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Abstract

In this paper, we use an economics decision-making experiment to test a key assumption underpinning the efficacy of price-level targeting relative to inflation targeting for business cycle stabilization and mitigating the effects of the zero lower bound on nominal interest rates. In particular, we attempt to infer whether experimental participants understand the stationary nature of the price level under price-level targeting by observing their inflation forecasting behaviour in a laboratory setting. This is an important assumption since, without it, price-level targeting can lead to worse outcomes than inflation targeting. Our main result suggests that participants formulate inflation expectations consistent with the target-reverting nature of the price level but that they do not fully utilize it in their forecasts of future inflation.

JEL classification: E32, E52
Bank classification: Monetary policy framework

Résumé

Les auteurs font une série d’expériences en laboratoire pour tester une hypothèse clé qui explique la supériorité que les cibles de niveau des prix affichent sur les cibles d’inflation en matière de stabilisation économique et d’atténuation des effets de la borne limitant les taux d’intérêt nominaux à zéro. Ils tentent en particulier d’établir si les participants à l’exercice reconnaissent la nature stationnaire du niveau des prix lorsque la cible est définie en fonction de ce dernier, et ce, en étudiant leur comportement prévisionnel en laboratoire. Cette hypothèse est cruciale, car si elle n’est pas respectée, le ciblage du niveau des prix peut donner de moins bons résultats que celui de l’inflation. La principale conclusion des auteurs est que les attentes d’inflation que formulent les participants cadrent avec la propension du niveau des prix à revenir à la cible, mais que leurs prévisions de l’inflation future n’intègrent pas entièrement cette information.

Classification JEL : E32, E52
Classification de la Banque : Cadre de la politique monétaire

1 Introduction

Since the early 1990s central banks have increasingly been using inflation targeting as a basis for their monetary policy framework. First adopted by the Reserve Bank of New Zealand in 1990, inflation targeting, as of 2010, has been implemented by more than 25 central banks worldwide, with several others in the process of moving toward it. The Bank of Japan, the European Central Bank and the U.S. Federal Reserve Bank remain important exceptions but they appear to have embraced many of the main elements of inflation targeting. This apparent convergence on a particular monetary policy framework begs the question: Is this as good as it gets? Is inflation targeting the best monetary policy for a central bank to follow?

In a similar way, the late 1970s and early 1980s witnessed a number of central banks converging on money demand targeting as a means to conduct monetary policy. This consensus, however, was broken in the mid-1980s when changes in banking led to unreliable money demand relationships, forcing many central banks to abandon money demand targeting as a money policy framework. The recent financial crisis may be having a similar effect, leading some to ask whether the current inflation targeting consensus needs to be re-visited.

An alternative approach to monetary policy implemented by the Riksbank in the 1930s and actively being studied by the Bank of Canada as a potential replacement for their current inflation targeting regime is price-level targeting.[1] Eggertson and Woodford (2003), Svensson (2003) and Evans (2010), among others, have proposed price-level targeting as a potential means to moderate the effects of the zero lower bound. Theoretically, price-level targeting performs better than inflation targeting in terms of business cycle stabilization and mitigating episodes at or near the zero bound on nominal interest rates, but its efficacy hinges on an important assumption: economic agents must forecast inflation rationally (in a Muth sense) and in a manner consistent with the price-level targeting regime. If agents do not, then it is entirely possible for price-level targeting to deliver results that are inferior to inflation targeting. Given the potential utility of price-level targeting, it is important to see if private agents would admit inflation expectations consistent with price-level targeting. Unfortunately, evidence regarding how inflation expectations evolve under price-level targeting is sparse. As such, we attempt to fill this important void by undertaking an experimental economics laboratory study to shed some light on the

[1] See Berg and Jonung (1998) for a lucid description of price-level targeting in Sweden in the 1930s, and the Bank of Canada 2006 Renewal Backgrounder for information on its price-level targeting research agenda. For the relative merits of price-level targeting versus inflation targeting, see Svensson (1999), Woodford (2003) and Vestin (2006).

question of inflation expectations formation under price-level targeting.[2]
This paper is structured as follows. Section 2 offers a comparison between inflation and price-level targeting, focusing on the importance of inflation expectations for monetary policy. Section 3 describes the experimental design and procedures while Section 4 reports the results based on our experiments. Section 5 concludes.

2 Inflation Targeting versus Price-Level Targeting

Recall that the inflation rate is simply the percentage change in the price level. For low levels of inflation, this relationship is well-approximated by the linear equation, $\pi_t = p_t - p_{t-1}$ where π_t is the inflation rate in period t and p_t is the logarithm of the price level. The equation can be rearranged to give $p_t = p_{t-1} + \pi_t$. When the relationship between the price level and inflation is written in this form, it is apparent that any shock to inflation will have a permanent effect on the price level unless offset by a future shock. For example, a positive shock to inflation in period t would increase the price level in period t and all future periods unless it is offset by a negative shock of equal magnitude at some point in the future.
Under inflation targeting (IT), no attempt is made to correct past deviations from target. If inflation is above target today, the central bank will not deliberately engineer inflation below target in the future, and vice versa. Thus, under IT, shocks to inflation are allowed to have a permanent effect on the price level. In contrast, price-level targeting (PLT) aims to bring the price level back to a price-level target in the following periods.
To highlight this difference between IT and PLT, consider the case of a purely transitory inflationary shock in a canonical new Keynesian macroeconomic model (see Gali and Gertler 1999). After the shock, inflation rises and economic activity falls (a consequence of monetary policy tightening in response to the shock) but, importantly, the expected rate of inflation remains anchored at the target since the shock is transitory and does not affect future inflation. In other words, inflation expectations

[2] While the question we ask is novel, the application of experimental economics to understanding the formation of inflation expectations is not. See, for example, Marimon and Sunder (1993, 1994), Hommes (2007), Adam (2007), and Pfajfar and Zakelj (2009) for an application of experimental economic to inflation expectations. More generally, experimental economics has been used to explore many topics central to macroeconomic issues such as optimal lifetime consumption and savings decisions, coordination, theories of money, commitment versus discretion, fiscal and tax policies, and central bank decision making with some success (Duffy 2008). Indeed, experiments are a widely accepted methodology in economics, with the 2002 Nobel Prize in economics being awarded for contributions in this area.

remain anchored on the target and therefore neither exacerbate, nor mitigate, the impact of the shock. As soon as the shock dissipates, inflation and activity return to their long-run averages. In contrast, the price level rises permanently.

Now consider the same transitory shock under PLT. In contrast to the scenario under IT, the expected rate of inflation falls, as agents anticipate the future lower inflation rates required to offset the increase in inflation and return the price level to its target. The decrease in inflation expectations increases the real interest rate which implies that monetary authority does not need to be as aggressive as under IT. In fact, this self-reinforcing mechanism moderates the movement in inflation and economic activity relative to the IT regime. The key point is that the movement of inflation expectations allows the central bank to achieve greater stabilization of inflation and economic activity under PLT than IT. If, on the other hand, expectations do not endogenously adjust, then PLT will lead to worse stabilization outcomes than IT. Therefore, how inflation expectations adjust under a price-level targeting regime is a key question.

3 Experimental Design

In our experiments, subjects are atomistic so their inflation expectations do not affect macroeconomic outcomes as our aim is to see if experimental participants are capable of producing inflation forecasts consistent with the target-reverting nature of the price-level under PLT. In the experiment, the subjects observe realized values of macroeconomic variables in the model economy (where all agents behave rationally) and attempt to predict inflation in the next period. The accuracy of their inflation forecasts determines the amount of their payout.

3.1 Monetary Policy and Payoffs

In an effort to isolate how subjects may change their inflation expectations formation behaviour, we generate inflation and price-level time series that are consistent with simple inflation targeting and price-level targeting rules. Under IT, we assumed that the central bank stabilizes expected inflation at zero, that is $E_t\pi_{t+1} = 0$. Under PLT, on the other hand, the central bank sets policy such that the expected price level next period is at its constant target, that is $E_t p_{t+1} = \bar{p}$. In other words, in any period the best inflation forecast under IT is the inflation target whereas under PLT the best prediction of inflation is the inflation rate that takes the price level back to its constant target. In addition, we ensured that the variability of inflation is the same

across IT and PLT regimes so that any gains in predicting inflation under price-level targeting would not be attributable to a change in the volatility of inflation.
There are three features of the current approach worth highlighting: (i) This experimental design matches the targeting horizon of the central bank and inflation forecasting period at one period such that the rational expectations inflation forecast is conceptually simple and does not require elaborate forecasting techniques to forecast the dynamic path of inflation multiple periods into the future; (ii) as the optimal forecasts are simple, any deviations from rational forecasts are straightforward to observe and analyze;[3] and (iii) since optimal forecasts of inflations have drastically different dynamics under IT and PLT (optimal inflation forecast is fixed under IT and it is perfectly negatively correlated with the current price level under PLT), the experiment allows us to clearly determine if participants exploit the additional information that the price level provides under PLT.

We discretized the forecasting strategy space to simplify and focus the subjects' decision making on the essence of the forecasting problem. That is, a participant is asked to choose an interval where he or she predicts next period's inflation rate will lie. If the correct interval is chosen, the payoff is maximized. There are 13 intervals comprised of 11 interior intervals and two unbounded intervals at the endpoints. The interior intervals span 0.5 percent with the middle interval centered on zero percent inflation and bounded by 0.25 and -0.25 percent. The other interior intervals are constructed similarly. The two endpoint intervals capture inflation forecasts that are either greater than 2.75 percent or less than -2.75 percent.[4]

A quadratic loss function based on forecasting accuracy determines payoffs. Incorrect intervals result in increasingly smaller payoffs depending on the distance from the correct one.[5] Owing to the flatness of a quadratic function at its maximum, the quadratic payoff function used in this experiment rewards inflation forecasts that are "close" almost as well as inflation forecasts that lie in the correct interval. The latter feature suggests that it may be more difficult for subjects to detect differences in optimal inflation expectations formation across IT and PLT regimes.

[3]In our experiment, rational expectations forecasts of inflation are optimal forecasts. Thus we use these two terms interchangeably.

[4]The endpoint intervals are constructed to match approximately two standard deviation realizations of inflation.

[5]The figure in the experimental instructions in Appendix B displays the loss function.

3.2 Experimental Procedures and Parameters

As a first step, we simulate stochastically the macroeconomic model, and store the resulting time-series data for inflation, output, aggregate price level and the short-term interest rate under two scenarios. First, we simulate an economy where the central bank targets a zero inflation rate, and second, an economy where the central bank targets a constant price level. As mentioned above, when we simulate the price-level targeting regime, we ensure that the variance of inflation is the same as in the IT regime.

We implement our simulated macroeconomy over the computer network in the experimental laboratory at Center for Interuniversity Research and Analysis on Organizations in Montreal, Canada. The computer provides an interface, which presents subjects with the history of the previous eight periods of their economy. This history consists of the variables required to make an optimal prediction of inflation: inflation and aggregate price level. These two variables are displayed in tables and graphs on the subjects' computer screen. The other variables are not displayed as they are not necessary inputs for making optimal forecasts. Indeed, by providing only inflation and the price level, we hope to focus the subjects' attention to the movement or lack of movement in inflation for making optimal forecasts.

At the beginning of the game, subjects are shown eight consecutive periods of macroeconomic results, and asked to predict annualized inflation for the next period. In the case of inflation targeting, a horizontal line fixed at zero in the inflation graph reminded the subjects of the central bank's target; in the case of price-level targeting, a line showing the price-level target was always present. After making their choice by selecting one of the 13 forecast intervals, the next period's results are displayed, and the previous seven periods shifted to the left, always providing a window with the last eight periods' results.

Subjects were instructed that their task is to predict the rate of inflation in a computer-simulated economy. To clarify the role of the central bank, we made the point that under IT, the central bank does not concern itself with the past price level. As well, subjects were reminded that under PLT, the central bank would act to bring the price level to its constant target. The instructions for the two different regimes were parallel, involving identical paragraph and sentence structures.[6]

Finally, subjects are given a broad overview of properties of the underlying model used to generate the time-series data, but not its details. They were also told that the underlying structure would not change, but that random shocks present in the model would make the underlying structure more difficult to discover. This type of

[6] Appendix B contains the instructions.

instruction where details of a complicated macro model are not revealed has been used by Blinder and Morgan (2007) and Engle-Warnick and Turdaliev (2010), and reflects the fact that people in the real world make forecasts of inflation without a complete understanding of macroeconomy.

We conducted two experimental treatments. Each treatment consists of one 20-period forecasting game, followed by two consecutive games, each lasting 40 periods. The first 20-period game allows the subject to "practice" under an initial regime. For these first 20 periods, subjects repeatedly predict inflation for the next period without pay. This gives subjects the opportunity to learn the system without fear of being penalized for experimentation. The following 40-period game was identical to the first except that the subjects were paid for the accuracy of their forecasts, and experienced a different draw from the database of simulations. Thus, after acquiring experience in an experiment designed to maximize experimentation and learning, they repeated the task with an economic incentive to make an accurate inflation forecast. More specifically, in the control treatment, IT-IT, subjects made their forecasts in three consecutive inflation-targeting economies whereas in the manipulated treatment, IT-PLT, subjects practiced under inflation targeting, forecasted for pay under inflation targeting, and then forecasted for pay after a regime change to price-level targeting. Note that regardless of whether a regime change is implemented of not, the session is stopped after the first 40 periods, and a single page of instructions is distributed for the second 40 periods. The instructions reminded subjects of the role of the central bank, and either stated that central bank continued with IT or shifted to a PLT regime.

As mentioned earlier, subjects are paid depending on the distance between their chosen interval and the correct realized interval. The payoff function is set using Monte Carlo simulations so that optimal forecasting would yield approximately $40 on average for 40 periods of forecasting. Twenty-eight subjects participated in the IT-IT treatments and 25 participated in the IT-PLT targeting treatment. The average payoff was approximately $30 in addition to a standard $10 show-up fee at the experimental laboratory.

4 Results

4.1 Simple Experiment

In this section we attempt to infer whether inflation expectations adjust in a manner consistent with price-level targeting or inflation targeting. To this end, we use the data generated in the experiments and summarize them using simple panel regressions of the form:

$$E_t\pi^i_{t+1} = a + \beta p_t + \gamma\pi_t + \varepsilon^i_t$$

where $E_t\pi^i_{t+1}$ is the i-th subject's expectation of inflation in the next period, p_t is log-deviations of price level from its constant trend, π_t is the current period rate of inflation and ε^i_t is a residual term. The parameters β and γ measure the sensitivity of inflation expectations to movements in the price level and inflation, respectively. Under IT we would expect to see $\hat{\beta}$ and $\hat{\gamma}$ to be equal to zero if expectations are rationally generated since optimal inflation forecasts under our IT rule are always zero. Under PLT and rational expectations, we would expect $\hat{\beta} = -1$ and $\hat{\gamma} = 0$ as the best prediction of inflation is perfectly negatively correlated with today's deviation of the price level from its target. Further, in an effort to account for potential subject heterogeneity in our regression results, we report White (1980) heteroscedasticity-robust standard errors.

The estimation results are reported in Table 1.[7] The second and fourth columns provide a sense of the effect of p_t and π_t on expected inflation under IT. The estimates of γ are approximately equal to 0.14 and statistically significant in both regressions, implying that subjects tend to forecast inflation as if it were persistent even though it is not. The overall level of inflation prediction errors is relatively high, with incorrect intervals chosen in 55 per cent of the cases. Interestingly, we see similar perceived inflation inertia under PLT in the right-most column of Table 1. The elasticity of expected inflation with respect to current realized inflation is about 0.17 (after controlling for the price level). This phenomenon of observing persistence in random data has been documented in the psychology literature and is referred to as the "hot hand" (see, for example, Tversky and Kahneman 1974). The experimental economics literature has also noted this behavior. Huber, Kirchler and Stockl (2008) develop a non-monetary policy laboratory experiment where subjects attempt to predict an unknown process (the process is, in fact a random series). After this experience, the subjects are asked to advise a second group of subjects on predicting the same unknown process. Consistent with our results, Huber et al. observe advice that would be consistent with predicting a persistent series.[8]

The effect of price-level deviations and the inflation rate on expected inflation

[7] We also investigated two alternative specifications. First, in an effort to account for subject heterogeneity, we ran subject-by-subject OLS regressions and then computed the mean regression coefficients across subjects. Second, to incorporate past experimental evidence of forecast smoothing, we included a lagged dependent variable in the regressions. Both alternative specifications returned quantatitively similar results.

[8] This literature, unfortunately, does not provide any direction on how to mitigate this type of behaviour.

under PLT is found in columns three and five. Recall that a good forecast of inflation under the current PLT experiment should, at least, exhibit a negative correlation with p_t. The results suggest that subjects tend to use this directionality property of PLT, on average, by admitting negative estimates of β ranging between -0.38 and -0.55. The later regression coefficient suggests that (after controlling for perceived inflation inertia), on average, people expected that 55 per cent of price deviations from target would be corrected by next period. The inflation forecasts are suboptimal since both estimates of β are statistically different from -1. In other words, subjects are not taking full advantage of a key property of PLT in forming their inflation forecasts. Overall, subjects seem to produce inflation forecasts consistent with the stationarity implication of PLT but the accuracy of those forecasts does not improve over IT as forecasting errors occur approximately 60 per cent of the time.

4.2 Richer Experiment

In this section, we report regression results based on a richer, potentially more realistic, experiment. We use a simple structural macroeconomic model based on Gali and Gertler (1999) to generate the data (see Appendix A). Relative to the earlier setup, the current experimental design does not force next period's inflation or price level back to its target in each period. Instead, the path of inflation is dictated by a historical monetary (Taylor) rule under IT and a PLT rule that maintains the same variance of inflation as under IT.[9] This new feature requires subjects to face the more difficult task of accounting for the dynamic path of inflation when calculating their inflation expectation. Adding to the difficulty, this experiment also requires subjects to provide point inflation forecasts rather than choose intervals, and the targeted price-level path grows at 2 percent rather than being a fixed value.

Again, we summarize the data using panel regressions.[10] The results are reported in Table 2 and can be compared to the parameter estimates obtained under the optimal prediction rule presented in Table 3. Overall, these results support the conclusions regarding PLT from the previous section. That is, once we account for the persistence in inflation, subjects tend to use the directionality implication of PLT implied by the negative estimates of β. More precisely, all the parameters estimates are relatively close to their optimal counterparts except for the coefficient corresponding to the price level term under PLT (right-most column in Table 2). In the latter case, the influence of the price level on expected inflation is less than 40 per cent of its optimal effect. This result is, however, consistent with the earlier conclusion that subjects

[9] See the final paragraph in Appendix A for a fuller description of the monetary rules.

[10] There are 50 subjects in the IT-IT treatment and 53 in the IT-PLT session.

use the directionality implication of PLT but not by the full amount.

5 Concluding Remarks

The objective of this paper has been to determine if agents would forecast inflation in a manner consistent with target-reverting nature of the price level under a regime of price-level targeting. The approach we use, experimental economics, to shed light on our question has been applied to examine other questions related to inflation expectation formation. Nonetheless, our conclusions are tentative because the results found in an experimental economic laboratory are only a rough guide to real-world behaviour. Yet with this caveat in mind, it is useful to write our conclusion as clearly as possible.

Looking across Tables 1 and 2, the results suggest that inflation forecasting behavior changes between IT and PLT regimes. In our simple experiment, subjects move from (incorrectly) relying only on inflation to predict future inflation under IT to using (not fully) the directionality implication of PLT under a PLT regime. An experiment based on a richer, potentially more realistic, economic model also shows subjects tend to rely on the target-reverting nature of the price level to generate their inflation forecasts under PLT. In a sense these results are surprising as experimental participants were able to modify their inflation expectations formation behaviour across IT and PLT regimes; despite having only little information about the economy and given no practice when the targeting regime shifted from IT to PLT. It should be emphasized that the shift to PLT in the experiments was explained only once to subjects. In the real world, a central bank would likely undertake an ongoing communication strategy to explain and remind the public about the implications of PLT, thereby helping agents to more fully exploit the properties of a PLT regime. This may be a useful avenue for future research.

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Table 1: Panel Regression Results for Expected Inflation

Independent Variables	Policy Regime			
	IT	PLT	IT	PLT
Price Level		-0.376*	-0.002	-0.551*
		(0.043)	(0.003)	(0.051)
Inflation	0.141*		0.142*	0.173*
	(0.021)		(0.021)	(0.036)
R-squared	0.066	0.104	0.066	0.126
Number of Observations	1160	1000	1160	1000

Henceforth * indicates significance at the 1 percent levels.
All regressions contain an unreported constant term.
Standard errors are in parentheses and based on
White (1980) consistent variance-covariance estimator.

Table 2: Panel Regression Results for Expected Inflation

Independent Variables	Policy Regime			
	IT	PLT	IT	PLT
Price Level		8.521*	-0.034	-1.140*
		(0.712)	(0.086)	(0.376)
Inflation	0.751*		0.751*	0.750*
	(0.010)		(0.013)	(0.012)
R-squared	0.725	0.067	0.725	0.746
Number of Observations	2145	2262	2145	2262

White (1980) robust standard errors in parentheses

Table 3: Panel Regression Results for Optimal Expected Inflation

Independent Variables	Policy Regime			
	IT	PLT	IT	PLT
Price Level		7.097*	-0.151	-2.967*
		(0.789)	(0.121)	(0.522)
Inflation	0.755*		0.701*	0.781*
	(0.012)		(0.014)	(0.013)
R-squared	0.562	0.038	0.562	0.640
Number of Observations	2145	2262	2145	2262

White (1980) robust standard errors in parentheses

A Appendix: Structural model

We use a simple New-Keynesian DSGE model to generate inflation, output, wage and other series for our experimental study. Since the model is quite standard in the recent macroeconomic literature, we will be brief in describing its main features. The model abstracts from capital accumulation and from fiat money. There are four types of agents in the economy: 1) the representative household who maximizes her life-time expected utility by choosing consumption, labour hours, and risk-free nominal bond holdings; 2) perfectly competitive final-good firms which produce final consumption goods from various intermediate good inputs; 3) monopolistically competitive intermediate-good producers producing different varieties of intermediate goods by utilizing labour hours supplied by the households, and 4) a monetary authority that sets the nominal interest rate via a Taylor rule.[11] We will describe the actions of each of the agents below, starting from the household.

A.1 Household's optimization problem

The representative household's problem is

$$\max_{C_t,B_t,H_t} \mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t - u_t \frac{H_t^{1+v}}{1+v} \right)$$

subject to the budget constraint

$$C_t + \frac{B_t}{P_t R_t} = \frac{1}{P_t} \left[W_t H_t + \int_0^1 D_{jt} \mathrm{d}j + B_{t-1} \right] \tag{1}$$

where C_t is the aggregate consumption; B_t is the quantity of nominal discount bonds purchased by the household in period t; H_t is the number of labour hours supplied by the household, W_t is the nominal wage rate in period t, D_{jt} is the period t nominal dividend paid by the intermediate firm j to the representative household, who owns all the intermediate firms in the economy; P_t is the period t price of final consumption goods; R_t is the gross nominal interest rate; and finally u_t is a preference shock which affects the labour supply (this will be the source of cost-push shocks in our economy). We assume that $\ln u_t$ follows an AR 1 process with normally distributed innovations

$$\ln u_t = \rho_u \ln u_{t-1} + \varepsilon_t^u, \quad \varepsilon_t^u \sim N\left(0, \sigma_u^2\right).$$

[11] The model economy should be thought of as a cashless limit of an economy with fiat money (as in Woodford 2003).

Assigning a Lagrange multiplier $\beta^t \Lambda_t$ to the budget constraint (1), we can state the first-order conditions of the household's problem as follows:

$$\Lambda_t = C_t^{-1}$$

$$\frac{1}{R_t} = \beta \mathbf{E}_t \left[\frac{\Lambda_{t+1}}{\Lambda_t} \frac{P_t}{P_{t+1}} \right] \tag{2}$$

$$u_t H_t^v = \Lambda_t \frac{W_t}{P_t}. \tag{3}$$

A.2 Firms and price setting

Final Good Production

The final good, Y_t, is produced by assembling a continuum of intermediate goods Y_{jt} for $j \in [0, 1]$ that are imperfect substitutes with a constant elasticity of substitution $\varepsilon > 1$. The production function is constant-returns to scale and is given by

$$Y_t \equiv \left[\int_0^1 Y_{jt}^{\frac{\varepsilon-1}{\varepsilon}} \mathrm{d}j \right]^{\frac{\varepsilon}{\varepsilon-1}}. \tag{4}$$

The final-good sector is perfectly competitive: the representative final-good firm solves the following problem:

$$\max_{Y_{jt}} P_t \left[\int_0^1 Y_{jt}^{\frac{\varepsilon-1}{\varepsilon}} \mathrm{d}j \right]^{\frac{\varepsilon}{\varepsilon-1}} - \int_0^1 P_{jt} Y_{jt} \mathrm{d}j$$

taking the final good price P_t and the intermediate good prices P_{jt} as given. Profit maximization leads to the following input-demand function for the intermediate good j

$$Y_{jt} = \left(\frac{P_{jt}}{P_t} \right)^{-\varepsilon} Y_t, \tag{5}$$

which represents the economy-wide demand for good j as a function of its relative price P_{jt}/P_t and of aggregate output Y_t. Imposing the zero-profit condition in the sector provides the final-good price index P_t:

$$P_t = \left(\int_0^1 P_{jt}{}^{1-\varepsilon} \mathrm{d}j \right)^{\frac{1}{1-\varepsilon}}. \tag{6}$$

Intermediate Good Production

After the current period productivity shock z_t is realized, a representative intermediate-good producing firm j, rents labour L_{jt} to produce Y_{jt} units of the intermediate good j with a concave production function

$$Y_{jt} = z_t L_{jt}^{\alpha}. \tag{7}$$

The stochastic productivity shock, z_t, follows an AR1 process with normally distributed innovations

$$\ln z_t = \rho_z \ln z_{t-1} + \varepsilon_t^z, \quad \varepsilon_t^z \sim N\left(0, \sigma_z^2\right).$$

This intermediate (-good producing) firm j maximizes the expected discounted sum of future (real) profits

$$\max_{\substack{P_{j,t+\tau}, Y_{j,t+\tau} \\ L_{j,t+\tau}}} \mathbf{E}_t \sum_{\tau=0}^{\infty} (\beta^{\tau} \Lambda_{t+\tau}/\Lambda_t) \left[\frac{P_{j,t+\tau}}{P_{t+\tau}} Y_{j,t+\tau} - \frac{W_{t+\tau}}{P_{t+\tau}} L_{j,t+\tau} \right], \tag{8}$$

subject to the demand for product j (5), the production function (7), and a timing restriction on its price adjustment described next.

In order to introduce nominal price stickiness into the model, producers of the intermediate goods are assumed to set prices according to Taylor-style staggered nominal contracts of fixed duration. Specifically, firms set the price of their good for J quarters and price setting is staggered so that every quarter, a fraction $1/J$ of firms is resetting prices. Further, the cohorts are fixed, so the same fraction $1/J$ of firms reset prices every J quarters.

Each quarter intermediate firms pay (nominal) dividends

$$D_{jt} = P_{jt} Y_{jt} - W_t L_{jt}, \tag{9}$$

to the households, whose marginal utility of income, Λ_t, shows in the stochastic discount factor $\beta^k \Lambda_{t+k}/\Lambda_t$ of future profits in (8).

The maximization problem thus consists of choosing labour input each quarter, as well as, prices, every J quarters, in order to maximize (8) subject to the economy-wide demand for product j (5) and the production function (7).

Substituting the demand constraint (5) and the production function (7) into the (8) we can rewrite the intermediate firm's problem as follows

$$\max_{P_{j,t+\tau}} \mathbf{E}_t \sum_{\tau=0}^{\infty} \beta^{\tau} \frac{\Lambda_{t+\tau}}{\Lambda_t} \left[\left(\frac{P_{j,t+\tau}}{P_{t+\tau}} \right)^{1-\varepsilon} Y_{t+\tau} - \frac{W_{t+\tau}}{P_{t+\tau}} \left(\frac{P_{j,t+\tau}}{P_{t+\tau}} \right)^{-\frac{\varepsilon}{\alpha}} \left(\frac{Y_{t+\tau}}{z_{t+\tau}} \right)^{\frac{1}{\alpha}} \right]. \tag{10}$$

With J period Taylor contracts we can be more specific. By assumption if a firm j resets its price in period t, this price $P_{j,t}$ will remain unchanged until it is reset again in period $t+J$. Thus, the firm will be choosing the price $P_{j,t}$ to maximize

$$\max_{P_{j,t}} \mathbf{E}_t \sum_{\tau=0}^{J-1} \beta^\tau \frac{\Lambda_{t+\tau}}{\Lambda_t} \left\{ \left(\frac{P_{j,t}}{P_{t+\tau}} \right)^{1-\varepsilon} Y_{t+\tau} - w_{t+\tau} \left(\frac{P_{j,t}}{P_{t+\tau}} \right)^{-\frac{\varepsilon}{\alpha}} \left(\frac{Y_{t+\tau}}{z_{t+\tau}} \right)^{\frac{1}{\alpha}} \right\}. \tag{11}$$

The first-order optimality conditions for this problem result in the following optimal reset price equation:

$$\left(P_{jt}^*\right)^{1+\varepsilon\frac{1-\alpha}{\alpha}} = \frac{\varepsilon}{\alpha(\varepsilon-1)} \frac{\mathbf{E}_t \sum_{\tau=0}^{J-1} \beta^\tau \Lambda_{t+\tau} P_{t+\tau}^{\frac{\varepsilon}{\alpha}} \left(\frac{Y_{t+\tau}}{z_{t+\tau}}\right)^{\frac{1}{\alpha}} w_{t+\tau}}{\mathbf{E}_t \sum_{\tau=0}^{J-1} \beta^\tau \Lambda_{t+\tau} P_{t+\tau}^{\varepsilon-1} Y_{t+\tau}}. \tag{12}$$

Since the Taylor pricing structure allocates firms within fixed cohorts through time, firms resetting prices all behave identically. We can therefore omit the j subscript from the optimal price and write P_t^*. In equilibrium, there are now only J different prices in the economy and, following the definition in (6), the aggregate price index P_t becomes:

$$P_t = \left(\frac{1}{J} \sum_{\tau=0}^{J-1} {P_{t-\tau}^*}^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}, \tag{13}$$

where $P_{t-\tau}^*$ is the optimal price of the $1/J$ portion of firms who reset their price τ periods ago.

A.3 Monetary Policy

In the experiment we will be looking at two monetary policy regimes: an inflation targeting regime (IT) and a price-level targeting regime (PLT). These two regimes will be different only in the form of the interest rate rule that the monetary policy follows.

Under IT the interest rate is set according to the following Taylor-type rule with interest rate smoothing:

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}} \right)^\omega \left[\left(\frac{P_t}{P_{t-1}} \frac{1}{\bar{\pi}} \right)^b \left(\frac{Y_t}{\bar{Y}} \right)^d \right]^{1-\omega}, \tag{14}$$

where $\bar{R}$, and $\bar{Y}$ are the steady state values of the nominal interest rate and output, and $\bar{\pi}$ is the target inflation rate.

Under PLT we have a slightly different rule:

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\omega} \left[\left(\frac{P_t}{P_0 \bar{\pi}^t}\right)^b \left(\frac{Y_t}{\bar{Y}}\right)^d\right]^{1-\omega}, \tag{15}$$

where P_0 will be normalized to one, without loss of generality.

The values of the parameters $\omega \in [0,1]$, $b > 0$ and $d > 0$ will be calibrated and are allowed to vary across IT and PLT rules. There is no government taxation or spending in the model.

A.4 Market Clearing and Equilibrium

For the labour market to clear, total supply of hours from the households must equal total demand arising from intermediate-good producing firms:

$$H_t = L_t = \int_0^1 L_{jt} \mathrm{d}j. \tag{16}$$

Also, for the goods market we have

$$C_t = Y_t. \tag{17}$$

The equilibrium of this economy consists of allocations and prices such that households, final-good producing firms and intermediate-good producing firms optimize, the monetary policy rule (14) or (15) is satisfied, and all markets clear.

We focus on cohort-symmetric equilibria in which all resetting, intermediate-good producing firms choose the same price P_t^* for the goods they produce. As described above, this implies that only J different prices coexist in equilibrium at any time. It also implies that the firms within each price-setting cohort are characterized by identical demand for their product (so we can write $Y_{\tau t},\ \tau = 0, ..., J-1$) and also by identical input demand ($L_{\tau,t},\ \tau = 0, ..., J-1$).

A.5 Calibration

We calibrate most benchmark parameters in the model by setting them at their conventional values. The elasticity of substitution across intermediate goods, ε was set to yield the average mark-ups of roughly 10 percent in line with Basu (1996) and Basu and Fernald (1997). We calibrate the inverse of Frisch labour supply elasticity η at unity following evidence in Kimball and Shapiro (2003), as well as in Chang and Sun-Bin Kim (2006). The estimates of the average number of quarters prices stay fixed (J in our model) range quite widely, with some of the recent estimates (e.g. Bils and Klenow 2004) pointing at 2-3 quarters. We pick the value of 2. The discount rate $\beta = 1$, was chosen higher than conventional to avoid dealing with discounting issues in a lab environment. The labour share, $\alpha = 2/3$ is standard. So are the persistence $\rho_z = 0.95$ and the standard deviation $\sigma_z = 0.01$ of productivity shocks. The target inflation rate $\bar{\pi}$ is set at 2 percent per year. The remaining five parameters

1) persistence of cost-push shocks, $\rho_u = 0$;

2) standard deviation of cost-push shocks, $\sigma_u = 0.0586$;

3) the weight on past interest rate in the IT monetary rule , $\omega = 0.9978$;

4) the weight on inflation in the IT monetary rule, $b = 41.95$;

5) and the weight on output in monetary rule, $d = 0.0001$

   were calibrated jointly to approximate five second moments from the Canadian data for the inflation targeting period. We calibrated the above five parameters to match the following five moments from 1993q1-2009q4 Canadian data: a) the standard deviation and the first-order autoregressive coefficient for the year-on-year (CPI) inflation (0.0091 and 0.70 correspondingly);[12] b) the standard deviation and the first-order autoregressive coefficient for the year-on-year real GDP growth rate (0.0199 and 0.94 correspondingly); c) the first-order autoregressive coefficient for the risk-free interest rate (0.94).[13]

The model generates: a) the standard deviation and the first-order autoregressive coefficient for the year-on-year inflation (0.0090 and 0.70 correspondingly); b) the standard deviation and the first-order autoregressive coefficient for the year-on-year real GDP growth rate (0.0196 and 0.77 correspondingly); c) the first-order autoregressive coefficient for the risk-free interest rate equal 0.92.

Not all the moments are matched perfectly but the two moments for inflation are close to their data counterparts. The calibrated parameters for an IT regime are summarized in Table 1. Table 2 compares simulated moments with their data counterparts.

Finally, we set the monetary policy rule parameters for a PLT regime (at $\omega^{PT} = 0$, $b^{PT} = 78.1$ and $d^{PT} = 33.2$) to match the variability and persistence of year-over-year inflation (inflation rate over four periods in the model) under IT. We made this

[12]We consider these two moments, to reflect the focus on this inflation rate in the current IT regime.

[13]Which was taken to be the market interest rate on the three months government bonds.

adjustment in order to make sure that any differences in forecasting performance across IT and PLT regimes is not driven by differences in variability or persistence of inflation rate in these two regimes.

Table A1: Structural model, benchmark parameter values for the historical IT regime

Parameter	Benchmark value
The discount factor, β	1
Inverse of Frisch elasticity of labour supply, η	1
Persistence of productivity shocks, ρ_z	0.95
St. Deviation of productivity shocks, σ_z	0.01
Labour share, α	2/3
Elasticity of substitution for goods, ε	10
Number of quarters prices are fixed, J	2
Annualized target inflation rate, $\bar{\pi}$	2%
Persistence of cost-push shocks, ρ_u	0
St. Deviation of cost-push shocks, σ_u	0.0586
Weight on past interest rate in monetary rule , ω	0.9978
Weight on inflation in monetary rule, b	41.23
Weight on output in monetary rule, d	0.0001

Table A2: Data moments and simulated moments from the structural model

Moments	Simulation	Data
St.Dev. of y-o-y real GDP growth rate %	1.96	1.99
St.Dev. of y-o-y (annualized) inflation rate, %	0.90	0.91
AR(1) coef. for real GDP growth rate	0.77	0.94
AR(1) coef. for y-o-y inflation rate	0.70	0.70
AR(1) coef. for nominal interest rate	0.92	0.94

B Appendix: Instructions

What you will be doing

You will predict inflation in a computer-simulated economy. Your pay will depend on how accurate your predictions are. Your pay will depend only on your decisions and the results generated by the simulated economy. It will not depend on the decisions of any other participants.

You make many decisions today. Each time you make a decision is called a period.

The economy

You can think of the computer economy as simulating the activity of a real economy. It can be thought of as consisting of households, who work and buy goods; intermediate firms, that provide the goods needed to make a final good; the firm that produces the final good that is purchased by the consumers; and a central bank that uses its short-term interest rate to achieve control over the economy.

The central bank

The central bank provides stability to the economy. The bank has one mandate: To stabilize inflation.

Inflation is the change of the average price of goods and services in the economy. It is the difference in the price level between the current period and the previous period. The central bank attempts to stabilize inflation at a target of 0 per period. That is, the central bank attempts to make the difference between the current price level and the previous price level 0.

If inflation moves higher or lower than 0, due to randomness in the economy, the central bank will act to return inflation back to the target. The bank uses its interest rate to achieve its objective of stabilizing inflation at 0.

This implies that the central bank is not concerned with achieving a price level target but instead attempts to maintain or return inflation to its target.

There will be a line on the screen showing you the inflation target.

How you make your decisions

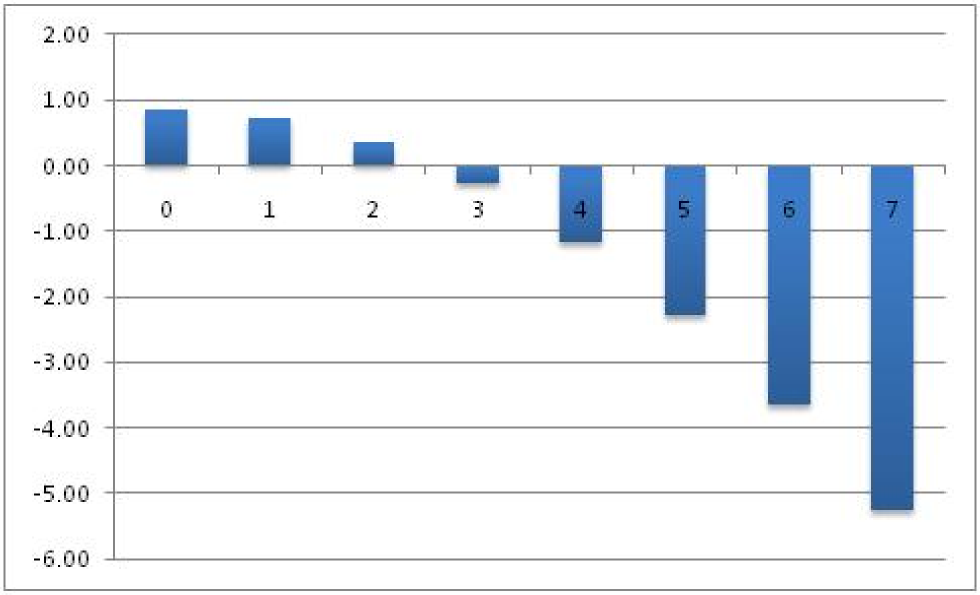
You will be shown the price level and inflation in your economy. The price level and inflation are determined by the structure of the economy, and some randomness that makes the structure difficult to determine.

At the start the computer will show you eight periods of economic results. You will then predict inflation for the next period. After you do, the computer will show you results for the next period, and you will predict inflation again for the subsequent period.

For your decision you choose an interval within which you expect the next period's inflation to fall. For example, one interval is 1.75% - 2.25%. In total there are 13 intervals. All of the intervals are 0.5% wide. You make your decision by clicking on the interval you choose.
When you choose your bin, you will see an asterisk, that is, the character "*", located underneath the center of the bin containing the previous period's inflation. This character is placed on the screen to assist you with your forecast of inflation for the next period.

The number of decisions you make
You will predict inflation for twenty periods for practice. You will not be paid for your practice. You may use the practice to learn how the simulation works.
You will then predict inflation for 80 periods for pay.
For each decision the relationships between economic variables are identical. The randomness, however, will be different, and independent of any past decisions you make.

How you will be paid
The better your prediction of inflation, the higher is your pay.
Each period the computer will determine how many bins there are between your prediction and the bin that actual inflation falls in. The closer your predicted bin is to actual inflation, the higher your pay.
This graph shows your pay, in dollars, for a period, depending on how many bins away your prediction is:
The horizontal axis, labeled 0,1,2,. . .,7, represents the distance between the bin you choose and the bin within which inflation actually falls. The vertical axis, labeled 2.00, 1.00, 0.00,. . .,-6.00 represents your pay for a decision in one period.
For example, if inflation falls within the bin you choose, then the distance between your prediction and actual inflation is 0, and you earn $0.83 for the period. For another example, if inflation falls 7 bins away from your prediction, then your pay for the period is approximately -$5.24. Since there are 13 bins, you could be as many as 12 bins off with your prediction, in which case you would earn approximately -$17.01 for the period.
The pay is scaled so that on average, if you make the best possible prediction every quarter, you can earn about $40.
During a period, it is possible to make negative earnings. Your earnings are computed by adding up your earnings for every period. You cannot make negative earnings in a session.
You will be paid in cash for all of your decisions.



The bottom line is that the better your prediction, the higher your pay.

A reminder of the role of the central bank

The central bank provides stability to the economy. The bank has one mandate: To stabilize inflation.

Inflation is the change of the average price of goods and services in the economy. It is the difference in the price level between the current period and the previous period. The central bank attempts to stabilize inflation at a target of 0 per period. That is, the central bank attempts to make the difference between the current price level and the previous price level 0.

If inflation moves higher or lower than 0, due to randomness in the economy, the central bank will act to return inflation back to the target. The bank uses its interest rate to achieve its objective of stabilizing inflation at 0.

This implies that the central bank is not concerned with achieving a price level target but instead attempts to maintain or return inflation to its target.

There will be a line on the screen showing you the inflation target.

The role of the central bank does not change.

The role of the central bank does not change with this reminder.

The simulation will restart, showing the first 8 periods exactly as at the start of the session. The simulation is independent of simulation you just completed.

Please raise your hand if you have any questions.
To continue, the password is the word "continue".

A reminder of the role of the central bank

The central bank provides stability to the economy. The bank has one mandate: To stabilize inflation.
Inflation is the change of the average price of goods and services in the economy. It is the difference in the price level between the current period and the previous period.
The central bank attempts to stabilize inflation at a target of 0 per period. That is, the central bank attempts to make the difference between the current price level and the previous price level 0.
If inflation moves higher or lower than 0, due to randomness in the economy, the central bank will act to return inflation back to the target. The bank uses its interest rate to achieve its objective of stabilizing inflation at 0.
This implies that the central bank is not concerned with achieving a price level target but instead attempts to maintain or return inflation to its target.
There will be a line on the screen showing you the inflation target.

The role of the central bank now changes

The central bank provides stability to the economy. The bank has one mandate: To stabilize the price level.
The price level is an average price of goods and services in the economy.
The central bank attempts to stabilize the price level at 5 every period.
If the price level moves higher or lower than 5, due to randomness in the economy, the central bank will act to return the price level back to the target of 5. The bank uses its interest rate to achieve its objective of stabilizing the price level around the target of 5.
This implies that the central bank is not concerned with achieving a constant inflation target but instead attempts to maintain or return the price level to its target.
There will be a line on the screen showing you the current price level target.
The simulation will restart, showing the first 8 periods exactly as at the start of the session. The simulation is independent of simulation you just completed.
You continue to predict inflation each period. The password is "continue".