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Working Paper

Estimating a New Zealand NAIRU

New Zealand Treasury Working Paper, No. 04/10

Provided in Cooperation with:

The Treasury, New Zealand Government

Suggested Citation: Szeto, Kam Leong; Guy, Melody (2004) : Estimating a New Zealand NAIRU, New Zealand Treasury Working Paper, No. 04/10, New Zealand Government, The Treasury, Wellington

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Estimating a New Zealand NAIRU

Kam Leong Szeto and Melody Guy

NEW ZEALAND TREASURY
WORKING PAPER 04/10

SEPTEMBER 2004



THE TREASURY
Kaitohutohu Kaupapa Rawa

M O N T H / Y E A R

September 2004

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A C K N O W L E D G E M E N T S

The authors would like to thank Mark Blackmore, Paul Gardiner, Özer Karagedikli, and Richard Downing for helpful suggestions at the initial stages of this research project. We would also like to thank Thomas Laubach and David Rae for providing us with files and data used in their studies. We are grateful to Özer Karagedikli, Paul Gardiner, Richard Downing, Khoon Goh, Angela Huang, Brendon Riches, Tony Booth, Peter Mawson, Brian Silverstone, Bob Buckle and Veronica Jacobsen for useful comments on drafts of this paper.

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D I S C L A I M E R

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Abstract

This paper estimates the non-increasing inflation rate of unemployment or NAIRU for New Zealand. A NAIRU that varies over time has important implications in considering inflationary pressures. This paper estimates the time-varying NAIRU using a Kalman filter on a reduced form approach and extends previous studies in several ways. Using different model specifications and dependent variables suggests a band of NAIRU estimates of between four and five percent (with further error bands around that). The results of this paper indicate that the NAIRU is a relevant concept and the unemployment gap should be one of the factors considered when assessing inflationary pressure.

JEL CLASSIFICATION E24 – Employment; unemployment; wages
E31 – Price level; inflation; deflation
C13 - Estimation
C22 – Time-series models

KEYWORDS NAIRU; Kalman filter; Unemployment; Phillips Curve;
New Zealand

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Estimating a New Zealand NAIRU

1 Introduction

Owing to its unobservable nature, NAIRU¹, which stands for the nonaccelerating inflation rate of unemployment, has been one of the most controversial concepts in Macroeconomics.² A large literature (for example, see the symposium in the *Journal of Economic Perspectives* (Winter issue, 1997) and Ball and Mankiw, 2002) has been devoted to discuss the usefulness of the NAIRU in forecasting and policy discussion. This paper sets out to estimate whether there is a relationship between the rate of inflation and unemployment and, if so, what that relationship is. That is: at what level of the unemployment rate will wage or price inflation begin to rise?

Comparisons of the current rate of unemployment with estimates of the NAIRU can be used to help gain an impression of spare capacity and the degree of inflationary pressures in the economy. This means that if measures of the NAIRU are robust enough to be informative, they can be important for monetary and fiscal policy, labour market policy, forecasting, and private sector decision making (Gibbs 1995). Over-time, structural changes in the economy may also affect the NAIRU. A NAIRU that varies over-time has important implications in considering inflationary pressures.

Recent studies have attempted to estimate a NAIRU for New Zealand using the Kalman filter technique (see Richardson et al., 2000, and Eaquib and Ward, 2001). This paper updates and extends this literature in several ways. This paper extends previous literature by using the Stock and Watson (1998) procedure to estimate the signal-to-noise ratio; including a survey measure of inflation expectations as a variable; estimating the NAIRU for three different measures of inflation and two different models; including measures of short-term shocks significant for New Zealand; and making use of quarterly data up to the end of 2003.

The next section covers important NAIRU concepts before discussing the New Zealand situation, including the possible implications for the NAIRU. Section 3 then discusses

¹ NAIRU has traditionally stood for non-accelerating inflation rate of unemployment. However, this is something of a misnomer and what is usually meant is non-increasing inflation rate of unemployment (see Richardson, Boone, Giomo, Meacci, Rae and Turner, 2000).

² It should be noted that it is not government policy that there is a NAIRU.

theoretical and practical issues around estimating a NAIRU for New Zealand. Section 4 then outlines the models and data used in this paper and the results obtained.

2 Overview of the NAIRU

2.1 Conceptual issues

The traditional NAIRU view established by Friedman (1968) is that in the long-run the structural rate of unemployment is reached and hence there is no long-term trade-off between inflation and unemployment. However, in the short-term the “Phillips Curve” suggests that a trade-off between inflation and unemployment exists so that if the rate of unemployment falls below (rises above) the NAIRU, inflation will rise (fall) until the rate of unemployment returns to the NAIRU, and then inflation will stabilise at that permanently higher (lower) level. Supply shocks and inflation expectations are also commonly felt to be important determinants of inflation and the NAIRU may change over time depending on the structure of the economy and government policy.

Within this framework, the OECD define three different NAIRU concepts, which vary by the timeframe they cover (Richardson *et al* 2000). One definition is the short-term NAIRU. The *short-term* NAIRU is the rate of unemployment required to stabilise the inflation rate at its current level in the next period. The short-term concept is more volatile by definition as it requires a level of NAIRU that will provide an inflationary offset to any impact from short-term supply shocks, expectations, and possible speed limit/persistence effects (so could be affected by the level of actual employment).³ Note that favourable short-term supply shocks may allow the unemployment rate to fall below our core NAIRU measure and disguise the inflationary impact, which may be New Zealand’s recent experience.

The second NAIRU definition applies to the *medium-term* concept. In this approach, the NAIRU is defined as the equilibrium rate which unemployment converges in the absence of temporary supply shocks and the dynamic adjustment of inflation to previous shocks is completed. This paper focuses on the medium-term NAIRU concept, which is here after simply referred to as the NAIRU.

The final definition is the *long-term* equilibrium unemployment rate which is equivalent to the long-term steady state, as the NAIRU has fully adjusted to all long and short-term supply and policy influences.

Of these three definitions the first two can be estimated, the short-term NAIRU can be directly estimated and the medium-term NAIRU can be estimated by controlling for appropriate short-term influences.⁴ However, the long-term NAIRU tends to not get

³ For a number of countries there is evidence of significant inertia which can delay the adjustment of the short-term NAIRU and keep it closer to the actual unemployment rates (Richardson *et al*, 2000). This implies that there could be inertia or speed-limit effects where if the actual unemployment rate is well above NAIRU the gap can only be closed slowly to avoid inflationary impacts.

⁴ Note that in reality it may be very difficult to control for all appropriate short-term influences so attempts to measure the medium-term NAIRU may actually measure a hybrid of a short and medium-term NAIRU.

estimated in a Phillips curve framework due to difficulties in identifying the effects of individual long-lasting supply influences in a timely fashion. In New Zealand, this could be incorporating the long-run impact of the Employment Contracts Act on the labour market.

2.2 The New Zealand labour market

Since 1999 the New Zealand labour market has been characterised by a rapidly falling unemployment rate. The March 2004 seasonally adjusted unemployment rate of 4.3% is the lowest since December 1987 when it was 4.2%. The fall in New Zealand's unemployment is due to particularly strong employment growth, which has more than offset a rising participation rate. Furthermore, inflationary pressures in the recent period have been milder than in previous periods when unemployment was this low. This observation could suggest that the New Zealand NAIRU has fallen. Many overseas studies have attempted to explain the movements in the NAIRU (see Gordon, 1996, Stiglitz, 1996 and Ball and Mankiw, 2002). The leading hypotheses include changes in demographics, changes in labour force, increases in competitiveness of labour and product markets, better job matching and higher productivity growth.

2.2.1 Possible structural determinants of the NAIRU

This section discusses some factors which could explain the movements of the New Zealand NAIRU over the 1988-2004 period. We begin in this section by first reviewing some key policy changes which could affect the competitiveness of the labour market. Then we turn our focus on the composition of the labour force.

Policy changes

Over the period 1988 to 2004 there were a number of policy changes which may have had a significant impact on unemployment and may help to explain changes in the NAIRU. One significant change is increased flexibility in wage bargaining as a result of the introduction of the Employment Contracts Act (ECA) in May 1991. Richardson et al., (2000) consider that the ECA could lower the NAIRU by up to ½% each year combined with the other structural labour market reforms.

Another substantial policy change is the benefit reforms introduced around the same time as the ECA. The reforms involved both reductions in basic benefits and a tightening in eligibility criteria. Maloney (1997) concludes that the 1990-91 benefit reforms substantially influenced labour market behaviour in New Zealand. He further suggests that 40 to 80% of the growth in employment between 1990 and 1995 can be attributed to the benefit reforms.

In addition, the Employment Relations Act (ERA) was introduced in October 2000, but there does not appear to be any evidence of it having a significant impact so far (Waldegrave, Anderson and Wong 2003).

Socio-demographic changes

The composition of the labour force can be an important determinant of the structural unemployment rate. For example, a hard to employ group (such as school leavers) becoming a more (less) significant part of the labour force is likely to raise (lower) the

aggregate unemployment rate. Carroll and Chapple (2001) suggest that over the period 1985-2000 the change in the ethnic composition is likely to have increased the rate of unemployment. On the other hand, the age structure and education level of the population is likely to have decreased the rate of unemployment. They estimate that the changing composition of the labour force may have reduced the rate of unemployment by around 1%, with most of the socio-demographic benefits occurring between 1985 and 1992.

3 Estimation issues

Estimation of the NAIRU is imprecise as the NAIRU cannot be directly observed and it appears to change over time. This means that estimates of the NAIRU tend to have wide error bands. For example, Staiger, Stock and Watson (1996) found a typical 95% confidence interval to be a gap of 2.6%. They point out three explanations for the large degree of uncertainty in estimates of the NAIRU. First, there is uncertainty arising from not knowing the correct parameters of the model (as with any econometric estimation). Secondly, the NAIRU is potentially stochastic (random). Thirdly, there is uncertainty over model specification, there are a number of potential models of the NAIRU and we do not know which one is “true”. For example, the NAIRU can be estimated as a constant, a slowly changing function of time, an unobserved random walk, as a function of other labour market variables etc, but all measures retain a large degree of uncertainty (Staiger *et al* 1996).

An additional area of imprecision is that most models require an estimate of inflationary expectations. One way to get around this is to assume that expectations are adaptive and equal to the previous period’s inflation so $\pi_t^e = \pi_{t-1}$. Other options are to use a survey measure of inflation expectations (which is used in this paper), or some function of the mean of inflation adjusted by the previous period’s inflation.

3.1 Theoretical models

There are a several techniques used to estimate the NAIRU. In this section, we discuss commonly used techniques and explain why this study uses the reduced form technique over structural or purely statistical models. Section 3.1.4 goes into more detail on the Kalman filtering technique used in this study. Section 3.2 outlines examples of studies which used the reduced form technique to estimate the NAIRU.

3.1.1 Structural models

Structural models compute the NAIRU as the equilibrium of a model of aggregate wage and price setting behaviours (Fabiani and Mestre 2000, Richardson *et al* 2000). The equilibrium level of unemployment is derived as the set of values for which inflation is stable. Structural models usually assume full adjustment of firms and workers to all shocks, so the derived equilibrium measure of unemployment corresponds more closely to the long-run equilibrium rate of unemployment described in section 2.1.

The key advantage of structural models is that they provide more information on the determinants of the NAIRU, as they are based on a theoretical framework that explains how macroeconomic shocks and policy instruments affect the long-term equilibrium rate of unemployment. However, structural models are not generally considered to be a preferred estimation method as they are very complex to estimate; are likely to be inaccurate as they rely on assumptions about the underlying behaviour of economic agents for which there is no general consensus; they face a number of econometric and measurement issues; and cannot generally be calculated in a timely manner (for a more detailed discussion see Richardson *et al* (2000)).

3.1.2 Pure statistical models

Pure statistical models split the actual unemployment rate into trend and a cyclical component and ignore all other information, including the relationship between the unemployment rate and inflation. Pure statistical models differ from the structural models discussed as they are only intended to be predictive, whereas the structural models attempt to help explain the relationship between inflation and unemployment. They rely on the assumption that equilibrating forces are strong enough to bring the unemployment rate back to trend relatively quickly so that on average the actual unemployment rate should fluctuate around the NAIRU.

Pure statistical models have the advantage of being timely and relatively simple to calculate, an example included in the results section of this paper uses the Hodrick Prescott (HP) filter to estimate trend unemployment as a weighted moving average of actual unemployment. The difficulty with these models include a lack of consensus about how the estimated trend is modelled in terms of its variance and relationship with the cyclical component; as filters tend to behave as a moving average they respond very slowly to apparent changes in unemployment; and most importantly, all information other than unemployment is ignored, including the relationship between inflation and unemployment.

3.1.3 The reduced form approach

Reduced form approach has several advantages over a pure statistical model including being directly related to the theoretical definition of the NAIRU as it is based on the expectation-augmented Phillips curve, and also because it allows us to control for a range of factors wider than the inflation/unemployment relationship. In addition, the simplicity of the approach means that it is consistent with a range of models and is therefore likely to be more robust than the structural approach which is based on a single model.

These advantages make the reduced form approach the most popular technique in recent studies. However, the reduced form approach also has a number of disadvantages. It requires some form of estimation of inflation expectations. The approach is atheoretical which has the advantage of not relying on assumptions about behaviour but the disadvantage is that it leaves the interaction between unemployment and inflation indeterminate so may not provide a measure of underlying NAIRU. The filters lack precision for end of sample estimates. The final disadvantage of the reduced form approach is that the results may be sensitive to arbitrary choices in the model. Note that if the

unemployment gap and all shock variables prove to be insignificant then the reduced form model becomes a purely statistical model. The key parameter that is usually chosen in an arbitrary manner is the signal-to-noise ratio, which in this study we have instead estimated using Stock and Watson's (1998) procedure.

3.1.4 Kalman (1960) filter

The previous section discussed how using filtering techniques on reduced form equations are currently the generally preferred NAIRU estimation method as it is based on the expectations augmented Phillips curve but also allows us to control for more factors than just the inflation/unemployment relationship. This paper uses the Kalman filtering technique, which is outlined in this section. The Kalman filter is the most commonly used reduced form filtering technique for estimating the NAIRU due to its simplicity of estimation (Greenslade, Pierse and Saleheen 2003, Richardson *et al* 2000).

The filtering process uses the rule that *ceteris paribus* stable inflation (when inflation is equal to inflation expectations) implies an unemployment rate that is at the NAIRU but rising (falling) inflation is suggestive of an unemployment rate that is below (above) the NAIRU. However, controlling for temporary shocks such as oil prices may allow the short-term NAIRU to deviate from the medium-term NAIRU concept referred to in Section 2.1.

For example, a general specification of this framework would be:

$$(\pi_t - \pi_t^e) = \alpha(L)(\pi_{t-1} - \pi_{t-1}^e) + \beta(L)(u_t - u_t^*) + \gamma(L)x_t + \varepsilon_t \quad \varepsilon_t \sim N(0, \sigma_\varepsilon^2) \quad (1)$$

$$u_t^* = u_{t-1}^* + \nu_t \quad \nu_t \sim N(0, \sigma_\nu^2) \quad (2)$$

The first equation is a Phillips curve and it models unexpected inflation as a function of: shocks (x_t), controlling for the appropriate temporary supply shocks allows us to calculate a NAIRU that is compatible with non-increasing inflation in the absence of temporary supply shocks; the unemployment gap ($u_t - u_t^*$), the NAIRU (u_t^*) is time varying and its movement is modelled by Equation (2).

Inflation expectations (π_t^e) are not model endogenous, which are picked up by the lagged inflation (π_{t-1}) or a survey measure. The random exogenous events or 'noise' (ε_t, ν_t) which are iid, normally distributed with a mean zero and variances σ_ε^2 and σ_ν^2 , and are uncorrelated with each other.

The unemployment gap can be thought of as the demand component of the equation, shocks generally being related to supply, and lagged inflation and/or inflation expectations picking up an inertia effect.

Equation (2) specifies how the NAIRU can change over time. The ratio of the variance of the two error terms ($\sigma_\nu^2 / \sigma_\varepsilon^2$) is the signal-to-noise ratio. This measures volatility in the

NAIRU in relation to volatility in inflation, so determines the smoothness of the estimated series. A very high signal-to-noise ratio implies a NAIRU that moves a lot and helps to explain almost all of the variance in inflation. A very low signal-to-noise ratio implies a NAIRU that is very constant over time, explaining less of the variation in inflation. One of the key assumptions required for estimation is setting the signal-to-noise ratio. Past studies have tended to arbitrarily select the signal-to-noise ratio, but this paper uses Stock and Watson's (1998) procedure.

If you can assume normally distributed errors, then the Kalman filter can compute a log-likelihood function that allows estimation of the parameters using the maximum likelihood method. For more detail on the Kalman filter see Harvey (1990).

Note that the Hodrick-Prescott multivariate filter (HPMV) is also sometimes used but the Kalman filter is generally preferred as it is more flexible (Richardson *et al* 2000). The HPMV filter requires a third equation specifying the gap between unemployment and the NAIRU, this means that the NAIRU estimates tend to follow actual unemployment more closely and without adjustments estimates tend to be drawn towards end point values (Richardson *et al* 2000).

3.2 Recent empirical studies

This section considers international and New Zealand specific studies that attempt to estimate the NAIRU. The methodology of this study is similar to that used in cross country studies by Laubach (2001) and Richardson *et al* (Richardson *et al* 2000). This section briefly outlines the methodology used in these studies and key differences with this study, and then discusses a number of previous New Zealand specific studies that investigated the NAIRU.

The Richardson *et al* (2000) paper includes a detailed review of NAIRU estimation methods and concludes that the reduced-form Phillips curve approach, utilising the Kalman filter, is the most promising framework for providing up to date estimates of the NAIRU. This general approach is applied across 21 OECD member countries, including New Zealand, for the period 1980 to the start of 1999.

The two reduced form equations used by Richardson *et al* (2000) are similar to those set out in section 3.1.4. As the OECD were attempting to measure a medium-term NAIRU concept they controlled for short-term supply shocks, with short-term supply shocks defined as those that would be expected to revert to zero over one or two years. The shocks the OECD selected were real detrended import prices and the change in real oil prices, as these were found to be statistically significant for a large number of countries.

Overall the methodology in this study is very similar to that used by the Richardson *et al* (2000). A key difference is that they somewhat arbitrarily chose their signal-to-noise ratio, whereas this paper uses Stock and Watson's (1998) procedure to select the signal-to-noise ratio. Other key differences include our use of several model specifications and measures of inflation, the use of a survey measure of inflation expectations, and our use of quarterly rather than six monthly data.

Laubach (2001) follows a basic methodology that is similar to that used in the Richardson *et al* (2000) study but considers the impact of allowing drift in the specification of the NAIRU and the impact of assuming a stationary process for the unemployment gap. The study estimates the NAIRU for the G7, excluding Japan and Australia over the period 1971 to 1998. In the study Laubach found that including the unemployment gap as a stationary process considerably improved the precision of the estimates. The short-term shocks Laubach (2001) controlled for were the nominal exchange rate and commodity prices, and the two measures of inflation considered are the all-items CPI and the GDP deflator.

Laubach (2001) found evidence supporting the presence of a NAIRU and reasonably precise error bands for the United States and to a lesser extent Canada. However, Laubach (2001) felt that the European data were too imprecise to be informative about the existence, let alone the level of the NAIRU.

The most similar New Zealand specific study reviewed is Equb and Ward (2001). They estimate constant and time-varying NAIRU series for the period 1977-1999 using ordinary least squares, recursive least squares, and the Kalman filter. They found the Kalman filter reduced-form estimates of a time varying NAIRU to be the most satisfactory.

Equb and Ward (2001) considered one measure of inflation, the private consumption deflator, and controlled for one supply shock, real non-oil import prices. It is surprising that oil prices are not included as a shock given the significant impact on the New Zealand economy over that time period. They found that lagged inflation, real non-oil import prices, and the unemployment gap to all be significant at explaining inflation.

Chapple (1995) used a number of techniques to examine the drivers of structural unemployment and concluded that rising unemployment from the mid-1980s to the mid-1990s was due to a failure of aggregate demand to expand at a sufficient rate to absorb increasing potential output rather than a rising NAIRU.

4 Model specification and results

This section outlines the models and data used to estimate the NAIRU and examines the results of these models. The basic models used are similar to the reduced-form models used in Richardson *et al* (2000) with the key difference being the estimation of the signal-to-noise ratio using Stock and Watson's (Stock and Watson 1998) procedure. Once the signal-to-noise ratio is estimated it is then used in the reduced-form models to estimate the NAIRU. To evaluate the NAIRU estimates of these models against each other and the HP filter alternative, we then compare the fit of ordinary least squares (OLS) equations attempting to explain unexpected inflation using the various NAIRU estimates.

4.1 Data and model specification

The model used in this paper is:

$$(\pi_t - \pi_t^e) = \alpha(L)(\pi_{t-1} - \pi_{t-1}^e) + \beta(L)(u_t - u_t^*) + \gamma(L)\Delta x_t + \varepsilon_t \quad \varepsilon_t \sim N(0, \sigma_\varepsilon^2) \quad (3)$$

$$u_t^* = u_{t-1}^* + \nu_t \quad \nu_t \sim N(0, \sigma_\nu^2) \quad (4)$$

where Δ is the first difference operator, π_t is the inflation rate, π_t^e is expected inflation, $(u_{t-1} - u_{t-1}^*)$ is the unemployment gap and x_t represents short-term supply shocks. The basic model is similar to that used by the Bank of England and OECD, with the key exception being the inclusion of survey based measure of inflation expectations.

Equation (3) represents a Phillips curve relationship and models unexpected inflation as a function of one lag, the deviation of the unemployment rate (u_t) from the NAIRU (u_t^*), and proxies for short-term supply shocks. Equation (4) specifies the time-series process generating the unobservable NAIRU, which is assumed to follow a random walk process.

Three measures of inflation are considered in this paper and they are the Consumer Price Index excluding interest costs (CPIX), CPI excluding government charges (CPIG), and the consumption deflator (COND).⁵ Inflation is measured by annualised quarterly growth rates of the price indexes. The data used in the paper covers the period 1988:3 to 2003:4 for both CPIX and COND. For CPIG, the data used covers 1989:1 to 2003:4. The inflation expectation variable used is "expected annual CPI one year from now", obtained from the Reserve Bank New Zealand survey of expectations.

As changes in Goods and Services Tax (GST) and government housing policy occurred during the sample period, we first removed the impact of the two policy changes on the dependent variable by regressing $(\pi_t - \pi_t^e)$ on two dummy variables. The first dummy

⁵ Note that you could also use a measure of wage inflation. We have not done this because we did not feel that neither the Statistics New Zealand Quarterly Employment Survey or Labour Cost Index are appropriate and because there is not a long enough time series of the unadjusted Labour Cost Index at this time.

variable is a GST dummy variable which is used to capture the increase in GST in 1989 Q3. The second one is to capture the change in government housing policy in 2001 Q1.⁶

Short-term supply shocks are defined as those that would be expected to revert to zero over one to two years, as we are attempting to estimate the medium term NAIRU concept. As it is impossible to control for all short-term shocks in reality our measure is a mix of the short and medium-term NAIRU definitions. The main proxies for short-term supply shocks used in this study are GDP imports deflator (NMPD) and petrol prices (PTGAS). Both variables enter Equation (3) as contemporaneous annualised quarterly growth rates. Another supply shock variable is the rate of change in local authority rates (LAR).

To avoid simultaneity issues, the unemployment gap should enter as lagged values in Equation (3). In this study, two model specifications are considered. In the first specification (Model 1), we allow only a contemporaneous unemployment gaps. In the alternative specification (Model 2), the first lag of the unemployment gap is included in the model. The decision on how many lags of $\pi_{t-1} - \pi_{t-1}^e$ is included is based on the significance of the last lag included and the significance of the autocorrelated errors.

⁶ There was also a major change in government housing policy in 1994. However, the coefficient on this dummy variable was not statistically significant.

Selection of the signal-to-noise ratio

One of the key issues in the estimation of an unobserved-components model is to choose the ratio of the variances of the error terms in the two equations, the signal-to-noise ratio. The ratio measures the volatility or variance of the NAIRU relative to the variance of changes in inflation and determines how the NAIRU can move around over time. A very high signal-to-noise ratio implies a NAIRU that moves a lot and helps to explain almost all of the variance in inflation. A very low signal-to-noise ratio implies a NAIRU that is very constant over time, explaining less of the variation in inflation. Therefore, the estimation results are very sensitive to the choice of the signal-to-noise ratio. Following Stock and Watson's (1998) procedure, we obtain the median-unbiased estimates of the signal-to-noise ratio.

The first step of the procedure is to rewrite Equation (3) as follows:

$$(\pi_t - \pi_t^e) = \alpha(L)(\pi_{t-1} - \pi_{t-1}^e) + \beta(u_{t-1}) + \gamma(L)\Delta x_t + c + \varepsilon_t \quad (5)$$

where c is a constant.

In the second step, we compute the exponential Wald statistic of Andrews and Ploberger (1994) for an intercept shift at unknown date in Equation (5). We then use Stock and Watson's result to obtain the medium-unbiased estimate of λ . The estimate of the standard deviation of v_t is (for further detail see Stock and Watson (1998)):

$$\hat{\sigma}_v = \frac{\lambda \hat{\sigma}_\varepsilon}{T \beta}$$

Table 1 – The results of the Stock and Watson's median-unbiased estimate of λ

	Model 1			Model 2		
	CPIX	CPIG	CON D	CPIX	CPIG	CON D
Exponential Wald Statistic	1.68	0.74	3.45	2.11	1.17	4.47
p-value	0.078	0.293	0.008	0.046	0.154	0.001
Median-unbiased Estimate of λ	6.8	3.5	10.1	7.6	5.2	11.6

Table 1 above reports the values of the exponential Wald statistic testing for an intercept shift in Equation (5). Using the median-unbiased estimate of λ , we impose the signal-to-noise ratio when estimating the remaining model parameters. The results from the final-stage of estimation are presented in Table 2.

4.2 Kalman filter NAIRU estimates

In general, the results in Table 2 suggest that Model 1 is better fit than Model 2 according to the values of log likelihood function. Furthermore, the estimates and z-statistics of the

coefficient on the unemployment gap are more significant in Model 1 than in Model 2. The results support a fairly strong negative relationship between the unemployment gap and inflation except for the CPIG based inflation measure for Model 2.

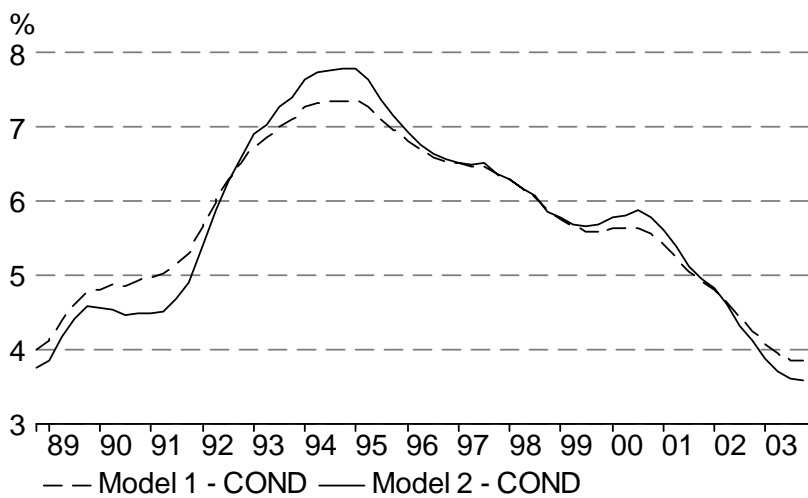
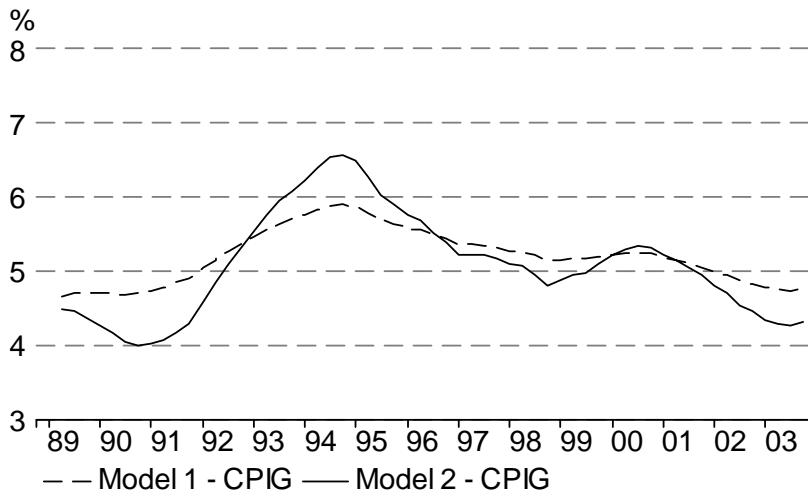
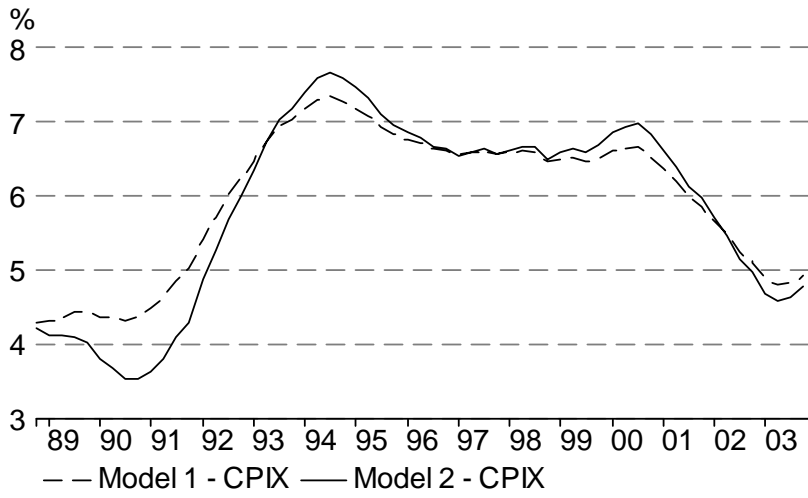
Table 2 – Models estimated using the Kalman Filter

Dependent Variable	$(\pi_t - \pi_t^e)$ CPIX	$(\pi_t - \pi_t^e)$ CPIG	$(\pi_t - \pi_t^e)$ COND
Model 1			
$(\pi_{t-1} - \pi_{t-1}^e)$	0.43*** (4.32)	0.45*** (3.73)	
$(u_t - u_t^*)$	-0.15** (-2.04)	-0.22* (-1.77)	-0.55*** (-4.89)
Δ Import prices			0.06** (2.06)
Δ Oil prices	0.03*** (3.50)	0.04** (2.46)	
Rate of change in Local Authority Rates	0.03*** (2.64)		
Log Likelihood	-89.4	-111.3	-119.8
Model 2			
$(\pi_{t-1} - \pi_{t-1}^e)$	0.45*** (4.44)	0.47*** (3.64)	
$(u_{t-1} - u_{t-1}^*)$	-0.12* (-1.64)	-0.17 (-1.40)	-0.53*** (-4.53)
Δ Import prices			0.06* (1.92)
Δ Oil prices	0.03*** (3.50)	0.04** (2.44)	
Rate of change in Local Authority Rates	0.03*** (2.79)		
Log Likelihood	-90.3	-112.6	-121.4

Z-statistics are in parentheses. *** significant at 1 % level, ** significant at 5% level and * significant at 10% level.

Figure 1 shows various Kalman filter smoothed NAIRU estimates. The resulting NAIRU estimates show large variation over time. In general, the NAIRU estimates derived from Model 2 display more variability than those obtained from Model 1. However, all the estimates rose during the first half of the 1990s and reached a peak ranging from 6% to 7.8% in 1994. For the latter half of the 1990s, the NAIRU profiles diverged slightly, especially for the COND-based NAIRU. Both CPIX and CPIG based NAIRUs declined since 1995 and flattened off during the 1997-2000 period, declining again thereafter. The period in which the fall in NAIRUs was temporarily halted, coincided with the onset of the Asian Crisis and two consecutive droughts. Hence, the flattening in NAIRUs may be attributable to the omission of supply shocks caused by the two droughts in the estimation (Buckle, Kim, Kirkham, McLellan and Sharma 2002). At the end of the sample period, the estimated NAIRUs ranged between 4.9% to 4.3% for both CPIX and CPIG based inflation measures.

Figure 1 – NAIRU estimates from the three inflation measures and two models



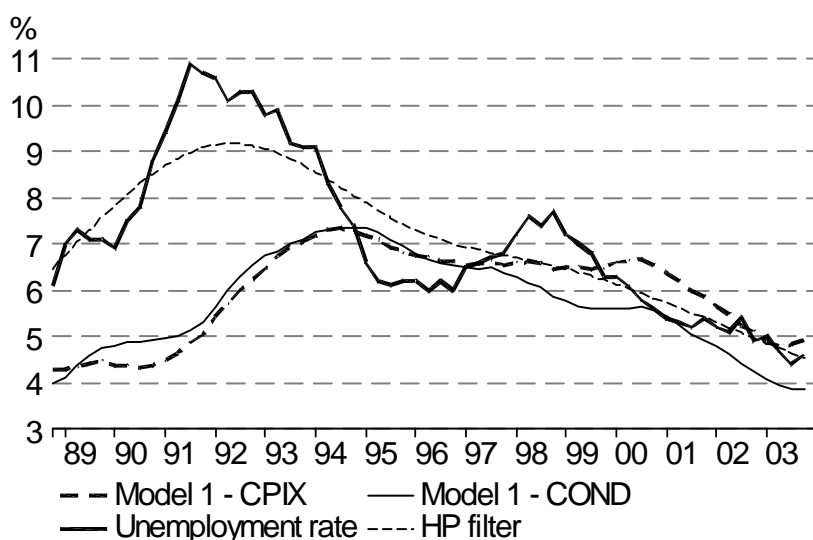
Source: The Treasury

Like other estimates of NAIURs, the COND-based NAIUR estimates fell for the latter half of 1990s but the main difference is that the flattening period did not start until 1999, reaching a sample low of 3.8% and 3.6% for Model 1 and Model 2 respectively.

4.3 Comparing the Kalman filter NAIUR estimates to HP filter estimates

In the rest of this section, we compare Kalman filter estimates of NAIUR based on Model 1 (our preferred model) with the HP filter NAIUR estimates. In this paper, the HP filter NAIUR estimates are derived using the λ of 1600, which is commonly used for quarterly data. Figure 2 presents the NAIUR estimates using the HP filter.

Figure 2 – Kalman and HP filter NAIUR estimates



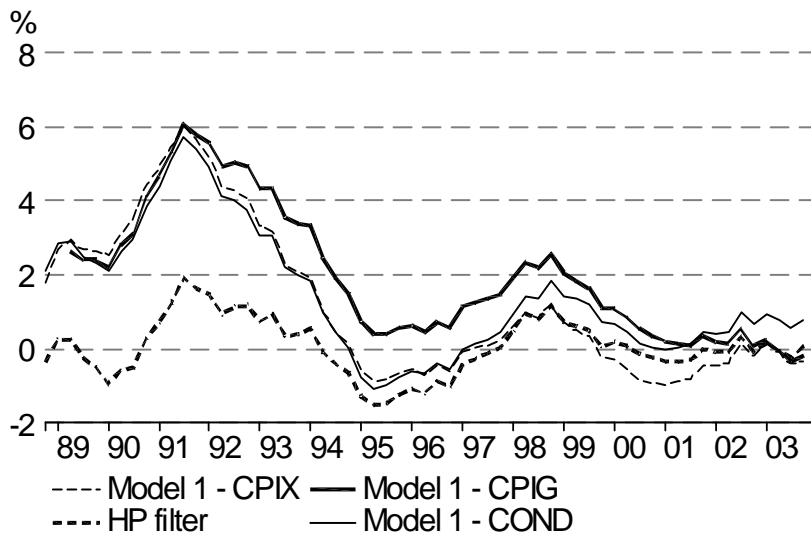
Sources: Statistics New Zealand and The Treasury

The key difference between the HP filter and the Kalman filter is that the HP filter NAIUR estimates move more closely with the actual level of unemployment. As a result, the size of unemployment gaps is smaller than those estimates based on the Kalman filter (see Figure 3).

Furthermore, some important economic insights can be drawn from the difference in the unemployment gaps between the HP filter and Kalman filter. According to the Kalman filter, disinflation policy, fiscal reform, and the world recession had a greater negative impact on demand during the early 1990s, than would have been suggested if the HP filter is used. The unemployment gap required to lower inflation was much larger according the Kalman filter estimates than the HP filter estimate. Chapple (1995) argued that the increase in New Zealand's unemployment rate between the mid-1980s and early 1990s could not be explained by an increase in the NAIUR. The Kalman filter unemployment gap estimates are generally consistent with Chapple's (1995) argument in that the rise in unemployment was largely due to aggregate demand failing to expand sufficiently, with a smaller impact

from a rising NAIRU. As the level of structural unemployment in the early 1990s is much smaller using the Kalman filter based measures in comparison with the HP filter base measures, consequently, the fall in the structural unemployment is also smaller for the Kalman filter based measures during the second half of 1990s.

Figure 3 – Comparison of the unemployment gaps derived from different NAIRU estimates



Source: The Treasury

In order to test which unemployment gaps are better in explaining the movement of inflation, the estimated unemployment gaps derived from both the Kalman filter and the HP filter are included in Equation (3), which is then estimated by OLS. Table 3 presents the results of the estimation. The fit of the estimated equation is a much better using the Kalman filter gaps than the HP filter gaps.

Table 3 – Estimating Equation (3) with OLS using the Kalman filter unemployment gaps and the HP filter unemployment gaps

	$(\pi_t - \pi_t^e)$ CPIX		$(\pi_t - \pi_t^e)$ CPIG		$(\pi_t - \pi_t^e)$ COND	
	Kalman	HP	Kalman	HP	Kalman	HP
$(\pi_{t-1} - \pi_{t-1}^e)$	0.36* (3.76)	0.51* (5.59)	0.42* (3.73)	0.44* (3.91)		
$(u_t - u_t^*)$	-0.23* (-3.36)	-0.26 (-1.37)	-0.27* (-2.77)	-0.77** (-2.38)	-0.66* (-7.34)	-1.27* (-4.01)
Δ Import prices					0.07* (3.30)	0.06** (2.41)
Δ Oil prices	0.03* (3.77)	0.03* (3.40)	0.04* (3.05)	0.03* (2.74)		
Rate of change in Local Authority Rates	0.03* (2.61)	0.03* (2.72)				
Adjusted R-squared	0.54	0.47	0.43	0.41	0.40	0.09

t-statistics are in parentheses. * significant at 1 % level, ** significant at 5% level and *** significant at 10% level.

5 Conclusion

This paper has updated and extended previous studies that estimated the NAIRU for New Zealand using the Kalman filter on a reduced form equation. Extensions to previous studies include using the Stock and Watson (1998) procedure to estimate the signal-to-noise ratio; including a survey measure of inflation expectations as a variable; estimating the NAIRU for three different measures of inflation and two different models; including measures of short-term shocks based on their significance for New Zealand; and making use of quarterly data up to the end of 2003.

This paper found evidence to support the concept of a NAIRU with the unemployment gap found to be a significant variable in helping to explain the deviation between inflation and inflation expectations in the models estimated. The paper also found that the Kalman filter reduced form estimates showed a larger cyclical dimension to the labour market in the early 1990s than the HP filter, with the HP filter tending to follow the actual unemployment rate more closely.

The results indicate that the NAIRU is likely to be around the current level of the unemployment rate, which supports our prior expectations based on signs of a tight labour market. However, this paper has presented a range of estimates from different possible models, which all also have error bands around their estimates. These models can only provide indications of the current level of the NAIRU rather than point estimates, but also provide a useful guide to how the NAIRU has changed over time. All of the models indicate a NAIRU that is rising over the late 1980s and early 1990s, and then gradually falling with a brief respite around 2000 with the impact of Asian Crisis and two droughts.

This paper provides estimates of the NAIRU using a basic Kalman filter model. A number of extensions and areas of further work have been suggested that could not be included in this paper but may warrant further work. One area of work is to include the soil moisture deficit (Buckle et.al., 2002) as one of the supply shock variables because the omission of such a variable could result in a different estimate of the NAIRU's variation.

A second area of work suggested is using nonlinear modelling to investigate whether the unemployment rate adjusts in a non-linear or asymmetric fashion, in which case the linear models used in this paper would be inappropriate (Skalin and Teräsvirta 2002). A third area is to investigate the performance of the various models by looking at the real-time versus ex-post properties of the various NAIRU measures (Graff 2004). Finally, adding a structural NAIRU equation to the models is an area which would be very challenging but if successful could help to understand the determinants of the NAIRU.

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