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Working Paper

Comparing inflation and price-level targeting: A comprehensive review of the literature

Cardiff Economics Working Papers, No. E2011/22

Provided in Cooperation with:

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Suggested Citation: Hatcher, Michael C. (2011) : Comparing inflation and price-level targeting: A comprehensive review of the literature, Cardiff Economics Working Papers, No. E2011/22, Cardiff University, Cardiff Business School, Cardiff

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**Cardiff Economics
Working Papers**

Michael Hatcher

*Comparing inflation and price-level targeting: A
comprehensive review of the literature*

E2011/22

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ISSN 1749-6101
August 2011

Comparing inflation and price-level targeting: A comprehensive review of the literature

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Abstract

This paper provides a detailed survey of the economic literature comparing inflation and price-level targeting as macroeconomic stabilisation policies. Its contributions relative to past surveys are as follows. First, rather than focusing on any particular topic, the survey gives equal emphasis to all key areas of the literature. Second, the paper discusses ‘new results’ in several areas, including the zero lower bound on nominal interest rates; the long-term impact of price-level targeting; and financial market considerations. Finally, the survey is written in such a way that it can be understood by economists with little or no prior knowledge of price-level targeting and the related academic literature. The survey concludes that whilst price-level targeting has a number of potential advantages, further research is needed to accurately quantify its costs and benefits and to test robustness. Potential obstacles to the introduction of price-level targeting in practice include: concerns about its credibility; lack of public understanding; and lack of prior experience with price-level targeting regimes.

Key words: Price-level targeting, inflation targeting, macroeconomic stabilisation.

JEL classification: E52, E58.

(a) This survey is based on the first chapter of my PhD thesis.

I am grateful to my supervisors, Professor Patrick Minford and Dr Panayiotis Pourpourides, for useful comments, and to the ESRC for funding this research.

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1 Introduction

Inflation targeting (IT) is currently the most popular monetary policy framework with central banks and has been adopted by 26 central banks worldwide (Roger, 2010).¹ However, recent research in the monetary policy literature has explored alternative policy options and their performance against IT in simulated models of the economy. This survey focus on one such alternative policy prescription: price-level targeting.

Price-level targeting (PLT), or stabilisation of the economy's aggregate price index around a predetermined target price path, has been the subject of extensive theoretical research in recent years. It is also a timely topic from a policy perspective since the Bank of Canada is currently conducting a research programme to evaluate the costs and benefits of switching from IT to PLT (see Bank of Canada; 2006, 2009),² and has left open the option to change its regime after 2011. The steady increase in literature on PLT has been driven in part by research at the Bank of Canada, but also reflects a renewed interest from academics following the publication of articles on PLT in leading economic journals. Moreover, other central banks are now following suit by investigating PLT for themselves (e.g. Bundesbank, 2010; Kahn, 2009).

Reflecting this interest, there have been a number of surveys on price-level targeting in recent years, including Ambler (2009), Cournède and Moccero (2009), Crawford *et al.* (2009), Parkin (2009) and Gaspar *et al.* (2007). However, each of these surveys focuses on some topics at the expense of others, and there has been research in the meantime that has not yet been surveyed. For example, Ambler (2009), the most comprehensive survey of PLT to date, contains only short sections discussing the zero lower bound and the long-term impact of PLT – two areas of the literature in which there have been important contributions in recent years. In the light of these advances, the aim of the current survey is to provide a balanced discussion of the literature that is both instructive and up-to-date.

The survey is written in such a way that it can be understood by economists with little or no prior knowledge of PLT, thereby opening up the topic to researchers in related areas and economics teachers in higher education. It is hoped that the survey will encourage further research comparing IT and PLT, as well as better coverage of the topic on undergraduate and postgraduate economics courses. Indeed, further research on PLT is needed in order to accurately quantify its costs and benefits vis-à-vis IT (Bank of Canada, 2009), and it is notable that lack of understanding of PLT is an obstacle to its introduction by central banks in practice (Ambler, 2009).

¹ Examples include the Bank of Canada, the Bank of England, the Swedish Riksbank and the Reserve Bank of New Zealand.

² The Bank of Canada began looking at PLT in the mid-1990s and the Review was announced in Bank of Canada (2006).

The survey proceeds as follows. Section 2 provides a simple explanation of PLT by way of a straightforward analytical example, diagrams, and a direct comparison with IT. The key points made in this section provide a solid foundation for understanding the discussion of the technical literature that follows. Section 3 begins this discussion by focusing on the potential benefits of PLT. Section 4 then discusses potential drawbacks, and is followed, in Section 5, by a discussion of practical issues surrounding the adoption of PLT. Finally, Section 6 concludes and discusses implications for future research.

2 Understanding price-level targeting

Under a price-level targeting (PLT) regime, monetary policymakers attempt to stabilise the aggregate price level around a predetermined long run target price path. Consequently, the target price level in any period is unaffected by past economic shocks. Hence, for example, if the current price level is above the target price path, below-average inflation is required next period in order to return the price level to target. In this respect PLT is effectively ‘average inflation targeting’, where the average is taken over a long horizon.

The PLT approach to monetary policy contrasts with the inflation targeting (IT) mandates pursued by many central banks worldwide. In the case of IT, the *rate of change* of prices (over a short horizon) and not the *level* of prices is the target of policy. Hence, if inflation rises above target, this deviation should not be offset in the future: ‘bygones and bygones’ and policymakers aim at the same inflation target in all future periods. Consequently, there is ‘base-level drift’ in the price level under an IT regime, whilst this is ruled out by successful implementation of PLT. The response of policy to past deviations from target is the defining feature of PLT. Indeed, in the absence of economic shocks that give rise to such deviations, PLT and IT will produce identical outcomes so long as the long run inflation target implied by the target price path is consistent with the short-term inflation target.³

In order to make the distinction between IT and PLT clear, the next section draws on a simple analytical example due to Minford (2004) in which the transmission mechanism of monetary policy is suppressed for simplicity. The PLT case is dealt with first. The implications of PLT for the level and volatility of the price level and inflation are explained using diagrams, impulse responses and equations. These results are then contrasted with a simple representation of IT.⁴ Each period in these examples should be interpreted as lasting either one quarter or one year; the

³ For example, a long run inflation target of 60% over 30 years would be consistent (ignoring compounding) with an annual inflation target of 2%.

⁴ Analogous expressions can be derived analytically from simple equilibrium models, as in Svensson (1999) and Vestin (2006).

former is more consistent with academic literature, whilst the latter is closer to empirical estimates of the ‘monetary policy transmission lag’.⁵

2.1 Price-level targeting: a simple analytical example

Suppose that in each period t a path for log prices $p_0 + \pi^*t$ is targeted by the central bank, where $p_0 > 0$ is the initial price level and $\pi^* > 0$ is the inflation target that is consistent with the target price path. It is assumed that deviations from the target price path are offset in full and without error in the following period, and that the central bank has perfect credibility. This example therefore describes the impact of PLT under the assumption that it is implemented successfully in a world where economic agents have rational expectations.

Under the above assumptions, the actual level of prices in period t will deviate from its target only if there is a current price shock. Therefore, assuming that price shocks are temporary and uncorrelated, the time- t price level will be given by

$$(1) \quad p_t = p_0 + \pi^*t + \varepsilon_t$$

where p_t is the log price level and ε_t is an IID shock to prices with mean zero and variance σ^2 .

Note that the time- t price level depends on only a single (current) price shock, since any past deviations from the target price path have been offset by policy. In order to make this feature of PLT clear, Figure 1 shows the response of the price level to a one-off positive shock $\varepsilon_1 > 0$ under the assumption that the long run inflation rate implied by the target price path is positive. The price shock in period 1 pushes the price level above its target level (denoted with a star), but in period 2 the price level is returned to the target price path.

We can also use this simple example to look at the implied rate of inflation. Taking the first-difference of Equation (1) implies that inflation is given by

$$(2) \quad \pi_t = \pi^* + \varepsilon_t - \varepsilon_{t-1}$$

⁵ For a short review of this literature, see Walsh (2003, Ch. 1).

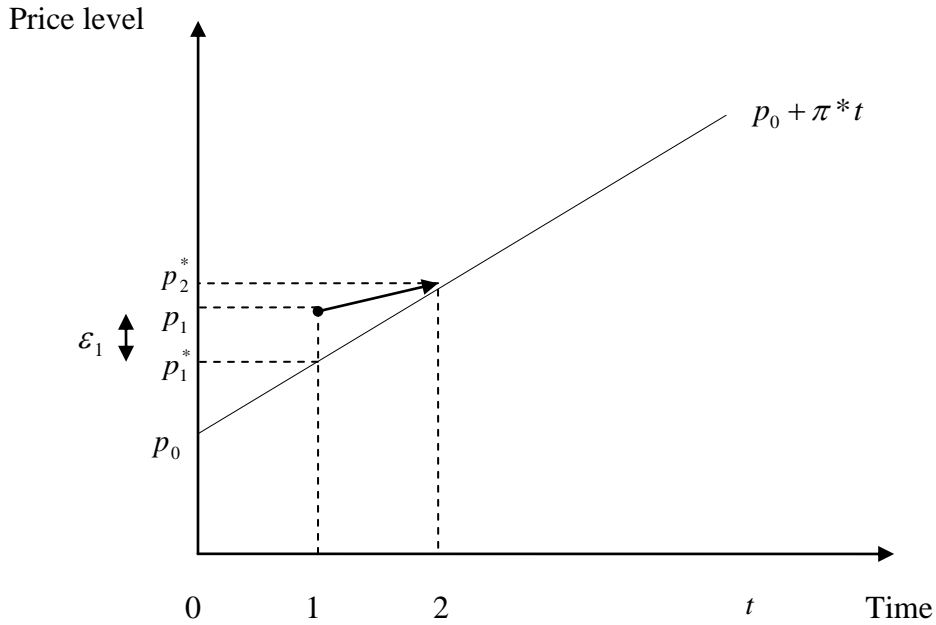


Figure 1 – Response of the price level following a price shock (PLT)

Equation (2) shows that inflation in period t is given by the inflation target implied by the target price path, plus the difference between the current shock to the price level and the shock in the previous period. Intuitively, the past shock to prices matters for current inflation because it is offset by the central bank in order to return the price level to its target path. For instance, in the face of an inflationary shock to the price level (inflation above target), inflation next period would need to undershoot its long run average in order to return the price level to target. Figure 2 shows this point explicitly by plotting the impulse response of inflation to a one standard deviation price shock. The standard deviation was set at $\sigma = 0.01$, since this implies an impulse response of one per cent on impact.

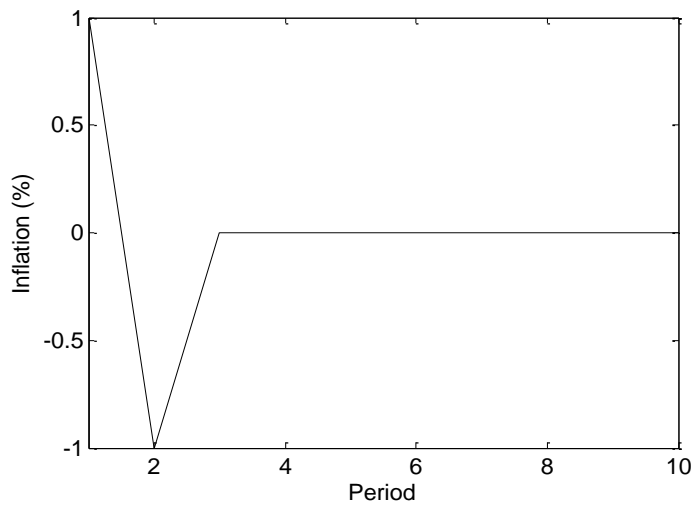


Figure 2 – Impulse response of inflation to a price shock (PLT)

2.2 Macroeconomic implications of price-level targeting

Firstly, note from Equation (2) that one-year-ahead inflation expectations are time-varying under PLT and are given by

$$(3) \quad E_{t-1}\pi_t = \pi^* - \varepsilon_{t-1}$$

where E_{t-1} is the rational expectations operator conditional on information available at $t-1$.

The intuition for this result is straightforward: past deviations from the inflation target are offset under PLT, and rational agents take this into account when forming their inflation expectations. Another way of thinking about this result is that inflation expectations follow a ‘state-contingent inflation target’, which, if met, will ensure that the price level is returned to its target path. Since the PLT regime is assumed to be perfectly credible, inflation expectations simply follow this state-contingent target. Consider next the impact of PLT on price-level and inflation uncertainty.

Using Equation (1), the k -period-ahead price level is given by

$$(4) \quad p_{t+k} = p_0 + \pi^*(t+k) + \varepsilon_{t+k}$$

Therefore, the uncertainty associated with the price level k periods hence is given by

$$(5) \quad \text{var}_t(p_{t+k}) = \sigma^2$$

Equation (5) states that future price-level uncertainty is independent of the forecast horizon. This result means that the long-term purchasing power of money is preserved over time. The reason is that any shocks to prices between periods t and $t+k$ will be offset by policy in the intervening periods. That is, although inflationary shocks cannot be forecast in advance, economic agents understand that they will be offset by a PLT central bank and take this into account when forming their forecasts of future price-level uncertainty. As a result, the only uncertainty in the future price level under PLT comes from the last period of forecast horizon – the only period whose shock cannot be offset prior to the end of period $t+k$.

Now consider the implications of PLT for inflation measured over a k -period horizon, that is, the percentage change in prices between period t and period $t+k$. This measure of inflation would be relevant for consumers or firms who enter into medium or long-term nominal contracts like mortgages or long-term bonds that begin in period t but end k periods hence.

Using equations (1) and (4), inflation over a k -period horizon is given by

$$(6) \quad \pi_{t \rightarrow t+k} = \pi^* k + \varepsilon_{t+k} - \varepsilon_t$$

where the subscript $t \rightarrow t+k$ indicates that inflation is measured over a horizon from period t to period $t+k$.⁶

Consequently, the conditional variance of inflation is given by:

$$(7) \quad \text{var}_t(\pi_{t \rightarrow t+k}) = \sigma^2$$

Equation (7) shows that k -period-ahead inflation volatility is independent of the forecast horizon k . This is an important result because it implies that, in a PLT regime, medium and long-term nominal contracts are no more risky in terms of purchasing power than short-term ones. As discussed below, this result contrasts with the IT case and therefore has potentially important welfare implications for economic agents with long-lasting nominal contracts (or substantial cash savings).

Finally, there is one last result regarding inflation volatility that should be noted. Using Equation (2), the unconditional variance of *short-term inflation* is given by

$$(8) \quad \text{var}(\pi_t) = 2\sigma^2$$

The intuition behind this result is straightforward: inflation depends on both a current shock and a past shock (which is offset by policy), so unconditional inflation volatility is simply two times the price shock variance.⁷ It is important to note that unconditional variances are usually considered to be important in monetary policy analyses, because they enable alternative policies to be evaluated across all possible ‘histories’ of shocks (see Damjanovic *et al.*, 2008).

2.3 Macroeconomic implications of inflation targeting

It is assumed that the central bank also has perfect credibility under IT, and that the short-term inflation target is consistent with the long-term average implied by the target price path under PLT (such that IT and PLT are directly comparable). Moreover, it is assumed that the price level is subject to an identical set of shocks, but that the central bank permits base-level drift in the price-level – as implied by the mandates of IT central banks.

⁶ Cochrane (2001) uses this notation to denote the holding period return on an asset held from period t to period $t+k$.

⁷ The intuition for this result can also be seen from the impulse response in Figure 2.

Under this assumption, the price level follows a random walk with drift, or

$$(9) \quad p_t = p_{t-1} + \pi^* + \varepsilon_t$$

Consequently, the dynamic evolution of the price level is somewhat different under IT. This point is demonstrated clearly in Figure 3, which shows the response of the price level following a one-off positive price shock $\varepsilon_1 > 0$ in period 1. This price level response can be contrasted directly with the PLT case in Figure 1. Starting from period 0, the central bank aims to meet its inflation target π^* in year 1. However, the price shock frustrates its attempt to meet the inflation target: the actual price level is p_1 , and inflation in period 1 is above target. Under PLT, the price shock was offset to return the price level to the target path. However, there is no such response under IT: ‘bygones are bygones’ and central bank ignores the past deviation from the inflation target, with the aim of achieving the inflation target in every period henceforth. Hence, for instance, the inflation target is met in period 2 because the price level is p_2 which lies above p_1 by exactly π^* .

As shown by the upward shift in Figure 3, it is as though the IT central bank starts with a target path for prices in period 0 and subsequently revises this path permanently upwards by the shock in period 1. Furthermore, this point holds more generally: each price shock will have a permanent effect by causing the central bank to adjust its implied price path so that the inflation target can be met in each future period. The term ‘base-level drift’ is an appropriate description of the behaviour of the price level, because price shocks lead to drift in the forecast path for prices, with each shock implying a new ‘target path’ with a different base (or starting point).

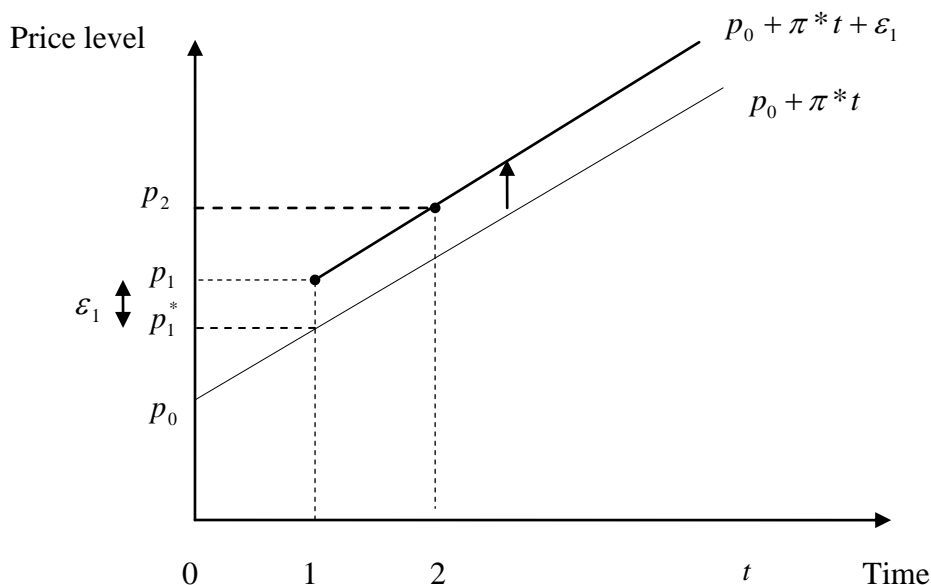


Figure 3 – Response of the price level following a price shock (IT)

Intuitively, since past shocks to inflation are treated as ‘bygones’, inflation in any period depends only on the current shock to prices. This point can be seen formally by subtracting the lagged price level on both sides of Equation (9) to get the following expression for short-term inflation:

$$(10) \quad \pi_t = \pi^* + \varepsilon_t$$

To provide a direct contrast with the PLT case, Figure 4 shows the impulse response of inflation to a one standard deviation inflation shock, again assuming that $\sigma = 0.01$. Clearly, the impact of the shock on inflation is temporary: inflation rises by one per cent on impact but is returned to steady-state (i.e. to target) in the following period. By contrast, PLT offsets the positive shock in period 2 by setting inflation one per cent below target.

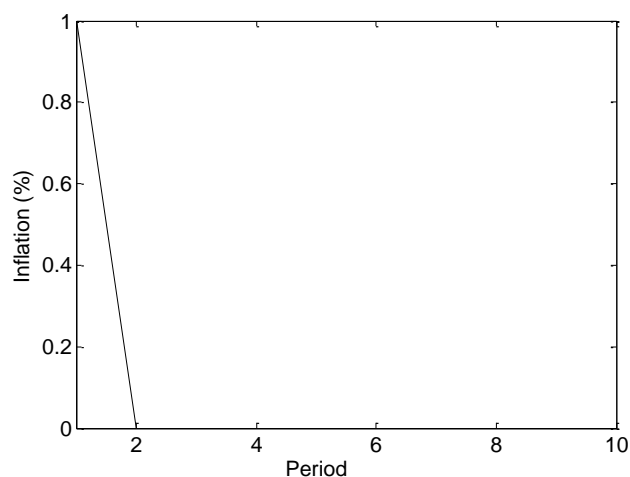


Figure 4 - Impulse response of inflation to a price shock (IT)

Using Equation (10), inflation expectations under IT are given by

$$(11) \quad E_{t-1}\pi_t = \pi^*$$

Hence inflation expectations are equal to the inflation target. Intuitively, the central bank has perfect credibility and inflation depends only on a current shock to prices, whose expected value is zero. By contrast, expected inflation varies under PLT because the central bank deliberately offsets past inflationary shocks in order to return the price level to its target path.

Finally, consider the implications of IT for price-level and inflation uncertainty. First, using Equation (9) and repeated substitution, the k -period-ahead price level is given by

$$(12) \quad p_{t+k} = p_t + \pi * k + \sum_{j=0}^{k-1} \varepsilon_{t+k-j}$$

Therefore, conditional on time- t information, uncertainty surrounding the k -horizon-ahead price level is given by

$$(13) \quad \text{var}_t(p_{t+k}) = k\sigma^2$$

Equation (13) states that uncertainty regarding the future price level is proportional to the forecast horizon k . Intuitively, since future price shocks are not known in advance and are not offset, shocks during the forecast horizon accumulate by base-level drift, with each one adding to forecast uncertainty. An important result that follows from Equation (13) is that price-level uncertainty is unbounded as the forecast horizon increases, that is, as $k \rightarrow \infty$. An equivalent expression of this result is that the unconditional variance of the period- t price level is given by $\text{var}(p_t) = t\sigma^2$, which is clearly not finite as t increases.

Now consider the implications of this result for inflation measured over a horizon of k periods. Using Equation (12), inflation over a k -period horizon is given by

$$(14) \quad \pi_{t \rightarrow t+k} = \pi * k + \sum_{j=0}^{k-1} \varepsilon_{t+k-j}$$

where the subscript $t \rightarrow t+k$ again indicates that inflation is measured over a horizon from period t to period $t+k$.

Consequently, the variance of horizon- k inflation, conditional on time- t information, is equal to the k -period-ahead price level variance:

$$(15) \quad \text{var}_t(\pi_{t \rightarrow t+k}) = k\sigma^2$$

Equation (15) demonstrates an important result: the variance of inflation is also unbounded as the forecast horizon increases. Inflation forecast uncertainty is likely to be important for economic agents who enter into medium or long-term nominal contracts like long-dated bonds or mortgages. For instance, if these contracts are fixed in nominal terms for say k periods, then the value of $\pi_{t \rightarrow t+k}$ will determine the real value of these contracts in the period when they are paid-off or yield a return. Provided economic agents are risk-averse, they will also care about $\text{var}_t(\pi_{t \rightarrow t+k})$, since this characterises the uncertainty associated with the real value of the contract

at time t when it is entered into.⁸ In the PLT case, by contrast, both the future price level and inflation variances (k periods ahead) were finite. Moreover, the k -period-ahead variances were equal to σ^2 – the yearly price shock variance – because all past price shocks were subsequently offset.

Finally, consider the unconditional variance of short-term inflation under IT. Using Equation (10), the unconditional variance of inflation in any period is simply

$$(16) \quad \text{var}(\pi_t) = \sigma^2$$

Relative to PLT, this variance is halved. The intuition for this result is simple: under IT, inflation in any year (or quarter) will deviate from the inflation target only if there is a current shock, because past shocks to prices are treated as bygones. Hence the inflation variance is simply given by the price shock variance. By contrast, inflation under PLT depends on the current price shock, and also on the shock from the previous period which is actively offset by policy. As such, yearly inflation is twice as volatile under PLT. The result that short-term inflation volatility is increased under PLT was emphasised in early literature, and provides a partial explanation for the current popularity of IT with central banks. A second reason behind the popularity of IT is that, as highlighted by Equation (11), it encourages agents' inflation expectations to converge on a constant inflation target.

Notably, however, more recent literature has argued that even short-term volatility could be reduced under PLT. The reasoning is that, in forward-looking models with nominal rigidities, monetary policy can actually influence the volatility of 'price-level shocks': the size of such shocks will depend on the extent to which firms choose to 'pass-on' an increase (decrease) in costs through higher (lower) goods prices. In such models, prices are less sensitive under PLT than IT because firms expect the aggregate price level to be restored to the target price path in the near future, and therefore have less incentive to change prices directly in line with costs when hit with 'cost-push shocks'. The assumption made in the above example that price level shocks have the same volatility under IT and PLT is therefore not innocuous. In the context of the simple example above, we could allow for this difference by letting price level shocks have a lower variance under PLT.

Table 1 summarises the macroeconomic implications of IT and PLT discussed in this section. Notably, it highlights the potential trade-off between reduced long-term risk and increased short-term volatility that dominated early literature on PLT, and also a topic of more recent interest – *viz.* the point that inflation expectations are time-varying under PLT but constant under IT.

⁸ For instance, risk-averse economic agents will, *ceteris paribus*, be less willing to enter into nominal contracts the higher the level of inflation uncertainty.

Although the comparison presented in this section is an extreme simplification of reality, it provides all the intuition that is needed to understand the results from the technical literature that follow.

Table 1 – Summary of inflation and price-level targeting

	IT	PLT	Notes
Inflation	$\pi_t = \pi^* + \varepsilon_t$	$\pi_t = \pi^* + \varepsilon_t - \varepsilon_{t-1}$	With PLT, inflation depends on a current shock and also the past one which is offset.
Expected inflation	π^*	$\pi^* - \varepsilon_{t-1}$	Constant under IT but not under PLT because rational agents expect the price level to be stabilised after a shock.
Medium & long-term inflation volatility	$k\sigma^2$	σ^2	Increases one-for-one with the horizon k under IT due to base-level drift, but PLT eliminates base drift.
Short-term inflation volatility	σ^2	$2\sigma^2$	Doubled under PLT because past price shocks are offset. However, recent literature argues that volatility is reduced.

3 Potential benefits of price-level targeting

The literature has identified three main potential benefits of PLT (see Ambler, 2009). In this section, each of these benefits is discussed in detail.

3.1 Short-term response to economic disturbances⁹

A first potential benefit of PLT identified in the literature is a reduction in short-term macroeconomic volatility that shifts inwards the trade-off between inflation and output gap volatility (see Taylor, 1979).¹⁰ In particular, PLT improves this trade-off when the expectations of economic agents are forward-looking and the central bank acts in a discretionary manner, re-optimising its decisions independently every period. The basic intuition for this result can be gleaned from one of the results in Section 2. In particular, it was shown that following an increase in inflation above target due to a price level shock, a credible PLT regime produces the expectation that inflation will be reduced below target in the following period. If current inflation depends positively on expected inflation – as it does in forward-looking models in which agents have rational expectations – then this expectation will reduce the extent to which inflation rises (falls) at times when inflationary pressure builds up (subsides), hence reducing deviations of inflation from target. These lower inflation deviations then feed through to lower output gap volatility via nominal rigidities.

A good starting point for understanding this result, and the surrounding literature, is the seminal paper by Svensson (1999). In this paper, Svensson reports a ‘free lunch’ to PLT: inflation volatility is reduced relative to IT for any given level of output gap volatility. This result means

⁹ This section draws heavily on the survey by Ambler (2009).

¹⁰ To be clear, ‘short-term’ should be taken to mean a quarterly or yearly horizon.

that PLT is desirable even if society has IT preferences. As in many papers in the monetary policy literature, Svensson assumes that social preferences take the form of a quadratic ‘social loss function’ which states that both inflation and output gap variations are costly for social welfare:¹¹

$$(17) \quad L_t = E_t \sum_{i=0}^{\infty} \beta^i \{ \pi_{t+i}^2 + \lambda x_{t+i}^2 \}$$

where $0 < \beta < 1$ is the social discount factor, λ is a constant indicating the relative importance of output gap fluctuations vis-à-vis inflation fluctuations, π_t is inflation in period t , and x_t is the output gap at time t .¹²

Aggregate supply in the economy is given by a New Classical Phillips curve:

$$(18) \quad \pi_t = E_{t-1} \pi_t + \varphi(x_t - \rho x_{t-1}) + e_t$$

where the parameter $0 < \rho < 1$ denotes the extent of output gap persistence, $\varphi > 0$ is the Phillips curve slope parameter, and e_t is an IID supply shock with a mean of zero and constant variance.

The aim of the central bank is to minimise its loss function subject to the Phillips curve in Equation (18). It is important to note that the loss function in Equation (17) is *assumed* to be the correct representation of social preferences. However, in the workhorse New Keynesian model discussed later on, this equation can be derived as a second-order approximation to the expected welfare loss of the representative household (Woodford, 2001), thus giving a model-consistent representation of social preferences and making microfounded welfare analysis feasible.

Svensson finds that in order to minimise the social loss function, it is better to delegate the central bank ‘PLT preferences’. In this context, PLT preferences can be represented by a central bank loss function which specifies that price-level rather than inflation deviations are costly, or

$$(19) \quad L_t^{PLT} = E_t \sum_{i=0}^{\infty} \beta^i \{ (p_{t+i} - p^*)^2 + \lambda^{PLT} x_{t+i}^2 \}$$

where p_t is the log price level at time t , p^* is the constant target price level and λ^{PLT} is the relative weight that the central bank places on output gap versus price-level deviations.¹³

¹¹ For simplicity, it is assumed that the target inflation rate and target output gap are zero.

¹² The output gap is defined as the proportional difference between actual output and the level of output in an economy with perfectly-flexible prices.

¹³ A constant target price level is assumed because this is consistent with the assumed inflation target of zero. The relative weight on output gap deviations can potentially differ from the IT case under PLT, but it is important to note that the ‘free lunch’ result holds for any given relative weight on output gap deviations.

Svensson shows that delegating Equation (19) to the central bank leads to a lower social loss than delegating the social loss function itself, because inflation volatility is reduced for any given level of output gap volatility.¹⁴ This result arises because the central bank re-optimises its decisions every period under discretion, such that policy is subject to ‘discretionary bias’.¹⁵ Indeed, under IT the central bank is not able to manipulate private sector inflation expectations if it lacks commitment, which in turn prevents it from dampening the impact of supply shocks on inflation. This is somewhat problematic since, if output gap deviations are strongly persistent, inflation will deviate from target for substantial periods of time following supply shocks.

However, this same problem does not arise under discretionary PLT. The reason is that PLT creates the expectation that inflationary shocks will be undone in the future, which then reduces actual inflation deviations through the expectations term in the Phillips curve, partly offsetting the destabilising impact of a persistent output gap. Hence inflation variations can be reduced, whilst there is no impact on output gap variability because only ‘inflation surprises’ matter for output. This result effectively shows that there is a critical value of output gap persistence above which extra fluctuations caused by offsetting past inflationary shocks under PLT are dominated by reduced volatility from stabilising inflation expectations. In fact, Svensson shows that an output gap persistence parameter of $\rho > 1/2$ is sufficient to deliver the free lunch result.

The free lunch result is viewed as important because it contradicts the conventional wisdom on PLT,¹⁶ and does so within a rational expectations setting. Moreover, it is important to note that this result is not limited to the case of endogenous output gap persistence. For instance, Cover and Pecorino (2005) use the same model as Svensson but assume that the output gap is not persistent (i.e. $\rho = 0$) and that the central bank must choose its policy before knowing the current value of the supply shock. This change in timing makes it necessary to specify an IS curve for aggregate demand. Aggregate demand is assumed to depend negatively on the *ex ante* real interest rate, which in turn is negatively influenced by expected inflation through the Fisher equation. Consequently, an increase in expected inflation will reduce the *ex ante* real interest rate, stimulating aggregate demand and the output gap.

PLT performs well in this framework because, in contrast to IT, it automatically stabilises the output gap via the impact of variations in expected inflation on the real interest rate. For example, following a demand shock both the output gap and inflation will increase, but under PLT this impact will be mitigated by a reduction in expected inflation for the next period, which then pushes up the *ex ante* real interest rate and stabilises output via the IS curve. This automatic stabilisation mechanism has become known as the ‘expectations channel’ of PLT.

¹⁴ Equivalently, output gap volatility is lower for any given level of inflation volatility.

¹⁵ By contrast, delegating the IT loss function will minimise IT social preferences under commitment.

¹⁶ See the discussion in Section 2.3.

Though these initial contributions highlight a key flaw in the conventional wisdom on PLT, they suffer from a major weakness: welfare analyses of monetary policy based on the New Classical Phillips curve are not microfounded, because the social loss function in Equation (17) cannot be derived as an approximation to the expected utility loss of the representative household.¹⁷ Furthermore, the New Classical Phillips curve has been widely criticised from an empirical perspective because it implies that only unanticipated inflation influences output, in direct contradiction to evidence from the structural VAR literature (e.g. Christiano *et al.*, 2005). For these reasons, most recent studies comparing IT and PLT have used the microfounded New Keynesian model (see Clarida *et al.*, 1999).

The New Keynesian model consists of households who maximise expected utility and profit-maximising firms. Firms are monopolistically competitive and produce their own individual differentiated output goods. Following Calvo (1983), a constant fraction of firms are unable to change the nominal price of their output in any given period, whilst the remaining fraction of firms are free to re-optimize their prices. Consequently, inflation in any given period comes solely from changes in output prices set by firms that are able to re-optimize. Profit maximisation by firms induces them to set their current output price as a function of marginal cost and the expected aggregate price level in the next period, with the latter entering firms' first-order conditions due to the possibility that nominal rigidities will prevent them from re-setting their output price. Moreover, under standard assumptions, all firms changing price in a given period will set the same output price,¹⁸ which simplifies greatly the task of aggregating across firms and gives rise to a simple Phillips curve describing economy-wide outcomes.

Log-linearisation of this equation around zero trend inflation yields the so-called New Keynesian Phillips curve:

$$(20) \quad \pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t$$

where $0 < \beta < 1$ is the discount factor of the representative household, $\kappa > 0$ is a constant that depends on the structural parameters of the model, and u_t is an AR(1) 'cost-push shock' to inflation with a persistence parameter $0 < \rho_u < 1$ and a constant variance IID innovation.

¹⁷ Woodford (2003, Ch. 3) shows that a New Classical Phillips curve (with no output persistence) can be derived when a fraction of monopolistically competitive firms must set their output prices one period in advance, whilst the remaining firms have fully flexible prices. However, the approximation of the representative household's expected welfare differs from Equation (17) and is not a sensible welfare criterion for monetary policy since only *unanticipated* fluctuations in inflation matter.

¹⁸ The assumptions are as follows: all firms face the same production technology, and demand curves whose elasticity of substitution is common and constant over time (Walsh, 2003); the aggregate capital stock is fixed, but capital can be reallocated costlessly and instantaneously across firms (Ambler, 2007); and finally, there is unfettered access to perfect financial markets (Rotemberg and Woodford, 1998).

It is important to note that the cost-push shock does not arise from the pricing conditions of firms; rather, it is appended to the New Keynesian Phillips curve to ensure that there is a trade-off between inflation volatility and output gap volatility (see King and Wolman, 1999). However, if firms' output demand elasticities are subject to exogenous fluctuations, then a microfounded justification for the addition of the cost-push shock emerges from their first-order conditions (Steinsson, 2003). The New Keynesian Phillips curve in Equation (20) has provided the foundation for most of the recent literature comparing the performance IT and PLT. The key difference relative to the New Classical Phillips curve in Equation (18) is that current inflation depends on expected future inflation, as opposed to the expectation of inflation in the current period. Consequently, monetary policy will be able to improve the trade-off between inflation and the output gap if it can favourably influence firms' expectations regarding future inflation.

Vestin (2006) was the first to compare IT and PLT with a New Keynesian Phillips curve. Like Svensson (1999), Vestin focuses on the case where IT and PLT policies are discretionary, though he uses the optimal commitment policy as a benchmark against which to compare the results under discretion. Two key results are found in favour of PLT. Firstly, if there is no persistence in the cost-push shock (i.e. $\rho_u = 0$), PLT can exactly replicate the optimal commitment policy. Secondly, in the more general case when there is cost-push shock persistence, PLT dominates IT because inflation volatility is lower for any given level of output gap volatility. This finding demonstrates that Svensson's free lunch result is robust to a change in Phillips curve specification from Equation (18) to Equation (20).

The intuition for the first result can be seen from the first-order condition for the optimal commitment policy in the New Keynesian model:¹⁹

$$(21) \quad \pi_t = -\frac{\lambda}{\kappa}(x_t - x_{t-1})$$

where λ is the relative weight on output gap stabilisation in the social loss function.

Equation (21) states that inflation should be traded-off against the *change* in the output gap and not its level. Therefore, if the output gap increases, inflation should be reduced and *vice versa*. In effect, then, the past output gap acts as a reference point that determines the course that optimal policy should take. This feature of optimal policy has become known as 'history dependence'. History dependence is present under PLT because the actual price level depends on the deviation from the target price path in the previous period. It can also be shown that Equation (21) implies that the optimal price level is stationary (see Clarida *et al.*, 1999), and hence that there is no base-level drift. Intuitively, since discretionary PLT implies both history

¹⁹ This condition will hold in the initial period only if Woodford's 'timeless perspective' is adopted (see Woodford, 2003; Ch. 7).

dependence and a stationary price level, it is able to exactly replicate the optimal commitment policy if there is no cost-push shock persistence.

In the more general case when cost-push shocks are persistent, PLT is unable to replicate optimal commitment exactly because there is a ‘discretionary bias’ which has the effect of increasing inflation volatility relative to the optimal commitment policy. However, PLT still reduces inflation volatility relative to IT, because history dependence and price-level stationarity – key features of the optimal commitment policy – are present under PLT but entirely absent under IT. Intuitively, the former is absent under IT because ‘bygones are bygones’, and the latter because it permits base-level drift in the price level.

To be clear, the key advantage of PLT is that it allows the central bank to dampen the impact of a cost-push shock on current inflation by creating the expectation that the shock will be offset in next period, so that less of an inflationary shock is passed through to output prices by firms. Indeed, price-setters effectively face a trade-off under PLT: setting a high price in current period protects current profits, but will lead to a sharp reduction in future demand if there is no opportunity to re-optimize the output price. Under IT, by contrast, there is no such trade-off: firms find it optimal to pass inflationary shocks straight into output prices, as they do not expect the central bank to make any attempt to offset such shocks.

The New Keynesian Phillips curve in Equation (20) is attractive to researchers because of its strong theoretical foundations, but is not without its own flaws. For example, it cannot account for structural inflation persistence observed in post-war inflation data (e.g. Fuhrer, 1997), because it does not include a term in lagged inflation. However, modifying the price-setting structure so that firms whose prices cannot be re-optimized are indexed to past inflation gives rise to a Phillips curve in which current inflation is, additionally, a function of the past inflation rate (Christiano *et al.*, 2005). Whilst it is difficult to justify this assumption theoretically given that price-setters are assumed to be rational (Minford and Peel, 2003; Le, 2008), it does at least give rise to more plausible inflation dynamics.

The resulting equation for aggregate inflation has been dubbed the ‘hybrid New Keynesian Phillips curve’ and takes the following form:

$$(22) \quad \pi_t - \gamma\pi_{t-1} = \beta(E_t\pi_{t+1} - \gamma\pi_t) + \kappa x_t + u_t$$

where $0 \leq \gamma \leq 1$ measures the extent of indexation to past inflation.

Note that with this hybrid specification of the New Keynesian Phillips curve, the quasi-difference of inflation $\pi_t - \gamma\pi_{t-1}$ replaces the inflation rate in the purely forward-looking version.

One implication of this result is that approximate measure of social welfare is no longer given by Equation (17): instead, the inflation rate in the social loss function is replaced with the quasi-difference of inflation (see Woodford, 2003). Gaspar *et al.* (2007) investigate the robustness of Vestin’s result in a model in which the New Keynesian Phillips is given by Equation (22) and the social loss function is appropriately adjusted. They find that, in general, it is optimal for monetary policy to fully offset price level shocks (as under PLT). The only time when it is not optimal to do so is the special case when price-setters fully index their prices to the past inflation rate (i.e. $\gamma = 1$). All in all, then, the result that PLT dominates IT is robust to the modification that price-setters index their prices to past inflation when unable to re-optimize output prices.

Steinsson (2003) derives a similar hybrid specification of the New Keynesian Phillips curve based on ‘rule-of-thumb’ price-setting but reaches a somewhat different result. More specifically, Steinsson assumes that some fraction of price-setters follow a rule-of-thumb which dictates that price is set as function of the lagged output gap and previous prices adjusted for lagged inflation. In this case, the hybrid New Keynesian Phillips curve is given by

$$(23) \quad \pi_t = \beta\theta_1 E_t \pi_{t+1} + \theta_2 \pi_{t-1} + \psi_1 x_t + \psi_2 x_{t-1} + u_t$$

where the weight on future expected inflation (θ_1) falls relative to the weight on past inflation (θ_2) as the fraction of rule-of-thumb price-setters is increased.

Furthermore, Steinsson derives the approximate social loss function in this case and uses it to investigate the form that optimal policy takes. He finds that the presence of rule-of-thumb price-setters means that it is no longer optimal to fully offset past shocks to the price level, and that the optimal level of price-level offset decreases as the fraction of rule-of-thumb price-setters increases. Consequently, the performance of PLT vis-à-vis IT deteriorates as the relative importance of rule-of-thumb price-setters increases, with the implication that Vestin’s result on the dominance of PLT no longer holds.²⁰

This result stands in contrast to the conclusion reached by Gaspar *et al.* (2007) when firms’ prices were indexed to past inflation. The reason is that in the Steinsson model there is a subset of firms – *viz.* those that follow the rule-of-thumb – whose price-setting behaviour is entirely backward-looking. This works against PLT because its benefits arise as a result of price-setters being forward-looking when setting output prices. On the other hand, in the model of Gaspar *et al.*, firms index to past inflation *only if* they are unable to re-set their output price, optimally resetting prices in a forward-looking manner the rest of the time. Consequently, *all firms* in the

²⁰ One criticism that can be made of the Steinsson model is that the implied social loss function does not have an intuitive interpretation. There are, for instance, additional terms in the lagged value of the output gap and the change in the inflation rate. It is difficult to reconcile these terms with the mandates delegated to central banks in practice.

economy enjoy periods when their prices can be reset optimally. The main lesson from Steinsson's analysis is that the assumption that one makes about firms' behaviour during periods when prices are 'sticky' is important for the IT-PLT welfare comparison. The theme that models with backward-looking expectations remove the benefits of targeting of the price level is returned to in Section 4 which discusses the potential costs of PLT.

3.2. Long-term inflation risk and nominal contracts

As noted in Section 2, inflation shocks have a cumulative effect on the price level and its forecast variance under IT: as the forecast horizon increases, so does uncertainty regarding the future price level. By contrast, by preventing base-level drift, PLT ensures that past price shocks cannot accumulate over the forecast horizon. As a result, price-level uncertainty is bounded as the forecast horizon increases, and the long-term purchasing power of money is preserved. This is the traditional argument put forward in favour of PLT (e.g. Duguay, 1994). With greater predictability of purchasing power, the real value of payments on long-lasting contracts denominated in nominal terms, or imperfectly-indexed to the price level, is less uncertain than under IT. Consequently, PLT should provide welfare gains to economic agents entered into medium and long-term contracts like mortgages, long-dated bonds, pensions, and wage contracts.

Increased nominal stability may also have non-trivial effects on the medium and long-term contracting behaviour of economic agents – for instance, nominal contracting might become more popular, whilst the incentive to index to prices (which is not without its own costs) may be reduced. Since longer-term assets and liabilities account for a substantial share in household portfolios,²¹ these effects may be an important factor in social welfare. Studies that have investigated the redistributive impact of an unanticipated increase in inflation have found that the impact is indeed sizeable (Meh *et al.*, 2010; Doepke and Schneider, 2006), suggesting that failure to contract optimally is costly for economic agents. In fact, Meh, Ríos-Rull and Terajima (2010) study redistribution and welfare effects of unanticipated inflation under IT and PLT and find that an unexpected 1 per cent increase in the price level in Canada implies a household sector welfare loss of 0.40 per cent of GDP under IT, compared to only 0.15 per cent under PLT. Since these results suggest that PLT can have important implications for longer-term contracting decisions, such behaviour should be endogenised in economic models in order to obtain reliable welfare results to guide policy.

²¹ For instance, in Canada 70 per cent of assets and liabilities have a term-to-maturity of more than one year (Meh and Terajima, 2009), whilst in the UK around one-third of the government bond portfolio consists of nominal bonds with a term-to-maturity of 15+ years.

In the context of the IT versus PLT debate, Ambler (2009, p. 998) emphasises the importance of endogenising contracting behaviour as follows:

Accounting for the effect of the monetary regime on contracting is difficult...However, comparing social welfare across monetary policy regimes that are vulnerable to the Lucas critique can potentially give seriously misleading results. Endogenising the degree of indexation and other features of price and wage setting across monetary regimes is an important and promising avenue for future research.

There is, in fact, a small but growing literature that focuses on endogenising contracting behaviour in the context of the IT versus PLT debate. However, as the above quote from Ambler suggests, more research is needed in this area to allow policymakers to conduct a reliable cost-benefit analysis of PLT vis-à-vis IT.

As the traditional argument in favour of targeting the price level, the topic of long-term inflation risk received considerable attention in early literature on PLT. Duguay (1994) surveys this literature and concludes that the potential benefits from PLT are substantial, though this view is disputed by Fischer (1996) who argues that such benefits are likely to be small compared to the potential increase in short-term output volatility. More recently, Dittmar *et al.* (1999) use a US-calibrated version of the New Classical Phillips curve model of Svensson (1999) to investigate medium- and long-term inflation volatility under IT and PLT. They estimate that PLT would lead to a substantial reduction in long-term inflation volatility, with the benefits to PLT increasing strongly with the forecast horizon due to the presence of base-level drift under IT.

Along similar lines, Gavin *et al.* (2009) set-up a microfounded New Keynesian model in order to investigate inflation risk at horizons of up to 10 years. The model nests a sticky-price model and a sticky-wage model as special cases, and includes exogenous disturbances to monetary policy, preferences and technology, plus investment adjustment costs. They find that the optimal (short-term) policy in both the sticky-price and sticky-wage cases generates a substantial amount of longer-term inflation volatility, but that a PLT monetary policy rule can eliminate much of this volatility. One issue highlighted by this result is that long-term inflation volatility has no role for social welfare in standard New Keynesian models, because it is only short-term fluctuations that matter for the utility of the representative agent. Therefore, as Gavin *et al.* (p. 73) note with regard to future research, “the effect of long-run inflation risk on social welfare needs to be explicitly modeled.” As is discussed in further detail below, recent research by the author addresses this issue by quantifying the long-term impact of inflation risk on social welfare within a DSGE framework.

Stuber (2001) and Crawford *et al.* (2009) both argue that PLT would lead to non-trivial reductions in long-term risk-premia on nominal debt contracts. Regarding this argument, it is notable that the empirical asset pricing literature provides evidence on the importance of

inflation risk premia on nominal bonds at various horizons. For instance, Veronesi and Yared (2000) estimate that the inflation-risk premium on five-year nominal bonds in the US was significantly higher during the relatively volatile 1968-90 period than post-1990, whilst estimates of the five-year inflation-risk premium in the literature tend to be positive and non-trivial at upwards of 30 basis points on average (Ang *et al.* 2008; Hördahl 2008). Moreover, estimates of inflation risk premia on longer maturity bonds tend to be higher (Bekaert and Wang, 2010), consistent with idea that inflation risk premia increase with the accumulation of inflation risk over the forecast horizon under IT.²² For instance, Buraschi and Jiltsov (2005) estimate the ten-year US inflation risk premium over the postwar period using a continuous-time general equilibrium model in which monetary policy and taxes are endogenous. Their results suggest that the ten-year premium has averaged 70 basis points.

In terms of IT versus PLT, there is somewhat less literature. Until recently, the single formal contribution was the paper by Meh *et al.* (2008a),²³ who build a small open economy model in which firms can finance investment using short-term or long-term nominal debt contracts. Firms have the choice to default on both types of debt, so there is a risk premium in the cost of capital. Although IT and PLT are not modelled explicitly, the former is assumed to be represented by a 'high' level of long-term price-level uncertainty, and the latter by a 'low' level of uncertainty. Reducing long-term price-level uncertainty has two effects. First, reducing the level of uncertainty lowers the risk premium on debt (since there is a lower probability of default), and with it the cost of capital. Second, a reduction in uncertainty leads to an increase in the fraction of agents using long-term nominal debt, which in turn boosts investment and output. These results suggest that switching from IT to PLT could have a beneficial impact on investment and output by lowering the inflation risk premium, as argued informally by Lilico (2000).

Recent research by the author has directly modelled the impact of PLT on long-term inflation risk premia within an overlapping generations framework (see Hatcher, 2011a). To do so, the author builds an overlapping generations model in which consumers save for old age using productive capital and long-term government bonds. Crucially, the overlapping generations life-cycle model is amended in order to capture the impact of base-level drift under IT and its absence under PLT, thereby capturing the impact of PLT on long-term inflation risk. A key result is that PLT leads to a reduction in the inflation risk premium on nominal bonds of between 90 and 95 per cent. Moreover, this result is robust for all bond maturities consistent with the life-cycle model (25 to 35 years) and to key calibrated parameters like risk aversion. However, an interesting finding from varying the menu of assets to which consumers have access is that the *absolute reduction* in the long-term inflation risk premium under PLT is likely

²² It should be noted here that although the US is not formally an inflation targeter, the Federal Reserve is widely considered to have an implicit target for inflation.

²³This paper is cited by Crawford *et al.* (2009).

to be larger in countries in which nominal assets play an important role and where indexed government bonds are not widespread.

The impact of PLT on other nominal contracting behaviour has been more widely researched, though primarily in the context of medium-term wage contracts. The initial papers in this literature were due to Minford and various co-authors, who focus on the optimal degree of indexation of multi-period wage contracts (Minford and Peel 2003; Minford *et al.* 2003; Minford and Nowell, 2003). Households have a strong incentive to insure against real wage fluctuations in these models, but are assumed to be unable to resort to financial markets for this purpose. The degree of wage indexation in the economy is chosen optimally to minimise such fluctuations, subject to monetary policy – hence the representative agent chooses optimal shares of indexed and nominal wage contracts in response to IT and PLT. Minford and co-authors find several important results.

Firstly, optimal wage indexation is substantially lower under PLT than IT. This result is driven by the multi-period nature of wage contracts: PLT reduces nominal volatility relative to IT over the contract horizon, making nominal wage contracts relatively better real-wage stabilisers. Secondly, when indexation is endogenised, PLT increases social welfare because a reduction in indexation makes the real wage more flexible in response to productivity shocks and hence stabilises employment – a point first made by Gray (1976) in the seminal paper on wage indexation. Finally, if indexation is held fixed as monetary policy shifts from IT to PLT, this gives the misleading conclusion that social welfare is reduced under PLT. This last point is crucial because it suggests that in order to obtain reliable welfare conclusions about PLT at a medium- or long-term horizon, it is necessary to endogenise the degree of nominal indexation in response to monetary policy.

The robustness of these results was subsequently investigated by Amano *et al.* (2007), who develop an alternative model in which there are staggered cohorts of labour-differentiated wages setters whose contracts are subject to multi-period nominal rigidities.²⁴ Moreover, in contrast to the model developed by Minford and co-authors, economic agents in this setting have unrestricted access to financial markets. Nevertheless, Amano *et al.* also find that optimal wage indexation is lower under PLT and that social welfare higher than in the IT case. Again, the welfare gains arise because reducing wage indexation increases employment stability in response to real shocks.

Meh *et al.* (2008b) extend the investigation of endogenous indexation to *financial contracts* that are imperfectly-indexed. More specifically, they develop a model with repeated moral hazard in which financial contracts are not fully indexed to inflation because nominal prices are observed

²⁴ In this context, ‘labour-differentiated’ means that each worker possesses a particular type of skilled labour that differentiates them from other workers.

with delay. Contracting in the model results from entrepreneurs entering into debt contracts with financial intermediaries so that they can finance investment. In concordance with the optimal wage indexation literature discussed above, Meh *et al.* find that the optimal degree of indexation falls with level of price-level uncertainty. One caveat, however, is that monetary policy does not enter the model explicitly, because the price level is exogenous. Nevertheless, these results do at least suggest that the optimal level of indexation of financial debt contracts would be lower under PLT than IT.

With regard to a long-term contracting horizon, the literature is rather sparse. The reason, as noted by Dib *et al.* (2008, p.30), is that “modeling long-term contracts in macroeconomics is a major challenge”. Carlstrom and Fuerst (2002) and Minford (2004) both argue that PLT would reduce real return volatility on long-term nominal bonds relative to IT but stop short of modelling this impact explicitly. Carlstrom and Fuerst explain the potential impact thus:

[T]he base-drift problem with IT leads to a great deal of uncertainty about what the price level 5, 10, or 30 years in the future will be. The central bank may miss its inflation target by a very small percentage in each year, but if these misses are not offset, they will accumulate and become quite large after 30 years. Therefore, a price-level target will reduce the uncertainty associated with buying and selling long-term fixed bonds.

Mankze and Tödter (2007) make a preliminary attempt at modelling the welfare impact of reduced long-term inflation risk under PLT by focusing on the real return on nominal bonds in an overlapping generations framework – a neat potential solution to modelling long-term contracts in a tractable way. The model they use for this purpose is the canonical life-cycle model of saving in which government bonds are ‘net wealth’ because they act as a store of value (e.g. McCandless and Wallace, 1991). Given that each period is taken to last 30 years, this is also the horizon over which real return volatility on bonds matters for welfare. Monetary policy is not modelled explicitly because money is absent from the model; instead, inflation is assumed to be an exogenous stochastic process with a lower variance under PLT by factor of 30. Mankze and Tödter’s results suggest that PLT would deliver a welfare gain of 0.066 per cent of long-term consumption over IT.

In order to understand these results, it is worth focusing briefly on the model. In real terms, the budget constraints of young and old consumers are given by

$$(24) \quad c_{t,Y} + b = Y$$

$$(25) \quad c_{t+1,O} = r_{t+1}b = \frac{(1+i)^{30}}{1+\pi_{t+1}}b$$

where $c_{t,Y}$ is consumption when young, b , is fixed holdings of nominal bonds and $Y > 0$ is the constant endowment income received by the young. Consumption in old age of the generation born in period t is given by $c_{t+1,O}$; $i > 0$ is the constant *yearly* nominal interest rate; π_t is the exogenous stochastic process for inflation; and r_{t+1} is the *ex post* real return on a nominal bond held from youth to old age.

Given that all young consumers are homogenous and have the same bond holdings, their consumption levels are equalised. However, old generations will be heterogenous *ex post* because their consumption levels depend on the stochastic process for inflation, which in turn determines the real return on bonds. Therefore, in this simple model, inflation uncertainty imposes a welfare cost for old generations through the uncertain real return on nominal bonds.

In particular, if welfare in old age is given by $u(c_{t,O})$, the ‘consumption risk premium’ is defined by the following equation:

$$(26) \quad u(c_{t,O}) = E(u(c_{t,O} + \lambda \bar{c}_O))$$

where λ is the risk-premium as a percentage of mean consumption in old age.

Mankze and Tödter assume that consumers have constant relative risk aversion (CRRA) utility with a risk aversion parameter δ . A second-order Taylor expansion of Equation (26) around mean consumption thus yields the following expression for the consumption risk-premium:

$$(27) \quad \lambda \approx \frac{\delta}{2} \left(\frac{\text{var}(c_{t,O})}{\bar{c}_O^2} \right) = \frac{\delta}{2} \left(\frac{(1+i)^{60} b^2}{\bar{c}_O^2} \right) \text{var}((1+\pi_t)^{-1})$$

where b is the constant level of bond holdings per generation.

This result makes clear that the consumption risk premium increases with the level long-term inflation risk (i.e. inflation risk over the 30-year saving horizon). Consequently, the estimated risk premium under IT was 0.068 per cent, compared to only 0.002 per cent under PLT. The difference between these two estimates gives the reported welfare gain of 0.066 per cent of consumption in old age.

The overlapping generations framework put forward by Mankze and Tödter provides a simple and intuitive way by which to model the impact of PLT on social welfare through the long-term inflation risk channel, thus addressing in part the issues raised by Gavin *et al.* (2009) and Dib *et al.* (2008). However, there are a number of weaknesses with Mankze and Tödter’s application of this framework, in addition to the fact that they do not model IT and PLT explicitly. First, the

model is a ‘partial equilibrium’ model of the life-cycle since all generations receive an exogenous endowment income and no output is produced. Second, the nominal return on bonds is not endogenously determined by supply and demand for bonds, but is instead assumed to be constant. Third, there is assumed to be a positive (net) supply of bonds, yet there is no economic entity responsible for supplying bonds in the model. Fourth, the model abstracts from real assets such as capital or indexed bonds that offer protection against inflation. Last but not least, the model is unable to address the issue of optimal indexation, because consumers have access to nominal bonds but not indexed bonds.

These weaknesses are addressed in Hatcher (2011b) and (2011c). In his model IT and PLT are modelled explicitly (such that the price level is endogenised) and consumers can hold money, productive capital, and indexed and nominal government bonds that provide imperfect insurance against inflation risk. Moreover, the extent of indexation of government bonds is determined endogenously in response to monetary policy as part of an optimal commitment Ramsey problem, such that the welfare results obtained should not be vulnerable to the Lucas critique. As Hatcher (2011c) demonstrates, this framework provides a microfounded justification for focusing on the long-term impact of PLT on social welfare, since a second-order Taylor expansion of the lifetime utility of generation t can be written in the form of a ‘loss function’ in long-term inflation risk. Several notable results are found using this framework.

Firstly, PLT increases social welfare compared to IT because it reduces long-term inflation risk by an order of magnitude, thereby reducing return risk on bonds and stabilising old generations’ consumption. Consumption risk is reduced substantially, but the potential gain in welfare is relatively small because volatility has only a second-order impact on social welfare.²⁵ Nevertheless, for the special case dealt with by Mankze and Tödter (2007) in which consumers hold only nominal bonds, the baseline estimated welfare gain is more than three times as large as they estimate. Secondly, optimal indexation is substantially lower under PLT than IT. Intuitively, optimal indexation is quite high under IT because consumers can insure themselves against the high level of long-term inflation risk by holding indexed bonds. Under PLT, however, the substantial reduction in long-term inflation risk makes nominal bonds a somewhat better store of value – in particular, because indexed bonds are not perfectly indexed to prices.²⁶

Finally, the potential welfare gain from PLT varies substantially across model specifications from 0.01 to 0.17 per cent of aggregate consumption, in line with the reduction in consumption risk under PLT which ranges from 13 to 95 per cent. The potential gains from PLT are largest if consumers can hold only nominal assets but are reduced somewhat if they have access to productive capital and/or indexed bonds, suggesting that the long-term benefits from PLT will

²⁵ As noted by Rudebusch and Swanson (2008), second-order impacts are typically 100 times smaller than those at first-order in DSGE models.

²⁶ Indexation is imperfect due to ‘indexation bias’ and because ‘indexation lags’ are taken into account.

be largest in countries in which nominal assets play an important role in the provision of retirement income and where indexation is not widespread.

To summarise, there is somewhat less formal literature on the long-term impact of PLT than on its short-term effects, though recent research has begun to redress the balance. This research provides a solid foundation for future efforts in this area to build upon.

3.3 Price-level targeting and the zero lower bound

The zero lower bound (ZLB) refers to the idea that a central bank will be unable to reduce its target nominal interest rate below zero in an economy that is inhabited by rational agents. The reasoning is that since money is a perfect store of nominal wealth, no rational economic agent would willingly hold bonds that promised to pay a negative return in money terms.

Mathematically, the ZLB can be represented as follows:

$$(28) \quad i_t \geq 0$$

where i_t is the nominal rate of interest.

Most research that has compared stabilisation of the economy under IT and PLT has ignored the ZLB by assuming that central bank is free to set negative nominal interest rates if required. Since there are good reasons for thinking that this assumption is in fact false, it is instructive to compare IT and PLT when the ZLB is taken into account.

In order to see the importance of the ZLB in the context of the IT-PLT comparison, consider the Euler equation for a nominal bond whose net return is denoted i_t :

$$(29) \quad U_{c,t} = \beta(1+i_t)E_t\left(\frac{U_{c,t+1}}{1+\pi_{t+1}}\right)$$

where $U_{c,t}$ is the marginal utility of consumption at time t , and π_{t+1} is the rate of inflation between period t and period $t+1$.

If we assume for simplicity that there is no government spending or investment, that the economy is closed, and that utility is of the constant relative risk aversion (CRRA) form with risk aversion coefficient $\delta \equiv 1/\sigma$, log-linearising Equation (29) gives an IS curve of the following form:

$$(30) \quad x_t = E_t x_{t+1} - \sigma(i_t - E_t \pi_{t+1}) + \sigma \times r_t^n$$

where $r_t^n \equiv \sigma^{-1} E_t (y_{t+1}^n - y_t^n) + r^n$ and $r^n \equiv -\log \beta$ is the long run natural rate of interest.

This equation can be solved forward for the output gap as follows:

$$(31) \quad x_t = -\sigma E_t \sum_{k=0}^{\infty} \{ (i_{t+k} - E_{t+k} \pi_{t+1+k}) - r_{t+k}^n \}$$

Equation (31) suggests that there are two routes by which monetary policy can influence current output: the current and expected future path of the nominal interest rate; and the current and future path of inflation expectations.²⁷ In the presence of the ZLB, however, the nominal interest rate will be constrained in a downward direction. As a result, the ‘inflation expectations channel’ becomes more important for policy outcomes. As explained above, this channel plays a crucial role under PLT but is absent under IT.

The likelihood of hitting the zero lower bound

An early paper investigating the potential implications of the ZLB for the IT-PLT comparison was Smets and Gaspar (2000). They investigate the likelihood of hitting the ZLB under IT and PLT using a simple model consisting of a hybrid New Keynesian Phillips curve and an IS curve with output gap persistence. The criterion they use to judge the probability of hitting the lower bound is nominal interest rate variability, the idea being that smaller deviations of the nominal rate should be associated with a lower probability of hitting the zero floor. The central bank in the model is assigned an IT loss function with an additional term in the squared deviation of the price-level from its target value. If the weight on this additional term is zero, the loss function corresponds to strict IT, while if the weight is positive the central bank engages in ‘hybrid targeting’ of inflation and the price level. Smets and Gaspar find that as the weight on the PLT objective is increased, nominal interest rate volatility initially falls, and remains below the level under IT unless the weight on price-level deviations is quite high. The reason is simply that smaller movements in the nominal rate are required to ensure stability with a price level objective, because the ‘inflation expectations channel’ automatically brings about stabilisation via the real rate of interest.

The robustness of these conclusions has been tested along a number of dimensions by other authors. Firstly, Amano and Ambler (2008) simulate a nonlinear version of the New Keynesian model and study the frequency with which nominal interest rates turn negative under IT and

²⁷ Economists generally take the view that monetary policy cannot influence the natural rate of interest.

PLT. In concordance with the results of Smets and Gaspar (2000), they find that negative nominal interest rates are required less often under PLT than IT. Secondly, Levine *et al.* (2008) compare discretionary IT and the optimal commitment policy using the Smets and Wouters (2003) model of the Euro Area. Levine *et al.* assume that the central bank must set a sufficiently high weight on interest rate volatility in their loss function to ensure that the probability of reaching the lower bound is close to zero. Under this modification, discretionary IT performs much worse relative to the optimal commitment policy, because a high relative weight on interest rate volatility is necessary to ensure that the interest rate does not reach zero, and this causes policy to deviate substantially from the unconstrained optimal. Intuitively, discretionary IT performs poorly because there is no stabilisation through expectations, in contrast to the optimal commitment policy which, like PLT, is characterised by ‘history dependence’.

An important caveat regarding the above studies is that they ignore, or side-step in some way, the existence of the lower bound – that is to say, the ZLB is not modelled explicitly as a (non-linear) constraint on the nominal interest rate. This approach could give misleading results because the expectations of economic agents will be influenced by the presence of the lower bound itself (Adam and Billi, 2006). In other words, economic agents will form their expectations with the knowledge that the central bank faces a constraint on how much it can cut rates in the future. Given that endogenous variables are typically influenced in important ways by future expectations, it is advisable to estimate the probability of hitting the ZLB using models in which the lower bound constraint is *occasionally binding*. Likewise, such models should also be advantageous from the point of view of evaluating social welfare.

The zero lower bound as an occasionally-binding constraint

More recent literature on the lower bound has drawn on advances in numerical simulation techniques to deal with its non-linear and asymmetric effects. Indeed, it should be emphasised that standard solutions techniques for DSGE models like log-linearisation and perturbation are unable to capture the impact of the ZLB (Ambler, 2009). Surprisingly, however, it is possible to solve for an analytical solution in a simple model, as is done in the seminal paper by Eggertsson and Woodford (2003). This section first discusses the results of Eggertsson and Woodford and then turns to the remainder of the literature that has employed numerical simulation techniques in more comprehensive models.

Eggertsson and Woodford make a number of important contributions. First and foremost, they derive the optimal commitment policy when the ZLB is an occasionally-binding constraint and show that it takes the form of a state-contingent PLT rule. Secondly, the performance of this optimal policy at the lower bound is compared to simple PLT and IT rules. Finally, a number of arguments are put forward in anticipation of criticisms that PLT would be ineffective or

infeasible in practice if the ZLB were reached. A discussion of this last point is postponed until Section 5, which discusses practical issues regarding PLT at the lower bound.

The model is deliberately simple, consisting of a forward-looking IS curve, the microfounded New Keynesian Phillips curve, and the ZLB constraint:

$$(32) \quad x_t = E_t x_{t+1} - \sigma(i_t - E_t \pi_{t+1} - r_t^n)$$

$$(33) \quad \pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t$$

$$(34) \quad i_t \geq 0$$

The central bank is assumed to minimise the microfounded loss function, Equation (17), which is repeated here for convenience:

$$(35) \quad L_t = E_t \sum_{i=0}^{\infty} \beta^i \{ \pi_{t+i}^2 + \lambda x_{t+i}^2 \}$$

Note that substituting the ZLB constraint into the IS curve yields the following inequality:

$$(36) \quad x_t \leq E_t x_{t+1} + \sigma(E_t \pi_{t+1} + r_t^n)$$

Using Equation (36), the optimal policy can be solved for by forming the following expected Lagrangian:

$$(37) \quad V_t = L_t + E_t \sum_{i=0}^{\infty} \beta^i \left\{ \varphi_{1,t+i} (x_{t+i} - x_{t+i+1} - \sigma \pi_{t+i+1} - \sigma r_{t+i}^n) + \varphi_{2,t+i} (\pi_{t+i} - \beta \pi_{t+i+1} - \kappa x_{t+i} - u_{t+i}) \right\}$$

The first-order conditions are given by

$$(38) \quad \pi_t + \varphi_{2t} - \varphi_{2,t-1} = \beta^{-1} \sigma \varphi_{1,t-1}$$

$$(39) \quad \lambda x_t + \varphi_{1t} - \beta^{-1} \varphi_{1,t-1} = \kappa \varphi_{2t}$$

$$(40) \quad \varphi_{1t} \geq 0, \quad i_t \geq 0, \quad \varphi_{1t} i_t = 0$$

where the inequalities in (40) are the Kuhn-Tucker conditions.

Note that since the Lagrange multiplier φ_{1t} is positive in some periods and zero in others, the nature of the optimal commitment rule differs in periods when the ZLB has been reached and in periods when it has not.

In fact, Eggertsson and Woodford show that the optimal commitment policy takes the form of a state-contingent PLT policy:

$$(41) \quad p_t + \frac{\lambda}{\kappa} x_t = p_t^*$$

where p_t^* is a price-level target that is updated using

$$(42) \quad p_{t+1}^* = p_t^* + \beta^{-1}(\delta_t - \delta_{t-1}) + \beta^{-1}\kappa\sigma\delta_t$$

and $\delta_t \equiv p_t^* - p_t + (\lambda/\kappa)x_t$ is the target shortfall in period t .

Three main points should be noted regarding this optimal rule. Firstly, when the ZLB has not been reached, the price-level target can always be met, since this is just the standard optimal commitment policy.²⁸ Second, when the ZLB is reached, the price level target becomes unattainable. For example, if the lower bound is reached in period T following a sharp fall in the natural rate, the target price level in period T will be given by Equation (42) with $\delta_T > 0$, because the central bank will be unable to cut rates to ensure that the price level does not fall below target. The optimal response to this target shortfall is to raise the *target price level* in the next period $T+1$. In the following period, $T+2$, the target price level will be raised even further, provided there is still a target shortfall.

This discussion brings us on to the third point: if the target shortfall grows (i.e. $\delta_{T+1} > \delta_T$), then the situation is worsening in the sense that the deviation from target is growing (say, in response to deflationary pressures). Intuitively, the optimal rule overcomes such pressures in exactly the way suggested by Krugman (1998) – by creating an expectation of future inflation through raising the target price level. This is the optimal policy because, with the nominal rate stuck at zero, the only way to achieve lower real interest rates is through stimulating inflation expectations by raising the target price level. It should be clear from this discussion that the state-contingent nature of the price-level target is crucial in achieving optimality. However, it is far from clear that such a rule would be feasible or credible in practice.

Having anticipated these concerns, Eggertsson and Woodford point out a much simpler PLT rule that is ‘near-optimal’:

$$(43) \quad p_t + \frac{\lambda}{\kappa} x_t = p^*$$

where p^* is a fixed price-level target.

²⁸ This can be seen by taking the first-difference of Equation (1.41) conditional on a target shortfall of zero.

The reason this rule performs well is that agents hold the belief that the future price level will be returned to the level defined by the constant price-level target. This belief creates an expectation of future inflation and reduces the real interest rate, increasing the current output gap and inflation – much like in the case of the optimal commitment policy. The key difference, however, is that the simple rule does not react to the *severity* of the situation by raising the target price level. It will therefore take longer for the economy to emerge from a ZLB episode.

Now consider the performance of an IT rule at the ZLB. Eggertsson and Woodford interpret such a policy as a commitment to adjust the nominal interest rate to ensure that inflation is equal to target, insofar as this is possible given the presence of the lower bound. The interest rate rule necessary to achieve this objective is given by

$$(44) \quad i_t = r_t^n + \pi^*$$

Note that the ZLB will prevent Equation (44) from holding if the natural rate of interest r^n is lower than $-\pi^*$; in this case, the central bank will set $i_t = 0$ and the real interest rate will be bounded by the negative of the inflation target. This constraint on real interest rates means that the IT rule performs substantially worse than the simple PLT rule or the optimal commitment policy at the ZLB (based on the social loss function). There are two major problems with IT.

First, if the inflation target is relatively low, the real interest rate will be only slightly negative at the ZLB and is therefore unlikely to provide the stimulus to inflation expectations that is necessary to end a lower bound episode. Second, there is no response of the real interest rate to the severity of a ZLB episode, because inflation expectations are fixed on the inflation target. By contrast, both the optimal commitment policy and the simple PLT rule produce a real interest rate response, because they are history dependent: future expectations of inflation are stimulated whenever the price-level target is undershot at the ZLB.²⁹

Although Eggertsson and Woodford (2003) make the major contribution of deriving the optimal commitment policy when the ZLB constrains policy, it should be noted that their numerical welfare analysis is only partial because it conditions on the occurrence of the lower bound by setting a large deterministic negative shock to the natural rate of interest in the initial simulation period. What is more interesting from the point of view of comparing IT and PLT, however, is performance in simulations in which the ZLB is free to bind or not as stochastic shocks dictate. Such simulations also permit the calculation of unconditional welfare, which gives an indication of the overall importance of the ZLB, and hence whether policies that perform well at the lower

²⁹ In concordance with Eggertsson and Woodford's welfare results, Wolman (2005) finds that PLT rules can improve performance at the ZLB relative to IT, though in his model prices are set in staggered fashion and fixed for constant duration à la Taylor (1980).

bound are likely to be worth pursuing in practice. The task of calculating unconditional welfare was undertaken by Adam and Billi (2006, 2007), and independently by Nakov (2008).

The main contribution of Adam and Billi (2006) was to calculate unconditional welfare under optimal commitment when the ZLB is an occasionally-binding constraint. The model follows Eggertsson and Woodford but is calibrated to US data, with shocks identified using US experience from the early 1980s to early 2000s. In order to calculate unconditional welfare, these shocks are then used to simulate the model, which is solved numerically using collocation methods. Intuitively, they find that the unconditional welfare implications of the ZLB are related to the frequency with which nominal rates reach zero under optimal commitment, which as noted takes the form of a state-contingent PLT policy. Since zero nominal interest rates occur rather infrequently – only about one quarter in every 17 years (or a probability of 1.5 per cent) – the additional unconditional welfare loss due to the ZLB is only one per cent of the welfare loss generated by sticky prices. This finding suggests that PLT will reach the ZLB rather infrequently and at relatively low cost when it does.

A direct comparison against IT is provided in a companion paper, Adam and Billi (2007), which calculates unconditional welfare losses in the discretionary case (i.e. IT). For ease of comparison, the discretionary results are compared directly with optimal commitment (i.e. state-contingent PLT), with losses expressed in terms of their welfare equivalent reduction in permanent consumption. The additional loss from discretionary policy relative to commitment increases by around two-thirds due to the presence of an occasionally-binding ZLB, suggesting that IT performs somewhat worse relative to PLT in unconditional terms even if the ZLB binds relatively infrequently.

The welfare analyses conducted by Adam and Billi (2006, 2007) are extended in a number of directions by Nakov (2008). His contribution is to compute unconditional welfare for a variety of simple *zero-truncated* Taylor-type interest rate rules – including IT and PLT rules – which he argues provide a more plausible representation of real-world monetary policy. Furthermore, the performance of these rules is compared against the optimal commitment policy (i.e. state-contingent PLT); the constant PLT rule of Eggertsson and Woodford (2003); and discretionary IT.

The IT rule allows for the possibility of ‘interest rate smoothing’ and is given by

$$(45) \quad i_t = \max \left\{ 0, \rho_i i_{t-1} + (1 - \rho_i) [r^* + \pi^* + \theta_\pi (\pi_t - \pi^*) + \theta_x x_t] \right\}$$

where r^* is the equilibrium real interest rate and $0 < \rho_i < 1$ indicates the extent of interest rate smoothing.

On the hand, the PLT rule is given by

$$(46) \quad i_t = \max \{0, r^* + \theta_p (p_t - p^*) + \theta_x x_t\}$$

where p is the log price level and p^* is a constant price level target.

With the exception of the constant price-level target policy suggested by Eggertsson and Woodford (2003), all the policies perform poorly relative to optimal commitment. On some level this finding is not surprising: simple interest rules rarely perform well in individual models of the economy, but have the advantage of robustness across models (Taylor, 1999). This point is clearly demonstrated by the substantial difference between the performance of the constant price-level target policy and the PLT Taylor rule. The constant price-level target delivers a loss in social welfare relative to commitment of only 56 per cent, whilst the corresponding loss for the PLT interest rate rule is 800 per cent. Even so, the PLT interest rate rule outperforms the IT one in terms of welfare loss, with lower inflation and output gap volatility regardless of whether or not interest rate smoothing is permitted. To summarise, Nakov's results suggest that constraining the IT-PLT comparison to simple Taylor-type rules reduces but leaves intact the potential welfare benefits of PLT.

The zero lower bound in medium and large-scale models

There is one other important strand of literature that has compared the performance of IT and PLT at the ZLB. These papers use more comprehensive models of the economy of the kind used by central banks for quantitative policy analyses. Such models have two potentially important advantages over those based on microfoundations: first, a wide array of economic mechanisms are at work, and these may help identify benefits and costs of certain monetary policies; and, second, since such models provide better 'fit' to data, they may provide a better basis for policy evaluation. However, this extra rigour comes at an additional cost in the context of the ZLB, since it is only computationally feasible for policy outcomes to be examined once the model has been 'deterministically guided' to the ZLB. In other words, a deterministic shock to the economy is chosen so that the nominal interest rate is pinned at zero temporarily, during which time the performance of alternative policies is evaluated.³⁰

The main papers in this literature result from a joint research project between researchers at the Bank of Japan (BoJ), the European Central Bank (ECB) and the Federal Reserve, whose results

³⁰ That is, policies are only evaluated conditional on the ZLB being reached.

are summarised in Fujiwara *et al.* (2006a). This research project focuses on three different central bank models: the FRB/US model, the BoJ JEM model, and the ECB Area-Wide model. *Inter alia*, these papers consider zero-truncated IT and PLT Taylor-type rules. The ZLB is modelled in the same way in all three papers: the economy is hit with a set of demand shocks that are *known by all agents* and which ensure that the short-term nominal interest rate is pinned at zero for four or five consecutive years. Policies are then evaluated based on an intertemporal loss function in inflation and output gap deviations whose horizon depends on the length of the ZLB episode. A robust conclusion that arises from these analyses is that PLT outperforms IT, though the relative benefits of PLT vary somewhat depending on the model under consideration, and, intuitively, are larger in the models in which forward-looking expectations play a more important role.

In terms of future research, there is a clear gap in this literature in the sense that IT and PLT have not yet been compared in medium or large-scale models in which the ZLB is modelled as an occasionally-binding constraint. Such a comparison would be of particular value in models with strong theoretical foundations like those due to Smets and Wouters (2003, 2007), because such models provide a model-consistent criterion by which to evaluate social welfare. In current work-in-progress the author is conducting a comparison of this kind using the Smets-Wouters model of the US economy (see Smets and Wouters, 2007).

4 Potential costs of price-level targeting

A number of potential costs of PLT have been identified in the literature. These costs include the following: increased short-term volatility in inflation and output when agents do not have rational expectations; a costly transition from IT to PLT; and potential time-inconsistency problems. This section, which draws heavily on the survey by Ambler (2009), discusses each of these topics in turn.

4.1 Inflation and output gap volatility

The traditional argument made against PLT was that it would increase short-term volatility in both inflation and the output gap (e.g. Fischer, 1996). The logic of this argument is sketched out clearly by Svensson (1999, p. 278):

In order to stabilize the price level under PLT, higher-than-average inflation must be succeeded by lower-than-average inflation. This should result in higher inflation variability than IT, since in the latter case, base level drift is accepted and higher-than-average inflation need only be succeeded by average inflation. Via nominal rigidities, the higher inflation variability should then result in higher output variability.

Early literature that investigated the performance of IT and PLT in simulated models of the economy tended to confirm this view (e.g. Lebow *et al.*, 1992; Haldane and Salmon, 1995). The conclusions of these studies differ from those reached by Svensson (1999) and later authors due to the assumption that agents have adaptive expectations. Adaptive expectations are purely backward-looking, with the result that the expectations channel by which PLT can stabilise inflation and the output gap is entirely eliminated. As a result, both inflation and output gap volatility increase via the channel described by Svensson.

As noted in Section 3.1, the short-term volatility benefits from PLT also arise under the assumption that the central bank operates in discretionary manner and cannot commit – a distinction which is completely irrelevant in purely backward-looking models with adaptive expectations. Moreover, as already noted, increased volatility is not limited to models where all agents are backward-looking: Steinsson (2003) shows that PLT is no longer optimal if a non-trivial fraction of firms are rule-of-thumb price-setters, with its performance vis-à-vis IT deteriorating as the fraction of rule-of-thumb price-setters is increased. An important situation where adaptive or backward-looking expectations may be highly relevant is the transition from IT to PLT, since economic agents are likely to ‘learn’ about the new monetary policy regime in place.

4.2 The transition from inflation to price-level targeting

The studies discussed thus far all assume that the economy has settled in a long run PLT regime in which individuals understand perfectly the workings of policy and have rational expectations. However, since PLT has been implemented only once in history whilst IT is widespread, it seems reasonable to suppose that there would be a transitional period of adjustment during which time agents would learn about the new PLT regime and gradually give it credibility (assuming, that is, that PLT is implemented as promised – insofar as this is possible given economic shocks). A number of papers have therefore investigated the IT-to-PLT transition, with a focus on whether the long run benefits from moving to PLT outweigh the short run transitional costs.

For instance, Gaspar *et al.* (2007) assume that the expectations of economic agents in the transition period are determined by recursive least squares learning (RLS). Under this assumption, the lagged data produced by the model are used to form forecasts of endogenous variables using least squares projection, with forecasts updated as new data becomes available. Notably, the Phillips curve in the model is the hybrid New Keynesian one that results from partial indexation to past inflation (see Section 3.1), enabling an investigation of the importance of the extent of indexation for the transition to PLT. Although Gaspar *et al.* find that the transition to PLT can be costly, the net gains from PLT remain positive unless learning is rather

slow. With their benchmark calibration, for instance, it takes seven years until the social loss under PLT is reduced to the level that prevails in the long run under IT, after which point the social loss is lower under PLT and converges on the optimal commitment policy.³¹ Moreover, these results are surprisingly robust to the weight on past inflation in the Phillips curve, suggesting that the transition to PLT will not be too costly in economies where both forward- and backward-looking expectations play non-trivial role in price-setting.

However, Kryvtsov and co-authors at the Bank of Canada (2008) reach a different result when imperfect credibility is modelled as an exogenous process that converges steadily towards perfect credibility over time. Indeed, an interesting insight from their model is that the expectations channel under PLT remains weak if imperfect credibility is highly persistent. In their model, it takes two-and-a-half years for the PLT central bank to earn enough credibility to outperform IT, but even this relatively short transitional period is enough to ensure that IT dominates PLT in net welfare terms. That is to say, the short run transition costs from PLT outweigh its long run welfare benefits.

Cateau *et al.* (2009) extend the analysis of the transition from IT to PLT using ToTEM, the Bank of Canada's main policy analysis model. This model is a medium-scale open-economy DSGE model built around optimising behaviour by firms and households. The goal of the paper is to test whether the conclusions reached by Kryvtsov *et al.* (2008) are robust in a more comprehensive economic model that retains forward-looking behaviour. Cateau *et al.* find results that are more favourable to PLT: the long run welfare gains dominate the short run transition costs, provided that the initial spell of imperfect credibility under PLT lasts less than 13 years. It is worth noting in this regard that the results of Carroll (2003) and Mankiw *et al.* (2003) suggest that US households incorporate new macroeconomic information into their expectations in around one year.

4.3 Time inconsistency

Kydland and Prescott (1977) were the first to point out that monetary policy faces a time-inconsistency problem if agents have rational expectations. That is to say, a policy which is *ex ante* optimal can be suboptimal *ex post*, giving policymakers an incentive to deviate from socially-optimal policies to which they are not committed by some form of 'commitment technology'. This is potentially problematic for PLT, because, as discussed in Section 3.1, it will only tend to reduce short-term volatility relative to IT if agents have rational expectations. The reasoning for this result is simply that PLT provides additional macroeconomic stabilisation through an 'expectations channel': firms move their prices less in response to shocks under PLT, because they expect shocks to be undone in future periods in order to return the price level to

³¹ As discussed in Section 3.1, it is optimal to offset shocks to the price level in this model unless there is full indexation to past inflation (i.e. $\gamma = 1$). In their benchmark case, Gaspar *et al.* assume that $\gamma = \frac{1}{2}$.

target. With prices less responsive to economic shocks, output gap variations are also lessened *ceteris paribus*.

However, if firms do hold such expectations and set prices accordingly, the central bank will then be faced with the temptation to deviate from the announced PLT policy *ex post* (Minford and Peel, 2003; Ambler, 2009). Intuitively, the central bank could ‘have its cake and eat it’ by benefiting from stabilised inflation by announcing a credible PLT policy, only to renege on the announcement to avoid the cost of (say) reducing inflation below trend in the following period. The central bank would be faced with this temptation in every period under a PLT regime, because reducing inflation below trend increases price dispersion across firms, causing aggregate output to deviate from its efficient level and imposing social welfare losses.

The reason that current models are unable to capture this temptation – even in the discretionary case – is that the central bank loss function depends on current and future price level deviations. That is to say, the central bank would thus harm its own welfare if deviated from the announced policy in the current period, because it would then wish to undo the price deviation in the next period in order to return the price level to target. In this sense, PLT rules out useless discretionary behaviour that is present under IT (Minford and Peel, 2003). However, what has been argued above is that the central bank may be prepared to deviate from its *loss function*. There is an inconsistency in the current literature in the sense that the central bank is assumed to be unable to commit to rules-based behaviour, yet able to commit to a particular loss function indefinitely – regardless of whether the loss function itself is a significant source of welfare losses.

5 Practical considerations

A number of practical and implementation issues regarding PLT are discussed in this section, including: credibility at the zero lower bound; the time horizon over which the price level should be returned to target; the idea of ‘hybrid targeting’ of inflation and the price level as a superior alternative to strict IT or strict PLT; open economy and financial market considerations; communication and credibility; and lack of practical experience.

5.1 Price-level targeting at the zero lower bound: credibility issues

One major issue regarding PLT at the lower bound is credibility of the target price path. The credibility assumption is crucial since, as we have seen, the benefits of targeting the price level at the ZLB result from the automatic stabilisation implied by the link between inflation expectations and the real rate of interest. To be more precise, PLT creates an expectation of future inflation, because a central bank that targets the price level promises to return the price

level to its target path as soon as this is feasible. This then lowers the real rate of interest and boosts current output and inflation, potentially providing an effective escape route from a ZLB episode. In short, for PLT to be beneficial at the lower bound, a high degree of credibility is a prerequisite.

It is worthwhile, then, to consider whether central banks would in practice be able to commit to PLT rules and to establish a reputation for following such rules. Eggertsson and Woodford (2003) forcefully argue that there is little reason for concerns about the credibility of PLT at ZLB.³² They put forward two reasons in support of this argument. First, the constant PLT rule they discuss is near-optimal and could be easily communicated to public, making it easy for the public to detect deviations from the announced rule. Second, they argue that the incentive to change policy at the ZLB and act in a time-inconsistent fashion is actually stronger under IT than PLT, because social welfare is lower under the former.

On the first point, it is notable that Nakov (2008) argues that it may be difficult to communicate and implement even the ‘simple’ PLT rule analysed by Eggertsson and Woodford. He argues that simple *interest rate rules* are superior in this regard. Furthermore, monetary policies that are optimal or near-optimal in a specific model are usually not robust in terms of performance across models (Taylor, 1999). Regarding the second point, Eggertsson and Woodford are essentially arguing that PLT is well-suited to the demonstration of commitment because it is equally optimal in both ordinary and extraordinary circumstances. In other words, by sticking to PLT in the past – prior to the occurrence of a ZLB episode – central banks could build-up a reputation for following through on promises and assuage any doubts agents may have about their commitment if the lower bound were reached.

One obvious objection to this argument is that central banks faced with the choice of adopting PLT in practice do not have the luxury of past experience as proof of their commitment. A second, more subtle, objection is that it may be difficult for economic agents to verify that PLT is being followed at the ZLB due to the possibility of *observational equivalence*. For instance, returning the price level to its target path would likely require a zero nominal interest rate for a prolonged period of time, but so would any other reasonable monetary policy! In summary, the potential for credibility problems is likely to be intensified at the ZLB. Rational economic agents will understand these trade-offs, and this could make it hard for PLT central banks to acquire and retain credibility if faced with difficult economic circumstances.

From the perspective of future research, it is notable that some progress has recently been made in terms of formally modelling credibility at the ZLB. Indeed, Bodenstein *et al.* (2010) numerically simulate optimal policy in the New Keynesian model when credibility is imperfect

³² See Section 3.3 for a detailed discussion of Eggertsson and Woodford’s results.

and the ZLB is an occasionally-binding constraint. They find that the optimal policy is qualitatively similar to the optimal commitment policy with perfect credibility, but an important difference is that policy must make more extreme promises for the nominal rate (and hence inflation and the output gap) in order influence expectations (see also Walsh (2010) on this point). This result suggests that imperfect credibility considerations might be enough to eliminate the stabilisation benefits of PLT at the ZLB, but a formal analysis of this kind has yet to be carried out.

5.2 The optimal horizon for returning the price level to target

In practice, IT central banks do not aim to instantly return inflation to target following a deviation. Instead, they aim to do so over the medium-term, which in this context means a period of 1 to 3 years. There are two reasons for this. First, changes in monetary policy affect inflation and output with a lag of 1-3 years (Christiano *et al.*, 2005; ECB, 2010). Secondly, responding with gradual changes in interest rates may prevent excessive volatility, as argued by Sack (2000). The optimal horizon for offsetting target deviations can be interpreted in terms of the relative weight on output gap stabilisation in the central bank loss function, with a higher weight implying a longer optimal targeting horizon.

With regards to PLT, the question arises as to whether the optimal horizon for offsetting deviations would change. This question has been investigated formally in a couple of papers. Smets (2003) investigates this issue in a New Keynesian model that is estimated on the Euro Area economy. The model consists of a hybrid New Keynesian Phillips curve and an IS curve with output gap persistence, as in Smets and Gaspar (2000). He finds that the optimal horizon for returning the price level to the target path is twice as long as the optimal horizon for returning inflation to target. This result arises because the expectations channel under PLT is relatively weak compared to the purely forward-looking case, as the model is partly backward-looking.

Hence whilst PLT can reduce inflation volatility relative to the IT case, the reduction is not that strong. As a result, both nominal interest rate volatility and output gap volatility rise for a given targeting horizon – such that, in order to bring down interest rate and output volatility to acceptable levels as under IT, a longer targeting horizon is necessary. Similarly, Coletti *et al.* (2008) compare IT and PLT in an open economy DSGE model and find that the optimal targeting horizon is higher under PLT, though in their model both horizons are short at less than one year. As noted by Cournède and Moccero (2009), an issue related to the target horizon that has not yet been addressed in the literature is the width of the optimal band around the target price path.

5.3 Hybrid targeting of inflation and the price level

Some papers have investigated the performance of PLT by focusing on hybrid targeting regimes in which the central bank places some weight on both inflation and price level deviations from target (Gaspar and Smets, 2000; Batini and Yates, 2003; Cecchetti and Kim, 2005). Notably, a positive weight on price level deviations precludes base-level drift in the long run, and variations in the target weights change the horizon over which the price level is returned to its target path.

Batini and Yates (2003) is a representative example from this literature. They use an open economy model in which the exchange rate enters the Phillips curve. An interesting conclusion from their analysis is that pure PLT increases inflation volatility compared to pure IT. The reason for this result is that exchange rate volatility is raised via the uncovered interest parity condition (since the Phillips curve in the model has a strong backward-looking component), so that substantial real interest rate volatility is required in order to return the price level to the target path. The optimal weight on the price-level objective is thus low but positive in this case. A general conclusion from studies of hybrid targeting is that an intermediate regime can be found that dominates strict IT or strict PLT if there are both forward and backward-looking inflation terms in the Phillips curve (Ambler, 2009).

Nessén and Vestin (2005) take a similar approach to these studies but investigate ‘average inflation targeting’. Under this policy, the central bank targets a moving average of current and past inflation rates. As the horizon of the moving average is extended, the amount of price-level drift is reduced, converging to PLT in the limit. Hence the length of the moving average window defines a spectrum with IT at one end and PLT at the other. The question Nessén and Vestin set out to answer in their paper is whether an intermediate point on the spectrum would outperform pure IT or pure PLT, for the case where the central bank operates under pure discretion.

The model is New Keynesian, with a moderate fraction of firms following backward-looking rule-of-thumb price-setting, and the remainder setting prices subject to nominal stickiness à la Calvo (1983). The supply side of the economy is thus described by the hybrid New Keynesian Phillips curve in Steinsson (2003). Nessén and Vestin find that if the size of the moving average window is chosen optimally, average IT performs better than either strict IT or PLT and provides a good approximation to the optimal commitment policy. Intuitively, Vestin (2006) shows that PLT is optimal if the New Keynesian Phillips curve is purely forward-looking, whilst Steinsson (2003) notes that IT outperforms PLT if the fraction of rule-of-thumb price-setters is high. It is therefore not surprising that a hybrid policy performs well if a moderate fraction of firms follow rule-of-thumb price-setting.

5.4 Open economy and financial market considerations

There has been a fair amount of work on the performance of PLT in an open economy, much of which has been carried out by, or in conjunction with, the Bank of Canada. For example, Coletti *et al.* (2008) compare IT and PLT in the two-country IMF Global Economy Model (GEM), a medium-scale DSGE model designed to enable open-economy issues to be investigated within a rigorous representative-agent framework (see Laxton, 2008). The model is calibrated for Canada using the Bank of Canada's ToTEM model, with the US as the second country in the model. The results focus on the implications of IT and PLT for macroeconomic stability in Canada. Coletti *et al.* find that a PLT Taylor-type rule slightly outperforms an IT one in terms of inflation and output gap volatility, primarily because shocks to the terms of trade strengthen the case for PLT due to its role as a nominal anchor through the expectations channel.

Dib *et al.* (2008) investigate the impact of PLT within a medium-scale open economy model whose parameters are estimated using Canadian data. The model is New Keynesian but is augmented with credit frictions as in Bernanke *et al.* (1999), plus one-period nominal debt contracts which entrepreneurs enter into in order to finance investment. They find that PLT is better than IT at minimising the distortion in the economy due to nominal debt contracts, because the former leads to less revaluation of nominal contracts given that inflation expectations are stabilised. Real risk faced by entrepreneurs is therefore reduced, with the result that resources are allocated more efficiently than under IT. Moreover, this increase in efficiency means that nominal interest rates do not need to vary as much in order to minimise the distortion associated with nominal price stickiness, such that real interest rate volatility is reduced, and the distortion from nominal debt is lessened.

In practical terms, this result suggests that PLT's role as a nominal anchor may enable policymakers to better deal with financial market distortions than under IT – a result also echoed by Covas and Zhang (2010). However, these findings should be taken with caution, as much of the extra volatility under IT is eliminated if the policymaker follows a Taylor rule with 'interest rate smoothing'. The reasoning is that this simple change in policy – albeit an artificial one – makes IT history-dependent, providing it with some of anchoring benefits of PLT at no additional stabilisation cost.

Covas and Zhang (2010) focus solely on financial market imperfections. They compare IT and PLT in a closed-economy New Keynesian model that includes financial market imperfections in both debt and equity markets, and whose structural parameters are estimated for the Canadian economy. They find that PLT outperforms IT because the expectations channel means that inflation is better anchored under PLT than IT, which in turn enables a PLT central bank to deal with financial market distortions whilst ensuring that inflation remains firmly anchored. It should be noted, however, that the benefits of PLT are smaller than in absence of financial

market imperfections, and decrease as financial market frictions are strengthened. Thus, whilst research so far suggests that the stabilisation benefits of PLT are robust in forward-looking models with simple financial frictions, allowing fully for financial market imperfections could substantially reduce, or even eliminate, the benefits to be had from targeting the price level.

5.5 Communication and credibility of price-level targeting

Central banks that follow IT typically produce their own forecasts for inflation. Such forecasts have obvious importance for policy, but they are also used as a basis for transparently communicating policy decisions to the public. This is usually done via central bank ‘inflation reports’. This strategy seems to have been effective thus far in the sense that inflation expectations, as measured by survey-based and market-derived measures, appear to have been well anchored around the target rate of inflation (Gürkaynak *et al.*, 2007; Demertzis and van der Crujisen, 2007). In other words, it seems that IT central banks have been perceived as credible.

A key issue that has remained unresolved is the way in which PLT would be communicated to the general public. For instance, one option would be to continue to publish inflation forecasts. However, as the short-term inflation target is time-varying under PLT, inflation forecasts could be a source of confusion, particularly in countries in which IT has been in place for a substantial period of time. A second option would be to publish price level forecasts instead, and perhaps ‘price level reports’ to go along with these forecasts. This approach would have the advantage that the forecasts could be directly compared to the predetermined target price path, which could of course be published well in advance. Indeed, if PLT could successfully stabilise prices around an established target price path, it could potentially attain credibility quite quickly.

On the other hand, there is considerable risk involved with this approach, because policymakers may find it more difficult to hit a price level target than an inflation target. Furthermore, as noted by Ambler (2009), the public has been conditioned by IT to think in terms of inflation and not the general price level. In this respect, the hybrid targeting results discussed above have practical importance because it would likely be easier to communicate a policy of ‘average IT’ or ‘medium-term IT’ given that the horizon of the inflation target and inflation forecasts could simply be altered (Ambler, *op. cit.*).

A second key issue is how quickly PLT would be able to attain credibility. As discussed above, credibility is likely to be a key factor in determining the transitional costs of switching from IT to PLT. If credibility is established quickly, the transition costs are likely to be low because agents’ expectations will shift more swiftly from backward-looking learning mechanisms to (forward-looking) rational expectations. In particular, PLT is more likely to gain credibility quickly if central banks behave in a transparent manner, since this would enable economic agents to more easily assess whether the stated objectives of PLT are (i) achievable, and (ii)

being pursued seriously by policymakers. In the long run it seems unlikely that credibility would be an issue, since central banks would have sufficient time to demonstrate their commitment to PLT through their policy actions.

5.6 The Swedish experiment 1931-37

An explicit PLT regime has been adopted only once in history, namely, in Sweden after it left the Gold Standard. A detailed account of the Swedish experience with PLT is given by Berg and Jonung (1999) and Straumann and Woitek (2009). The PLT regime was intended to stabilise prices against the backdrop of deflation that was widespread during the Great Depression. In particular, the price-level target related to the Consumer Price Index (CPI) – the average level of consumer goods prices – and was a constant target set at the September 1931 value, which was normalised to 100 for simplicity. A floating exchange rate was initially adopted as part of the PLT regime, but in July 1933 the Riksbank decided to peg the krona to the British pound. The Swedish experiment with PLT ended officially in April 1937 when the Riksbank chose to maintain the peg against the Pound – a strategy that was seen as inconsistent with the price-level target given that the CPI was consistently above target in the early part of 1937. The main features of the Swedish PLT regime are summarised in Table 2, and for reference the evolution of the CPI from 1928 to 1940 is shown in Figure 5.

The CPI does seem to have stabilised during the PLT period, and it is notable that the deviation of the CPI from target was never greater than 3.8 per cent. Furthermore, the price level was successfully returned to target after falling more than 3 per cent in 1932 and 1933. Given the difficult economic backdrop, the performance of PLT in Sweden seems fairly good. For instance, the US experienced almost 10 per cent deflation between September 1931 and April 1933 alone (Dittmar *et al.* 1999), and real indicators like industrial production and real income also fared well compared with most other countries (Berg and Jonung, 1999).

Table 2 – The Swedish price-level targeting regime

Feature	Description
Introduction	As soon as the Gold Standard was suspended (September 27, 1931)
Operational target	CPI at the date of introduction (normalised to 100), but other price indices were also monitored
Instrument	Discount rate
Role of the exchange rate	The krona was pegged to the Pound from July 1933 to the beginning of WWII
Role of money aggregates	No role mentioned in the Monetary Programme
Goal independence	No – policy goals were set by the Riksdag
Instrument independence	Yes
End date	April 1937

Source: Adapted from Guender and Oh (2006)

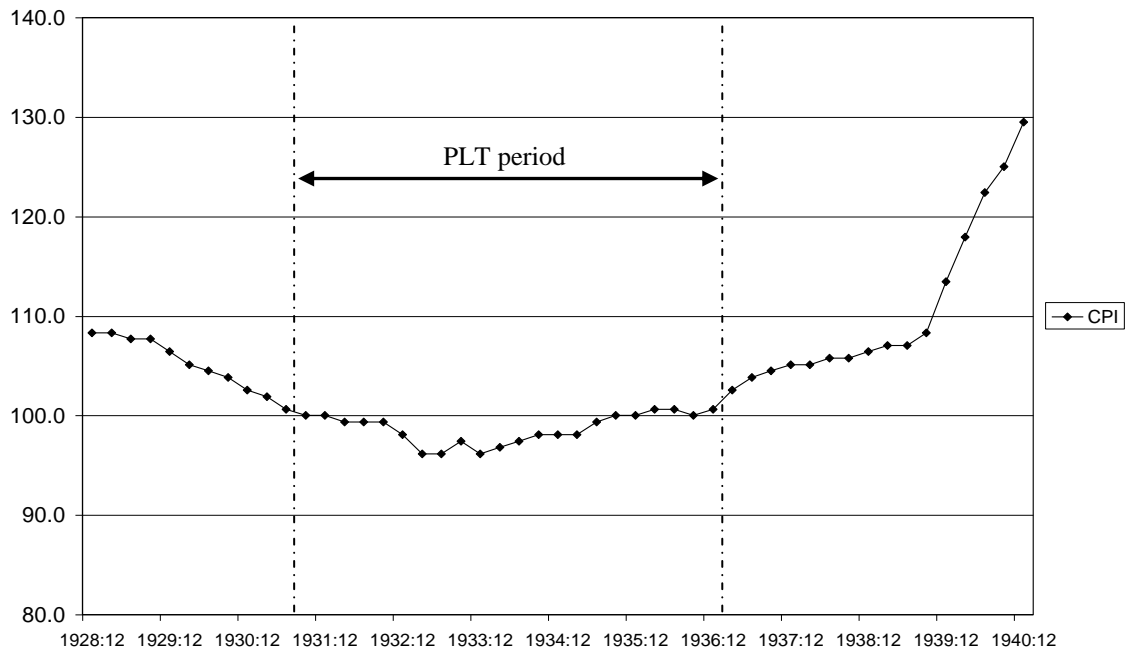


Figure 5 – The Swedish experience with price-level targeting³³

Although PLT appears to have performed well, there are a number of reasons to be sceptical about whether PLT was responsible for the relatively strong performance of the Swedish economy. Firstly, countries that left the Gold Standard at an early point tended to perform better during the Great Depression and in its aftermath (Bernanke, 1995). Hence it could be that the decision to leave the Gold Standard was mainly responsible for Sweden’s good performance and not PLT. Secondly, since the krona was pegged to the Pound from July 1933, it is far from clear that PLT was in fact being pursued during this time. Indeed, as Figure 5 makes clear, the deviations of the CPI from target were highest when the exchange rate was floating. Therefore, if only the September 1931 to July 1933 period was truly a PLT regime, the performance of PLT appears less favourable.

Straumann and Woitek (2009) go even further and argue that, after leaving the Gold Standard, the Riksbank was targeting the exchange rate with the Pound rather than the price level. They argue (p. 252) that “although being a major innovation in the history of Swedish economic thought, price-level targeting had no practical importance for the Riksbank in the 1930s.” Their argument rests on both archival and econometric evidence. First, in terms of archival evidence, they present a series of statements by the Riksbank governor at the time, Ivar Rooth, which suggest that in practice the policy implemented was not the PLT one that was announced publicly. They also show that some support for these statements can be found in private correspondence between the Riksbank and the Bank of England.

³³ Source: Statistics Sweden website.

Second, Straumann and Woitek run a time-varying Bayesian VAR covering the period 1920-1939. The resulting impulse responses cast doubt on whether the price level was the target of policy, because the discount rate (the Riksbank's instrument at the time) barely responds to a price shock – a result which is robust at different lag lengths and to various choices of the price index. Moreover, the impulse responses also suggest that there was no regime change after the 1930s. These results provide further evidence against the hypothesis that PLT was adopted since, if the price level and not the exchange rate was the target of policy from September 1931, we would expect to see a structural break around July 1933 when it was officially announced that the krona would be pegged to the Pound.

Whilst neither the econometric or archival evidence that Straumann and Woitek present are entirely convincing, there is enough to cast doubt on whether the Riksbank really did adopt PLT. Furthermore, even if the Riksbank did target the price level, it must be remembered that this would provide only a single example in history during an extraordinary period. Consequently, the question of whether Sweden did or not adopt PLT has little relevance for the current debate on IT versus PLT. In fact, the most important contribution of this episode may have been to highlight at an early stage the role that management of expectations can play in effective monetary policymaking.

6 Conclusion

This survey has provided an exhaustive review of the literature on price-level targeting (PLT), focusing on its costs and benefits compared to inflation targeting (IT), and building upon past surveys. The three main contributions of the survey are as follows. First, rather than concentrating on one or two key issues, the survey provides a balanced discussion of all key areas from the literature. Secondly, the survey discusses recent literature not covered in other surveys, including 'new results' in several important areas – *viz.* the zero lower bound on nominal interest rates; the long-term impact of PLT; and robustness to financial market considerations. Lastly, the review is written in such a way that it should be accessible to economists with little or no prior knowledge of PLT and the related academic literature. In order to do so, the survey began with a simple analytical comparison of IT and PLT before delving into the technical academic literature. The main findings of the survey are as follows.

In terms of theoretical literature, the impact of PLT on short-term macroeconomic volatility has now been investigated in a wide range of models. As emphasised by Ambler (2009), the key finding from this literature is that PLT will tend to outperform IT in models in which agents are strongly forward-looking, because PLT reduces inflation volatility through the 'inflation expectations channel'. More recent literature has shown that this result is robust to the

introduction of simple financial frictions, though the potential gains from PLT are lower than with complete financial markets – hence highlighting the need for further research in this area.

The theoretical literature has also reached the conclusion that PLT will outperform IT when the zero lower bound on nominal interest rates is a binding constraint on monetary policy. However, more research is needed to address robustness to imperfect credibility considerations and to compare IT and PLT in medium- and large-scale models in which the lower bound is treated as an *occasionally-binding constraint*. As discussed above, further research is forthcoming in both these areas. Finally, one important area in which there is a relative lack of literature is the impact of PLT on the welfare of economic agents with long-term nominal contracts. However, as discussed above, there have been several recent contributions in this area which provide a solid foundation for future research efforts.

From a practical perspective, there are a number of areas in which further research on PLT is advisable. The key ones are as follows: the macroeconomic impact of PLT immediately following its adoption when credibility would likely be imperfect; the importance of time-inconsistency problems under PLT (including at the zero lower bound on interest rates); and communication and implementation of PLT in practice. Encouragingly, central banks themselves will be in a strong position to address many of these practical issues; in fact, the Bank of Canada is already carrying out work in this direction as part of its review of PLT.

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