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Forecasting Australian Unemployment Rates

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Abstract
Cyclical asymmetry has been recognized as a non-linear phenomenon in recent studies examining unemployment rate time series. The probabilistic structure of such time series is different during economic upswings as compared with economic downswings. So, with forecasting unemployment rates in mind, it seems intuitive that models should reflect this change in structure by incorporating non-linearities. This allows for the switching in optimizing behaviour between different phases of the business cycle. Accordingly, this paper evaluates the point forecasts from models of the monthly, Australian unemployment rate series, these models being drawn from both the linear and non-linear classes. The non-linear model is based on a standard logistic smooth transition autoregressive (LSTAR) model of unemployment which includes a lagged level term and a seasonal, rather than first-difference transition variable. Forecasts from this model are evaluated against the best-fitting linear autoregressive (AR) alternative. Dynamic point forecasts over twenty four months, suggest that the LSTAR forecasts are more accurate than the linear AR alternative. However, there is no statistical difference between the forecasts from both models on a one-to-twelve step-ahead basis.

1. Introduction
The issue of asymmetry in the business cycle can be traced back more than seventy years (Mitchell, 1927; Keynes, 1936; Hicks, 1950). Qualitative and structural differences in the behaviour of the economy at different stages in the business cycle tend to produce an asymmetrical pattern. This asymmetry is evident in the sharp and regular short-lived contractions during economic downturns, and in gradual expansions during recoveries. In respect to counter-cyclical series such as the unemployment rate, asymmetry implies that the probabilistic structure of such time series is different with increased unemployment during economic downturns and a gradual reduction in the unemployment rate during economic upswings.

Visual inspection of the graph of the Australian unemployment rate suggests asymmetry in the series (for example, see figure 1, p. 43). Not only does the unemployment rate rise quickly to its peak and then descend to close to its original level in a slow and protracted fashion, but the duration between trough to peak is much shorter than between peak to trough.

There have been a number of economic theories advanced to explain this phenomenon.

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Asymmetric adjustment costs of labour have been credited with an important role in generating asymmetries. These costs include the Blanchard and Summers (1987) and the Lindbeck and Snower (1988) insider-outsider mechanisms for wage settings. Blanchard and Summers (1987) assume the insiders (employed persons) ability to ignore the outsiders (unemployed) in wage setting. They focus on the implications of insider power and how this, when combined with rules for defining insider status, alters the size of the insider group in the presence of shocks. Labour turnover costs, or the difference between hiring and firing costs (see Burgess 1988, Burgess and Donaldo 1989, and Pfann and Palm 1993) have been advanced as another cause. Lindbeck and Snower (1988) examine the sources of insider power and conclude that such power results from a range of turnover costs which make it costly for employers to replace insiders with outsiders. The outsider ineffectiveness hypothesis (see Layard et al, 1991) assumes that insiders are insulated from wage setting in the external labour market. The reason being that a portion of the outsiders are long term unemployed and, as such, are not viable as substitutes for insiders or the short term unemployed. Search-theoretic models (Pissarides, 1992) suggest the presence of asymmetries as a result of loss of skills and a reduction in job search effectiveness due to long-term unemployment. Empirical evidence suggests that job losses occur at a higher rate during a recession than during an economic recovery. This loss is not compensated by an asymmetry in job creation. The result is an asymmetrical pattern in employment.

Univariate linear time series models with symmetrically distributed random shocks cannot generate output with asymmetric fluctuations. Modelling asymmetry requires univariate non-linear time series models. Non-linear or piecewise-linear models are capable of producing complex outcomes like limit-cycles, jumps and discontinuities. These outcomes are all typical of the economic behaviour underlying unemployment. As a consequence, asymmetry in the business cycle has been recognised as a non-linear phenomenon by recent studies using postwar unemployment rate series.[1]

The concept of hysteresis (or full persistence) in the unemployment rate attempts to explain its tendency to remain at an equilibrium level before an equally likely movement in either direction. Blanchard and Summers (1987) reinforced this explanation when they used an 'insider' model to demonstrate that employment followed a random walk with error. However, as pointed out in Skalin and Teräsvirta (1999), this view of the dynamics of unemployment rates contradicts the notion of asymmetry as measured by sharp increases followed by slow decreases. If the underlying generating process is linear, then the existence of a unit root may explain the hysteresis view of market oscillations. It follows that the test of a unit root is tantamount to a test of the presence of hysteresis in the data under the assumption that the underlying data process is linear.

With the exception of some U.S. studies, most analyses of unemployment rates have found evidence of a unit root and conclude that hysteresis is present in the data. As a consequence, these studies use the first-difference rather the level of the unemployment rate in order to induce stationarity. However, if the underlying data generating process is non-linear, then

1. Evidence of univariate non-linear behaviour was found by Luukkonen and Teräsvirta (1991), as well as by Teräsvirta and Anderson (1992), after testing thirteen OECD unemployment rate series for linearity against non-linear alternatives. Using U.S. monthly aggregate and sectoral unemployment rates, Ham and Sayers (1990) and Rothman (1998) also found strong evidence of non-linearity of the threshold-type, while Rothman (1991) was the first to identify asymmetric evidence within a Markov chain context. Skalin and Teräsvirta (1999) focus on the asymmetry observed in a number of OECD unemployment rate series. They found that, for those series for which non-linearities were found by testing, univariate non-linear models of the threshold-type provided the better fit. A study by Peat and Stevenson (1996) provided empirical evidence of business cycle asymmetry using aggregate seasonally-adjusted data drawn from the Australian labour market.

the presence of a unit root may not contradict the visual reality that most unemployment rate series exhibit asymmetrical behaviour. Using a simulation study, Skalin and Teräsvirta (1999) demonstrated that this was indeed the case when a particular non-linear model was used as the underlying data generating process capable of generating asymmetrical patterns.[2] Further, with the unemployment rate bounded, they assumed stationarity in the first instance, and tested for linearity against the logistic smooth transition (LSTAR) alternative that incorporated asymmetry. When the series was modelled, levels and not first-differences were used.

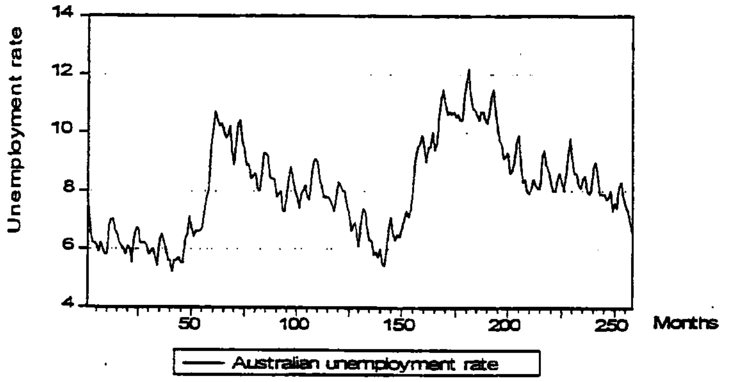
We adopt the same approach in this paper. After testing for asymmetry and (LSTAR) non-linearity, we estimate and evaluate forecasts of the Australian unemployment rate series from both the univariate linear and non-linear (LSTAR) time series models. We assume that the unemployment rate series is stationary and estimate and forecast from a model of the level of the unemployment rate. We use seasonally unadjusted Australian aggregate unemployment rate data and deal with seasonality in the data at the modelling stage.

In the following section we discuss the Australian unemployment rate analysed in this study. In Section 3 we outline the procedure we use to test for, and to model asymmetric patterns in the data. Section 4 contains test results for asymmetry in the data and the estimation of models. Out-of-sample forecasting and forecast evaluation is carried out in Section 5. Section 6 contains concluding remarks.

2. Data

The data used in this study are drawn from the aggregate monthly Australian unemployment rate series as supplied by the Australian Bureau of Statistics (ABS). This series is compiled from the Labour Force Survey and span the period from February, 1978 until July, 1999.[3] As forecasting the Australian unemployment rate series is a prime motivation of this study, we held out two years of observations to use in the forecast evaluation stage. This resulted in 234 observations being used in the estimation of time series models.

Figure 1 The Australian Unemployment Rate, February 1978 to July 1998.



2. They chose a model from the non-linear autoregressive class known as the logistic smooth transition autoregressive (LSTAR) model.
3. We chose to use the monthly aggregate unemployment rate series following our Chow breakpoint test results on the quarterly aggregate unemployment rate data (available on request). These results indicate the existence of a possible structural break in the quarterly series at the beginning of 1978. The structural break identified coincides with the introduction of survey-based monthly unemployment statistics by the ABS.

Visual inspection of this data series reveals it is obviously asymmetrical in nature. Clearly, it is also a bounded series. As previously discussed, we assumed stationarity of the data and then tested for the suitability of a linear model. Depending on the presence of a unit root in the data, and whether the linear model is the accepted model, the data may need to be differenced before estimation of a model and forecasting can take place. If a non-linear model that incorporates asymmetry is the appropriate model, then Skalin and Teräsvirta (1999) have demonstrated that non-linearity and asymmetry are not contradictory and that modelling the unemployment level is justified.

3. Tests for Asymmetry and Non-linearity of the Australian Unemployment Rate Series

The testing procedure used to study possible asymmetry of the Australian unemployment rate series comprises a specific test for the presence of asymmetry based on skewness statistics, as well as a time series test for testing linearity against a pre-specified type of non-linear autoregressive model. For the time series test, the null hypothesis that aggregate unemployment data was generated by a univariate linear process, was tested against the alternative of a well-known univariate non-linear process, the logistic smooth transition autoregressive (LSTAR) model. Skalin and Teräsvirta (1999) found this model was useful in capturing asymmetry when it was present in a range of quarterly unemployment rate series from OECD countries. They also showed how the model was easy to interpret and how it fitted the data much better than a linear autoregressive model.

A Specific Test of Asymmetry based on Skewness Statistics

DeLong and Summers (1986) tested for asymmetry of a time-series by testing the null hypothesis of zero skewness. If m_2 and m_3 are the second and third centred moments of a stationary time series, then the test statistic is given by

$$SK = \frac{m_3}{\sqrt{m_2^3}}$$

Under the null hypothesis, the estimate of the skewness coefficient, $\hat{SK}$, is normally distributed.

We followed the Monte Carlo approach of DeLong and Summers (1986). Firstly, we fitted an AR model to our data to filter out serial correlation. We then calculated the $\hat{SK}$ coefficient from the fitted values. The variance of the SK coefficient was found by simulation whereby $\hat{\sigma}_{SK}$ was calculated from 300 simulated series using the fitted AR model. The z-score of $\hat{SK}$ was calculated in the usual way with $z = \dfrac{\hat{SK} - 0}{\hat{\sigma}_{SK} / \sqrt{n}}$.

A Time Series Test for Non-linearity

Following Luukkonen and Teräsvirta (1991), assume that a white noise innovation process, $\{e_t\}$, and a time series, $\{Y_t\}$, are observed at $t = 0,1,2,\ldots$. Suppose the following relationship between the innovation series and the time series and its lags at time, t, is given by:

$$h(Y_t, Y_{t-1}, Y_{t-2}, \ldots) = e_t \ , \tag{1}$$

where h is a given function, either linear or non-linear. If the process is stationary and ergodic, then the relation given in (1) may be approximated by a univariate linear autoregressive model with coefficients, h_j,

$$\sum_{j=0}^{p} h_j Y_{t-j} = e_t, \quad p < \infty \ , \tag{2}$$

as long as the roots of $\sum_{j=0}^{p} h_j Z^j = 0$ lie outside the unit circle.

As Mittnik and Niu (1993) point out, if the linear model given by (2) is to be retained and asymmetric cycles are to be accounted for, then a non-symmetric error distribution is necessary. If we want the error distribution to be symmetric (possibly normal), and our model to generate asymmetric cycles, then (2) is no longer appropriate. They categorized the sources of asymmetric behaviour by viewing the variable as output from a stochastic dynamic system as depicted in figure 2.

Figure 2 Components of a Stochastic Dynamic System

Noise/Shocks → [Economic System/ Transmission Mechanism] → Observed Variables

$e_t \quad + \quad g(e_{t-1}, e_{t-2}, \ldots.) \quad = \quad Y_t$

The system is represented by

$$Y_t = g(e_{t-1}, e_{t-2}, \ldots) + e_t, \tag{3}$$

where Y_t denotes the variable of interest, e_t is an innovation or noise-input sequence and the function, g, represents the economic system or transmission mechanism. Asymmetry of the output, Y_t, can be viewed as being caused by different combinations of the transmission mechanism, g, and input noise, e_t. The four categories that explain the symmetrical nature of the observed variables from the above dynamic system are summarized in table 1 below.

Table 1 Explanations for Asymmetry of Time Series Output

Category	*Noise Input*	*Transmission Mechanism*	*Output*
1	Symmetric	Linear	Symmetric
2	Asymmetric	Linear	Asymmetric
3	Symmetric	Nonlinear	Asymmetric
4	Asymmetric	Nonlinear	Asymmetric

Asymmetries in time series output can result from either a linear or non-linear transmission mechanism with either symmetrical or asymmetrical innovations. Our testing procedure involves determining the superiority of a non-linear LSTAR model as opposed to a linear alternative.

In order to facilitate discussion of the LSTAR model and the testing procedure followed in this paper, the usual specification of the linear autoregressive model is parameterised using first differences.[4] This parameterisation, in contrast with equation 2, is given by equation 4 below. It is this parameterisation that is used throughout the remainder of this paper.

$$\Delta Y_t = \mu_1 + \alpha_1 Y_{t-1} + \sum_{j=1}^{p} \beta_{1j} \Delta Y_{t-j} + \sum_{i=1}^{s-1} \Pi_{1i} D_{it} + e_t \tag{4}$$

where Y_t is the unemployment rate in percent, D_{it} denotes seasonal dummies, i=1,2, ..., s=12 for monthly data, and $e_t \sim NID(0,\sigma_e^2)$.

The LSTAR model is defined by equation 5 below, with the transition function, $G(\Delta_s Y_{t-d};\gamma,c)$, incorporating asymmetry into the model by providing the mechanism that allows for the smooth transmission from one equilibrium to the next. Importantly, the variable in the transition function, $\Delta_s Y_{t-d}$, is a lagged seasonal difference while the unemployment rate process, Y_t, is expressed in levels and remains bounded in probability.

$$\begin{aligned}\Delta Y_t &= \mu_1 + \alpha_1 Y_{t-1} + \sum_{j=1}^{p} \beta_{1j} \Delta Y_{t-j} + \sum_{i=1}^{s-1} \Pi_{1i} D_{it} + \\ &\cdots + \left[\mu_2 + \alpha_2 Y_{t-1} + \sum_{j=1}^{p} \beta_{2j} \Delta Y_{y-j} + \sum_{i=1}^{s-1} \Pi_{2i} D_{it}\right] G(\Delta_s Y_{t-d};\gamma,c) + e_t\end{aligned} \tag{5}$$

For the LSTAR model, the transition function is defined by:

$$G(\Delta_s Y_{t-d};\gamma,c) = \left[1 + \exp\{-\gamma(\Delta_s Y_{t-d} - c)/\sigma(\Delta_s Y_t\}\right]^{-1} \tag{6}$$

Patterns of asymmetry in the data are captured by the way the LSTAR model reflects rapid growth to the upper regime before a slow decline in the series toward its lower regime. If the change in the unemployment rate is close to zero, then the resulting small value of the G(•) function ensures the subsequent change in the unemployment rate will also be small. A large positive shock increases the value of ΔY_{t-1} and the value of G(•) through the large value of γ. Growth continues as G(•) approaches its upper value of one, until a negative shock slows the process. Further negative shocks tend to hold the unemployment rate in the upper regime before gradually returning it to the lower regime.

The time series test of linearity used in this study was the Lagrange Multipler (LM) test as described in Granger and Teräsvirta (1993). This test is constructed by expanding the transition function given by (6) as a Taylor's series. After merging terms and reparameterising, the resultant auxiliary regression equation forms the basis of the test [5]. What is clear from equations (4) and (5) is that the LSTAR model has a univariate linear

4. It is important to note that we are not taking first-differences of a model of the level of unemployment, but rather incorporating first-differences into the model of levels through parameterisation.

autoregressive model nested model within it. The LM test used in this study is a nested test in which the null hypothesis of a univariate linear model is obtained as a special case of the non-linear alternative. Given our focus on developing a forecasting model, along with the success experienced by Skalin and Teräsvirta (1999) in fitting the LSTAR model to asymmetrical unemployment data, we adopted the Granger and Teräsvirta (1993) LM test. We favoured it from among the many available nested and non-nested tests, because of its optimality in terms of power against the alternative of LSTAR non-linearity.

Conclusions from our non-linear time series test provide the first stage in determining from which of the above categories in table 1, the most suitable model is likely to come. The second stage is an evaluation stage comprising of tests of the residuals from the fitted models. They provide evidence of the symmetrical nature of the noise and, therefore, a clue to the appropriate functional form of the underlying stochastic dynamic system.

4. Testing for Asymmetry, Linearity and Model Estimation

The test results reported in this section enable us to first determine whether the Australian unemployment rate series studied (the output in table 1) is asymmetric or not. Next, we determine whether the transmission mechanism is linear or non-linear, and if the residuals from the preferred model are symmetric. On the basis of these results, we conclude which category of table 1 best describes the input and model of the stochastic dynamic system that generates the Australian unemployment rate series as output.

Test Based on Skewness Statistics

Table 2 contains the results of the DeLong and Summers (1986) test for asymmetry. For the Australian unemployment rate series, we note that $\hat{SK}$, the estimate of SK, is significantly different to zero at the 1% level of significance. We conclude that this series exhibited an asymmetrical data pattern.

Tests Based on Time Series Techniques

In order to provide a benchmark for comparing the non-linear model, a linear autoregressive model of order p was fitted to the level of the Australian unemployment rate series. The maximum order of the autoregressive process, p, draws on the information criterion proposed by Akaike (1974) for the identification of parsimonious models. The order of the chosen linear AR(p) model for this series is given below in table 3.

As a test for the existence of white noise residuals in the AR(p) process, we included the value of the Ljung-Box Q statistic for the residuals from the linear model. It is a test statistic for white noise when compared with the chi-squared distribution. From the Ljung-Box Q statistic (L-B) in table 3, we concluded that white noise in the residuals cannot be rejected at either the 5% or 1% level of significance. The autocorrelation and partial autocorrelation functions of the residuals from the linear autoregressive model were also characterised by a lack of obvious remaining serial correlation.

Our test for ARCH effects was confined to the Engle (1982) Lagrange Multiplier (LM) test of the residuals from the linear model. According to the probability value for this statistic in table 3, the residuals appear clean of ARCH effects. An absence of autocorrelation,

5. See equation (6.2.14) of Granger and Teräsvirta (1993).

Table 2 Results of the Asymmetry Test Bases on the Skewness Statistic for the Australian Unemployment Rate Series

	$\hat{SK}$	SE(SK)	z
Unemployment Rate	0.253	0.0175	14.446 **

* = Significance at the 0.05 level
** = Significance at the 0.01 level

Table 3 Summary Statistics for the Liner AR(p) Model of the Australian Unemployment Rate Series

	n	*p*	*AIC*	*L-B(DF)*	*J-B (p-value)*	*ARCH-LM (p-value)*
Unemployment Rate	234	7	0.048	11.08(24)	3.46(0.177)	23.32(0.501)

Key: n = Number of Observations
p = Autoregressive Order: AR(p)
AIC = Minimum AIC
L-B = Ljung-Box Q Statistic for Residuals
$\begin{cases} \sim \chi^2(24 \;\; ; \;\; 0.05) = 36.415 \\ \sim \chi^2(24 \;\; ; \;\; 0.01) = 42.980 \end{cases}$
J-B = Jacque-Bera Statistic for Testing Normality
ARCH-LM = Lagrange Multiplier (LM) Test for Autoregressive Conditional Heteroscedasticity (ARCH) Effects in Residuals

along with normality of the residuals, implies independence. The Jacque-Bera (J-B) Test is a test of the normal distribution of a data series and is based on the Gaussian assumption of independence of the sample mean and variance. The distribution of this statistic is asymptotically standard normal under the null hypothesis that the residuals from the AR(p) model are Gaussian. From table 3, the residual series from the aggregate linear autoregressive model are Gaussian white noise according to the L-B and J-B tests and, as such, conform to independent, identically distributed (i.i.d.) behaviour.

We need to consider how the nature of the distribution of the residuals from the linear model, along with a linear transmission mechanism, fit with the results of the DeLong and Summers (1986) test for asymmetry of data and our classification system in table 1. Recall that the aggregate unemployment rate series tested significant to asymmetrical output, with the residuals from the linear model (the noise input in table 1) symmetric. There is no admissible category in table 1 that allows for a linear transmission mechanism with symmetric noise input and which generates asymmetric output. It follows that we need to explore the possibility that a non-linear transmission mechanism may explain the asymmetry of the data via category 3 of table 1.

To determine whether a non-linear transmission mechanism was more appropriate for models of the unemployment rate, we relied on the LM test detailed in the previous section. Table 4 contains the results of this time series test with significance being a p-value less than 0.05. The lag structure that is detailed in table 4, refers to the number of autoregressive lags in the linear and non-linear components of the Granger and Teräsvirta (1993) LM test statistic. For the cases where linearity was rejected for more than one number of autoregressive lags, we chose the number of lags that was associated with the minimum Akaike Information Criterion (AIC) value for the overall model. LSTAR non-linearity was suggested by the LM test for the Australian unemployment rate series.

Table 4 Summary of Nonlinear Test Results

Lag	*LM (p-values)*
1	0.168
2	0.038
3	0.001
4	0.000
5	0.000
6	0.000
7	0.000
8	0.000
9	0.000
10	0.000
11	0.000
12	0.002

Table 5 contains the summary statistics for the best-fitting LSTAR model. In fitting the LSTAR model, different lag lengths, d, were used in the seasonal difference term that is part of the transition function given by equation (6). Once the number of autoregressive lags was established, we chose a seasonal difference term with a lag length of one month for our best fitting non-linear model, again based on minimising the Akaike Information Criterion (AIC).

For the Australian unemployment rate, the minimum Akaike Information Criteria (AIC) point to the non-linear LSTAR model as the preferred model when compared to the corresponding linear equivalent. There appears to be little autocorrelation in the residual series as indicated by the Ljung-Box (L-B) statistic and no ARCH effects according to the Arch-LM test. The residuals are also symmetric, with the probability value of the Jacques-Bera (J-B) statistic in table 5 indicating no rejection of the null hypothesis of normality.

Non-linearity of the transmission mechanism along with symmetry of the residuals (as implied by their Gaussian nature) should result in asymmetric output. Recall that this scenario was depicted as category 3 in table 1. The Australian unemployment rate series appears to fit this category. Table 6 is a summary of our general findings.

Table 5 Summary Statistics for the LSTAR Model of the Australian Unemployment Rate Series

	n	*p*	*AIC*	*L-B(DF)*	*J-B (p-value)*	*ARCH-LM (p-value)*
Unemployment Rate	234	7	-0.025	21.11(24)	0.43(0.805)	23.07(0.516)

Key:
- n = Number of Observations
- p = Autoregressive Order: AR(p)
- AIC = Minimum AIC
- L-B = Ljung-Box Q Statistic For Residuals

$$\begin{cases} \sim \chi^2(24 \; ; \; 0.05) = 36.415 \\ \sim \chi^2(24 \; ; \; 0.01) = 42.980 \end{cases}$$

- J-B = Jacque-Bera Statistic For Testing Normality
- ARCH-LM = Lagrange Multiplier (LM) Test For Autoregressive Conditional Heteroscedasticity (ARCH) Effects In Residuals

Table 6 Summary of General Findings

	Asymmetry Tests	*Nonlinear Tests*	*Best-Fitting Model*	*Asymmetry Explanation*
Australian Unemployment Rate	Asymmetric	Nonlinear	Nonlinear	Category 3

5. Out-of-Sample Forecasting and Evaluation

Out-of-sample forecasting performances of univariate non-linear models, relative to linear alternatives, has been considered for U.S. unemployment data by Parker and Rothman (1997), Rothman (1998) and Montgomery, Zarnowitz, Tsay and Tiao (1998).

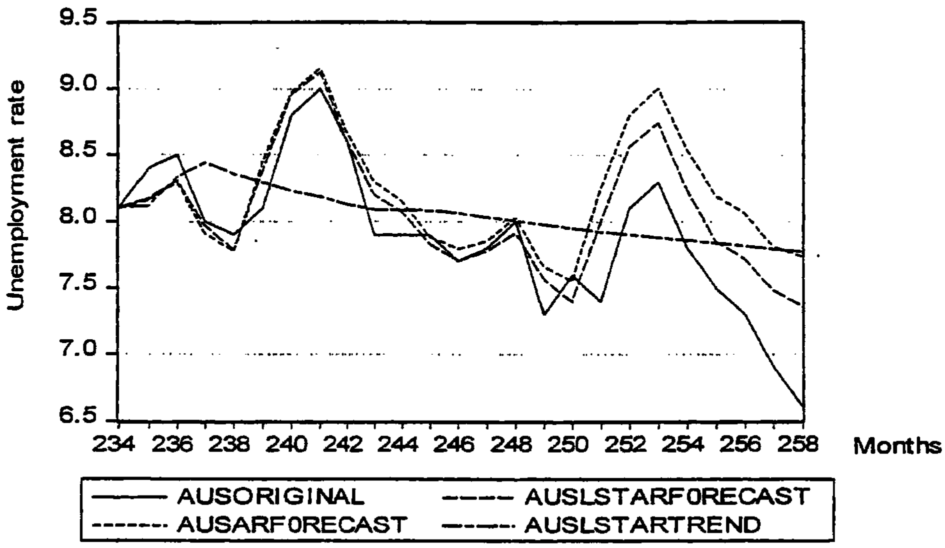
For the Australian unemployment rate series, dynamic and one to twelve step-ahead forecasts were generated from the univariate LSTAR and corresponding linear models, with both models estimated over the period from July, 1978 to July, 1997.[6] In order to evaluate their respective forecasting capabilities, we chose a 'hold-out' period of two years of monthly data extending from August, 1997 until July, 1999.

Figure 3 diagrammatically depicts the dynamic forecasts over the 'hold-out' period from both the non-linear (AUSLSTARFORECAST) and linear (AUSARFORECAST) models of the Australian aggregate unemployment series. Also included in figure 3 is a plot of the original data and an estimate of the trend (AUSLSTARTREND) from the non-linear model.

6. Dynamic forecasts are multi-step forecasts that start from the first period in the forecast sample.

The trend was forecast by removing the seasonal dummies from the LSTAR specification. From a visual inspection of the original data and the dynamic forecasts from both the linear and non-linear models, it is obvious that both sets of forecasts do a good job at tracking the trend and seasonal component of the unemployment rate. Both forecasts seem efficient at picking the turning points in the data, with the LSTAR forecast providing greater accuracy the longer the time horizon. This is to be expected as the LSTAR model is designed to provide a better model of the asymmetry in the data. However, during the forecast period, the Australian unemployment rate has been gradually dropping. Given the evidence reported in earlier sections of this paper as to the asymmetrical nature of this series, what is of interest is how well both models are able to cope with any future sharp increase in the unemployment rate.

Figure 3 Original Australian Unemployment Rate Series Plus ARLSTAR, and LSTAR Trend Forecasts



For a rigorous forecasting comparison, both models were estimated recursively. That is, the k step-ahead forecasts made in period t are based on models estimated using data through to period t. Alternative forecasts are evaluated at the one step-ahead, two step-ahead, through to the twelve step-ahead forecast horizons.

As a first check, the bias of the forecast from each model was computed. Bias was calculated by regressing the forecast error on a constant. The forecast error is the difference between the actual value and the predicted for each out-of-sample observation. The estimated constant term from this regression is the estimated bias. The bias of forecasts from the levels of the Australian unemployment rate series are reported in table 7 below. The p-values for the null hypothesis that the bias equals zero are included in parentheses. Neither the linear nor non-linear forecast series exhibited significant bias, with no consistent over-prediction or under-prediction of the true values.

Table 7 Estimated Bias of Linear and Nonlinear Out-of-Sample Forecasts

Forecast Step	*Australia*	
	Linear	*Nonlinear*
1	-0.037 (0.486)	-0.038 (0.431)
2	-0.043 (0.453)	-0.039 (0.479)
3	-0.043 (0.434)	-0.040 (0.482)
4	-0.455 (0.473)	-0.037 (0.528)
5	-0.051 (0.431)	-0.044 (0.472)
6	-0.036 (0.580)	-0.031 (0.619)
7	-0.051 (0.444)	-0.044 (0.499)
8	-0.057 (0.417)	-0.049 (0.473)
9	-0.066 (0.376)	-0.058 (0.421)
10	-0.049 (0.522)	-0.042 (0.569)
11	-0.063 (0.442)	-0.055 (0.489)
12	-0.089 (0.298)	-0.078 (0.346)

Note: Probability values are included in parentheses

A further evaluation of forecasts from alternative models involves testing whether the difference between the two sets of predictions is statistically different. Such a rigorous comparison of the forecasts from the linear and non-linear models can be determined using the ratio of mean squared prediction errors (MSPE) which is a variation of the Theil's (1966) U-statistic[7]:

$$U = \frac{1/n \sum_{j=1}^{n} e_{1j}^{2}}{1/n \sum_{j=1}^{n} e_{2j}^{2}}$$

7. The MSPE of a forecast, Y_i, is given by MSPEi $= 1/n \sum_{j=1}^{n} e^{2}_{ij}$, where e_{ij} is the jth forecast error from model i.

Mizrach (1991) provides statistical foundations for robust forecast comparisons using the U-statistic. He assumes that the prediction errors from each model are draws from a bivariate normal population, (E1, E2). With U = E1 - E2 and V = E1 + E2, then the robust statistic of Mizrach (1991) is based on the sample noncentral covariance between U and V. Under the assumption that the forecast errors are biased, he derived the variance of this noncentral moment by further assuming the forecast errors to be dependent draws from a bivariate population, only requiring stationarity of moments up to the forth order. He applies the Newey and West (1988) weights to guarantee the variances are positive semi-definite functions. Tests with the robust statistic are run against the two-sided alternative hypothesis that the sample noncentral covariance between U and V is non-zero. The robust statistic is asymptotically distributed standard normal, and is properly sized in both normal and non-normal populations.

MSPE ratios and their p-values for the non-linear and linear forecasts of the Australian unemployment rate series are reported below in table 8.[8]

Table 8 MSPE Ratios for Linear and Non-linear Out-of-Sample Forecasts

Forecast Step-Ahead	*Australian Unemployment Rate Series*	*Forecast Step-Ahead*	*Australian Unemployment Rate Series*	*Forecast Step-Ahead*	*Australian Unemployment Rate Series*
1	0.767 (0.197)	5	0.838 (0.280)	9	0.875 (0.352)
2	0.819 (0.234)	6	0.847 (0.373)	10	0.883 (0.412)
3	0.829 (0.0970)	7	0.872 (0.368)	11	0.873 (0.368)
4	0.831 (0.2420)	8	0.879 (0.368)	12	0.881 (0.423)

Note: Probability values are included in parentheses

For the aggregate unemployment rate series, the MSPE ratios are less than one for all of the step-ahead forecasts. This suggests that the forecasts from the non-linear model generated lower MSPE's than did those from the linear forecasts. For the three step-ahead forecast, this reduction was statistically significant at the 10% level. The conclusion as to whether the linear autoregressive or the non-linear logistic smooth transition autoregressive model was the best-fitting model for the aggregate series favoured the former. On the basis of forecast accuracy, the non-linear model seems to possess the greater predictive power with most MSPE ratios less than one. However, with one exception, this difference in predictive accuracy was not statistically significant.

8. The MSPE ratios reported in this study have the MSPE for the non-linear model on the numerator and that of the linear model on the denominator.

6. Conclusion

This paper has examined the issue of asymmetry in the Australian aggregate unemployment rate series using monthly data from February, 1978, to July, 1999. Evidence of asymmetry was found for this series. Further, a test of linearity suggested that a non-linear model was a more appropriate model than the linear autoregressive model nested within it. We estimated both the linear autoregressive model and a non-linear autoregressive model, known as the logistic smooth transition autoregressive (LSTAR) model, for the period from February, 1978 to July, 1997. The LSTAR model provided a better fit to the Australian aggregate unemployment data and we concluded that this was due, in part, to the ability of the non-linear model to capture the established asymmetry in the data.

From both the linear and non-linear models we generated up to twelve step-ahead forecasts over a forecast period from August, 1997 to July, 1999. While predictions from both models suggested greater accuracy was generally obtained from the non-linear model, differences in forecast errors from the both models was not statistically significant except for the three step-ahead forecasts.

The unemployment rate during the forecast period was gradually declining so it was not surprising that the linear model produced reasonable forecasts up to twelve steps ahead. This was evident from the graph of the forecasts from the both models, as well as from the statistical analysis of their forecast errors. What promises to be of interest to policy-makers, and others interested in business cycle fluctuations, is the ability of the LSTAR model (and other models from the non-linear autoregressive class) to correctly forecast the sharp rises in unemployment that are likely to characterise future asymmetric behaviour of the business cycle.

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Editors' Note

In July 2000, a decision was made to revamp the *Australian Journal of Labour Economics (AJLE)* so as to improve its presentation, expand the geographical coverage of the editorial board, and widen the scope of the *AJLE* in terms of the topics addressed and the rigour of published papers. A new editorial team was appointed to run the *AJLE* comprising Siobhan Austen, Paul Flatau (Managing Editor), Peter Kenyon, and Alison Preston. The editors embarked on an extensive program to improve the profile of the journal in the Australian and international labour economics and labour relations community.

The response of labour and industrial relations economists to the editors' initiatives has been very strong as evident in the significant increase in the number of submissions to the *AJLE* over the last nine months and the enthusiastic take-up of editorial board invitations by a broad range of economists.

This issue (volume 4, number 1, 2000-01) is the first of the 'new look' *AJLE*. Volume four of the journal will include a special issue devoted to the theme of *Social Security and the Labour Market*. A special issue on *Unemployment Policy* is planned for volume 5 (2002).

The editors would like to take this opportunity to thank the previous editors Charles Mulvey and Keith Norris for all their efforts and to express our gratitude to Pat Madden, the *AJLE*'s editorial assistant and subscriptions manager, for her work on behalf of the Journal.