



Reserve Bank of New Zealand Analytical Notes

Estimating the NAIRU and the Natural Rate of Unemployment for New Zealand

AN2018/04

Punnoose Jacob and Martin Wong

March 2018

Reserve Bank of New Zealand Analytical Note Series
ISSN 2230 - 5505

Reserve Bank of New Zealand
PO Box 2498
Wellington
NEW ZEALAND

www.rbnz.govt.nz

The Analytical Note series encompasses a range of types of background papers prepared by Reserve Bank staff. Unless otherwise stated, views expressed are those of the authors, and do not necessarily represent the views of the Reserve Bank.

NON-TECHNICAL SUMMARY

Indicators of labour market slack such as the unemployment rate provide an important input into the Reserve Bank's assessment of capacity pressures in the economy, and therefore wage and price inflation. A measure of capacity pressure in the labour market is the unemployment gap, the difference between the headline rate of unemployment and some 'equilibrium' level of unemployment. Economists typically refer to this underlying level as the natural rate of unemployment or the Non-Accelerating Inflation Rate of Unemployment (NAIRU), and the two terms are sometimes used interchangeably. In this *Analytical Note*, we distinguish between these two unobservable measures of equilibrium unemployment. Then, using estimated macroeconomic relationships, we filter the data to obtain measures of the NAIRU and the natural rate for New Zealand.

While the natural rate of unemployment and the NAIRU are synonymous in the long run, there is an important distinction between the two concepts over shorter horizons. The natural rate is essentially a steady-state concept – it is the level of unemployment that reflects the structure of the labour market (for example, its demographic make-up, institutional and contractual factors, and technology), and after transitory shocks have fully worked through labour and product markets.

The NAIRU concept is similar to the extent that it is affected by similar structural forces in the economy. However it is not a steady-state concept – instead it represents the level of unemployment consistent with stable inflation in the short to medium term. The NAIRU takes into account the influence of structural changes and other shocks in the economy, and how they interact with frictions in labour and product markets. In the long run, the NAIRU converges to the natural rate of unemployment once the effects of the shocks hitting the economy have faded.

Much of this *Analytical Note* focuses on the NAIRU, which is the more relevant concept for understanding inflationary pressure over the medium-term time horizon relevant for monetary policy. The focus of monetary policy is to minimise fluctuations in cyclical unemployment, as indicated by the gap between the unemployment rate and the NAIRU, while also maintaining its objective of price stability. Monetary policy has limited influence on the natural rate of unemployment. However, since the natural rate can be influenced via structural policies, it is the more relevant measure of equilibrium unemployment for the long-term objectives of the Government.

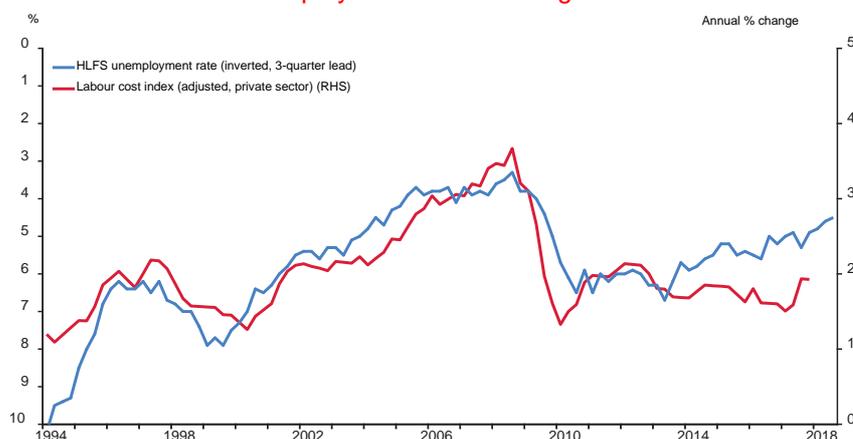
For 2017Q3, the end-point of our sample, our NAIRU estimates correspond to an unemployment gap that is around zero. This is consistent with other measures of capacity pressures. However, we emphasise that point estimates of the NAIRU and the natural rate are imprecise and highly sensitive to sample periods, data choices, and

model specifications. The confidence interval of our estimates approximately spans from 4.0 to 5.5 percent. This imprecision suggests that other observable indicators are needed to supplement estimates of equilibrium unemployment in assessing the overall degree of labour market slack.

1 Introduction¹

Indicators of labour market slack such as the unemployment rate and wage inflation (Figure 1) are important inputs to the Reserve Bank’s assessment of capacity pressures in the economy. A measure of capacity pressure in the labour market is the unemployment gap, the difference between the headline rate of unemployment and some ‘equilibrium’ level of unemployment. Economists typically refer to this underlying rate as the natural rate of unemployment or the Non-Accelerating Inflation Rate of Unemployment (NAIRU), and the two terms are sometimes used inter-changeably. In this *Analytical Note*, we distinguish between these two unobservable measures of equilibrium unemployment. Relying on estimated macroeconomic relationships, we filter the data to obtain measures of the NAIRU and the natural rate for New Zealand.

Figure 1: New Zealand unemployment rate and wage inflation



Source: Statistics New Zealand. HLFS denotes the Household Labour Force Survey.

The natural rate was first introduced by Phelps (1967) and Friedman (1968), and stems from the notion that there is no long-run trade-off between inflation and unemployment. Given forward-looking economic agents, an unemployment rate below the natural rate cannot be maintained by policy-makers without ever-increasing rates of inflation.² The natural rate is defined as the level of unemployment to which the economy converges in the long run in the absence of business cycle fluctuations and structural changes. Institutional settings and structural change in labour and goods markets are therefore key determinants of the natural rate of unemployment.

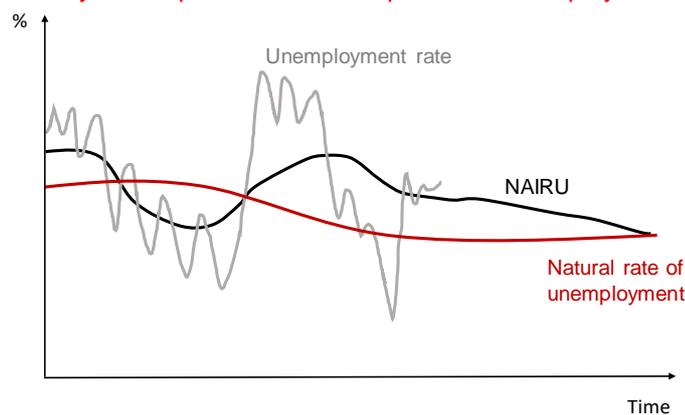
The NAIRU is a related theory of equilibrium unemployment introduced by Modigliani and Papademos (1975). It can be more narrowly defined as the rate of unemployment consistent with actual inflation at its expected level over the medium term. The NAIRU

¹ We wish to thank Tom Cusbert, Michelle Lewis, Murat Ozbilgin, Roger Perry, Amy Rice, Karam Shaar, Christie Smith, Tom Smith, Kam Szeto, Hao Wang, and Rebecca Williams for their inputs.

² If monetary policy attempted to maintain an unemployment rate below the natural rate, then inflation expectations today would adjust higher, and workers would demand higher nominal wages, in turn leading to higher inflation today. Higher wages today would lead to layoffs and thus the unemployment rate would increase back towards the natural rate, but inflation would be higher.

is affected by the same structural forces as the natural rate. However, it is not a steady-state measure and is estimated from the relationship between inflation and unemployment (the Phillips curve). Unlike the natural rate, the NAIRU may be distorted by the influence of transitory shocks, for example to wage- and price-setting behaviour, over shorter horizons. As indicated by Figure 2, estimates of the NAIRU are thought to fluctuate more than the natural rate.³ In the long run, the NAIRU converges to the natural rate once the effects of the shocks hitting the economy dissipate.

Figure 2: RBNZ stylised representation of equilibrium unemployment



Much of this *Analytical Note* focuses on measuring a time-varying NAIRU since its dynamics, in response to shocks, are more relevant for understanding inflationary pressure over recent history. It can be used to supplement other observable labour market indicators to provide a richer understanding of capacity pressures relevant for the time horizon of monetary policy. The focus of monetary policy is to minimise fluctuations in cyclical unemployment, as indicated by the gap between the unemployment rate and the NAIRU, while also maintaining its objective of price stability. Monetary policy has limited influence on the natural rate of unemployment. However, since the natural rate can be influenced via structural policies, it is the more relevant measure of equilibrium unemployment for the long-term objectives of the Government.

The two econometric approaches explored in this *Note* provide a historical estimate for the time-varying NAIRU, and cannot be used to forecast changes in the NAIRU arising from technological change or government policy going forward. The first approach uses a suite of reduced-form price and wage Phillips curves while the second approach relies on a structural New Keynesian model. While both approaches provide estimates of the NAIRU, the latter (New Keynesian) approach additionally provides estimates of the natural rate of unemployment as the steady-state of the NAIRU. In 2017Q3, the end-point of our sample, the point estimates of the NAIRU estimates centre around 4.7 percent and the confidence interval approximately spans from 4.0 to 5.5 percent,

³ For further discussion of this distinction, see Estrella and Mishkin (1999) and Richardson, Boone, Giorno, Meacci, Rae and Turner (2000).

implying a high degree of uncertainty on the magnitude of the unemployment gap.⁴ The NAIRU estimates appear to be slightly lower than the natural rate estimate from the structural New Keynesian model of about 5 percent.

We proceed as follows. Section 2 explores some of the factors that have influenced the rate of unemployment in New Zealand. We then describe the Phillips Curve framework underpinning the NAIRU in section 3. Section 4 presents the estimation strategy and results, and section 5 concludes.

2 Background: Forces influencing New Zealand's unemployment rate

The headline unemployment rate in New Zealand has been trending down over time. This fall in the unemployment rate has not been accompanied by a rise in inflation, suggesting that the underlying natural rate and the NAIRU may have also declined through time.⁵ In this section, we document some of the changes in the New Zealand economy that have influenced the unemployment rate over history.

As a first step, we disaggregate the unemployment rate into three sub-components as follows:

- a. **Cyclical unemployment** results from changes in aggregate demand conditions over the course of a business cycle. As firms experience weaker demand, existing workers may be laid off and fewer new workers will be hired.
- b. **Frictional unemployment** refers to the regular short-term churn in the labour market, both within, and in and out of, the labour force.⁶ It is determined by the efficiency of the matching process given the diversity of job-seekers and vacancies.
- c. **Structural unemployment** represents a more fundamental mismatch between those hiring and job seekers given their skills and geographic location. This could arise from long-lasting changes in the structure of the economy such as socio-demographic trends, technological change, or a rapid change in the mix of industries.

The lines between these categorisations can be indistinct. For example, some argue that a prolonged period of cyclical unemployment could also lead to hysteresis effects

⁴ This compares with the New Zealand Treasury's NAIRU estimate of 4.3 percent.

⁵ We detect a statistical break in the unemployment rate in 2000Q3 where the average unemployment rate has declined from about 7 percent before the break to around 5 percent after. The break date of 2000Q3 arises from regressing the unemployment rate on a constant between 1987Q1 and 2017Q3, and conducting a Bai-Perron sequential break test in the econometric software E-Views.

⁶ See also Armstrong and Karagedikli (2017) for a discussion of labour market gross flows in New Zealand.

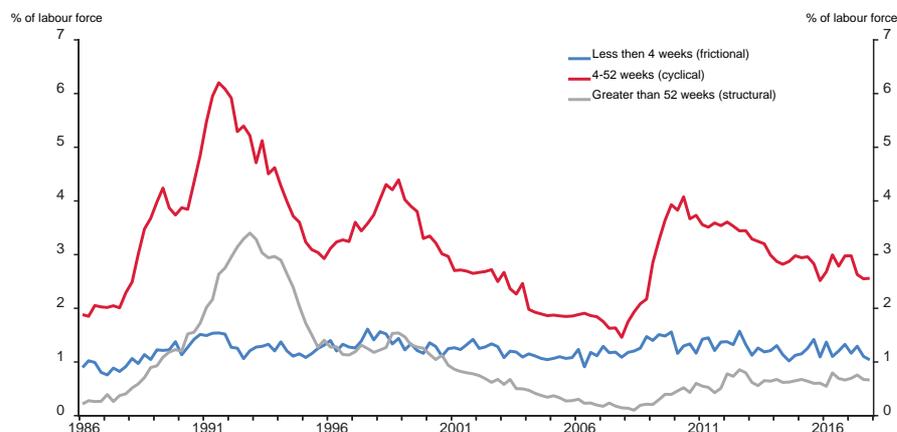
that could spill over to structural unemployment.⁷ For example, an extended period of unemployment may lead to an erosion of human capital making workers less attractive to employers and hence reducing their bargaining power.

In principle, frictional unemployment and structural unemployment should be captured by the trend in the NAIRU or the natural rate, as both forms of unemployment may continue to exist even if the labour market is in equilibrium. This is because those that are structurally unemployed may not be easily drawn back into employment despite an increase in labour demand and an upward adjustment in wages. In addition, the level of frictional unemployment is largely determined by the efficiency with which potential workers and employers can find jobs. In contrast, cyclical unemployment captures when the labour market may be operating below capacity as a result of a shortfall in demand.

Monetary policy has little influence over the level of frictional and structural employment. These are largely determined by the evolution of technology and the obsolescence of skills, and by structural policies to facilitate the acquisition of new skills and improve the match between employers and job-seekers. For example, policies that affect the cost of hiring (e.g. employment protection laws), the incentives for job finding (e.g. unemployment insurance), or the bargaining power of workers (unionisation and labour contract laws).

In Figure 3, we decompose the pool of unemployed workers on the basis of unemployment durations. In particular, we categorise those who have been unemployed for less than 4 weeks as contributing to frictional unemployment, 4 to 52 weeks as cyclical unemployment, and greater than 52 weeks as structural unemployment.⁸

Figure 3: Unemployment by duration (seasonally-adjusted)



Source: Statistics New Zealand.

⁷ See Blanchard (2018).

⁸ The disaggregation by the duration of unemployment follows Ballantyne, De Voss and Jacobs (2014) in their analysis on the Australian labour market.

The late 1980s to early 1990s can be characterised as a period of high cyclical and structural unemployment. Structural forces came through product market reforms in the second half of the 1980s as a number of industries were deregulated. At the same time over this period there was a global recession, disinflationary policy, and fiscal consolidation, which all had a negative impact on aggregate demand.⁹ Meanwhile, frictional unemployment has been broadly stable over the history of the sample.

In the early 1990s, there were a number of government policy changes affecting the labour market, with the most significant ones being the Employment Contracts Act in 1991 and the benefit reforms over 1990-91. Several studies have concluded that these early reforms were successful in encouraging higher employment growth and a lower unemployment rate on average.¹⁰ This is consistent with structural unemployment falling in the 1990s, and with most of the subsequent swings in the aggregate unemployment rate being driven by cyclical unemployment.^{11 12}

Other studies point to changes in the age structure and educational attainment of the population between 1985 and 2000 as contributing to the decline in the underlying unemployment rate (Carroll and Chapple, 2001). A more recent factor has been the rise in the labour force participation of older workers (those aged over 55). From 2000 to 2017, this group contributed 6.5 percentage points to the increase in the labour force participation rate. The increased participation by older workers has helped to offset the 3.2 percentage point drag from the effects of population ageing as workers retire (Culling and Skilling, 2018). Since workers aged over 55 are less likely to be unemployed compared to younger cohorts, population aging has potentially placed downward pressure on the equilibrium rate of unemployment.

Another lens is the inverse relationship between inflation and unemployment, also known as the Phillips Curve. This relationship implies that when there is excess capacity in the labour market, wage and price inflation would be expected to fall. The downward-sloping Phillips curve is apparent in Figure 4 which plots core inflation against headline unemployment for New Zealand. There has been also an apparent shift inwards of this relationship where lower rates of unemployment have become possible for a given level of inflation, particularly relative to the 1990s. The simple plot in Figure 4 does not take into account other factors such as changes in inflation expectations or import prices, which also have the potential to shift the Phillips Curve.¹³

⁹ Chapple, Harris and Silverstone (1996) conclude that cyclical factors were more significant in driving up unemployment over this period.

¹⁰ See Richardson et al. (2000) and Maloney and Savage (1996).

¹¹ Borland (2014) reached a similar conclusion from examining matching efficiency and Okun's Law in New Zealand.

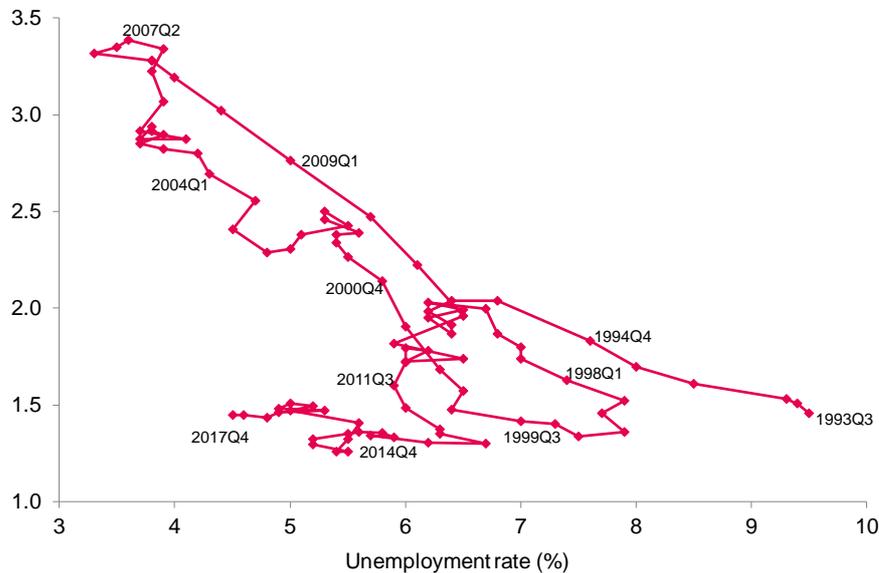
¹² Subsequent policy changes such as the Employment Contracts Act (2000), Working for Families scheme (2005), and the 90-day trial period (2009) may have also impacted structural unemployment at the margin.

¹³ We control for these factors in our estimation later in section 4.

Another potential reason for the inward shift could be a fall in the equilibrium rate of unemployment.

Figure 4: New Zealand Phillips curve (1993 - 2017)

Core inflation - sectoral factor model (annual % change)



Source: Reserve Bank of New Zealand, Statistics New Zealand.

3 The time-varying NAIRU: Framework

There are a number of ways to model the NAIRU in the empirical literature. Some estimate the NAIRU as a function of policy and institutional variables that impact the labour market.¹⁴ Others model the NAIRU by incorporating the matching efficiency of the unemployed and job vacancies, also known as the Beveridge curve.¹⁵ Others simply use the Hodrick-Prescott (HP) filter to extract the trend component in the unemployment rate. We choose to estimate the NAIRU using the framework of the accelerationist Phillips curve which specifies inflation as a function of inflation expectations and the unemployment gap. We then extract the estimate of the unobserved NAIRU using estimated macroeconomic relationships via the Kalman filter. It is important to emphasise that estimates of the NAIRU tend to be imprecise given its unobservable nature. For example, Staiger, Stock and Watson (1996) found a typical 95 percent confidence interval of ± 1.3 percent around a central NAIRU estimate for the United States.¹⁶

Our approach allows us to generate timely estimates of the NAIRU as we rely on quarterly macroeconomic data that are updated regularly. Unlike the approaches linking the NAIRU to structural or policy determinants, our framework is less affected by data

¹⁴ See Gianella, Koske, Rusticelli and Chatal (2008) for a study of a panel of OECD economies.

¹⁵ See Dickens (2011).

¹⁶ This level of imprecision was true whether the NAIRU was modelled as a constant, an unobserved random walk, a function of labour market fundamentals, or a slowly changing function of time.

limitations. The Kalman filter approach has an advantage over traditional statistical univariate filters such as the HP filter as it enables the incorporation of economic structure. But, as with the HP filter, estimates may still suffer from end-point issues meaning the historical path could be substantially revised as new data become available.

At a purely conceptual level, the accelerationist Phillips Curve (in equation (1)), shows that unemployment can be pushed away from its equilibrium level (u^{NAIRU})¹⁷ in the short run given aggregate demand shocks or inertia in wage- or price-setting. The impact of this deviation is inversely related to inflation as measured by $(-\alpha)$.

$$\pi_t = \pi_t^e - \alpha(u_t - u^{NAIRU}) \quad (1)$$

If expected inflation is well approximated by the previous period's inflation rate, then equation (1) can be re-written as equation (2). Equation (2) also includes supply-shock factors (Δv_t) that impact on inflationary pressure.¹⁸

$$\pi_t - \pi_{t-1} = -\alpha(u_t - u^{NAIRU}) + \Delta v_t \quad (2)$$

All else equal, equation (2) shows that inflation will be increasing if the actual unemployment rate (u_t) is less than the NAIRU, and inflation will be decreasing if the unemployment rate is greater than the NAIRU (i.e. when the labour market is below capacity). Inflation will increase or decrease until the unemployment rate returns to the NAIRU. Equation (2) highlights that unemployment cannot be kept permanently below the NAIRU without ever-increasing inflation.

In practice, different studies estimate variations of equation (2) with quite different regressors. For example, the researcher may choose to use either backward- or forward-looking measures of inflation expectations, depending on how economic agents actually form their inflation expectations.¹⁹ There are also a variety of inflation measures that could be used, including 'core' measures that exclude volatile components like food and energy, price indices that exclude the impact of government charges, or the household consumption deflator. As capacity pressure in the labour market may be reflected in wages before goods prices, one could also opt to use a wage Phillips Curve instead. There are pros and cons to each of these choices and some will depend on country-specific factors. The range of specifications adds another level of imprecision to the estimation of the NAIRU, in addition to parameter and model uncertainty.

¹⁷ Hereafter, the NAIRU will be denoted by u^{NAIRU} while the natural rate will be denoted by u^* .

¹⁸ This representation of the Phillips Curve is part of the 'triangle' model of inflation popularised by Gordon (1997).

¹⁹ See Rusticelli, Turner and Cavalleri (2015) for a comparison of NAIRU estimates using a traditional backward-looking Phillips Curve versus inflation expectations anchored around the central bank's inflation objective.

The inclusion of high frequency supply shocks in equation (2) mean that the NAIRU is consistent with steady inflation in the absence of temporary supply influences. This is how the medium-term concept of the NAIRU is typically regarded.²⁰ In practice, it is difficult to control for all temporary supply influences that affect price and wage inflation, and therefore these factors could be captured by apparent changes in estimates of the NAIRU.

A simple way to estimate the NAIRU from equation (2) would be to back it out from the parameters estimated from a least squares regression. In such a framework, the NAIRU would be a function of the intercept term that keeps inflation equal to inflation expectations, on average, over the whole sample.²¹ However, we find that the estimates from this approach are not stable over time. There is evidence of a structural break in several of the regression models and a rolling window analysis also indicates a time-varying pattern in the NAIRU estimate. The approaches we explore in the next section estimate the NAIRU as a time-varying unobserved variable.

4 Estimation strategy and results

We present two empirical strategies for estimating a time-varying NAIRU. The first uses a reduced-form Phillips Curve model – a standard approach used by a number of central banks, as well as the OECD. The second approach uses a small-scale New Keynesian model, where additional structural relationships are imposed on the data, along with the Phillips Curve. The latter also allows the natural rate to be estimated as a long-term steady-state of the NAIRU. The Kalman filter is used to extract the unobserved NAIRU from the observed data series used in both estimation techniques.

The approaches we explore rely on estimated historical macroeconomic relationships and are not explicitly linked to structural or institutional determinants in the labour market, for example, employee bargaining power or disruption from technological change. Therefore, the frameworks in this *Note* do not allow us to analyse the implications of these shocks for the NAIRU.

4.1 Approach one: Reduced-form Phillips Curve models

In the reduced-form approach, we estimate the NAIRU through the Phillips Curve framework that was described in section 3. We examine two different models. The first model uses information from both a price and wage Phillips Curve to estimate the NAIRU following the methodology in Cusbert (2017) and Ballantyne et al. (2014). In the second model, we use a price Phillips Curve where the dependent variable is specified

²⁰ See Richardson et al. (2000).

²¹ The NAIRU can be calculated by dividing the estimated constant by the slope coefficient on unemployment.

as an inflation gap as in Szeto and Guy (2004), Greenslade et al. (2003), and Richardson et al. (2000).

Model (1)

For Model (1), the wage and price Phillips Curves are described by equations (3) and (4) respectively.²² Wage inflation (π_t^w) is measured using Statistics New Zealand's Labour Cost Index adjusted for productivity growth. CPI inflation (π_t) is used in the price Phillips Curve and has been adjusted for GST rate changes. For inflation expectations (π_t^e), we use estimated long-term inflation expectations,²³ but also repeat the estimation with a less forward-looking measure using the RBNZ 2-year ahead surveyed expectations.²⁴ Lags of wage and price inflation are included to account for any inertial effect. In each Phillips Curve equation, we select the lag structure by estimating the equation using the least squares technique and sequentially dropping the lags associated with statistically insignificant coefficients. The inclusion of the variable $\frac{\Delta u_{t-1}}{u_t}$ (Δ indicating a change) also controls for possible 'speed-limit' effects where the rate of change in unemployment could have differing impacts on inflationary pressure. Temporary supply shocks are controlled for using changes in CPI petrol prices (Δp_t^o) and import prices (Δp_t^m).

$$\pi_t^w = \alpha_w \pi_t^e + \rho_1 \pi_{t-4}^w + \rho_2 \pi_{t-6}^w + \beta_w \left(\frac{u_t - u_t^{nairu}}{u_t} \right) + \omega_w \left(\frac{\Delta u_{t-1}}{u_t} \right) + \gamma_w \Delta p_t^o + \theta_w \Delta p_t^m + \varepsilon_t^w \quad (3)$$

$$\varepsilon_t^w \sim N(0, \sigma_w^2)$$

$$\pi_t = \alpha_p \pi_t^e + \varphi_1 \pi_{t-1} + \varphi_2 \pi_{t-4} + \beta_p \left(\frac{u_t - u_t^{nairu}}{u_t} \right) + \omega_p \left(\frac{\Delta u_{t-1}}{u_t} \right) + \theta_p \Delta p_t^m + \gamma_p \Delta p_t^o + \varepsilon_t^p \quad (4)$$

$$\varepsilon_t^p \sim N(0, \sigma_p^2)$$

Equations (3) and (4) are estimated jointly with a transition equation for the NAIRU given by equation (5) where the NAIRU is specified as a time-varying random walk.²⁵

$$u_t^{NAIRU} = u_{t-1}^{NAIRU} + v_t \quad v_t \sim N(0, \sigma_v^2) \quad (5)$$

Model (2)

²² See appendix (I) for full details of the data and their sources for the reduced-form approach.

²³ This is modelled from survey-based measures of inflation expectations as in Lewis (2016).

²⁴ As mentioned before, there are a number of inflation expectations measures one can include in the reduced-form approach. Our choices are based on the consistency of the resulting NAIRU estimates with alternative indicators of spare capacity in the economy over history.

²⁵ The covariance of the error terms in the Phillips Curve equations with v_t is assumed to be zero.

The second model is shown by the price Phillips Curve in equation (6). It relates the inflation gap (π_t^g) to the unemployment gap $\left(\frac{u_t - u_t^{nairu}}{u_t}\right)$ implying that inflation is stable ($\pi_t = \pi_t^e$) when unemployment is equal to the NAIRU, all else constant. As in Model (1), lags of the inflation gap (π_{t-4}^g) are also included to account for any inertia effect. In this specification, π_t^e is proxied using a 2-year adaptive measure of inflation expectations.²⁶ The same controls for speed-limit effects and temporary supply shocks from Model (2) are also included. Equation (6) is estimated jointly with the same transition equation for the NAIRU as in Model (1) (i.e. equation (5)).

$$\pi_t^g = \alpha_1 \pi_{t-4}^g + \beta_g \left(\frac{u_t - u_t^{nairu}}{u_t}\right) + \theta \Delta p_t^m + \gamma \Delta p_t^o + \omega_g \left(\frac{\Delta u_{t-1}}{u_t}\right) + \varepsilon_t^g \quad (6)$$

$$\varepsilon_t^g \sim N(0, \sigma_g^2)$$

$$\text{where } \pi_t^g = \pi_t - \pi_{t-8}^e$$

Results

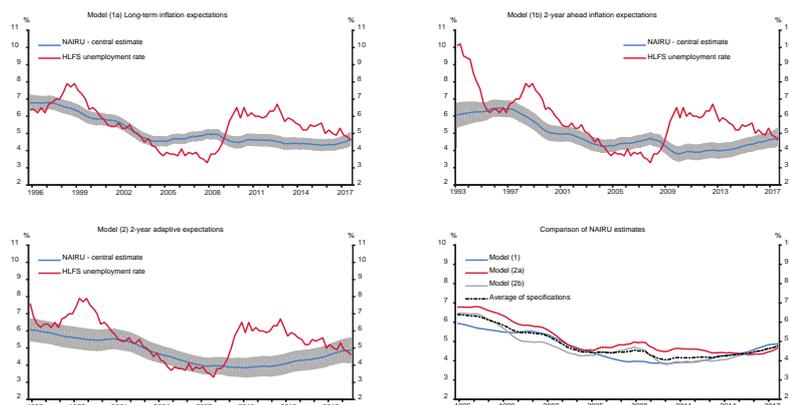
The parameters of the Phillips Curve models and the unobserved NAIRU are estimated by maximum likelihood using the Kalman filter.²⁷ For further detail on the Kalman filter technique for estimating the NAIRU, see Greenslade et al. (2003). The NAIRU estimates for each Phillips Curve model are presented in Figure 5. The first model is estimated using long-term inflation expectations and then 2-year ahead inflation expectations in (1a) and (1b) respectively. The NAIRU at 2017Q3 is estimated to be at 4.7 percent for Model (1a) and 4.8 percent for Model (1b) and 4.9 percent for Model (2), although the error bands can be as large as 0.80 percentage points in some cases.²⁸ All three central estimates show that the NAIRU has settled around 4 to 5 percent since the early 2000s. This is consistent with the observation in section 2 that cyclical unemployment has likely been more prominent following the economic reforms in the early 1990s.

²⁶ In McDonald (2017), the adaptive measure was shown to outperform surveyed inflation expectations in producing forecasts of non-tradables inflation over history.

²⁷ The signal-to-noise ratio of the NAIRU is estimated from the data rather than being restricted in the filtering procedure.

²⁸ The NAIRU estimates can range from 3.5 percent to 6.0 percent across both models depending on the choice of inflation expectations used, reflecting the specification uncertainty associated with the reduced-form approach.

Figure 5: NAIRU estimates from all Phillips Curve models



Note: The grey shaded bands represent ± 1 RMSE. The estimation samples differ due to the availability of data for the inflation expectation measures.

Given the concerns around stationarity in the HLF5 unemployment series, the Phillips Curve models are re-estimated using a shorter sample beginning at the break date of 2000Q3. Doing so gives slightly lower NAIRU estimates of 4.6, 4.4 and 4.7 percent in 2017Q3 for specifications (1a), (1b) and (2) respectively. These differences are within the error bounds for each model.

4.2 Approach two: A small-scale New-Keynesian model

Departing from the reduced-form set-up explored in the previous section, we now adopt a more elaborate structural business cycle framework that enables us to jointly estimate the NAIRU and the natural rate of unemployment.

In any period t , the NAIRU u_t^{NAIRU} is assumed to be composed of two elements: $u_t^{NAIRU} = \bar{u}^* + \hat{u}_t^{NAIRU}$. The first component \bar{u}^* is the natural rate of unemployment, the long-run steady-state of the NAIRU. Importantly, the natural rate is also identical to the steady-state of actual unemployment. In the long run, once the effects of the shocks hitting the economy dissipate, the NAIRU and the actual unemployment rate settle at the natural rate of unemployment. In statistical terms, when we estimate the model, \bar{u}^* is the mean of the unemployment rate, conditional on the model. On the other hand, in the short run, the NAIRU can deviate from the natural rate of unemployment because the second component \hat{u}_t^{NAIRU} is specified as a cyclical deviation from the steady-state that can potentially be persistent:

$$\hat{u}_t^{NAIRU} = \rho_n \hat{u}_{t-1}^{NAIRU} + \eta_t^n, \rho_n \in [0,1], \quad \eta_t^n \sim N(0, \sigma_n^2). \quad (8)$$

Along the lines of Benes et al. (2010), the difference between the unemployment rate u_t and the NAIRU, which we term the unemployment gap, is linked to the output gap \hat{y}_t through an empirical relationship:

$$u_t - u_t^{NAIRU} = \rho_{ugap}(u_{t-1} - u_{t-1}^{NAIRU}) - (1 - \rho_{ugap})u_y \hat{y}_t \quad (9)$$

$$\rho_{ugap} \in [0,1), u_y > 0.$$

The unemployment gap is negatively correlated to the output gap and increases with a rise in the lagged unemployment gap. In the long run, as the unemployment rate and the NAIRU approach the natural rate, and output is at the economy's potential, the unemployment gap and the output gap converge to zero.

In the rest of the model, the cyclical dynamics of the output gap, price and wage inflation, inflation expectations, and the short-term interest rate are driven by structural disturbances within a standard New Keynesian environment.²⁹ The output gap is negatively correlated to the expected real interest rate. Price inflation rises with an increase in the real wage and nominal wage inflation is positively correlated to the output gap. Monetary policy reacts to price inflation using an empirical rule. We replace the rational expectations structure of the New Keynesian economy, with laws of motion for price and wage inflation expectations that are more backward-looking. Apart from the exogenous process defined for the NAIRU, we embed six other shocks in the model; a demand shock, cost-push shocks to price and wage inflation, shocks to price and wage inflation expectations, and a monetary policy shock.

We use Bayesian methods to estimate the model using seven quarterly data series; output growth, the HLFs unemployment rate, CPI inflation, Labour Cost Index wage inflation, the 90-day interest rate, and the RBNZ survey measures of 2-year ahead CPI and wage inflation expectations. The appendix (section II) offers a formal description of the model and also details of the estimation methodology.³⁰

Just as in the reduced-form Phillips Curve framework, the Kalman filter helps us to extract the unobserved NAIRU from the observed data series used in the estimation. However, a key difference from the former approach is that the estimate of the NAIRU offered by this framework is disciplined by the structural general equilibrium relationships that we have imposed on the data.

Estimates of the NAIRU

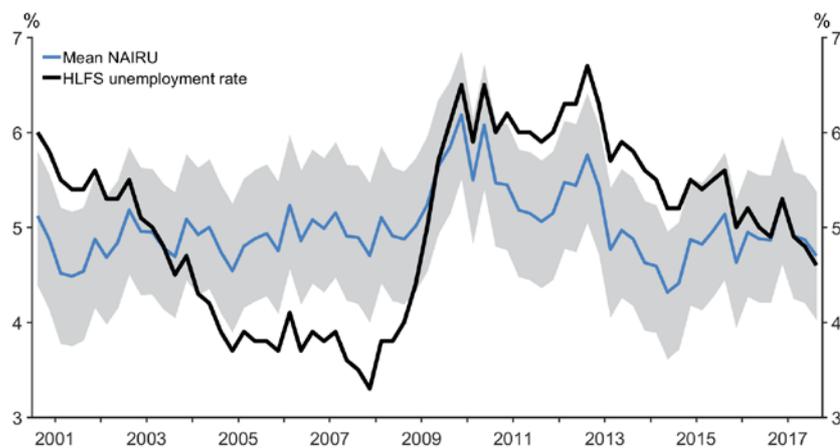
To address concerns over the stationarity of the HLFs unemployment series, we first estimate the model on a restricted sample beginning 2000Q3, reflecting the detected structural break, and ending in 2017Q3. The model is simulated for a wide range of

²⁹ See Bodenstein and Zhao (2017) for a recent review of the New Keynesian model.

³⁰ We have also considered variants of the baseline New Keynesian model where we experiment with purely rational expectations, or use different combinations of data series and shocks. The results are broadly in line with those presented in this paper.

potential parameter values and Figure 6 presents the estimated mean and the 90 percent probability bounds of the NAIRU from the restricted sample. The estimates are seen to be very imprecise. However, the NAIRU has been significantly below the unemployment rate, i.e. the unemployment gap has been positive, for most of the period subsequent to the Global Financial Crisis (GFC). At the end of the sample, while the mean NAIRU touches the 4.7 percent mark, the 90 percent probability interval, obtained from simulating the model for a wide range of potential parameter values, spans from 4 to 5.4 percent. The full range of estimated NAIRUs at the end of the sample is even wider, spanning 3.1 to 6.3 percent. This implies a high degree of uncertainty on the magnitude of the unemployment gap.

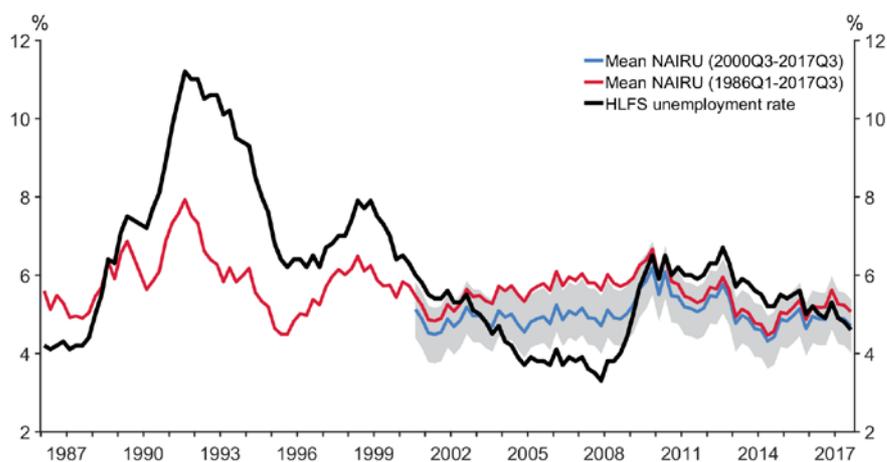
Figure 6: The NAIRU estimated from the New Keynesian model



Note: The shaded area indicates the 90 percent probability bounds for the estimated NAIRU.

In Figure 7, we plot the estimated NAIRUs for two different samples. The first sample spans 2000Q3-2017Q3 during which the HLFS unemployment rate is confirmed to be stationary. The mean estimate obtained from the restricted sample is plotted in blue. In the second sample, we disregard the apparent non-stationarity in the unemployment series and estimate the model using all the available data of the HLFS, beginning from 1986Q1. The full sample estimate is plotted in red and is seen to be significantly higher than the estimate from the restricted sample in the period prior to the GFC. However, towards the end of history, the two measures are not significantly different, as the full sample estimate falls within the 90 percent probability interval from the restricted sample estimate.

Figure 7: NAIRU estimates over different samples



Note: The shaded area indicates the 90 percent probability bounds for the estimated NAIRU using the sample from 2000Q3 to 2017Q3.

Estimates of the natural rate of unemployment

The New Keynesian model also provides a framework to pin down the rate of unemployment that the economy will settle at in the long run, once the effects of structural change and the shocks hitting the economy fade away. This measure, known as the natural rate, is the steady-state value of the NAIRU as well as the actual unemployment rate. For the baseline sample, the natural rate is estimated at 4.98 with a standard deviation of 0.41 (Table 1). This is above the NAIRU estimate of about 4.7 percent estimated for 2017Q3. Over the full sample, the natural rate is estimated to be still higher at 5.65.

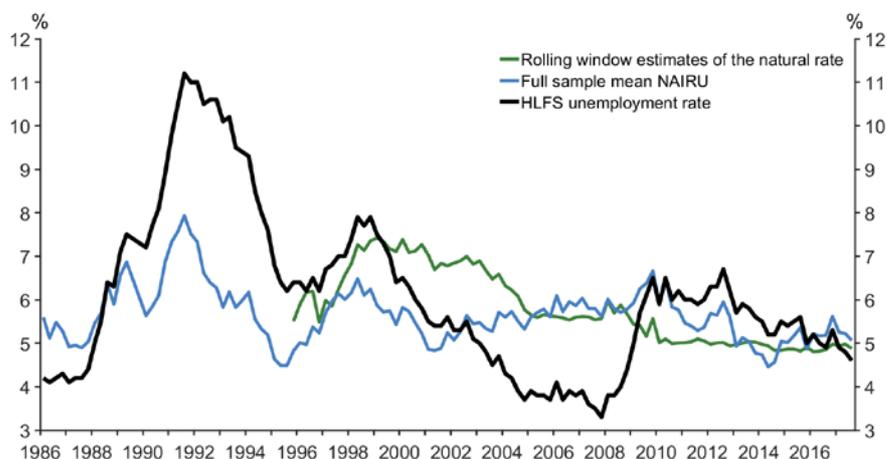
Table 1: The natural rate of unemployment estimated from the New Keynesian model

Sample:	2000Q3-2017Q3	1986Q1-2017Q3
Mean (Std. dev.)	4.98 (0.41)	5.65 (0.59)

In contrast to the NAIRU which can vary within a given sample period, the natural rate represents a constant steady-state for any fixed period. However, as the sample under consideration changes, the natural rate can also change. To provide a flavour of how the natural rate has shifted over time, we estimate the New Keynesian model over a sequence of different sample periods. In Figure 8, we present the results from an estimation exercise that uses a rolling window of 10 years starting in 1986Q1. The rolling window estimate shows that the natural rate has declined from about 7 percent in early 2000 and settled to around 5 percent in the more recent estimation windows.

This is again consistent with the influence of institutional reforms prior to the 2000s and recent socio-demographic trends discussed in section 2.

Figure 8: A rolling window estimation of the natural rate

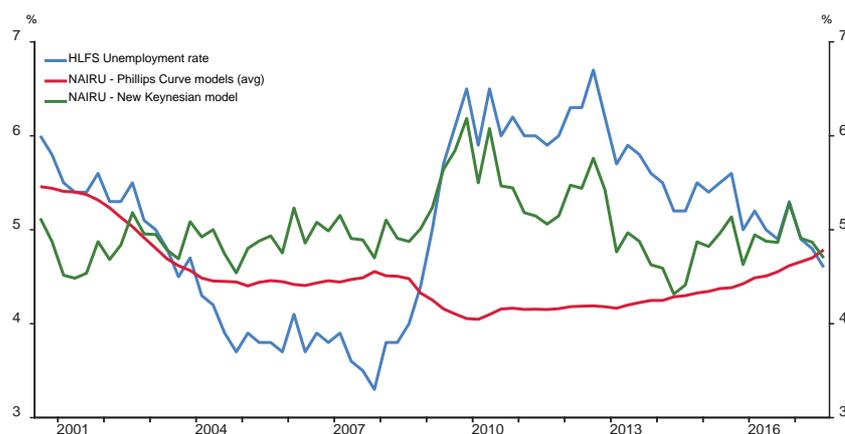


Note: We use a 40-quarter rolling window beginning in 1986Q1.

4.3 Comparison of NAIURU estimates

In Figure 9, we plot the NAIURU estimates from the Phillips Curve models (as an average of the three specifications) and the estimate from the New Keynesian model. Even though the two methodologies produce different historical trajectories for the NAIURU, they suggest a mean NAIURU of around 4.7 at the end of the sample. Given that the actual HLFS unemployment rate was 4.6 percent as at 2017Q3, this points to an unemployment gap around zero.

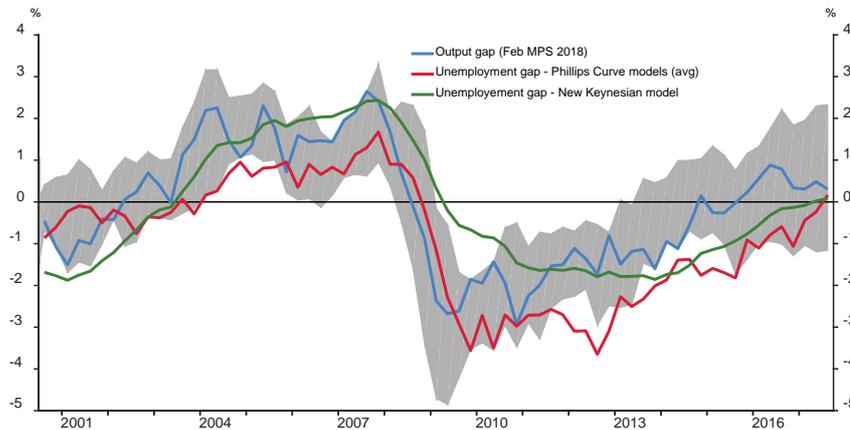
Figure 9: The NAIURU estimated using the two approaches



To assess the plausibility of our estimates, we now compare the estimated unemployment gaps with alternative indicators of capacity pressures in the economy. The implied unemployment gaps, shown in Figure 10, are broadly consistent with the historical path for the RBNZ's output gap estimate as at the February 2018 *MPS*. The unemployment gaps are also broadly consistent with the suite of output gap indicators

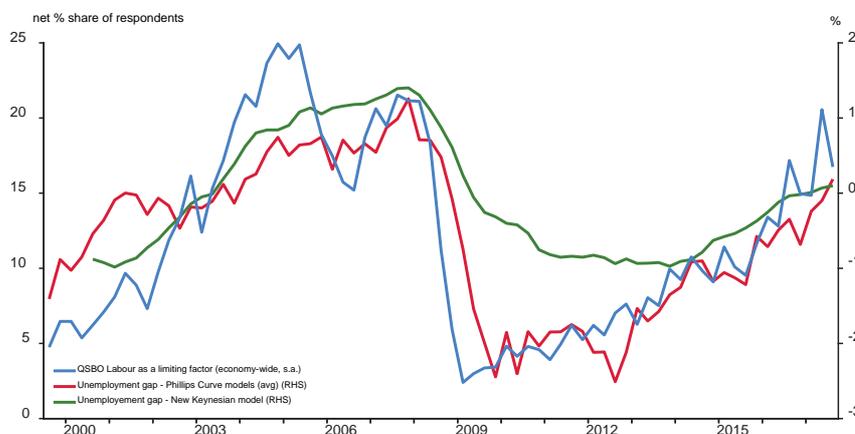
over history. They indicate a labour market operating above capacity in the mid-2000s and a prolonged period of excess slack since the GFC.³¹ Figure 11 shows that the unemployment gaps also correspond with the trend in surveyed measures of labour market capacity from the NZIER Quarterly Survey of Business Opinion (QSBO).

Figure 10: The estimated unemployment gaps and the output gap indicator suite



Note: The grey shaded band represents the range of output gap estimates from the Bank's output gap indicator suite, excluding the unemployment gap indicators. The unemployment gaps have been inverted and rescaled for ease of comparison.

Figure 11: The estimated unemployment gaps and surveyed labour capacity



While the unemployment gap is commonly used for assessing capacity pressures, it is important to note that the measured unemployment rate provides only one view of labour utilisation. There are a wide range of other indicators to consider, for example the adjustment of hours worked in response to a change in labour demand, which may have led to some workers becoming 'underemployed'. Analysis of gross labour market flows can also provide important insights such as the role of non-participants that are marginally attached to the labour force, who transition in and out on a frequent basis.³²

³¹ See Armstrong (2015) for full details on the output gap indicator suite.

³² See Armstrong and Karagedikli (2017).

Such factors may indicate greater or less labour market slack than is captured by estimates of the unemployment gap presented in this *Analytical Note*.

5 Conclusion

This paper estimated two measures of equilibrium unemployment, the NAIRU and the natural rate of unemployment, for New Zealand. The natural rate is a steady-state concept while the NAIRU is more narrowly defined as the unemployment rate consistent with stable inflation in the short to medium term. Both concepts are influenced by similar structural forces, with the difference reflecting the temporary adjustment process as the effects of shocks hitting the economy dissipate. In the long run, the NAIRU and the natural rate of unemployment converge.

We estimated the two measures using reduced-form as well as structural econometric methodologies relying on the Kalman filter. At the end of our sample, the mean NAIRU estimate centres around 4.7 percent and the confidence interval approximately spans from 4.0 to 5.5 percent implying a high degree of uncertainty on the magnitude of the unemployment gap. Given that the HLFSS unemployment rate in 2017Q3 was 4.6 percent, these NAIRU estimates correspond to an unemployment gap that is broadly around zero. This is broadly consistent with other indicators of capacity pressures. The NAIRU estimates appear to be slightly lower than the natural rate estimate from the structural New Keynesian model of about 5 percent.

We emphasise that, as with any other unobservable series, point estimates of the NAIRU are highly uncertain, and sensitive to sample periods, data choices, and model specification. The unemployment rate is only one measure of slack in the labour market and should be supplemented with other indicators and analysis. Our purpose in this paper has been to detect changes in equilibrium unemployment based on macroeconomic relationships without delving deeper into the influence of institutional and structural factors on the NAIRU and the natural rate. We leave this for future work.

REFERENCES

- Adjemian, S., H. Bastani, F. Karamé, M. Juillard, J. Maih, F. Mihoubi, G. Perendia, J. Pfeifer, M. Ratto, and S. Villemot, S. (2011). 'Dynare: Reference Manual Version 4'. *Dynare working papers*, CEPREMAP.
- An, S. and F. Schorfheide (2007). 'Bayesian analysis of DSGE models'. *Econometric Reviews*, Vol. 26(2-4), pp.113-172.
- Armstrong, J. (2015). 'The Reserve Bank of New Zealand's output gap indicator suite and its real-time properties'. *Reserve Bank of New Zealand Analytical Note* (AN2015/08).
- Armstrong, J., and Ö. Karagedikli (2017). 'The role of non-participants in labour market dynamics'. *Reserve Bank of New Zealand Analytical Note* (AN2017/01).
- Arnold, R. W. (2008). 'Re-estimating the Phillips Curve and the NAIRU'. Congressional Budget Office, Working paper (2008-06).
- Ballantyne, A., D. De Voss, and D. Jacobs (2014). 'Unemployment and spare capacity in the labour market'. *Reserve Bank of Australia Bulletin*, pp.7-20.
- Ball, L., and N. G. Mankiw (2002). 'The NAIRU in theory and practice'. *The Journal of Economic Perspectives*, 16(4), 115-136.
- Benes, J., K. Clinton, R. García-Saltos, M. Johnson, D. Laxton, P. Manchev, and T. Matheson (2010). 'Estimating potential output with a multivariate filter'. *IMF Working Paper* (WP/10/285).
- Blanchard, O. (2018). 'Should we reject the Natural Rate Hypothesis?'. *Journal of Economic Perspectives*, Vol.32 (1), pp.97-120.
- Bodenstein M. and J. Zhao (2017). 'On targeting frameworks and optimal monetary policy'. *Finance and Economics Discussion Series* (2017-098), Board of Governors of the Federal Reserve System (U.S.).
- Borland, J. (2014). 'Recent unemployment experience in New Zealand'. *New Zealand Treasury Working Paper* (No. 14/01). New Zealand Treasury.
- Carroll, N. and S. Chapple (2001). 'A perspective on New Zealand's unemployment rate 1985-2000'. Department of Labour.
- Chapple, S., R. Harris and B. Silverstone (1996). 'Chapter 2: Unemployment'. In Silverstone, Brian, Alan Bollard and Ralph Lattimore, *A Study of Economic Reform: The Case of New Zealand*, Elsevier Science B.V., Amsterdam.
- Culling, J., and H. Skilling (2018). 'How does New Zealand stack up? An international comparison of labour supply'. *Reserve Bank of New Zealand Bulletin* (forthcoming).
- Cusbert, T. (2017). 'Estimating the NAIRU and the unemployment gap'. *Reserve Bank of Australia Bulletin*, pp.13-22.
- Dickens, W. (2011). 'Has the recession Increased the NAIRU?'. Brookings Institution *Mimeo*.
http://www.brookings.edu/~media/research/files/papers/2011/6/29%20recession%20nairu%20dickens/0629_recession_nairu_dickens.pdf.
- Estrella, A., and F.S. Mishkin (1999). 'Rethinking the role of NAIRU in monetary policy: Implications of model formulation and uncertainty'. In *Monetary Policy Rules*, pp.405-436. National Bureau of Economic Research.

-
- Friedman, M. (1968). 'The role of monetary policy'. *American Economic Review*, Vol. 58, pp.1–17.
- Gianella, C., I. Koske, E. Rusticelli, and O. Chatal (2008). 'What drives the NAIRU? Evidence from a panel of OECD Countries'. *OECD Economics Department Working Paper* (No 649).
- Gordon, R. (1997). 'The time-varying NAIRU and its implications for economic policy'. *Journal of Economic Perspectives*, Vol.11(1), pp.11-32.
- Greenslade, J. V., R. G. Pierse and J. Saleheen (2003). 'A Kalman filter approach to estimating the UK NAIRU'. *Bank of England Working Paper* (No. 179).
- Jacob, P. and A. Munro (2017). 'Technical appendix to A prudential stable funding requirement and monetary policy in a small open economy'. <https://sites.google.com/site/reubenpunnoosejacob/research>.
- Kamber G., C. McDonald, N. Sander and K. Theodoridis (2015). 'A structural model for policy analysis and forecasting: NZSIM'. *Reserve Bank of New Zealand Discussion Paper Series* (DP2015/05).
- Lewis, M. (2016). 'Inflation expectations curve: a tool for monitoring inflation expectations'. *Reserve Bank of New Zealand Analytical Note* (AN2016/01).
- Maloney, T. and J. Savage (1996). 'Chapter 6: Labour Markets and Policy'. In Silverstone, Brian, Alan Bollard and Ralph Lattimore, *A Study of Economic Reform: The Case of New Zealand*, Elsevier Science B.V., Amsterdam.
- McDonald, C. (2017). 'Does past inflation predict the future?'. *Reserve Bank of New Zealand Analytical Note* (AN2017/04).
- Modigliani, F. and L.Papademos, (1975). 'Targets for monetary policy in the coming year'. *Brookings Papers on Economic Activity*, Vol.6 (1), pp.141-166.
- Phelps, E. S. (1968). 'Money-wage dynamics and labour market equilibrium'. *Journal of Political Economy*, Vol. 76, pp.678–711.
- Richardson, P., L. Boone, C. Giorno, M. Meacci, D. Rae and D. Turner (2000). 'The concept, policy use and measurement of structural unemployment'. *OECD Economics Department Working Papers* (no. 250).
- Rusticelli E., D. Turner and M. Cavalleri (2015). 'Incorporating anchored inflation expectations in the Phillips curve and in the derivation of OECD measures of the unemployment gap'. *OECD Journal: Economic Studies*, Vol. 2015/1.
- Staiger, D., J. H. Stock and M.W. Watson (1996). 'How precise are estimates of the natural rate of unemployment?'. *National Bureau of Economic Research, Working Paper* (No 5477).
- Silverstone, B., and W. Bell (2011). 'Gross labour market flows in New Zealand: Some questions and answers'. *Waikato University: Department of Economics Working paper in Economics* (15/11).
- Szeto, K., and M. Guy (2004). 'Estimating a New Zealand NAIRU'. *New Zealand Treasury Working Paper* (No. 04/10). New Zealand Treasury.

APPENDIX

I. Data used for reduced-form Phillips Curve models

Variable	Description	Source
π_t	CPI inflation (excluding GST changes) – annualised quarterly percent change	Statistics New Zealand
π_t^e (Model 1a)	Long-term inflation expectations – annual percent change ³³	RBNZ estimate
π_t^e (Model 1b)	2-year ahead inflation expectations – annual percent change	RBNZ inflation expectations survey
π_t^e (Model 2)	2-year ahead inflation expectations (adaptive) – annual percent change	Constructed from Statistics New Zealand
u_t	HLFS unemployment rate - percent of labour force	Statistics New Zealand
π_t^w	Labour Cost Index, private sector salary and wage rates, adjusted – annualised quarterly percent change	Statistics New Zealand
Δp_t^m	Overseas Trade Indices, total imports (prices) – annualised quarterly percent change	Statistics New Zealand
Δp_t^o	CPI (petrol class) - – annualised quarterly percent change	Statistics New Zealand

II. Description of New Keynesian model and estimation methodology

A formal description of the model equations follows. In our notation, a deviation of a variable during period t , from its long-run trend value, is indicated by an upper hat. The symbol E represents rational expectations of the future. Δ indicates a change in a model variable. All shocks are normally distributed.

The output gap (\hat{y}_t) is negatively correlated to the excess of the nominal short-term interest rate (\hat{r}_t) over the expected inflation rate ($\hat{\pi}_t^{pe}$), given the expected path as well as past realisations of the output gap:

$$\hat{y}_t - h\hat{y}_{t-1} = (E_t\hat{y}_{t+1} - h\hat{y}_t) - (1-h)(\hat{r}_t - \hat{\pi}_t^{pe}) + \varepsilon_t^{dem}.$$

The parameter $h \in [0,1)$ influences the history-dependence of aggregate demand due to habit-formation. ε_t^{dem} is a demand shock which is assumed to be autoregressive of order one.

³³ The long-term inflation expectation measure is the ‘perceived target focus’ – the point that inflation expectations converges to in the long run. For further details, see Lewis (2016).

CPI price inflation ($\hat{\pi}_t$), for any given path of expectations ($\hat{\pi}_t^{pe}$) and history, is positively correlated to the real wage (\hat{w}_t).

$$\hat{\pi}_t - \iota_p \hat{\pi}_{t-1} = \beta(\hat{\pi}_t^{pe} - \iota_p \hat{\pi}_t) + \frac{\bar{\mu}_p - 1}{\varphi_p} \hat{w}_t + \eta_t^{cpi}, \quad \eta_t^p \sim N(0, \sigma_p).$$

The price elasticity of demand $\bar{\mu}_p > 1$ and the price stickiness parameter $\varphi_p > 0$ influence the response of inflation to the real wage. $\beta \in (0,1)$ is the economy's discount factor and $\iota_p \in [0,1]$ measures the degree of history dependence of inflation through price indexation.

The process for CPI inflation expectations formation is adapted from Kamber et al. (2015). Inflation expectations are specified as a combination of past expectations, past inflation outturns, and the rational expectations forecast:

$$\hat{\pi}_t^{pe} = \rho_{pe} \hat{\pi}_{t-1}^{pe} + (1 - \rho_{pe})(e_{pe} E_t \hat{\pi}_{t+1} + (1 - e_{pe}) \hat{\pi}_{t-1}) + \eta_t^{pe}, \quad \eta_t^{pe} \sim N(0, \sigma_{pe}),$$

$$e_{pe} \in [0,1], \quad \rho_{pe} \in [0,1].$$

Nominal wage inflation ($\hat{\pi}_t^w$), for any given path of expectations ($\hat{\pi}_t^{we}$) and history, covaries positively with the output gap. The wage elasticity of labour demand $\bar{\mu}_n > 1$ and the nominal wage stickiness parameter $\varphi_w > 0$ influence the response of wage inflation to the output gap. Wage inflation expectations are assigned a law of motion similar to that of CPI inflation expectations.

$$\hat{\pi}_t^w - \iota_w \hat{\pi}_{t-1}^w = \beta(\hat{\pi}_t^{we} - \iota_w \hat{\pi}_t^w) + \frac{\bar{\mu}_n - 1}{\varphi_w} \left(\hat{y}_t - \frac{h}{1-h} \Delta \hat{y}_{t-1} \right) + \eta_t^w, \quad \eta_t^w \sim N(0, \sigma_w),$$

$$\hat{\pi}_t^{we} = \rho_{we} \hat{\pi}_{t-1}^{we} + (1 - \rho_{we})(e_{we} E_t \hat{\pi}_{t+1}^w + (1 - e_{we}) \hat{\pi}_{t-1}^w) + \eta_t^{we}, \quad \eta_t^{we} \sim N(0, \sigma_{we}),$$

$$e_{we}, \iota_w \in [0,1], \quad \rho_{we} \in [0,1].$$

The monetary policy authority follows an empirical rule to set the interest rate, in response to expected CPI inflation:

$$\hat{r}_t = \rho_r \hat{r}_{t-1} + (1 - \rho_r) E_t \hat{\pi}_{t+1} + \eta_t^r, \quad \rho_r \in [0,1], \quad \eta_t^r \sim N(0, \sigma_r).$$

Finally, the unemployment gap is linked to the output gap \hat{y}_t through an empirical relationship:

$$u_t - u_t^{NAIRU} = \rho_{ugap} (u_{t-1} - u_{t-1}^{NAIRU}) - (1 - \rho_{ugap}) u_y \hat{y}_t, \quad u_y > 0, \quad \rho_{ugap} \in [0,1],$$

$$\hat{u}_t^{NAIRU} = \rho_n \hat{u}_{t-1}^{NAIRU} + \eta_t^n, \quad \rho_n \in [0,1], \quad \eta_t^n \sim N(0, \sigma_n),$$

$$u_t^{NAIRU} = \bar{u}^* + \hat{u}_t^{NAIRU}.$$

The baseline model is fitted on seven quarterly data series: output growth, the HLFS unemployment rate, CPI inflation, LCI nominal wage inflation, the 90-day interest rate, and the 2-year ahead CPI and wage inflation expectations from the RBNZ survey. None of the data series are pre-processed using statistical filters. We estimate the model using Bayesian methods. An and Schorfheide (2007) provide a formal introduction to the methodology and a less technical overview is available in Jacob and Munro (2017). In a nutshell, the Bayesian approach involves supplementing the likelihood function of the data with prior information about the parameters to formulate the posterior distribution of the parameters. The posterior distribution is then simulated by Markov Chain Monte Carlo methods to obtain a large set of potential parameter values. The Kalman smoother is used to back out the NAIRU for each set of parameter values. The estimation is implemented in the Matlab-based toolbox Dynare Version 4.5.3 (Adjemian et al., 2011). Additional details on the estimation are available on request.