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ASYMMETRIC UNEMPLOYMENT RATE DYNAMICS IN AUSTRALIA

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Asymmetric unemployment rate dynamics in Australia*

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Abstract

The unemployment rate in Australia is modelled as an asymmetric and non-linear function of aggregate demand, productivity, real interest rates, the replacement ratio, and the real exchange rate. If changes in unemployment are big, the management of of demand, real interest rates and the replacement ratio will be good policy instruments to start bringing it down. 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 which points to the fact that the unemployment rate in both the U.S. (Hansen, 1997, Verbrugge, 1997, Parker and Rothman, 1998, Rothman, 1998, Koop and Potter, 1999, Altissimo and Violante, 2001) and Europe (Acemoglu and Scott, 1994, Peel and Speight, 1998, Brännäs and Ohlsson, 1999, Akram and Nymoen, 2006, Skalin and Teräsvirta, 2002) exhibits asymmetric behaviour in the sense that it increases more quickly than it decreases. Various explanations of this non-linear behaviour have been offered in the literature. For example, Aolfatto (1997) uses Pissarides (1985) simple search and matching model to explain cyclical asymmetry in unemployment rate fluctuations in the U.S. He finds that the asymmetry comes from an adverse productivity shock, which brings about the destruction of certain jobs in the economy that are not recreated as aggregate economic conditions improve, forcing individuals to seek out new job opportunities. Jovanovic (1987), Greenwood, MacDonald, and Zhang (1996), and Mortensen and Pissarides (1994) also use various search and matching models to explain the behaviour of the unemployment rate in the US. A related literature has pointed to asymmetries in Okun's Law where changes in output can cause asymmetric changes in the unemployment rate (Lee, 2000, Crespo-Cuaresma, 2003, Silvapulle, Moosa, and Silvapulle, 2004, Huang and Chang, 2005). Finally, several papers relate non-linearities to hysteresis (Akram, 2005, Papell, Murray, and Ghiblawi, 2000, Proietti, 2003).

Empirical evidence also exists on the non-linear properties of the aggregate Australian unemployment rate (Peat and Stevenson, 1996, Bodman, 1998, 2001, 2002, Skalin and Teräsvirta, 2002). While these non-linear models show that the aggregate unemployment rate in Australia does indeed behave differently during periods of low and high unemployment, they do not have an effective explanation of what drives the unemployment rate to increase at such a rapid rate or what contributes to its much slower decrease.

This paper makes two contributions. In the first instance, it is demonstrated that aggregate demand, the real interest rate, productivity, the replacement ratio, and the real exchange rate are all important factors in the asymmetry in the Australian unemployment rate. The second contribution is methodological. It is shown that automated model-selection techniques for linear models, introduced by Hoover and Perez (1999) and developed by Hendry and Krolzig (1999, 2001) and Doornik (2009), can be adapted quite easily to applications in non-linear environments, by testing a linearized expansion of the non-linear model against its linear alternative.

The rest of the paper is structured as follows. Section 2 sets out a simple LSTAR model of the unemployment rate and demonstrates the key features of the model that enables it to capture asymmetries in the data. Section 3 looks at the asymmetry in the Australian unemployment rate and explores possible candidate drivers of unemployment variation. In Section 4 an enhanced non-linear modelling cycle is implemented based on the automated model-selection procedures available in the *Autometrics* software Doornik (2009). The empirical results obtained are evaluated in Section 5. The end result is a model of the Australian unemployment rate with non-linear behaviour due to rigidities caused by a complex interplay of many factors. Section 6 is a brief conclusion.

2 Asymmetries in Unemployment

Figure 1 plots the evolution of the Australian unemployment rate from 1979 to 2010. It shows how large, swift upward changes are followed by slow, downward drifts. This casual empiricism lends support to the hypothesis that there is a relationship between aggregate economic shocks and the rate of unemployment which may be further clarified within the context of a model of asymmetric unemployment dynamics.

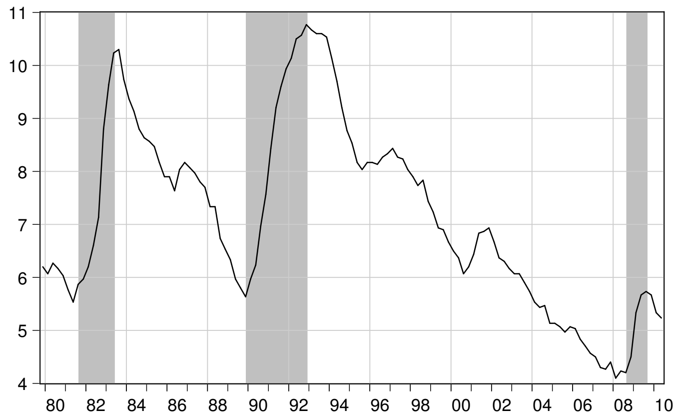

Figure 1: Australia's aggregate unemployment rate for the period 1979:4 to 2010:2. The shaded areas represent recessions in the classical cycle.

There are several additional interesting aspects of the period 1979-2010. According to the Melbourne Institute of Applied Economic and Social Research,[1] Australia experienced two classical recessions during this time, namely September 1981 to May 1983 and December 1989 to December 1992. To these may be added

[1]See http://www.ecom.unimelb.edu.au/iaesrwww/bcf/bdates5197.html.

the downturn due to the current global financial crisis. The dates of these three recessions, and the subsequent recoveries, appear to coincide with the rapid increases and the gradual decreases in the rate of unemployment.

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. They propose a simple univariate LSTAR model as a useful way of summarizing the main features of the asymmetric behaviour of the unemployment rate. To highlight the main properties of the model, a version with only first-order dynamics in equilibrium correction (EqC) form is considered

$$\Delta U_t = -\alpha_1 \left(U_{t-1} - \frac{\mu_1}{\alpha_1} \right) - \alpha_2 \left(U_{t-1} - \frac{\mu_2}{\alpha_2} \right) G_t + \varepsilon_t$$

with $0 < (\alpha_1 + \alpha_2) < 1$ and

$$G_t = \left[(1 + \exp\{-\gamma\,(\Delta U_{t-1} - c)\}) \right]^{-1} , \qquad \gamma > 0 \, .$$

The parameter c is the threshold that determines the size of the shock that is required for the activation of the transition function $G(\cdot)$ and the value of γ determines the speed of the change in $G(\cdot)$ from the value of zero to unity in the vicinity of the threshold.

Assume a constant long-run equilibrium rate of unemployment μ_1/α_1 for which $\Delta U_t = 0$, and therefore $G_t = 0$. Suppose a positive shock affects unemployment such that $\Delta U_t > c$ and $G_t = 1$. In the next period, the growth in unemployment ΔU_t will be given by

$$\Delta U_t = -(\alpha_1 + \alpha_2) \left(U_{t-1} - \frac{\mu_1 + \mu_2}{\alpha_1 + \alpha_2} \right) + \varepsilon_t,$$

which will imply a rapid increase in U_t towards $(\mu_1{+}\mu_2)/(\alpha_1{+}\alpha_2)$. The restrictions on the parameters ensure that ΔU_t will fall below c as U_t approaches $(\mu_1{+}\mu_2)/(\alpha_1{+}\alpha_2)$, which has the effect of resetting the transition function G_t to zero and returning the process for ΔU_t to

$$\Delta U_t = -\alpha_1 \left(U_{t-1} - \mu_1/\alpha_1 \right) + \varepsilon_t \, .$$

If the value of α_1 is relatively small, the return of the unemployment rate towards its long-run equilibrium level μ_1/α_1 is likely to be slow, mimicking the observed near-hysteresis properties of unemployment rates.

This deceptively simple model, therefore, has the potential to mimic the asymmetric fluctuations in the Australian unemployment rate and therefore provides a useful point of departure for the empirical investigation. The parameter estimates[2] this benchmark univariate specification, enhanced with slightly richer dynamics and using the lagged two-quarter-ended growth rate of unemployment, $\Delta_2 U_{t-1}$, as the transition variable, are reported in Table 1.

Table 1: A benchmark LSTAR model of the Australian unemployment rate for the period 1979:4 to 2010:2. The transition variable is $\Delta_2 U_{t-1}$.

Coefficients	Estimates	Std. Errors	t-values
Linear parameters:			
μ_1	0.12	0.104	1.15
U_{t-1}	-0.03	0.015	-2.20
ΔU_{t-1}	0.11	0.166	0.64
Transition parameters:			
γ	24.47	20.490	1.20
c	0.15	0.040	3.82
Non-linear parameters:			
μ_2	0.55	0.223	2.48
U_{t-1}	-0.04	0.029	-1.43
ΔU_{t-1}	0.53	0.209	2.53

Diagnostics:			
RSS	6.06	$\hat{\sigma}$	0.23
AIC	-2.89	SC	-2.73
$F_{AR(1-5)}$ (5,110)	1.00 [0.42]	$F_{RESET}(2, 113)$	2.84 [0.06]

The coefficient on U_{t-1} in the linear regime of -0.03 implies a relatively slow adjustment to equilibrium to the implied long-run unemployment level of 4%. Assume that a shock to aggregate demand induces a 6 month rise of 0.15 percentage points in the unemployment rate, the speed of adjustment to the higher unemployment equilibrium level of 9.6% is nearly doubled to -0.07. This disparity in the

[2]Estimation of the LSTAR models was conducted using Ivar Pettersen's *STR2* compiled *OxPack* routines translated from Gauss programmes written by Timo Teräsvirta and the non-linear algorithms in *Oxmetrics6*. The following abbreviations will be used for the diagnostics reported with the estimation results: residual sum of squares, RSS; the standard error of the regression, $\widehat{\sigma}$; Akaike Information Criterion, AIC; Schwartz Information Criterion, SC; the chi-square version of the test for normality of the regression residuals, $\chi^2_{\text{normality}}$, with the appropriate degrees of freedom in brackets; and the F-forms of the Lagrange Multiplier tests for autocorrelation, F_{AR}, heteroskedasticity, F_{het} and functional form, F_{RESET}, with the appropriate degrees of freedom in brackets.

speeds of adjustment in the two regimes is of the order of magnitude that would support the pattern of asymmetry in the behaviour of the unemployment rate illustrated in Figure 1.

The estimate of the parameter governing the speed of the transition from periods of low to periods of high unemployment, $\widehat{\gamma} = 24.47$, indicates a very abrupt transition in the vicinity of the threshold, $\widehat{c} = 0.15$. This fact that $\widehat{\gamma}$ is not statistically significant is characteristic of LSTAR models where the value of this parameter is difficult to pin down with great precision (Eitrheim and Teräsvirta, 1996).

This specification is only a preliminary one and as such only a minimum set of diagnostics are reported, but there does appear to be support from this simple univariate model for the hypothesis that a non-linear model may be required to capture the behaviour of the Australian unemployment rate. The interesting economic question to ask, however, is what fundamental economic drivers are responsible for the non-linear behaviour, so that this univariate, autoregressive specification can be improved upon.

3 Sources of Variation in Unemployment

Empirical studies on Australia have consistently found statistical support for a negative relationship between aggregate demand and unemployment and a positive relationship between real wages and unemployment (Pitchford, 1983, McMahon and Robinson, 1984, Trivedi and Baker, 1985, Dao, 1993, Valentine, 1993). These findings are also consistent with results obtained from reduced-form equations of the unemployment rate in structural labour market models (Pissarides, 1991, Huay and Groenewold, 1992, Scarpetta, 1996, Powell and Murphy, 1997, Debelle and Vickery, 1998, Downes and Bernie, 1999). Further support is provided by more descriptive work, which demonstrates that a common theme in papers on unemployment in Australia is that business cycle fluctuations and real wage growth are the two primary factors influencing Australian unemployment (Gregory, 2000, Le and Miller, 2000, Thomson, 2000, Borland, 1997, Goodridge, Harding, and Lloyd, 1995).

Theories of unemployment, however, identify more diverse sources of unemployment variation, many of which are nicely summed up in the matching model of unemployment (Cahuc and Zylberberg, 2004, chapter 9). In this model, unemployment is predicted to be positively correlated with the replacement ratio, productivity, and the real interest rate, and negatively correlated with shocks to aggregate demand. Some of these effects are also predicted by other labour market models, like the efficiency wage theories, and some are in line with standard macroeconomic theory. As a special case, one notion of disequilibrium unemployment is that in steady state of most growth models, as for example in the Ramsey model, the real interest rate is equal to the real growth rate of output. This explanation of unemployment was indeed verified empirically by Hendry (2001). Furthermore, these predictions are roughly in line with the conclusions drawn from the seminal study of of Layard, Nickell, and Jackman (1991). Finally, the importance of the real exchange rate has to be taken into account in a small open economy like Australia. An increase in the real exchange rate will increase the consumer price level. Nominal wages must go up to keep real consumption wages unchanged, increasing real product wages and therefore reduce employment and increase unemployment.

Informed by these theories of unemployment, the data used to model the Australian unemployment rate, U, are seasonally adjusted, quarterly observations for the period 1978:3 to 2010:2 of the following variables: real GDP, Y; the long-term real interest rate, R; the replacement ratio, RPR; labour productivity, PR; and the real exchange rate, RXR.

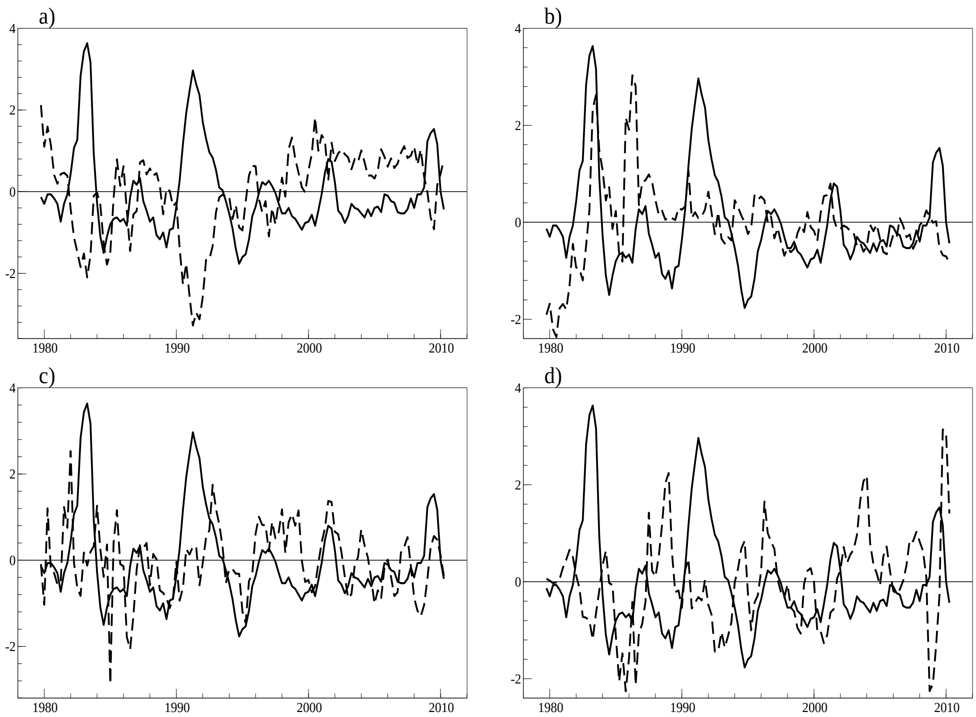

Figure 2: The four-quarter change in the unemployment rate $\Delta_4 U_t$ compared to the four-quarter interest corrected growth rates of output, $(\mathbb{D}_4 Y - R)$ (panel a), four-quarter productivity growth $\mathbb{D}_4 PR$ (panel b), four-quarter growth rate of the replacement ratio $\mathbb{D}_4 RPR$ (panel c), and the four-quarter growth rate of the real exchange rate, $\mathbb{D}_4 RXR$ (panel d).

The potential significance of these candidate drivers of unemployment[3] is illustrated in Figure 2, which plots the four quarter changes in the unemployment rate, $\Delta_4 U_t$, against the interest corrected annualized output growth rate $(\mathbb{D}_4 Y - R)$, four-quarter productivity growth $\mathbb{D}PR$, the four-quarter growth rate of the replacement ratio, $\mathbb{D}RPR$, and the annualized growth rate of the real exchange rate, $\mathbb{D}RXR$. As can be seen, four-quarter changes in the unemployment rate seem negatively correlated with interest corrected output growth rates (panel a) and the four-quarter appreciation of the real exchange rate (panel d). There also seems to be a positive correlation with annualized productivity growth (panel b), while the linear dependence on the replacement ratio four-quarter growth rate (panel c) after the upward shift in unemployment benefits in 1985-86 is less clear. These observations suggest that the tentative dynamic specification of the aggregate unemployment rate in Australia will, at the very least, need to be augmented by the inclusion of aggregate demand, the replacement ratio and productivity. In addition the effects of interest rates and the real exchange rate will need to be controlled for.[4]

Having established null hypotheses both about the general functional form as well as the forcing variables, the most important task of specifying and testing the model remains. Since all variables can enter both linearly and non-linearly, the problem of model specification is highly accentuated. We therefore propose to use automated model selection techniques to test both the general functional form of the model as well as the specific way the candidate forcing variables enter the proposed model.

4 Automated Model Selection

In this section, a modelling cycle of specification, estimation, evaluation and encompassing of a non-linear econometric model within an automated modelling environment is described. Consider the general smooth transition model

$$\Delta U_t = \phi' X_t + \theta' X_t \, G_t(\gamma, c, S_t) + \epsilon_t \tag{1}$$

$$G_t = \left[(1 + \exp\{-\gamma (S_t - c)\})\right]^{-1}, \qquad \gamma > 0 . \tag{2}$$

$$S_t = \frac{\Delta_2 U_{t-1}}{\sqrt{\mathrm{var}\left(\Delta_2 U_{t-1}\right)}}, \tag{3}$$

[3]Appendix A provides a detailed description of the data and the relevant sources. For simplicity, the following notational conventions are adopted. The k-period *difference* of the variable x_t is denoted $\Delta_k x_t$, so, for example, the four-quarter difference is $\Delta_4 x_t$. Note, however, that the corresponding k-period *growth rate* of the variable x_t will be denoted $\mathbb{D}_k x_t \equiv \Delta_k x_t / x_{t-k}$.

[4]Unit root tests confirmed that the relevant changes and growth rates of the variables and the level of the interest rate are stationary. These results are not reported but are available from the authors.

where

$$X_t = [1,\, U_{t-1},\, \Delta U_{t-l},\, \mathbb{D}_4 Y_{t-m},\, R_{t-m},\, \mathbb{D}RPR_{t-m},\, \mathbb{D}PR_{t-m},\, \mathbb{D}RXR_{t-m}]'\ ,$$

for $l = 1, \cdots, 4$ and $m = 0, \cdots, 4$.

Following Teräsvirta (1994, 1998), the non-linear smooth-transition model may be linearized by using a Taylor expansion of the logistic function in equation (2), to give

$$\Delta U_t = \beta_0' X_t + \beta_1' X_t S_t + \beta_2' X_t S_t^2 + \beta_3' X_t S_t^3 + \nu_t\,. \tag{4}$$

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, could be to test not only against non-linearity, but simultaneously to test down the general linear specification of equation (4) to obtain a correctly specified linear model. With the model in this form, the testing down of the general linearized model (4) may be conducted by means of an automated model-selection program.[5] For this purpose the automated modelling procedures available in the software *Autometrics*, developed by Doornik (2009) are used.

The modelling cycle may now be described as follows.

Step 1: Specification.

Given the number of variables in the full Taylor expansion in equation (4), the suggestion of Teräsvirta (1998) is followed and only the 3rd-order term is used. The general linear model that is passed to *Autometrics* for testing is

$$\Delta U_t = \beta_0 X_t + \beta_3' X_t S_t^3 + \nu_t\,. \tag{5}$$

Autometrics conducts a specification search of equation (5) and returns the chosen specification. If the chosen model 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 *Autometrics* includes non-zero values for any of the elements of β_3, then the hypothesis of linearity is rejected. 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

[5] We are grateful to David Hendry who suggested this approach to us—see also Castle and Hendry (2010).

elements in β_0 and β_3 in the specification chosen by *Autometrics* in Step 1. The LSTAR model to be estimated is then

$$\Delta U_t = \delta_0' X_{0,t} + \delta_3' X_{3,t} G_t (\gamma, c, S_t) + \varepsilon_t, \quad (6)$$

where the function $G_t(\cdot)$ and the transition variable S_t are given in equations (2) and (3) respectively.

Step 3: Evaluation and encompassing.

Step 2 yields estimates of the parameters $\widehat{\gamma}$ and $\widehat{c}$ which may then be used to create an observed transition function, $\widehat{G}_t(\widehat{\gamma}, \widehat{c}, S_t)$. Augmenting the general linearized model (5) to include this function yields the linear equation

$$\Delta U_t = \theta_0' X_t + \theta_3' X_t S_t^3 + \kappa_3' X_{3,t} \widehat{G}_t (\widehat{\gamma}, \widehat{c}, S_t) + \eta_t \quad (7)$$

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 *Autometrics* evaluate (7), and see if the outcome is the estimated LSTAR from (6). If so, the test statistic is the F-test of omitted variables in the final specification.

5 Empirical Results

The results obtained in each of the steps of the enhanced modelling cycle described in the previous section are now discussed in turn.

5.1 Step1: Specification

The specification of the general linear model chosen by *Autometrics* is reported in Table 2. These results suggest that, although there are strong and significant linear effects from both output growth ($\mathbb{D}_4 Y_t = -0.15$) and labour productivity growth ($\mathbb{D} PR_t = 0.08$), the model rejects the hypothesis of linearity through the joint significance of the many interaction terms. The presence of the cubic terms is rejection of a null hypothesis of linearity with a LSTR specification as the alternative, see Teräsvirta (1994). It is interesting to note the coefficients of mean reversion, respectively $U_{t-1} = -0.07$ and $S_t^3 \cdot U_{t-1} = -0.08$. When changes in unemployment are below the threshold required to trigger the transition function, the Australian unemployment rate exhibits strong hysteresis. This would be consistent with the long slow decline in the unemployment rate observed at various times the data. When unemployment changes are big, the adjustment speed towards the higher equilibrium level more than doubles to $U_{t-1} + S_t^3 \cdot U_{t-1} = -(0.07 + 0.08)$. In addition, the replacement ratio enters in interaction with the transition variable which may be due to this variable having stronger effect in periods of high unemployment.

5.2 Step 2: Estimation

Based upon the results of the specification stage, a corresponding LSTR model is estimated using non-linear least squares and the results are reported in Table 3. The results are quite impressive. The resulting LSTR model provide evidence that the automated search procedure on the lineearized model seems to provide a test with good power against linearity. Comparing the linear and the non-linear specifications, the similarities in the estimates as well as their significance are striking. The *Autometrics* procedure seems to have indicated very precisely the form of the LSTR specification, both in terms of which variables entering linearly and non-linearly as well as the form of their lag-polynomials. Finally, it can be seen that the LSTR model provides a good explanation of the data when compared against the simple univariate specification (Table 1) with both the standard error of the regression and the relevant information criteria (AIC and SC) substantially reduced.

The size of the steepness parameter ($\gamma = 19.02$) indicates a rapid change in the transition between periods of low and high unemployment. This suggests that a potential simplification of the LSTR model can be achieved by estimating a switching regression model, originally developed by Quandt (1958)

$$\Delta U_t = \sum_{i=1}^{q} \rho_{1i} X_{it} + \sum_{i=1}^{q} \rho_{2i} X_{it} I_t + \varepsilon_t \, , \tag{8}$$

where I_t is the Heaviside indicator function

$$I_t = \begin{cases} 1 & \text{if} \quad S_t > c \\ 0 & \text{if} \quad S_t < c \end{cases} . \tag{9}$$

In addition, the model can be further simplified by testing several interesting restrictions that have clear interpretations. For example, the coefficient estimates on $\mathbb{D}_4 Y_{t-2}$, $\mathbb{D}_4 Y_{t-3}$, R_{t-2}, and R_{t-3} suggest restrictions that would allow these terms to appear in the form $\Delta_2 \left(\mathbb{D}_4 Y - R\right)_{t-2}$. The interpretation of this restricted form is that unemployment decreases with positive changes in aggregate growth above the steady state.

Table 2: The baseline linearized model of the unemployment rate for the period 1979:4 to 2010:2 with S_t given by equation (3). The individual coefficient significance level is 10 percent.

Coefficients	Estimates	Std. Errors	t-values
$Const.$	0.56	0.090	6.26
U_{t-1}	-0.07	0.014	-4.88
ΔU_{t-2}	0.25	0.106	2.35
$\mathbb{D}_4 Y_t$	-0.15	0.015	-9.79
$\mathbb{D}_4 Y_{t-2}$	0.05	0.015	3.37
$\mathbb{D}_4 Y_{t-4}$	-0.03	0.011	-2.34
R	0.06	0.02	4.58
R_{t-2}	-0.05	0.014	-3.25
R_{t-4}	0.04	0.012	3.83
$\mathbb{D}PR_t$	0.08	0.014	5.42
$\mathbb{D}PR_{t-1}$	0.09	0.015	5.69
$\mathbb{D}PR_{t-2}$	0.04	0.012	3.04
$\mathbb{D}RXR_{t-1}$	-0.01	0.004	-2.95
S_t^3	1.13	0.352	3.20
$S_t^3 \cdot U_{t-1}$	-0.08	0.045	-1.77
$S_t^3 \cdot \Delta U_{t-2}$	-1.54	0.220	-6.98
$S_t^3 \cdot \Delta U_{t-3}$	1.03	0.180	5.75
$S_t^3 \cdot \mathbb{D}_4 Y_t$	-0.21	0.04	-4.77
$S_t^3 \cdot R_{t-2}$	0.38	0.063	6.03
$S_t^3 \cdot R_{t-3}$	-0.42	0.071	-5.98
$S_t^3 \cdot \mathbb{D}PR_{t-3}$	-0.26	0.063	-4.12
$S_t^3 \cdot \mathbb{D}RPR_t$	0.22	0.034	6.38

Diagnostics:

RSS	2.24	$\hat{\sigma}$	0.15
AIC	-3.66	SC	-3.16
$F_{AR(1-5)}$ (5,97)	0.35 [0.60]	$F_{RESET}(2, 100)$	3.66 [0.03]
$\chi^2_{normality}$ (2)	0.30 [0.86]	F_{het} (42,81)	0.88 [0.67]

Table 3: The LSTAR model of the unemployment rate with S_t from equation (3) as the transition variable for the period 1979:4 to 2010:2.

Coefficients	Estimates	Std. Errors	t-values
Linear parameters:			
μ_1	0.54	0.081	6.04
U_{t-1}	-0.06	0.014	-4.63
ΔU_{t-2}	0.17	0.091	1.84
$\mathbb{D}_4 Y_t$	-0.14	0.016	-8.63
$\mathbb{D}_4 Y_{t-2}$	0.04	0.015	2.87
$\mathbb{D}_4 Y_{t-4}$	-0.03	0.011	-2.70
R	0.06	0.012	5.20
R_{t-2}	-0.06	0.014	-3.92
R_{t-4}	0.05	0.012	4.30
$\mathbb{D}PR_t$	0.07	0.014	4.76
$\mathbb{D}PR_{t-1}$	0.07	0.015	4.74
$\mathbb{D}PR_{t-2}$	0.02	0.013	1.85
$\mathbb{D}RXR_{t-1}$	-0.01	0.004	-3.18
Transition parameters:			
γ	19.02	22.660	0.84
c	0.71	0.081	8.81
Non-linear parameters:			
μ_2	1.45	0.614	2.36
U_{t-1}	-0.20	0.114	-1.74
ΔU_{t-2}	-0.98	0.230	-4.25
ΔU_{t-3}	0.97	0.354	2.74
$\mathbb{D}_4 Y_t$	-0.26	0.126	-2.08
R_{t-2}	0.29	0.077	3.71
R_{t-3}	-0.27	0.091	-3.01
$\mathbb{D}PR_{t-3}$	-0.17	0.100	-1.72
$\mathbb{D}RPR_t$	0.08	0.040	2.13

Diagnostics:			
RSS	2.13	$\hat{\sigma}$	0.15
AIC	-3.67	SC	-3.18
$F_{AR(1-5)}$ (5,94)	0.49 [0.79]	$F_{RESET}(2,97)$	2.76 [0.07]

Table 4: The estimated threshold model of the unemployment rate with S_t defined in equation (3) as the transition variable for the period 1979:4 to 2010:2. The individual coefficient significance level is 5 percent.

Coefficients	Estimates	Std. Errors	t-values
$Const.$	0.63	0.071	8.86
U_{t-1}	-0.07	0.012	-5.71
$\mathbb{D}_4 Y_t$	-0.15	0.013	-11.7
R	0.06	0.009	6.08
$\Delta_2 (\mathbb{D}_4 Y - R)_{t-2}$	0.04	0.009	4.55
$\mathbb{D}PR_t + \mathbb{D}PR_{t-1}$	0.08	0.010	7.58
$\mathbb{D}PR_{t-2}$	0.03	0.011	2.94
$\mathbb{D}RXR_{t-1}$	-0.01	0.003	-3.85
I	1.24	0.298	4.15
$I \cdot U_{t-1}$	-0.16	0.037	-4.41
$I \cdot \Delta^2 U_{t-2}$	-0.76	0.143	-5.28
$I \cdot \mathbb{D}_4 Y_t$	-0.25	0.059	-4.22
$I \cdot \Delta R_{t-2}$	0.19	0.052	3.62
$I \cdot \mathbb{D}RPR_t$	0.05	0.018	2.76

Diagnostics:			
RSS	2.38	$\hat{\sigma}$	0.15
AIC	-3.72	SC	-3.40
$F_{AR(1-5)}$ (5,104)	0.43 [0.83]	$F_{RESET}(2, 107)$	3.44 [0.04]
$\chi^2_{normality}$ (2)	0.30 [0.86]	F_{het} (25,97)	0.98 [0.50]

5.3 Step 3: Evaluation and encompassing

The chosen model to be examined in terms of the evaluation and encompassing phase of the modelling cycle is, therefore, the restricted specification of Table 3 simplified to be a threshold model, with transition variable S_t as defined in equation (3), threshold parameter $\hat{c} = 0.71$ and augmented with all the terms of the general linear model (5). This general model is then tested down using *Autometrics*.

The final preferred model is documented in Table 4. It is clear from these results that the chosen model encompasses the general linearized model. *Autometrics* chooses the simplified threshold model as the final specification, and the F-test of restrictions on the augmented generalized linear model has a p-value of $\mathsf{F}_{p\mathsf{GUM}} = 0.89$.

The results suggest that when unemployment is low and changes in unemployment are small, the Australian unemployment rate is predominantly a function of short-run shocks: the growth rate in aggregate demand $\mathbb{D}_4 Y_t = -0.15$, and the real interest rate $R_t = 0.06$; medium term effects: weighted average growth in productivity $(\mathbb{D}PR_t + \mathbb{D}PR_{t-1} + 0.5\mathbb{D}pr_{t-2})$ and competitiveness $\mathbb{D}RXR_{t-1} = -0.01$; long-run effects: $\Delta_2 \left(\mathbb{D}_4 Y - R\right)_{t-2} = 0.04$.[6] Furthermore, the adjustment towards equilibrium unemployment is very slow $U_{t-1} = -0.07$ and depends strongly upon the earlier history $\Delta^2 U_{t-2} \equiv \Delta\Delta U_{t-2} = -0.76$.

If unemployment increases by more than .7 percentage points over 6 months, exceeding the threshold level, the dynamics are much more complex, with a quicker mean reversion towards the upper level of unemployment $U_{t-1} + I_t \cdot U_{t-1} = -0.23$. The main driver of continued high growth rates of unemployment is negative demand growth, $\mathbb{D}_4 Y_t + I_t \cdot \mathbb{D}_4 Y_t = -0.4$, while lowering real interest rates will facilitate bringing unemployment down. Another rather interesting result is the influence of the replacement ratio. Any move to increase the replacement ratio is likely to be counterproductive, although the effect is a small one $I \cdot \mathbb{D}RPR_t = 0.05$ compared to the influence of negative growth in aggregate demand.

Figure 3: The unemployment rate and the transition function.

[6]The estimated parameters of the contemporaneous terms were checked for simultaneity bias by estimating the specification with Instrumental Variables, using lagged variables as instruments. Since only marginal changes in the estimates were found, the results are not reported.

The model is consistent with the following plausible economic scenario. Suppose there is a large shock to unemployment caused by negative demand, as experienced during the three recessions covered by the current sample. This would cause the growth rate of unemployment to rise above the threshold level. During this period of rapid increase, the effects of aggregate demand are naturally stronger than in more normal times—the reaction is non-linear—and the mean reversion towards a new higher level is faster. This potential scenario is supported by Figure 3 which compares the estimated transition function from the model with the unemployment rate. The rapid increases in the unemployment rate, which occurred in Australia during the recessions of 1982/1983, 1990/1991 and 2008/2009 are associated with a switch in the transition function to the second regime where the main source of high unemployment growth is negative growth in aggregate demand. During this transition period, the development in unemployment is also sensitive to movements in the real interest rate and in the replacement ratio. In 'normal' times, the derived linear model is consistent with the predictions of a variety of economic theory models, predicting that movements in unemployment are caused by low output growth, increases in real interest rates, changes in productivity, and in competitiveness.

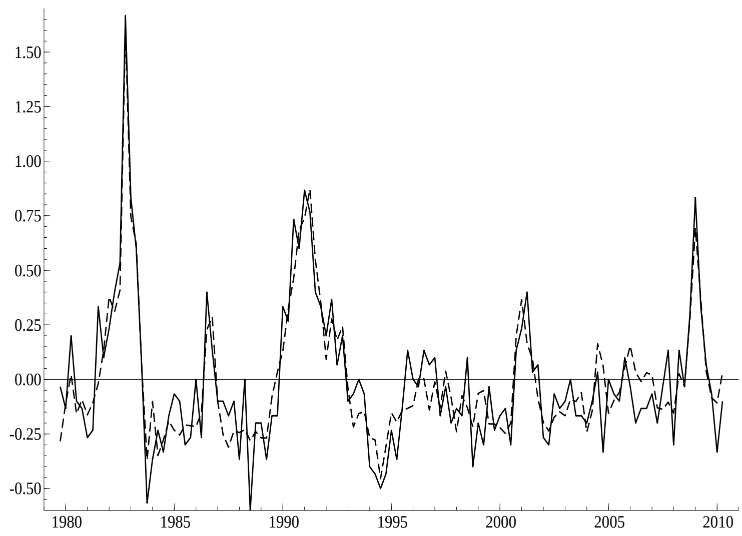

Figure 4: Actual and fitted values from the preferred threshold model using coefficient estimates reported in Table 4.

Given its simplicity and parsimony, the switching model does a surprisingly good job of describing the unemployment process (Figure 4) which plots fitted values of the model against the actual unemployment rate. Clearly, the non-linear model does a good job of explaining the sharp pick-up in unemployment in Australia observed in the early 1980s, 1990s, and during the recent financial crisis.

6 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. Consequently, this paper is concerned with building a non-linear model of the unemployment rate for Australia.

One of the interesting conclusions to emerge from this line of research is that automatic model selection has a potentially valuable role to play in non-linear econometric modelling. A cycle of specification, estimation, evaluation and encompassing is implemented to aide in the search for an effective model of the Australian unemployment rate. The final empirical model is both simple and parsimonious and is able to capture the dynamics of the Australian unemployment rate. The non-linear specification chosen represents an improvement in explanatory power by comparison with a baseline linear model.

From an economic perspective and in contrast to earlier, purely time-series-based models, it is found that several macroeconomic variables are important determinants of the unemployment rate in Australia. It is shown that changes in unemployment are predominantly a result of low output growth, increases in real interest rates, changes in productivity, and in competitiveness. Further, if changes in unemployment are big, the management of of demand, real interest rates and the replacement ratio will be good instruments to start reducing unemployment.

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A Data description and sources

- **Unemployment:** U
  Definition: Number of unemployed people as a proportion of the civilian labour force (%). Seasonally adjusted.
  Source: Reserve Bank of Australia, g07hist.xls.
- **Real output:** Y
  Definition: Real GDP, chain volume measure. Seasonally adjusted.
  Source: Reserve Bank of Australia, g10hist.xls.
- **Replacement ratio**: RPR
  Definition: The ratio of nominal unemployment benefits per week (single over 21, no children) to average weekly earnings of all employees. Seasonally adjusted.
  Source: Department of Social Security and the Reserve Bank of Australia, g06hist.xls.
- **Real interest rate**: R
  Definition: 10 years government bonds less annual inflation in consumer price index.
  Source: Reserve Bank of Australia, f02hist.xls and g02hist.xls.
- **Productivity**: PR
  Definition: GDP per hour worked, index. Seasonally adjusted. Series ID: A2304192L
  Source: Australian Bureau of Statistics, 5206001_key_aggregates-1.xlsx.
- **Real exchange rate:** RXR
  Definition: Real trade-weighted index.
  Source: Reserve Bank of Australia, f15hist.xls