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A SMOOTH-TRANSITION MODEL OF THE AUSTRALIAN UNEMPLOYMENT RATE

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Abstract

Models of the aggregate unemployment rate have traditionally been estimated from structural models of the labour market or in a linear single-equation framework. However, theory as well as evidence suggest that the unemployment rate is asymmetric and should be modelled in a non-linear framework. In this paper the unemployment rate in Australia is modelled as a non-linear function of aggregate demand and real wages. Negative changes in aggregate demand cause the unemployment rate to rise rapidly, while real wage rigidity contributes its to slow adjustment back towards a lower level of unemployment. The model is developed by exploiting recent developments in automated model-selection procedures.

Keywords

unemployment,
non-linearity,
dynamic modelling,
aggregate demand,
real wages.

JEL Classification: C12; C52; C87; E24; E32.

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1 Introduction

There is a growing body of research in the US and Europe which models the unemployment rate in a nonlinear framework. In part, this literature derives from the fact that the unemployment rate exhibits asymmetric behaviour in the sense that it increases more quickly than it decreases. Skalin and Teräsvirta (2002) find that the unemployment rates for Denmark, Finland, Sweden and Germany follow non-linear processes, while Akram and Nymoen (2001) conclude that there is evidence of asymmetric adjustment in the Norwegian unemployment rate. Hansen (1997), Verbrugge (1997), Parker and Rothman (1998), Rothman (1998), Koop and Potter (1999) and Altissimo and Violante (2001), *inter alia*, provide statistical evidence of asymmetry in the US unemployment rate by respectively applying different non-linear models to various transformations of this series. In addition, Brännäs and Ohlsson (1999) successfully fit a non-linear model to the Swedish unemployment rate; Peel and Speight (1998) find evidence of asymmetry in the unemployment rate for the US, Germany and the UK, while Acemoglu and Scott (1994) estimate a nonlinear model of the UK unemployment rate.

Empirical evidence also exists on the nonlinear properties of the aggregate Australian unemployment rate. Both Peat and Stevenson (1996) and Bodman (1998, 2001) conclude that there is asymmetry in this series, and Skalin and Teräsvirta (2002) use a logistic, smooth transition autoregressive (LSTAR) model to capture the asymmetric structure.

While all of these non-linear models show that the aggregate unemployment rate in Australia does indeed behave differently during periods of low and high unemployment, none can explain what drives the unemployment rate to increase at such a rapid rate and what contributes to its much slower decrease. The main objectives of this paper, therefore, are not only to contribute to the growing evidence that nonlinear models are necessary to explain the behaviour of the unemployment rate in Australia, but also to demonstrate that aggregate demand shocks and real wage rigidities are the main macroeconomic sources of the asymmetric behaviour of the unemployment rate. The empirical modelling undertaken in the paper will make use of automated model-selection techniques recently developed by Hendry and Krolzig (1999, 2001) and is now generally available in PcGets.

The rest of the paper is structured as follows. Section 2 looks briefly at the apparent asymmetry in the Australian unemployment rate and examines in an informal way, its positive relationship with aggregate demand and its negative relationship with real wages. The properties of the data used in the paper are discussed in Section 3. Section 4 reports the empirical results of applying a standard LSTAR model to the unemployment rate. In Section 5, an enhanced non-linear modelling cycle is implemented based on the automated model-selection procedures in PcGets, while the empirical results are evaluated in Section 6. The end result is a model of the Australian unemployment rate which is linear in demand shocks, with non-linear behaviour caused by real wage rigidities. Section 7 concludes.

2 The asymmetric role of business cycle fluctuations and real wage growth

Deficient aggregate demand and high real wages appear to be two macroeconomic variables which are widely recognized as explaining the existence of unemployment in Australia. Empirical studies have consistently found statistical support for a negative relationship between aggregate demand and unemployment and a positive relationship between real wages and unemployment (see, for example, Pitchford (1983), McMahon and Robinson (1984), Trivedi and Baker (1985), Dao (1993) and Valentine (1993)). These findings are also consistent with results obtained from reduced-form equations of the unemployment rate in structural labour market models including Pissarides (1991), Huay and Groenewold (1992), Scarpetta (1996), Powell and Murphy (1997), Debelle and Vickery (1998) and Downes and Bernie (1999). Moreover, these empirical findings are supported by the more descriptive work of Gregory (2000), Le and Miller (2000), Thomson (2000), Borland (1997) and Goodridge et al. (1995) who show that the common link between the plethora of papers on unemployment in Australia is that business cycle fluctuations and real wage growth are the two primary factors influencing Australian unemployment.

This is hardly surprising. The negative linear relationship between unemployment and output growth is widely known as Okun's Law and is still viewed as one of the most consistent relationships in macroeconomics, while the argument that high unemployment is the result of the level of real wages being above the market-clearing level is a central tenet of a classical theory of unemployment. Modern textbook expositions of unemployment are predominantly devoted to explaining how shocks to aggregate demand produce swift, sizeable swings in the unemployment rate compared with the more sluggish movements in the unemployment rate caused by shocks to real wages (Layard et al., 1994; Romer, 2001). Moreover, the stylized fact of real wage rigidity over the business cycle suggests that unemployment is affected by real wages in a manner different from that caused by business cycle fluctuations.

Since 1980, the Australian unemployment rate has been characterized by large, swift upward changes followed by slow, downward drifts, an observation which is supported by visually inspecting the graph of this series over the sample period (Figure 1). According to Skalin and Teräsvirta (2002), this non-linear behaviour is consistent with large, linear responses to economic shocks, followed by slow, non-linear movements towards equilibrium. The critical question to be asked, therefore, is whether the large, swift increases which characterise the Australian unemployment rate are correlated with negative changes in output growth and whether its slow downward adjustment is positively correlated with sluggish changes in real wages?

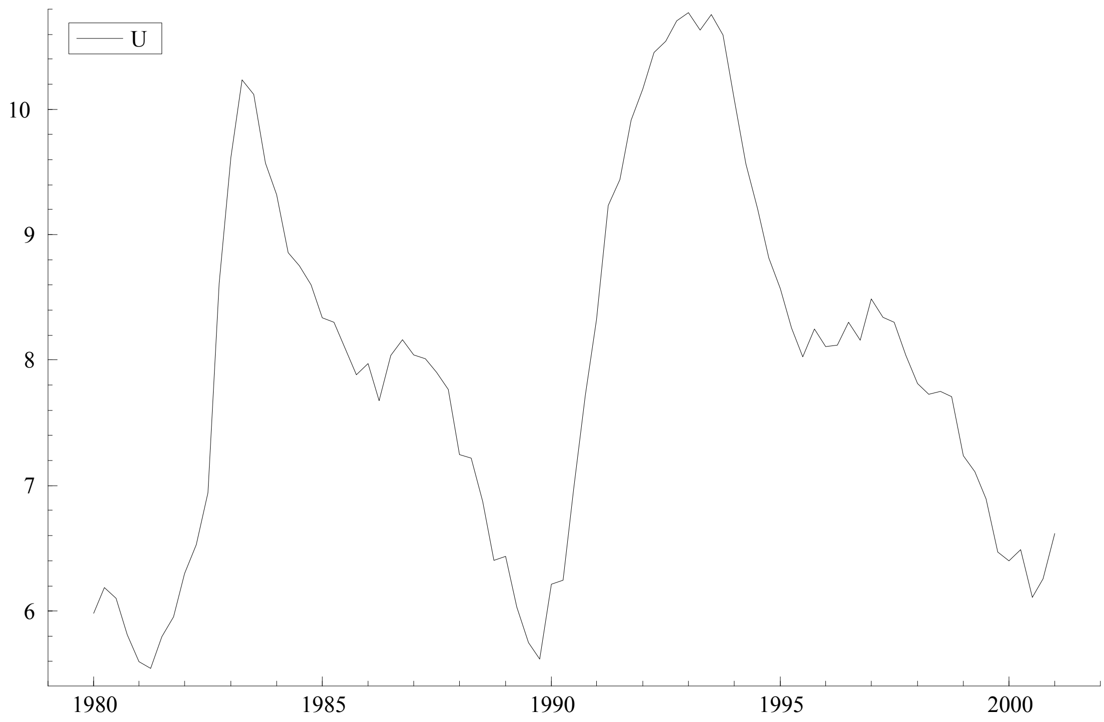

Figure 1: Australia's actual, aggregate unemployment rate measured for the period 1980:1 to 2001:1.

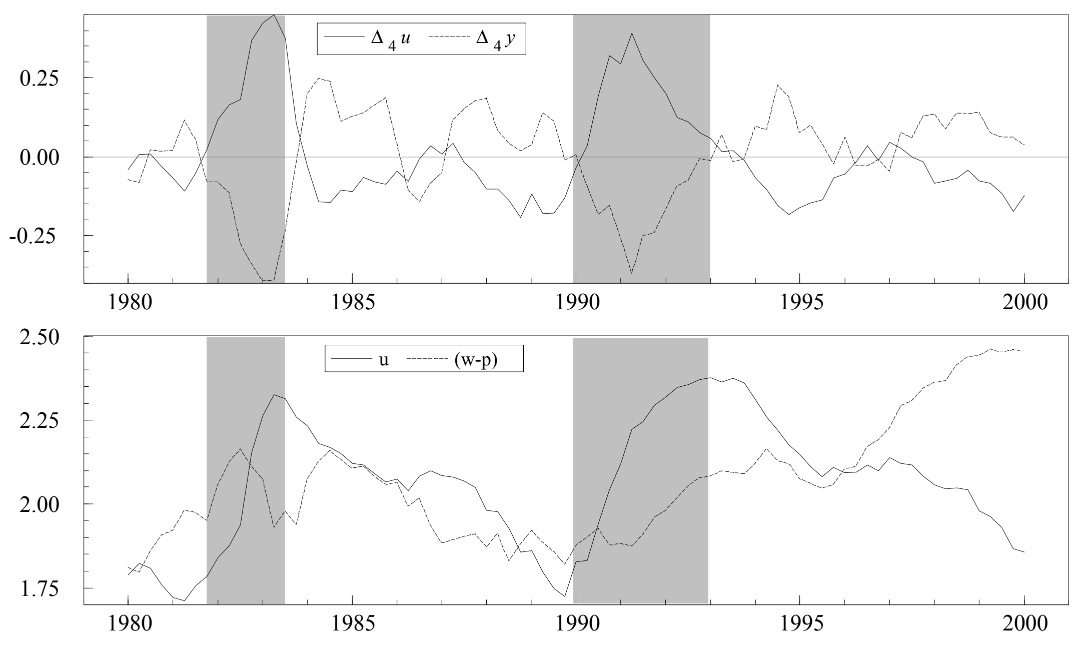

Figure 2: Four-quarter-ended growth rates of the (logs) unemployment rate and real GDP (upper panel) and levels of (logs) the unemployment rate and real wages (lower panel). Means and scales are adjusted.

Figure 2 provides support for this hypothesis for the case of Australia. As can be seen, changes in the unemployment rate are negatively correlated with changes in GDP, while the sluggish decrease in the unemployment rate from very high peaks, parallels similar behaviour in real wages. Since 1996, a divergence in the positive relationship between the unemployment rate and real wages in Australia is apparent. This phenomenon can be explained by the surge in labour producitivty in Australia during the 1990s which has accelerated greatly in the last half of the decade. As such, high real wages did not affect unemployment as greatly given the more than commensurate increase in productivity. This observation does not detract from the long-run correlation between these two variables. As such, there is substantial support for considering a non-linear, dynamic specification of the aggregate unemployment rate in Australia with respect to the role of demand shocks and real wages. This is the focus of Section 4

3 The data

The data are measured quarterly for the sample period 1980:1 to 2001:1 (85 observations) and all are seasonally adjusted.[1] The variables used are the unemployment rate, u; the four-quarter-ended growth rate of real, non-farm gross domestic product (GDP), $\Delta_4 y$; real wages, rw; average labour productivity, pr; and, real unemployment benefits, rub. Lower case letters denote logarithms of raw variables. Figure 3 plots these series, while Figure 4 plots their first differences (except for $\Delta_4 y$). Comparing these two graphs provides informal support for the hypothesis that these variables are $I(1)$. Tests of integration provide formal support for this conclusion.[2]

[1] Appendix A provides a detailed description of the data and its sources.

[2] The results of standard unit-root tests are not reported but can be obtained from the authors upon request

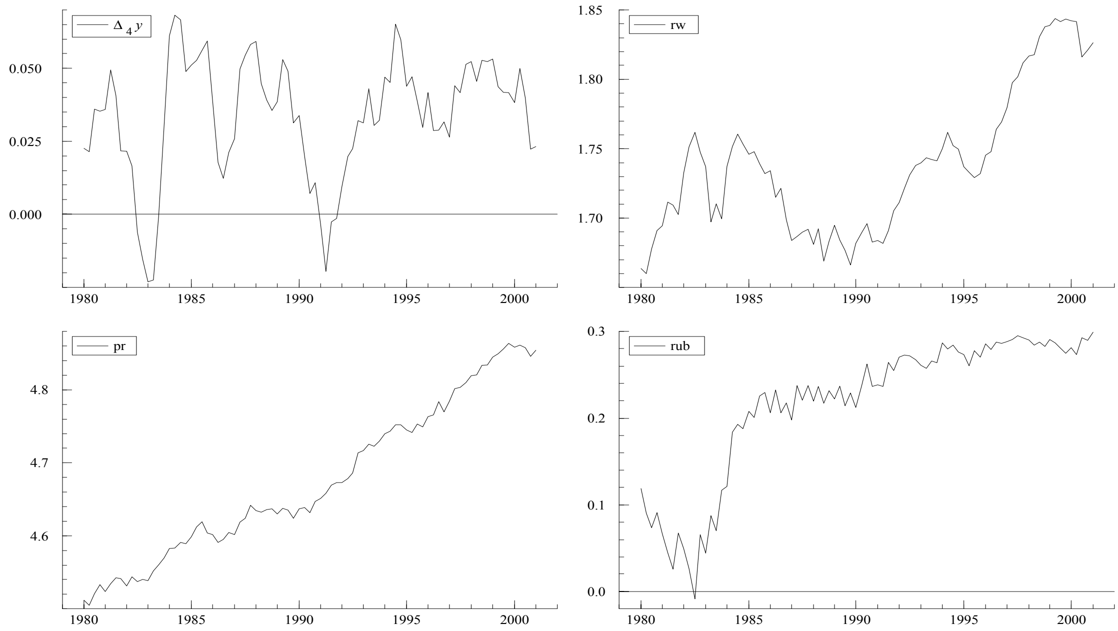

Figure 3: Data series (logs), measured quarterly 1980:1 to 2001:1 four-quarter-ended growth of real GDP (upper-left panel), real wages (upper-right panel), aggregate labour productivity (lower-left panel) and real unemployment benefits (lower-right panel).

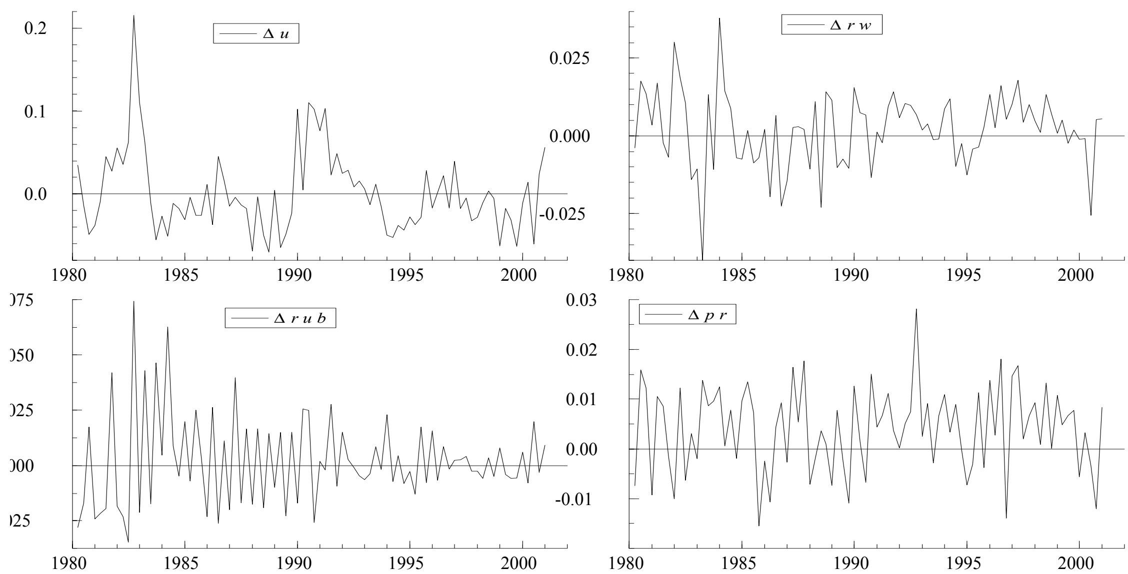

Figure 4: First differences (logs) of data series, measured quarterly 1980:1 to 2001:1 the unemployment rate (upper-left panel), real wages (upper-right panel), real unemployment benefits (lower-left panel) and aggregate labour productivity (lower-right panel).

There are several interesting aspects of the sample period 1980-2000. Figure 1 shows that the asymmetry in the unemployment rate is particularly evident from the early 1980s, while the sample period also covers two complete, asymmetric cycles of the unemployment rate. In addition, this period includes two widely recognized economic downturns in the Australian economy, covered by the shaded areas in Figure 2.[3] The dates of these two recessions, and the subsequent recoveries, appear to coincide with the rapid increases and the gradual decreases in the rate of unemployment. This lends support to the hypothesis that there is a relationship between economic growth and the rate of unemployment which may be further illustrated with this model.

4 A benchmark LSTAR model

Consider the following logistic smooth-transition autoregressive (LSTAR) model of the unemployment rate

$$\Delta u_t = \mu_{10} + \alpha_1 u_{t-1} + (\mu_{20} + \alpha_2 u_{t-1})\, G_t + \varepsilon_t, \tag{1}$$

with transition function

$$G_t(\gamma, c; s_t) = \left[(1 + \exp\{-\gamma\,(s_t - c)\,/\sigma\,(s_t)\})\right]^{-1}, \quad \gamma > 0, \tag{2}$$

where s_t is the transition variable.[4] Note that as $\gamma \to \infty$ this smooth-transition model tends in the limit to a regime-switching regression model with two regimes in the unemployment rate, u, associated with small and large values of the transition variable, s_t, with respect to the threshold, c.

Given that the Australian unemployment rate is associated with observed periods during which the unemployment rate rapidly increases, peaks and then begins to decrease, at a much slower rate than that at which it increased, it appears reasonable to limit consideration to a two-regime model such as (1). In addition, given that the observed behaviour of the unemployment rate is commonly associated with changes in the business cycle, during which there

[3] According to the Melbourne Institute of Applied Economic and Social Research (2000) Australia experienced two classical recessions during this time. These periods include September 1981 to May 1983 and December 1989 to December 1992.

[4] As highlighted by Teräsvirta (1994, 1998), there can be problems related to the estimation of the slope parameter of the transition function. Because the value of γ depends on the magnitude of the values of s_t, it is advisable to standardize the exponent of the transition function by dividing it by the sample standard deviation of the transition variable $\sigma(s_t)$.

are periods of expansion and contraction in economic growth, the two-regime LSTAR specification appears to be adequate.[5]

Using the lagged four-quarter-ended growth rate of unemployment, $\Delta_4 u_{t-1}$, as the transition variable, Skalin and Teräsvirta (2002) show that equation (1) captures the main features of asymmetric behaviour of the (seasonally unadjusted) unemployment rate in Australia. The first stage in this empirical analysis, therefore, is to compare their results with a univariate LSTAR model estimated using the seasonally adjusted unemployment defined earlier. The parameter estimates of the baseline LSTAR model are reported in Table 1, together with the diagnostic tests.[6]

$$\widehat{\Delta u_t} = \underset{(0.05)}{0.09} - \underset{(0.02)}{0.05}\, u_{t-1} + \left(\underset{(0.18)}{0.85} - \underset{(0.08)}{0.36}\, u_{t-1} \right) G_t$$

$$G_t = \left\{ 1 + \exp\left[\underset{(33.46)}{-159.3} \left(\frac{\Delta_4 u_{t-1} - \underset{(0.004)}{0.164}}{s.e.(\Delta_4 u_{t-1})} \right) \right] \right\}^{-1}$$

Estimation statistics

RSS	0.102	$\hat{\sigma}$	0.0366	T	82
AIC	−6.54	SC	−6.37	p	6

Misspecification tests

$\mathsf{F}_{\mathsf{AR}(1-4)}\,(4,72)$	1.90 [0.12]	$\mathsf{F}_{\mathsf{ARCH}(1-4)}\,(4,68)$	5.63 [0.00]
$\chi^2_{\mathsf{normality}}\,(2)$	2.44 [0.29]	$\mathsf{F}_{\mathsf{hetero}}\,(7,68)$	2.28 [0.04]

Notes

P-values of test outcomes are given in brackets after the test statistics.

Table 1: The baseline LSTAR specification of the unemployment rate. Details of diagnostic tests are provided.

A number of comments can be made when comparing these results with those obtained by Skalin and Teräsvirta (2002). *First*, and most important, the statistical significance of the logistic function, G_t indicates that the un-

[5] As discussed in van Dijk et al. (2002), there exist several alternative specifications which allow for multiple regimes.

[6] Estimation of the LSTAR models was conducted using Ivar Pettersen's *STR2* compiled *OxPack* routines translated from Gauss programmes written by Timo Teräsvirta.

employment rate in Australia displays significant nonlinearity. *Second*, these results also provide evidence of hysteresis, especially during periods of high unemployment ($u_{t-1} = -0.049$, $u_{t-1} \cdot G_t = -0.356$) and are similar to the corresponding estimates reported by Skalin and Teräsvirta (2002), namely, -0.08 and 0.30. Hysteresis in unemployment is a widely recognized economic phenomenon and these results indicate that when unemployment is high it is quite slow to decrease, an observation which is mirrored by the behaviour of the unemployment rate in Australia (Figure 1). *Third*, the parameters of the transition function estimated in this analysis ($\hat{\gamma} = -158$, $\hat{c} = 0.164$) are quite different when compared with the same parameters reported by Skalin and Teräsvirta (2002) ($\hat{\gamma} = -3.36$, $\hat{c} = 0.74$). In this analysis, the smoothness parameter indicates a very rapid transition from periods of low to high unemployment, while the results reported by Skalin and Teräsvirta (2002) suggest that this transition is much smoother. *Fourth*, these results indicate that the location about which unemployment switches into the second regime is lower compared with the findings of Skalin and Teräsvirta (2002).

The disparity between the results in Table 1 and those reported by Skalin and Teräsvirta (2002) may be due to the use of different series in these analyses, different sample periods and the smoothing due to seasonal adjustment. In spite of these differences, however, the results indicate that there is support for the hypothesis that an equation for the Australian unemployment rate can be estimated using a non-linear framework. The task is now one of discovering whether or not the addition of macroeconomic variables can improve upon this purely autoregressive specification.

5 Automated model selection

In this section a modelling cycle of specification, estimation, evaluation and encompassing, as proposed for smooth-transition models by Teräsvirta (1994, 1998) is implemented. As a precursor to the description of the modelling cycle, it should be noted that the non-linear smooth-transition model may be linearized by using a Taylor expansion of the logistic function (Teräsvirta, 1994, 1998) in equation (2). This allows the smooth-transition model to be expressed in linear form

$$\Delta u_t = x_t'\beta_0 + (x_t s_t)'\beta_1 \\ + \left(x_t s_t^2\right)'\beta_2 + \left(x_t s_t^3\right)'\beta_3 + v_t, \tag{3}$$

with the result that a test for linearity against the LSTR specification involves an F-test of the joint hypothesis

$$H_0 : \beta_1 = \beta_2 = \beta_3 = 0.$$

A more efficient approach, however, is to test not only against non-linearity, but simultaneously to test down the general linear specification of equation (3) to obtain a correctly specified linear model. With the model in this form, following Hendry and Krolzig (2003), the testing down of the general linearised model (3) may be effected by means of the automated model-selection program, PcGets, recently developed by Hendry and Krolzig (1999, 2001).

The enhanced modelling cycle may now be described as follows.

Step 1: Specification.

The endogenous variable is the first difference of the unemployment rate, Δu_t, the transition variable is $s_t = \Delta_4 u_{t-1}$, while the information set x_t consists of

$$x_t = [1, u_{t-1}, \Delta u_{t-m}, \Delta_4 y_{t-m}, \Delta rw_{t-m}, \Delta pr_{t-m}, \Delta rub_{t-m}]', \quad m = 0, \ldots, 2.$$

Given the number of variables in the full 3-order Taylor expansion (3), the suggestion of Teräsvirta (1998) is followed and only the 3rd-order term in the Taylor expansion is used. The general linearized model which is passed to PcGets for testing is therefore

$$\Delta u_t = x_t'\beta_0 + \left(x_t s_t^3\right)'\beta_3 + v_t \tag{4}$$

PcGets conducts a specification search of equation (4) and returns the chosen specification. If the model chosen by PcGets returns the coefficient values

$$\beta_3 = 0,$$

then the final model is linear and the modelling cycle is complete. If, on the other hand, the model chosen by PcGets includes non-zero values for any of the elements of β_3, then the hypothesis of linearity is rejected and the chosen model contains non-linear elements. In this instance, the modelling cycle proceeds to Step 2.

Step 2: Estimation.

Let $x_{0,t}$ and $x_{3,t}$ contain those elements of x_t with corresponding non-zero elements in β_0 and β_3 in the specification chosen by PcGets in Step 1. The LSTR model to be estimated is then

$$\Delta u_t = x'_{0,t}\delta_0 + x'_{3,t}\delta_3 G_t(\gamma, c, s_t) + \varepsilon_t, \tag{5}$$

with the function $G_t(\cdot)$ given by equation (2) and with $\Delta_4 u_{t-1}$ used as the transition variable, s_t.

Step 3: Evaluation and encompassing.

Step 2 yields estimates of the parameters of the transition function which are then used to create the observed function, $\widehat{G}_t(\widehat{\gamma}, \widehat{c}, s_t)$. Augmenting the general linearized model (4) with the LSTR part:

$$\Delta u_t = x'_t\theta_0 + \left(x_t s_t^3\right)'\theta_3 + \left(x_{3,t}\widehat{G}_t(\widehat{\gamma}, \widehat{c}, s_t)\right)'\kappa_3 + \eta_t \tag{6}$$

enables a test of parsimonious encompassing (Hendry, 1995, p. 511), corresponding to the joint test of

$$H_0 : \theta_0 = \delta_0, \ \theta_3 = 0, \ \kappa_3 = \delta_3,$$

conditional on $\widehat{G}_t(\widehat{\gamma}, \widehat{c}, s_t)$. This test is again easily implemented by letting letting PcGets evaluating (6), and see if the outcome is the estimated LSTR from (5). If so, the test statistic is the F-test of omitted variables in the final specification.

6 Empirical Results

6.1 Specification

The specification chosen by PcGets is reported in Table 2. These results suggest that although there are strong and significant linear effects from both output ($\Delta_4 y_t = -2.26$) and labour productivity growth ($\Delta pr_t = 1.02$; $\Delta pr_{t-2} = 1.26$), the baseline model rejects the hypothesis of linearity ($F_{pNull} = [0.00]$). The weak effect of the unemployment level term in the linear specification ($u_{t-1} = 0.03$) makes it quite likely that the Australian unemployment rate behaves quite differently in periods of high and low unemployment. In addition, real wages and real unemployment benefits both enter in interaction with the transition variable which may be due to these variables having stronger effects in periods of high unemployment. The presence of the cubic terms also suggest that a LSTR model might be appropriate (Teräsvirta, 1994).

$$
\begin{aligned}
\widehat{\Delta u}_t = & + \underset{(0.0384)}{0.137} - \underset{(0.0191)}{0.0312}\, u_{t-1} - \underset{(0.19)}{2.26}\, \Delta_4 y_t \\
& + \underset{(0.174)}{0.47}\, \Delta rub_{t-1} + \underset{(0.392)}{1.02}\, \Delta pr_t + \underset{(0.373)}{1.26}\, \Delta pr_{t-2} \\
& - \underset{(5.27)}{14.1}\, \Delta u_{t-2} s_t^3 - \underset{(14.6)}{52.8}\, \Delta_4 y_t s_t^3 + \underset{(23.6)}{61.7}\, \Delta_4 y_{t-1} s_t^3 \\
& - \underset{(25.5)}{62}\, \Delta rw_{t-1} s_t^3 + \underset{(17.4)}{42.4}\, \Delta rub_t s_t^3 + \underset{(0.0283)}{0.0802}\, 1990p1_t
\end{aligned}
$$

Estimation statistics

RSS	0.0498	$\hat{\sigma}$	0.0267	T	82	F_{pNull}	0.00
AIC	-7.1146	SC	-6.7624	p	12	F_{pGUM}	0.6041

Misspecification tests

$F_{Chow(1991:1)}(41, 29)$	$= 0.80$ [0.75]	$F_{AR(1-4)}(4, 66)$	$= 0.61$ [0.66]
$F_{Chow(1999:1)}(9, 61)$	$= 1.48$ [0.18]	$F_{ARCH(1-4)}(4, 74)$	$= 0.49$ [0.74]
$\chi^2_{normality}(2)$	$= 8.40$ [0.02]	$F_{hetero}(21, 60)$	$= 1.77$ [0.04]

Notes

The sample is 1980:4 to 2001:1. Standard errors are in parentheses below parameter estimates. P-values of test outcomes are given in brackets after the test statistics.

Table 2: The baseline linear model of the unemployment rate.

6.2 Estimation

Based upon the findings presented above, therefore, a LSTR model is estimated using non-linear least squares. The specification is documented in Table 3.

$$\widehat{\Delta u_t} = \underset{(0.04)}{0.11} - \underset{(0.018)}{0.03}\ u_{t-1} - \underset{(0.21)}{1.75}\ \Delta_4 y_t + \underset{(0.16)}{0.51}\ \Delta rub_{t-1}$$

$$+ \underset{(0.36)}{0.89}\ \Delta pr_t + \underset{(0.35)}{1.09}\ \Delta pr_{t-2} + \underset{(0.026)}{0.085}\ 1990p1_t$$

$$+ \left(\underset{(0.15)}{0.52} - \underset{(0.07)}{0.24}\ u_{t-1} - \underset{(0.58)}{1.31}\ \Delta rw_{t-2} + \underset{(0.31)}{0.66}\ \Delta rub_t \right) \cdot G_t$$

$$G_t = \left\{ 1 + \exp \left[\underset{(72.1)}{-153} \left(\frac{\Delta_4 u_{t-1} - \underset{(0.007)}{0.165}}{\hat{\sigma}(\Delta_4 u_{t-1})} \right) \right] \right\}^{-1}$$

Estimation statistics

RSS	0.034	$\hat{\sigma}$	0.024	T	82
AIC	−7.31	SC	−6.93	p	13

Misspecification tests

$\mathsf{F}_{\mathsf{AR}(1-4)}\,(4, 65)$	0.59 [0.67]	$\mathsf{F}_{\mathsf{ARCH}(1-4)}\,(4, 61)$	0.34 [0.85]
$\chi^2_{\mathsf{normality}}\,(2)$	4.02 [0.13]	$\mathsf{F}_{\mathsf{hetero}}\,(20, 48)$	0.93 [0.55]

Notes

Standard errors are in parentheses below parameter estimates.

P-values of test outcomes are given in brackets after the test statistics.

Table 3: The LSTR model of the unemployment rate.

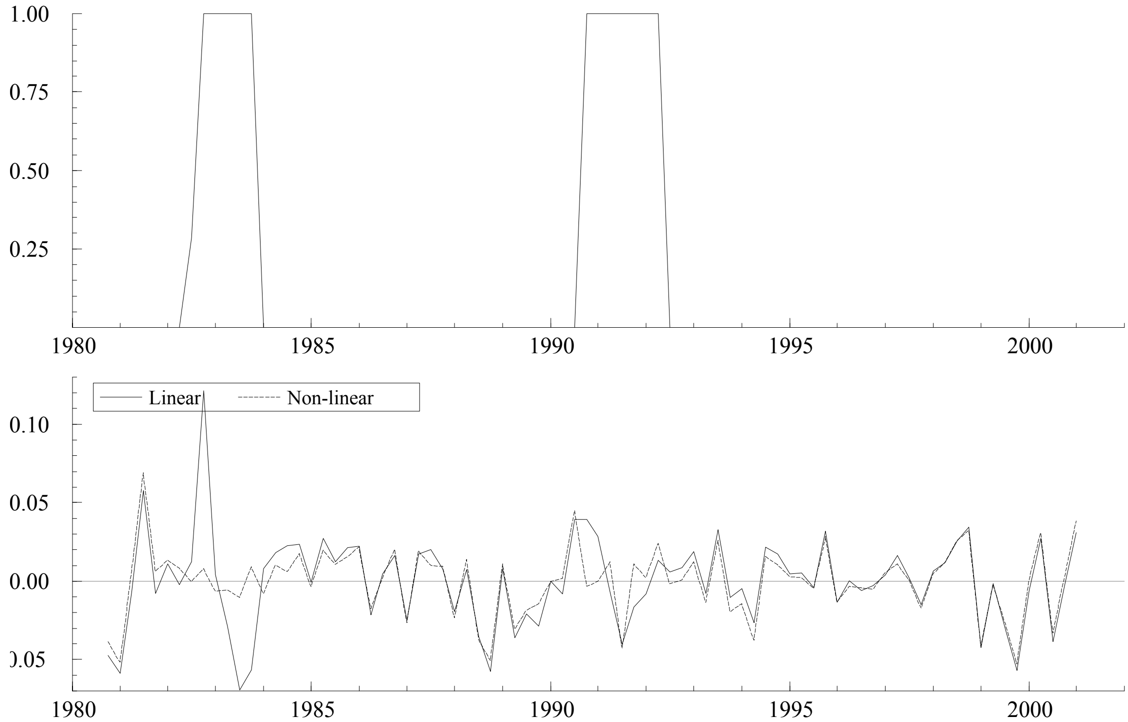

Figure 5: The transition function of the LSTR model (upper panel) and the comparison of prediction errrors from the linear and non-linear specifications (lower panel).

The hypothesis of linearity is strongly rejected in favour of the alternative model, where the level of unemployment, together with real wages and unemployment benefits, enter non-linearly. This finding is also supported by Figure 5 which graphs the residuals of the linear baseline specification against the non-linear alternative. Clearly, the non-linear model does a better job of explaining the periods of high unemployment in Australia observed in the early 1980s and 1990s. The coefficients on the unemployment level terms $\{u_{t-1} = -0.03; u_{t-1} \cdot G = -0.24\}$ are consistent with the original hypothesis that unemployment displays hysteresis, especially when unemployment is very high. Moreover, it can be seen that the LSTR model provides a good explanation of the data ($\hat{\sigma} = 0.024$), when compared against the univariate specification (Table 1) where ($\hat{\sigma} = 0.036$).

The steepness parameter ($\gamma = 153$) indicates a very rapid change in the transition between periods of low and high unemployment. This suggests that the LSTR specification can be simplified to a switching regression model, originally developed by Quandt (1958)

$$\Delta u_t = \sum_{i=1}^{q} \rho_{1i} x_{it} + \sum_{i=1}^{q} \rho_{2i} x_{it} I_t + \varepsilon_t, \tag{7}$$

where I_t is the Heaviside indicator function

$$I_t = \begin{cases} 1 \; if \; s_t > c \\ 0 \; if \; s_t < c \end{cases}. \tag{8}$$

The chosen model is, therefore, the specification of Table 3, simplified to a threshold model, with transition variable $s_t = \Delta_4 u_{t-1}$ and threshold parameter $\hat{c} = 0.165$.

6.3 Evaluation and encompassing

The final stage of the modelling cycle is to evaluate the chosen model against the general linearized model (4). The chosen model is, therefore, augmented with all the terms of the general linearized model (4) and the model is again tested down, using PcGets. The outcome, documented in Table 4, shows that the chosen model encompasses the general linearized model. PcGets chooses the simplified threshold model as the final specification, and the F-test of omitted variables from the augmented generalized linear model (6) has a p-value of $\mathsf{F}_{p\mathsf{GUM}} = 0.92$.

$$\widehat{\Delta u_t} = \underset{(0.0354)}{0.114} - \underset{(0.0177)}{0.0297}\ u_{t-1} - \underset{(0.197)}{1.8}\ \Delta_4 y_t + \underset{(0.158)}{0.491}\ \Delta rub_{t-1}$$

$$+ \underset{(0.355)}{0.859}\ \Delta pr_t + \underset{(0.342)}{1.06}\ \Delta pr_{t-2} + \underset{(0.026)}{0.085}\ 1990p1_t$$

$$+ \left(\underset{(0.133)}{0.514} - \underset{(0.0606)}{0.24}\ u_{t-1} + \underset{(0.513)}{1.47}\ \Delta rw_{t-2} + \underset{(0.273)}{0.667}\ \Delta rub_t \right) I_t$$

$$I_t = \begin{cases} 1 & if \quad \Delta_4 u_{t-1} > 0.165 \\ 0 & otherwise \end{cases}$$

Estimation statistics

RSS	0.0404	$\hat{\sigma}$	0.0239	T	82	$F_{p\text{Null}}$	0.0
AIC	−7.3461	SC	−7.0233	p	11	$F_{p\text{GUM}}$	0.92

Misspecification tests

$F_{\text{Chow}(1991:1)}\ (41, 30)$	0.69 [0.87]	$F_{\text{AR}(1-4)}\ (4, 67)$	0.33 [0.86]
$F_{\text{Chow}(1999:1)}\ (9, 62)$	1.96 [0.06]	$F_{\text{ARCH}(1-4)}\ (4, 74)$	0.36 [0.84]
$\chi^2_{\text{normality}}\ (2)$	3.24 [0.20]	$F_{\text{hetero}}\ (18, 63)$	1.29 [0.22]

Notes

P-values of test outcomes are given in brackets after the test statistics.
Standard errors are in parentheses below parameter estimates.

Table 4: The estimated threshold model of the unemployment rate.

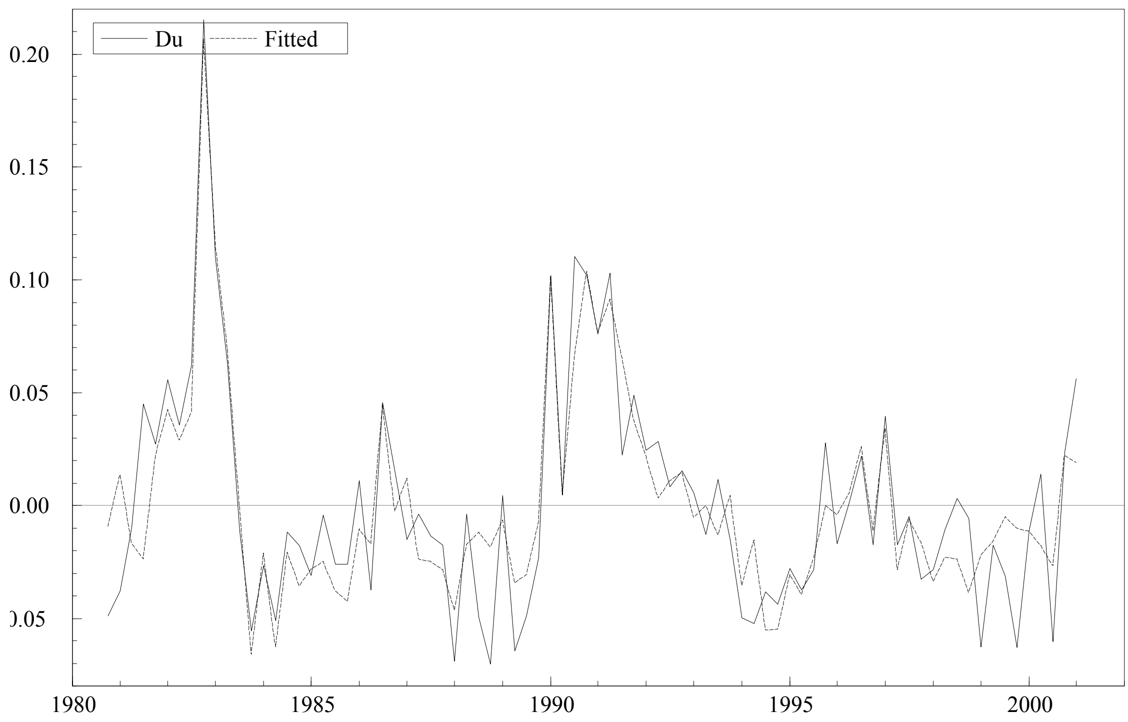

Figure 6: Actual and fitted values from the treshold model.

Given its simplicity and parsimony, the switching model does a surprisingly good job of describing the unemployment process (Figure 6). It is evident from the threshold model that changes in the Australian unemployment rate are predominantly a function of the growth rate in aggregate demand $\{\Delta_4 y_t = -1.75\}$, together with lay-offs caused by productivity growth[7] $\{\Delta pr_{t-2} = 0.93\}$. Further, during periods when unemployment is high ($I_t = 1$), the effects of real wages and unemployment benefits are accentuated ($\Delta rw_{t-2} = 1.47$, $\Delta rub_t = 0.67$).

These findings illustrate a plausible economic scenario. Suppose there is a large, negative demand shock in the economy as would occur, for example, during an economic recession, which causes unemployment to increase. While aggregate demand remains low, the unemployment rate continues to rise, eventually switching into a period of very high unemployment. It then remains high for several periods due to high real wages and generous unemployment benefits, which increase the reservation wage of workers such that

[7] Recognizing the possibility of simultaneity bias, the model was also evaluated with instrumental variables. The changes in the parameter estimates, however, are negligible and so are not reported.

they may remain unemployed for an increased period of time. After several periods, however, the unemployment rate begins to fall, but at a much slower rate than that at which it increased: the result of hysteresis in the unemployment rate, which is accentuated when unemployment is high ($u_{t-1} = 0.03$, $u_{t-1} \cdot I_t = 0.24$). Clearly, this same scenario may also occur following a shock to productivity, during which an increase in labour productivity reduces the number of workers firms need to hire and may also result in lay-offs.

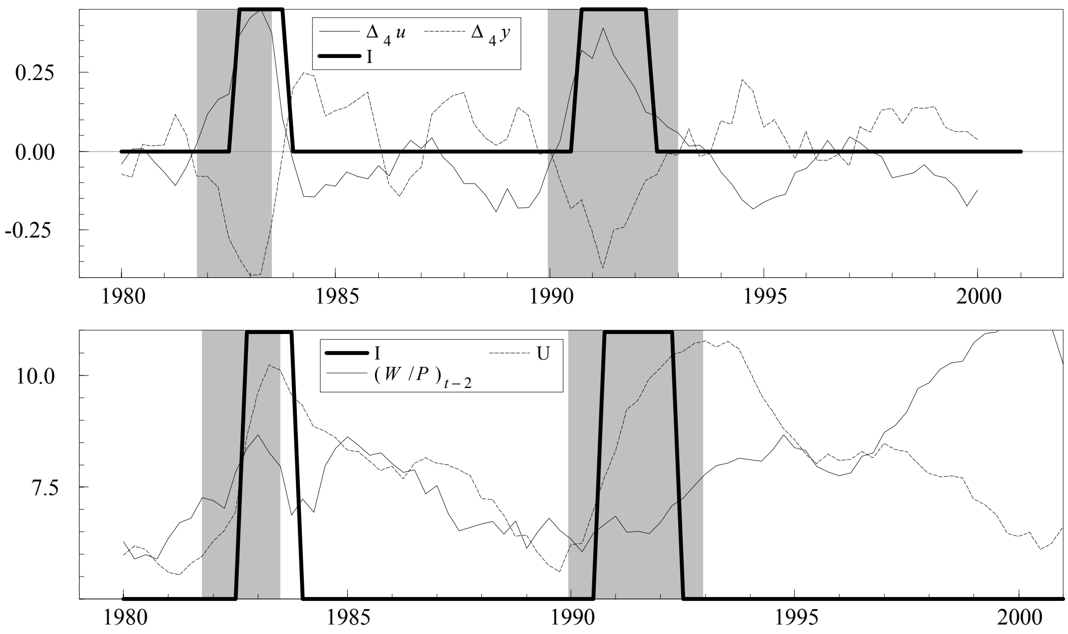

Figure 7: Annual percentage changes in unemployment and GDP (upper panel) and the unemployment rate and real wages lagged two periods (lower panel), compared with two classical recessions in the Australian economy (shaded areas) and two regimes from the threshold model (thick black line). Means and scales are adjusted.

This scenario is further supported by Figure 7 which compares the transition function from the LSTR model, which has the same transition variable as the threshold model, with the annual percentage change in the unemployment rate and GDP and the unemployment rate and the real wage. From this graph, it can be seen that the rapid increase in the unemployment rate, which occurred in Australia during the recessions of 1982/1983 and 1990/1991, is associated with the switch in the transition function to the second regime where the main sources of increasing unemployment are negative aggregate demand shocks and high productivity growth. If, however, the changes are big enough, so that unemployment is in the second regime, real wages and real unemployment benefits tend to delay the movement back towards its previously lower levels.

7 Conclusion

The existing empirical work on Australian unemployment which models the unemployment rate directly in a single-equation framework makes the assumption that the unemployment rate is linear. This is inconsistent with empirical evidence which suggests that the structure of Australia's unemployment series is asymmetric and should be modelled as such. Consequently, this paper estimates a nonlinar model of the unemployment rate for Australia. The final empirical model is both simple and parsimonious and is able to adequately describe the process of unemployment, with an improvement in explanatory power when compared to the linear model. In contrast to earlier, purely time-series-based models, it is found that several macroeconomic variables are also important determinants of the unemployment rate in Australia. The results from this modelling exercise indicate that changes in unemployment are predominantly a result of deficient aggregate demand and productivity growth. Further, as unemployment rises, it continues to remain high due to high real wages and generous unemployment benefits. For policy-makers the message is important: the old dictum that the unemployment rate increases more rapidly than it decreases should still be heeded.

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A Data description and sources

- **Unemployment Rate (U)**:

  Definition: Number of unemployed people as a proportion of the total labour force (%). (Unemployment/Civilian Labour force) *100. The labour force is defined as the sum of both employed persons and unemployed persons.

Source: ABS Cat. No. 1364.0 (NIF Modeller's databbase Table 10).

- **Real, Non-farm Gross Domestic Product (Y):**

Definition: ($m: average 1998/99 prices). This series is used to construct the four-quarter-ended domestic growth rate which is defined as the difference between real GDP this quarter and real GDP in the same quarter in the previous year.
Source: Reserve Bank of Australia Bulletin Statistics Table G9.

- **Average Wage Earnings**:

Definition: Average, total weekly non-farm earnings for all employees ($A, seasonally adjusted, nominal).

Earnings are average gross (before tax) earnings of employees and do not relate to average award rates nor to the earnings of the 'average' person. Employees refer to all wage and salary earners who received pay for any part of the reference period, including part-time workers.
Source: Economic Data: Unit Labour Cost Index March 2001 - Commonwealth Treasury (http://www.treasury.gov.au).

- **Consumer Price Index (P)**:

Definition: All groups, consumer price index (CPI). Index 1989/90=100.
Source: Prices ABS Cat. No. 6401.0 Table 9(b): *CPI - Analytical series.*

- **Aggregate Labour Productivity (PR)**:

Definition: Real, non-farm GDP per person. Seasonally adjusted.

A person is defined as all wage and salary earners, the self-employed and unpaid helpers.

Source: Economic Data: Unit Labour Cost Index March 2001. Commonwealth Treasury (http://www.treasury.gov.au)

- **Nominal unemployment benefits (UB):**

Description: Weekly payment in dollars per week for single persons, over 21 with no children.

Source: RBA & Department of Social Security. Unpublished data obtained through personal correspondence with David Gruen.