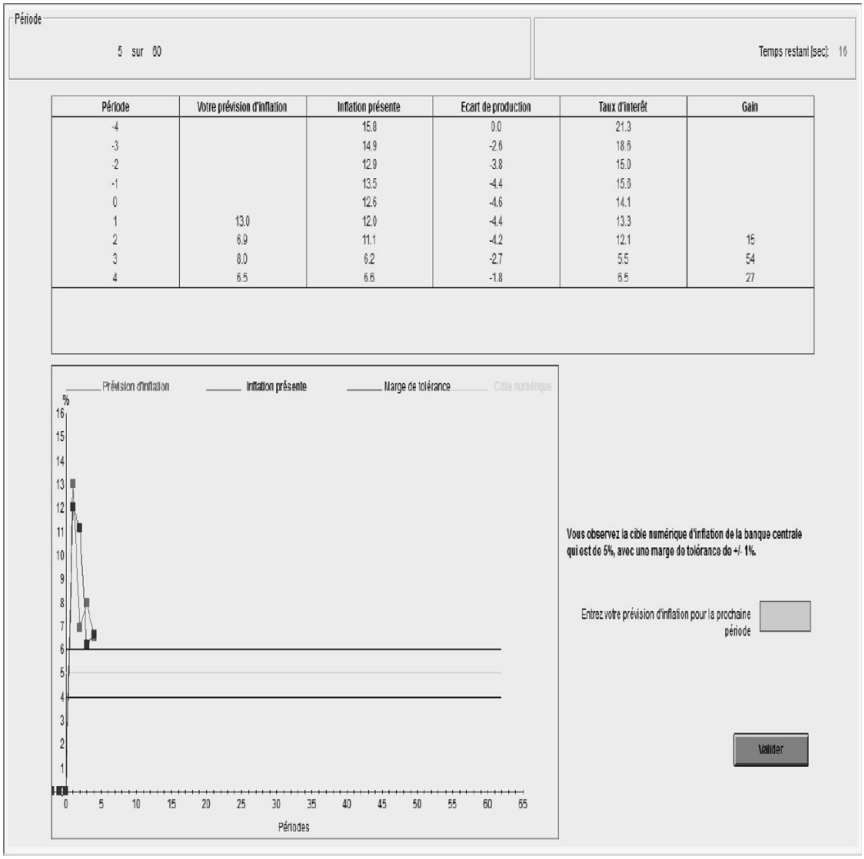

FIGURE G.2. Explicit IT: Example of screen.

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