THE PHILLIPS CURVE IN AUSTRALIA

David Gruen*, Adrian Pagan** and Christopher Thompson*

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*Economic Research Department, Reserve Bank of Australia
**Australian National University

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Abstract

In this paper we discuss the development of Phillips curves in Australia over the forty years since Phillips first estimated one using Australian data. We examine the central issues faced by researchers estimating Australian Phillips curves. These include the distinction between the short and long-run trade-offs between inflation and unemployment, and the changing level of the non-accelerating inflation rate of unemployment (NAIRU), particularly in the 1970s. We estimate Phillips curves for prices and unit labour costs in Australia over the past three decades. These Phillips curves allow the NAIRU to change through time, and include a role for import prices and 'speed-limit' effects. The paper concludes by presenting an extended discussion of the changing role of the Phillips curve in the intellectual framework used to analyse inflation within the Reserve Bank of Australia over the past three decades.

JEL Classification Numbers: E24, E31, E52

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1. Introduction

In 1959, A.W. (Bill) Phillips spent a sabbatical year in Australia at the University of Melbourne. During his time there he produced what might have been the second ‘Phillips curve’ in the world. Since that time Phillips curves have appeared for many countries under many guises, have found their way into textbooks and conferences, and have become part of the standard set of tools available to macroeconomists when thinking about the effects of policy actions. At the same time, it has become apparent that there is no real agreement over exactly what the term ‘Phillips curve’ implies. The original concept of the equation related wage inflation to unemployment, but modern versions are as likely to relate price inflation to ‘output gaps’. The diverse uses to which Phillips curves have been put can be seen from the trinity of benefits that Stiglitz (1997) mentions as accruing from the possession of a Phillips curve:

1. It is useful for describing the determinants of inflation.
2. It is useful in providing a framework for policy.
3. It is useful for forecasting inflation.

As might be expected, it is unlikely that a single curve can be used for all three purposes. When forecasting or explaining history the curve might have to be augmented with a large array of variables representing both demand and supply influences and institutional factors relating to price and wage controls. Good examples of such a curve are the ‘triangle’ models of Gordon (1997). However, when it comes to establishing a policy framework, simpler versions of the curve may be desirable. Moreover, since policy has to be set within a systems context, a single equation can only be regarded as one of the building blocks of a system. Tensions created by the need to address such a range of issues have been evident both in the Australian and wider literatures and partly account for the large number of Phillips curves that have been estimated. Because of this, it is useful to have some way of organising the discussion, and the trinity of uses distinguished above is a convenient way of summarising its main conclusions. It is what we do in the present paper, although we focus only upon the first two items in the list.

The next section of this paper sets out a general framework that has been the basis of much work on the Phillips curve in Australia. It involves fairly standard descriptions of mark-up pricing and expectations-augmented wage curves, with adjustments made to reflect the fact that Australia is a small, open economy. The framework has been used within the Reserve Bank to study issues such as inflation targeting (for example, see de Brouwer and O'Regan (1997)). Furthermore, since many of the important studies of the Phillips curve in Australia emerged from the Research Department of the Reserve Bank, and since the people involved in these studies also had some input into the formulation of monetary policy, it is of interest to pay special attention to them.

Section 2 derives Phillips curves that reflect most of the historical research on the subject in Australia. Because this work has exhibited a dual focus, sometimes treating the Phillips curve as determining price inflation and sometimes labour cost movements, we derive two such curves. This duality is a feature of the paper, although, as will become clear, our preference is for the labour cost version. In conducting the research we also make some general comments about the difficulties faced by those endeavouring to estimate a Phillips curve for Australia.

Most of the research discussed in Section 2 is aimed at satisfying the first item in Stiglitz' list in that it seeks to provide a list of variables that are likely to be most influential in producing a change in inflation. While an understanding of such determinants is important, for policy there can be little doubt that it is the NAIRU and its measurement that comes to the fore, and the Phillips curve has frequently been used in this endeavour. Of course, there are well known difficulties in using a Phillips curve for this purpose and these are accentuated in the Australian case because the NAIRU has clearly not been constant over the past three decades. Consequently, in Section 3, we examine the significant recent contribution of Debelle and Vickery (1997) in which the NAIRU is allowed to change through time. Because Debelle and Vickery's model is a simpler specification than most Phillips curves recently estimated, we derive a richer specification which includes additional relevant regressors. Our results imply estimates of the NAIRU in 1997 of around 5½–7 per cent. We also examine whether the NAIRU depends, in a systematic way, on changes in the replacement ratio or in the proportion of long-term unemployed, although we are unable to find such dependence.

In Section 4 of the paper we look at the role of the Phillips curve in providing a framework for the formulation of monetary policy in Australia. We discuss the changing views about the Phillips curve within the Reserve Bank over the past three decades, and examine how these views have informed analysis of the inflationary process in Australia. Although the importance of the Phillips curve framework has fluctuated over the years, it currently has an influence comparable to that in the early 1970s when the (expectations-augmented) Phillips curve was first embraced to explain stagflation. The paper ends with a brief conclusion.

2. Early Studies of the Australian Phillips Curve

Phillips curve research within Australia can be usefully encapsulated within the context of the following three equations:

$$\Delta_k \ln P_t = c + \beta_1 \Delta_k \ln ULC_t + \beta_2 \Delta_k \ln PM_{t-j} + \beta_3 x_{1t} \tag{1}$$

$$\Delta_k \ln ULC_t = \phi \Delta_k \ln P_t^e + \psi z_t + \alpha x_{2t} \tag{2}$$

$$\Delta_k \ln P_t^e = (1-\delta)\Delta_k \ln P_{t-1} + \delta x_{3t}. \tag{3}$$

In Equation (1), P_t is the consumer price level excluding interest rates and other volatile items, and its rate of change is the underlying inflation rate, until recently the series targeted by the Reserve Bank of Australia.[1] ULC_t is unit labour costs and PM_t is tariff-adjusted import prices. The presence of import prices reflects the fact that a significant proportion of goods consumed within Australia are imported

1 As discussed later, the Reserve Bank has a target for inflation of 2–3 per cent per annum on average over the medium term. This target was expressed in terms of underlying inflation until October 1998.

and that the cost structure of Australian industry is affected by imported goods as well.[2] The second of the equations describes the evolution of unit labour costs. In most studies of the Phillips curve that have concentrated on labour compensation, ULC_t is decomposed into its components of wages and productivity growth. Wage movements, or more broadly unit labour costs, are driven by expectations of the price level P_t^e, by 'demand factors' z_t, and 'other' factors x_{2t}. Finally, expectations are modelled by combining a backward-looking component and some other (possibly forward-looking) measure, x_{3t}. The unit of observation is usually a quarter (since both price and wage data are available with that frequency) and the choice of k in Δ_k determines the period over which wage and price movements are measured. Setting $k = 4$ produces annual wage and price movements.

Phillips' (1959) Australian version of his classic paper estimated a wage version of Equation (2) with quarterly data and $k = 4$.[3] However, compared with his British work there were some significant changes, mostly in response to the institutions governing the way in which Australian wages were set. Until the 1990s, wage setting in Australia was quite centralised and distinctive. A legal system set *award* and minimum wages for most industries and 'collective bargaining' amounted to unions and employers arguing cases before an *Arbitration Court*, which made decisions regarding award wage changes. Thus, the equations Phillips presented were based on wage inflation that was closer to 'award wages' than actual 'earnings'; the difference, frequently referred to as 'earnings drift', arose from strong unions' capacity to negotiate above-award wages outside the Arbitration Court system. His equations also featured unemployment as well as import and export price inflation. The influence of the institutional features upon his thinking

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2 Gali and Gertler (1998) effectively consider a model in which P_t is a mark-up over ULC_t. In our data set $\ln P_t$ and $\ln ULC_t$ are I(1) processes and a dynamic equilibrium mark-up model would naturally be formulated in an error correction form. In this case, Equation (1) would include an error correction term which could be interpreted as the labour share of income. de Brouwer and Ericsson (1995, 1998) include such a term in their model of Australian inflation, but over our sample period this term does not appear to be stationary. Moreover, when it is added to the Phillips curve equations which we estimate in Section 3, it is of marginal significance.

3 Perry (1980) and Pitchford (1998) provide good discussions of this paper.

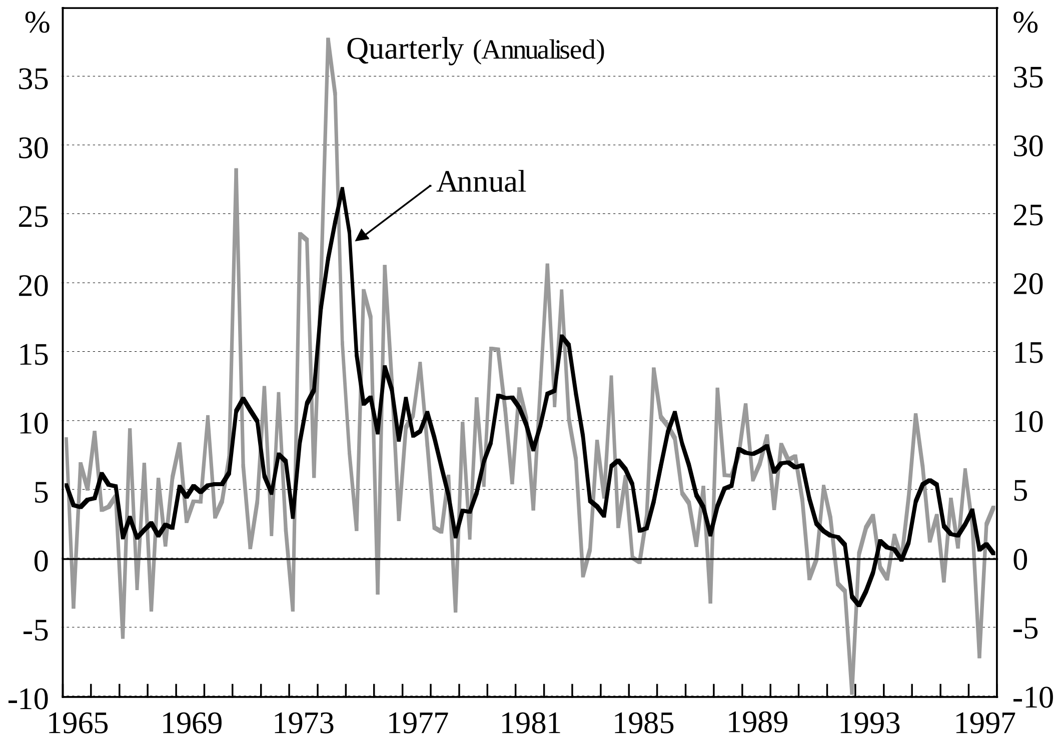
was particularly evident in the comments he made about the effects of the latter upon wages:

> It seems that the decisions of the Arbitration Court were strongly affected by the rapidly rising export prices…
>
> (Phillips 1959, p. 3)

The importance of the courts in determining wage inflation in Australia was manifested in many ways. As well as cases relating to specific industries, one had ‘National Wage Cases’ in which the whole structure of awards was generally adjusted upwards. The table in Appendix A details the outcomes of each of these National Wage cases between 1968 and 1981 (the end of wage indexation in Australia) and also gives the change in average earnings in the year after each decision came into effect. The exact timing and magnitude of these decisions rendered quarterly movements in wages very erratic, which even conversion to annual changes could not entirely smooth out (Figure 1). Such a series, particularly the quarterly one, may be hard to model.

Figure 1: Unit Labour Cost Inflation

Percentage change



Two responses could be made to the erratic movements evident in Figure 1. First, one might treat the Phillips curve as determining prices rather than wages. Pitchford (1968) seems to have been the first to do this in Australia, although it had been popular in the US for some time. A useful benchmark Phillips curve involving price inflation, that we will frequently refer back to later, is constructed from the following two equations:

$$\Delta_4 \ln P_t = \phi \Delta_4 \ln P_t^e + \gamma z_t \tag{4}$$

$$\Delta_4 \ln P_t^e = (1-\delta)\Delta_4 \ln P_{t-1} + \delta \Delta P_t^*, \tag{5}$$

where ΔP_t^* is a measure of expected inflation and z_t measures 'excess demand'. Almost all of the early work on the Phillips curve in Australia (including Phillips (1959)) accepted that there was a trade-off between inflation and unemployment, even in the 'long-run'. In the early 1970s, however, this proposition was increasingly questioned and a lot of time was spent testing whether a long-run trade-off actually existed, i.e. whether $\phi = 1$. As we discuss later, Michael Parkin was an influential figure in that debate and Chart 1 in Parkin (1973, p. 135) suggests that the estimates made of ϕ had been slowly converging on unity.[4] Henceforth, we assume that $\phi = 1$. Doing so, and replacing z_t with the difference

[4] The proposition that $\phi = 1$ could be tested because the relevant studies modelled wages rather than prices. Given any information set used by agents, one could replace $\Delta_k \ln P_t^e$ with $\Delta_k \ln P_t$ and then instrument $\Delta_k \ln P_t$ with elements of that set, provided the instruments were not correlated with the error term of the wage equation. To ensure this, the minimal information set was assumed to be composed of award wages, overseas prices and productivity movements (in fact, instrumental variables estimation was rarely performed directly but rather these three instruments were substituted for the actual inflation rate and a restriction was imposed upon the three weights, that they added to unity, thereby reducing the three unknown weights to two). It was therefore possible to avoid the Lucas/Sargent critique by working with a wage equation (a strategy that would clearly fail if one had price rather than wage inflation as the dependent variable). We do not comment further on this debate here.

between the unemployment rate U_t and the NAIRU U_t^*, enables us to reparameterize Equations (4) and (5) as:

$$\Delta_4 \ln P_t - \Delta_4 \ln P_{t-1} = \delta\left(\Delta P_t^* - \Delta_4 \ln P_{t-1}\right) + \gamma\left(U_t - U_t^*\right). \tag{6}$$

Furthermore, if the NAIRU is constant, Equation (6) may be re-written as:

$$\Delta_4 \ln P_t - \Delta_4 \ln P_{t-1} = a + \delta\left(\Delta P_t^* - \Delta_4 \ln P_{t-1}\right) + \gamma U_t, \tag{7}$$

where $a = -\gamma U^*$.

Equation (6) is a useful specification which we will retain in later work. By making the acceleration in inflation the dependent variable, the equation becomes one that involves an ‘accelerationist’ form of the Phillips curve. If the NAIRU is constant, U^* can be treated as a parameter and then Equation (6) can be estimated as a non-linear regression (alternatively, Equation (7) could be estimated as an OLS regression and U^* recovered from the estimated parameters a and γ).

To estimate Equation (6), we first replace U_t with $\mathrm{MA}_4(U_t)$, where MA_4 is a fourth-order moving-average operator.[5] Second, we use inflation expectations computed by Debelle and Vickery (1997) from bond yield data to represent ΔP_t^*.[6] In this, and all subsequent estimations, log levels and their differences are multiplied by 100. Estimating Equation (6) as a non-linear regression over the period 1965:Q2–1997:Q4 gives (with absolute values of *t*-ratios in brackets):

$$\delta = 0.070\ (2.62) \quad \gamma = -0.095\ (3.46) \quad U^* = 5.41\%\ (6.88).$$

5 If one does not do this then a transitory rise in the unemployment rate will have a peculiar effect upon quarterly inflation rates due to the fact that the annual inflation rate is just the sum of the quarterly inflation rates. Specifically, these would fall in the first quarter then rise in subsequent quarters. In practice, it makes almost no difference to the point estimates whether we use U_t or $\mathrm{MA}_4(U_t)$ as the U_t series is already very smooth. Many studies have used $\mathrm{MA}_4(U_t)$, e.g. Jonson, Mahar and Thompson (1973).

6 Appendix E contains descriptions and the sources for the data which we use in this paper.

While the signs are as expected, the fit is very bad, with $R^2 = 0.09$ and $DW = 0.91$. Moreover, fitting the relation over the sub-period 1965:Q2–1976:Q1 generates an estimate of $U^* = 2.2\%$, indicating that the relation has not been particularly stable.

Table 1 summarises early research on wage and price Phillips curves in Australia. When it came to modelling wage inflation, rather than price inflation, researchers in policy institutions mostly examined movements in labour costs conditional upon the decisions taken by the Arbitration Court. Technically, x_{2t} in Equation (2) was set to changes in award wages and what was modelled was essentially 'earnings drift', that is, the gap between award wages and those actually paid; something likely to be affected by the state of the labour market. Some of these studies are also summarised in Table 1. Of course, such a 'solution' was less helpful in a forecasting environment as some prediction needed to be made about future Arbitration Court decisions, i.e., an equation for x_{2t} was necessary. There were a number of attempts to do this and Higgins (1973) and Jonson, Mahar and Thompson (1973) were among the earliest of these studies. Generally, modelling of earnings given award wages was quite successful. In contrast, it was difficult to model either earnings without conditioning upon award wages or award wages themselves. Given the frequency of Arbitration Court decisions, it was probably inevitable that annual wage movements ($k = 4$) became the preferred series to model.

Table 1: Summary of Early Phillips Curve Studies in Australia

Wage equations

Author(s)	Dependent variable	Excess labour demand variable(s)	Other variable(s)
Phillips (1959)	Annual % change in wages	$1/U^2$	• Import prices • Export prices
Hancock (1966)	Annual % change in wages	$\ln U$, $\Delta \ln U$	• Minimum wages
Schott (1969) [(a)]	Level of wages	Level U, V	• Company profits • Ratio of union membership to labour force • Lagged price inflation
Jonson (1972) [(a)]	Annual % change in wages	$1/U$	• Inflation expectations (survey measure) • Minimum wages • Working days lost due to strikes
Parkin (1973) [(a)]	Annual % change in wages	$1/U$, $\Delta(1/U)$, $V-U$	• Award wages • Productivity • Tradeables inflation
Higgins (1973)	Annual % change in wages	V/U, $\Delta(V/U)$	• Lagged price inflation • Award wages
Jonson, Mahar and Thompson (1974) [(a)]	Annual % change in wages	V/U, $\Delta(V/U)$	• Foreign reserves • Award wages • World prices • Productivity
Carmichael and Broadbent (1980) [(a)]	Quarterly % change in wages	$V-U$	• Inflation expectations
Kirby (1981)	Quarterly % change in wages	U	• Inflation expectations (various measures)
Gregory (1986)	Quarterly % change in wages	U, V, O	• Dummy for 1974:Q3 • Inflation expectations (various measures)
Simes and Richardson (1987)	Quarterly % change in wages	U, O	• Lagged price inflation

continued next page

Table 1: Summary of Early Phillips Curve Studies in Australia *(continued)*

Price equations

Author(s)	Dependent variable	Excess labour demand variable(s)	Other variable(s)
Pitchford (1968)	Annual % change in prices	$V-U$	• Export prices • Import prices • Minimum wages • Productivity
Nevile (1977)	Annual % change in prices	U, $V-U$	• World prices • Indirect taxes • Award wages

Notes: U is the unemployment rate (or level, where indicated).
V is the vacancy rate.
O is overtime hours worked.
(a) These studies were undertaken in the Research Department of the Reserve Bank of Australia.

Equation (8) is an equation for unit labour costs that parallels the 'price equation' in Equation (6):

$$\Delta_4 \ln ULC_t - \Delta_4 \ln P_{t-1} = \delta\left(\Delta P_t^* - \Delta_4 \ln P_{t-1}\right) + \gamma\left(\mathrm{MA}_4(U_t) - U_t^*\right) . \qquad (8)$$

Estimates of its parameters over the period 1965:Q2–1997:Q4 are:

$$\delta = 0.219\ (2.28) \quad \gamma = -0.608\ (6.16) \quad U^* = 6.32\%\ (14.07)$$

with $R^2 = 0.23$ and $DW = 0.49$.[7] By and large, the effects are better determined than in the price equation. However, the instability in the price equation is also

[7] Because the Phillips curve is a single equation in a system, our estimates of Equations (6) and (8) are based on some exogeneity assumptions. Appendix B contains a discussion of the exogeneity assumptions relevant to estimating Phillips curves.

present in the wage equation, with an estimated NAIRU over the earlier sub-sample (1965:Q2–1976:Q1) of 2.5 per cent.[8]

How might one improve upon the specifications of these two Phillips curve equations? As mentioned earlier, it is unlikely that one could capture the impact of import prices upon final goods prices with what is effectively just wage pressures. Moreover, there may be 'speed-limit' effects, so that a rapid change in the unemployment rate has an impact on prices, implying that the demand measure might also include changes in the unemployment rate. Finally, there is a decision to be made about whether to model quarterly or annual movements in wages and prices. We choose to model annual movements, which leads us to the following specification for the change in annual price inflation:[9]

$$\begin{aligned}\Delta_4 \ln P_t - \Delta_4 \ln P_{t-1} = a + \delta\left(\Delta P_t^* - \Delta_4 \ln P_{t-1}\right) + \gamma\,\mathrm{MA}_4\left(U_t\right) + d\,\Delta U_{t-1} + \\ \alpha_1\left(\Delta_4 \ln PM_{t-1} - \Delta_4 \ln PM_{t-2}\right) + \alpha_2\left(\Delta \ln P_{t-1} - \Delta \ln P_{t-4}\right).\end{aligned} \tag{9}$$

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8 One response to this instability by earlier researchers was to experiment with different measures of demand pressure. Stimulated by the emerging literature on the role of 'insiders' and 'outsiders' in the wage-setting process, a range of these demand pressure variables have been proposed. For example, Gregory (1986) looked at overtime hours worked while Cockerell and Russell (1995) constructed a measure of 'inside unemployment'. Neither of these alternatives produces much of an improvement in our equations though; with overtime the crucial fit statistics are $R^2 = 0.19$ and $DW = 0.53$, while using inside unemployment results in $R^2 = 0.23$ and $DW = 0.60$.

9 As observed previously, annual movements were favoured in early work on the Phillips curve but, after Kirby (1981), there was a shift towards modelling quarterly wage and price movements. From an economic viewpoint, it is of more interest to explain annual movements in inflation than quarterly movements. This explains our choice of dependent variable in Equation (9). Consider deriving Equation (9) from an equation that has quarterly inflation ($\Delta \ln P_t$) as the dependent variable and three lagged changes in quarterly inflation ($\Delta \ln P_{t-j},\ j = 1 \ldots 3$) as regressors. These regressors have associated coefficients φ_j. Since annual inflation is the sum of four consecutive quarterly price changes, changing to annual inflation as the dependent variable simply means that the regressors $\Delta \ln P_{t-j}$ now have coefficients $(1+\varphi_j)$. In an equation with annual inflation as the dependent variable, the coefficients on these regressors can be freely estimated, and any restrictions upon the φ_j can be tested and imposed.

Since the dependent variable in this equation is the change in annual inflation, the augmented list of regressors is extended to include $\Delta \ln P_{t-4}$. When the four lagged quarterly inflation rates are added to the regressor set we find that $\Delta \ln P_{t-1}$ and $\Delta \ln P_{t-4}$ had close to equal and opposite signs, accounting for the formulation shown. The import-price inflation term was also entered in the specific way described, as that was an acceptable simplification of more complex dynamics.[10] One advantage of this specification is that it ensures that the estimate of the NAIRU is independent of the steady-state rate of either domestic or imported inflation.

Estimating Equation (9) over the sample period 1965:Q3–1997:Q4 produces the following estimates:

$$a = 0.232\ (2.15) \qquad \delta = 0.032\ (1.89) \qquad \gamma = -0.039\ (2.26)$$
$$d = -0.413\ (3.00) \qquad \alpha_1 = 0.053\ (4.66) \qquad \alpha_2 = 0.745\ (12.90).$$

The $R^2 = 0.67$, $DW = 2.29$ and the $\chi^2(4)$ statistic for testing that the first four serial correlation coefficients are zero is 10.48 (p-value = 0.03). Normality of the residuals is very strongly rejected, the Jarque-Bera test giving a value of 220. The reason for this becomes clear by plotting the histogram of the dependent variable (Figure 2). Like many financial asset prices there are too many small movements in the acceleration in inflation for this variable to be treated as normally distributed.

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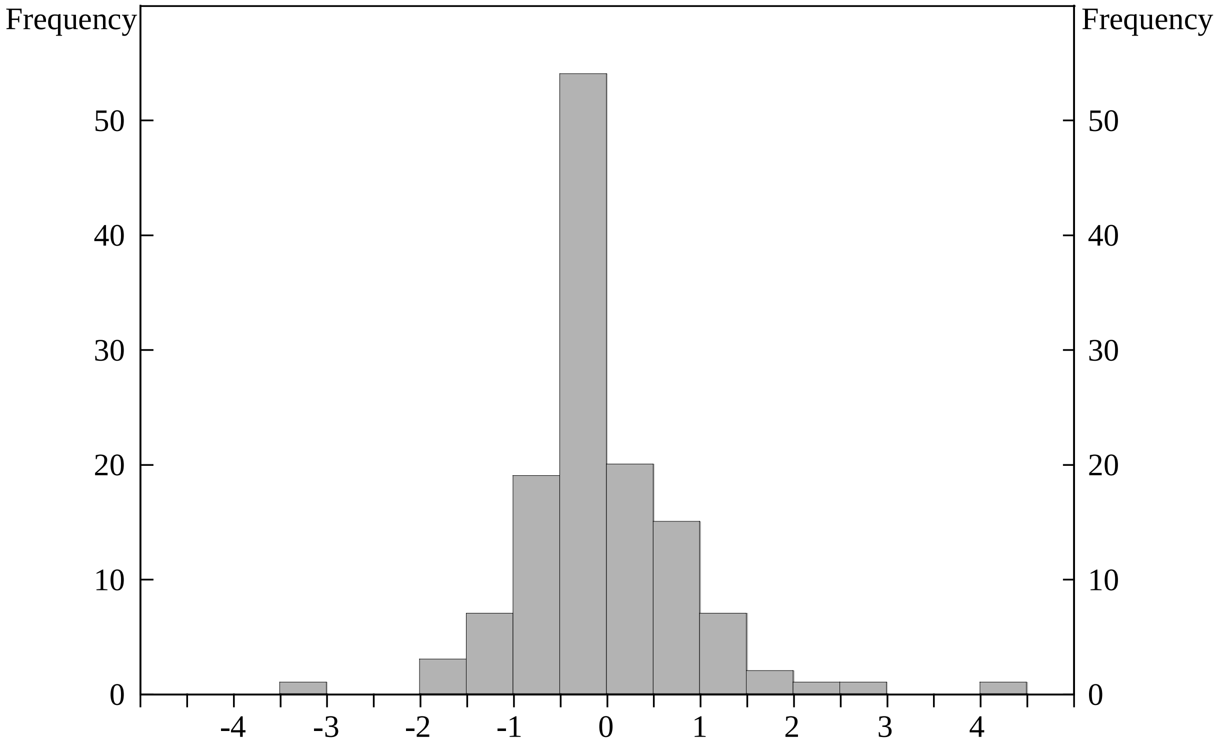
[10] Since the import price index is constructed from the contemporaneous exchange rate which we would expect to appear as the last variable in any recursive system, it is natural to exclude PM_t from Equation (9) and only allow lagged values of that variable to enter the equation. Research in Australia points to a strong relationship between the terms of trade and the exchange rate (Gruen and Dwyer 1996). Moreover, movements in the terms of trade tend to be dominated by variations in foreign-currency denominated export prices. Thus, by excluding PM_t from the equation, we are implicitly assuming that the impact of export prices upon the price level within the quarter is quite small, which is consistent with Gruen and Dwyer's results.

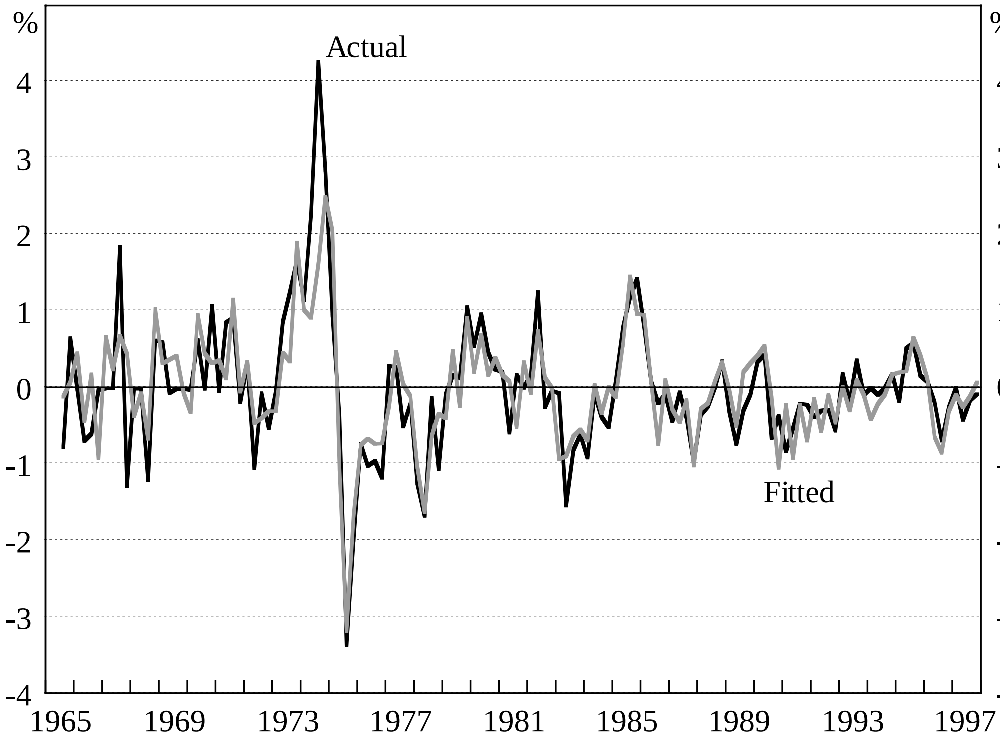
Figure 2: Histogram of Changes in Annual Inflation

1965:Q2–1997:Q4



The fit of the equation is quite impressive. Looking at the fitted and actual values in Figure 3, one sees that the very strong movements of inflation in 1974 defeat it, but apart from that, the equation produces quite a good fit. The implied natural rate over the period is 5.95 per cent with a standard error of 1.19 per cent. However, there are some less attractive aspects of the equation. The most important one stems from the low estimated coefficient on the unemployment rate, which implies that the direct effects of deviations from the NAIRU account for a relatively small amount of the movements in annual inflation. Thus, a 3 percentage point departure from the NAIRU would only cause a change in annual inflation of 0.12 per cent in the next quarter. This is a small number when compared with the maximum increases and decreases in the sample, which were 4.26 per cent and -3.37 per cent. The very small estimated coefficient δ implies that inflation expectations are predominantly backward looking, while the non-zero value for d supports the idea that there are speed-limit effects on inflation.

Figure 3: Changes in Annual Inflation



It is interesting to use a similar specification to explain annual real unit labour cost inflation.[11] However, in light of the different dependent variable, the specification is adjusted in two ways: import prices are removed and a lagged dependent variable is added based on its significance in the equation (the corresponding variable did not appear in the price equation because it was insignificant). Specifically, we estimate:

$$\begin{gathered}\Delta_4 \ln ULC_t - \Delta_4 \ln P_{t-1} = a + \delta\left(\Delta P_t^* - \Delta_4 \ln P_{t-1}\right) + \gamma\, \mathrm{MA}_4\left(U_t\right) + d\, \Delta U_{t-1} + \\ c\left(\Delta_4 \ln ULC_{t-1} - \Delta_4 \ln P_{t-2}\right) + \alpha_2\left(\Delta \ln ULC_{t-1} - \Delta \ln ULC_{t-4}\right)\end{gathered} \tag{10}$$

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[11] The variable being explained is not strictly movements in real unit labour costs, since the deflator is the price level in the previous period rather than the current one.

over the sample period 1965:Q3–1997:Q4, producing:

$$a = 1.228\ (3.38) \qquad \delta = 0.112\ (2.12) \qquad \gamma = -0.187\ (3.23)$$
$$d = -1.158\ (2.54) \qquad c = 0.723\ (14.82) \qquad \alpha_2 = 0.464\ (7.16).$$

The $R^2 = 0.80$, $DW = 2.29$ and the $\chi^2(4)$ test statistic for serial correlation is 9.90 (p-value = 0.04). The Jarque-Bera test for normality of the residuals has a value of 14.85.[12] The estimated NAIRU is 6.58 per cent with a standard error of 0.81 per cent. Figure 4 shows the actual and fitted values of the dependent variable from this equation. Generally, the fit of the equation is quite good and tends to be superior to that of the price equation. Given the history recounted earlier about the difficulty of modelling wages, it is perhaps a little surprising that the equation works so well compared with the price equation. One difference between our work and most of that in the past is that we model unit labour costs rather than wages. Since unit labour costs are relevant to pricing decisions, focusing on them seems a reasonable strategy. Our use of a longer sample period than was available in earlier studies may also be relevant since the wage-setting process has become less regulated over time, especially in the 1990s.[13]

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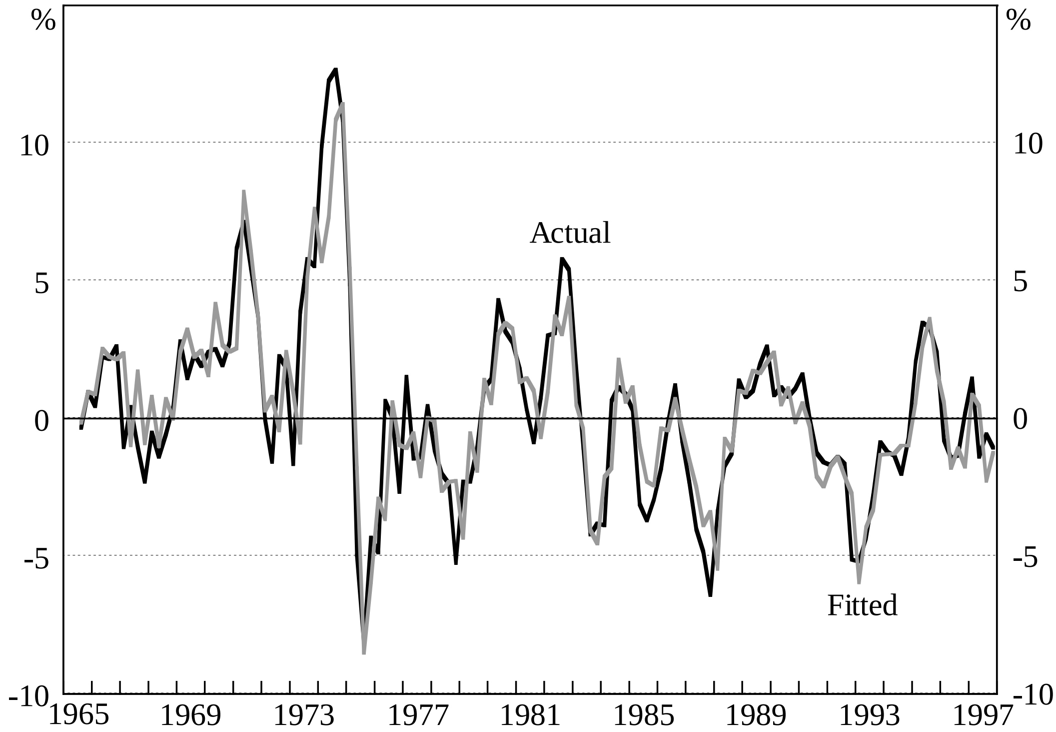
[12] The Jarque-Bera test implies that this equation's residuals are also non-normal. In contrast to the price equation, however, this is caused by the influence of a few quarters of large rises in the dependent variable (which coincide with large wage-case decisions) rather than the presence of many small movements. Excluding these observations, normality of the unit-labour-cost residuals cannot be rejected.

[13] One test of the importance of the longer sample period is to see how well the equation performs over a sample finishing in 1973:Q1. The answer is that, in this regression, all of the variables are insignificant apart from the wage inflation variables. We are, of course, only using 31 observations in this regression and so no precision could be expected. By contrast, however, when the sample is restricted to the *last* 31 observations, all of the variables are significant, with the exception of the change in unemployment.

Figure 4: Real Unit Labour Cost Inflation*

Year-ended percentage change



Note: * Unit labour cost inflation deflated by lagged price inflation.

3. Recent Work on the Phillips Curve

Figures 5 and 6 show recursive estimates of the NAIRU from Equations (9) and (10). Contrasting the beginning and end points reveals quite clearly the shift in the NAIRU, although it appears to have been fairly stable since the early 1980s. These outcomes are consistent with estimates of the NAIRU made in previous research in Australia which had the NAIRU creeping up as data from the early 1970s was included (Borland and Kennedy 1998). Moreover, as seen in Figure 7, the unemployment rate rose sharply in the mid 1970s and has not returned to its pre-1973 level. Consequently, the idea that the NAIRU can be treated as a constant is not very attractive.

Figure 5: NAIRU from the Price Phillips Curve

Derived from recursive estimation

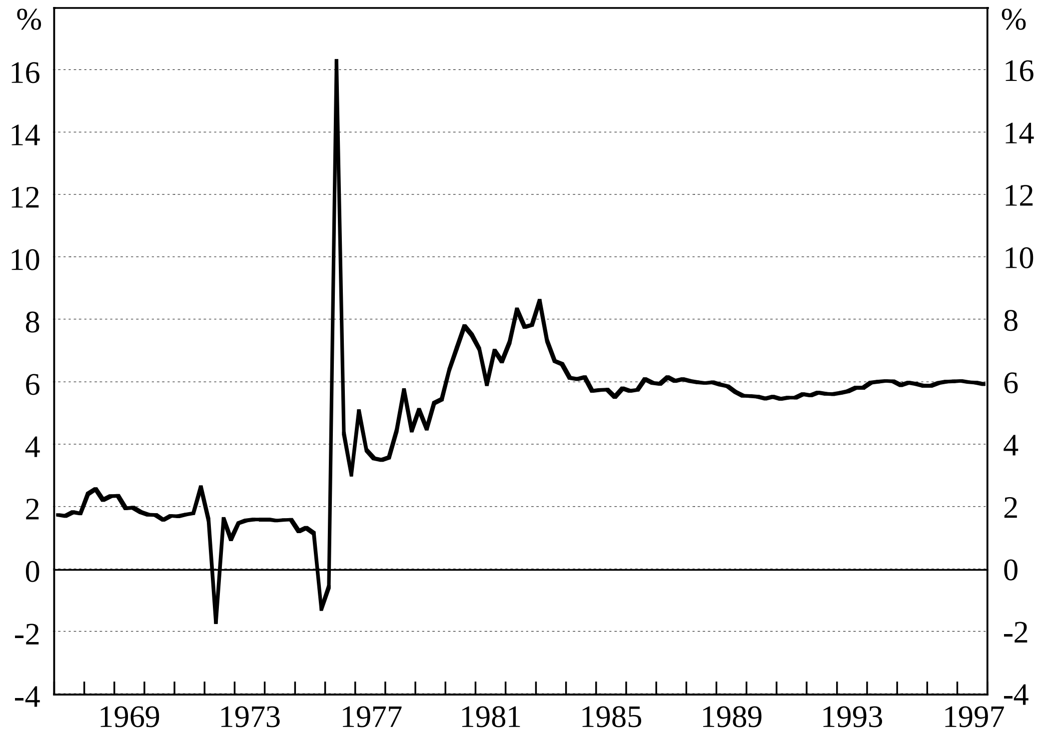
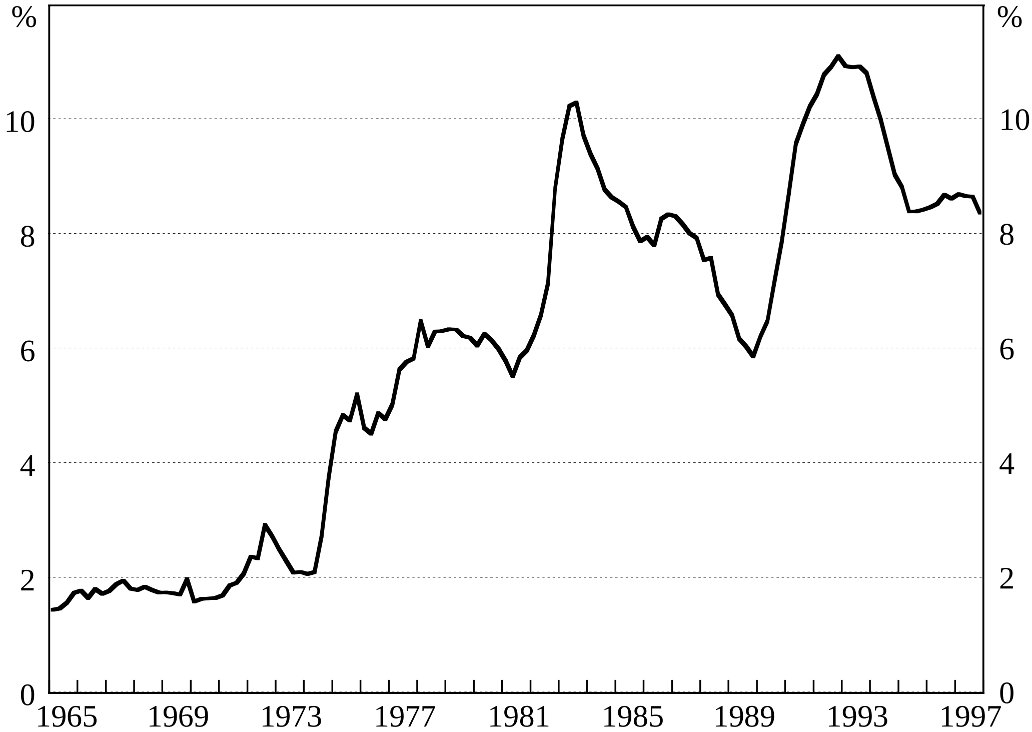


Figure 6: NAIRU from the Unit Labour Cost Phillips Curve

Derived from recursive estimation

Figure 7: Unemployment Rate



If one is to allow the NAIRU to shift over time, then the task becomes one of finding the best way to do that. In Phillips curve specifications such as those estimated earlier, the NAIRU is absorbed into the intercept, presenting the possibility of using statistical procedures to determine the number and location of breaks in that coefficient. Once located, shifts in the NAIRU could be captured by a series of dummy variables. Early work on Treasury's NIF-10 model of the Australian economy did something like this, albeit in an informal way, and the current Treasury macroeconomic model (TRYM) allows for a single shift in the level of the NAIRU in 1974.[14]

[14] We formally tested for breaks in our Phillips curve relations, Equations (9) and (10), by applying the battery of tests in Bai and Perron (1998). Generally, these tests suggest one or two breaks in each relation. For the price equation, the breaks are in 1972:Q4 and 1974:Q4. However, given how close these are to one another, it seems best to regard them as a single break around 1973. For the wage equation, the most significant break identified was in 1977:Q2 with a less significant break in 1973:Q4. Thus, the time pattern of the NAIRU

The logic of imposing breaks in the NAIRU based on an inspection of the history of the unemployment rate follows from the observation that, within a few years of a shock to the NAIRU, the unemployment rate adjusts back to this new equilibrium level in most macroeconomic models in use in Australia. In the TRYM model, for example, this adjustment takes about three years (Downes and Stacey 1996) and the outcome is similar in the class of models associated with Chris Murphy (Powell and Murphy 1997). Following a shock, the lengthy period of time during which the two series have not converged, however, suggests that it may well be difficult to derive reliable information about the (time-varying) level of the NAIRU simply from the behaviour of the unemployment rate.

There is now an emerging literature (for example, Debelle and Laxton (1997) and the references in Laxton *et al* (1998)) which involves treating the NAIRU as a unit-root process of the form:

$$U_t^* = U_{t-1}^* + \nu_t, \tag{11}$$

where ν_t is assumed to be $N(0, \sigma_\nu^2)$. The argument for a unit-root in the NAIRU is apparent from applying 'unit-root accounting' to both sides of Equation (6). The dependent variable in that equation has little persistence; defining it as y_t, an augmented Dickey-Fuller-style regression of y_t against y_{t-1} and Δy_{t-j}, $j = 1 \ldots 4$, gives a coefficient on y_{t-1} of 0.53. Since most of the other variables are in differenced form and U_t behaves like a unit-root process (Appendix C), this suggests that U_t^* and U_t must cointegrate. Of course, the variable $\Delta P_t^* - \Delta_4 \ln P_{t-1}$ is quite persistent (0.93 being the first-order term in the augmented Dickey-Fuller-style regression) and so we expect that this would also be true of the difference $U_t - U_t^*$.

evident in the recursive estimates shown in Figures 5 and 6, seems to hold up to more formal testing.

For Australia, Debelle and Vickery (1997) use a Phillips curve framework to estimate the NAIRU as a time-varying coefficient using the Kalman filter.[15] Equation (12), which is a modified version of Equation (6), is Debelle and Vickery's preferred functional form for the price Phillips curve (to which we have added an error term ε_t that is assumed to be $N(0, r)$).

$$y_t = \Delta_4 \ln P_t - \Delta_4 \ln P_{t-1} = \delta\left(\Delta P_t^* - \Delta_4 \ln P_{t-1}\right) + \gamma \frac{\left(U_t - U_t^*\right)}{U_t} + \varepsilon_t . \qquad (12)$$

This equation is a non-linear Phillips curve. Apart from appearing in both of Phillips' original papers (Phillips 1958, 1959) many other estimated Australian Phillips curves have used this non-linear specification, e.g. all those associated with Murphy's models and TRYM. Debelle and Vickery (1997) review the arguments for and against the non-linear Phillips curve specification.

As we have previously discussed, one might expect both import price and speed-limit terms to appear in a price Phillips-curve relationship like Equation (12). This suggests a richer specification, based on Equation (9) from the previous section:

$$\begin{aligned} \Delta_4 \ln P_t - \Delta_4 \ln P_{t-1} = \delta\left(\Delta P_t^* - \Delta_4 \ln P_{t-1}\right) + \gamma \frac{(U_t - U_t^*)}{U_t} + d\,\frac{\Delta U_{t-1}}{U_t} + \\ \alpha_1\left(\Delta_4 \ln PM_{t-1} - \Delta_4 \ln PM_{t-2}\right) + \alpha_2\left(\Delta \ln P_{t-1} - \Delta \ln P_{t-4}\right). \end{aligned} \qquad (13)$$

We therefore estimate Equation (13) by maximum likelihood, assuming that the NAIRU evolves as a random walk, as in Equation (11).[16] The coefficient estimates,

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[15] Given the fact that the Kalman filter does make some normality assumptions, and the change in inflation is clearly non-normal (Figure 2), one might wish to be cautious when interpreting the results from this estimation.

[16] Appendix D provides a discussion of some of the technical issues involved in this estimation. Two changes were made to the specification in Equation (9). One was to make the speed limit term – the lagged change in unemployment – a ratio of the unemployment rate, in line with

and associated *t*-ratios (for the sample period 1966:Q1–1997:Q4) are:

$$\delta = 0.051\ (2.09) \quad \gamma = -0.388\ (1.74) \quad d = -1.538\ (1.99) \quad \alpha_1 = 0.046\ (4.26)$$
$$\alpha_2 = 0.705\ (11.40) \quad \sqrt{r} = 0.470\ (13.89) \quad \sigma_\nu = 0.566\ (1.52).$$

These estimates imply that import prices make a very significant contribution to the acceleration in inflation. Speed-limit effects, while less significant, also seem to contribute.[17] One notable feature of the results is that the magnitude of γ is much smaller than that found with Debelle and Vickery's specification ($\gamma = -1.25$), i.e. the influence of deviations of the unemployment rate from the NAIRU upon the acceleration in inflation is much smaller. No doubt part of this is due to the inclusion of the speed-limit term, but it is also due to the fact that other regressors explain variations in inflation movements that were attributed to the NAIRU gap in Debelle and Vickery's specification.

Figure 8 shows both one and two-sided estimates of the NAIRU from Equation (13). For each period, the one-sided estimate is derived using data up to and including the previous period, while the two-sided estimate is based on data from the whole sample. As we would expect, both estimates of the NAIRU rise sharply in the early 1970s. From the mid 1970s until the late 1980s, the estimated NAIRU declines gradually, which may be explained, at least after 1983, as a

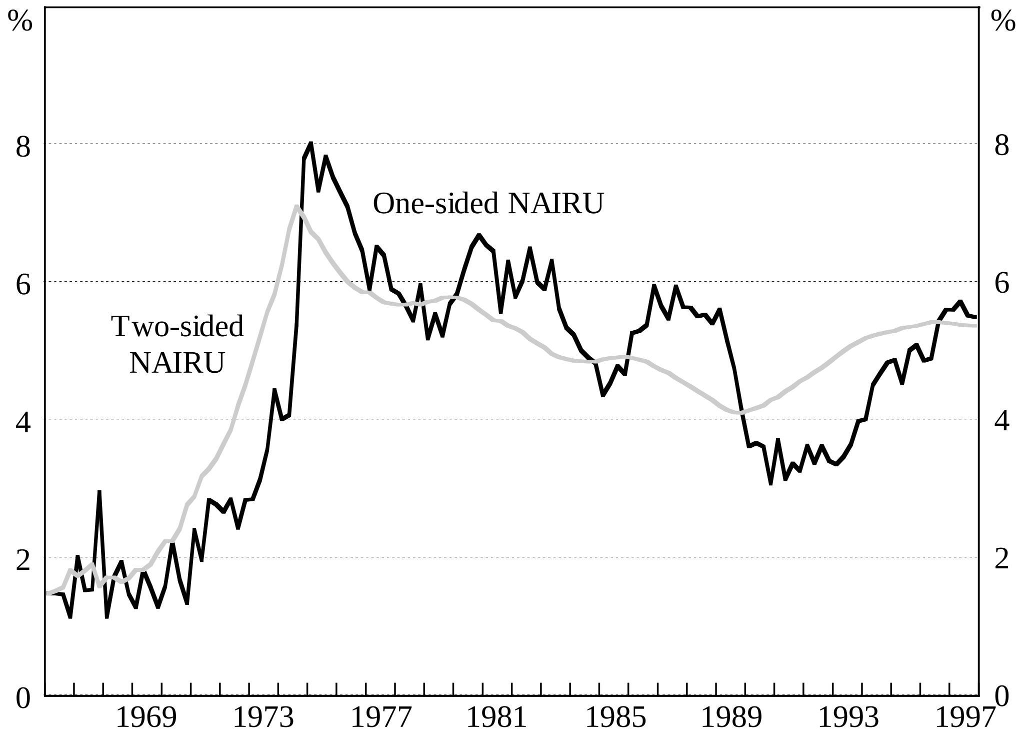
---

the non-linear structure of the Phillips curve. The second was to use the unemployment rate rather than a moving average of it when defining the excess demand variable. As was mentioned earlier, from the point of view of fit, it matters little whether one uses $\mathrm{MA}_4(U_t)$ or U_t as the measure of unemployment, and the former was preferred earlier because it improves the shape of the implied lag distributions to a temporary shock. However, it would be difficult to work with $\mathrm{MA}_4(U_t - U_t^*)$ in the context of the Kalman filter. We also estimated models in which the Phillips curve was linear in the unemployment rate but, based on the values of the maximised log likelihoods, such models were always rejected in favour of the non-linear versions.

17 Debelle and Vickery (1997) also tested for speed-limit effects, but generally found them to be of the wrong sign (and insignificant). This result is presumably a consequence of the omission of other relevant inflation explanators from their equation.

consequence of the Accord. By the early 1990s, however, the one-sided estimate of the NAIRU has fallen to an implausibly low level, although this problem is less serious when the estimate is based on the whole sample. By the end of the sample, the estimate of the NAIRU is around 5½ per cent, although this estimate is imprecise.[18]

Figure 8: NAIRU from the Price Phillips Curve



Note that, at a steady rate of both import-price and consumer-price inflation, Equation (13) implies that a steady unemployment rate will be equal to the NAIRU only when inflation expectations, ΔP_t^*, are equal to actual inflation, $\Delta_4 \ln P_{t-1}$. Furthermore, while ever inflation expectations exceed actual inflation, a steady unemployment rate must be above the NAIRU for actual inflation to remain steady. These are general properties of all the Phillips curves we estimate in this paper, and also of the Debelle-Vickery Phillips curve. This point is of empirical

[18] The final estimate of the NAIRU is sensitive to the parameters γ and σ_ν. Since both are estimated imprecisely, with t-ratios less than 2, the NAIRU is also estimated imprecisely.

relevance because our measure of inflation expectations exceeds actual inflation for extended periods, with the gap averaging 2.1 per cent per annum over the period 1980–1997 (although it has disappeared by the end of the sample).

A similar analysis can be carried out by estimating a non-linear version of our unit labour cost Phillips curve, Equation (10), augmented to allow for a time-varying NAIRU:

$$\begin{aligned}\Delta_4 \ln ULC_t - \Delta_4 \ln P_{t-1} = \delta\left(\Delta P_t^* - \Delta_4 \ln P_{t-1}\right) + \gamma \frac{(U_t - U_t^*)}{U_t} + d\,\frac{\Delta U_{t-1}}{U_t} + \\ c\left(\Delta_4 \ln ULC_{t-1} - \Delta_4 \ln P_{t-2}\right) + \alpha_2\left(\Delta \ln ULC_{t-1} - \Delta \ln ULC_{t-4}\right),\end{aligned} \tag{14}$$

producing (for the sample period 1966:Q1–1997:Q4):

$$\begin{gathered}\delta = 0.132\ (2.02) \quad \gamma = -1.868\ (2.01) \quad d = -4.372\ (1.68) \quad c = 0.666\ (11.76) \\ \alpha_2 = 0.454(7.42) \quad \sqrt{r} = 1.460\ (14.52) \quad \sigma_v = 0.365\ (2.55).\end{gathered}$$

These estimates imply some role for speed-limit effects in the determination of unit labour costs, as they did for the acceleration in price inflation. Figure 9 shows both one and two-sided estimates of the NAIRU from this equation. The unit-labour-cost Phillips curve appears to give a somewhat more plausible picture of movements in the NAIRU than does the price Phillips curve, with much less movement in the estimates of the NAIRU since the mid 1970s. The dip in the unit-labour-cost NAIRU in the mid 1980s also appears more consistent with the timing of the Accord. While there has been considerable debate over whether the Accord reduced the NAIRU, our evidence seems to suggest that it did – at least for some time. At the end of the sample, the NAIRU is estimated to be around 7 per cent, although this number is again estimated imprecisely.

Figure 9: NAIRU from the Unit Labour Cost Phillips Curve

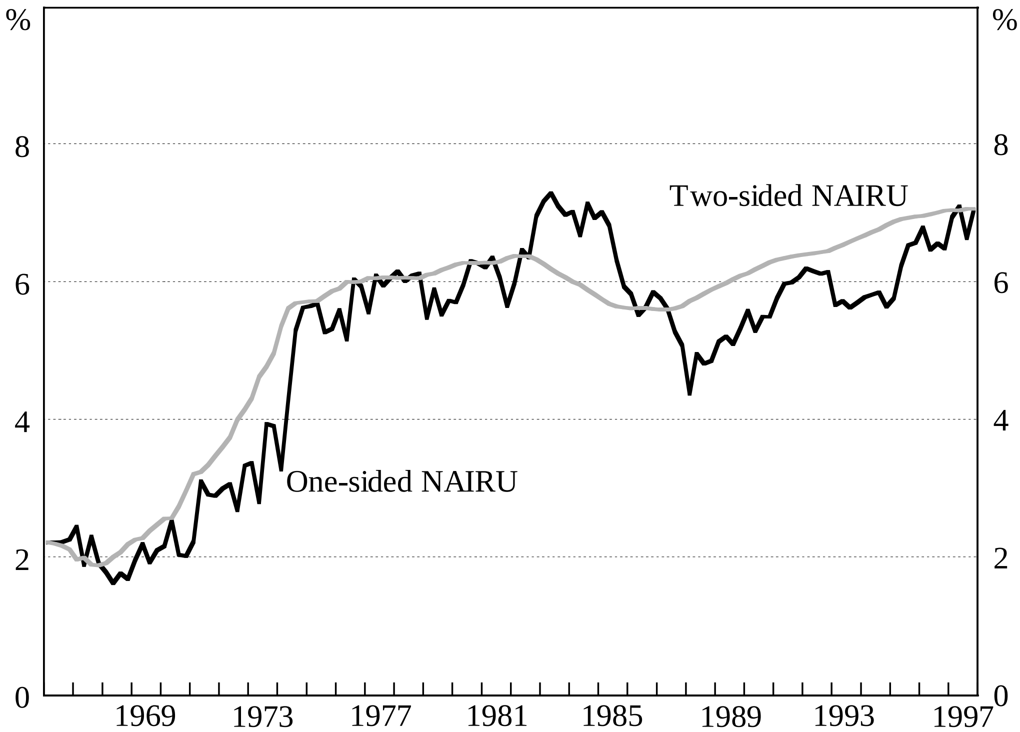
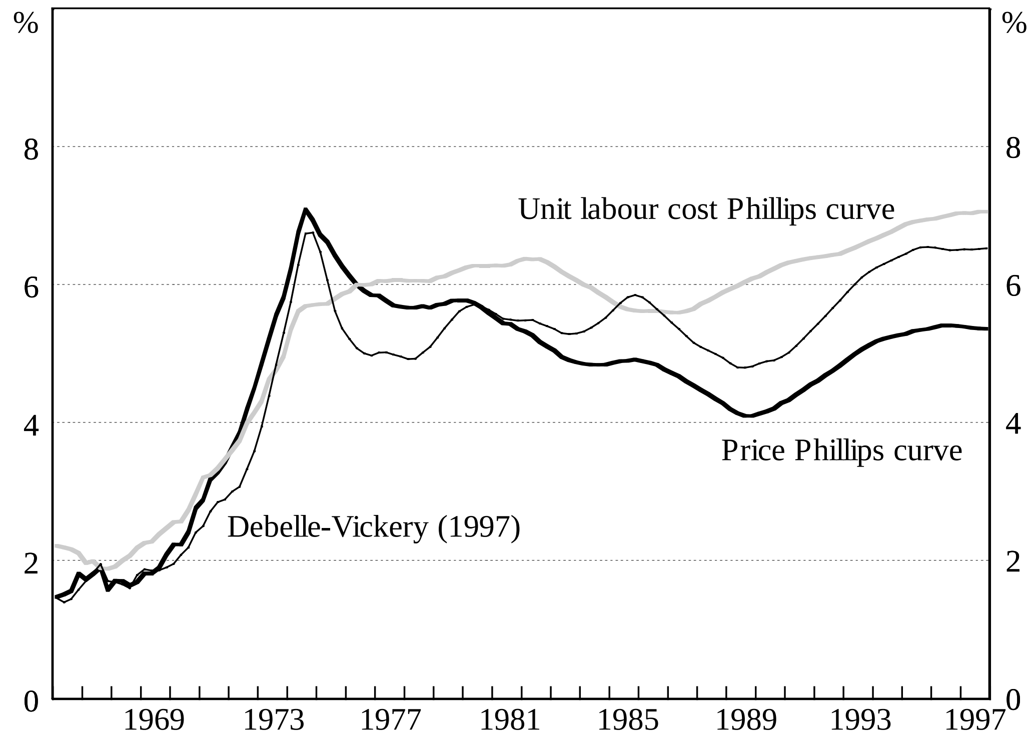


Figure 10 presents a comparison of two-sided (that is, whole-sample) estimates of the NAIRU from our two preferred Phillips curves Equations (13) and (14) and from Debelle and Vickery's price Phillips curve Equation (12). The time-profiles of these three estimated NAIRUs are fairly similar, suggesting that the added complexity of our Phillips curve equations appears to add little to our understanding of the evolution of the NAIRU.

There is, however, an advantage to our approach. Debelle and Vickery generate a relatively smooth time-profile for the NAIRU by *imposing* the assumption that shocks to the NAIRU have a small variance (their key assumption is that the parameter q takes the value 0.4, where $q = \gamma^2\sigma_v^2$ and σ_v^2 is the variance of shocks to the NAIRU). However, when the parameters in the Debelle-Vickery system are freely estimated by maximum likelihood, q takes the value 7.1.[19] Not surprisingly, the imposed value $q = 0.4$ is clearly rejected by a likelihood ratio test.

Figure 10: Comparison of NAIRU Estimates



Notes: This figure shows estimates of the NAIRU based in each case on the whole sample of data (two-sided estimates). The Debelle and Vickery (1997) results use their price Phillips curve specification and their methodology estimated over our sample period (1966:Q1–1997:Q4).

The results generated by maximum-likelihood estimation of the Debelle-Vickery system are, however, unsatisfactory because they imply an unrealistically volatile profile for the NAIRU, with values ranging from less than zero to more than 20 per cent over the sample (results not shown). By contrast, the extra terms in our more complex specifications explain much of the variation in inflation that must instead be attributed to the unemployment gap in the Debelle-Vickery specification. As a consequence, we generate smooth (maximum-likelihood)

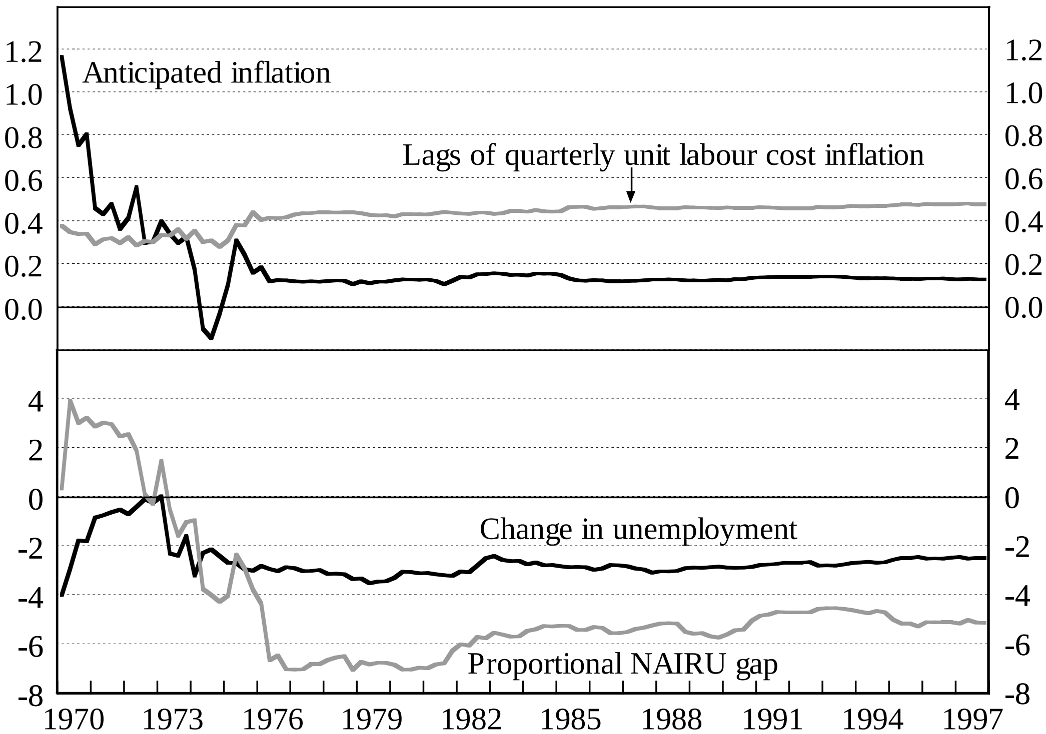
[19] Other parameters also take different values, but the value of q is the key difference.

estimates of the time-profile of the NAIRU without the need to impose restrictions on the parameters which are rejected by the data.

We now examine the stability of our time-varying models of the NAIRU, focusing on our preferred unit labour cost Phillips curve model Equation (14). The results of recursively estimating the parameters in that model are shown in Figure 11, where the coefficients on the following variables are plotted: $\Delta P_t^* - \Delta_4 \ln P_{t-1}$ (anticipated inflation), $(U_t - U_t^*)/U_t$ (proportional NAIRU gap), $\Delta U_{t-1}/U_t$ (change in unemployment) and $\Delta \ln ULC_{t-1} - \Delta \ln ULC_{t-4}$ (lags of quarterly unit labour cost inflation). The coefficient on the lagged dependent variable is extremely stable, and so is omitted from the figure. The difficulties that any wage or price equation

Figure 11: Parameter Estimates from the Unit Labour Cost Phillips Curve

Derived from recursive estimation



faces with data from the early 1970s are very clear, but the equation seems reasonably stable apart from that.[20]

While treating the NAIRU as a stochastically time-varying coefficient is a useful approach, there are other ways to deal with the fact that the NAIRU is unobservable. For example, it is often of considerable interest to know whether unemployment is above or below the NAIRU, without being so concerned about its distance from the NAIRU. One way to determine this is to treat $\gamma(U_t - U_t^*)$ in Equation (6) as a latent variable ξ_t, and to estimate an equation of the form:

$$\Delta_4 \ln P_t - \Delta_4 \ln P_{t-1} = \delta\left(\Delta P_t^* - \Delta_4 \ln P_{t-1}\right) + \xi_t . \qquad (15)$$

The question then becomes one of how to model the latent variable ξ_t. One strategy is to treat it in the same way as Hamilton (1989) and assume that it involves two states, with the draws in each state coming from different normal densities $N(\mu_1, \sigma_1)$ and $N(\mu_2, \sigma_2)$.[21] Transition probabilities then govern the movement from one state to another. Applying this methodology to the price Phillips curve Equation (13), and replacing $\gamma(U_t - U_t^*)/U_t$ with a two-state latent variable, the resulting parameter estimates, for the sample period 1966:Q1–1997:Q4, are:

$$\delta = 0.030\ (2.04) \quad d = -2.260\ (2.68) \quad \alpha_1 = 0.034\ (4.22) \quad \alpha_2 = 0.759\ (12.78)\ .$$

The signs of the estimated values of μ_1 and μ_2 are different, with μ_1 being positive. Since γ is expected to be negative, this sign suggests that the first state occurs when unemployment is below the NAIRU. Figure 12 shows the estimated probability of being in this state (below the NAIRU). In the same figure we also show the proportional NAIRU gap $(U_t - U_t^*)/U_t$ estimated from the price Phillips

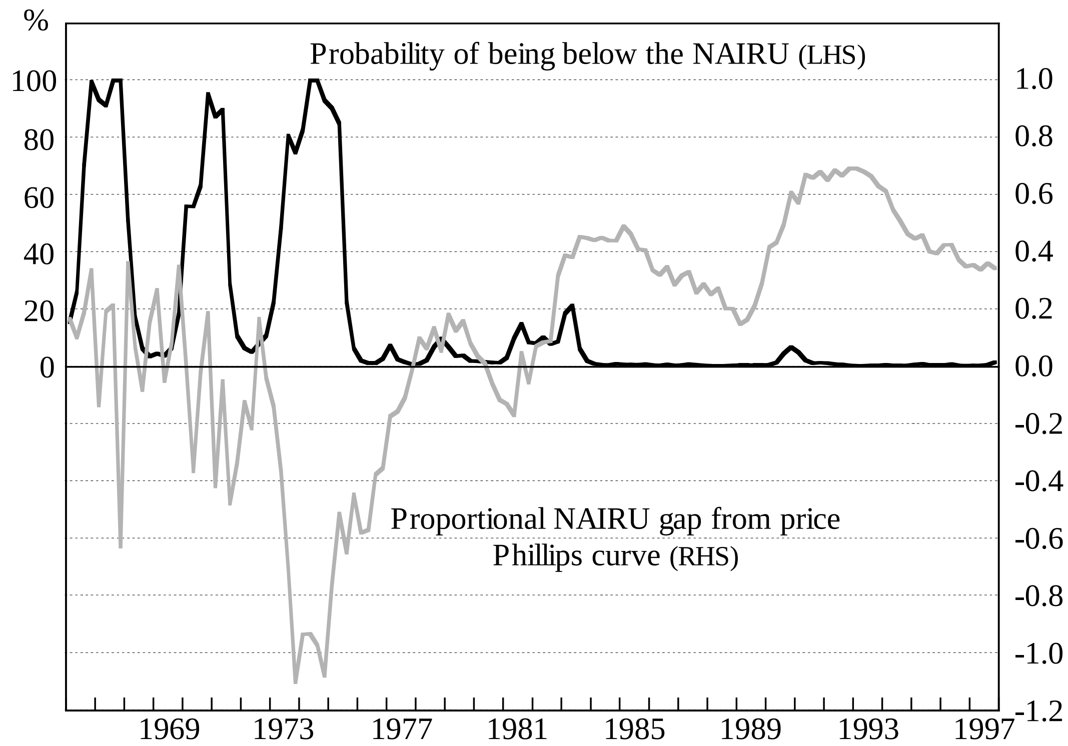
---

20 An alternative approach for testing the structural stability of the equation is to apply the tests described in Bai and Perron (1998). These tests suggest that there may be a structural break, although their sequential test suggests no break.

21 Another would be to allow the gap between the unemployment rate and the NAIRU to evolve as an autoregressive process.

curve Equation (13). Figure 12 confirms what has long been believed, that the late 1960s and early 1970s were periods when the economy was below the NAIRU, but, apart from a period at the beginning of the 1980s, the Australian economy has since been above the NAIRU.

Figure 12: Measures of Excess Labour Demand



Making the NAIRU a strictly exogenous variable as in Equation (11) means that OLS can be applied under the same conditions as when the NAIRU is assumed fixed.[22] However, as there has been a great deal of debate over determinants of the

22 A stochastically varying NAIRU also makes it computationally difficult to treat the unemployment rate as an endogenous variable in a (possibly) non-recursive system. Thus the type of analysis conducted by King and Watson (1994) is difficult to perform unless one conditions upon estimates of the NAIRU, but doing so fixes one of the equations of the system.

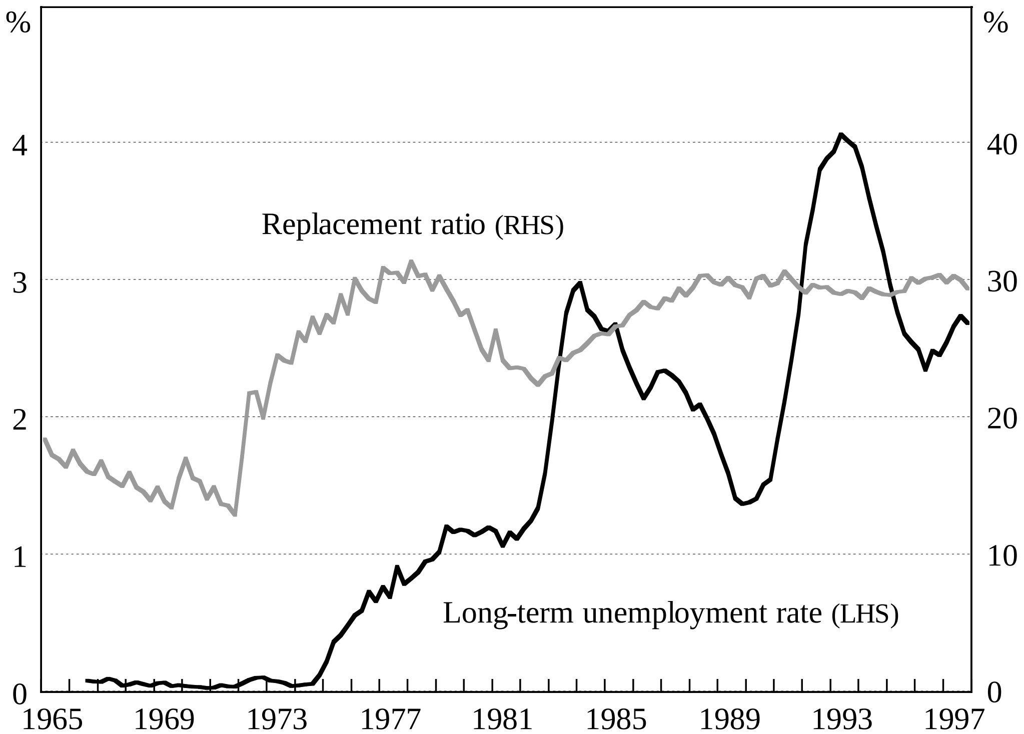
NAIRU, it seems worthwhile to experiment with some modifications to Equation (11). Specifically, we estimate models of the form:

$$U_t^* = U_{t-1}^* + a_1 \Delta f_{1t} + a_2 \Delta f_{2t} + \upsilon_t, \tag{16}$$

where the factors f_{1t} and f_{2t} are taken to be I(1) and are therefore entered in differenced form. Two I(1) variables which are thought to influence the NAIRU are the replacement ratio and the long-term unemployment rate (Figure 13). The latter is taken to represent 'hysteresis' effects. After jointly estimating Equation (14) with the augmented specification for the NAIRU in Equation (16), the coefficients a_1 and a_2 are found to be neither statistically nor economically significant. Other experiments in which the factors were taken to be the lagged values of the unemployment rate itself produced the same conclusion.

Our inability to explain changes in the NAIRU using either the replacement ratio or the long-term unemployment rate, while disappointing, accords with international studies which have also found it difficult to explain differences in unemployment rates between countries and across time on the basis of a small number of measurable, causal factors (Jackman 1998).

Figure 13: Long-term Unemployment and the Replacement Ratio



4. The Phillips Curve and Monetary Policy

The Phillips curve is clearly a useful empirical device for examining the determinants of inflation in Australia. It also, however, provides an intellectual framework for the analysis of monetary policy. In this section, we discuss the intellectual development of the Phillips curve framework within the Reserve Bank of Australia, and particularly within its Research Department. This is of particular interest because many of the Australian empirical studies of the Phillips curve came from this part of the Reserve Bank. It also seems likely that the ideas formulated in this research would have had an influence, perhaps after some time, on the formulation of monetary policy in Australia.

In earlier sections of this paper we showed how conceptions of the Phillips curve and its determinants in Australia had changed over the past three decades and so it is useful to look at monetary policy developments in the light of the results that we have established. In the 1960s, the policy framework in Australia, as in most countries, almost certainly accepted the unemployment/inflation trade-off implicit in the first generation of Phillips curves. Nevertheless, strong economic growth at the time meant that the perceived trade-off did not need to be exploited. In the last year of that decade, the Reserve Bank began issuing research discussion papers, and among the crop of seven papers produced in that year was one titled ‘An Equation for Average Weekly Earnings’, by K.E. Schott. This paper was part of a project within the Reserve Bank to construct a macroeconometric model of the Australian economy, which was released in its initial form in January 1970, and became known as the RBI model (Norton 1970). The Schott paper refers to Phillips’ (1958) original *Economica* paper, but makes no reference to either the Phelps (1968) or Friedman (1968) papers, which introduced the idea that there was no long-run trade-off between inflation and unemployment. Given this omission, it is perhaps not surprising that the econometric results presented by Schott implied the existence of a trade-off between inflation and unemployment in the long-run, although this implication is not drawn out in the paper.

With the dawning of the 1970s, and the rapid acceleration of inflation in Australia, the question of whether there was a long-run trade-off became one of greater urgency. In mid 1971, the Head of Research Department, Austin Holmes, wrote an internal paper on the problems of inflation which made a clear statement about the distinction between the short-run and long-run trade-offs between inflation and unemployment:

> Inflationary expectations can help to explain the differences over time in the apparent trade-off between wage rises (and the rate of inflation) and the rate of unemployment. Empirical studies linking these two have often found that the relationship is improved if the recent rate of increase in prices (a proxy for expectations) is included. If, as seems likely, wage claims are specified in real terms, the interpretation of Phillips' curves becomes somewhat clouded. They can rule only for a given set of expectations about prices. Changes in these expectations lead to equivalent changes in the rate of increase in wages for a given level of unemployment.
>
> (Research Department 1971, p. 4)

Much of the analysis contained in this 'Inflation' paper remains of interest in the late 1990s. In a later section, the paper argues that inflationary expectations, once raised, might prove hard to reduce. It canvasses the possibility that expectations might not respond to announcements of the anti-inflation resolve of the authorities, and might be difficult to lower without a period of higher unemployment. Given their contemporary relevance, it is worth quoting these arguments at some length.

> Suppose an economy has proceeded for some time with activity high and inflation positive but moderate. Expectations of future growth in prices have been formed.
>
> Suppose this situation is disturbed by an upsurge in demand resulting from, say, an export or investment boom. Does this require only an application of traditional fiscal and monetary measures to reduce demand? And, after the faster price rises generated by the excess expenditure have worked their way through the economy (this could, of course, take some time), can the economy return to its previous acceptable pattern of activity and price performance? This seems to depend a good deal on what has happened to expectations about prices.
>
> Where inflationary expectations are unaffected by these hypothetical developments (our knowledge about what actually affects these expectations is far from perfect), the economy can resume its previous pattern. However, if the episode leads to, say, an upward revision in the community's expectations about inflation, the answers seem to change somewhat. It is assumed, of course, that the revised expectations persist in the face of pronouncements of concern by the authorities and even of the announcement and effects of the fiscal and monetary measures.
>
> In this situation, there is a rise in the economy's aggregate supply schedule. With demand given, this would lead to a lower level of activity but a faster rate of increase in prices than previously. Attempts to restore activity lead to even faster growth in prices. In other words, following a change in inflationary expectations, the fiscal and monetary policies consistent with a given level of employment have to be more expansive than before the change.

> It does not require a burst of demand to induce the change in expectations. This could result from a sudden awareness that, say, previous expectations about stable prices ought to be abandoned in the face of *x* years of positive price increase. Perhaps the inflationary expectations can be imported. Whatever the cause, a return to price stability with high employment requires a change in price expectations. If these are firmly entrenched, as they might be if a fairly long history of price increases figures in their formation, one cannot be too optimistic about the ability of fiscal and monetary measures to do this without a period of higher unemployment.
>
> (Research Department 1971, p. 6)

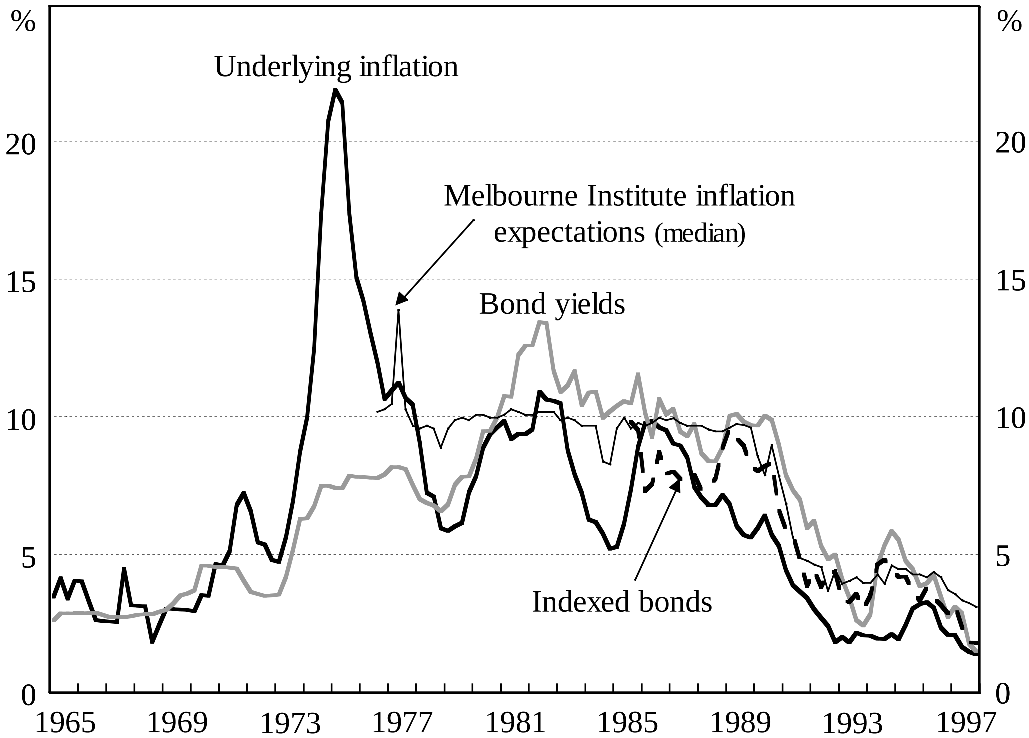
It was not too long before empirical support for the arguments set out in the 'Inflation' paper was provided by econometric evidence from the Australian economy. In a Reserve Bank Research Discussion Paper issued in August 1973, Jonson, Mahar and Thompson estimated several equations for the annual growth in average weekly earnings. As well as variables capturing demand effects, the equations included growth in award wages and in world prices as explanators. In their preferred equation, the sum of the coefficients on the 'price' terms was insignificantly different from one, from which the implication was drawn that there was no long-run trade-off between the rate of inflation and the state of the labour market in Australia. This preferred equation for average weekly earnings, as well as an equation for award wages, were soon incorporated into the Bank's RBI macroeconometric model with only minor amendments.

Professor Michael Parkin, a visitor to the Bank at the time, seems to have played an influential role within the Research Department by providing a unifying interpretation of the available econometric evidence. Jonson, Mahar and Thompson (1973) credit Parkin with pointing out that their empirical results implied the absence of a long-run inflation-unemployment trade-off. Furthermore, the Jonson, Mahar and Thompson paper was a revised version of a paper by Jonson and Mahar, issued in November 1972, which contained much the same econometric exercise as the later paper (using a slightly shorter sample), but did not draw any implications from the results about the long-run inflation-unemployment trade-off.

Parkin also produced a research paper on 'The Short-run and Long-run Trade-offs between Inflation and Unemployment in Australia' in the second half of 1973, in which he presented a critical analysis of the long-run inflation-unemployment trade-offs implied by several recent econometric studies of wage and price inflation in Australia. On both theoretical and empirical grounds, he argued that those studies which implied a non-zero long-run trade-off were flawed. His paper led to a series of responses and rebuttals in the pages of *Australian Economic Papers* that continued for several years.[23]

Of course, the intellectual framework for analysing the inflationary process was not the only thing that was changing around this time. The economic landscape was also changing. As well as the rapid deterioration in the inflation performance (Figure 14), it is now clear that the NAIRU in Australia also rose significantly in the early 1970s.[24]

Figure 14: Underlying Inflation and Inflation Expectations



[23] See, for example, Challen and Hagger (1975), McDonald (1975), Nevile (1975), Parkin (1976) and Rao (1977). Hagger (1978) later reviewed the debate at length.

[24] The rapid deterioration in inflation is consistent with our earlier empirical finding that the unemployment rate was below the NAIRU for much of the decade 1966–75 (see the proportional NAIRU gap in Figure 12). The significant rise in the NAIRU is clear from both the price and unit labour cost Phillips curves (Figures 8 and 9).

For the Phillips-curve framework to be useful as a guide for monetary policy, it was of course necessary to have some reasonable idea of the level of the NAIRU – in order to be able to assess the inflationary implications of any given rate of unemployment.[25] While we would now date the beginning of the significant rise in the NAIRU somewhere around 1970–1972 (based on both the price and unit labour cost Phillips curves in Figures 8 and 9), this rise was far from clear at the time. For example, in the paper discussed above, Parkin (1973) argued that the natural unemployment rate had probably *fallen* since the early 1960s, to be in the 1½ to 2 per cent range at the time of writing in late 1973.

By early 1976, however, the then Head of the Research Department, W.E. Norton, argued in a published paper that recent experience in several countries (including Australia) suggested that the NAIRU (which he called 'the lowest sustainable rate of unemployment') seemed to have increased, although he offered no quantitative estimate of the extent of the increase (Norton 1976).

The difficulties inherent in coming to a view about the level of the NAIRU in the mid 1970s probably also made some contribution towards another important change in the Reserve Bank's thinking about the inflationary process. As with the introduction of the idea that the long-run Phillips curve was vertical, this change also owed a large debt to intellectual developments overseas.

In the 1971 'Inflation' paper, the causes of inflation were discussed under the subheadings: labour costs, material costs (including, importantly, the price of imported goods), taxes and profits. The paper argued that inflation was caused by both excess demand and adverse supply shocks. Excess demand led to higher inflation primarily because of rising labour costs (although firms' mark-ups on costs might also rise) as the economy travelled up a short-run Phillips curve. The result was higher inflation – rather than a once-off rise in the price level – because inflationary expectations were disturbed. In light of later developments, it is of

[25] Wieland (1998) provides a modern discussion of the optimal interplay between policy gradualism and experimentation when there is uncertainty about the level of the NAIRU.

interest to note that the paper did not discuss excess money growth as one of the causes of inflation.

Quite soon after the ‘Inflation’ paper was penned, however, monetary growth began to play a more prominent role in explanations of the inflationary process within the Research Department. Jonson, in an internal paper written in October 1973, put the argument in these terms:

> …our positive knowledge of the workings of the economic system establishes a general presumption that if we desire to control inflation we should carry out any stabilization policy within the constraint of an average rate of growth of the money stock determined by the growth of ‘full employment’ demand at current inflation rates.
>
> (Jonson 1973, p. 4)

In common with developments overseas, money came to play a central role in the second half of the 1970s, both in macroeconometric models developed within the Bank, as well as in the formulation of Australian monetary policy itself. A second generation of macroeconometric models (called RBII) developed within the Research Department appeared in a series of versions during the second half of the 1970s, and well into the 1980s (the last Research Discussion Paper to use RBII was written in 1987). Money had a key role in this generation of models, with several transmission channels through which money growth had a direct and immediate influence on both real and nominal magnitudes within the economy, including, in particular, both wage and inflation outcomes.

In the formulation of Australian monetary policy, money growth became an intermediate target in 1976, when the Government began announcing an annual projection for growth in the broad monetary aggregate, M3. This practice was maintained, with only slight variations, until early 1985 when, faced with evidence of a breakdown in the empirical relationship between growth in M3, nominal income and interest rates, the Government abandoned the M3 projection.[26]

In principle, analysis of the inflationary process based on a Phillips curve framework, with allowance made for open-economy aspects and supply shocks, could exist along side an analysis based on money growth. The two intellectual frameworks need not be seen as incompatible. To the extent, however, that excess monetary growth was seen at the time as the fundamental cause of inflation, it was natural that a framework that highlighted the importance of controlling money growth would gain pre-eminence over one that focused on the demand/supply balance in the markets for labour and goods.

With the end of money-growth targeting in Australia, there was a transition period for monetary policy, in which policies became more pragmatic and there was a search for alternative guiding principles. For a time, there was a policy ‘checklist’, which was a range of variables, which were to be consulted in assessing economic conditions and making policy decisions. An early description of the checklist approach by Governor Johnston makes clear the very wide range of variables that were considered relevant. They included:

> …all the monetary aggregates; interest rates; the exchange rate; the external accounts; the current performance and outlook for the economy, including movements in asset prices, inflation, the outlook for inflation and market expectations for inflation.
>
> (Johnston 1985, p. 812)

The checklist was essentially an amalgam of instruments, intermediate and final policy objectives, and general macroeconomic indicators. Although the demand/supply balance in the labour and goods markets would undoubtedly have been considered relevant elements of the checklist, the Phillips curve certainly did not play a central role in this view of the inflationary process.

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[26] See Argy, Brennan and Stevens (1990) for a comparison of the monetary targeting experience of Australia and other countries.

In the late 1980s and into the 1990s, the framework for monetary policy evolved gradually. A medium-term inflation target formed the centrepiece of the framework from around 1993, although many of its essential elements were in place several years earlier.[27] A monetary policy framework with a medium-term focus on inflation as the policy objective, no intermediate objective, the short-term interest rate as the instrument, and a transmission process that works via the effect of interest rates on private demand, had been analysed in several pieces published by the Bank in 1989, including its conference volume.[28]

In many ways, the intellectual framework for analysing the inflationary process within the Reserve Bank has come full circle. The framework of the 1990s has much in common with the one enunciated in the 'Inflation' paper written in 1971, although the modern version would perhaps contain a few elements not present in the earlier version. These are the main elements of the modern version.

In the short-run, output above potential (or, equivalently, unemployment below the NAIRU) generates rising wage growth and, perhaps, increases in firms' mark-ups, which in turn, feed into inflation. Speed-limit effects are also relevant, so that strong output growth (or rapidly declining unemployment) also generates inflationary pressures.[29]

Inflationary expectations are central to the inflationary process; the Phillips curve is indeed of the expectations-augmented variety, so that there is no trade-off between inflation and unemployment in the long-run. Inflationary expectations seem relatively immune to announcements of the authorities' anti-inflation resolve.

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[27] The numerical objective of 2–3 per cent underlying inflation began appearing in public statements by Governor Fraser in 1992 and 1993. International organisations (for example, the Bank for International Settlements) date the adoption of the Australian inflation target from 1993. Grenville (1997) discusses the history of the inflation target in more detail.

[28] See Macfarlane and Stevens (1989), Macfarlane (1989) and Grenville (1989).

[29] Recall that speed-limit effects are present in both the price and unit labour cost Phillips curves presented earlier. The Bank's 1995 Annual Report also drew attention to them: '…unemployment remains well above the point at which serious inflationary pressures are likely to be experienced. The relatively rapid speed of its fall over the past two years, however, has been such as to prompt a pick-up in labour costs' (p. 15).

To achieve a sustained reduction in inflation and inflationary expectations, it appears to be necessary to run the economy for a period with output below potential and unemployment above the NAIRU. Furthermore, inflationary expectations take a long time to fully adjust to a fall in the trend rate of inflation – especially after an extended period of high inflation. Thus, for example, the transition to low inflation in Australia was complete by 1992. Nevertheless, while inflationary expectations both in the bond market and among consumers fell to some extent at that time, the fall in inflationary expectations in the bond market did not fully reflect the lower trend rate of inflation until 1997, and even then, consumers' inflationary expectations appeared not to have fully adjusted to the lower trend rate of inflation (Figure 14).

Open-economy aspects are also important to the inflationary process. A fall in the exchange rate, triggered, for example, by a fall in the world price of Australian commodity exports, leads to a rise in import prices, which feeds into consumer prices with a lag. Whether a once-off fall in the real exchange rate translates into a rise in the rate of consumer inflation (rather than simply a once-off rise in the level of consumer prices) depends on whether inflationary expectations are disturbed. This is an empirical issue; there should not, however, be an automatic presumption that inflationary expectations are immune to such an exchange-rate-induced rise in consumer prices.

The rate of money (or credit) growth is an important indicator of the pace of financial intermediation in the economy. Money growth does not, however, have an independent effect on either activity or inflationary expectations in the economy, once the effects of the level of real interest rates and asset prices, including the exchange rate, have been allowed for.

5. Conclusion

In this paper, we have examined the history of the Phillips curve in Australia in the forty years since Phillips first estimated one using Australian data. We focused on the changing perspectives of researchers trying to estimate Australian Phillips curves, as well as on the fluctuating fortunes of the Phillips curve in the intellectual framework used to analyse inflation in Australia within the Reserve Bank.

Several themes stand out from this history. First, from Phillips (1959) onwards, researchers estimating Australian Phillips curves have had to deal with the unique institutional features of the Australian labour market, particularly in the era when the Arbitration Court set both award and minimum wages. As a consequence of the Court's role in that era, it has been particularly difficult to model the evolution of wages in Australia without taking explicit account of arbitrated movements in award wages.

A second important theme is the crucial role of inflation expectations in the Phillips curve framework. Here the Australian experience mirrors that of other countries. In the 1960s, there was a widespread assumption, implicit or explicit, that in response to a change in the trend rate of inflation, inflationary expectations either did not adjust, or adjusted only incompletely. As a consequence, there was a presumed trade-off between inflation and unemployment, even in the long run.

With the deterioration of the inflationary performance in the early 1970s, however, this presumption was challenged, by Austin Holmes in an internal Reserve Bank paper written in 1971, and by Michael Parkin in an academic paper written while he was visiting the Reserve Bank in 1973. In the aftermath of these papers (which drew their inspiration from the 1968 papers of Friedman and Phelps) the idea of a long-run trade-off between inflation and unemployment was soon discredited.

A third recurring theme in the history of the Australian Phillips curve concerns the difficulties posed by the changing level of the non-accelerating inflation rate of unemployment (NAIRU). While it is now clear that the NAIRU was rising rapidly in the early 1970s, this was far from obvious at the time – with Parkin even arguing that it may have fallen since the early 1960s, to be in the range 1½–2 per cent by late 1973. It was not until a few years after 1973 that analysts became confident that the NAIRU had indeed risen significantly.

One response to this problem by researchers estimating Phillips curves had been to simply impose a structural break in the level of the NAIRU, on the basis of an examination of the history of the unemployment rate. An alternative response, introduced into the Australian literature by Debelle and Vickery (1997) and also adopted in this paper, was to estimate the Phillips curve in conjunction with an equation that allows the NAIRU to evolve through time.

Using this approach, we estimated Phillips curves for both prices and unit labour costs in Australia over the past three decades. These Phillips curves suggest a role for both the level of unemployment and its rate of change (‘speed-limit’ effects) in the determination of inflation outcomes. Our results imply that the NAIRU in Australia rose from around 2 per cent in the late 1960s to around 6 per cent in the mid 1970s. Since then, the NAIRU was estimated to have dipped slightly in the mid 1980s, before rising slightly to be around 5½–7 per cent at the end of our sample in 1997.

The difficulty of assessing the actual level of the NAIRU in the early 1970s also played a part in a final theme in the history of the Phillips curve in Australia: its changing influence in the intellectual framework used to analyse inflation within the Reserve Bank.

An expectations-augmented version of the Phillips curve had formed the centrepiece of the analysis presented by Austin Holmes in his 1971 internal paper, ‘Inflation’. This centrepiece was not of much use, however, if one had very little idea about the actual level of the NAIRU, which left the way open for other explanations of the inflationary process to gain prominence. In particular, those based on excess money growth were becoming influential around the developed world. As in other countries, this confluence of events led to a downplaying of the importance of the Phillips curve in the framework used to analyse inflation in the Reserve Bank, and an increase in the focus on money growth.

From the mid 1970s to the mid 1980s, money growth remained at centre-stage, both as an intermediate target for monetary policy, and in the modelling of the inflationary process in the Reserve Bank. With the end of money-growth targeting, a transition period followed, in which the framework for monetary policy gradually evolved.

By the 1990s, however, the intellectual framework for analysing inflation had come full circle. The framework of the 1990s had much in common with the one enunciated in the 1971 ‘Inflation’ paper. The intervening years had led to some refinement of the analysis, but the expectations-augmented Phillips curve had returned and once again was at centre-stage.

Appendix A: National Wage Case Outcomes (1968–1981)

Date at which National Wage Case became *operative*	Award wage rates increased by	Minimum wage increased by	Percentage change in AWE over the following year
December 1968	$1.35	$1.35 (3.5%)	7.1
December 1969	3.0%	$3.50 (9.0%)	8.7
January 1971	6.0%	$4.00 (9.5%)	7.3
May 1972	$2.00	$4.70 (10.0%)	11.8
May 1973	2.0% plus $2.50	$9.00 (17.5%)	20.8
May 1974	2.0% plus $2.50	$8.00 (13.0%)	22.8
December 1974[(a)]		$8.00 (12.0%)	
May 1975	3.6%	$4.00 (5.0%)	16.7
September 1975	3.5%	$2.80 (3.5%)	16.1
February 1976	6.4%	6.4%	13.1
April 1976[(a)]		$5.00 (5.5%)	
May 1976	3.0% for awards to $125/wk then flat $3.80	3.0%	10.8
August 1976	$2.50 for awards to $166/wk then 1.5%	$2.50 (2.5%)	9.7
November 1976	2.2%	2.2%	10.0
March 1977	$5.70	$5.70 (5.5%)	10.5
May 1977	1.9% for awards to $200/wk then flat $3.80	1.9%	8.6
August 1977	2.0%	2.0%	9.1
December 1977	1.5%	1.5%	7.2
February 1978	1.5% for awards to $170/wk then flat $2.60	1.5%	8.8
June 1978	1.3%	1.3%	6.9
December 1978	4.0%	4.0%	9.9
June 1979	3.2%	3.2%	11.6
January 1980	4.5%	4.5%	12.9
July 1980	4.2%	4.2%	10.8
January 1981	3.7%	3.7%	13.8
May 1981	3.6%	3.6%	14.0

Note: (a) Minimum wage decision only.

Sources: *Australian Economic Review*, various issues, 1968–1981.
ACTU Living Wage Case Submission, November 1996, Section B, pp. 78–81.

Appendix B: Exogeneity Assumptions Relevant to Estimating Phillips Curves

As the Phillips curve is a single equation in a system, estimating Equations (6) and (8) in Section 2 means that some exogeneity assumptions must be invoked. In many recursive vector autoregression (VAR) studies, prices are ordered after output, implying that the latter is weakly exogenous in the price equation. For examples, see the US studies by Sims (1980) and Leeper and Gordon (1992). Australian VAR research has also continued this tradition, as seen in the work by Smith and Murphy (1994) and Dungey and Pagan (1997). The logic behind this ordering comes from the perceived short-run rigidity of prices and the role of inventories in facilitating a de-coupling of prices and output in the short run. Moreover, when unemployment appears as the variable affecting prices, the argument for weak exogeneity is even stronger because movements in the unemployment rate are generally regarded as lagging output. In any case, some identification assumption needs to be invoked and Phillips curve research in Australia has invariably chosen the identification assumption we have just described.

A further consideration is that the forward-looking component of inflation expectations may be correlated with the error term in the price equation if the information set which agents use to forecast inflation is much broader than that formed from the past history of inflation and the contemporaneous and lagged gaps between the unemployment rate and the NAIRU. For example, this may be the case in Equation (6) since it is well known that import prices are useful for forecasting inflation in Australia. This is, however, only an argument for expanding the specification of Equation (6), which we do in the paper. The crucial assumption in Equation (6) is that expectations of inflation are formed before prices are determined.

Appendix C: Time-series Properties of the Variables

Variable	**DF test statistic**[(a)]	**Order of ADF test**[(b)]	**ADF test statistic**[(c)]	$\hat{\rho}$ **from ADF test**
$\Delta_4 \ln P_t - \Delta_4 \ln P_{t-1}$	-6.108*	4	-4.437*	0.525
$\Delta P_t^* - \Delta_4 \ln P_{t-1}$	-1.793	1	-2.703	0.932
U_t	-1.238	4	-1.439	0.988
$\Delta_4 \ln ULC_t - \Delta_4 \ln P_{t-1}$	-3.797*	4	-3.480*	0.761
$\Delta_4 \ln PM_t - \Delta_4 \ln PM_{t-1}$	-11.002*	3	-8.929*	-0.379

Notes: * Denotes significance at the 5 per cent level using critical values from Fuller (1976). The tests were conducted over the sample period 1965:Q1–1997Q4.

(a) This is the *t*-ratio on (ρ–1) in the Dickey-Fuller (DF) regression:

$$\Delta y_t = \alpha + (\rho - 1)\, y_{t-1} + \varepsilon_t \,.$$

(b) The order of the augmented Dickey-Fuller (ADF) test was determined by maximising the Schwarz Bayesian Criterion.

(c) This is the *t*-ratio on (ρ–1) in the ADF regression (j is the order of the ADF test):

$$\Delta y_t = \alpha + (\rho - 1)\, y_{t-1} + \sum_j \Delta y_{t-j} + \varepsilon_t \,.$$

Appendix D: Technical Issues Involved in Estimating the Kalman Filter

In this appendix we discuss some of the technical issues involved in estimating the NAIRU as a time-varying parameter using the Kalman filter.

Recall that we are treating the NAIRU as a unit root process of the form:

$$U_t^* = U_{t-1}^* + \nu_t , \tag{D1}$$

where ν_t is assumed to be $N(0,\sigma_\nu^2)$, and we begin with a price Phillips curve equation which corresponds to Debelle and Vickery's (1997) preferred functional form:

$$y_t = \Delta_4 \ln P_t - \Delta_4 \ln P_{t-1} = \delta\left(\Delta P_t^* - \Delta_4 \ln P_{t-1}\right) + \gamma \frac{\left(U_t - U_t^*\right)}{U_t} + \varepsilon_t , \tag{D2}$$

where ε_t is assumed to be $N(0,r)$.

Expanding Equation (D2) gives the following estimating equation:

$$y_t = \delta\left(\Delta P_t^* - \Delta_4 \ln P_{t-1}\right) + \gamma - \gamma \frac{U_t^*}{U_t} + \varepsilon_t \tag{D3}$$

which can be written more generally as:

$$y_t = x_t' \alpha - \gamma U_t^{-1} U_t^* + \varepsilon_t , \tag{D4}$$

where $\alpha' = [\delta \quad \gamma]$ and $x_t' = \left[\left(\Delta P_t^* - \Delta_4 \ln P_{t-1}\right) \quad 1\right]$.

When α is known to be constant we can define a state variable $z_t = -\gamma U_t^*$ and then Equations (D1) and (D2) constitute a state space form (SSF):

$$y_t = x_t'\alpha + H_t z_t + \varepsilon_t \tag{D5}$$

$$z_t = z_{t-1} + \zeta_t, \tag{D6}$$

where $H_t = U_t^{-1}$, $\zeta_t = -\gamma\, v_t$, $\mathrm{var}(\zeta_t) = q = (\gamma\, \sigma_v)^2$ and $\mathrm{var}(\varepsilon_t) = r$.

Because of the ability to represent the equations as a SSF, most researchers using this approach to account for a time-varying NAIRU have estimated the state z_t, conditional upon the past history of y_t (and contemporaneous x_t), with the prediction segment of the Kalman filter. This produces $E_{t-1}(z_t)$. To do that it is necessary to initiate the recursion with an initial value for the state $z_{1|0}$ and its variance $P_{1|0}$. In most instances $z_{1|0}$ is treated as a parameter and $P_{1|0}$ is set to zero (Pagan 1980). Subsequently, conditional upon the values of r, σ_v and $z_{1|0}$ one can derive the innovations $\eta_t = y_t - E_{t-1}(y_t)$ and their conditional variances h_t, whereupon the log likelihood will be:

$$L = -\frac{n}{2}\log(2\pi) - \frac{1}{2}\sum \log(h_t) - \frac{1}{2}\sum \frac{\eta_t^2}{h_t}. \tag{D7}$$

Maximising Equation (D7) then provides a way of estimating any unknown parameters.[30]

One of the most important parameters to be estimated is q. Apart from fixing it, as Debelle and Vickery do, there have been other suggestions in the literature. Laxton *et al* (1998, p. 29) report setting $q = r$ when using annual data, because the resulting estimates of the NAIRU were not excessively volatile. This suggests that one needs to study the impact of varying q more carefully in order to understand

30 Debelle and Vickery (1997) do not proceed in this way. Instead, they set r = 1, pre-specify $z_{1|0}$ and $P_{1|0}$, and then seem to determine q by how well the resulting estimated path of the NAIRU accords with their priors. Thus, the role of data in determining their NAIRU estimates is more limited than it need be.

exactly how the estimates of the NAIRU are made. To do so, it is best to concentrate α and $z_{1|0}$ out of the likelihood, leaving only r and q as parameters. The key to doing this is to examine the Kalman prediction equations. One can show that the prediction of the state $z_t = -\gamma U_t^*$ using past information is:

$$z_{t+1|t} = b_t z_{t|t-1} + K_t(y_t - x_t' \alpha), \tag{D8}$$

where $K_t = P_{t|t-1} H_t (H_t P_{t|t-1} H_t + r)^{-1}$ is the gain of the Kalman filter, $P_{t|t-1}$ is the variance of z_t conditional on past information (a quantity that is computed by the Kalman filter algorithm and depends only on r and q) and $b_t = 1 - H_t K_t$. Recursively solving Equation (D8) gives:

$$z_{t|t-1} = \phi_t \, z_{1|0} + s_{yt} - s_{xt}' \, \alpha, \tag{D9}$$

where

$$\phi_j = b_j \, \phi_{j-1} \tag{D10}$$

$$s_{yj} = b_j \, s_{yj-1} + K_{j-1} \, y_{j-1} \tag{D11}$$

$$s_{xj}' = b_j \, s_{xj-1}' + K_{j-1} \, x_{j-1}' \tag{D12}$$

are also generated recursively for $j = 1 \ldots n$ using initial conditions $\phi_1 = 1$, $s_{y1} = 0$ and $s_{x1} = 0$.

With this information, the innovations $\eta_t = y_t - E_{t-1}(y_t)$ can be written as:

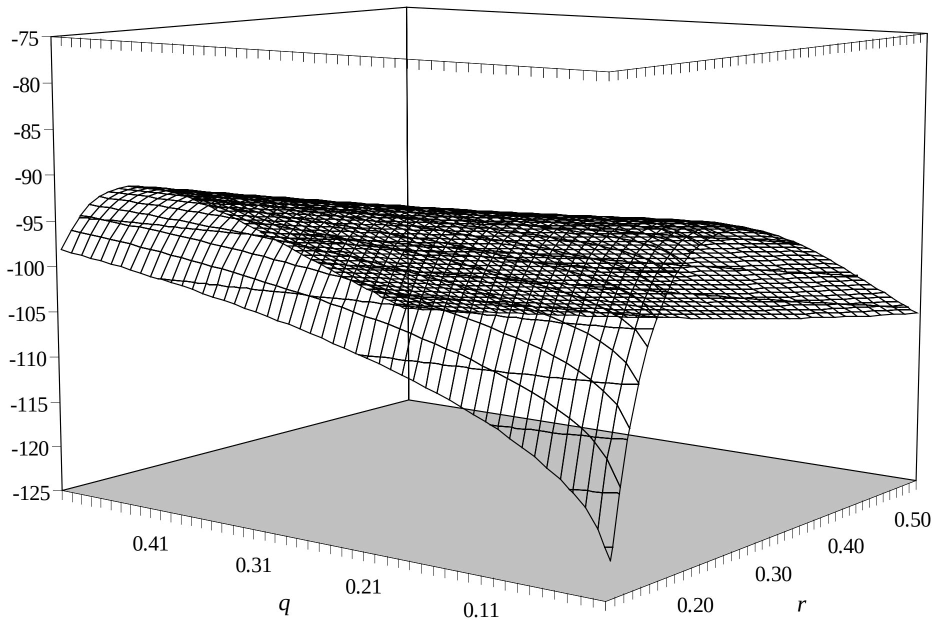
$$\eta_t = y_t - x_t' \alpha - H_t(\phi_t \, z_{1|0} + s_{yt} - s_{xt}' \, \alpha). \tag{D13}$$

Since the maximum likelihood estimates of α and $z_{1|0}$ maximise Equation (D7) it is clear that, for a given r and q, they can be estimated by performing a weighted least squares regression of $y_t - H_t \, s_{yt}$ against $x_t - H_t \, s_{xt}$ and $H_t \, \phi_t$, where the weights are the inverse of the standard deviation of the innovations (their estimated variance h_t depends only on r and q). Thus we can easily concentrate α and $z_{1|0}$ out of the log likelihood, leaving only r and q.

The result just described is useful for producing graphical representations of the sensitivity of the log likelihood to variations in q as well as helping us to understand how the NAIRU is estimated. Equation (D8) shows that the estimate of the state z_t is a weighted average of all past values of $y_t - x_t'\alpha$ with weights that decline like b_t but which also vary with K_t. If a linear version of the Phillips curve had been used, H_t would not vary with time, and one could have used the asymptotic version of the Kalman filter; this results in a constant gain K and, hence, constant weights b. In that case one would simply be doing a geometrically weighted average of the residuals $y_t - x_t'\alpha$ when forming the estimated z_t. To derive an estimate of the NAIRU from z_t one also needs to divide by the estimate of γ. This analysis points to the fact that estimates of the NAIRU made using this methodology will depend upon the ability of x_t to predict the change in inflation y_t, and not just on r and q. Moreover, the NAIRU is very sensitive to the estimate made of γ. In this respect, the problems of getting a precise estimate of the time-varying NAIRU are the same as with the constant-NAIRU version in an equation such as Equation (9), where the intercept in the regression is divided by γ. All that happens now is that the numerator is replaced by a weighted average of some residuals rather than an estimated intercept. The explicit formula in Equation (D8) could be useful for those papers looking at monetary policy in the face of a changing NAIRU, for example, Wieland (1998), where the authorities need to solve a signal extraction problem when devising an optimal policy.

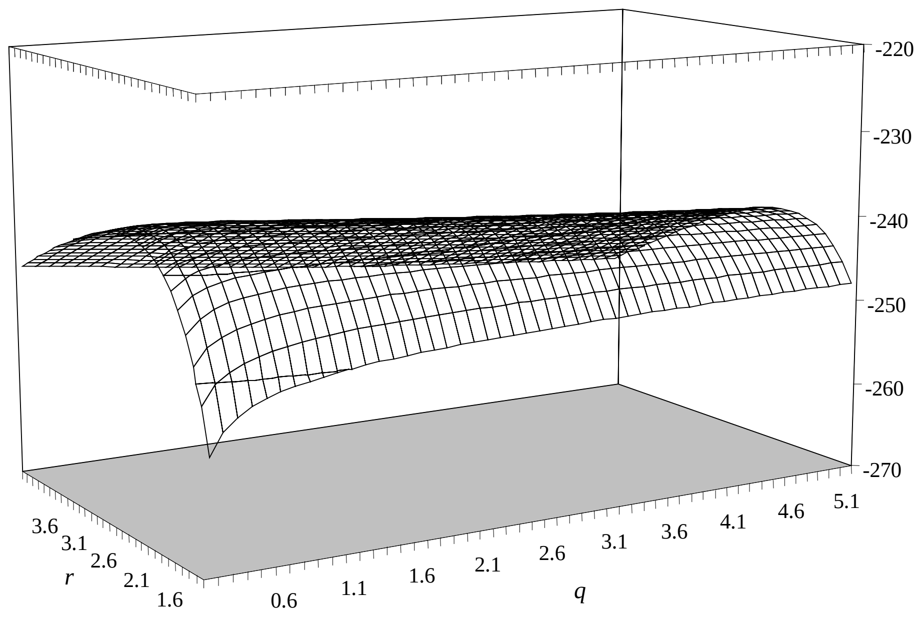
An important message from this analysis is that close attention needs to be paid to devising a suitable specification for the equation linking y_t and x_t. For this reason Equation (9), from Section 2, seems a suitable source of extra regressors in x_t over and above those used by Debelle and Vickery (1997). Such an extension produces the specification for the price Phillips Curve Equation (13), which we estimate in Section 3. Parameter estimates (and the associated *t*-ratios) for that equation are presented in the text. Here we examine the sensitivity of the log likelihood to variations in r and q using the technique just described. Figure D1 shows a three dimensional plot of the concentrated log-likelihood function against values of r and q. This figure shows that we could accept a wide range of hypotheses about values of q, which means that, for given r, our model is unable to provide a precise estimate of the variation in the NAIRU.

Figure D1: Concentrated Log-likelihood Function for the Price Phillips Curve



Similarly, for our preferred unit labour cost Phillips curve Equation (14), Figure D2 shows the concentrated log-likelihood function. Here again we see that we could accept a wide range of hypotheses about values of q.

Figure D2: Concentrated Log-likelihood Function for the Unit Labour Cost Phillips Curve



Appendix E: Data Description and Sources

All data are quarterly and seasonally adjusted, unless otherwise indicated. All constant price data are expressed in 1989–90 prices and are contained in the Australian Bureau of Statistics (ABS) publications issued before implementation of chain-volume measures.

Unemployment rate

Number of unemployed people as a proportion of the total labour force (*Labour Force*, ABS Cat. No. 6203.0, Table 2).

Prior to 1978:Q3, labour force data were obtained from the *National Income Forecasting* (NIF) database, ABS Cat. No. 1342.0, Table 7.

Underlying consumer prices

Treasury underlying consumer price index (*Consumer Price Index*, ABS Cat. No. 6401.0, Table 10).

Prior to 1971:Q1, spliced with headline (all items) consumer price index (*Consumer Price Index*, ABS Cat. No. 6401.0, Table 10).

Tariff-adjusted import prices

Implicit price deflator for endogenous goods imports. Endogenous goods imports are defined as total merchandise imports excluding exogenous imports (civil aircraft, fuels and lubricants, ADP equipment and parts).

Current and constant price series for merchandise imports less exogenous items were taken from *Balance of Payments,* ABS Cat. No. 5302.0, Tables 13 and 15.

From September 1981, current and constant price series for ADP equipment and parts were taken from *Balance of Payments,* ABS Cat. No. 5302.0, Tables 13 and 15. Between September 1969 and June 1981, these are unpublished data provided by the ABS.

Prior to 1969:Q3, the implicit price deflator for endogenous goods imports was spliced with a price index for imported ‘endogenous goods’ taken from the NIF database, ABS Cat. No. 1342.0, Table 8.

The tariff rate is the ratio of customs duty collected on international trade (Reserve Bank of Australia *Bulletin*, Table E.1) to the value of total merchandise imports (*Balance of Payments*, ABS Cat. No. 5302.0, Table 13).

Unit labour costs

Unit labour costs per person. Equal to wages per person divided by non-farm productivity per person.

From 1981:Q3, wages per person are average weekly ordinary-time earnings (AWOTE) per full-time adult (*Average Weekly Earnings*, ABS Cat. No. 6302.0, Table 2). Before 1981:Q3, wages per person are average weekly earnings (AWE) per full-time adult (*Average Weekly Earnings*, ABS Cat. No. 6302.0, Table 2).

Non-farm productivity per person is equal to the ratio of constant price non-farm GDP(A) (*National Income, Expenditure and Product*, ABS Cat. No. 5206.0, Table 48) to total non-farm employment (NIF database, ABS Cat. No. 1342.0, Table 7).

Inflation expectations

Measure of inflation expectations used by Debelle and Vickery (1997). This was obtained by subtracting a measure of the equilibrium world real interest rate from the nominal 10-year bond yield. The equilibrium world real interest rate depends on the outstanding stock of world government debt. See Debelle and Vickery for details.

Overtime

Average number of overtime hours worked per employee (NIF database, ABS Cat. No. 1342.0, Table 11).

Replacement ratio

Unemployment benefits (per single adult male 21 years or older with no dependents) as a proportion of after tax male average weekly earnings.

Unemployment benefits are unpublished data provided by the ABS. Average weekly earnings (before tax) per single adult male were taken from *Average Weekly Earnings,* ABS Cat. No. 6302.0, Table 2.

The implied average tax rate on individuals was calculated as the ratio of net tax instalments paid by individuals (NIF database, ABS Cat. No. 1342.0, Table 12) to total wages, salaries and supplements (*National Income, Expenditure and Product*, ABS Cat. No. 5206.0, Table 66).

Inside unemployment rate

Total number of unemployed people with at least 2 weeks of full time work in the past 2 years taken as a proportion of the sum of total employment plus insider unemployment (*Labour Force*, ABS Cat. No. 6203.0, Table 30).

Prior to 1980:Q1, inside unemployment was constructed using the methodology of Cockerell and Russell (1995). This involves splicing the unemployment gap ratio (the difference between actual unemployment and unemployment 'smoothed' by a Hodrick-Prescott filter, divided by smoothed unemployment) onto the existing inside unemployment rate series. See Cockerell and Russell for more details.

Long-term unemployment rate

Total number of people unemployed for 52 weeks or more as a proportion of the total labour force (*Labour Force,* ABS Cat. No. 6203.0, Table 26).

Before 1978:Q3, the definition of long-term unemployment was different. Where available, we have used data on the number of people unemployed for the longest recorded duration to represent long-term unemployment. For example, between 1975 and 1978, long-term unemployment is defined as 26 weeks or more. Before 1978, however, long-term unemployment is defined as 13 weeks or more. Data on long-term unemployment (as defined) prior to 1978:Q1 was obtained from *Labour Force Experience*, ABS Cat. No. 6206.0, Table 19.

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