RESERVE BANK
OF NEW ZEALAND
TE PŪTEA MATUA

DP2016/07

New Zealand's Experience with Changing its Inflation Target and the Impact on Inflation Expectations

Michelle Lewis and C. John McDermott

May 2016

JEL classification: E17, E31, E52, E58

www.rbnz.govt.nz

Discussion Paper Series

ISSN 1177-7567

DP2016/07

New Zealand's Experience with Changing its Inflation Target and the Impact on Inflation Expectations*

Michelle Lewis and C. John McDermott†

Abstract

We document the experience of the Reserve Bank of New Zealand in changing its inflation target, particularly the effects on inflation expectations. Firstly, the Reserve Bank of New Zealand's DSGE model is used to highlight expectation-formation in the transmission following a change in the inflation target. Secondly, a Nelson-Siegel model is used to combine a number of inflation expectation surveys into a continuous curve where expectations can be plotted as a function of the forecast horizon. Using estimates of long-run inflation expectations derived from the Nelson-Siegel model, we find that numerical changes in the inflation target result in an immediate change in inflation expectations.

* The Reserve Bank of New Zealand's discussion paper series is externally refereed. The views expressed in this paper are those of the author(s) and do not necessarily reflect the views of the Reserve Bank of New Zealand. We are grateful to Punnoose Jacob, Gunes Kamber, Leo Krippner, Nick Sander and Jed Armstrong for assistance with this project. We are also grateful to our colleagues at the Reserve Bank for their helpful comments and the two anonymous referees for their helpful comments.

† Michelle Lewis: Economics Department, Reserve Bank of New Zealand, 2 The Terrace, PO Box 2498, Wellington, New Zealand. *email address:* michelle.lewis@rbnz.govt.nz. John McDermott: Economics Department, Reserve Bank of New Zealand, 2 The Terrace, PO Box 2498, Wellington, New Zealand. *email address:* John.McDermott@rbnz.govt.nz

Non-technical Summary

We study the macroeconomic consequences of a change in the inflation target by the central bank. New Zealand's experience with changing the inflation target makes it a natural laboratory to pursue our objective. We document the various changes that have been made to the Policy Targets Agreement since it was first introduced in 1990 until the most recent change in 2012. Using the Reserve Bank of New Zealand's macroeconomic model, NZSIM, we provide an illustration of how the macroeconomy responds to changes in the inflation target. A distinctive feature of NZSIM is that it allows for different expectations formation, and hence we are able to trace out the transmission channel from changing the inflation target under different assumptions for how inflation expectations are formed. Any change in target results in a corresponding change to inflation and inflation expectations in the long run. There are no long run changes to any real variable, such as output, but there may be changes in the short run depending how expectations are formed.

We test how inflation expectations, across an array horizons, changed following changes to the Policy Targets Agreement. Using term structure modelling techniques, we estimate inflation expectation curves based on survey measures of inflation expectations that have horizons from 1 to 10 years ahead. We find evidence of expectation rigidities, where inflation expectations adjust adaptively to past inflation. However, inflation expectations adjusted immediately to the 2002 change in the Policy Targets Agreement. Following the 50 basis point increase in the mid-point of the inflation target range in 2002, inflation expectations increased significantly at all horizons, with long-run inflation expectations immediately increasing 19 basis points.

1 Introduction

The essential characteristic of an inflation targeting regime is an explicit and publicly announced inflation target. The target needs to specify the index used to measure inflation, the target level, the tolerance interval, the time frame over which the inflation target is to be met, and possible circumstances when temporary deviations from the target are warranted.

Recently, there has developed a debate about the benefits and risks of changing an inflation target. One strand of the debate emphasises the risk of unanchoring inflation expectations, while another strand focuses on the likelihood of the central bank hitting the Zero Lower Bound (ZLB). We contribute to this debate by quantifying the effects of changing the inflation target, in the context of New Zealand. Having changed its inflation target a number of times since 1990, New Zealand provides a natural laboratory to understand the macroeconomic consequences of changing an inflation target.

As a first step, we use the official DSGE model (NZSIM) of the Reserve Bank of New Zealand to highlight the effects of changing the inflation target on key macroeconomic variables. Subsequently, we determine the likelihood of hitting the ZLB within the model environment. We highlight the pivotal role played by inflation expectations in determining the economy's response to any change in the inflation target. In the empirical analysis that follows, we apply the Nelson-Siegel model on inflation expectations data in New Zealand to generate expectations curves fitted over various time-horizons. Examining such curves enables us to understand how expectations have shifted in response to changes in the inflation target.

The simulation results from NZSIM show that when inflation expectations adjust slowly to changes in the inflation target, there are short-run effects on real variables. In contrast, when inflation expectations adjust rationally to changes in the inflation target, there are no short-run effects on real variables. In addition, for any given level of the inflation target, the probability of hitting the ZLB is higher when inflation expectations are formed adaptively relative to when they are formed rationally.

The results from the Nelson-Siegel model suggest that changes to the inflation target change inflation expectations significantly. In particular, long-run inflation expectations change in response to numerical changes to the inflation target.

As noted earlier, we focus on quantifying the effects of changing an inflation target. We do not examine the desirability of changing the inflation target, which has been the focus of a recent literature. Orphanides and Williams (2005) show that uncertainty about an inflation target worsens macroeconomic performance. Recently, Blanchard, Dell'Ariccia, and Mauro (2010), controversially, suggested that to reduce the risk of deflation, developed countries should increase their inflation targets from the current level of about 2 percent to 4 percent. The argument was that such a change would reduce the likelihood of central banks hitting the ZLB and thus provide more scope for monetary policy in serious downturns. However, this suggestion was criticized by Buiter (2010) as being 'the first step on the slippery slope of inflation creep'. Buiter is reflecting the political economy concerns that raising the inflation target will reduce central banks' credibility and lead to inflation expectations becoming unanchored. In contrast, Granville (2013) argues that having an unrealistic target band could result in 'negative consequences such as a political backlash against the IT [Inflation Targeting] regime'.

Clearly there is a need to be cautious about making changes to the inflation target but there may well be circumstances when a change to an inflation target is warranted. Quantitative estimates of the impact of variations in the inflation target, such as those presented in this paper, are useful in any assessment of such a significant institutional change.

The rest of the paper is set out as follows. We provide a condensed account of New Zealand's experience of making changes to its inflation targeting regime in section 2. The Reserve Bank's DSGE model is used in section 3 to highlight the response of macroeconomic variables to a change in the inflation target. In addition, we also calculate the probability of being at the ZLB within this model environment. In section 4, we empirically assess the response of expectations to changes in the inflation target. Section 5 concludes.

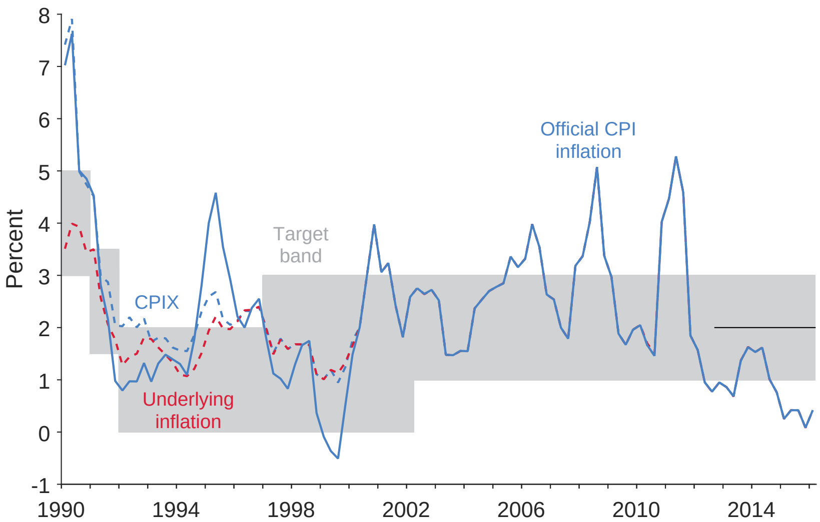
2 Changes to the Inflation Target

The details of New Zealand's inflation targeting regime have changed considerably since it was introduced in the first Policy Targets Agreement (PTA) signed by the Minister of Finance and the Governor on 2 March 1990. The changes evolved with experience and have reflected the growing international consensus for the need of an inflation targeting regime to be flexible. The changes over time have been to all parameters of the regime, including: the numerical values of the target ceiling and floor (and by implication the mid-point of the target band), the measure of inflation, and the timeframe in which the inflation target was to be met.[1]

Figure 1 shows inflation in New Zealand since the start of inflation targeting, as measured by the official CPI inflation, CPIX inflation (official CPI excluding some items), and underlying inflation (a definition introduced by the Reserve Bank in order to exclude some items). The grey area on the figure shows the target range for inflation over time and the black line indicates the introduction of the explicit midpoint of the target range.

Below we provide our condensed account of New Zealand's experience with changing its inflation target. This account focuses on five changes to the PTA: the start of inflation targeting in 1990, an increase of the target ceiling in 1996, the introduction of secondary objectives in 1999, an increase of the target floor in 2002, and the introduction of an explicit reference to a midpoint in 2012. Other changes to the PTA in 1992, 1997, 2007, and 2008 did not alter the parameters of the inflation targeting regime and so are not discussed.

Figure 1: New Zealand's Inflation Target



Note: New Zealand's inflation target and CPI inflation since the start of the inflation targeting regime. The grey band reflects the inflation target range over time and the black line represents the increased focus on the midpoint since September 2012. The dashed blue line, CPIX, is the official CPI inflation measure excluding some items.

[1] The various vintages of the PTA can be viewed at http:/www.rbnz.govt.nz/monetary_policy/policy_targets_agreement/. Further details on the history of the PTA can be found in Reserve Bank of New Zealand (2000, 2007).

2.1 A time varying start before settling on 0 to 2 percent

The first numerical target for inflation in New Zealand was specified as an annual inflation rate in the range of 0 to 2 percent of an adjusted consumer price index. The adjustment to the headline CPI was required because, at the time, the Bank believed that consumer price inflation would be better represented by an index in which housing costs and mortgage interest rates were replaced by a measure of the rental value of a owner-occupied house.

The adjustment was made to avoid the problem of targeting a measure of inflation that includes interest rates. If inflation was too high, then interest rates would need to be increased to moderate inflationary pressures, but inflation may actually increase further because of the interest rate component. Moreover, the Bank could, in the short run, hit its inflation target by moving interest rates in the opposite direction to what would be required for medium-term price stability.

When the target was introduced, the PTA specified a transitional period for the Bank to bring inflation down to its target. The PTA indicated that the Bank should implement monetary policy to 'achieve a steady reduction in the annual rate of inflation through the period to December 1992'. The first Monetary Policy Statement (MPS), issued in April 1990, made the idea of a steady reduction more specific by providing the target for annual increases in the CPI of:

- 3-5 percent for the year to December 1990;
- 1-.5-3.5 percent for the year to December 1991; and
- 0-2 percent for the year to December 1992.

After December 1992 the inflation target was specified as 0 to 2 percent. The targeted measure of inflation evolved into what became known as 'underlying' inflation. This measure started with the official Consumer Price Inflation (CPI), deducted interest rates and sometimes deducted other items, such as: significant changes in the terms of trade, significant change in indirect tax rates (such as the Goods and Services Tax), and significant price level changes arising from changes to government or local authority levies.

2.2 Target band widened to 0 to 3 percent

On 10 December 1996, the inflation target band was widened to 0 to 3 percent (from 0 to 2 percent). The official measure of inflation, the CPI, was still not used as the target measure. Instead, the Bank published its measure of 'underlying' inflation. While this approach was consistent with the intent of the PTA, there was a significant problem with the Bank calculating its own target measure. This left a perception, in some quarters, that the Bank was potentially able to manipulate the measure of inflation on which the Bank's, and the Governor's, performance was judged.

By December 1997 the Bank chose to target Statistics New Zealand's published CPI excluding credit services (denoted CPIX) rather than the Bank's measure of underlying inflation. Following a review by Statistics New Zealand of the content and calculation of the CPI in June 1999, mortgage interest rates were excluded from the official calculation and so the Bank started targeting the CPI all groups measure produced by Statistics New Zealand. Since the Bank no longer had to make technical adjustments to the CPI, public communication about inflation became far easier.

2.3 Introducing secondary objectives

In December 1999, secondary objectives were added to the PTA to increase the flexibility of the framework. Clause 4(b) of the PTA now stated that:

> "In pursuing its price stability objective, the Bank shall implement monetary policy in a sustainable, consistent and transparent manner and shall seek to avoid unnecessary instability in output, interest rates and the exchange rate."

The desire to avoid unnecessary instability in a set of macroeconomic variables formalised the recognition that attempting to use monetary policy to offset short-term impacts on inflation would typically aggravate any financial market turbulence or economic volatility. The implication for the practice of monetary policy is that interest rates would be adjusted more gradually than otherwise.[2]

The explicit mention of financial variables, such as interest rates and exchange rates, is unusual by international standards, especially since it is sometimes necessary to move interest rates aggressively to stabilize output and inflation. For example, it was necessary to reduce the Official Cash Rate (OCR) by 575 basis points in 2008/09 to help stop a downturn in output and inflation. Nevertheless, in more normal times, it is generally desirable for interest rates to be stable to facilitate business and household investment decisions. Also, unnecessarily volatile exchange rates have the potential to adversely affect profits in the export and import-competing sectors and discourage firms from investing in these sectors of the economy.

[2] To a degree, these changes to the PTA cemented what was already being practised. Real economy considerations are always present when thinking about how to set monetary policy to achieve an inflation target. For further details on the Bank's contemporary interpretations of Clause 4(b) of the PTA, see Hunt (2004) and Bollard and Karagedikli (2006).

2.4 Target band narrowed to 1 to 3 percent but more flexibility allowed over the target horizon

In September 2002, a new PTA was introduced that changed the inflation target in a number of dimensions, including:

- the target floor was raised from 0 to 1 percent, while the target ceiling remained at 3 percent; and
- the target horizon was redefined to 'future CPI inflation outcomes... on average over the medium term'.

This numerical change to the band both narrowed the tolerance interval for what could be deemed satisfactory inflation outcomes and raised the midpoint of the target band, making it the second time the value of the midpoint has been changed. In addition, the timeframe required to meet this target was made more flexible. The PTA required the Bank to take a forward-looking, medium-term approach to achieving its target, firmly embedding the idea of a flexible framework.

The Bank has interpreted this target to mean that the Bank should set monetary policy so that in response to deviations of inflation from target, and in the absence of significant unforeseen events, inflation will be back with the target band in the latter half of a three-year horizon.[3] Moreover, it was thought that if inflation projections were too close to the edge of the target band, then there was a risk of being pushed outside the band from even minor surprises.[4] Therefore, the Bank would set policy so that inflation would gradually move toward the centre of the band and settle 'comfortably' inside the 1 to 3 percent band.

The specification of the target in terms of 'future CPI inflation outcomes ... on average over the medium term' allowed the Bank more leeway in responding to one-off deviations that would not be expected to disturb the medium-term trend of inflation. This new target gave the Bank a framework in which to clearly communicate its judgement about whether deviations of inflation from target were temporary or not. Clearer communication provided the public with information that any deviation did not signal the existence of an ongoing inflationary problem. A 'medium-term' target horizon depends on the circumstances at the time and, in particular, how well inflation expectations are anchored to the target.

[3] The intention to bring inflation back to a comfortable part of the target band in a specified timeframe following any deviation from target was stated publicly in Bollard (2002, 2008).

[4] Hargreaves (2002) conducts simulation experiments to show how inflation variability would change if the Bank used the target band as a 'zone of inaction'. That is, monetary policy does not respond when inflation is inside the target band. He finds that such a strategy would make breaches of the target band much more likely.

2.5 Explicit reference to the 2 percent midpoint

In September 2012, an explicit reference to the midpoint of the target band was added to the PTA. Clause 2(b) of the PTA adds 'a focus on keeping future average inflation near the 2 percent target midpoint'. This addition was motivated by the desire to anchor inflation expectations more firmly to 2 percent (see Kendall and Ng, 2013). The explicit focus on the 2 percent midpoint could be viewed as communicating that the edges of the target band are less tolerable than the centre of the band. However, as noted above, even prior to the explicit mention of a midpoint, monetary policy was always set with the aim of moving inflation gradually to the centre of the target band. The addition is perhaps better seen as formalising the flexible approach to inflation targeting that is practiced in New Zealand.

3 Changing the Inflation Target in NZSIM

The most memorable changes to the inflation target have been those that altered the midpoint of the target range. Here we demonstrate that the macroeconomic consequences of changing the midpoint of the inflation target depend crucially on inflation expectations. First, we examine the macroeconomic impact of a change in the inflation target under both adaptively and rationally formed inflation expectations. This exercise illustrates model dynamics under each assumption, which are well-established in the literature, and sets the scene for the empirical results in section 4. Second, we calculate the probability of hitting the ZLB as a function of the inflation target, again under both adaptively and rationally formed inflation expectations. This exercise allows us to assess different inflation targets, in terms of the risk that policy hits the zero lower bound in a typical business cycle.

3.1 Predicted effects of target changes in NZSIM

To help inform us about the macroeconomic impacts of changing the inflation target we can look at simulations from macroeconomic models. Here, we use the Reserve Bank of New Zealand's estimated dynamic stochastic general equilibrium (DSGE), referred to as NZSIM. For a description of the underlying structure of

NZSIM and model equations see Kamber et al (2015).[5]

NZSIM is used in the policy formation process at the Bank and reflects institutional views on the key monetary policy transmission channels and business cycle dynamics. At the core of NZSIM is a conventional small open economy New Keynesian model, with three types of optimising agents: households, domestic firms, and import distributing firms. The central bank targets inflation to diminish the inefficiencies associated with the presence of sticky nominal prices. The model is kept parsimonious to ensure it is transparent and easy to communicate, while the core structure gives confidence in providing policy analysis through a model-consistent framework.

A key feature in NZSIM that makes it suitable for our analysis is that it allows inflation expectations to potentially be adaptive. In particular, inflation expectations are a convex combination of its lagged value and the rational expectation. The motivation for using the adaptive expectations process comes, firstly, from empirical tests for New Zealand, which suggest inflation expectations are likely to be adaptive.[6] Secondly, adaptive expectations provide a better fit to the data when using inflation expectations as an observable series. Many conventional models used at other central banks, and in the literature, use rational expectations and do not usually use inflation expectations as an observable series in the estimation.[7] Using NZSIM in this exercise means we are able to assess the effects from changing the inflation target in both environments, when inflation expectations are formed rationally and when they are formed adaptively. Other models estimated for New Zealand use purely rational expectation formation and are hence less suitable for our purpose (for example, Jacob and Munro 2016, Justiniano and Preston 2010, and Kam, Lees and Liu 2009).

The monetary policy rule we use in the current exercise is

$$i_t = \phi_i i_{t-1} + (1-\phi_i)\{\overline{\pi}_t + \phi_\pi(E_t\pi_{t+1} - \overline{\pi}_t + \phi_y y_t\} + \varepsilon_t^i \tag{1}$$

[5] Kamber et al (2015) provide a technical description of the NZSIM model that is based on a standard open economy dynamic stochastic general equilibrium. The version of NZSIM used in the forecasting process, and in this paper, also includes additional semi-structural auxiliary equations. The equations are in the Appendix.

[6] See, for example, Karagedikli and McDermott (2016), Kamber et al. 2015, Hargreaves, Kite, and Hodgetts (2006), and Razzak (1997) for discussions on modelling inflation expectations in New Zealand.

[7] For a discussion of the Bank of England's core DSGE model, COMPASS, that uses rational expectations and an alternative model MAPS for different expectation formation processes see Burgess et al (2013). For a discussion on the Bank of Canada's TOTEM and TOTEM II models, which uses forward-looking and rule-of-thumb expectations, see Dorich et al (2013).

where i_t is the policy interest rate, $E_t\pi t+1$ is the rational expectations of inflation at time $t+1$ formed at time t, y_t the output gap at time t, ε_t^i is a monetary policy shock and $\overline{\pi_t}$ is the inflation target. Our experiment is performed by making permanent changes to $\overline{\pi_t}$.

Inflation expectations are formed according to the following process

$$\pi^e_{t,t+1} = \rho_1\pi^e_{t-1,t} + (1-\rho_1)[\rho_2 E_t\pi_{t+1} + (1-\rho_2)\pi_{t-1}] \quad (2)$$

where $\pi^e_{t,t+1}$ is the level of expectations of inflation in period $t+1$ held by business and household agents at time t and π_{t-1} is the level of inflation at time $t-1$. This approach of how expectations are formed is applied consistently to non-tradable inflation, tradable inflation and wage inflation in the model.

Impulse responses for a one percentage point increase in the inflation target are computed under two scenarios: (i) inflation expectations follow an adaptive process with $\rho_1 = 0.92$ and $\rho_2 = 0$, and (ii) inflation expectations are fully rational with $\rho_1 = 0$ and $\rho_2 = 1$. The parameter values used to generate adaptive expectations are the same values used in the version of NZSIM that is used to produce the forecasts in the Monetary Policy Statement. Qualitatively similar results can be obtained for a wide range of values of $\rho_1 = 0$. To illustrate the role of the parameters, as $\rho_1 = 0$ falls and $\rho_2 = 0$ increases, agents become more forward looking and the persistence of variables, particularly price variables, falls. As Kamber et al. (2015) explain, the lower persistence occurs because agents place less emphasis on past expectations of future marginal costs and more emphasis on future expectations, which makes prices less sticky.[8]

In the adaptive expectations scenario any change of the inflation target changes inflation expectations slowly, requiring monetary policy to be more aggressive to ensure actual inflation converges to target. Under the rational expectations scenario inflation expectations adjust immediately to changes in the inflation target. For these scenarios the target is taken to be the midpoint of the tolerance interval.

Figure 2 shows the outcomes of these simulations for a range of macroeconomic

[8] The parameter ρ_1 needs to be high but less than unity under adaptive expectations. The value of 0.92 was chosen because that is the estimated value in NZSIM.

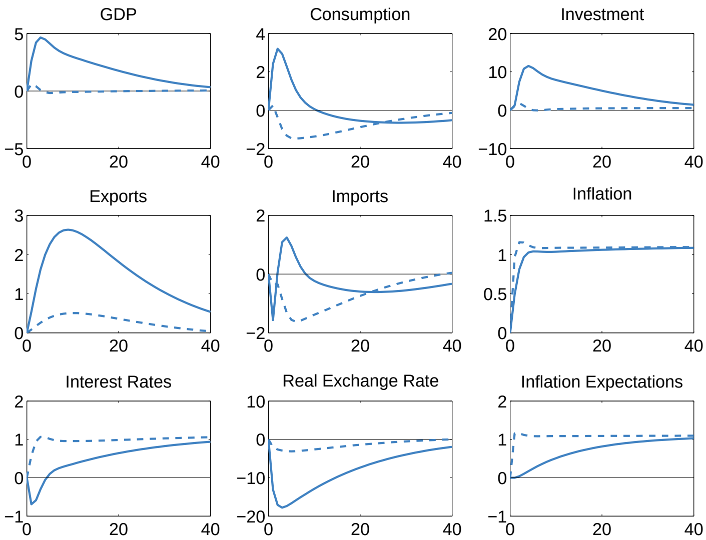
variables for a one percentage point increase in the inflation target.[9] The solid line in the figure reports the results from the adaptive inflation expectations scenario while the dashed lines show the results from the rational expectations scenario.

When inflation expectations adjust slowly to information about an increase in the inflation target, nominal interest rates need to be lowered immediately in order to generate a positive output gap to move inflation to the new target. Even after inflation reaches the new target there is still a need to run a positive output gap for a lengthy period to force inflation expectations to adjust upward to the new target. As inflation expectations gradually increase, nominal interest rates need to increase, ultimately to one percentage point higher than the neutral level under the old inflation target. The temporary boost to the level of GDP is composed of increases in consumption, investment and exports. However, consumption and imports later fall below their initial level but the output gap remains positive. This shift away from consumption toward net exports reflects a real exchange rate depreciation.

In contrast, under the rational expectations scenario there is virtually no boost to the level of GDP while consumption falls temporarily, offsetting the small temporary increases in investment and net exports. In both scenarios, inflation increases permanently by exactly the amount of the increase in the inflation target. In the long run, inflation expectations and nominal interest rates increase permanently so that the long-run level of real interest rates is constant.

[9] These experiments are conducted under the assumption that only small changes in the inflation target are considered, so that the model's structure can be assumed constant despite the change in institutional settings (i.e. the Lucas critique is not an issue). If changes to the inflation target were large enough we may see threshold effects where the private sector, in order to avoid the costs of inflation, engages in speculative activity rather than productive activity, reducing the economy's supply potential. For evidence of how inflation beyond a certain threshold reduces growth, see Khan and Senhadji (2001).

Figure 2: Effect of an inflation target increase in selected variables in NZSIM



Solid: Benchmark NZSIM model, where inflation expectations are adaptive; dashed: NZSIM model with rational expectations. Note: a fall in the exchange rate denotes a depreciation

3.2 Avoiding the Zero Lower Bound

As noted in the introduction, one of the motivations posited by some authors for increasing the inflation target is to reduce the likelihood of hitting the zero lower bound (ZLB). A higher target results in both trend inflation being further from zero and trend nominal interest rates being further from zero. Higher trend nominal interest rates provide more scope for monetary policy to deal with adverse shocks. We use NZSIM to determine the probability of hitting the ZLB and staying there for a significant period. In this exercise we focus on a period of five quarters which is close to the typical length of a New Zealand recession.[10] In particular, we calculate what shocks would be required to keep interest rates at the ZLB for five consecutive quarters and the probabilities of those shocks occurring over a business cycle.

Intuitively, we impose the result that interest rates are at the ZLB for five consecutive quarters and calculate the combination of shocks in NZSIM that would be most consistent with this outcome. For each of the shocks we then calculate a

[10] See Hall and McDermott (2009, 2011 and 2015) for evidence on the New Zealand business cycle. The average duration of the nine recessions since 1947 is 4.2 quarters with a standard deviation of 1.6. The last recession lasted 5 quarters from December 2007 to March 2009.

metric of its ‘implausibility’. An ’implausibility index’ of the ZLB event is then the average of the ‘implausibility’ of all the shocks and the probability of being at the ZLB for five quarters is simply one minus the ‘implausibility index’.[11]

The implausibility index we use was introduced by Doan, Litterman and Sims (1983). Suppose that forcing the model to be at the ZLB for h quarters requires the following future values for the k^{th} shock to be set to $\varepsilon^k_{t+1}, ..., \varepsilon^k_{t+h}$ where k is an index of shocks in NZSIM. The Waggoner and Zha (1999) algorithm is used to compute the values $\varepsilon^k_{t+1}, ..., \varepsilon^k_{t+h}$ for $k = 1, ..., K$, where K is the total number of shocks used from the model. There are 21 shocks in NZSIM and all of these shocks are used in the exercise.

To select the shocks in this exercise we use the Waggoner-Zha algorithm, which is a common and agnostic approach for adding judgement in structural models. In particular, the algorithm determines the combination of shocks with the smallest variances that are consistent with the conditional forecast. From a probabilistic point of view, the most likely sequence of shocks is chosen, given the structure of the model and its parameterisation. The Implausibility index then evaluates the variance of the shocks used, comparing the size of the shocks used to generate the scenario to what has been experienced in history.

The implausibility index for h horizons is then given by

$$I_h = \frac{1}{K.h} \sum_{k=1}^{K} \sum_{i=1}^{h} \frac{\left(\hat{\epsilon}^k_{t+i}\right)^2}{\sigma^2_k} \tag{3}$$

where σ^2_k is the historical variance of the k^{th} shock. If we need large values of $\hat{\epsilon}^k_{t+i}$ relative to the variance σ^2_k to generate the ZLB outcome then that outcome would seem to be implausible, hence the name of the index. We can convert this index into a probability of being at the ZLB for h quarters using the cumulative distribution function of a half normal random variable with unit variance. That is

$$\Pr(ZLB, h) = 1 - \int_0^{I_h} \sqrt{\frac{2}{\pi}} \exp\left(-\frac{1}{2}x^2\right) dx. \tag{4}$$

[11] The concept of an implausibility index can seem unintuitive. An alternative way of expressing the concept follows. In this exercise, starting from equilibrium, we generate a scenario where interest rates are at the zero lower bound for five consecutive quarters using all the shocks in the model. The shocks used to generate this scenario are compared to history to inform us whether the required shocks are ‘plausible’ given what we have observed in history. This exercise is done for different inflation targets.

Figure 3 shows the probability of being at the ZLB for five quarters as a function of the inflation target assuming the neutral real interest rate is 2.5 percent.[12] In this exercise, under rational expectations the probability of being at the ZLB for five consecutive quarters for any non-negative inflation target is zero.

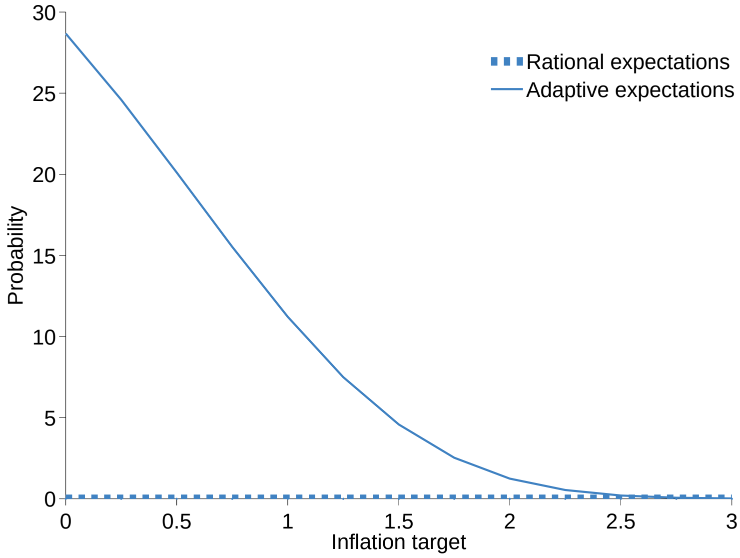
In contrast, when expectations are adaptive then there is a possibility of being stuck at the ZLB. The probability of being at the ZLB for five quarters when the inflation target is zero is 0.29 and steadily declines as the inflation target increases. The midpoint of the original 0 to 2 percent target and the midpoint of the 1996 0 to 3 percent target produce probabilities of being at the ZLB for 5 quarters of 0.12 and 0.05, respectively. With the current mid-point of the target at 2 percent, the probability of being at the ZLB for 5 quarters is 0.02. This indicates that the potential gains from increasing the target above 2 percent are likely to be trivial.[13]

To generate a ZLB outcome in NZSIM with adaptive expectations the Waggoner and Zha algorithm requires four large shocks, two moderate shocks, and the remainder of the shocks are very small. The large shocks that are doing most of the work are the inflation expectations, migration, monetary policy and retail interest rate shocks. Exchange rate and consumption shocks are also required but these tend to be moderate on average.

[12] The neutral real interest rate chosen here is the same value as used in the version of NZSIM that is used to produce the forecasts in the Monetary Policy Statement. This value matches the average of a range of models used to estimate the neutral real interest rate. For details see Richardson and Williams (2015).

[13] These results do have to be treated with some caution. Exclusion of rare but large shocks from the model would alter the calculated probabilities. Research prior to the global financial crisis showed that episodes at the ZLB would be infrequent. For example, Reifschneider and Williams (2000) found that a 2 percent inflation target for the US would result in monetary policy being constrained at the ZLB about 5 percent of the time. Recent events suggest the standard models omitted an important shock for the US. Reinhart and Rogoff's (2009) 800 year history of financial crisis suggests that standard models are likely to be estimated over too short a period to capture episodes of banking crisis and so may underpredict the likelihood of being constrained at the ZLB. That said, Calomiris and Haber (2014, p454) note that Australia, Canada and New Zealand have had a crisis-free banking system since 1970. Therefore, using standard models to calculate the probability of being constrained at the ZLB may be more appropriate in these countries.

Figure 3: Probability of hitting the ZLB for five consecutive quarters



Note: the real neutral interest rate is assumed to be 2.5 percent in all cases. The probability of hitting the ZLB reflects the scenario's plausibility given the structure of NZSIM and historical shocks.

To illustrate the size of the shocks required to generate a ZLB outcome consider an inflation target of 2 percent, then the average inflation expectations shock over a five quarter horizon is 4.1 times its standard deviation, even when the other shocks are non-zero. With an inflation target of zero the average inflation expectations shock is 2.3 times its standard deviation. Under rational expectations, the equivalent numbers needed to generate the ZLB outcome are 16 and 9 times their standard deviation.

4 Impact on inflation expectations of changes in the inflation target

The results from NZSIM highlight why it is important to know how inflation expectations change if we are to understand the quantitative effects of changes in the inflation target. Thus our task now is to get a measure if inflation expectations and test how changes in the target impact on this measure. First, we combine a number of surveys of inflation expectations using a Nelson-Siegel model. This allows us to extract information on the long-run level of expectations, which can be used as proxy for the perceived inflation target. Second, we test the impact of any PTA change on the perceived inflation target.

4.1 Combining Surveys of Inflation Expectations using Nelson-Siegel model

Household and business surveys are a common way to gather information on inflation expectations. These surveys ask respondents what they believe inflation will be at some future date. Different surveys can refer to different future dates. Examining expectations at different time horizons can provide a measure of an expected path of inflation, something that we call an inflation expectations curve.

Conceptually, applying a term structure model to various expectation measures is akin to model averaging. Each of the surveys is likely to carry some measurement error, bias, and hence forecast error. Combining the various measures and using a formal model to represent the various horizons, in principle improves the representation of inflation expectations.[14] In addition, the term structure approach we use means an estimate of the inflation target perceived by survey respondents can be extracted. The benefit from our approach is we are able to use information from a range of inflation expectation surveys rather than relying on a single measure.

Similar exercises of fitting term structure models to inflation expectation survey data have been done in Lewis (2016), Aruoba (2016) and Aruoba (2014). Lewis (2016) fit curves to various survey data for New Zealand and shows how they can be used in the context of formulating monetary policy in practice. Aruoba (2016) and Aruoba (2014) use expectations curves for the United States to study the effects of unconventional monetary policy since 2008 on inflation expectations and real interest rates.

The inflation expectations curve at any point in time can be derived using conventional yield curve modelling techniques. We follow the approach adopted by Lewis (2016) and use a Nelson-Siegel model to estimate inflation expectations curves.

The Nelson-Siegel model, a technique widely used at central banks and in academic research for modelling yield curves, can be thought of as a dynamic factor

[14] For studies on the benefits of model averaging and combing data, see, for example, Stock and Watson (2002) and Wright (2008).

model with prespecified factors that describe the shape of the curve.[15] With only three factors determining the Level, Slope and Curvature of the curve, the Nelson-Siegel model is a parsimonious way to obtain a curve from expectation surveys. Typically when these models are applied to interest rates, the model needs to be augmented to be made an arbitrage-free, however since we are working directly with expectations the non-arbitrate-free Nelson-Siegel model is used. This is consistent with the approach in Lewis (2016) and Aruoba (2016).

We use a forward rate representation of the Nelson-Sigel model since the survey data relate to expectations at a point in the future. This can be represented as:

$$\pi^e(\tau)_t = H\beta_t + e_t \tag{5}$$

where τ is the horizon of the expectation measured in years, $y(\tau)_t$ is the vector of expectations observed at time t for K horizons collected in the $K \times 1$ vector τ, β_t is the 3×1 vector of expectation components (Level, Slope and Curvature) at time t, and the error term is $e \sim N(0, R)$. The defining feature of the model is the sensitivity matrix H given by:

$$H = \begin{bmatrix} 1 & exp(-\lambda\tau_1) & \lambda\tau_1 exp(-\lambda\tau_1) \\ 1 & exp(-\lambda\tau_2) & \lambda\tau_1 exp(-\lambda\tau_2) \\ \vdots & \vdots & \vdots \\ 1 & exp(-\lambda\tau_K) & \lambda\tau_1 exp(-\lambda\tau_K) \end{bmatrix} \tag{6}$$

As Lewis (2016) notes, the expectations survey data refer to annual inflation. The forward rate equation is adjusted from the instantaneous forward rate to an annual forward rate, where the inflation expectation of horizon τ_i is referenced against horizon $\tau_i - 1$ to create an annual rate.

$$\pi^e(\tau - 1, \tau)_t = H\beta_t + e_t \tag{7}$$

where

[15] See Diebold and Rudebusch (2012) for a discussion of the use of Nelson-Sigel models for modelling bond yields as well as for the derivation of the models.

$$H = \begin{bmatrix} 1 & [\text{Slope loading}]_1 & [\text{Curvature loading}]_1 \\ 1 & [\text{Slope loading}]_2 & [\text{Curvature loading}]_2 \\ \vdots & \vdots & \vdots \\ 1 & [Slopeloading]_K & [Curvatureloading]_K \end{bmatrix}$$

$$[\text{Slope loading}] = \frac{1}{\lambda}\{exp(-\lambda[\tau_i - 1] - exp(-\lambda\tau_1)\}$$

$$\begin{aligned}[\text{Curvature loading}] = \frac{1}{\lambda}\{exp(-\lambda[\tau_i - 1] - exp(-\lambda\tau_1)\}+ \\ \{[\tau_i - 1]exp(-\lambda[\tau_i - 1]) - \lambda exp(-\lambda\tau_1)\}\end{aligned}$$

The parameter, λ, determines the speed of time decay for the Slope and Curvature components. There could be in principle a time subscript on λ but the usual practice is to keep it constant across time. The optimal λ is the one that minimizes the squared errors across time of the squared errors between observed and model-derived expectations across each curve.[16]

When applied to inflation expectations, the Level component can be interpreted as a measure of a perceived inflation target, while the Slope and Curvature components can be interpreted as the survey respondents' expectations of how fast the central bank plans to return inflation to target. In New Zealand, the Bank has often stated that deviations in inflation from the inflation target would be expected to be corrected in 18 to 24 months. If such an announcement was credible we should expect to see this in the Slope and Curvature components.

Inflation expectations curves are estimated over the period 1996q1 to 2016q1.[17] The data used are the various surveys of inflation expectations that are available in New Zealand. We use 12 surveys that range from 1 to 10 years ahead and cover expectations from business and economists. Household surveys are available but they are excluded from this analysis given the substantial level bias. Table 1 provides a description of the data and Lewis (2016) provides a description of the statistical properties of the data and notes these data show characteristics that would be expected for a flexible inflation targeting regime. Specifically, all surveys are less volatile than headline CPI inflation and volatility in inflation expectations

[16] See Lewis (2015) for a detailed description of the estimation method.

[17] Due to some survey data being unavailable, we are unable to analyse the earlier inflation targeting period. Unfortunately, this means we cannot formally test whether the 1996 change to the PTA altered inflation expectations.

Table 1: Inflation expectation surveys details

Survey	Number of respondents	Respondent type	Beginning of survey
ANZ	400-600	Businesses	1983
RBNZ surveys	60-70	Businesses /economists	1987
Aon	7	Economists	1993
Consensus Economics	Confidential	Economists	1996

declines as the time horizon increases, which is consistent with the initial effects of shocks hitting the economy and then dissipating over time.

The specific surveys used are: the RBNZ, Aon and ANZ measures at the 1-year horizon; the RBNZ and Consensus Economics measure at the 2-year horizon, Consensus Economics at the 3-, 4-, 5-, and 6- year horizons and the Aon measure for each of the 4-year and 7-year horizons. The Consensus Economics measure of inflation at the 10-year horizon is also used. Thus for the current application we have $\tau = (1, 2, 3, 4, 5, 6, 7, 10)'$ and the globally estimated value of λ is 0.859.

The model fits the data well, with an average absolute error (difference between actual survey data and estimated horizon points) of only 13 basis points. This compares well to the literature for fitting bond yields (see, for example Lewis 2015 for New Zealand results and Gurkaynak, Sack, and Wright 2007 for US results) and fitting the expectations curve in Aruoba (2016).

The available inflation expectations surveys provide information at eight horizons. However, what we need is to be able to test how changes to the target change expectations across all horizons and for any particular idiosyncratic behaviour in individual surveys to be smoothed out, which we can get from the Nelson-Siegel model. Of particular relevance is the long-horizon expectation. This information can be used to test whether inflation expectations are anchored. For this it would be tempting to use just the forecast of inflation at the 10 year horizon. However, forecasts always contain some forecasting error. As noted earlier, in principle, this error can be reduced by combining surveys using the Nelson-Siegel model.

Table 2 reports parameter estimates around the time of PTA changes in 1996, 1999, 2002, and 2012. The most interesting feature to examine is the estimates of the Level component which, as noted earlier, can be interpreted as a measure of long-run inflation expectations. The estimates show that around the time of the 1996 PTA change, when the target band moved to 0 to 3 percent from 0 to 2 percent, expectations shifted upwards, but not in a statistically significant way. The positive Slope parameter would indicate an expectation of generally increasing

Table 2: Nelson-Siegel Model Estimates (selected periods)

	Parameter Estimates				Parameter Estimates		
Date	Level	Slope	Curvature	Date	Level	Slope	Curvature
1996q3	1.793	0.537	-1.165	2002q2	1.822	1.277	-0.58
	-0.413	-0.918	-2.324		-0.275	-0.754	-0.037
1996q4	1.833	0.115	-0.602	2002q3	2.159	0.541	-0.645
	-0.416	-0.943	-2.351		-0.323	-0.625	-0.37
1997q1	1.847	0.09	0.26	2002q4	2.318	0.474	-0.828
	-0.288	-0.672	-0.172		-0.415	-0.942	-2.348
1997q4	1.813	-0.04	0.044	2003q3	2.191	-0.44	0.444
	-0.41	-0.944	-2.311		-0.297	-0.678	-0.14
1999q3	1.699	-0.34	0.156	2012q2	2.44	-0.455	0.559
	-0.292	-0.715	-0.155		-0.289	-0.708	-0.155
1999q4	1.611	0.671	0.221	2012q3	2.463	-0.545	0.201
	-0.296	-0.711	-0.096		-0.301	-0.681	-0.149
2000q1	1.708	0.872	-0.211	2012q4	2.425	-0.742	0.441
	-0.39	-0.963	-2.215		-0.302	-0.698	-0.147
2000q4	1.819	1.922	-0.842	2013q3	2.271	-0.574	0.674
	-0.293	-0.722	-0.063		-0.3	-0.692	-0.128

Note: Nelson-Siegel parameters and standard errors (in parenthesis).

inflation. While the point estimates are positive during this period, they are not statistically significant. The Curvature parameters are not statistically significant during this period.

Figure 4 shows the estimated inflation expectations curve around the 1996 PTA change. From this figure we can also see that inflation expectations increased immediately across short-to-medium horizons, and the change at the 10-year horizon is small, consistent with the finding that there is no statistical difference in the Nelson-Siegel Level estimates over this period. The increase in inflation expectations occurred at a time when CPI inflation was declining, as shown in the insert graph in Figure 4.

The parameter estimates around the 1999 PTA change, when secondary objectives were explicitly introduced, show that the Level and Slope components both increased while the Curvature component increased in absolute value. The increase in the Level and Slope components suggests an expectation of higher inflation in the long term, but the change is not statistically significant. There is a large change in the Curvature component, indicative of more uncertainty about the speed of adjustment to target.

Figure 5 shows the estimated inflation expectations curves around the 1999 PTA change. In this instance, inflation expectations are more dispersed at short horizons. The long-term anchor for inflation expectations shifts upwards marginally as inflation increases through the period. The large change in Slope and Curvature indicates an expectation of increased deviations from target in the short run.

The parameter estimates around the time of the 2002 PTA show that expectations shifted upwards sharply, with the Level component sitting at 1.8 percent prior to the new PTA and jumping 0.34 percentage points in the quarter the PTA was changed. A Chow test for whether there is a break in the mean of the Level series is 353 compared a one percent critical value from the F(1,76) distribution of 6.96, indicating the change in the PTA in 2002 resulted in a statistically significant change in inflation expectations. The Slope estimates decline (in absolute value) as long-term expectations move upwards towards the existing short term expectations.

Figure 6 shows the estimated inflation expectations curve around the 2002 PTA change. Inflation expectations increased, particularly at long-horizons. Inflation was stable at the time of the PTA change and then subsequently fell in 2003. These developments suggest that the change in inflation expectations was indeed due to the change in the PTA.

The parameter estimates around the time of the 2012 PTA change shows a small reduction in long-term expectations. The Slope parameter is negative indicating that in the short term inflation is expected to be below target and gravitate toward target over the 3 year forecast horizon used by the Bank.

Figure 7 shows the estimated inflation expectations curve around the 2012 PTA. Initially, the expectations curve does not change but over time expectations have shifted lower. Movements at the short end of the curve likely to reflect lower CPI inflation outturns as oil prices declined rapidly. The shift in the long end of the curve suggests that private sector participants have incorporated the Bank's focus on the midpoint into their expectations.

Inflation expectation curves following PTA changes

Figure 4: 1996 PTA

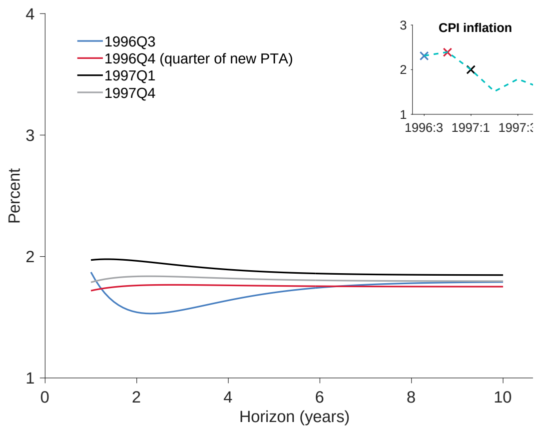


Figure 5: 1999 PTA

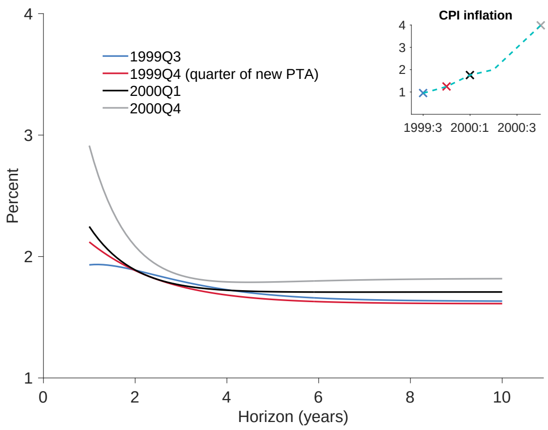


Figure 6: 2002 PTA

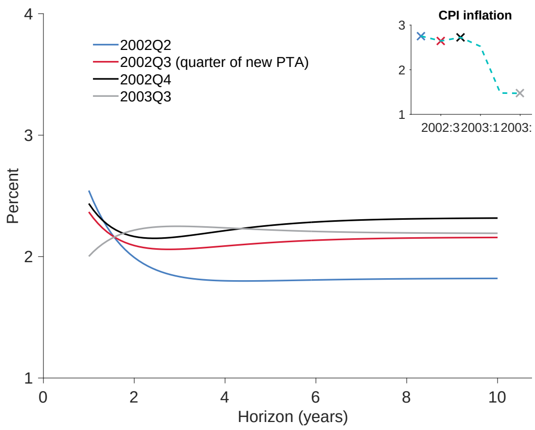
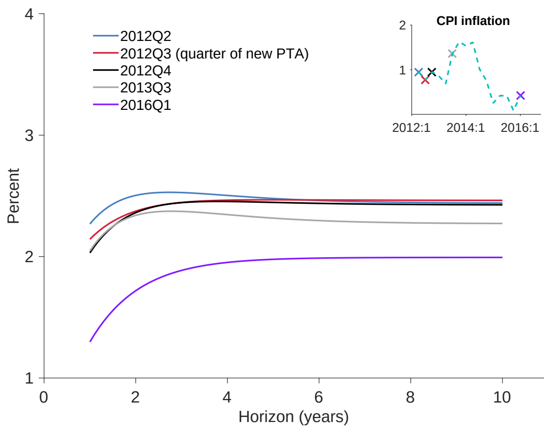


Figure 7: 2012 PTA



Note: The expectation curves in figures 4 to 7 show inflation expectations behaved one quarter before the PTA change, the quarter of the change, one quarter following, and one year after. The insert graph shows headline CPI inflation at the time.

4.2 Testing the Impact of PTA Changes on Inflation Expectations

The results above suggest that changes to the inflation target do affect inflation expectations. However, examining only periods around PTA changes may be misleading. Changes in expectations may occur because of changes in past inflation.

To test whether changes in the PTA influences long-run inflation expectations, we regress the Level from the inflation expectations curve on a constant, the lagged Level, distributed lags of inflation, and dummy variables indicating the timing of the changes to the PTA. Lags of annual inflation are included in the regression to control for the impact of past inflation on inflation expectations. The lagged Level term is included to account for the persistence typically observed in inflation expectations. Thus we estimate the following regression

$$\hat{\beta}_{1t} = \alpha_0 + \alpha_1 \hat{\beta}_{1t-1} + \sum_{k=0}^{2} \gamma_k \pi_{t-k*4} + \sum_{k=1}^{4} \delta_k D_k + \varepsilon_t \tag{8}$$

where $\hat{\beta}_{1t}$ is the estimate of the Level from equation 7 at time t, π_t is annual inflation at time t, and $D_1 = 1$ if $t \geq$1994Q4 and 0 otherwise, $D_2 = 1$ if $t \geq$ 2002Q3 and 0 otherwise, otherwise, $D_3 = 1$ if $t \geq 2012Q3$ and 0 otherwise, and ε_t is a regression residual. The parameter values γ_k show the marginal impact of a new PTA relative to the preceding period.

The results of this regression are reported in Table 3. First, lagged annual inflation and the lagged Level are statistically significant at the 5 and 10 percent level, respectively. Thus controlling for past inflation and inflation expectations is necessary. This evidence indicates that inflation expectations do adjust adaptively to past inflation.

The estimated coefficient on the dummy variable for the 2002 PTA change is positive and statistically significant, indicating that inflation expectations immediately increased 0.19 percentage points when the target midpoint was increased 0.5 percentage points. The coefficient estimates on the 1999 and 2012 dummies are not statistically significant but economically the changes are consistent with the changes to the PTA. Following the introduction of the secondary objectives but no change to the numerical inflation target in the 1999 PTA, inflation expectations increased 0.05 percentage points. This is consistent with more flexibility in achieving the inflation target. The 2012 PTA change, which put more emphasis on the 2 percent midpoint of the target range, is associated

Table 3: Impact of PTA changes on Inflation Expectations

Variable	Coefficient	Estimate	Standard error
Constant	α_0	0.62*	0.16
Level (lagged 1 quarter)	α_1	0.59*	0.1
Inflation		0.02	0.01
Inflation (lagged 1 year)	γ_1	0.02	0.01
Inflation (lagged 2 years)	γ_2	0.01	0.01
PTA change 1999Q4	δ_1	0.05	0.04
PTA change 2002Q3	δ_2	0.19*	0.06
PTA change 2012Q3	δ_3	-0.04	0.03

Note: OLS estimates for the 1998Q1 to 2016Q1 sample period. Newey-West standard errors are reported using the Bartlett kernel with a bandwidth of 4. The R-squared is 0. 962008, the standard error of the regressions is 0. 957853. The Breusch-Godfrey test of serial correlation (using 4 lags) is 5.79 and the White test for heteroskedasticity is 5.32. Neither test is significant at the standard level of significance. * denote significant at the 5 percent level.

with a 0.04 percentage point fall in inflation expectations. At the time of the 2012 PTA change, actual inflation and the Level component had been averaging 2.5 percent.

The regression results provide evidence that the publicly announced changes to the inflation target influence expectations, although significant changes to the numerical target are more likely to have significant influences on long-term expectations. Changes in the PTA are reflected in expectations even though inflation expectations tend to move more gradually to changes in inflation.[18]

5 Conclusion

New Zealand provides a natural laboratory to analyse the effects of changing an inflation target. Since the start of inflation targeting in 1990 there have been a number of changes to the Policy Targets Agreement between the Minister of Finance and the Governor of the Reserve Bank. Changes that alter the parameters

[18] For a study on the role of expectations in the determination of inflation in New Zealand see Karagedikli and McDermott (2016).

of the inflation target have tended to occur on average every five years or so (the term of a Governor's appointment).

The process of inflation expectations formation is pivotal for predicting the effects of a change to the inflation target. The Reserve Bank's DSGE model of the New Zealand economy, NZSIM, predicts that a change in the inflation target will result in a permanent one-for-one change in inflation and inflation expectations. The model also predicts that changes in the target may result in a temporary boost to output under adaptive expectations but there is no boost to output under rational expectations.

Evidence suggests that there is some degree of inertia in inflation expectations. That being the case, the probability of being at the Zero Lower Bound (ZLB) in New Zealand for five consecutive quarters is likely low, given the current 2 percent target midpoint. Any increase in the target would seem to offer diminishing protection from the ZLB but a reduction in the target would likely increase the risk of the ZLB, on average over the business cycle.

Evidence from estimated inflation expectation curves show that changes in the inflation target are quickly reflected in inflation expectations. Particularly striking is the estimated immediate 0.19 percentage point increase in inflation expectations when the target midpoint was increased 0.5 percentage points in 2002. Thus we can conclude that changing the numerical inflation target is likely to feed into inflation expectations but unlikely to provide even a temporary boost to output or other real economic variables.

The periodic 'fine-tuning' of the inflation target has steadily introduced more flexibility into the New Zealand regime. This flexibility has been gained while still keeping inflation expectations anchored.

Appendices

NZSIM Model Equations

Here we list the NZSIM model equations used to generate the macroeconomic responses of an inflation target change and the probability of hitting the zero lower bound. The version of the model listed here is, with exception of the monetary policy rule, the model used for the production of forecasts in the Reserve Bank of New Zealand's *Monetary Policy Statement*.

1. Consumption

$$\begin{aligned} c_t &= \frac{1}{1+\chi}\left(E_t c_{t+1} + \chi c_{t-1}\right) \\ &\quad -\alpha_1 E_t \Delta y_{t+1} - \alpha_2\left[ir_t - \pi^e_t + \zeta b_t + \epsilon^c_t\right] + \omega_c\left(p_{H,t} - p_t\right) \end{aligned}$$

where ϵ^c_t is the consumption shock, c_t is consumption, y_t is GDP, ir_t the nominal retail interest rate, b_t is foreign debt, $p_{H,t}$, is the house price level, p_t is π_t is inflation and the ^{e} subscript above any variable means adaptive expectations for the next quarter. The notation E_t preceding a variable means rational expectations taken at time t. In this equation and subsequent equations the variables of interest are log-deviations from steady state so, for example, y_t can equivalently by denoted as the output gap.

2. Non-tradable inflation Phillips curve

$$\pi_{N,t} - \gamma_N \pi_{N,t-1} = \beta\left(\pi^e_{N,t} - \gamma_N \pi_{N,t}\right) + \kappa_N\left[w_t - p_{N,t} + \varphi y_t\right] + \epsilon^N_t$$

where ϵ^N_t is the non-tradable inflation shock, $\pi_{N,t}$ is non-tradable inflation, w_t is the nominal wage, and $p_{N,t}$ is the non-tradable price level,

3. Tradable inflation Phillips curve

$$\begin{aligned} \pi_{T,t} - \gamma_T \pi_{T,t-1} &= \beta\left(\pi^e_{T,t} - \gamma_T \pi_{T,t}\right) \\ &\quad +\kappa_T\left[\tau_T(p^*_{M,t} - s_t - p_{T,t}) + (1-\tau_T)(p_{N,t} - p_{T,t})\right] + \epsilon^T_t \end{aligned}$$

where ϵ^T_t is the tradable inflation shock, $\pi_{T,t}$ is tradable inflation, s_t is the nominal exchange rate, $p_{T,t}$ is the tradable price level and $p_{M,t}$ is the import price. The * superscript refers to the foreign variable equivalent.

4. Wage Phillips Curve

$$\pi_{w,t} - \gamma_w \pi_{w,t-1} = \beta\left(\pi^e_{w,t} - \gamma_w \pi_{w,t}\right) + \kappa_w\left[\frac{\eta}{\alpha} y_t - (w_t - p_t)\right] + \epsilon^w_t$$

where ϵ^w_t is the nominal wage shock and $\pi_{w,t}$ is nominal wage inflation.

5. Policy interest rate rule

$$i_t = \phi_i i_{t-1} + (1 - \phi_i) \{\bar{\pi}_t + \phi_\pi (E_t \pi_{t+1} - \bar{\pi}_t + \phi_y y_t\})\} + \epsilon_t^i$$

where ϵ_t^i the monetary policy shock, i_t is the nominal policy interest rate and $\bar{\pi}_t$ is the inflation target.[19]

6. Retail interest rate

$$ir_t = i_t + \epsilon_t^{ir}$$

where ϵ_t^{ir} is the retail interest rate shock.

7. Uncovered interest parity

$$i_t - i_t^* + \Delta E_t s_{t+1} + \epsilon_t^s = \tau \left[i_{t-1} - i_{t-1}^* + \Delta s_t\right]$$

where ϵ_t^s is the exchange rate shock.

8. GDP expenditure

$$y_t = \frac{C}{Y} c_t + \frac{I_K}{Y} ik_t + \frac{I_H}{Y} ih_t + \frac{G}{Y} g_t + \frac{X}{Y} x_t - \frac{M}{Y} m_t$$

where ik_t is capital investment, ih_t is housing investment, g_t is government spending, x_t is exports, m_t is imports. Capital letters without time subscripts refer to steady state values.

[19] The monetary policy rule specified here is different to the one used in NZSIM. First, we have included a time variant inflation target so we can generate impuse response functions from a change to the target. Second, we have simplified the rule so interest rates react to expected inflation 1 quarter ahead rather than 4 quarters ahead. We avoid using the 4 quarter ahead rule because under full rational expectations it is possible to generate policy responses with plausible parameters in the interest rate reaction function that result in indeterminate equilibria. Introducing some inertia in the policy rule eliminates the indeterminacy and produces simulations that are qualitatively similar to those reported here. However, using a 1 quarter ahead policy rule simplifies the experiments and makes the results easier to interpret.

9. Import demand

$$
\begin{aligned}
m_t \quad = \quad & \frac{C_T}{Y_T}\left(c_t - \xi(p_{T,t} - p_t) + \epsilon_t^m\right) \\
& + \frac{Ik_T}{Y_T}\left(ik_t - \xi_i\left(1 - \upsilon_{T,Ik}\right)\left(p_{T,t} - p_{N,t}\right)\right) \\
& + \frac{Ih_T}{Y_T}\left(ih_t - \xi\left(1 - \upsilon_{T,Ih}\right)\left(p_{T,t} - p_{N,t}\right)\right) \\
& + \frac{G_T}{Y_T}\left(g_t - \xi\left(1 - \upsilon_{T,g}\right)\left(p_{T,t} - p_{N,t}\right)\right) \\
& + \frac{X_T}{Y_T}\left(x_t - \xi\left(1 - \upsilon_{T,x}\right)\left(p_{T,t} - p_{N,t}\right)\right) \\
& + \left(1 - \frac{M}{Y_T}\right)\xi_T(p_{T,t} - p_{M,t})
\end{aligned}
$$

where ϵ_t^m is the import demand shock, Y_T, C_T, $Ik_{,T}$, $Ih_{,T}$, G_T, and X_T are the steady state values of the tradables parts of aggregate demand components.

10. Tradable share of consumption

$$\frac{C_T}{Y_T} = \upsilon_T \frac{cy}{yty}$$

11. Tradable share of capital investment

$$\frac{Ik_T}{Y_T} = \upsilon_{T,Ik} \frac{iki}{yty}$$

12. Tradable share of housing investment

$$\frac{Ih_T}{Y_T} = \upsilon_{T,Ih} \frac{ihi}{yty}$$

13. Tradable share of government spending

$$\frac{G_T}{Y_T} = \upsilon_{T,g} \frac{gy}{yty}$$

14. Tradable share of exports

$$\frac{X_T}{Y_T} = \upsilon_{T,x} \frac{xy}{yty}$$

15. Tradable share of output

$$yty = v_T * cy + v_{T.Ik} * iki + v_{T,Ih} * ihi + v_{T,g} * gy + v_{T,x} * xy$$

$$v_T = 0.4359,\ v_{T,Ik} = 1,\ v_{T,Ih} = 0.2,\ v_{T,g} = 0.6,\ v_{T,x} = 0.4$$

16. Shares

$$\begin{aligned} cy &= 0.5852,\ gy = 0.1936,\ iy = 0.2063,\ xy = 0.3069, \\ my &= 0.2920,\ ihi = 0.05434,\ iki = 0.1520 \end{aligned}$$

17. Balance of payments

$$b_t - \frac{1}{\beta}b_{t-1} = \frac{P_M M}{Y}\left(p_{M,t} + m_t\right) - \frac{P_X X}{Y}\left(p_{X,t} + x_t\right) + \epsilon_t^b$$

where ϵ_t^b, is the debt shock, $p_{X,t}$ is the export price and any capital letters without time subscripts refer to steady state values.

18. Adaptive Expectations

$$\pi^e_{N,t+1} = \rho_1\pi^e_{N,t} + (1-\rho_1)[\rho_2 E_t\pi_{N,t+1} + (1-\rho_2)\pi_{N,t-1}] + \epsilon^e_t$$

$$\pi^e_{T,t+1} = \rho_1\pi_{T,t} + (1-\rho_1)[\rho_2 E_t\pi_{T,t+1} + (1-\rho_2)\pi_{T,t-1}] + \epsilon^e_t$$

$$\pi^e_{w,t+1} = \rho_1\pi^e_{w,t} + (1-\rho_1)[\rho_2 E_t\pi_{w,t+1} + (1-\rho_2)\pi_{w,t-1}]$$

$$\pi^e_t = 0.55\pi^e_{N,t} + 0.45\pi^e_{T,t}$$

where ϵ^e_t is the inflation expectations shock.

19. House price inflation

$$\begin{aligned} \pi_{H,t} - \delta_{H,1}\pi_{H,t-1} &= \delta_{H,2}\pi^e_{H,t} - \delta_{H,3}\left(ir_t - \pi^e_t + \zeta b_t\right) + \delta_{H,4} im_t \\ &\quad -\delta_{H,5}(p_{H,t} - p_t) - \delta_{H,6} b_t + \epsilon^{\pi H}_t \end{aligned}$$

where $\epsilon^{\pi H}_t$ is the house price inflation shock, $\pi_{H,t}$ is house price inflation and im_t is migration.

20. Housing investment

$$i_{H,t} = \Upsilon_{H,1}\pi_{H,t} + \Upsilon_{H,2} im_t - \Upsilon_{H,3}\left(i_t - \pi^e_t + \zeta b_t\right) + \epsilon^H_t$$

where ϵ^H_t is the housing investment shock.

21. Capital investment
$$i_{K,t} = \gamma_i y_t + \epsilon_t^K$$
where ϵ_t^K is the capital investment shock.

22. Export determination
$$x_t = \rho_{xx} x_{t-1} + \mu(p_{X,t} - \rho_t) + y_t^* + \epsilon_t^X$$
where ϵ_t^X is the export shock.

23. Government expenditure process
$$g_t = \rho_g g_{t-1} + \epsilon_t^G$$
where ϵ_t^G is the government expenditure shock.

24. Migration process
$$im_t = \rho_{im} im_{t-1} + \epsilon_t^{im}$$
where ϵ_t^{im} is the migration shock.

25. Foreign sector
$$\begin{aligned}
i_t^* &= \rho_{if} i_{t-1}^* + \epsilon_t^{if} \\
y_t^* &= \rho_{yf} y_{t-1}^* + \epsilon_t^{yf} \\
p_t^* &= p_{t-1}^* + \pi_t^* \\
p_t^* &= \rho_{pf} p_{t-1}^* + \epsilon_t^{pf} \\
p_{X,t}^* &= \rho_X p_{X,t-1}^* + \epsilon_t^{pX} \\
p_{M,t}^* &= \rho_M p_{M,t-1}^* + \epsilon_t^{pM}
\end{aligned}$$
where ϵ_t^{if} is the foreign interest rate shock, ϵ_t^{yf} is the foreign output shock, ϵ_t^{if} is the foreign interest rate shock, ϵ_t^{pf} is the foreign price level shock, ϵ_t^{pX} is the export price shock, and ϵ_t^{pM} is the import price shock.

References

Aruoba, S. B. (2014), "Term Structure of Inflation Expectations and Real Interest Rates: The Effect of Unconventional Monetary Policy," University of Maryland and Federal Reserve Bank of Minneapolis.

Aruoba, S. B (2016), "Term structures of inflation expectations and real interest rates. Working Papers 16-9, "Federal Reserve Bank of Philadelphia.

Blanchard, O., G. Dell'Ariccia, and P. Mauro (2010), "Rethinking Macroeconomic Policy, "IMF Staff Position Note SPN/10/03.

Bollard, A. (2002), "The Evolution of Monetary Policy in New Zealand," speech delivered on 25 November 2002.

Bollard, A. (2008), "Flexibility and the Limits of Inflation Targeting," speech delivered on 30 July 2008.

Bollard, A. and O. Karagedikli (2006), "Inflation Targeting in the New Zealand Experience and Some Lessons," paper prepared for the Inflation Targeting Performance and Challenges Conference by the Central Bank of the Republic of Turkey, Istanbul, 19-20 January, 2006.

Buiter, W. (2010), "Don't Raise the Inflation Target, Remove the Zero Lower Bound on Nominal Interest Rates Instead," *Global Macro View Citigroup Global Markets* (March 5).

Burgess, S, Fernandez-Corugedo, E, Groth, C, Harrison, R, Monti, F, Theodoridis, K and Waldron, M (2013), "The Bank of England's forecasting platform: COMPASS, MAPS, EASE and the suite of models" , Bank of England Working Paper No. 471.

Calomiris, C. W. and S. H. Haber (2014), *Fragile by Design: The Political Origins of Banking Crisis and Scarce Credit*, Princeton University Press, Princeton.

Diebold, F. X. and G. D. Rudebusch, (2012), *Yield Curve Modeling and Forecasting: The Dynamic Nelson-Siegel Approach*, Economics Books, Princeton University Press, 1(1), number 9895.

Doan, T., R. B. Litterman, and C. A. Sims (1983), "Forecasting and Conditional Projection Using Realistic Prior Distributions," *National Bureau of Economic Research*, 1202.

Dorich J, Johnston M K, Mendes R R, Murchison S, Zhang Y. (2013), "ToTEM II: An Updated Version of the Bank of Canada's Quarterly Projection

Model," Technical report, Bank of Canada 2013.

Granville, B. (2013), *Remembering Inflation*, Princeton University Press, Princeton.

Gurkaynak, R., and Wright, J. (2012), "Macroeconomics and the term structure," *Journal of Economic Literature*, 50, 331-67

Hall, V. B. and C. J. McDermott (2009), "The New Zealand business cycle," *Econometric Theory*, 25, 1050-1069.

Hall, V. B. and C. J. McDermott (2011), "A Quarterly Post-Second World War Real GDP Series for New Zealand," *New Zealand Economic Papers*, 45(3), 273-298.

Hall, V. B. and C. J. McDermott (2015), "Recessions and Recoveries in New Zealand's Post-Second World War Business Cycles," SEF Working paper: 09/2015.

Hargreaves, D. (2002), "The Implications of Modified Inflation Targets for the Behaviour of Inflation," in Reserve Bank of New Zealand, The Policy Targets Agreement: Reserve Bank Briefing Note and Related Papers, September, 57-59, http://www.rbnz.govt.nz/monetary_policy/policy_targets_agreement/0124760.html

Hargreaves, D, H Kite, and B Hodgetts (2006), "Modelling New Zealand inflation in a Phillips curve," Reserve Bank of New Zealand Bulletin, Vol 69 (3), 23-37.

Hunt, C. (2004), "Interpreting clause 4(b) of the Policy Targets Agreement: Avoiding Unnecessary Instability in Output, Interest Rates and the Exchange Rate," Reserve Bank of New Zealand *Bulletin*, 67, No. 2, 5-20.

Jacob P and Munro A (2016), "A macroprudential stable funding requirement and monetary policy in a small open economy," Reserve Bank of New Zealand Discussion Paper DP 2016/04.

Justiniano, A. and B. Preston (2010), "Monetary Policy and Uncertainty in an Empirical Small Open-Economy Model, " *Journal of Applied Econometrics*, 25(1), 93-128.

Kam, T., K. Lees, and P. Liu (2009), "Uncovering the Hit List for Small Inflation Targeters: A Bayesian Structural Analysis, " *Journal of Money, Credit and Banking*, 41(4), 583-618.

Kamber, G., C. McDonald, N. Sander, and K. Theodoridis (2015), "A

Structural Forecasting Model for New Zealand: NZSIM," Reserve Bank of New Zealand.

Karagedikli, O., and C. J. McDermott (2016), "Inflation expectations and the decline of inflation in New Zealand " Reserve Bank of New Zealand.

Khan, M. S. and A. S. Senhadji (2001), "Threshold Effects in the Relationship Between Inflation and Growth," *IMF Staff Papers*, 48(1), 1-21.

Kendall, R. and T. Ng (2013), "The 2012 Policy Targets Agreement: An Evolution in Flexible Inflation Targeting in New Zealand," Reserve Bank of New Zealand *Bulletin* 76(4), 3-12.

Lewis, M. (2015), "Forecasting with Macro-Finance Models: Applications to United States and New Zealand," Master of Commerce in Economics Thesis, Victoria University of Wellington, School of Economics and Finance.

Lewis M (2016), "Inflation expectations curve: a tool for monitoring inflation expectations." Reserve Bank of New Zealand *Analytical Note*, AN2016/01.

Orphanides, A. and J. C. Williams (2005), "Imperfect Knowledge, Inflation Expectations, and Monetary Policy," in B. S. Bernanke and M. Woodford (eds.) *The Inflation-Targeting Debate*, National Bureau of Economic Research, Chicago.

Razzak, W. (1997), "Testing the rationality of the National Bank of New Zealand's survey data," Reserve Bank of New Zealand Discussion Paper, G97/5.

Reifschneider, D. and J. C. Williams (2000), "Three Lessons for Monetary Policy in a Low Inflation Era," *Journal of Money, Credit and Banking*, 32, 936-966.

Reserve Bank of New Zealand (2000), "The Evolution of the Policy Targets Agreements," `http://www.rbnz.govt.nz/monetary_policy/about_monetary_policy/0096846.html`

Reserve Bank of New Zealand (2007), "Supporting Paper A1: Monetary Policy Framework and Goals," in Reserve Bank of New Zealand: Select Committee Submission, 24-35, http://www.rbnz.govt.nz/monetary_policy/about_monetary_policy/3075587.pdf

Richardson A. and R. Williams (2015), "Estimating New Zealand's Neutral Interest Rate," Reserve Bank of New Zealand *Analytical Note*, AN2015/05.

Reinhart, C. M. and K. S. Rogoff (2009), *This Time is Different: Eight Centuries of Financial Folly*, Princeton University Press, Princeton.

Stock, J. S, and Watson, W. W (2002), "Macroeconomic forecasting using diffusion indexes. " *Journal of Business and Economic Statistics*, 20(2), 147-162.

Waggoner, D. F. and T. Zha (1999), "Conditional Forecasts in Dynamic Multivariate Models," *Review of Economics and Statistics*, 81(4), 639-651.

Wright, J. H (2009), "Forecasting US inflation by Basyesian model averaging," *Journal of Forecasting*, 28(2), 131-144.