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Abstract

The challenges of a low interest rate, low inflation environment have led to calls to re-examine the basic framework of flexible inflation targeting (IT). Interest in alternatives such as price-level targeting (PLT) and average inflation targeting (AIT) arises from the way in which these policy regimes cause inflation expectations to work as automatic stabilizers, a factor that can be of major importance if the central bank is constrained at the ELB. I show that the performance of PLT deteriorates significantly relative to IT and AIT in the presence of wage rigidities, shocks to productivity, and deviations from rational expectations. A central bank able to credibly commit to the optimal policy consistent with PLT is likely to face a much higher probability of needing balance sheet policies to implement policy than would be the case under IT or AIT. These results suggest it is too early to count IT out in the competition over policy design.

Keywords: Optimal monetary policy; Inflation targeting; Price-level targeting; Average inflation targeting
JEL classification: E52, E58

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1 Introduction

Ten years ago, in June 2009, the Great Recession in the U.S. officially ended. Far from marking a return to normalcy however, the last decade has brought to prominence monetary policy challenges for the U.S. and the euro zone that Japan has faced for more than two decades. These challenges are reflected in the difficulty central banks have had in reaching their inflation targets from below and the fear that the new normal involves a low natural real rate of interest and low inflation, implying there will be little room to cut nominal rates in a recession. These challenges are particularly pressing in Japan. Figure 1 shows the past 20 years of CPI inflation (less food and energy) and the 10-year government bond rate for Japan (blue solid lines) and the U.S. (red dashed lines). With the exception of the rise in 2014 due to the increase in the consumption tax, the inflation rate in Japan has remained below 1% and has averaged essentially zero over this period, compared to an average inflation rate of 2.1% over the same period in the U.S. The cumulative effect on the price level in the two countries is illustrated in figure 2, which shows the CPI (less food and energy) in each country, expressed as an index equal to 100 in 1970Q1.

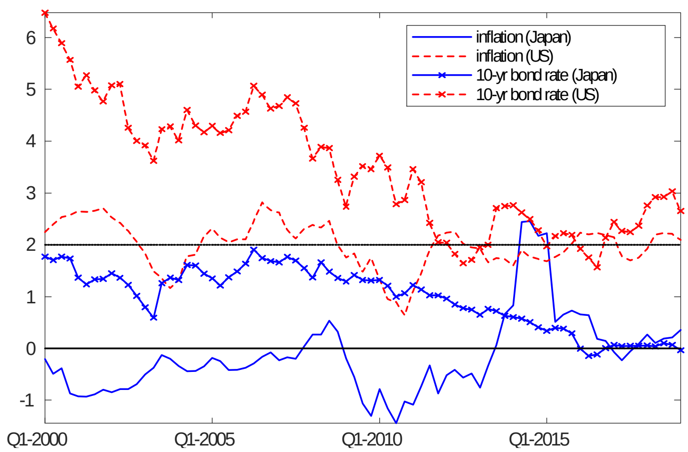

Figure 1: Inflation and 10-yr. government bond rates in Japan and the U.S., 2000Q1-2019Q1. Source: Federal Reserve Bank of St. Louis.

This environment has prompted re-evaluations of the widely held monetary policy consensus that characterized the academic and policy community on the cusp of the Global Financial Crisis. This consensus involved agreement on the importance of (1) a commitment to price stability, defined in practice as a low and stable rate of inflation (commonly 2% among major economies), (2) the use of a short-term interest rate as the primary instrument of policy, and (3) a commitment to transparent communications about the objectives of policy.[1] Put into practice, this consensus provided the underpinning of flexible inflation targeting (IT) which came to exemplify best practices in monetary policy. To a large degree, IT has survived the financial crisis intact. For example, Stan Fischer in drawing the lessons of the Global

[1] See Goodfriend (2007) for a discussion of this consensus.

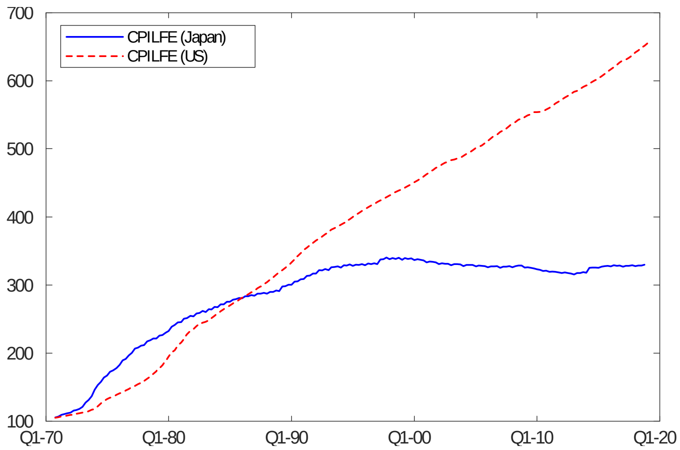

Figure 2: Consumer price indexes (less food and energy) for Japan (solid blue line) and US (dashed red line), 1970Q1 = 100. Source: Federal Reserve Bank of St. Louis.

Financial Crisis for monetary policy concluded: "How to summarize all these conclusions? Simply: *flexible* inflation targeting is the best way of conducting monetary policy."[2] At the time Fischer wrote, the continuing persistent decline in the natural rate of interest was less clear, but the recent evidence suggests that real rates will continue to remain low.[3] Thus, IT may no longer provide the best design for monetary policy in the environment faced by the Bank of Japan, the U.S. Federal Reserve and other central banks.

In 2010, Blanchard, Dell'Ariccia, and Mauro (2010) launched the debate over policy design, albeit still within the context of flexible inflation targeting, by proposing that the 2% inflation target adopted by many central banks be doubled to 4%. An increase in the inflation target, by lifting average levels of nominal rates further from the effective lower bound (ELB) on nominal rates, would make hitting the ELB less common and provide more room for monetary policy to cut interest rates if necessary in responding to contractionary shocks. Evaluating such a proposal involves assessing the benefits – less frequent episodes at the ELB and a more stable macro economy – against the costs – higher steady-state inflation. Such a calculation parallels the evaluation of any insurance: are the annual costs of the insurance arising from higher average inflation less than the expected benefits of less frequent episodes at the ELB? In any case, no major central bank has raised its inflation target.[4]

As an alternative to raising the inflation target, attention has also focused on replacing IT. The proposed alternatives are all designed to generate endogenous movements in inflation expectations that would help achieve the central bank's inflation and real objectives. Such alternatives may be particularly relevant in environments of discretionary policymaking in which policymakers' statements about future policy are not of sufficient credibility to move

[2] Fischer (2013), p. 14, emphasis in original.
[3] See Holston, Laubach, and Williams (2017).
[4] Billi (2011), Coibion, Gorodnichenko, and Wieland (2012) and others suggest optimal inflation, even in the face of the ELB, is still quite low.

private sector expectations. And they may be especially valuable when policy actions are constrained by the effective lower bound (ELB) on nominal interest rates.[5]

In this paper, I examine two of the primary candidates to replace inflation targeting – price-level targeting (PLT) and average inflation targeting (AIT). Both PLT and AIT have received attention recently, but much of this literature–see, for example, Bernanke, Kiley, and Roberts (2019) or Mertens and Williams (2019)–examines whether, in a regime of inflation targeting, the central bank should include the price level or a measure of average inflation in an instrument rule that helps guide policy. In my view, this type of analysis does not provide a meaningful evaluation of price-level targeting. If a central bank finds an instrument rule a useful guide for implementing a policy designed to achieve its inflation target, then the policy framework is still one of inflation targeting, whatever variables might appear in the reference instrument rule.

In contrast, I evaluate PLT and AIT as targeting frameworks, with each altering the goals of monetary policy. A regime of inflation targeting establishes the inflation target as the objective of monetary policy, and the appropriate way to evaluate alternatives to IT is to consider the implications of assigning objectives other than inflation, the price-level for example, to the central bank. This is the approach adopted to evaluating PLT, speed limit policies, nominal income policies and other policy frameworks in Svensson (1999), Jensen (2002), Walsh (2003), Vestin (2006), Nessén and Vestin (2005), Cateau, Kryvtsov, Shukayev, and Ueberfeldt (2009), Billi (2017), Bodenstein and Zhao (2019b), and Nakata (2018), among others.[6] For each framework I assume a flexible regime in which deviations from the price level or average inflation target are traded off against ensuring greater stability in the real economy. With this approach, PLT and AIT are treated equivalently to IT as frameworks for monetary policy.

A second and crucial aspect of the specification of the policy framework is deciding whether to model policy as conducted with commitment or with discretion. The work that treats policymakers as implementing a pre-specified instrument rule assumes an ability to commit to the rule; the assumption implicit in the inflation targeting literature is that the central bank can commit to its goals.[7] The literature on IT often assumes that, given the goals of the central bank, actual policy is implemented with discretion, while the Ramsey policy that maximizes social welfare provides a benchmark against which to compare IT. I follow this tradition, but I also evaluate outcomes under IT, PLT, and AIT when the central bank can implement a commitment policy. The commitment solution is of interest because central banks do seem purposefully committed to behaving in ways consistent with past statements

[5] I will take it as given that there is some efective lower bound on nominal rates. For proposals to remove any lower bound, see, for example, Goodfriend (2016), Bordo and Levin (2019), and Lilley and Rogoff (2019).

[6] Billi (2017), Bodenstein and Zhao (2019b), and Nakata, Schmidt, and Yoo (2018) are distinguished by their focus on the implications of the ELB.

[7] See Walsh (2015) for a discussion of using goals versus rules in evaluating central bank performance.

about policy actions, as evidenced, for example, by the effects of forward guidance.[8] Work by Kurozumi (2008), Kurozumi (2012), and Nakata (2018) suggests commitment equilibria may be sustainable in new Keynesian models even absent a formal commitment mechanism. And it may be feasible for policymakers to commit to time-inconsistent actions if those actions can be justified on the grounds that they help achieve the ultimate goals to which the central bank is (publicly) committed. In a rule-based approach, it may be harder to justify time-inconsistent responses to variables such as the past price level, as called for under approaches that add the price level to an instrument rule, if the actual goal the central bank is committed to is an inflation target and not the price level.

Even with commitment, alternative policy regimes may still differ from the Ramsey policy if the central bank's objectives differ from the model-consistent measure of social welfare. In fact, central banks are not asked to maximize social welfare; instead, they are assigned more limited objectives, such as price stability.[9] Price stability may contribute to social welfare, but the latter is vastly broader than the former. I assume that in each targeting regime, the central bank focuses on a dual mandate that involves stabilizing a measure of real economic activity and a nominal variable (the price level or a measure of inflation), even if other variables appear in the model-consistent definition of social welfare.

The alternatives to IT I consider address the challenges of low inflation and a low natural rate by generating endogenous movements in expectations that act as automatic stabilizers. The idea of monetary policy as an automatic stabilizer is not new, and was central to the classic analysis of the instrument choice problem by Poole (1970). In Poole's analysis, the choice was between using a monetary aggregate or a nominal interest rate as the policy instrument. The timing was such that the policymaker had to set the instrument before observing current shocks. When shocks occurred, the variable chosen as the instrument, either the interest rate or the monetary aggregate, remained unchanged while the other responded endogenously. And it was this endogenous response that governed the automatic stabilizing (or destabilizing effects) of monetary policy.[10]

Poole's framework offered two key insights. First, the policy choice affects the way economic activity and inflation respond to shocks. Second, the optimal choice of the instrument will depend on the nature of the shocks of greatest concern. In the simple Poole example, if aggregate demand shocks are the major source of volatility, the monetary aggregate is the better instrument choice; if money demand shocks are of primary concern, the interest rate is the better choice. This last insight is particularly relevant: if low inflation and low interest rates are currently the major concerns, then policy frameworks, such as IT, developed in an environment of high inflation and high interest rates may no longer be appropriate in the new

[8] See, for example, the work by Swanson (2018).

[9] As noted by O'Flaherty (1990), when you call a plumber to fix a leak, you don't want her to arrive and begin to bake a cake, even if, in the moment, you'd prefer a piece of cake to having the leak fixed.

[10] See Friedman (1990) for a survey of the instrument choice problem. See also Walsh (1990), or Chapter 12, section 3.1 of Walsh (2017).

policy environment. New designs for monetary policy need to be examined, and the notion of creating automatic stabilizers through the choice of monetary policy design offers a useful perspective for such an examination.

If the goals of the central bank involve the price level or average inflation, policy will respond to past target misses, something that is not true to the same extent under inflation targeting.[11] Responding to past target misses affects private sector expectations about future inflation. Because PLT and AIT regimes are designed to make expectations react in a stabilizing fashion, they are very much in line with the emphasis on expectations in modern macro models and the importance of inflation expectations when policy is constrained by the ELB. As Woodford (2005) noted even before the financial crisis, "*For not only do expectations about policy matter, but, at least under current conditions, very little else matters.*"

Managing expectations is crucial when, as at the effective lower bound for nominal interest rates, direct actions such as changing the central bank's normal instrument may not be feasible. Yet the search for frameworks in which expectations act as automatic stabilizers predates the period when major central banks (other than the Bank of Japan) were concerned with the ELB. For example, Svensson (1999) and Vestin (2006) showed that price-level targeting could, in an environment of discretionary policy making, dominate inflation targeting by inducing movements in expectations that mimicked those generated under an optimal commitment policy. Under PLT, any shortfall of prices from target would generate expectations of the higher future inflation necessary to regain the target price level. And at the ELB, a rise in expected inflation is desirable. Reifschneider and Williams (2000) showed how instrument rules that respond to cumulated past target misses could perform well. Similarly, average inflation targeting (AIT), unlike simple IT, ensures that a temporary decline in inflation relative to target would generate expectations of the higher future inflation need to achieve the target for average inflation.

The rest of the paper is organized as follows. In section 2, I argue that the relative performance of different targeting regimes is altered once one moves beyond the very simple textbook version of the new Keynesian model, specifically by introducing wage stickiness. In the face of wage rigidity and productivity shocks, IT and AIT defined over 4 to 16 quarters perform similarly and marginally outperform PLT. I carry out the analysis under both discretion and commitment when the central bank has a dual mandate defined in terms of minimizing the volatility of a measure of inflation or the price level and a measure of real economic activity (an output gap). By interpreting the interest rate in the model as a shadow rate along the lines of Wu and Zhang (2017), I compare how frequently balance sheet policies would be required to implement optimal policy under each regime. While PLT is designed to make expectations act like automatic stabilizers, policymakers seem to place great store

[11] If the inflation process is purely forward looking, optimal discretion in an IT regime does not respond to lagged inflation and therefore does not respond to past target misses. This is no longer true if current inflation depends in part on lagged inflation.

on anchoring expectations, so in section 3, I contrast the performance of PLT, IT and AIT when expectations are anchored, while in section 4, I compare outcomes when expectations are assumed to follow an ad hoc partial adjustment model that allows for deviations from rational expectations. Conclusions are summarized in the final section.

2 Alternatives to flexible inflation targeting

How do IT, PLT and AIT compare? To address this question, and to evaluate alternative policy regimes consistently, I interpret the design of a policy regime to consist of a loss function adopted (or assigned) to the central bank. For example, flexible IT is modeled as a regime in which the policymakers minimizes a dual loss function in inflation π_t and an output gap x_t of the form

$$L_t = \frac{1}{2}\mathrm{E}_t \sum_{i=0}^{\infty} \beta^i \left(\pi_{t+i}^2 + \lambda_x x_{t+i}^2 \right). \tag{1}$$

This loss function is then minimized, subject to the structural constraints that characterize the macroeconomy, under either discretion or commitment. Hence, there is a commitment to the objective function, but implementation of policy may or may not involve credible promises of future policy actions by the central bank. In either case, the assumption is that policymakers act systematically to pursue well-defined objectives; they do not commit to mechanically follow a simple instrument rule such as a Taylor rule.

Similarly alternative policy regimes such as PLT or AIT are evaluated as regimes in which the objective assigned to a central bank is a loss function of the form

$$L_t^j = \frac{1}{2}\mathrm{E}_t \sum_{i=0}^{\infty} \beta^i \left(n_{t+i}^2 + \lambda_{j,x} x_{t+i}^2 \right), \tag{2}$$

where n_t equals either p_t or π_t^k, where p_t is the log price level and π_t^k denotes the k period average inflation rate, defined as

$$\pi_t^k \equiv \left(\frac{1}{k} \right) \left(p_t - p_{t-k} \right).$$

More generally, the goals of a central bank targeting the price-level would include $\left(p_t - p_t^T\right)^2$ rather than $\left(\pi_t - \pi^T\right)^2$, where p_t^T is the target for the price level and π^T is the inflation target. I normalize both the log price level target and the inflation target to zero.

While the U.S. Federal Reserve has had an explicit dual mandate of price stability and maximum sustainable employment, most inflation targeting central banks whose formal goals are defined in terms of price stability act as "flexible inflation targeters," in that deviations from the inflation target are tolerated in order to limit volatility in real economic activity.[12]

[12] As of February 2019, the Reserve Bank of New Zealand also has a dual mandate which calls

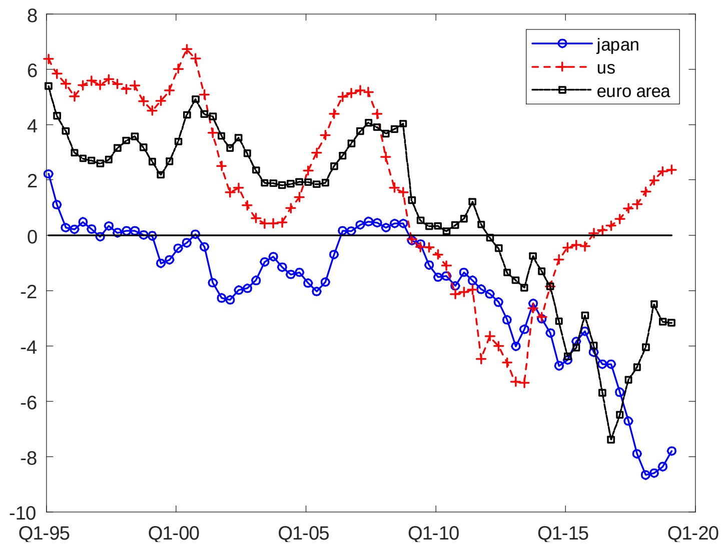

Figure 3: Estimated shadow interest rates for Japan, the US, and the euro area, Jan. 1995 - May 2019. Source: Krippner (2016). Data downloaded from https://www.rbnz.govt.nz/research-and-publications/research-programme/additional-research/measures-of-the-stance-of-united-states-monetary-policy/comparison-of-international-monetary-policy-measures. .

I therefore interpret alternative regimes such as price level targeting or average inflation targeting as similarly involving a degree of flexibility, as reflected in the loss function given by (2).

While recent discussions of alternative policy frameworks have stressed their importance in mitigating the consequences of ELB episodes, I consider these policy frameworks when the ELB is ignored. In part, this is because the underlying intuition concerning the potential value of PLT under discretion in new Keynesian models predates any concern, at least in the U.S. and European context, with the ELB. In addition, Swanson and Williams (2014) and Swanson (2018) question the extent to which the ELB constrained the Federal Reserve, while Wu and Xia (2016) and Wu and Zhang (2017) argue that the net impact of interest rate and balance sheet policies can be measured by a shadow interest rate that, as seen in figure 3, was significantly negative for Japan, the U.S. and the euro area.[13]

Therefore, I interpret the policy interest rate that is implied under optimal policy in the comparisons of IT, PLT and AIT regimes as a shadow rate that can take on positive and negative values. Implementing negative values of the shadow rate would require using unconventional policies such as quantitative easing or other balance sheet policies. The frequency with which the shadow rate is negative under the different regimes then provides

for monetary policy to "keep inflation between 1 and 3 percent over the medium term, with a focus on keeping inflation near the 2 percent mid-point; and support maximum sustainable employment." (https://www.rbnz.govt.nz/news/2019/02/new-rbnz-monetary-policy-committee-remit-reiterates-focus-on-price-stability-and-employment)

[13] Ichiue and Ueno (2018) provide an alternative measure of the U.S. shadow rate based on survey measured of expectations.

some insights into the extent to which balance sheet policies would need to be relied on. This issue is discussed further in section 2.4.

If central banks can credibly commit to a policy regime (IT or PLT) but conduct meeting-by-meeting policy in a discretionary fashion, then the case for PLT appears strong. In a basic NK model, it outperforms IT away from the ELB (Vestin (2006)) and at the ELB. This makes PLT look like a win-win choice, avoiding the insurance related trade-off of balancing better performance at the ELB against poorer performance away from the ELB. The first step, therefore, is to extend the analysis of PLT by Vestin (2006) and AIT by Nessén and Vestin (2005) to the case of commitment and to a (slightly) richer model.

To evaluate policy regimes, I employ a standard log-linearized new Keynesian model, based on Erceg, Henderson, and Levin (2000), that incorporates sticky prices and sticky wages.[14] Outcomes in which the central bank minimizes (2) will be ranked based on the model-consistent measure of social welfare. As is well-known, a loss function such as (2) with $n_t = \pi_t$ does not coincide with the standard quadratic approximation to social welfare in the Erceg, et. al. model. As those authors showed, a welfare cost is also generated by fluctuations in the rate of wage inflation, a factor missing from (2). The quadratic loss function that provides a second-order approximation to the welfare of the representative agent in the Erceg, Henderson, and Levin (2000) model, assuming an efficient steady state, is

$$L_t = \frac{1}{2}\mathrm{E}_t \sum_{i=0}^{\infty} \beta^i \left[\pi_{t+i}^2 + \lambda_x x_{t+i}^2 + \lambda_w \left(\pi_{t+i}^w\right)^2\right], \tag{3}$$

where λ_x and λ_w are functions of the model's structural parameters.[15] However, no central bank has explicitly targeted wage inflation, and I take a loss function that depends on targets related to price inflation (or the price level) and real economic activity (represented by the output gap) as the relevant objective of the central bank. That is, I maintain the dual mandate form of the social loss function by assuming the central bank seeks to minimize (2) even when the true social loss function includes a term in wage inflation. Assigning an objective that differs from social welfare introduces a distortion and will therefore lead to a cost relative to the fully optimal commitment policy. By evaluating PLT and AIT under commitment, I can assess the implications of the costs associated with what might be called a "misspecification" of the central bank's objectives. Such misspecification is relevant to consider as part of the rationale for delegating a targeting regime is as a means of assessing the central bank's performance (see Walsh (2015)). Performance measures need to be relatively simple to promote transparency and accountability, while social welfare is inherently more complex and difficult to assess in practice.

[14] The version of the model I use follows the presentation of Galí (2015). For recent evaluations of policy regimes using this model, see Bodenstein and Zhao (2019a) and Nakata, Schmidt, and Yoo (2018).

[15] See Erceg, Henderson, and Levin (2000) or Galí (2015) for details.

2.1 The model and its calibration

The Erceg, Henderson, and Levin (2000) model represents the standard benchmark new Keynesian model with nominal price and wage rigidities. It has been employed by Galí (2013) and Billi and Galí (2019) to investigate the effects of wage flexibility, by Nakata, Schmidt, and Yoo (2018) to evaluate speed limit policies, and by Bodenstein and Zhao (2019b) who examine price-level and speed limit policies.

The calibration of the structural parameters of the model follows that employed in Billi and Galí (2019) with the exception of the value of σ, the inverse elasticity of intertemporal substitution, as explained below. I include an i.i.d. price markup shock, as in Nakata, Schmidt, and Yoo (2018) and Bodenstein and Zhao (2019a), and a persistent productivity shock that affects both the natural rate of interest and the economy's efficient level of output. The persistence of the productivity shock is taken to be 0.8, following Billi and Galí (2019). I calibrate the standard deviations of these two shocks to match the standard deviation of U.S. output and inflation over the 1960Q1 - 2019Q1 period under optimal discretionary inflation targeting when both prices and wages are sticky.[16] Under optimal policy unconstrained by the ELB, demand shocks play no role and σ, the inverse elasticity of intertemporal substitution, only influences the volatility of the nominal interest rate required to implement the optimal policy. I calibrate σ to match the fraction of quarters the federal funds rate was less than or equal to 25 basis points, the effective lower bound in the U.S. During 1960Q1 - 2019Q1, this fraction was equal to 0.118, and this is matched when $\sigma = 0.65$. Setting $\sigma = 1$, a more standard value, implies greater volatility of the policy rate and would generate a higher frequency at the ELB in the model than observed in the U.S. data. Values of the structural parameters used in the calibration exercises are given in Table 1.

Table 1: Parameters

Discount factor	β	0.995
CRRA	σ	0.65
Inverse labor supply elasticity	η	5
Demand elasticity: goods	θ^p	9
Demand elasticity: labor	θ^w	4.5
Calvo parameter: prices	ϕ_p	0.75
Calvo parameter: wages	ϕ_w	0.75
Persistence of productivity shock	ρ_z	0.8
Persistence of markup shock	ρ_u	0

[16] I match the standard deviation of HP filtered log real GDP and the inflation rate as measured by the GDP deflator. Their respective standard deviations are 2.32 and 0.58.

2.2 Results with sticky prices only

Arguments in favor of a price level target rather than an inflation rate target emphasis the manner in which a credible price-level targeting regime causes inflation expectations to adjust automatically so as to contribute to stabilizing the economy. This was first demonstrated in a standard, sticky price NK model by Vestin (2006). When inflation is forward-looking, as implied in sticky-price models, a negative cost shock that pushes the price level below its target path will generate expectations of higher future inflation, as this will be necessary if the price level is to return to target. This rise in expected future inflation acts to boost current inflation, limiting the impact of the inflation shock and allowing current inflation to be stabilized with a smaller rise in economic activity. This mechanism is particularly important at the ELB, as shown by Eggertsson and Woodford (2003), a situation in which, in a policy regime of discretion, the adjustment of inflation expectations may be the primary channel by which monetary policy can stimulate the economy.

Regimes that focus on average inflation also generate stabilizing movements in expectations by ensuring the central bank reacts to past actual inflation. If the objective is to stabilize inflation averaged over several periods, then a temporary fall (rise) in inflation below (above) target will generate expectations of higher (lower) future inflation. Regimes of average inflation targeting have been analyzed by Nessén and Vestin (2005). Both PLT and AIT regimes ensure policy continues to respond to past target misses in ways that are similar to optimal commitment policies.

Table 2 reports the results for inflation targeting, average inflation targeting with average inflation defined over 4 to 16 quarters, and price-level targeting (PLT) when the only shocks arise from stochastic fluctuations in the price markup (cost shocks) and only prices are sticky.[17] Loss is expressed as a percent of steady-state consumption. Also reported is the loss under each policy relative to Loss_R, the loss under the Ramsey policy that minimizes social loss under commitment. Given that social loss depends only on output gap and inflation volatility when wages are flexible ($\lambda_w = 0$ in the social loss function (3)), the central bank's objective (2) coincides with social loss. In this case, inflation targeting under discretion generates a loss that is approximately 27% larger than achieved by the Ramsey policy, while loss under PLT is less than 2% higher than under the Ramsey outcome. The different forms of average inflation targeting actually perform worse than traditional inflation targeting, with loss increasing in the length of the averaging period.[18]

[17] I did not consider average inflation targets defined over more than 16 quarters. Issues of communicating policy to the public are crucial for monetary policy, and there may be difficulty in demonstrating a credible commitment to targeting average inflation if the average is defined over a very long period.

[18] As Vestin (2006) and Nessén and Vestin (2005) showed, performance of these targeting regimes can be improved by allowing the weight placed on output gap stabilization to differ from the value places on x_t^2 in the social loss function. I maintain the same λ_x for the different regimes, which for my calibration implies PLT comes very close to the Ramsey outcome. Most policy-focused discussion of alternative regimes have focused on the definition of the nominal target and have not emphasized any need to alter the 'flexibility" of a new regime.

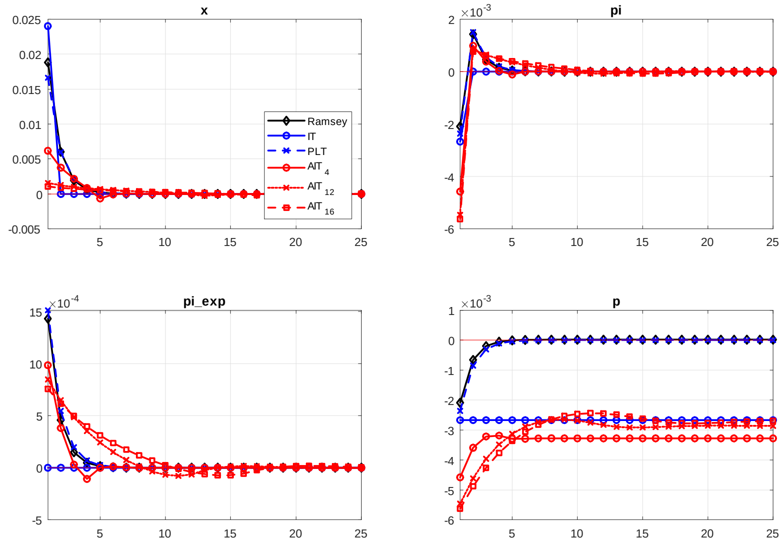

Figure 4: Response under discretion of the output gap (x), inflation (pi), expected inflation (pi_exp) and the price level (p) to a negative i.i.d. cost shock in the sticky price, flexible wage model.

Table 2: Social loss*: flexible wages

	Discretion		Commitment	
Policy	Loss	Loss/Loss$_R$	Loss	Loss/Loss$_R$
(1)	(2)	(3)	(4)	(5)
IT	0.706	1.274	0.554	1.000
4Q	0.937	1.691	0.879	1.586
8Q	1.155	2.086	1.091	1.969
12Q	1.265	2.283	1.203	2.171
16Q	1.332	2.414	1.227	2.305
PLT	0.562	1.014	0.600	1.083

*Loss as percent of steady-state consumption. Loss$_R$ is loss under the Ramsey policy.

Figure 4 illustrates the responses to a negative i.i.d. cost shock under the different regimes. As is well-known, the Ramsey policy restores the price level to its pre-shock value, as does price level targeting (see the figure in the lower right). The variations on inflation targeting all fail to do so. The lower left panel of the figure (labeled pi_exp) reports expected future inflation $E_t\pi_{t+1}$ under each policy. For an i.i.d. shock, expected inflation is simply zero under IT, as both inflation and the output gap return immediately to their steady state values. Expected inflation under PLT mirrors its behavior under the Ramsey policy.

The fourth and fifth columns of Table 2 illustrates the performance of the alternatives if the central bank can credibly commit to minimizing the present discounted value of its loss function (2). Normally, assigning the central bank an objective that differs from social welfare is a means of overcoming a distortion that arises when the central bank carries out policy in a discretionary fashion. However, it is also plausible to view central banks, particularly those with successful experience as inflation targeters, as having gained a great deal of credibility. If the central bank commits to an objective such as (2), it is of interest to see how economic performance is affected if policymakers' statements about future policy come to be credible. With only sticky prices, inflation targeting under commitment coincides with the Ramsey policy. However, notice that the optimal commitment policy under PLT generates outcomes that are 8.4% worse than under IT. AIT under commitment performs much more poorly than either IT or PLT.

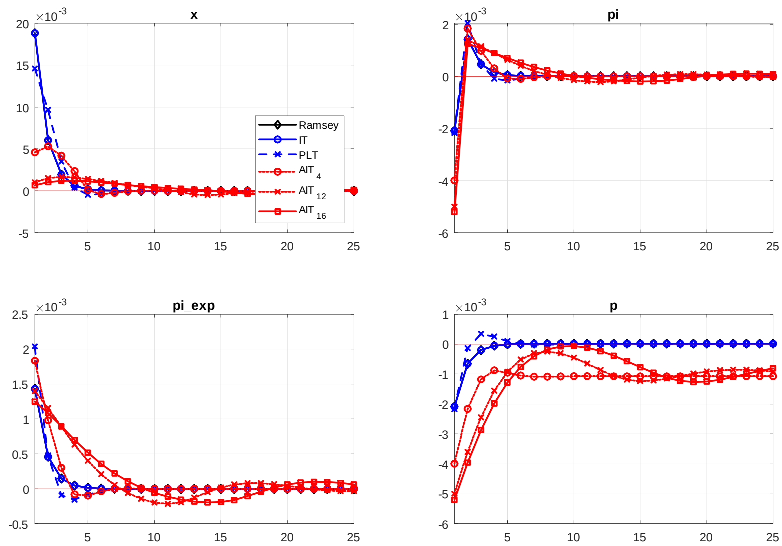

Figure 5: Response under commitment of the output gap (x), inflation (pi), expected inflation (pi_exp) and the price level (p) to a negative i.i.d. cost shock in the sticky price, flexible wage model.

Figure 5 shows the response under commitment to a temporary cost shock. Compared to the Ramsey policy and IT (which are identical), PLT generates expectations that the price level will overshoot (see the lower right subfigure), producing somewhat less inflation variability than the Ramsey policy, while the various forms of AIT produce smaller movements in the output gap and significantly greater inflation volatility.

Table 3: Std. deviations*: flexible wages

	Discretion		Commitment	
Policy	σ_π^2	σ_x^2	σ_π^2	σ_x^2
IT	1.035	1.211	1.000	1.000
4Q	1.826	0.381	1.755	0.424
8Q	2.064	0.201	1.997	0.263
12Q	2.166	0.138	2.107	0.198
16Q	2.229	0.104	2.175	0.158
PLT	1.111	0.897	1.176	0.895

*Standard deviations expressed relative to values under the Ramsey policy.

Table 3 shows how the components of social loss arising from variability in its components, the variance of inflation and the output gap, vary under the different policy regimes. Values are reported relative to their values under the Ramsey policy. Under discretion, IT generates more volatility in both inflation and the output gap than the Ramsey policy (under commitment, IT and Ramsey coincide in the sticky price model). Average inflation targeting performs worse than either IT or PLT; as the length of the averaging period increases, inflation becomes increasingly volatile, while the variance of the output gap falls so that under discretion with 16 quarter averaging, σ_x^2 is less than 16% of its value under the Ramsey policy. Relative to Ramsey, discretionary PLT generates more volatility in inflation but a more stable output gap, so that social loss is similar to the Ramsey result (Table 2). PLT performs somewhat worse if the central bank can implement PLT under commitment, primarily because of the more volatile inflation that results.

The results in Tables 2 and 3 assume the weight λ_x from the social loss function is also the weight on the output gap in the central bank's objective function. It is clear from Table 3 that outcomes could be improved under average inflation targeting and PLT by having the central bank place relative less weight on output gap stabilization, as both forms of policy excessively stabilize the output gap.[19] For IT, both inflation and the output gap are more variable under discretion, so whether more or less weight on inflation objectives is less clear, though Clarida, Galí, and Gertler (1999) show that, for a serially correlated inflation shock, welfare is improved if a weight less than λ_x is placed on x_t^2 in the central bank's loss function (i.e., if a Rogoff (1985) conservative central banker is appointed).

2.3 Results with sticky prices and wages

While models with sticky prices but flexible wages provide useful platforms for gaining insights into many policy issues, policy models that are taken to the data generally incorporate sticky prices and wages. When wages are sticky, productivity shocks as well as cost shocks will affect the output gap, price inflation, and wage inflation. In addition, the social loss function will depend on the volatility of wage inflation, price inflation and the output gap. Because the dual mandate loss function (2) ignores wage inflation, the alternative regimes will be distorted relative to the Ramsey policy even if the central bank is able to implement the commitment policy associated with its targeting regime.

Table 4 shows that adding sticky wages increases social loss under all regimes, but, importantly, PLT generates the largest loss among the alternatives regimes. Now, 16-quarter average inflation targeting (the longest horizon considered here) does the best, though the differences across all regimes are small. Figure 6 shows the response to a negative i.i.d. cost shock when wages as well as prices are sticky. Recall that when only prices were sticky, it was the way expected inflation moved that gave PLT its advantage over IT. When wages are

[19] Nessén and Vestin (2005) show that this depends on the value of λ_x in the social loss function.

also sticky, inflation expectations move similarly under all the regimes, unlike the case shown in figure 4. The fact that expected inflation rises after a negative cost shock even under IT eliminates the sharp contrast between IT and PLT seen in the model with flexible wages.

Table 4: Social loss*: sticky prices and wages

	Discretion		Commitment	
Policy	Loss	Loss/Loss$_R$	Loss	Loss/Loss$_R$
(1)	(2)	(3)	(4)	(5)
IT	1.484	1.037	1.482	1.036
4Q	1.479	1.034	1.460	1.021
8Q	1.475	1.031	1.460	1.021
12Q	1.471	1.029	1.456	1.018
16Q	1.468	1.027	1.454	1.017
PLT	1.651	1.155	2.673	1.869

*Loss as percent of steady-state consumption. Loss$_R$ is loss under the Ramsey policy.

Even though all the alternatives now yield approximately the same social loss, the components of loss differ, as shown in Table 5. Output gap volatility is much higher under PLT, while IT and the various AIT regimes stabilize the output gap much more than occurs under the Ramsey policy. I have used the same weight on x_t^2 in (2) as in the social loss function. Clearly, outcomes under PLT would be improved if the weight on the output gap were increased relative to λ_x, that is, if PLT were made more flexible, while the variants of inflation targeting could be improved if less weight were put on x_t^2.[20]

Table 5: Std. deviations*: sticky prices and wages

	Discretion			Commitment		
Policy	σ_π^2	σ_x^2	$\sigma_{\pi_w}^2$	σ_π^2	σ_x^2	$\sigma_{\pi_w}^2$
IT	1.017	0.748	1.493	0.989	1.767	2.704
4Q	1.017	0.270	1.445	1.002	0.935	1.956
8Q	1.017	0.173	1.372	1.005	0.717	1.784
12Q	1.016	0.127	1.305	1.007	0.592	1.597
16Q	1.016	0.097	1.246	1.008	0.500	1.432
PLT	0.965	3.968	4.070	0.940	7.458	9.124

* Standard deviations expressed relative to values under the Ramsey policy.

[20] In a model with sticky prices but flexible wages, Vestin (2006) and Nessén and Vestin (2005) optimize the value of λ_x^j for PLT and average inflation targeting. Bodenstein and Zhao (2019b) does so for PLT and speed limit policies in a model with sticky prices and wages.

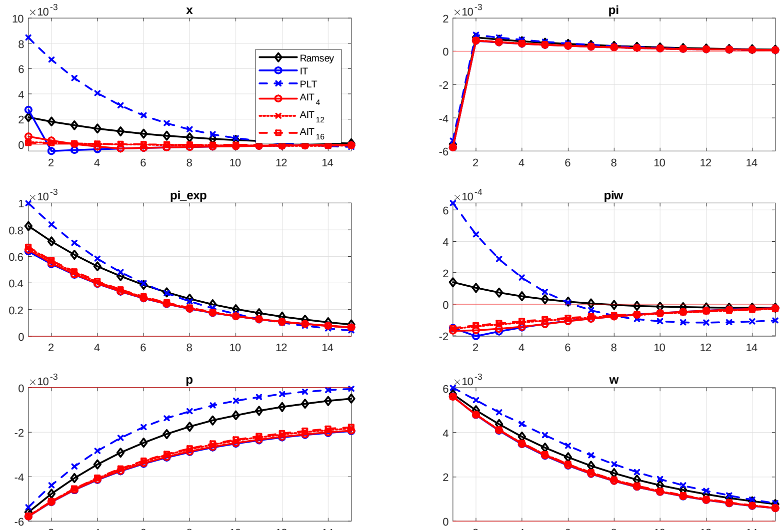

Figure 6: Response under discretion of the output gap (x), inflation (pi), expected inflation (pi_exp), wage inflation (piw), the price level (p), and the real wage level (w) to a negative i.i.d. cost shock in the sticky price, sticky wage model.

The deterioration in PLT when sticky wages are added is also apparent in figure 7, which shows the impulse responses to a persistent productivity shock. The top left panel shows the extreme volatility of the output gap, while the lower left panel shows that while PLT ensures the price level is stationary, the Ramsey policy and all the inflation related regimes allow for a much slower return of the price level to its initial level. Because a shift in productivity requires a persistent change in real wages, and because both wages and prices are sticky, PLT forces too much of the adjustment to fall on wages.

The combination of sticky wages and persistence productivity shocks leads to a huge increase in the volatility of the output gap and wage inflation under PLT relative to the Ramsey outcome (Table 5). The large increase in the variability of the output gap and wage inflation under PLT explains why it performs worse than IT under both discretion and commitment. The fact that this translates into a relatively modest deterioration in PLT as measured by social loss in Table 4 is due to the small weight placed on output gap volatility in the social loss function and the small variance of wage inflation under the Ramsey policy.[21]

[21] These results might appear to conflict with those of Bodenstein and Zhao (2019b) who find, in a basic NK model with sticky prices and wages, that PLT does better than IT under discretion but worse under commitment: I find IT performs better in both cases. Several aspects could account for the different conclusions, including differences in the parameter calibrations and in the specification of the exogenous shock processes. Bodenstein and Zhao also optimize the weight on x_t^2 for IT and PLT. They find, as I do, that IT outperforms PLT in the face of persistent productivity shocks. The fact that PLT does better than IT when both cost shocks and productivity shocks are present in their model may arise from the different specifications of the shocks volatilities. Bodenstein and Zhao parameterize the shock processes based on their estimation of the Smets and Wouters (2007) model. Employing these estimates for the shock processes in the simple sticky price and wage NK model I employ implies volatilities for output and inflation that are much greater than observed in the data. I set the shock processes so that simple model matches U.S. output and inflation volatility.

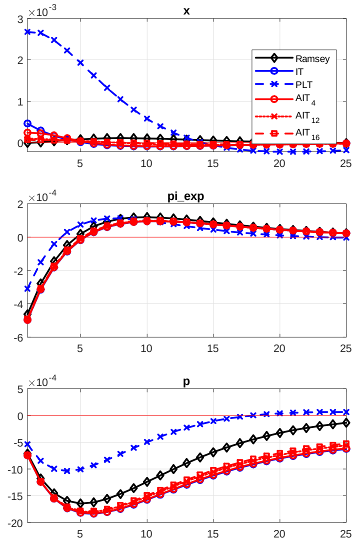

Figure 7: Response under discretion of the output gap (x), inflation (pi), expected inflation (pi_exp), wage inflation (piw), the price level (p), and the real wage level (w) to a persistent productivity shock in the sticky price, sticky wage model.

2.4 The policy rate as a shadow rate

The results reported so far have ignored the effective lower bound constraint on the nominal policy rate. In the linearized model, the nominal interest rate i_t appears as a deviation from its steady state value, implying the ELB constraint takes the form $i_t \geq -r^n$, where r^n is the steady-state real rate, given that the implicit inflation target in the model equals zero.[22] If the model's i_t is interpreted not as the policy rate itself but as a shadow interest rate, along the lines of the shadow rate NK model of Wu and Zhang (2017), then the outcomes reported in Table 2-5 would require the use of balance sheet policies whenever $i_t < -r^n$. In fact, the effectiveness of balance sheet policies is widely debated. To illustrate the range of views, Eberly, Stock, and Wright (2019) conclude that forward guidance and balance sheet policies "were able to offset perhaps one percentage point of the zero lower bound constraint" (p. 2), while Debortoli, Galí, and Gambetti (2019), using responses of U.S. macro variables to shocks obtained from an estimated VAR, argue the evidence is consistent with the hypothesis of that the ELB is irrelevant, suggesting unconventional monetary policies have been able to substituted fully for conventional policies. Examining the frequency with which $i_t < -r^n$ provides some insight into how often balance sheet policies would be required to implement the optimal policy under the alternative targeting regimes.

Table 6 provides evidence on how frequently the ELB constraint is violated under each of the alternative policy regimes. Recall that the model has been calibrated to match the frequency of the ELB observed in the U.S. under a counterfactual policy of optimal discre-

[22] Alternatively, if one assumed complete indexation to the inflation target π^T by "non-adjusting" firms, the constraint would be $i_t \geq -\left(r^n + \pi^T\right)$.

tionary inflation targeting. All other regimes lead to less frequent occurrences of $i_t < -r^n$, with the constraint binding 8.9% of the time under the Ramsey policy and between 9.4% and 9.9% for the other regimes. PLT leads to the lowest frequency at the ELB, while IT has the highest frequency. Thus, both PLT and AIT reduce the frequency of ELB episodes relative to IT. When the model is simulated under the alternative policies, the maximum duration of an ELB episode was 9 quarters for all regimes except PLT, under which the maximum duration was 7 quarters.[23]

Table 6: ELB episodes: discretion, sticky prices and wages

Policy	Frequency	Mean duration*	Maximum duration*
IT	11.8%	1.844	9
4Q	9.6%	2.341	9
8Q	9.8%	2.279	9
12Q	9.9%	2.250	9
16Q	9.8%	2.279	9
PLT	9.4%	2.186	7
Ramsey	8.9%	2.171	9

*Duration measured in quarters.

Table 7 reports characteristics of ELB episodes when the central bank has developed credibility for its policy regime, enabling it to implement the optimal commitment policy. Moving from optimal discretion to optimal commitment reduces the probability of ELB under IT and AIT, with the largest reductions occurring for the shorter duration regimes (i.e., IT and 4-quarter AIT). The major difference under commitment is that implementing a credible PLT policy more than doubles the probability of being at the ELB, with this probability rising from 9.4% under discretion to 18.7% under commitment.

Table 7: ELB episodes: commitment, sticky prices and wages

Policy	Frequency	Mean duration*	Maximum duration*
IT	8.3%	2.184	9
4Q	8.4%	2.211	9
8Q	9.1%	2.116	9
12Q	9.5%	2.159	9
16Q	9.6%	2.233	9
PLT	18.7%	2.253	7
Ramsey	8.9%	2.171	9

*Duration measured in quarters.

[23] Each regime is simulated using the same stochastic realizations of the exogenous shocks.

2.5 A lower natural rate

The results under sticky prices and wages employed a benchmark calibration in which the steady-state level of the nominal interest rate, given that the implicit inflation target underlying the Calvo inflation equation was zero, equals the steady-state real interest rate. This steady-state rate, when expressed at an annual rate, was $400(\beta^{-1} - 1) = 2.01\%$. An increase in β would lower the steady-state nominal rate and result in an increase in the frequency with which the shadow rate would be negative. Table 8 reports outcomes when β is increased to 0.998, reducing the steady-state nominal interest rate to 0.80% and leading to more frequent occurrences of a negative shadow rate. The column labeled Loss/Loss$_R$ reports social loss relative to loss under the optimal Ramsey policy for the different policy regimes. Comparing this to Table 4 shows that reducing the steady-state real interest rate has little effect on the relative performance of IT, AIT and PLT *if one assumes balance sheet policies can be used to implement the optimal shadow rate policy.* A lower steady-state real rate significantly increases the frequency with which the shadow rate would be negative for all policies regimes, but the increase is similar across all policy regimes (compare with Table 6). Mean and maximum durations also increase, but for the latter, the major difference that stands out in comparing Tables 6 and 8 is the effect under PLT. The maximum duration of an ELB episode under PLT, which was 7 quarters under the benchmark calibration, increases to 22 quarters when the steady-state value for the nominal interest rate falls. If, as suggested by Eberly, Stock, and Wright (2019), balance sheet and forward guidance policies are able to offset only a fraction of the ELB constraint, then the high fraction of periods in which the shadow rate is below the effective lower bound under all the policy regimes, even when the central bank is able to fully commit, suggests that none of the alternatives would eliminate the need to rely on balance sheet policies. The potential for long-duration spells at the ELB under PLT certainly warrants further study.

Table 8: Loss and ELB outcomes when $\beta = 0.998$

Policy	Loss/Loss$_R$	Frequency	Mean duration*	Max duration*
IT	1.038	34.0%	2.371	12
4Q	1.035	31.3%	3.330	12
8Q	1.032	31.2%	3.216	12
12Q	1.029	31.7%	3.302	12
16Q	1.027	31.6%	3.258	12
PLT	1.152	31.8%	3.495	22
Ramsey	1.000	30.9%	3.090	12

*Duration measured in quarters.

2.6 Summary on outcomes with rational expectations

To summarize these results, price-level targeting is often promoted as superior to inflation targeting because of the way expectations serve as an automatic stabilizer under PLT even in an environment of discretionary policymaking. This intuition is based on simple new Keynesian models with sticky prices and flexible wages, and is shown clearly in figure 4. Incorporating sticky wages and persistent productivity shocks dramatically alters the relative ranking of PLT, IT and AIT. Sticky wages introduce a lagged endogenous variable, the real wage, into the model. As shown by Walsh (2003) in a model with flexible wages but lagged inflation in the inflation adjustment equation, the performance of PLT deteriorates relative to IT as the lagged endogenous variable becomes more important. And figure 6 shows that expected inflation under all the inflation regimes mimics the behavior of expected inflation under the Ramsey policy; all the regimes lead to movements of expected inflation that help stabilize the economy. And when persistent productivity shocks are included, a PLT regime, defined here as a flexible regime that cares about output gap volatility but not wage inflation, generates excessive volatility in the output gap and wage inflation that is costly from the perspective of social welfare. In contrast to PLT, IT and the various AIT regimes perform similarly when wages are sticky. Of the variants of IT considered, 16-quarter average inflation targeting led to the best outcomes in terms of social loss, though the gain from switching from IT to 16-quarter AIT was small. Despite the fact that IT dominates PLT and in turn is dominated by AIT based on social loss when policy is implemented with discretion, IT would require greater reliance on balance sheet policies for its implementation, as episodes at the ELB were more frequent though of shorter duration than for the other regimes.

These results for both markup (cost) and productivity shocks do suggest that under the alternative policies considered, the mean duration of ELB episodes is relatively short, significantly less than 2.5 quarters under all policies. This short duration seems inconsistent with the decade long experience of Japan, and with that of the U.S., where the Federal Reserves' traditional policy instrument remained below 25 basis points for 7 years. And both countries have experienced low real economic growth, inflation below target, and extremely low, even negative interest rates in the case of Japan, outcomes that call into question the basic new Keynesian macro framework that has dominated policy analysis of the ELB.

3 Anchored expectations

Adopting a policy such as price-level targeting or average inflation targeting that explicitly seeks to produce stabilizing movements in inflation expectations would be a distinct shift from the focus on "anchoring" expectations that has been common among policymakers. This emphasis on anchoring reflects one of the legacies of the 1970s and 1980s, when many countries struggled with the task of reducing inflation and then maintaining it at low levels. The fear was that a shock that pushed up inflation, or an interest rate cut designed to offset an anticipated negative shock to demand, might lead the public to expect higher inflation. If they did, the monetary authorities would be faced with the choice of contracting the real economy to prevent inflation from rising or validating expectations by tolerating a rise in inflation to avoid a contraction in real activity. Anchoring expectations would, in effect, anchor the short-run Phillips curve.

Having fought to anchor inflation expectations, it was perhaps not surprising that even during the recessions following the global financial crisis, few, if any, policymakers proposed letting inflation rise temporarily above target, though that is what theoretical models of optimal policy suggest they should have done. The fear of unanchoring expectations was too great.[24] I think there is little disagreement about the importance of anchoring longer-term inflation expectations at the central bank's target. However, suggestions for alternative policy regimes such as PLT and AIT effectively want to keep inflation expectations anchored in the longer-term while unanchoring them in the medium- to short-run, thereby allowing expectations to work as automatic stabilizers.

Should expectations be used by policymakers as short-run automatic stabilizers, or should they strive to ensure expectations remain anchored? The answer depends on the gains from managing expectations and the costs of anchoring inflation expectations. In a simple NK model with sticky prices, a credible, discretionary regime of price-level targeting causes expectations to move in a manner that closely replicates an optimal commitment equilibrium under rational expectations, thereby improving over a discretionary regime of inflation targeting (see Table 2). However, in the same simple NK model, discretionary inflation targeting *exactly* replicates the optimal commitment equilibrium if expectations are completely anchored. An open question is whether the gains from having anchored expectations might mitigate any advantage of price-level targeting.

To address this question, I begin by contrasting two extremes: rational expectations and fixed expectations. The latter corresponds to the case in which inflation expectations are so firmly anchored that they do not respond at all in the short-run.[25] Results for the sticky price, flexible wage model with i.i.d. cost shocks are reported in Table 9.[26] The second column repeats the results under rational expectations from Table 2. The third column reports

[24]For example, in July 2008 during testimony before the House Committee on Financial Services, Federal Reserve Chairman Bernanke stressed that the Fed would prevent a rise in inflation as the economy recovers from the current recession, stating "....that it is important to assure the public and the markets that the extraordinary policy measures we have taken in response to the financial crisis and the recession can be withdrawn in a smooth and timely manner as needed, thereby avoiding the risk that policy stimulus could lead to a future rise in inflation." See the discussion in Walsh (2009).

[25]The basic model contains $\mathrm{E}_t\pi_{t+1}$ and $\mathrm{E}_t x_{t+1}$. The discussions surrounding monetary policy have focused in inflation expectations, and so I consider alternative assumptions about expectations of inflation while continuing to assume expectations about future economic activity coincide with model consistent expectations. $\mathrm{E}_t x_{t+1}$ appears in the aggregate expenditure condition arising from household consumption choices. It may be reasonable to assume households have more informed expectations about their own consumption plans than they do about aggregate inflation.

[26]Recall that all of the policies prevent the productivity shock from affecting either the output gap or inflation when wages are flexible.

loss when inflation expectations are completely anchored, and the fourth column shows the ratio of the loss with anchored expectations to that with rational expectations. In both column 2 and 3, losses under rational expectations (RE) and anchored expectations (AE) are expressed relative to outcomes under the Ramsey policy. Values greater than one in column 3 measure the cost of having inflation expectations remain completely anchored. Column 4 shows loss with anchored expectations relative to the loss under rational expectations. Because future expected inflation remains at zero under inflation targeting and the Ramsey policy when expected future inflation remains at zero, the column 3 value for IT equals one. Not surprisingly, column 4 shows that anchoring expectations leads to the largest rise in loss under price-level targeting, illustrating how the endogenous movement of expectations plays a major stabilization role under PLT. This contribution to stabilizing the economy is absent when expectations of inflation are anchored. For similar reasons, average inflation targeting operates, in part, by inducing stabilizing movements in expected inflation, so when expectations are anchored, AIT regimes perform more poorly, though the deterioration of AIT is less than that experienced by PLT.

Table 9: Social loss*: anchored expectations, sticky prices

Policy	RE/Ramsey	AE/Ramsey	AE/RE
(1)	(2)	(3)	(4)
IT	1.274	1.000	1.000
4Q	1.691	1.670	1.258
8Q	2.086	2.003	1.224
12Q	2.283	2.142	1.195
16Q	2.414	2.215	1.169
PLT	1.014	1.250	1.571

*RE (AE) denotes outcomes under rational (anchored) expectations.

The importance of rational expectations for the performance of PLT is even more pronounced when wages, as well as prices, are sticky, as shown in Table 10.[27] With price and wage inflation expectations anchored, social loss increases 13% to 14% under the IT and AIT policies (relative to outcomes under rational expectations – see last column of Table 10). For PLT, however, social loss rises by over 300% and is almost four times larger than achieved under IT. Table 11 shows the variances of the inflation rate, the output gap, and wage inflation under anchored expectations relative to rational expectations. Inflation volatility is increased when expectations are anchored for all regimes. Anchoring expectations decreases output gap volatility for IT and AIT except for 16-quarter AIT. Output gap volatility rises very significantly under PLT when expectations are anchored, while wage inflation volatility decreases when expectations are anchored for all regimes except PLT.

[27] I assume expectations of both price and wage inflation are anchored.

Table 10: Social loss: anchored expectations, sticky prices and wages			
Policy	RE/Ramsey	AE/Ramsey	AE/RE
IT	1.037	1.000	1.128
4Q	1.034	1.002	1.134
8Q	1.031	1.002	1.137
12Q	1.029	1.002	1.140
16Q	1.027	1.003	1.143
PLT	1.155	4.037	4.092

*RE (AE) denotes outcomes under rational (anchored) expectations.

Table 11: Std. dev.: anchored expectations, sticky prices and wages			
Policy	$\sigma_\pi(AE)/\sigma_\pi(RE)$	$\sigma_x(AE)/\sigma_x(RE)$	$\sigma_{\pi_w}(AE)/\sigma_{\pi_w}(RE)$
IT	1.070	0.882	0.300
4Q	1.071	0.841	0.285
8Q	1.072	0.876	0.296
12Q	1.073	0.959	0.310
16Q	1.074	1.073	0.323
PLT	1.101	5.103	1.575
Ramsey	1.088	0.617	0.415

*RE (AE) denotes outcomes under rational (anchored) expectations.

* Standard deviations expressed relative to values with rational expectations.

Table 12: ELB episodes: anchored expectations			
Policy	Frequency	Mean duration	Maximum duration
IT	9.5%	1.696	8
4Q	6.2%	2.000	6
8Q	5.9%	2.034	6
12Q	5.7%	1.966	5
16Q	5.8%	1.933	5
PLT	28.1%	5.204	27
Ramsey	8.7%	1.776	8

*Duration measured in quarters.

Table 12 provides information on the frequency and duration of episodes at the ELB under discretion in the model with sticky prices and wages when expectations are firmly anchored. In comparison to the case under rational expectations (see Table 6), anchoring expectations reduces the frequency, mean duration, and maximum duration of ELB episodes under IT and AIT relative to the case in which expectations are formed rationally. This is not the case, however, under PLT. The frequency of ELB periods rises from 9.4% to 28.1% when expectations are anchored, the mean duration raises from 2.2 quarters to 5.2 quarters, and the maximum duration in the simulation increases from 7 quarters to 27 quarters. The deterioration of outcomes under PLT when expectations are anchored is not surprising. PLT works under rational expectations by generating endogenous movements in expectations that serve as an automatic stabilization mechanism. When expectations are anchored, they cannot act as automatic stabilizers, leading to a marked decline in the performance of PLT.

4 Partial adjustment of expectations

Completely anchored expectations is an extreme assumption. In his Keynote address at the 2017 BOJ-IMES Conference, Gertler (2017) showed how the power of forward guidance was greatly affected if expectations adjust only gradually to changes in the central bank's target inflation rate. In this section, I investigate how deviations from rational expectations affect the performance of alternative targeting regimes.

I adopt a very simple ad-hoc model to capture the evolution of expectations. Let π_t^e denote expectations of next period's rate of inflation. Suppose expected future inflation follows a partial adjustment model given by

$$\pi_t^e - \pi_{t-1}^e = \delta_1 \left(\bar{\pi}_t - \pi_{t-1}^e \right), \tag{4}$$

where

$$\bar{\pi}_t = \delta_2 \mathrm{E}_t \pi_{t+1} + (1 - \delta_2)\, \pi_{t-1}$$

for $0 \leq \delta_1, \delta_2 \leq 1$. According to (4), expected future inflation is updated based on deviations of $\bar{\pi}_t$ from past expectations, where $\bar{\pi}_t$ is a weighted average of the fully rational expectation of future inflation and lagged inflation. This specification nests a number of special cases. For example, if $\delta_1 = \delta_2 = 1$, $\pi_t^e = \mathrm{E}_t \pi_{t+1}$ and expectations are fully model consistent and coincide with rational expectations. If $\delta_1 = 1$ but $\delta_2 = 0$, then $\pi_t^e = \pi_{t-1}$ and expectations are backward-looking, equal to lagged inflation. For $\delta_1 = 1$ and $0 < \delta_2 < 1$, expectations equal a weighted average of $\mathrm{E}_t \pi_{t+1}$ and π_{t-1}. For a given δ_2, variations in δ_1 affect the degree of updating, with smaller values of δ_1 implying π_t^e displays more inertial behavior. Completely anchored expectations are captured by setting $\delta_1 = \delta_2 = 0$.[28] When wages as well as prices are sticky, I assume a similar process for expected future wage inflation.[29]

[28] An alternative, closer to Gertler (2017) would be

$$\pi_t^e = \delta_1 \left(\pi_t - \pi_{t-1}^e \right) + \delta_2 \pi_{t-1}^e,$$

Gertler assumes $\delta_1 = 0.125$ and $\delta_2 = 0.95$. He assumed expectations of trend inflation, which I have assumed to be zero, evolve as

$$\bar{\pi}_t^e = 0.5 \left(\pi_t - \bar{\pi}_{t-1}^e \right) + \bar{\pi}_{t-1}^e.$$

[29] Allowing price inflation expectations to follow (4) while wage inflation expectations remain rational does

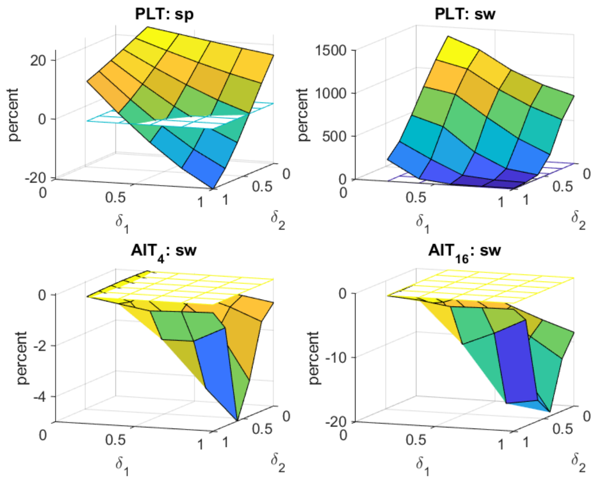

Figure 8: Performance relative to IT when expectations follow (4). Sticky price, flexible wage model denoted by *sp*: sticky price, sticky wage model denoted by *sw*.

Because expectations of nominal variables such as inflation and wage inflation have been the central focus of policy discussions, I continue to assume rational expectations apply to agent's expectations of future income.

Consider first results when only prices are sticky. The upper left subfigure figure 8 shows the loss under PLT as a percent of the loss under IT for values of δ_1 and δ_2 with each parameter running from zero to one. The right front corner in the figure corresponds to rational expectations ($\delta_1 = \delta_2 = 1$). As δ_1 declines, expectations display more inertia, while as δ_2 declines, less weight is placed on the model-consistent expectation of π_{t+1}. For high values of both δ_1 and δ_2, including the case of rational expectations, PLT outperforms IT. However, as either δ_1 or δ_2 decline, IT eventually dominates PLT. However, when sticky wages are introduced (and assuming a similar process to (4) for expectations of future wage inflation), IT dominates PLT for *all* combinations of δ_1 and δ_2, as shown in the upper right subfigure of figure 8.

The lower row of figure 8 compares 4-quarter average inflation targeting and 16-quarter average inflation targeting to IT when prices and wages are sticky and price and wage inflation expectations are given by (4). In contrast to PLT, average inflation targeting leads to better macro outcomes except when expectations are very inertial and relatively insensitive to either lagged inflation or the model-consistent expectations of future inflation (i.e., when δ_1 is very small). With rational expectations, both versions of AIT dominate IT, though the differences are small relative to the case of PLT (compare the scales for the sticky prices and wages model in the top right subfigure with the scales in the subfigures in the bottom row). Except for

not affect the basic conclusions.

very small values of δ_1, AIT generates lower social loss regardless of the value of δ_2, that is, regardless of whether expectations respond to the true, rational expectation of future inflation or to lagged actual inflation. Thus, IT and especially AIT seem more robust to the type of deviations from rational expectations considered here than is true of PLT.

5 Conclusions

The intuition for why discretionary optimal policies under PLT and AIT would dominate IT was developed before concerns about the ELB were considered and was based on a new Keynesian model with sticky prices. Extending that model to incorporate sticky wages and shocks to productivity leads to significant deterioration in the performance of PLT, primarily because, when both prices and wages are sticky, inflation expectations under IT and AIT behave much as they do under PLT. And in the face of persistent productivity shocks, PLT causes large swings in the output gap as it returns the price level to target much faster than occurs under the optimal Ramsey policy, IT or AIT.

Rather than emphasize the use of inflation expectations as automatic stabilizers, policy-makers usually stress the importance of anchoring expectations. Not surprisingly, both PLT and AIT do more poorly when expectations are truly anchored. I also examine the relative performance of the alternatives in a case in which expectations deviate from rational expectations is a simple but ad hoc manner. In this case, IT generally dominates PLT, while AIT generally dominates IT.

Whether alternative policy regimes such as IT, PLT or AIT are evaluated under the assumption of discretion or commitment, with rational expectations, anchored expectations or partially anchored expectations, incorporating sticky wages makes a critical difference for how regimes are ranked. This result aligns with those of Bodenstein and Zhao (2019a) who suggest that in the face of model uncertainty concerning the labor market, a robust policy is one designed to do well in a sticky price *and* sticky wage model. And while the model I have used is admittedly simple, much of the intuition for the potential superiority of PLT comes from even simpler models, models that incorporate only sticky prices as in Vestin (2006) or new Keynesian models of the ELB developed by Eggertsson and Woodford (2003) that are being increasingly questioned as models of the ELB.

Several aspects of the analysis reported here are important to keep in mind, and five aspects are particularly important to highlight. First, even when alternatives to rational expectations were examined, a maintained assumption was that private agents believed the central bank was committed to its goals (be they price-level targeting or average inflation targeting). This ignores the issue of how the economy transitions from one policy regime to a new one.[30] One advantage of a regime defined in terms of goals is that it may be easier to

[30] An exception in the literature that does consider learning during the transition to PLT is Cateau, Kryvtsov, Shukayev, and Ueberfeldt (2009).

communicate and explain policy actions in terms of a goal than in terms of an instrument rule of the type often used to characterize alternative policies.

Second, I have treated the weight given to stabilizing the output gap as the same under all policy regimes. Performance of each can be improved if λ_x is optimized for each policy alternative. Much of the discussion over alternatives to IT have focused on the nominal variable on which policy should focus rather than on the appropriate weight to place on any real objectives. For that reason, I have treated λ_x as the same across regimes. If, for example, productivity shocks are believed to be important, than the results from the simple model suggest a PLT regime would need to place much greater weight on stabilizing the volatility of the output gap than is the case under IT.[31]

Third, the results were based on a simple NK model that lacks the features commonly included in versions that are taken to the data. These features, such as habit persistence, wage and price indexation, capital and capital adjustment costs, as well as the specification of the shocks included in the model will affect the relative performance of different regimes. For example, Bodenstein and Zhao (2019b) obtain findings that are much more favorable to PLT (and even more so to the speed-limit policies introduced in Walsh (2003)) in a model that incorporates these data-friendly features. However, the basic intuition for PLT and AIT is based on the simple sticky price, flexible wage NK model. The finding that allowing for sticky wages and productivity shocks can alter the ranking of the various policies is a useful reminder that intuition about how a policy handles a particular shock may not carry over if other shocks are important. This lesson is one that should be familiar from the analysis of Poole (1970).

Fourth, the analysis has not imposed an effective lower bound on the nominal interest rate, interpreting the policy interest rate in the model as a shadow rate that would require the use of unconventional policy tools to implement. Such tools are unlikely to be this effective. In this case, the results on the frequency with which the shadow rate would be negative under different policy alternatives may provide some evidence on how often each regime would need to resort to unconventional policies.

Finally, the analysis has been conducted within the framework of a new Keynesian model. The experience of major economies with long periods at the ELB and the struggles in Japan and the eurozone with getting inflation up to their targets may require re-examining not just monetary policy frameworks, but the core theoretical model and the assumption of rational expectations that have provide the insights that shape much of our understanding of monetary policy.

[31] The issue of the optimal weight to put on output stabilization is not ignored by Nessén and Vestin (2005), Vestin (2006), or Bodenstein and Zhao (2019b).

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