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Phillips Curve and the Equilibrium Unemployment Rate*

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Abstract

A time-varying Phillips curve was estimated as a means to examine the changing nature of the relationship between wage inflation and the unemployment rate in Australia. The implied time-varying equilibrium unemployment rate was generated and the analysis showed the important role played by variations in the slope of the Phillips curve in changing the equilibrium unemployment rate. The deviations of actual unemployment rates from the estimated equilibrium unemployment rates also performed remarkedly well as measures of inflationary pressure.

Key words: Phillips curve, equilibrium unemployment rate, inflation

JEL classification: E24, E31, E32, E52

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1 Introduction

In 1958 A.W.Phillips published his famous article "The Relationship between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861-1957" in which he documented the negative relation between money wage inflation and the unemployment rate. In 1959, when Phillips was on sabbatical leave at the University of Melbourne, he estimated his second "Phillips Curve" and once again established a negative relationship between changes in money wages and the unemployment rate, this time for Australia over the period 1947-1958.

Lipsey (1960, 1974), formalized the empirical relation examined by Phillips in terms of the reaction of (nominal) wages to the presence of excess demand for labour. Friedman (1968) and Phelps (1967, 1968) pointed out that it was real, not money, wages which varied to clear the labour market and derived the appropriate equilibrium condition. They also proposed an expectations-augmented Phillips Curve and argued that, since all expectations are fully realized in the long run, a 'natural rate of unemployment' will prevail.

Parkin (1973) appears to have been the first to have estimated an expectations-augmented Phillips Curve for Australia, albeit with mixed results. Since then, numerous Phillips Curves have been estimated. Amongst other developments since Phillips's original article, we have seen experimentation with different dependent variables - various measures of the rates of nominal wage growth, price inflation and the growth in unit labour costs (i.e., nominal wage divided by real output per unit of labour).[1] Increasingly elaborate specifications and econometric techniques have been applied to extract the Phillips curve and in particular the NAIRU (non-accelerating inflation rate of unemployment). More interestingly, with developments in econometric techniques, the NAIRU has been modelled as time varying (Debelle & Vickery (1998), Gruen, Pagan & Thompson (1999) and Kennedy, Luu, and Goldbloom (2008)). These models assume that the NAIRU evolves as a random walk.

[1]Recent summaries of studies for Australia can be found in Gruen, Pagan & Thompson (1999) and Borland & McDonald (2000).

In contrast to the approach which assumes that the NAIRU is a random walk, the aim of this paper is to estimate a Phillips curve which captures the evolution of labour market conditions and behaviors and infers the implied time varying equilibrium (natural) unemployment rate. In other words, we recognize that the natural rate of unemployment for the economy varies over time not least because labour market environments (for example industrial relations) change over time. Since the sample period spans regimes with different policies and labour market reforms, the approach allows naturally for the testing of time-varying behavior including asymmetric wage responses to increases and decreases in unemployment. It also obviates any need for the a priori assumption that the natural unemployment rate is a non-stationary series without precluding the possibility that it may indeed be non-stationary.

The research questions considered in the paper are motivated by the same concerns as those flagged by Stiglitz (1997). First, we aim to explain the variations in the equilibrium unemployment rate over time; second, we examine whether the deviations of actual unemployment rates from their equilibrium rates serve as robust indicators of inflationary pressures; and third, we examine whether the inflation unemployment trade-offs have played a role in the conduct of monetary policy in Australia.

The paper is organized as follows. Section 2 sets out the basic relationship between wages and unemployment and derives the implied time-varying equilibrium unemployment rate. Section 3 provides the empirical analysis and contains a comparison of the equilibrium rates generated in this paper with the NAIRUs generated by others for Australia. This section also discusses the evolution of the equilibrium rate of unemployment in the context of structural and policy changes in the Australian economy. Section 4 considers the relevance of unemployment gaps (deviations of actual unemployment rates from the derived time-varying equilibrium rates) in an inflation targeting monetary policy framework. Concluding remarks are in Section 5.

2 Wage Inflation and the Unemployment Rate

Utilizing the expectations-augmented Phillips curve, write the hypothesized relationship between wage inflation (ω) and the unemployment rate (u) as:[2]

$$\omega_t = \gamma\pi_t^e + h_t + \alpha - \beta u_t + \varepsilon_t \tag{1}$$

where h_t is the rate of Harrod neutral technological progress (i.e., the equilibrium rate of growth in labour productivity), π_t^e is the expected rate of inflation, and α, γ and β are parameters.[3] Note the negative sign in front of the slope parameter.

The equilibrium rate of unemployment u^* is defined as the rate which would be observed when expected inflation is equal to actual inflation and when the rate of growth in the real wage is equal to the rate of Harrod neutral technological progress:[4]

$$\pi^e = \pi \tag{2}$$

$$\omega - \pi - h = 0 \tag{3}$$

We set γ to unity to ensure a vertical Phillips Curve and this assumption will be maintained henceforth. Imposing conditions (2) and (3) then yields:

$$u^* = \frac{\alpha}{\beta} \tag{4}$$

This method yields a single unique equilibrium rate. Until recently the literature has assumed that the equilibrium rate of unemployment was constant over time (or, at best, subject to one or two discrete jumps). However, recognizing structural changes over time, Gruen, Pagan and Thompson (1999), for

[2] The unemployment rate can enter non-linearly. For example the equation might be written with $1/u$ on the RHS. Also many researchers include the change in the unemployment rate ($u_t - u_{t-1}$) as an additional explanatory variable.

[3] It is common in Australia to add import prices (Gruen, Pagan & Thompson (1999)), the terms of trade (Phillips (1959) and Wallis (1993)) or oil prices (Debelle & Vickery (1998)) and long-term unemployment and the replacement rate to the RHS of the equation.

[4] For simplicity we put aside the explicit modelling of changes in price-cost mark-ups. In our model, this appears as a change in α.

example, suggested viewing the natural rate of unemployment as a random walk process and proposed a model where wages (and prices) react to the deviations of actual unemployment from the evolving natural rate. Their idea may be set up in the framework adopted in this paper as:[5]

$$\omega_t = \pi_t^e + h_t - \beta(u_t - u_t^*) + \varepsilon_t \quad (5)$$

$$u_t^* = u_{t-1}^* + \eta_t \quad (6)$$

The first drawback of this approach is the a priori imposed assumption that the natural rate is inherently non-stationary. Many empirical studies have shown that, within the sample period examined, the *actual unemployment rate* may be viewed as a non-stationary series. But, this is not the same as assuming that, over the long run, the *equilibrium rate* is non-stationary.

The second weakness of this approach is the assumption that the behavioral parameters (in particular, β) in the labour market have remained fixed throughout the sample period. This is a strong assumption given the structural changes and policy reforms which have taken place in Australia, especially in the 1980's and 1990's.

An alternative approach to recover a time-varying equilibrium rate would be to estimate the model in (1) but with time-varying behavioral coefficients and to then extract the implied time varying unemployment rate. The model estimated in this paper allows for time variation in both the α and β parameters, and consequently time variation in the equilibrium rate of unemployment. The proposed model is given by:

$$\omega_t = \pi_t^e + h_t + \alpha_t - \beta_t u_t + \varepsilon_t \quad (7)$$

$$\alpha_t = \alpha_{t-1} + \eta_{1,t} \quad (8)$$

$$\beta_t = \beta_{t-1} + \eta_{2,t} \quad (9)$$

and imposing (2) and (3) yields the time-varying equilibrium rate as:

$$u_t^* = \frac{\alpha_t}{\beta_t}. \quad (10)$$

[5] Note that we set $\alpha = 0$ to ensure that $u_t = u_t^*$ when $(\omega_t - \pi_t^e - h_t) = 0$.

This approach shows that variations in the equilibrium rate of unemployment can be attributed to two sources: those that effect the (semi-) elasticity[6] of nominal wage growth with respect to the unemployment rate (i.e., changes in the slope of the Phillips curve, β_t), and those which effect the wage growth which would occur at any given rate of unemployment (i.e., changes in the intercept of the Phillips curve, α_t). Variations in these two coefficients over time are likely to have quite different origins, for example the slope of the curve reflects the degree of wage flexibility or wage responsiveness to excess demand in the labour market. One could imagine that this might have risen over the last few years (and thus the curve became steeper) with the diminishing role of unions and the spread of enterprise bargaining. Earlier studies have focused on the intercept rather than the slope; the approach adopted in this paper assesses the relative contribution of changes in both the intercept *and* the slope to variations in the equilibrium rate of unemployment.

An intuitive understanding of the difference between the equilibrium unemployment rate generated from equations (7)-(9) with that generated using equation (5) which assumes that u_t^* is a random walk is to note that the time-varying model described in equation (7) can be rewritten as:

$$\omega_t = \pi_t^e + h_t - \beta_t(u_t - u_t^*) + \varepsilon_t \quad (11)$$

$$\beta_t u_t^* = \beta_{t-1} u_{t-1}^* + \eta_{1,t} \quad (12)$$

$$\beta_t = \beta_{t-1} + \eta_{2,t} \quad (13)$$

which differs from equation (5), the random walk model, in that the slope coefficient is time-varying. Assuming that β is a constant, then comparing (6) with (12) we find that $\eta_t = \eta_{1,t}/\beta$. Thus, the more stable and closer β is to unity, the more u_t^* will behave like a random walk. An advantage of our approach is that the behaviour of β can be tested in the empirical analysis.

[6] A "semi-elasticity" since it refers to the percentage change in nominal wages resulting from a 1 percentage point change in the unemployment rate.

3 Empirical Analysis

3.1 Data

Average weekly earnings is the measure of money wages used in this paper and the sample period starts from 1960Q1, the earliest available quarterly data. The data for ω_t is the annualized rate of change in average weekly earnings (persons) and u_t is the Australian unemployment rate over the period 1960Q1 to 2008Q4 ($T = 196$). The measure of productivity h_t is GDP per employed person while the inflation variable π_t is headline inflation, excluding the effect of the GST.

Table 1: Unit Root Tests*

variable	unit root tests				Zivot-Andrews[e]		
	ADF[a]	PP[b]	BNP[c]	KPSS[d]	ZA1	ZA2	ZA3
ω_t	−1.766	−2.960*	0.025*	0.588*	−4.362	−4.395	−5.391*
π_t	−1.958	−1.971	0.019*	0.421	−4.677	−4.330	−5.147*
u_t	−1.992	−1.635	0.053*	0.979*	−3.307	−4.593*	−4.579
h_t	−3.647*	−6.370*	0.003	0.221	–	–	–
5% c.v.	−2.877	−2.877	0.010	0.463	−4.80	−4.42	−5.08

* Denotes significance at the 5% level

a: Augmented Dickey-Fuller unit root test with SIC optimal lag length

a: Phillips-Perron unit root test

c: Breitung non-parametric unit root test

d: Kwiatkowski, Phillips, Schmidt and Shin unit root test

e: Zivot-Andrews unit root tests with a null of a unit root and alternatives of stationary with a structural break in the mean (ZA1), in the trend (ZA2) and in the mean and trend (ZA3).

The unit root tests are shown in Table 1. The results of the well-known Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are corroborated by the robust Breitung Non Parametric (BNP) test (with null that the series has a unit root) and the Kwiatkowski, Phillips, Schmidt and Shin

(KPSS) test (with null that the series is stationary). However, when the series were subjected to Zivot-Andrews tests which allow for an alternative hypothesis of stationarity allowing for a break, we found that ω_t, π_t and u_t can all be treated as stationary with a break. These tests find a break for ω_t and π_t, sometime in the early 1970's, while the break for the unemployment series u_t occurred sometime in the early 1990s.[7] Thus, *apriori,* the time series properties of the data generating process suggest the possibility of behavioral changes over time.

Figure 1 shows a scatter plot of wage inflation and unemployment rates over the years 1960:1 to 2008:4. It is obvious that there is no simple inverse relationship between them - certainly not one that has been stable over time.

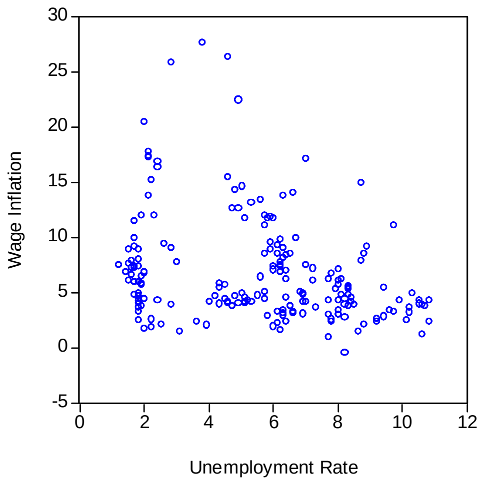

Figure 1: Scatter Plot of Wage Inflation and the Unemployment Rate

Rather than impose shifts and changes in the natural rate exogenously in an arbitrary fashion, we allow the relationship to evolve over time in response to the policy changes, international shocks and other influences over the 5 decades in the sample.

[7]This is consistent with the finding in Dixon, Freebairn and Lim (2007) that there was a sustained rise in the exit rate from the pool of unemployed relative to its entry rate in the early 1990s.

3.2 Estimation

In the estimation, expected inflation was modeled as a function of lagged price inflation and the rate of change in productivity-adjusted lagged wage rate (i.e., the nominal unit labour cost) with time-varying parameter φ_t.

$$\pi_t^e = (1-\varphi_t)\pi_{t-1} + \varphi_t(\omega_{t-1} - h_{t-1}) \tag{14}$$

A priori, we expect the coefficient φ_t to pick up the dominant influence of labour market conditions during periods of strong wage demands in the inflationary expectations process. The specification also implies that in the steady-state, when there are no lagged adjustment effects, so that $(1-\varphi)(\omega - \pi - h) = \alpha - \beta u$; the long run Phillips curve will be vertical because $(\omega - \pi - h) = 0$; which ensures that $u^* = \alpha/\beta$.

The time-varying model becomes:[8]

$$\omega_t = (1-\varphi_t)\pi_{t-1} + \varphi_t(\omega_{t-1} - h_{t-1}) + h_t + \alpha_t - \beta_t u_t + \varepsilon_t; \quad \varepsilon_t \sim N(0, \sigma_\varepsilon^2) \tag{15}$$

$$\alpha_t = \alpha_{t-1} + \eta_{1,t}, \qquad \eta_{1,t} \sim N(0, \sigma_{\eta 1}^2) \tag{16}$$

$$\beta_t = \beta_{t-1} + \eta_{2,t}, \qquad \eta_{2,t} \sim N(0, \sigma_{\eta 2}^2) \tag{17}$$

$$\varphi_t = \varphi_{t-1} + \eta_{3,t}, \qquad \eta_{3,t} \sim N(0, \sigma_{\eta 3}^2) \tag{18}$$

The estimates of the parameter set $\left(\sigma_\varepsilon^2,\ \sigma_{\eta 1}^2,\ \sigma_{\eta 2}^2,\ \sigma_{\eta 3}^2\right)$ are obtained by maximizing the log-likelihood

$$L \propto -\frac{1}{2}\sum_t \left(\ln \Psi_{t|t-1} + \frac{\left(\omega_t - \omega_{t|t-1}\right)^2}{\Psi_{t|t-1}}\right). \tag{19}$$

The one-step ahead estimate prediction error, $\omega_t - \omega_{t|t-1}$, and its variance-covariance, $\Psi_{t|t-1}$, are obtained using the Kalman filter.[9] Figure 2 plots the

[8] As a preliminary check, the OLS results with heteroscedastic robust standard errors (in parenthesis) for the Phillips curve relationship is: $\widehat{\omega}_t = \pi_{t-1} + h_t + \underset{(0.384)}{1.398} - \underset{(0.061)}{0.239} u_t + \underset{(0.076)}{0.715}(\omega_{t-1} - \pi_{t-1} + h_{t-1})$ and the graph of recursive residuals suggests possible changes in the mid 1970's.

[9] The parameter estimates are: $\sigma_\varepsilon = 1.598$, $\sigma_{\eta,1} = 0.257$, $\sigma_{\eta,2} = 0.030$ and $\sigma_{\eta,3} =$

time varying intercept α_t, slope β_t as well as the time-varying expectations parameter φ_t.

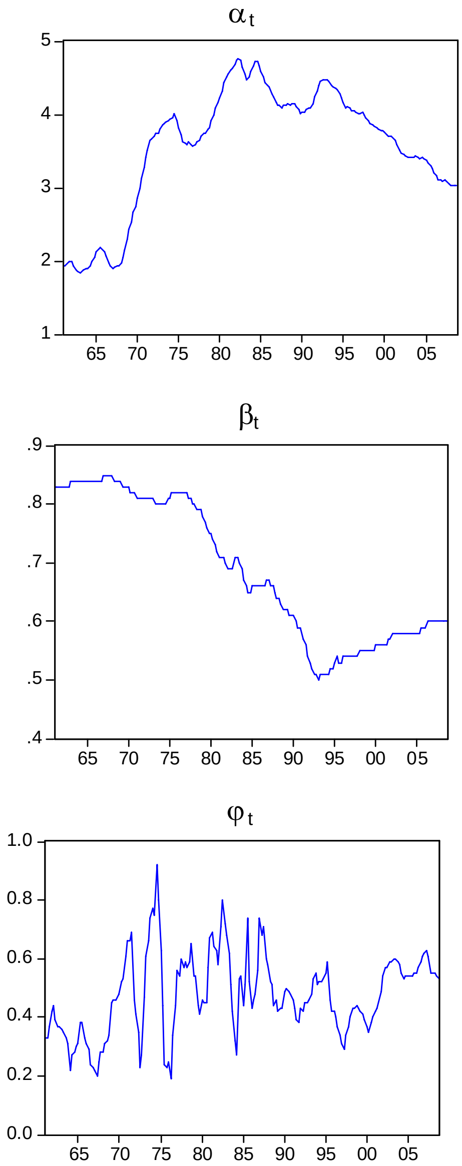

Figure 2: Time Varying Parameters

0.161.The model was also estimated subject to the addition of import prices with little change to the explanatory capacity of the model or the estimate of the natural rate of unemployment.

These figures suggest significant time variation in the intercept α_t and slope β_t (i.e., the sensitivity of the rate of change in wages to the unemployment rate u_t). Figure 2 shows that α_t rose from the early 1960s to a peak in the early 1980s and has been trending down since then; whereas β_t had been falling since the early 1970s to a low in the early 1990s and rising steadily since then. Comparing values across the beginning and end of our sample period we see that α_t is about 60% higher while β_t is about 40% lower at the end than they were at the beginning of the sample period (and as a result u_t^* is correspondingly higher).[10]

The time-path of φ_t provides useful information about the relative contribution of lagged price inflation versus lagged wage inflation (adjusted for productivity) in the changing nature of the expectation generating process for inflation. As shown in Figure 2, the early 1970s and 1980s appears to be the periods where φ_t was volatile.[11] In contrast, since the beginning of the 1990s, with the introduction of inflation targeting, the role of lagged changes in unit labour costs appears to be gaining importance as a determinant of inflationary expectations rising from a share of around 0.3, and since about 2002, stabilizing at a value of around 0.6.

3.3 Discussion of Results

We begin with a discussion of the new series for the equilibrium rate of unemployment, focussing on how it has evolved over time and how the results compare with results reported by other researchers. This series u_t^*, computed as α_t/β_t is shown, together with the actual unemployment rate, in Figure 3.[12]

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[10] Since the focus of the paper is the fundamental relationships, we have presented the smoothed rather than the filtered or one-step estimates. We note, however, the value of the one-step estimates in forecasting and will report the results of using the one-step equilibrium unemployment rate in the monetary policy section of the paper.

[11] It is worth noting that the variability exhibited by φ_t confirms that it is appropriately modelled as a time-varying parameter.

[12] Confidence intervals for α_t and β_t and hence for u_t^* are available on request. The confidence bounds for the equilibrium level of unemployment are straightforward to obtain using Kalman smoother based simulation of α_t, β_t subject to $\alpha_t > 0$, $\beta_t > 0$, and the

The analysis shows that the equilibrium rate of unemployment had been roughly constant at around 2% till the beginning of the 1970s; it then began to drift upwards till the mid-1990s and since then it has been trending downwards, reaching a value of about 5.0 % in 2008. Comparing values across the beginning and end of our sample period we see that the equilibrium rate is 113% higher in 2008 than it was in the early 1960s. Since $u_t^* = \alpha_t/\beta_t$, and given (as we have already seen) that α_t is 60% higher while β_t is 40% lower at the end than they were at the beginning of the sample, we can say that the rise in the equilibrium rate over the entire sample period has resulted not only from a rise in α but also from a fall in β over the period. This ability to obtain information about the two different (proximate) sources of change in u_t^* is one of the benefits of the approach adopted in this paper.

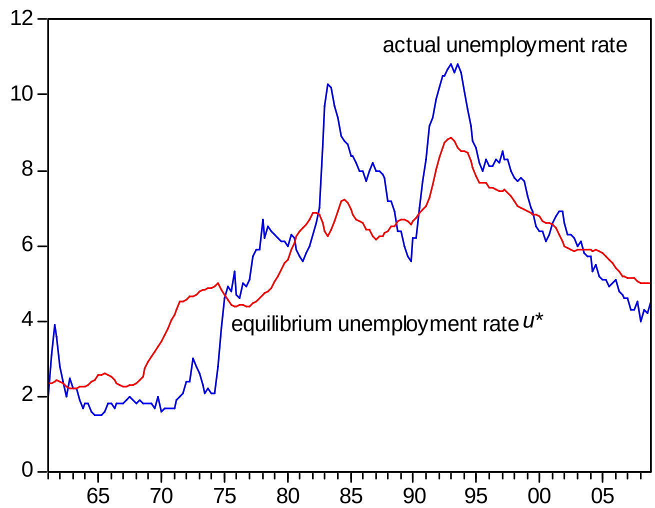

Figure 3: Actual and Time Varying Equilibrium Rate of Unemployment

How does the equilibrium rate of unemployment computed in this paper compare with other studies? The u^* series computed here is markedly different from early estimates which implicitly assume that β was constant and

restriction φ_t belongs to (0,1), such that equilibrium unemployment is restricted to the positive real range (see, for example, Kim and Nelson, 1996). To avoid cluttering up the figure, we have not plotted the confidence bands.

allowed only for shifts in α (see for examples, Crosby and Olekalns (1998)[13] and Downes and Bernie (1999)[14]). The analysis here shows large changes in *both* α and β, and casts doubt on these earlier studies.

There are three studies of inflation and unemployment in Australia which allow for time variation in u^* - Debelle and Vickery (1998) using data for the period 1959-1997; Gruen, Pagan and Thompson (1999), using data for the period 1965–1997, and more recently, Kennedy et al (2008) who (inter alia) updates Gruen et al's estimates of the time-varying NAIRU from 1978 to mid 2007.

The alternative series which are most appropriate for comparisons with our u^* series are the Debelle and Vickery (1998) two-sided NAIRU estimated with a non-linear model[15] and the Gruen, Pagan and Thompson (1999) two-sided NAIRU estimated from the "W-curve" (i.e. with the rate of change in real labour costs rather than price inflation as the dependent variable). Like ours both these series are roughly constant at around 2% in the sixties and then the series rise sharply. Also both place the NAIRU at around 7% in the mid to late 1990s like the u^* series computed here. The main difference between their series and ours is to be found in the period spanning the early 1980s through to early 1990s where our u^* series is rising faster and to greater heights than theirs.

The most recent estimates of NAIRU for Australia are to be found in Kennedy, Luu and Goldbloom (2008) which is an update of the Gruen, Pagan and Thompson (1999) model with the rate of price inflation as the dependent variable.[16] Their NAIRU "rose sharply until the mid-1970s, followed by a gradual decline over the next 15 years. From 1990 until the early

[13] Crosby and Olekalns (1998, p125), using data for the period 1959 - 1997 estimate that the NAIRU rose in a series of discrete jumps. According to them, the NAIRU was 2.3% over the period 1959-1973, 5.04% over the period 1974-1984 and 9.18% over the period 1984-1997.

[14] Downes and Bernie (1999) estimate the NAIRU over the period 1971–1999 and find that there is a once and for all upwards shift in 1974 when it rose from 4.05% to 6.45% and then remained constant right through to 1999.

[15] It should be noted that their NAIRU series is estimated from a model with the rate of price inflation as the dependent variable.

[16] Gruen, Pagan and Thompson (1999) refer to this as a "P-curve". The Kennedy, Luu and Goldbloom NAIRU series is given in Figure 4 of their paper.

2000s, the NAIRU began to gradually drift upwards, although not reaching its 1974 peak. After peaking at around 6 per cent in early 2000, the NAIRU fell to around 4.7 percent towards mid-2007" (Kennedy et al, 2008, p 289). More specifically, Kennedy, Luu and Goldbloom have the NAIRU falling from about 6% in 1978 to about 3.5% in 1988/89, then rising to about 6% in 2000 after which it falls, whereas our u^* series is rising over most of this period from about 5% in 1978 to about 6.5% in 1988/89 then to 9% in 1993 and then falling continuously to a value close to 5% in 2007. While some of these differences may be attributable to changes in the slope coefficient (β) which we allow for but they do not, it is difficult for us to completely rationalize the differences except to note that their dependent variable is the rate of price inflation while ours is the rate of wage inflation.[17]

3.4 Relative contribution of α_t and β_t to u_t^*

Fundamental to the approach in the paper is the notion that variations in the equilibrium rate of unemployment can be attributed to two sources - those that effect the (semi-) elasticity of nominal wage growth with respect to the unemployment rate (i.e., changes in the (negative) slope of the Phillips curve, β) and those which effect the rate of wage growth which would occur at any given level of unemployment (i.e., changes in the intercept of the Phillips curve, α).

Values for α, β and u^* are given in Table 2 for the beginning and end of the sample period and at the two major turning points of u^*. The table also includes the (annual average) percentage changes between each of the dates noted in the upper part of the table.

Table 2 also contains information about $1/\beta$, which is "the natural measure of wage rigidity as it is the extra unemployment which occurs in the face of a deflationary shock" (Grubb, et al, 1983, p 12f) where a real shock

[17] It is important to note at this juncture that our implied equilibrium unemployment rate is similar to, but not exactly the same as, the NAIRU. Computations of NAIRU tend to be based on studies with price inflation as the dependent variable, whereas the dependent variable in this study is wage inflation and it is for this reason that we prefer to use the term commonly applied to labour market equilibrium namely, the 'equilibrium rate of unemployment'.

is one that "leads to a different equilibrium real wage - for example, a fall in productivity growth relative to trend or a shift in the terms of trade" (Coe, p. 115)). Thus the lower is β (i.e. the higher is $1/\beta$) the greater is real wage rigidity and the greater the unemployment cost of real shocks.

Table 2: Values of α, β and u^*

	u^*	α	β	$1/\beta$
values at a point in time				
1961 : 1	2.34	1.94	0.83	1.20
1968 : 2	2.36	1.98	0.84	1.19
1993 : 1	8.87	4.44	0.50	2.00
2008 : 4	5.05	3.03	0.60	1.67
average annual % change over sub-samples				
1961 : 1 – 1968 : 2	0.12	0.28	0.17	−0.17
1968 : 2 – 1993 : 1	5.50	3.32	−2.07	2.12
1993 : 1 – 2008 : 4	−3.51	−2.40	1.16	−1.15

Before discussing the changes in α_t and β_t, it is appropriate at this juncture to first assess the relative importance of each in shaping the evolution of the equilibrium rate of unemployment. We consider two decompositions, shown in Figure 4.

To gauge their relative contribution, first consider a log version of the expression for u_t^*:

$$\log(u_t^*) = \log(\alpha_t) + \log(1/\beta_t) \tag{20}$$

The top graph in Figure 5 shows plots of $\log(u_t^*)$ as the stacked sum of $\log(\alpha_t)$ and $\log(1/\beta_t)$. The significant point to note here is that since the early 1990s, variations in β have contributed more to the variations in u_t^*.

An alternative way to view the relative contribution is to consider deviations from the sample mean (assuming zero covariance between α_t, β_t) :

$$\begin{aligned} u_t^* - \overline{u}^* &= \frac{\alpha_t}{\beta_t} - \frac{\overline{\alpha}}{\overline{\beta}} = \frac{\alpha_t\overline{\beta} - \overline{\beta}\overline{\alpha} + \overline{\beta}\overline{\alpha} - \overline{\alpha}\beta_t}{\overline{\beta}\beta_t} \\ &= \frac{\overline{\alpha}\overline{\beta}}{\overline{\beta}\beta_t}\left(\frac{(\alpha_t - \overline{\alpha})}{\overline{\alpha}}\right) - \frac{\overline{\alpha}\overline{\beta}}{\overline{\beta}\beta_t}\left(\frac{(\beta_t - \overline{\beta})}{\overline{\beta}}\right) \end{aligned} \tag{21}$$

The bottom graph of Figure 4 plots $(u_t^* - \overline{u}_t^*)$ as the sum of the term involving $(\alpha_t - \overline{\alpha})$ and the term involving $(\beta_t - \overline{\beta})$. One thing which is immediately apparent from the figure is that changes in the slope have been an important source of variation in the time-varying equilibrium rate. Overall, we see the role of the term involving $(\beta_t - \overline{\beta})$ in pulling the natural rate down over the 1960-1974, and up over the period 1988-2000. Between 1975-1980 and since 2000, the effect due to $(\beta_t - \overline{\beta})$ has overwhelmed the effect due to $(\alpha_t - \overline{\alpha})$, whereas between 1973-1982, the effect of $(\beta_t - \overline{\beta})$ is negligible.

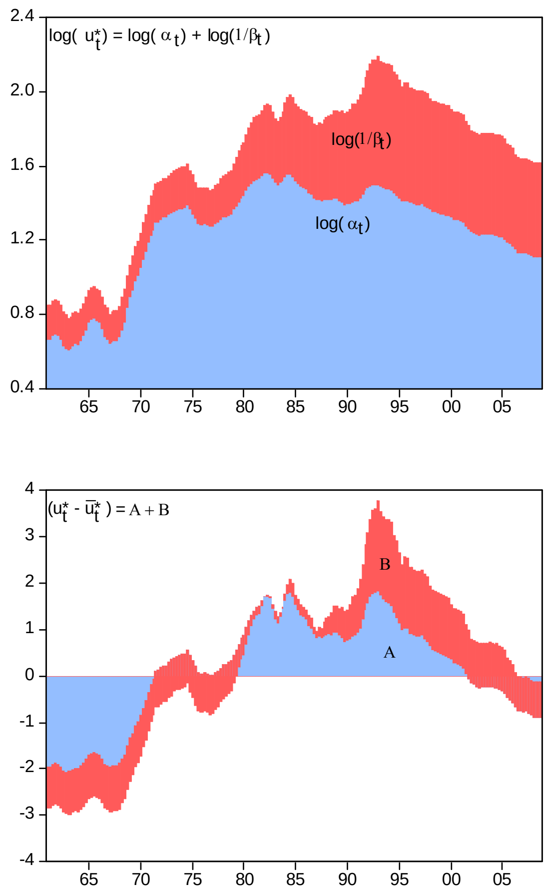

Figure 4: Contributions of α_t and β_t to u_t^*

Taken together the findings on the importance of variations in β provide justification for the time-varying parameter approach which focuses on β as well as α as time-varying parameters. We turn now to some of the factors influencing the time-varying nature of α_t and β_t.

The parameter β is the (semi-) elasticity of nominal wage growth with respect to the unemployment rate. The results support a negative relationship between wage growth and unemployment throughout the period. It appears that wages exhibited the strongest sensitivity to unemployment (i.e. β was highest) in the 1960s and 1970s. Thereafter wage sensitivity to the unemployment rate fell to its lowest level in the early-1990s. While it has been consistently increasing since then it has still (in 2008) not regained the levels it exhibited in the first part of our sample period.

Given that the inverse of β is the degree of real wage rigidity, we can put all this in terms of real wage rigidity. Real wage rigidity appears to have been roughly constant over the period 1961 to mid 1970's; it then trend upwards reaching a peak in the early 1990s. Since then it has been falling steadily, perhaps flattening out in 2008.[18]

There are three points which might be made in this context. First, in the 1970s much was made about a 'real-wage overhang'. In hindsight we see that the degree of wage-rigidity then was low compared with the early 1990s and even today. Second, our findings shed new light on the recession of the early 1990s, the 'recession we had to have'. Our series for real wage rigidity shows it to have been at the highest level in the late 1980s and early 1990s and this may go some way towards explaining how economic policy had such calamitous effects on the unemployment rate at that time. Thirdly, and as we have already seen, the rise in the equilibrium rate in the 1980s was due primarily to the rise in real wage rigidity (a rise in $1/\beta$, as α was roughly

[18] The 'sacrifice ratio' usually refers to the loss of output associated with a reduction in (price) inflation. Our series for $1/\beta$ is a measure of an analogous related concept, namely the rise in the unemployment rate associated with a rise in the nominal wage rate *ceteris paribus.* Our results suggest that the sacrifice ratio has been time varying and that it is lower now that it was at the time of the previous (early 1990s) recession – see Figure 2. To the extent that the 'sacrifice ratio' can inform policy, the result implies that monetary policy may be pursued more aggressively in the 2000s than it was in the 1990s.

stationary over that period).[19] Clearly, an explanation for the rise in real wage rigidity (the fall in β) over that period is required.

The period 1983-1996 was the period of successive Accords between the Australian Labour party (ALP) and the ACTU (the political and industrial wing of the labour movement) during which unions agreed to moderate wage demands while the (ALP) government undertook to introduce a number of social and economic reforms. The degree of labour market regulation under the Accords changed over the thirteen years the ALP was in government. The initial emphasis was on limiting nominal wage increases with the aim of achieving sustained decreases in inflation with little or no increase in unemployment (Chapman, 1998). Over time, and especially after 1993 the industrial system became more directed to enterprise bargaining which "paved the way for more radical changes during the latter part of the 1990s, after Labor lost office" (Lansbury, 2002, p 31). These latter years marked a period of steady de-centralization and de-unionisation of the labour market and it is over this period that we see β rising and thus real wage rigidity falling.

In short, the variations in β that have contributed to changes in the equilibrium unemployment rate appear to be the result of changes in labour market regulation and institutions and their effect on promoting (or not promoting, as the case may be) the degree of wage flexibility.

An important finding in this paper is that while α is higher at the end of the sample period compared to its value at the beginning of the sample period, the most significant change (not only in terms of the size of the change in α but also in terms of the consequences for the equilibrium rate of unemployment) occurred in the period 1968-1993 when α rose steeply by about 3.3 % per annum.

Variations in α_t capture information regarding the characteristics of the unemployed and their search intensity. Examples include the level and eligibility requirements for social security benefits, structural changes in industrial relations, and the extent and effectiveness of labour market programs.

[19] It is only in recent years that the equilibrium rate has fallen to the level it was at before it began to rise in the 1980s (ie 5%).

Influenced by Gruen et al (1999) we examined the relation between α_t on the one hand and the replacement ratio and the long-term unemployment rate, on the other. We find that α_t is significantly and positively related to the long-term unemployment rate (p value = 0.000) but that it appears to be unrelated to the replacement ratio (p value = 0.589).[20]

4 Inflation and Unemployment

One motivation for re-visiting the Phillips curve is to consider the implication of the inflation unemployment trade-off for the conduct of monetary policy. In this section, we report on the performance of our implied $(u_t - u_t^*)$ series as a signal of inflationary pressure and provide a perspective on the role of the unemployment gap in the practice of monetary policy since the adoption of inflation targeting in 1993.

4.1 Inflationary Pressures

The u_t^* derived here may be interpreted as the underlying unemployment rate consistent with setting the 'right' wage, namely when the rate of growth in the real wage is equal to the rate of productivity growth. According to the model, when actual u_t is less than u_t^* (i.e., the unemployment deviation terms, $u_t - u_t^*$, are negative) then, in line with Phillips' original hypothesis on the relationship between wage inflation and labour conditions, wage and price inflation would adjust upwards. Conversely, when actual u_t is greater than u_t^*, there is slack in the labour market and wage and price inflation are unlikely to be on the rise.

[20] The data we use for the replacement rate is simply an updated version of the (RBA) series used by Gruen et al (1999) and is the level of the unemployment benefit or newstart allowance for a single adult male as a proportion of after tax male average weekly earnings. We also find that the slope parameter (β_t) is significantly and positively related to the long-term unemployment rate but is unrelated to the replacement ratio. We take this to indicate that the effectiveness of the 'competition' of the unemployed and the employed for jobs – and thus their ability to influence the wage - is related to the characteristics of the unemployed. See Llaudes (2005) for further discussion of the relationship between long term unemployment and the Phillips Curve.

To check how well the equilibrium rate measure we have generated serves as a signal of rising inflationary pressures, in Figure 8, we plot the deviations of $(u - u^*)$ along with actual price inflation over the sample period. Over the period 1960-1975, when $(u - u^*) < 0$, inflation rose to a peak in 1975. From 1975 to 2000, when inflation was falling, $(u - u^*) > 0$. Since 2000 till the end of the sample period in 2008, the unemployment deviation terms, $u_t - u_t^*$, have been negative and Australia was in an inflationary phase.

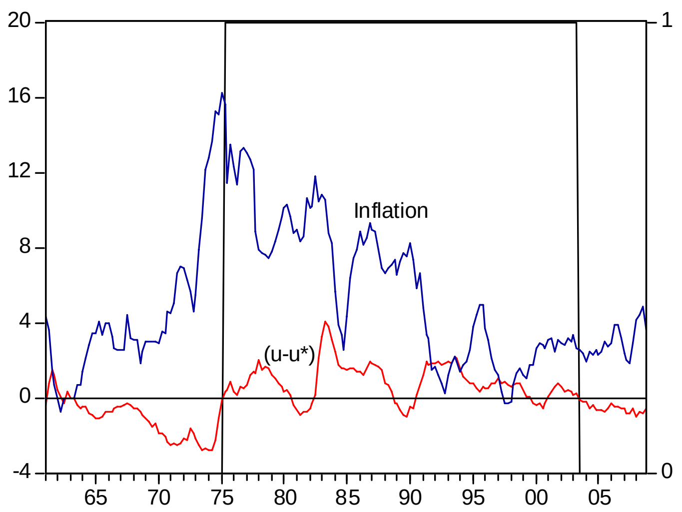

Figure 5: Inflation and the Unemployment Gaps

4.2 Inflation Targeting and the Unemployment Gap

In this section, we provide a graphical view about the practice of inflation targeting in Australia with respect to unemployment as well as estimate a simple model of monetary policy expressed as a function of the inflation and unemployment gaps.

In Figure 9, the vertical axis shows the inflation gap (deviation of actual inflation from the mid-point of the target band of 2.5%), while the horizontal axis shows the unemployment gap (deviation of actual unemployment from the equilibrium rate, u^*). The top left hand quadrant shows the occasions when the inflation gaps were high and the unemployment gaps low, namely states of the economy when monetary tightenings (positive changes in the cash rate) were warranted. In contrast, the bottom right-hand quadrant shows the occasions when monetary loosenings (negative changes in the cash rate) were warranted as the inflation gaps were low and the unemployment gaps high. The number of points in the top right hand quadrant provides some indication of the priority given to keeping inflation low, despite the unemployment gap. In contrast, the number of points denoting negative changes in the cash rate in the top left hand quadrant (observations for 2008) suggests concerns about a slowing in economic activity as the equilibrium unemployment rates were greater than actuals.

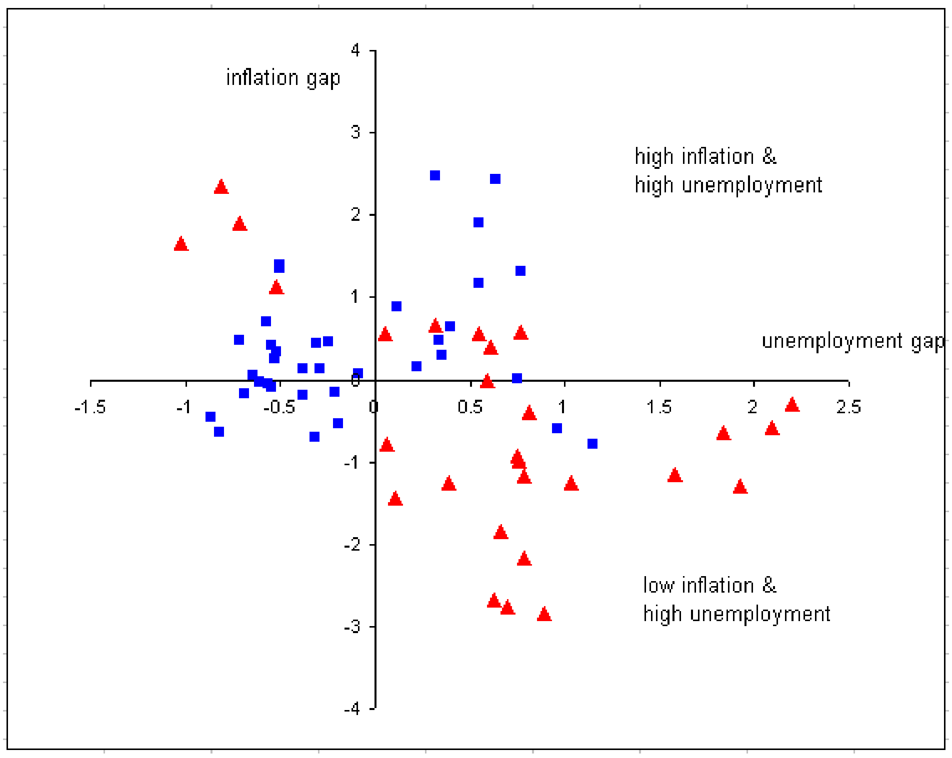

Figure 6: Inflation gap, Unemployment Gap and Changes in the Cash Rate (+ squares and - triangles), 1993:1-2008:4

4.3 A Model of the Cash Rate

A simple monetary policy model was estimated to assess the role played by the inflation and unemployment gaps in the determination of the official cash rate (R). The model takes the form:[21]

$$R_t = \gamma_0 + \gamma_1(\pi_t - 2.5) + (1 - \gamma_1)(u_t - \widetilde{u}_t^*) + \varepsilon_t \tag{22}$$

where γ_1 indicates the share of the inflation gap in the monetary policy decision and $\widetilde{u}_t^*$ is the **one-step predicted** equilibrium rate. In keeping with the flavour of the paper to track variations in the parameters, the model was estimated (from the start of inflation targeting in 1993:1 to 2008:4) using recursive least squares as there are insufficient observations for a time-varying model.

Figure 7 shows the estimated recursive coefficients for γ_0 and γ_1 over the period 2000:1 to 2008:4. Both coefficients are of the correct sign and more importantly they show the fall in the weight given to the inflation gap when inflation was not an issue in the early 2000's; the attention paid to the inflation gap between 2004 and 2007 when inflation was on the rise, and the sharp fall in the weight given to the inflation gap (conversely the sharp rise in the unemployment gap) in the determination of the cash rate in 2008. We thus see the extent to which high unemployment gaps have affected the operation of monetary policy aimed at targeting inflation and especially the variations over time of the weights given to each component in the Reserve Bank's policy reaction function.

[21] A variant using lagged cash rate was also estimated: the results for γ_1 were not qualitatively affected and showed the same time-varying behaviour.

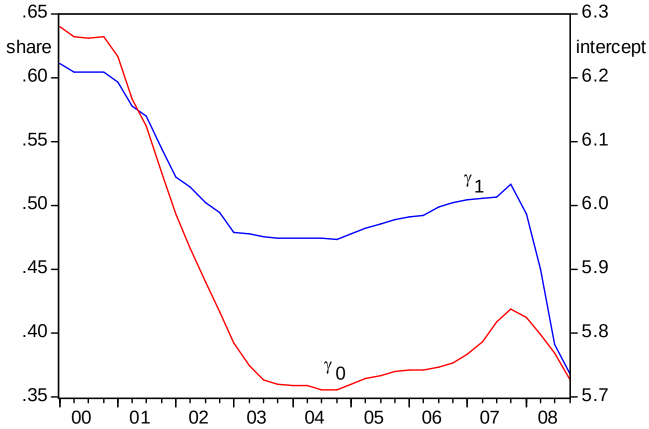

Figure 7: Recursive OLS estimates

5 Concluding Remarks

The aim of the paper was to determine whether there was a negative relationship between wage inflation and the unemployment rate and how the relationship and the equilibrium rate of unemployment have changed over time. To this end we estimated a time-varying Phillips curve for the period 1960:1-2008:4. A new series for the equilibrium rate of unemployment rate u^* was generated.

Three results followed from an analysis of the series. First, the analysis showed that, since 2001 the time-varying equilibrium unemployment rate u^* which is compatible with the condition - real wage growth equal productivity growth - is around 4.5% rising to 5% in 2008. Second, the analysis points to the important role played by the fall in wage rigidity, since 1993, in reducing the equilibrium unemployment rate.[22] Third, the approach yields a timely

[22] The success of inflation targeting (politically as well as in its role as a system of economic management) was clearly helped by the improvement in real wage flexibility (hence reduction in the real costs of unemployment). It suggests that the long boom (and the low unemployment associated with it) which followed the recession was not only due to the successful winding down of inflation expectations associated with the monetary policy of inflation targeting (see Macfarlane (2006)), it was also due to the reforms in the labour

measure of the inflation-unemployment trade-off. We find that the deviations of actual from the equilibrium unemployment rates (the unemployment gaps) performed remarkably well as measures of inflationary pressures. In fact, a simple model of the determination of the cash rate suggests that the Reserve Bank of Australia considers the unemployment gaps as well as the inflation gaps in its implementation of monetary policy.

market under the Keating and Howard governments which markedly reduced real wage rigidity.

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