

Dynamic Asymmetries in the Australian Labour Market

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This paper examines whether Australian labour market variables, in particular aggregate employment and unemployment, exhibit particular forms of nonlinearity and asymmetry that are of economic interest. The analysis uses nonparametric tests - the BDS test and the triples test. The BDS test assesses whether general residual unexplained nonlinearity remains once linear modeling has been applied to the data. The triples test is used to test for 'steepness' and 'deepness' asymmetries at the business cycle frequency. Evidence is found of nonlinearities. There is little evidence of deepness in the Australian macroeconomy but there is evidence of asymmetric steepness for both employment and unemployment as well as the CPI. Nominal or real wages exhibit neither forms of asymmetry. The evidence suggests that unemployment (employment) rises (falls) rapidly in recessions and only recovers slowly over time. Unemployment and employment are also found to exhibit asymmetric responses to positive and negative shocks over the cycle. The 'current depth of recession' does not provide a rebounding effect out of recessions - positive shocks do not have a stronger effect than negative shocks in recessions. However, some evidence is found for both aggregate employment and unemployment of an 'overheating' effect in expansions - negative shocks have stronger effects than positive shocks. This evidence suggests that unemployment displays a tendency to ratchet up in recessions and that the Australian labour market appears to exhibit significant 'speed limits' in expansion. The depth of GDP recessions is also found to have significant influence on the labour market.

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1 Introduction

The presence or otherwise of cyclical asymmetries in economic data has important implications for both theoretical economic modelling, economic forecasting and the analysis of economic policy. Whilst the theoretical idea that economic variables vary asymmetrically over time and that the economy may operate differently in different phases of the business cycle (e.g. the ineffectiveness of monetary policy due to a 'liquidity trap' in recessions) is not new, there was almost no systematic investigation of cyclical asymmetries until the study of DeLong and Summers (1986). As such there was little questioning of economists tendency to model aggregate fluctuations as linear stochastic processes - as stationary, symmetric, cyclical fluctuations around a linear trend component. In their study, DeLong and Summers searched for (one form of) asymmetry in six OECD economies. They failed to find any significant evidence of it in 17 of the 18 series they investigated. As such, they concluded: 'asymmetry is probably not a phenomenon of first-order importance in understanding business cycles.'

More recently this apparent lack of evidence of important asymmetries has been questioned. Sichel (1994, 1993), Durland and McCurdy (1994), Ramsey and Rothman (1996), Verbrugge (1997), Kakes (1998) and Boldin (1999) have all documented forms of asymmetry in numerous US economic time series. Verbrugge (1998), Speight and McMillan (1998) and Speight (1996) also document business cycle asymmetries for some other OECD economies. Bodman (1998) and Layton (1994) have documented important non-linearities in Australian output and coincident indices. Olekalns (2001) found little evidence of significant steepness or deepness asymmetries in several (HP filtered) Australian economic time series using the parametric, moment-based skewness test. However, Bodman (2001) did find some evidence of significant steepness and deepness asymmetries in price, money supply and labour market variables for Australia using using the non-parametric, triples test for skewness. Bodman and Crosby (2002) find little evidence of asymmetric shock persistence over the business cycle for Australian GDP using the parametric, (threshold autoregression) models of Beaudry and Koop (1993) and Pesaran and Potter (1997).

Since standard linear stochastic processes cannot generate asymmetric sample paths, this suggests that both theoretical and empirical models grounded in such assumptions will fail to characterise important aspects of the true underlying, nonlinear data generating process. Ignoring nonlinear, asymmetric aspects of the data may result in misinterpretation of the effect

of policy over the cycle¹ and important errors in the prediction of turning points.

As Boldin (1999) suggests : *“policymakers should worry about asymmetries in business cycles because most econometrics models cannot capture empirically important asymmetries most econometric model builders do not seem concerned with them I conclude that the symmetry / asymmetry question has as much, and maybe even more, practical significance than debates over identification assumptions that have influenced much of the empirical macroeconomic literature over the past 20 years.”*

Of course, as Koop and Potter (1999) point out, *“... the general message coming out of this empirical literature is that, although there is some evidence in favor of the hypothesis that economic time series contain nonlinearities, the evidence is not overwhelming nor is it precise on the exact form or meaning of the nonlinearity. In the face of this mixed message, most economists remain unconvinced about the usefulness of considering nonlinearity in empirical specification. For some this reluctance to consider alternatives to linear models is due to the perceived weakness of the statistical evidence. Others accept the statistical evidence but argue that statistically significant results are fragile due to data mining. Still others argue that statistical significance does not imply economic significance.”*

Theoretically, there are many economic reasons why cyclical asymmetries might occur in various macroeconomic aggregates and macroeconomic relationships. It could be the case that the type of shocks which occur at one stage of the cycle are quite different from those experienced at another stage of the cycle or that the propagation mechanism might be different over the cycle. Azariadis and Smith (1998), Holly and Jones (1997), Acemoglu and Scott (1997), Gertler and Gilchrist (1994), Thoma (1994), Potter (1994)), Ball and Mankiw (1994), Friedman (1993), Bernanke and Gertler (1989), and DeLong and Summers (1988) have all provided analyses where either output, prices, investment or monetary variables exhibit such asymmetries. Alternatively, the economy might react asymmetrically to positive shocks as opposed to negative shocks as suggested in Pesaran and Potter (1997), Beaudry and Koop (1993).

Whatever the source of these asymmetries and non-linearities, they clearly can have important implications for economic policy-making and macroeconomic modeling . Whether economic data exhibits asymmetric, non-

¹An interesting recent paper discussing the implications for monetary policy of non-linear economic relationships, such as a nonlinear, convex Phillips curve, is Debelle and Vickery (1998).

linear cyclicality is thus an important issue for econometric estimation, testing and forecasting. Exploitation of any information pertaining to possible non-linear structure could be of great consequence in obtaining accurate forecasts.

This paper focuses mainly on labour market variables for Australia (with some preliminary evidence for New Zealand provided in Appendix 5). Neftci (1984), Davis (1984), Falk, (1986), Brock and Sayers (1988), Hussey (1992), Rothman (1991, 1998), Burgess (1992), Storer (1994), Acemoglu and Scott (1994), Franses (1995), Peel and Speight (1998), Koop and Potter (1999), Chauvet, Juhn and Potter (2001) and others have all documented nonlinearities and asymmetries in labour market data for various countries in North America and Europe. Others, such as Andolfatto (1997) have tried to explain these asymmetries through modelling the optimal search activities of individuals in the economy. Search models of the type developed by Mortenson and Pissarides (1994), Greenwood, MacDonald and Zhang (1994) and Jovanovic (1987) can all display dynamics that exhibit asymmetries over the cycle, particularly if adjustment costs or externalities are allowed for. The kinds of empirical work at the microeconomic level by Davis and Haltiwanger (1992, 1990) and others suggests that job creation is sharper and more cyclical than job creation - hiring is sluggish due to matching imperfections whereas jobs can be destroyed more quickly. Similarly, insider-outsider theories, such as those discussed in Lindbeck and Snower (1988) and Lindbeck (1992), and Blanchard and Summers (1986) type theories of hysteresis can also be interpreted or extended to imply asymmetries.

In this paper, BDS tests for general nonlinearity (versus an i.i.d. null) are used to provide further evidence of nonlinearities often overlooked in the use of linear ARIMA models. The paper then investigates the existence in Australian labour market series of two particular forms of asymmetry introduced by Sichel (1993): 'steepness' or growth rate asymmetry - whether the distribution of growth rates in a trendless time series is asymmetric such that the rates of expansion and contraction differ over the cycle; and 'deepness' or level asymmetry - whether the distribution of the levels of the trendless (or detrended) time series is asymmetric. Deepness examines the relative positions of the peak and trough over the cycle.² In order to do this the paper uses the nonparametric, triples test of Randles, Flinger, Policello and Wolfe (1980), recently introduced into the economics literature by Ver-

²Ramsey and Rothman (1996), note that steepness is a form of transversal asymmetry whilst deepness is a form of longitudinal asymmetry and that other forms of transversal and longitudinal asymmetry are possible.

brugge (1997) and utilised in Bodman (2001) for Australian data. This test can be shown to have considerably more power than the more commonly used parametric test based on the coefficient of skewness. Verbrugge (1997) demonstrates that the triples test has significant advantages over moment based tests in that it cannot be dominated by outliers and as such is not subject to the kind of small sample bias highlighted by Bryan and Cecchetti (1996).

The paper then turns its focus specifically towards employment and unemployment data and the particular threshold autoregression models developed by Beaudry and Koop (1993) and Pesaran and Potter (1997). These simple reduced form models examine whether positive shocks affect a series differently from negative shocks over different phases of the cycle. In support of Elwood (1998) for US data, Bodman and Crosby (2002) find no evidence of such ‘current depth of recession’ or ‘overheating’ asymmetries for Australian GDP. It is therefore of interest to examine whether labour market variables provide a richer source of such asymmetries.

The final section of the paper provides a preliminary attempt to link asymmetric behaviour in the the goods market and the labour market. An examination of whether the depth of recession in GDP affects either the level of unemployment, employment growth, or the depth of recession in these variables, is one step in the direction of assessing whether it is particularly deep recessions that cause most problems for the labour market.

2 The Data

The economic time series investigated here are the natural logarithms of the Australian, quarterly, seasonally adjusted real GDP, total civilian employment, and the CPI over the period 1959:4-2001:3; the natural logarithms of the Australian, quarterly, seasonally adjusted nominal wages (average earnings : national accounts basis) and real wages (average earnings / CPI) over the period 1965:4-2001:3; and the unemployment rate (total, persons, seasonally adjusted) over the period 1959:4-2001:3. All data series were obtained from various databases in the dX Database. Employment, unemployment and real wages are illustrated in Appendix 1.

3 Linear Models and BDS Tests for Nonlinearity

The first step in the analysis is to specify the best-fitting, linear ARIMA model of each time series. The residuals from the estimated linear models can then be tested for omitted nonlinearities using tests such as the BDS

test i.e. if all linear structure is removed / modeled by fitting the correct ARIMA process to the data, then any remaining dependence must be non-linear.³ The choice of appropriate, linear ARIMA model is made here using both Augmented Dickey-Fuller tests for nonstationarity⁴ and standard Box-Jenkins methodology (see for example Enders (1995) for a detailed explanation of both of these standard procedures). The choice of ARIMA model for each series is reported in Table 1. Optimal lag length in the ADF tests and Box-Jenkins estimation is chosen using the Schwartz Bayesian information criterion. Critical values for the ADF tests were taken from Davidson and MacKinnon (1993). Unit root tests were also carried out on the 1st differences of each series and rejected the null of a unit root (i.e. of I(2) processes) in all cases.

Table 1
ARIMA Models and BDS tests - Australia

	ADF(lags)	ARIMA(p,d,q)	GARCH(p,q)	BDS (p-value)
GDP	-1.071(0)	(0, 1, 0)	<i>GARCH</i> (1, 1)	5.209(0.000)
Unemployment	-1.922(2)	(2, 1, 0)	<i>No</i>	2.942(0.009)
Employment	-0.086(2)	(2, 1, 0)	<i>No</i>	1.667(0.089)
Nominal Wages	-2.328(2)	(2, 1, 0)	<i>No</i>	2.960(0.021)
CPI	-1.791(4)	(4, 1, 0)	<i>ARCH</i> (1)	2.846(0.011)
Real Wages	-2.362(0)	(0, 1, 0)	<i>No</i>	1.665(0.096)

Given the possible concern over size distortion problems with the BDS tests and that BDS tests might have low power against ARCH alternatives (Brock *et al* (1991)), LM tests for ARCH(1) and ARCH(4) were performed. The ARCH(j) tests, distributed $\chi^2(j)$, were significant at the 5% level, for both the (logged) GDP series and CPI series. Models were therefore estimated for these series that incorporated ARCH and / or GARCH components. Choice of model was made according to the minimised AIC and SBC. Once the appropriate linear model was specified (possibly including GARCH effects), BDS tests, were performed on the residuals of the linear models to test for evidence of significant non-linearities in the residuals that are not

³Hsieh and LeBaron (1991) have emphasised the potential dependence of the properties of the BDS test on the prior linear filter chosen - the test may find nonlinearity simply as a result of left-over linear dynamics in the data. Where choice of appropriate ARIMA model was marginal versus a 'close' alternative, both models were used and tested. No sensitivity of results was observed in any case.

⁴Phillips-Perron tests were also conducted on the levels of the series and yielded similar results.

otherwise captured. The p-values reported in Table 1 are bootstrapped probabilities based on 10,000 repetitions.⁵

All of the estimated BDS statistics have p-values of less than 0.10 implying rejection of the null hypothesis of i.i.d. residuals at the 10% level. Omitted nonlinearity of some form or other appears to be a fairly ubiquitous feature of linear ARIMA modeling of Australian macroeconomic time series, even when ARCH and GARCH effects are accounted for. The results give a first indication that use of some form of nonlinear model can provide a better explanation and characterisation of the data than does linear modeling.

The BDS test is a very general test for nonlinearity and as such gives very little indication of the form of the nonlinearity that might have been omitted from the linear specification (in that sense it is somewhat uninformative). It does indicate however, that some form of nonlinearity / asymmetry is present in the data and is worth exploring. Therefore the remainder of the paper involves testing and estimation of a couple of particular forms of nonlinearity and asymmetry that have the potential to be economically interesting.

4 Steepness and Deepness

The steepness and deepness asymmetry test used in this paper is the non-parametric triples test of Randles et al (1980). The excellent power properties of this test, compared to such moment based tests as the standard skewness test, has been documented in Eubank et al (1992). The test has been applied in the economics literature recently by Verbrugge (1997) and Bodman (2001). The test is described formally in the appendix but the intuition behind the test is as follows: take all possible triples of observations (X_i, X_j, X_k) from a sample of size N (ie. $\binom{N}{3}$ combinations) on a random variable X (in this case a time series of data). If 'most' of these triples are right skewed, such that the middle observation is closer to the smaller observation than it is to the larger observation, then infer that this is true of the underlying distribution. In the context of this time series analysis, the triples test has the null hypothesis that the data generating process underlying X is a linear ARMA process with well-behaved i.i.d. symmetric errors. As such, the asymptotic distribution of the triples test statistic is standard normal and conventional critical values can be used.

The triples test, like the skewness test, only applies to stationary, trendless time series - a trending series is asymmetric by definition. As many

⁵See Appendix 1 for details concerning the BDS test.

macroeconomic time series are argued to contain a stochastic trend (Nelson and Plosser (1982)) or a deterministic trend with possible breaks (Perron (1989)) it is necessary to detrend such series (render them stationary) using some filter e.g. first differencing, Hodrick-Prescott (1982) filter, the structural time-series model approach of Harvey (1985) or the Beveridge and Nelson (1981) decomposition.

Another important point to note is that the test procedure is applied to the actual (detrended) time series itself, not the residuals from the relevant, fitted ARMA process representing the series. This contrasts, for example, with the application of BDS tests to the residuals of ARMA regressions to test for omitted nonlinearities. This is because ARMA representations can often overfit the trend, including asymmetric components of the series, and can remove part of the asymmetry from the series leaving the residual (representing the cyclical component of the series) noisy and too symmetric. For this reason, Potter (1994) failed to find much evidence of asymmetry in residuals. Such criticisms have also been noted by Verbrugge (1997), Westlund and Öhlen (1991) and Clark (1987).

The detrending filter used in practice therefore needs to extract the appropriate cyclical component for the type of asymmetry being tested for. The filter must also be linear to ensure that spurious asymmetries are not introduced into the resulting series to be tested.

Testing for asymmetric deepness, or level asymmetry implies that it is necessary to apply the triples test to the *level* of the *cyclical component* of a *trendless* series. As in the recent study of Bodman (2001) and Olekalns (2001) the method used here to extract the cyclical component of the series of interest is the widely used Hodrick-Prescott (1982) HP filter with standard $\lambda = 1600$ weight chosen for quarterly time series. This filter is linear, it renders stationary any time series that is integrated of order 4 or less, has been extensively and critically studied, and has been widely applied in the macroeconomics literature; see for example Guay and St-Amant (1997), Baxter and King (1995), Cogley and Nason (1995), Harvey and Jaeger (1993) and King and Rebelo (1993). The cyclical component generated by application of the HP filter to a quarterly time series corresponds closely to that generated by a two-sided linear approximation to an optimal band pass filter that retains those features of the data with a periodicity between six and thirty-two quarters.

Secondly, since a time series that exhibits (negative) asymmetric steepness has decreases that are larger but less frequent than the increases in the series, testing for asymmetric steepness, or difference asymmetry, implies applying the triples test to the first-differences of the cyclical component

of the time series of interest. The first-difference filter provides a natural parallel with the definition of steepness.

The results of the triples tests for deepness and steepness are presented in Table 2 below. The reported p-values are the asymptotically valid, standard normal, two-sided p-values.

Table 2
Deepness and Steepness (triples) tests - Australia

	Deepness ($\hat{\eta}$)	(p-value)	steepness ($\hat{\eta}$)	(p-value)
GDP	-0.023	(0.09)	+0.017	(0.22)
Unemployment	-0.004	(0.62)	+0.038	(0.00)
Employment	+0.015	(0.29)	-0.032	(0.00)
Nominal Wages	+0.011	(0.47)	+0.007	(0.62)
CPI	+0.015	(0.36)	+0.045	(0.00)
Real Wages	+0.019	(0.18)	+0.001	(0.99)

For Australian GDP, neither test statistic is significant at conventional (5% or 1%) significance levels. This finding of an apparent lack of asymmetry in GDP strongly supports the results of Bodman and Crosby (2002) who document the lack of asymmetry in Australian GDP using the threshold autoregression models of Beaudry and Koop (1993) and Pesaran and Potter (1997).

None of the results presented in the table concerning deepness, or level asymmetry, are significant at conventional (5% or 1%) significance levels. This supports the conclusions of DeLong and Summers (1986) and contrasts with the results of Sichel (1993) and Beaudry and Koop (1993) for the US.

Turning to the results for steepness we find that such difference asymmetry is a much more prevalent feature of Australian data. Both the Australian unemployment rate and the CPI exhibit positive steepness suggesting that they have a tendency to rise sharply but then decline only slowly over time.

The evidence for positive steepness in the CPI relates closely to the recent literatures on asymmetric price adjustment (e.g. Verbrugge (1998), Bryan and Cecchetti (1996), Ball and Mankiw (1995) and Caballero and Engel (1993)) and asymmetric monetary transmission over the business cycle (e.g. Kakes (1998), Sims and Zha (1998), Thoma (1994) and Gertler and Gilchrist (1994)).

The tendency for Australian unemployment to display positive difference asymmetry over the cycle and to ratchet up in recessions was also documented in Bodman (1998) using the reduced form modeling approach

of Acemoglu and Scott (1994). This conclusion concerning the asymmetric, nonlinear behaviour of Australian labour markets is further supported through the finding that employment exhibits significant negative steepness suggesting that employment falls rapidly in recessions and then only recovers slowly. Nominal wages show no evidence of either type of asymmetry. This result stands in contrast to the findings in Dwyer and Leong (2000) who do find asymmetries in nominal wage data which they relate to downward nominal wage rigidity in Australia. Interestingly, real wages also show no sign of either deepness or steepness despite the strong evidence for steepness in the CPI.

5 Current Depth of Recession

The evidence presented so far provides some (nonparametric) statistical evidence of important nonlinearities and asymmetries in Australian labour market variables. In order to further investigate the possible nature of these asymmetries, the Current Depth of Recession, CDR_t , is constructed, following Beaudry and Koop (1993) and Parker and Rothman (1998) for employment and unemployment. This variable is intended to capture information concerning peak-reverting behaviour in the data. Information about *relative levels* of employment and unemployment, not captured in linear models, could be useful in determining the pace of economic recovery - the growth performance of the variables will depend on the size of recent shocks to the level of the variables. In particular, large negative shocks to employment lead to predictions of high employment growth until the previous peak employment level is achieved. Similarly, large positive shocks to unemployment (raising the unemployment rate) should lead to predictions of rapid declines in the unemployment rate until the previous trough unemployment level is achieved.

5.1 Employment

Following Beaudry and Koop (1993) an n th order autoregression is estimated and in order to test whether the CDR variable helps to predict employment growth, m lags of CDR_t are included as an additional regressors. This nonlinear model contains two regimes with endogenous switching between the two.

$$\dot{E}_t = \gamma_0 + \sum_{i=1}^n \gamma_i \dot{E}_{t-i} + \sum_{j=1}^m \alpha_j CDR_{t-j} + \varepsilon_t \quad (1)$$

where $CDR_t = [E_t - \max\{y_{t-j}\}_{j \geq 0}]$, E_t is the log level of employment and \dot{E}_t is the growth rate of employment. CDR_t measures how far in percentage points employment is below its maximum value to date. In this way the previous maximum employment level acts as a kind of reflective barrier or floor and the CDR_t variable acts as a ratchet effect. As employment falls below its previous maximum (the floor) pressure starts to build up for it to return to its previous maximum level and the further it falls the greater the pressure. Therefore a significant, negative sum for the α_j coefficients implies that the further employment is below its peak, the larger is the upward kick to employment.

The CDR_t variable is shown, together with employment growth, in Figure 1. The CDR_t variable becomes strictly negative after business cycle peaks and remains negative until the employment level equals its previous peak (or alternatively, until the negative cumulative growth between previous peak and subsequent trough is eliminated by sufficient cumulative positive growth in the recovery). The figure illustrates only the specification of the CDR variable which requires at least two consecutive quarters below the previous peak - a specification often required in the business cycle dating literature following Okun's two consecutive quarters of negative growth in GDP rule.

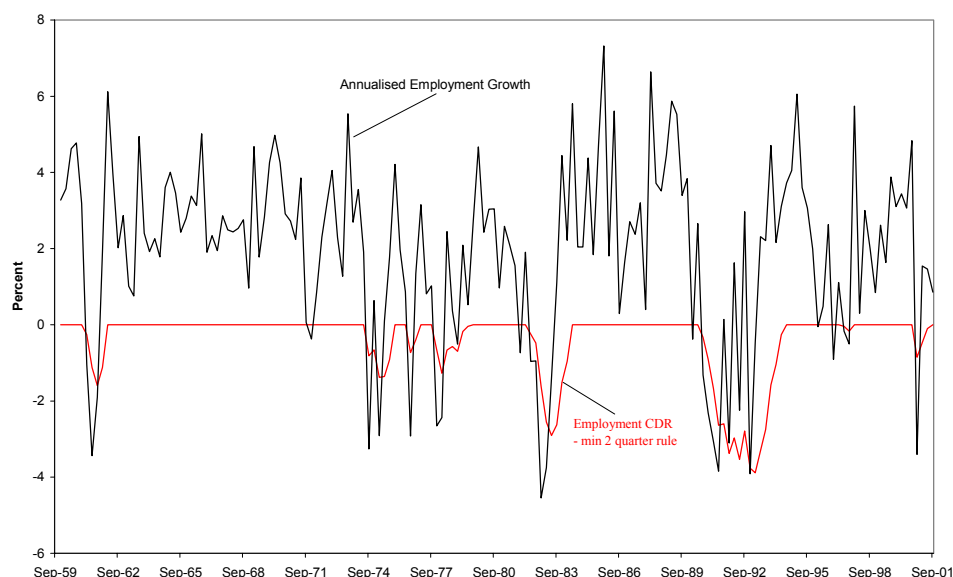


Figure 1. Australian Employment Growth and the Current Depth of Recession

The results of estimating these Beaudry and Koop (1993) type models are presented in Table 3. The best fitting ARMA model for employment growth was found to be an AR(2) model, a specification determined using a minimum AIC and SBC criterion and analysis of residuals. Newey-West standard errors are presented in parentheses and the Wald test of $H_0 : \alpha_j = 0 \quad \forall j$, together with its p-value, based on the Newey-West covariance matrix, is also presented.

Table 3 Australian Employment Growth and Current Depth of Recession

Employment Growth					
	γ_0	γ_1	γ_2	$\sum \alpha_j$	Wald Test
CDR	0.651	0.336	0.274	-ve ($m = 1$)	p-value=0.401
	(0.362)	(0.089)	(0.081)		
CDR - min	0.657	0.335	0.274	-ve ($m = 1$)	p-value=0.408
2 quarters	(0.357)	(0.089)	(0.080)		

The results suggest that α is negative as expected but is not significant at conventional levels.⁶ This suggests that any bounceback in employment that might occur after recessions does not depend on the depth of the recession. Hence the evidence in this section suggests that when the Australian labour market falls into recession this does not lead to expectations that high employment growth will quickly follow.

5.2 Unemployment

When examining unemployment, as opposed to GDP or employment, several other important issues arise, largely revolving around the trending nature of Australian unemployment rates. Unlike US data, Australian unemployment rates appear to exhibit stochastic trends, as indicated by standard unit

⁶Hess and Iwata (1997) find that the t-statistic on CDR does not have an asymptotic normal distribution. The t-statistic could be large even when the true DGP is a random walk, or alternatively a large t-statistic could occur because the data is stationary. Given the finding that the t-statistics are insignificant even using the standard normal critical values, this issue is noted but not investigated further.

root tests of the type developed by Dickey and Fuller. Also, because the unemployment rate lies between zero and one it is bounded and this conflicts with the results from the unit root tests. One method of overcoming this boundedness issue is to take a logistic transformation of the data, although the stationarity issue still remains after transformation. In this paper the augmented autoregressive CDR models for unemployment were run using unemployment rates for untransformed data.⁷

As pointed out by Parker and Rothman (1998), the specification of the CDR variable needs to be amended for a series like unemployment which is a counter-cyclical series and which lacks a strong secular trend. For example, if the same global minimum specification was used as for employment then the Australian economy has been in recession since September 1960!

To constrain the definition of the CDR to the use of local minima, the CDR variable was specified as

$$CDR_t = \min\{U_{t-s}\}_{s=0,\dots,k} - U_t \quad (2)$$

where k is the length of the ‘look-back window’. Now CDR_{t-1} takes on a negative value if the last quarter’s unemployment rate was higher than the minimum value of U_t over the last k quarters. The optimal truncation of s can be found by estimating a large set of CDR models and choosing the model for which the AIC or SBC is minimised.⁸

Two CDR_t variables for the various specifications of unemployment models are shown in Figure 2. For the unemployment rate, the CDR_t variable becomes strictly negative after recent local troughs (unemployment rate minima) and remains negative until the unemployment rate falls below its recent peak.

⁷Some investigation using logistically transformed data was undertaken. The results presented in the paper do not seem to be affected by the lack of transformation.

⁸An alternative definition of the CDR variable, rather than relating the current state of unemployment to a local minima criterion, would be to define it in relation to the gap from an estimated time-varying NAIRU. This may be considered in future research in this area.

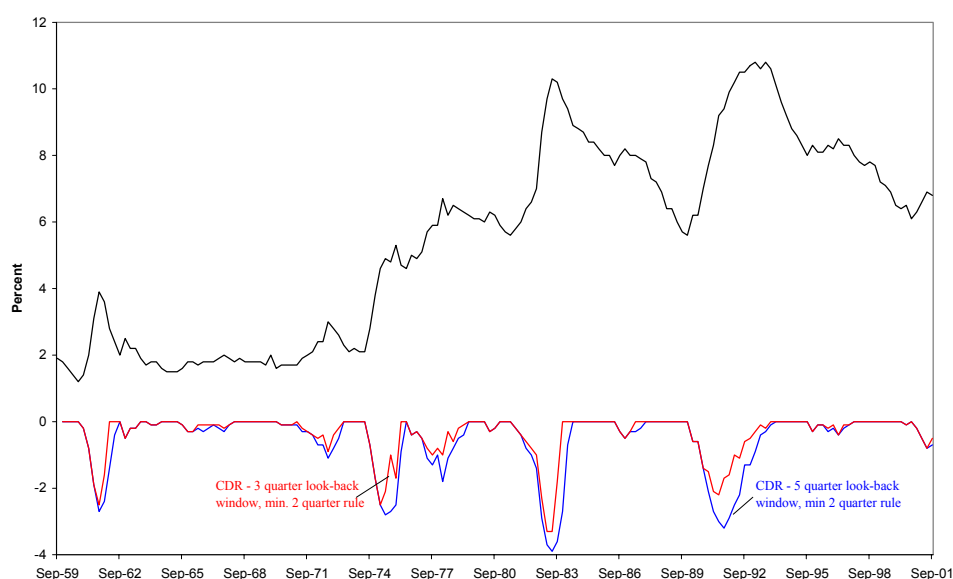


Figure 2. Australian Unemployment and the Current Depth of Recession

Note: the CDR variables shown are for a 3-period and 5-period look-back window and exclude recessionary periods of less than 2 quarters.

Again following Beaudry and Koop (1993) an n th order autoregression is estimated with m lags of CDR_t are included as an additional regressors.

$$U_t = \gamma_0 + \sum_{i=1}^n \gamma_i U_{t-i} + \sum_{j=1}^m \alpha_j CDR_{t-j} + \varepsilon_t \quad (3)$$

The results of the various regressions are included in Table 4. The best fitting ARMA model for the unemployment rate was found to be an AR(2) model, a specification determined using a minimum AIC and SBC criterion and analysis of residuals. Newey-West standard errors are presented in parentheses and the Wald test of $H_0 : \alpha_j = 0 \quad \forall j$, together with its p-value, based on the Newey-West covariance matrix, is also presented. Given that the unemployment rate for Australia appears to exhibit a stochastic trend (cannot reject the null of a unit root at conventional significance levels using tests like the ADF test - this applies to logistically transformed data also)

then the models were also run using the first difference of the unemployment rate and the results are also reported in the table.⁹

Table 4 Australian Unemployment and Current Depth of Recession

Unemployment Rate					
	γ_0	γ_1	γ_2	$\sum \alpha_j$	Wald Test
CDR (s=3)	0.093 (0.046)	1.396 (0.135)	-0.411 (0.133)	-ve ($m = 1$)	p-value=0.772
CDR - min 2 quarters (s=3)	0.093 (0.047)	1.386 (0.135)	-0.401 (0.133)	-ve ($m = 1$)	p-value=0.704
ΔU_t					
CDR - min 2 quarters (s=3)	0.021 (0.033)	0.444 (0.104)		+ve ($m = 1$)	p-value=0.953

6 Overheating

Pesaran and Potter (1997) further develop the reduced form modelling approach to documenting asymmetric responses to shocks over phases of the cycle by refining the *CDR* variable and introducing a ceiling or overheating effect to capture asymmetries in business cycle peaks. Relating this to employment rather than output, it is argued that if employment grows faster than some threshold value for a number of successive periods then it is more likely that positive shocks will produce a smaller effect on output growth than will negative shocks.

6.1 Employment

The definition of a ceiling regime used here for employment is the overheating specification in which a ceiling level of employment growth r_c is specified and then employment growth above this level cumulates over time until

⁹The issue of whether unemployment rates for countries like Australia exhibit unit roots or whether these findings occur due to structural breaks in the series is investigated in Papell, Murray and Ghiblawi (2000). They indeed find that the Australian unemployment rate does not exhibit unit root behaviour once at least one structural break is allowed for. In fact, they find two structural breaks in the Australian series, one in 1974 and another in 1982.

the current growth rate falls to, or below, the specified ceiling level (an alternative approach would be to specify the regime as continuing until the cumulated excess growth has been cancelled - this definition is called a ‘hard ceiling.’) Thus, overheating, OH_t , is defined as:

$$C_t = \mathbf{1}(\dot{E}_t > r_c)$$

$$OH_t = (OH_{t-1} + \dot{E}_t - r_c) \quad OH_0 = 0$$

where $\mathbf{1}(\cdot)$ is an indicator function equal to 1 if the statement in parentheses is true such that the ceiling regime turns on, 0 otherwise.

Rather than estimate the threshold ceiling level r_c , the investigation pursued here uses three different specifications of the overheating regime as follows:

$$OH_{1,t} = \begin{array}{l} \text{cumulative excess of growth in } \% \text{ terms above } r_c = \text{average} \\ \text{employment growth rate for expansions} \end{array}$$

$$OH_{2,t} = \begin{array}{l} \text{cumulative excess of growth in } \% \text{ terms above } r_c = \text{average} \\ \text{growth rate for expansions} \\ \text{plus: not active if in a recovery period such that } CDR_t < 0 \\ \text{plus: must have at least 2 consecutive quarters of growth} \\ \text{above the ceiling} \end{array}$$

$$OH_{3,t} = \begin{array}{l} \text{cumulative excess of growth in } \% \text{ terms above } r_c = \text{average} \\ \text{growth rate for the sample} \\ \text{plus: not active if in a recovery period such that } CDR_t < 0 \\ \text{plus: must have at least 2 consecutive quarters of growth} \\ \text{above the ceiling} \end{array}$$

The first specification implies that any growth above average during expansions leads to positive shocks to employment having a smaller impact on employment. The second specification is the same as the first, but allows for high growth in recovery phases, and rules out asymmetry whenever there is only one period of above average growth. The final specification switches on the overheating variable whenever growth is above the sample average.

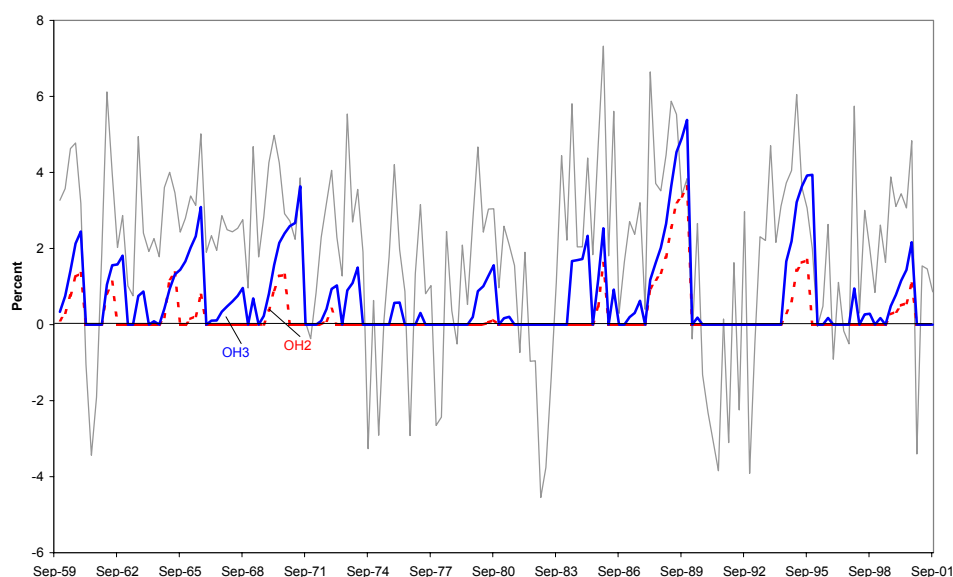


Figure 3. Australian Employment Growth and Overheating (OH2 and OH3 variables shown only)

These various definitions of overheating are incorporated (lagged m periods) into n th order autoregressions either *e.g.*

$$\dot{E}_t = \gamma_0 + \sum_{i=1}^n \gamma_i \dot{E}_{t-i} + \sum_{j=1}^m \delta_j OH_{t-j} + \varepsilon_t \quad (4)$$

It is expected that $\sum \delta < 0$ since excess growth above the average (for either expansions or the sample average depending on the definition of r_c) should imply that the following periods growth rate should tend to be below the mean growth rate (or alternatively that in the ceiling regime positive shocks will affect output growth less than negative shocks to employment growth).

Results of the estimation of the various models are presented in Table 4. In all cases the estimate of $\sum \delta$ was negative as expected and were significant at the 10 percent level.¹⁰ The evidence suggests that, for Australian employment, the persistence of negative shocks to employment in expansions is

¹⁰Again it is noted that Hess and Iwata (1997) find that the test statistic on such CDR variables does not have an asymptotic normal distribution. Investigation of the implications of such distributional issues is not undertaken here but is noted as a requirement to confirm the findings presented.

different from the persistence of positive shocks.¹¹ The more that employment growth is above its “normal” level in expansions, the more likely it is that employment growth will slow. This tendency for Australian employment to ‘overheat’ suggests that in the presence of important adjustment costs and matching imperfections, the faster that labour market matches are put together the more likely it is that many of them will dissolve when negative shocks hit the labour market.

Table 5 Australian Employment Growth and Overheating

Employment Growth					
	γ_0	γ_1	γ_2	$\sum \delta_j$	Wald Test
OH1	0.987	0.323	0.255	-ve ($m = 4$)	p-value=0.01
	(0.242)	(0.091)	(0.091)		
OH2	0.969	0.304	0.248	-ve ($m = 4$)	p-value=0.04
	(0.241)	(0.085)	(0.085)		
OH3	1.021	0.307	0.295	-ve ($m = 5$)	p-value=0.09
	(0.252)	(0.089)	(0.090)		

6.2 Unemployment

Similar problems arise in the specification of an overheating variable for unemployment as arise in the specification of a CDR variable. For models involving the levels of unemployment rates (transformed or untransformed), the simplest definition of an overheating variable is to replace *min* with *max* in the CDR definition :

$$OH_t = \max\{U_{t-s}\}_{s=0,\dots,k} - U_t \quad (5)$$

where k is again the length of the ‘look-back window’. Now OH_{t-1} takes on a positive value if the last quarter’s unemployment rate was lower than the maximum value of U_t over the last k quarters. One problem with this definition is that the OH variable can switch on even if the CDR is switched on at the same time - the unemployment rate can still be above its recent local minimum even though it has peaked and is now falling below its recent maximum. To avoid this, and to ensure that the variable derived really does

¹¹The relationship between the extent of overheating and persistence is explored in more detail in section 7 of Pesaran and Potter (1997).

represent a period where unemployment is declining strongly compared to its recent history the following definition is used:

$$OH_t = \max\{U_{t-s}\}_{s=0,\dots,k} - U_t \quad \text{iff} \quad CDR_t = 0 \quad (6)$$

Overheating variables derived for $s = 3$ and $s = 5$ are displayed in Figure 4.

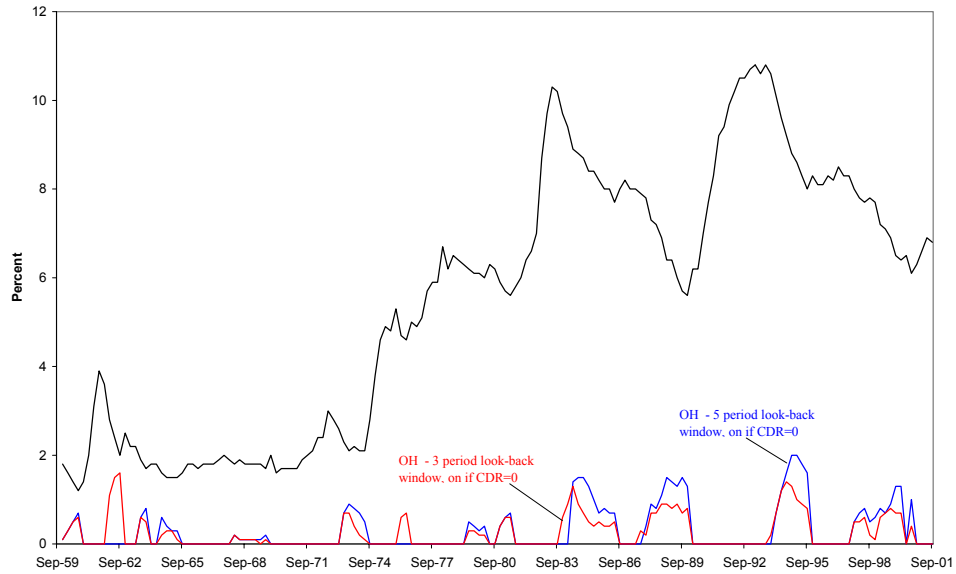


Figure 4. Australian Unemployment and Overheating

Note: the OH variables shown are for a 3-period and 5-period look-back window and exclude expansionary periods of less than 2 quarters. The OH variables in the figure are also restricted to exclude periods where a CDR variable of similar look-back length would be switched on.

The OH variables were incorporated into nth order autoregressions of the following specification:

$$U_t = \gamma_0 + \sum_{i=1}^n \gamma_i U_{t-i} + \sum_{j=1}^m \delta_j OH_{t-j} + \varepsilon_t \quad (7)$$

It is expected that $\sum \delta > 0$ since excess decline in the unemployment rate (OH becoming more positive) should imply that the following periods unemployment rate should tend to be higher than the recent unemployment rate (or alternatively that in the ceiling regime positive shocks will affect unemployment (increase it) more than negative shocks to unemployment). In other words, the further below the recent peak that the unemployment rate falls, the greater the pressure for the unemployment rate to rise

Table 6 Australian Unemployment and Overheating

Unemployment Rate	γ_0	γ_1	γ_2	$\sum \delta_j$	Wald Test
OH (s=3); min 2 quarters; CDR=0	0.093 (0.059)	1.474 (0.096)	-0.489 (0.097)	+ve ($m = 3$)	p-value = 0.008
OH (s=5); min 2 quarters; CDR=0	0.089 (0.046)	1.473 (0.114)	-0.488 (0.115)	+ve ($m = 3$)	p-value = 0.001
OH (s=3); min 2 quarters	0.095 (0.057)	1.471 (0.089)	-0.487 (0.091)	+ve ($m = 3$)	p-value = 0.049

Note: Numbers in parentheses are Newey West standard errors

The results indicate evidence for a significant overheating effect in unemployment rates. This effect is in the same direction as the overheating effect for employment and is even more significant. The further that unemployment falls below its recent peak (local maximum) the more that positive shocks will drive the unemployment rate back up. Attempts to lower the unemployment rate quickly may be reversed rapidly since the faster the unemployment rate falls the more likely it is to bounce back up to its previous peak.

7 Does the GDP CDR Affect Either the EMP CDR or the UMP CDR?

The analysis so far has focused on univariate linear and nonlinear models of employment and unemployment (and other macroeconomic aggregates). The results of the previous section suggest that the own current depth of recession has little explanatory power for movements in employment and unemployment over the cycle - positive shocks do not seem to have stronger effects than negative shocks in recessions. One other interesting question

that one might ask at this stage is whether the depth of recession in output has any explanatory power in explaining either the level or change in the unemployment rate and in the behaviour of employment growth. In other words, is it only the fluctuations in GDP growth that matters for the movements in labour market variables or does the depth of the cyclical movements matter also?

One simple way to examine the relationships between the depth of output recessions and unemployment movements is to augment the simple autoregression models for unemployment or employment with lagged GDP CDR terms and test for their significance.¹² Given that the inclusion of such variables might be proxying for the growth rate of GDP itself, lags of GDP should also be included to ensure that the CDR effects are in fact picking up a true nonlinear adjustment effect. To examine this, the following dynamic Okun's Law type regressions were run:¹³

$$U_t = \gamma_0 + \sum_{i=1}^2 \gamma_i U_{t-i} + \sum_{j=1}^n \alpha_j GDP_{t-j} + \sum_{k=1}^m \beta_k GDP_CDR_{t-k} + \varepsilon_t \quad (8)$$

where GDP_{t-j} are lags of the GDP growth rate.

For employment, regressions of the following form were run:

$$\dot{E}_t = \gamma_0 + \sum_{i=1}^2 \gamma_i \dot{E}_{t-i} + \sum_{k=1}^m \beta_k GDP_CDR_{t-k} + \varepsilon_t \quad (9)$$

Lag lengths were chosen according to analysis of residuals and minimising the AIC and SBC. For all cases, Wald tests of $H_0 : \beta_k = 0 \forall k$ were then performed. The results of these estimations are presented in Table 7. Newey West Standard errors are presented in parentheses. Bolded numbers indicate significance at the 10% level.

¹²The GDP CDR terms incorporated here include only periods for which output is below its previous peak for at least two consecutive quarters.

¹³Lee (2000) also examines possible asymmetries in Okun's Law relationships. He finds mixed evidence of such asymmetries over a range of OECD countries.

Table 7
Reduced Form Nonlinear Models
The Labour Market and the Depth of GDP Recessions

Dependent Variable	U_t	U_t	\dot{E}_t	\dot{E}_t	\dot{E}_t
Coefficient					
γ_0	0.074	0.145	1.195	1.020	0.939
	(0.054)	(0.059)	(0.275)	(0.306)	(0.302)
γ_1	1.308	1.281	0.246	0.239	0.252
	(0.083)	(0.081)	(0.081)	(0.080)	(0.079)
γ_2	-0.322	-0.297	0.203	0.206	0.273
	(0.082)	(0.081)	(0.077)	(0.077)	(0.079)
α_1		-0.014		0.042	-0.0002
		(0.005)		(0.032)	(0.035)
β_1	-0.027	-0.017	0.136	0.106	0.253
	(0.009)	0.010	(0.062)	(0.066)	(0.084)
β_2					-0.222
					(0.079)
Wald Test $\sum \beta_k = 0$ (p-value)	0.009	0.092	0.030	0.103	0.005
$\sum \beta_k$	-ve	-ve	+ve	+ve	+ve

The results of estimating these CDR models suggest that the depth of recession for GDP does have a significant effect on both the level of the unemployment rate and on employment growth. The negative sign on the CDR variable in the unemployment equations implies that as the GDP recession deepens positive shocks to output have a larger effect on unemployment than negative shocks and the unemployment rate increases. The depth of the output recession matters for the size of the increase in the unemployment rate. Similarly, the positive effect of the CDR in the employment equation indicates that negative shocks to output have a larger impact on employment in recessions than do positive shocks.

In support of these results, some simple bivariate Granger causality tests between the CDRs for GDP, employment and unemployment were performed. Lag length in the VAR was determined using the minimised AIC and SBC. Lag length order was 2 in each case. Results are presented in Table 8. Bolded numbers represent significance at the 5% level.

Table 8
GDP CDR Granger Causality Tests

Null Hypothesis	p-value
GDP CDR does not Granger Cause U CDR	0.00029
U CDR does not Granger Cause GDP CDR	0.04569
GDP CDR does not Granger Cause EMP CDR	0.00001
EMP CDR does not Granger Cause GDP CDR	0.15655
GDP CDR does not Granger Cause U_t	0.00218
U_t does not Granger Cause GDP CDR	0.00222
GDP CDR does not Granger Cause EMP_t	0.00082
EMP_t does not Granger Cause GDP CDR	0.17976

The results of the Granger causality tests strongly support the results of the simple nonlinear models in the first part of the section. There is strong evidence of uni-directional causality between the GDP CDR and both employment and the employment CDR. The sum of the significant lags of GDP CDR is positive in both cases suggesting that a deeper output recession causes slower employment growth and leads to a deeper employment recession.

There is evidence of bi-directional causality between the GDP CDR and both the unemployment rate and the unemployment depth of recession. The sum of the significant coefficients again suggests that there is a positive relationship between the GDP CDR and the unemployment CDR - a deeper output recession leads to a deeper unemployment recession (unemployment rises even further).

What is the message from this section of the paper? Given the results of the simple models estimated it would seem that deeper output recessions have important negative effects on the labour market. Avoidance of recessions may well be impossible, but avoidance of deep recessions in output would help to prevent deeper recessions in unemployment and employment.

8 Conclusions

This paper has used the BDS test and the triples test to examine whether key Australian labour market variables exhibit significant nonlinearity and two forms of cyclical asymmetry, steepness, or difference asymmetry, and deepness, or level asymmetry. Results from the BDS tests suggest that omitted nonlinearity of some form or other appears to be a fairly ubiquitous feature of linear ARIMA modeling of Australian macroeconomic time series. However, no evidence is found of deepness in any of the series examined. Employment, unemployment and the CPI are found to exhibit steepness (at conventional significance levels). Employment falls faster than it rises over the cycle whilst unemployment and the CPI rise faster than they fall.

To further investigate the possible nature of economically interesting asymmetries, measures of the Current Depth of Recession, CDR_t , and Overheating, OH_t , are constructed, following Beaudry and Koop (1993), Parker and Rothman (1998) and Pesaran and Potter (1997), for employment and unemployment. The CDR variable is intended to capture information concerning peak-reverting behaviour in the data. Information about *relative levels* of employment and unemployment, not captured in linear models, could be useful in determining the pace of economic recovery - the growth performance of the variables will depend on the size of recent shocks to the level of the variables. In particular, if the current depth of recession matters, large negative shocks to employment lead to predictions of high employment growth until the previous peak employment level is achieved. Similarly, large positive shocks to unemployment (raising the unemployment rate) should lead to predictions of rapid declines in the unemployment rate until the previous trough unemployment level is achieved.

The ceiling or overheating effect captures asymmetries in business cycle peaks. Relating this to employment (unemployment) rather than output suggests that if employment grows (unemployment falls) faster than some threshold value for a number of successive periods then it is more likely that positive shocks will have a smaller (larger) effect on employment (unemployment) growth than will negative shocks. This overheating effect is suggestive of some sort of '*speed limits*' to employment growth and to the decline in the unemployment rate.

The evidence provided here suggests that these kinds of CDR related rapid recovery effects are *not* a feature of the Australian labour market. These results contrast with those of Parker and Rothman (1998) who found a significant CDR effect in US unemployment data. What does seem to occur is that the labour market exhibits tendencies to overheat if it grows

(employment rises, unemployment falls) too quickly. This result accords quite strongly with the results of Koop and Potter (1999) who find that shocks which lower the US unemployment rate tend to have a smaller effect than shocks which raise the unemployment rate. These relatively simple nonlinear reduced form models in the TAR class of models indicate that important nonlinearities do exist in the Australian labour market in both employment and unemployment and allow a fuller understanding of Australian labour force dynamics than would linear models. The findings presented suggest important asymmetries in persistence and speed of adjustment over the cycle. These asymmetries can be rationalised through the search and matching literatures, the literature on job creation and job destruction and on hysteresis and insiders-outsiders, all of which suggest conditions under which such important asymmetries can and might arise.

Finally, the paper examined a simple relationship between the state of the business cycle (GDP) and the state of the labour market. It did this by examining whether the depth of output recessions matters for the depth of labour market recessions. There seems to be clear evidence that this is the case using some simple reduced form models and Granger causality tests. This helps put some empirical evidence behind the idea that whilst avoidance of recessions may well be impossible, avoidance of deep recessions in output is very desirable as this would help to prevent very deep recessions in unemployment and employment.

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10 Appendix 1 - Employment, Unemployment and the Real Wage - Some Pictures

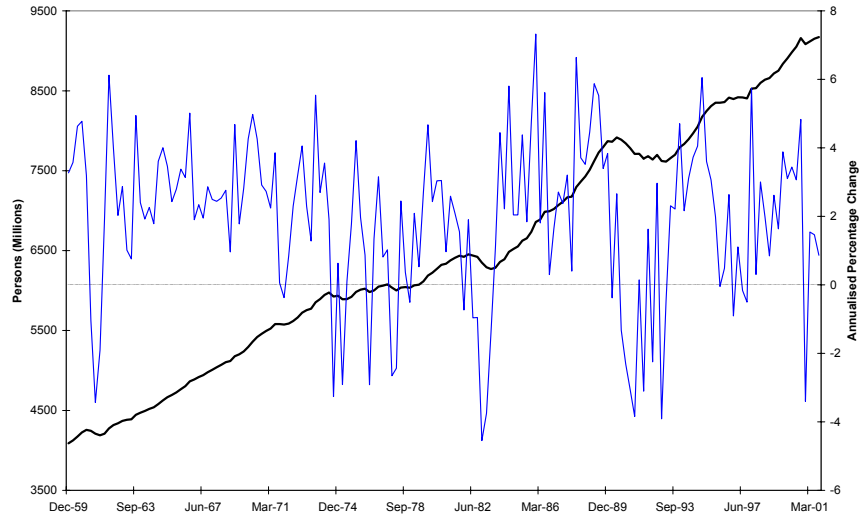


Figure A1.1 Australian Employment (Total Civilian) and Employment Growth [1959:4 - 2001:3]

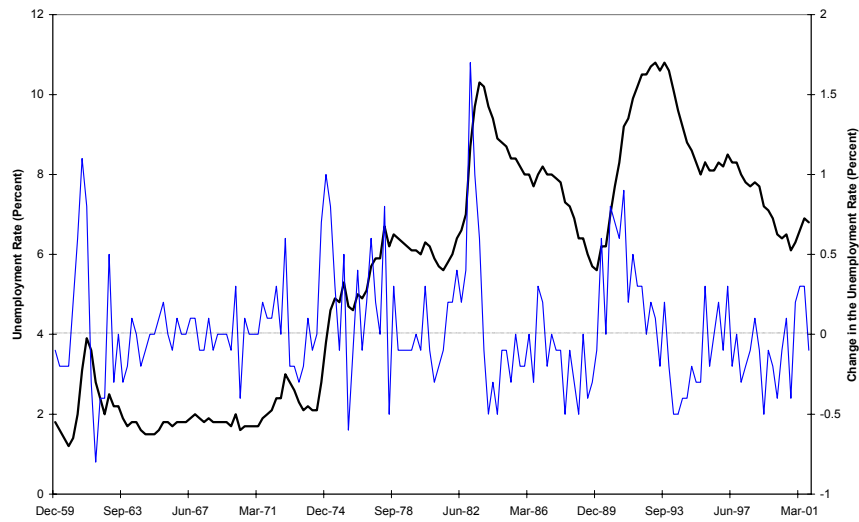


Figure A1. 2 Australian Unemployment and the Change in Unemployment (Percent) [1959:4 - 2001:3]

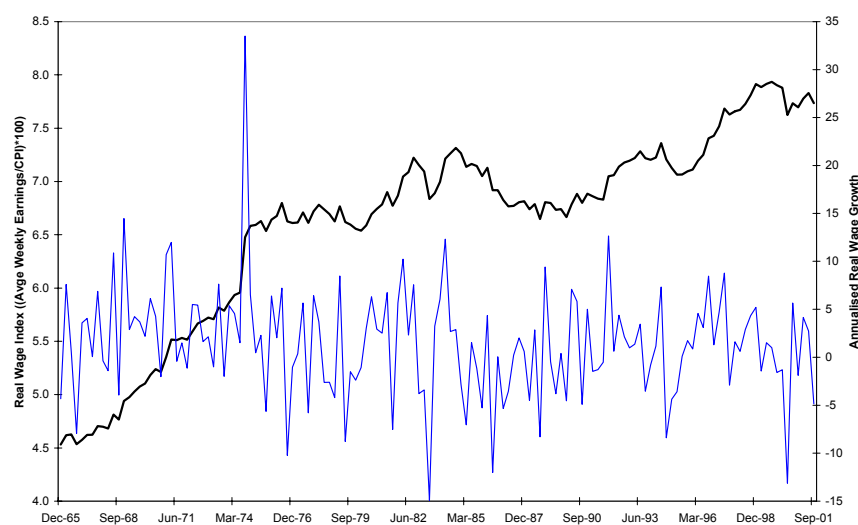


Figure A1.3 Australian Real Wages and Real Wage Growth
[1965:4 - 2001:3]

11 Appendix 2

11.1 The BDS test

Brock *et al* (1996) have developed a statistical test of whiteness versus an unspecified nonlinear alternative. This so-called BDS statistic is based on the correlation function (a.k.a. the correlation integral) and tests the null hypothesis that a time series is i.i.d. against a variety of alternatives that exhibit non-random structure (general dependence). In contrast to many other traditional tests for persistence, the test has power against nonlinear alternatives (See Brock *et al* (1991)). Barnett *et al.* (1997) confirm the excellent power properties of the BDS test against a vast class of nonlinear alternatives, although they note that the general nature of the alternative implies that other tests, such as the Hinich (1982) test or the Lyapunov Exponent tests for chaos should be employed to narrow down the class of possible nonlinear models further.

The BDS statistic is based on the m^{th} correlation integral which represents the fraction of all possible pairs of m consecutive points of the series that are closer than $\epsilon > 0$ to each other. Closeness to each other is defined

by the Euclidean norm. If we let N denote the number of observations, $C_{m,N}(\epsilon)$ the m^{th} correlation integral and $\sigma_{m,N}(\epsilon)$ an estimate of the standard deviation under the null hypothesis, then the BDS test statistic is

$$W_{m,N}(\epsilon) = \sqrt{N} \frac{C_{m,N}(\epsilon) - C_{1,N}(\epsilon)^m}{\sigma_{m,N}(\epsilon)}$$

The null distribution of the BDS statistic depends on the two nuisance parameters, embedding dimension m and proportionality factors ϵ . m , the embedding dimension, is the dimension of the histories used to calculate the correlation integral, that measures the proportion of the m -dimensional points which are ϵ -close to each other according to the supnorm principle. (See Brock *et al* (1991) or Brock *et al* (1996) for further technical details.) BDS tests are presented for embedding dimensions $m = 4$ and proportionality factors ϵ chosen as the standard deviation of the residual series. Like the correlation functions, on which the tests are based, the BDS statistics are asymptotically distributed $N(0, 1)$ if the (residual) series is an i.i.d. process, although Brock *et al* (1991) show that the BDS test can exhibit serious size distortion. The asymptotic distribution may be a poor approximation for finite samples and the appropriate critical values may be much larger in finite samples. The appropriateness of the asymptotic distribution for all of the BDS test statistics presented in the paper was verified through simple bootstrap experiments (10,000 replications, using the parameters from the estimated ARIMA model and sampling with replacement from the associated ARIMA residuals). In all cases the distributional assumptions appeared valid.

12 Appendix 3

12.1 The HP filter

Given the classical decomposition of a time series X_t as

$$X_t = \tau_t + c_t + \epsilon_t$$

with τ_t the nonstationary trend component, c_t the cyclical component and $\epsilon_t \sim N(0, \sigma_\mu^2)$ the irregular component, then the HP filter chooses τ_t to satisfy

$$\min \sum_t \{(X_t - \tau_t)^2 + \lambda[(1 - L)^2 \tau_t]^2\}$$

where L is the lag operator and λ is the smoothness parameter reflecting the ratio of the variance of c_t to the variance of τ_t , usually chosen to be 1600 in quarterly data applications. The first term in the HP filter represents the degree of fit between the series and its estimated trend whilst the second part represents the degree of smoothness in the trend. λ represents the judgment made a priori about the relative weight desired between fit and degree of smoothness.

Of course the HP filter is also known to statisticians as the cubic smoothing spline and to actuaries as the Whitaker-Henderson Type A smoother.

Given recent criticisms of the HP filter (and similarly of the band pass filter introduced by Baxter and King (1995) - that it tends to induce spurious dynamic properties to the data and extracts a cyclical component that fails to capture a significant fraction of the variance contained in business cycle frequencies (see Guay and St-Amant (1997) and Harvey and Jaeger (1993)) - the robustness of the tests for level asymmetry to such filtering was examined using other filters such as the Beveridge and Nelson decomposition and even simple linear filters (linear time trend, first difference operator), as well as other choices for λ , the weight in the HP filter. Results are not reported here for purposes of brevity but are available from the author upon request. The results reported in the paper were found to be fairly robust to the choice of the HP filter with standard $\lambda = 1600$ weight, although application of simple linear filters was of course not appropriate in many cases as the resulting cyclical component of the series was not trendless (stationary). Filtering out a linear time trend from the GDP series, for example, does leave a cyclical component that exhibits very marked cyclical asymmetries.

13 Appendix 4

13.1 The triples test

Verbrugge (1997) demonstrates that the triples test has significant advantages over moment based tests in that it cannot be dominated by outliers and as such is not subject to the kind of small sample bias highlighted by Bryan and Cecchetti (1996). For example, consider a standard normal random variable X and suppose we observe 20 realisations of the variable that are centred around the mean (0 in the case of the symmetric, standardised Gaussian distribution), then assume we get a complete outlier draw such as $X=2,000,000!$ The standard, moment-based skewness test will strongly suggest extreme asymmetry in the underlying distribution, whereas the triples test weights that outlier appropriately such that it does not bias the test

towards the ‘wrong’ result. An alternative case might be that the distribution of some random variable (time series in this case) is actually negatively skewed but a large positive outlier biases the moment-based skewness test towards finding symmetry. Again the triples test would weight the positive realisation accordingly and the test would reject symmetry.

A triple of observations (X_i, X_j, X_k) is a right triple (is skewed to the right) if the middle observation is closer to the smaller observation than to the larger observation.

Let

$$f^*(X_i, X_j, X_k) = [\text{sign}(X_i + X_j - 2X_k) + \text{sign}(X_i + X_k - 2X_j) + \text{sign}(X_j + X_k - 2X_i)]/3$$

where $\text{sign}(a) = -1, 0$ or $+1$ as $a <, =,$ or > 0 . $f^*(X_i, X_j, X_k)$ can only take on the values $-\frac{1}{3}, 0, \frac{1}{3}$. A *right triple* is one for which $f^*(X_i, X_j, X_k) = \frac{1}{3}$ and which ‘looks skewed to the right.’ Analogously, a left triple is one which maps into $-\frac{1}{3}$.

The triples U statistic is given by

$$\hat{\eta} = \binom{N}{3}^{-1} \sum_{i < j < k} f^*(X_i, X_j, X_k)$$

such that

$$\hat{\eta} = [(\text{number of right triples}) - (\text{number of left triples})] / 3 \binom{N}{3}$$

Randles et al (1980) show then that the test statistic given as

$$\frac{\hat{\eta} - \eta}{\sqrt{\hat{\sigma}_\eta^2 / N}}$$

has a limiting distribution that is normal with mean zero and variance one, $N(0, 1)$, so that conventional critical values can be used, and where $\hat{\sigma}_\eta^2$ is estimated by

$$\hat{\sigma}_\eta^2 = \frac{1}{\binom{N}{3}} \sum_{c=1}^3 \binom{3}{c} \binom{N-3}{3-c} \hat{\zeta}_c$$

where

$$\begin{aligned} \hat{\zeta}_1 &= \frac{1}{N} \sum_{i=1}^N (f_1^*(X_i) - \hat{\eta})^2 \\ \text{with } f_1^*(X_i) &= \frac{1}{\binom{N-1}{2}} \sum_{\substack{j < k \\ i \neq k, j \neq k}} f^*(X_i, X_j, X_k) \\ \hat{\zeta}_2 &= \frac{1}{\binom{N}{2}} \sum_{j < k} (f_2^*(X_j, X_k) - \hat{\eta})^2 \\ \text{with } f_2^*(X_j, X_k) &= \frac{1}{N-2} \sum_{\substack{i=1 \\ i \neq j \neq k}} f(X_i, X_j, X_k) \end{aligned}$$

$$\hat{\zeta}_3 = \frac{1}{9} - \hat{\eta}^2$$

The null hypothesis is $H_0 : \eta = 0$ versus the alternative $H_1 : \eta \neq 0$, or possible a one sided alternative.

14 Appendix 5 : Is New Zealand Different from Australia?

This appendix contains some preliminary analysis of data for New Zealand.

14.1 Data

The economic time series investigated here are the natural logarithms of the New Zealand, quarterly, seasonally adjusted real GDP, total employment, nominal wages (average ordinary time earnings), the CPI and real wages (average earnings / CPI) over the period 1970:1-2001:3 and the unemployment rate (total, persons, seasonally adjusted) over the period 1970:1-2001:3. Data series were obtained from various databases in the dX Database augmented with data supplied by the RBNZ and Dr Peter Summers of the Melbourne Institute.

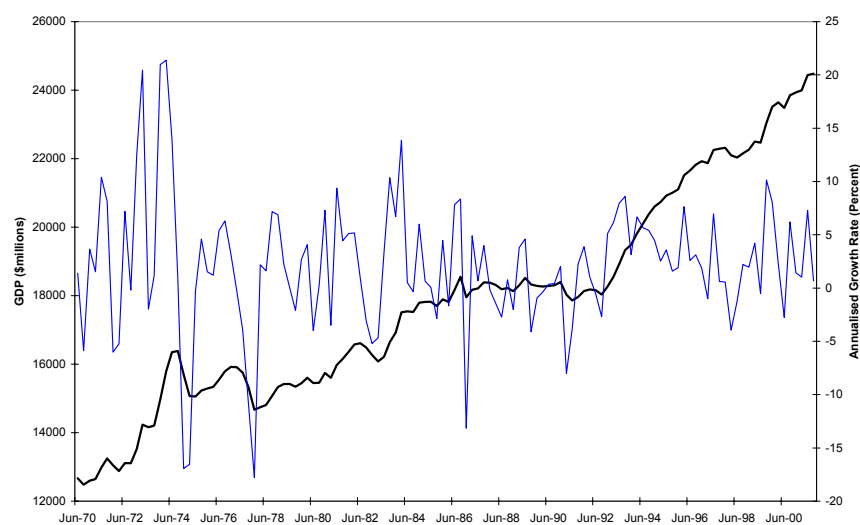


Figure A5.1 New Zealand GDP and Annualised Growth Rate [1970:1-2001:3]

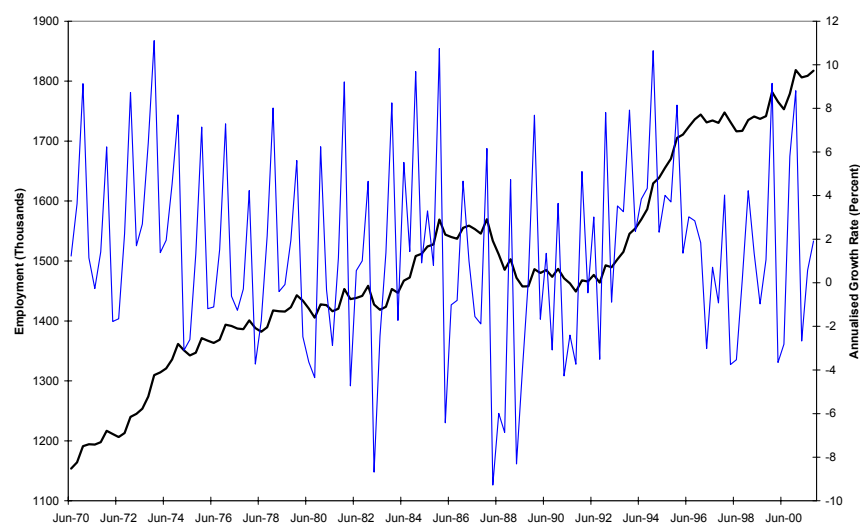


Figure A5.2 New Zealand Employment (Seas unadj.) and Annualised Growth Rate [1970:1-2001:3]

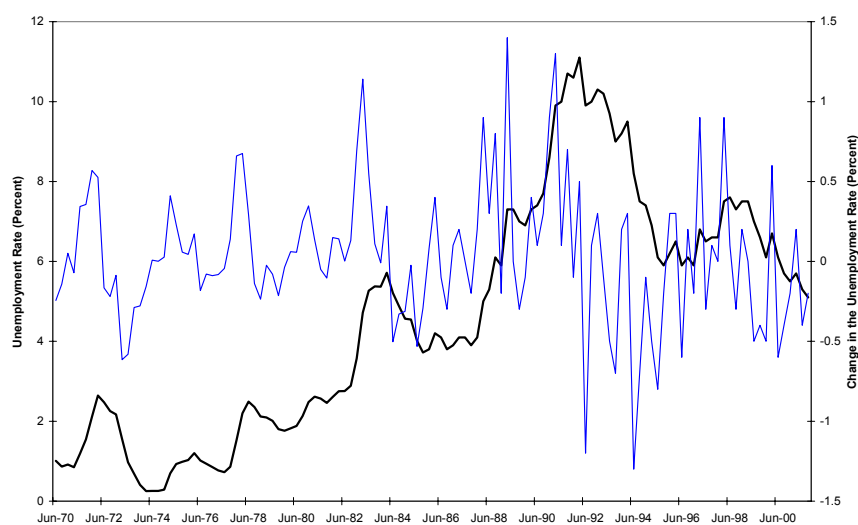


Figure A5.3 New Zealand Unemployment (Seas unadj.) and Annualised Growth Rate [1970:1-2001:3]

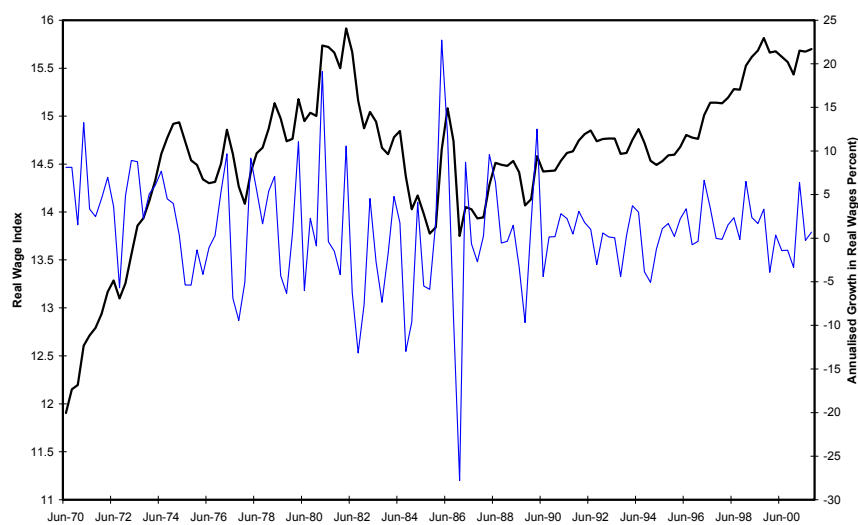


Figure A5.4 New Zealand Real Wage Index and Annualised Growth Rate [1970:1-2001:3]

14.2 ARIMA and BDS

As in the body of the paper, the first step is to specify the best-fitting ARIMA model for each series, including tests for ARCH and incorporating ARCH or GARCH effects if found. The procedure is then to test the residuals for residual nonlinearities using the BDS test. For New Zealand data the models and tests are as follows:

Table 1A
BDS tests - New Zealand

	ADF(lags)	ARIMA(p,d,q)	GARCH(p,q)	BDS (p-value)
GDP	-0.717(1)	(0, 1, 1)	<i>GARCH</i> (1, 1)	4.561(0.000)
Unemployment	-1.999(4)	(4, 1, 0)*	<i>No</i>	5.005(0.000)
Employment	-0.903(2)	(2, 1, 0)	<i>No</i>	0.606(0.545)
Real Wages	-3.502(2)	(2, 1, 0)	<i>No</i>	5.097(0.000)

* Note: these models also included a significant seasonal MA term.

GDP, unemployment and employment all appear to contain stochastic trends. Again GDP data contains significant GARCH components. Real wages appear to be stationary in log levels. Once filtered using apparently appropriate linear models, BDS tests indicate that significant omitted nonlinearities are present for GDP, unemployment and real wage data. The BDS test statistic is not significant for employment data.

14.3 Triples Tests for Deepness and Steepness

Are the nonlinearities indicated by the BDS tests of the form of steepness and deepness asymmetries? Once again, triples tests were performed on the cyclical components of the series derived using the HP filter. Results are presented in Table 2A.

Table 2A
Deepness and Steepness (triples) tests - New Zealand

	Deepness ($\hat{\eta}$)	(p-value)	steepness ($\hat{\eta}$)	(p-value)
GDP	-0.018	(0.09)	-0.007	(0.62)
Unemployment	0.014	(0.62)	+0.023	(0.28)
Real Wages	+0.011	(0.52)	+0.008	(0.63)

Neither steepness or deepness asymmetries are indicated for any of the series as determined by the insignificance of the triples tests at conventional significance levels. The search for the source of asymmetries / nonlinearities will have to rest elsewhere with other tests and models.

14.4 Asymmetries in Okun's Law for New Zealand (and Australia)

Lee (2000) examined various issues concerning the robustness of Okun's Law, a relationship between output growth and unemployment changes) for several OECD countries. In particular he provided a simple analysis of whether unemployment changes have asymmetric effects on output growth, dependant on whether the changes were positive or negative.

This section extends this part of the Lee (2000) analysis to New Zealand data and provides a comparison with the evidence from updated Australian data. To remain consistent with the Lee analysis and with standard textbook estimates of Okun's Law, the analysis is carried out for annual data, derived from the quarterly data used in the rest of the paper.

The first step is to analysis simple Okun's Law relationships for New Zealand and Australia. Okun's Law has generally been analysed using one of two forms of the relationship between output and unemployment:

1. The first difference model:

$$\Delta y_t = \beta_0 + \beta_1 \Delta x_t + \varepsilon_t \quad \beta_1 < 0$$

2. The 'gap' model

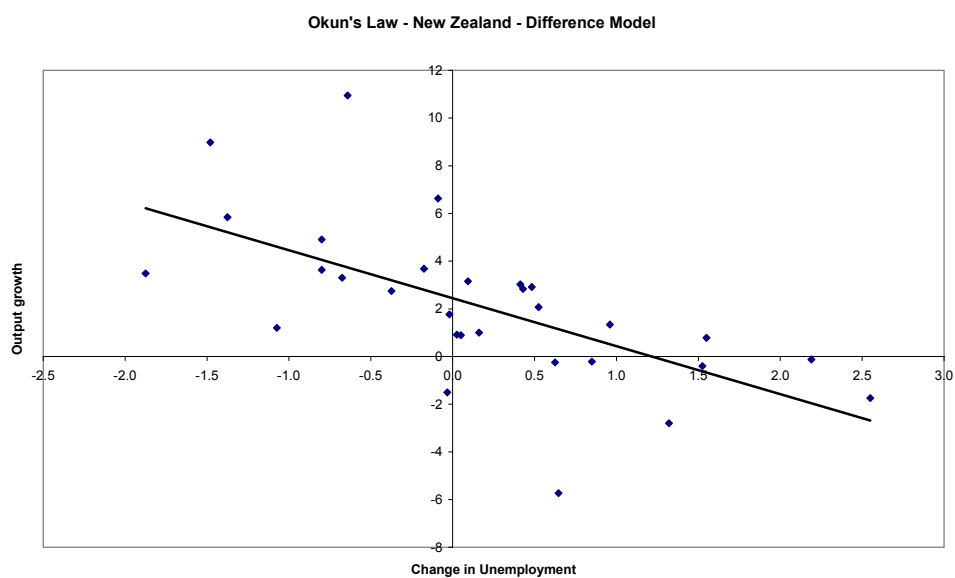
$$y_t - y_t^* = \beta_1 (x_t - x_t^*) + \varepsilon_t \quad \beta_1 < 0$$

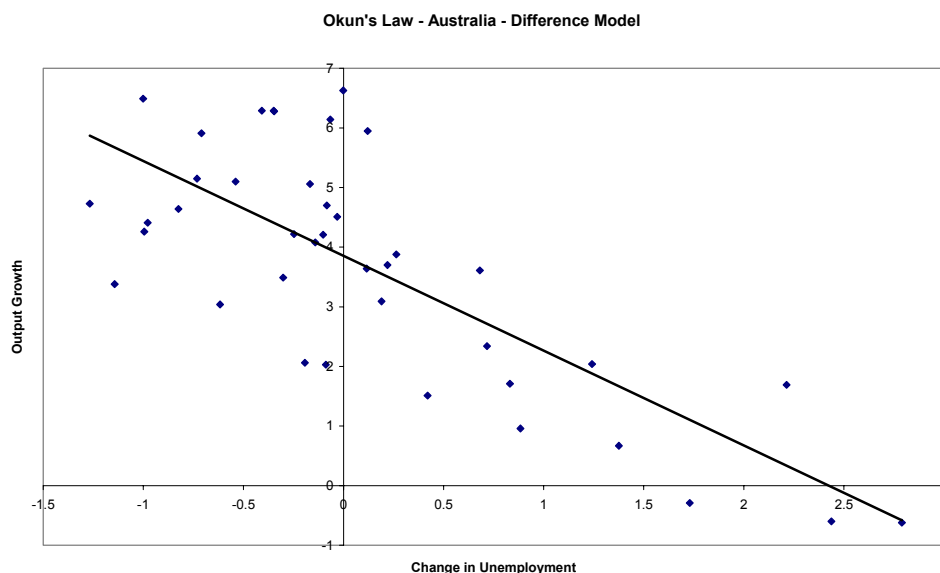
where y_t^* and x_t^* are estimates of the trend and natural rate in the output (log level) and unemployment rate series respectively. Generally unemployment has been used as the explanatory variable x_t in these models. However, when testing for asymmetries, it is of interest to run the regressions with unemployment as the dependent variable instead. Results for the first difference model are reported in what follows (noting that no qualitative difference in results was obtained using the gap model). Note that no lags are included in the specifications (unlike the analysis for quarterly data in section 7) because of the low frequency of the data and because none were found to be significant in practice.

Estimation of these simple models using annual data over the period 1971-2000 for New Zealand and 1961-2000 for Australia suggests the following results (using output as the dependent variable, Newey West standard errors in parentheses. Bolded numbers represent significance at the 10 percent level):

Table A5.1

New Zealand		
First Difference Model	$\hat{\beta}_0$	$\hat{\beta}_1$
Δy_t	2.463	-2.025
	(0.501)	(0.534)
R squared = 0.389		
SBC = 4.977		
Australia		
First Difference Model	$\hat{\beta}_0$	$\hat{\beta}_1$
Δy_t	3.906	-1.629
	(0.279)	(0.202)
R squared = 0.604		
SBC = 3.490		





For New Zealand this implies the simple familiar textbook specification of Okun's Law to be:

$$\Delta u_t = -0.494(\Delta y_t - 2.463)$$

For Australia this implies :

$$\Delta u_t = -0.614(\Delta y_t - 3.906)$$

One extra point of unemployment costs around 1.6 percent of GDP in Australia and around 2 percent of GDP in New Zealand.

To examine whether these Okun coefficients are sensitive to the existence of simple asymmetries, the Okun equations are now augmented to allow for different effects of non-negative and negative values of unemployment changes. Similarly, the equations are reversed, with unemployment change the dependent variable, to examine whether GDP growth has asymmetric effects on the change in unemployment rate. Specifically:

$$\Delta y_t = \beta_0 + \beta_1^+ I_t^+ \Delta u_t + \beta_1^- I_t^- \Delta u_t + \varepsilon_t \quad \hat{\beta}_1^+, \hat{\beta}_1^- < 0$$

$$\Delta u_t = \beta_0 + \beta_1^+ I_t^+ \Delta y_t + \beta_1^- I_t^- \Delta y_t + \varepsilon_t \quad \hat{\beta}_1^+, \hat{\beta}_1^- < 0$$

where I_t is the Heavside indicator function such that

$$I_t^+ = \begin{cases} 1 & \text{if } \Delta y_t, \Delta u_t \geq 0 \\ 0 & \text{if } \Delta y_t, \Delta u_t < 0 \end{cases}$$

$$I_t^- = \begin{cases} 1 & \text{if } \Delta y_t, \Delta u_t > 0 \\ 0 & \text{if } \Delta y_t, \Delta u_t \leq 0 \end{cases}$$

Results from the estimation of these models for both countries are reported in the following table together with p-values from Wald tests for the equality $\hat{\beta}_1^+ = \hat{\beta}_1^-$. (Newey West standard errors in parentheses. Bolded numbers represent significance at the 10 percent level).

Table A5.2

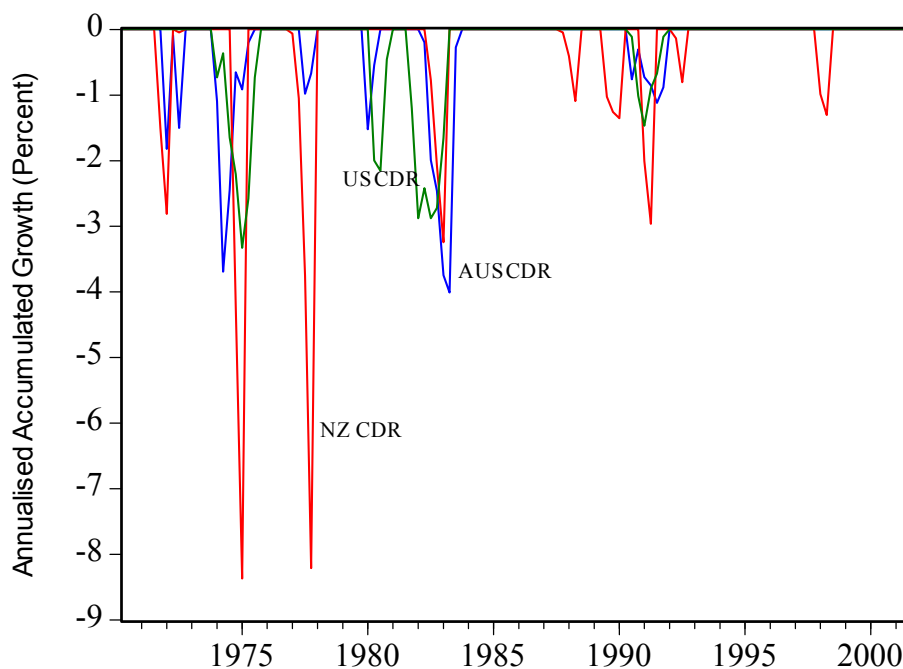
New Zealand				
First Difference Model	$\hat{\beta}_0$	$\hat{\beta}_1^+$	$\hat{\beta}_1^-$	Wald Test
Δy_t	2.181	-1.725	-2.474	0.598
	(0.640)	(0.359)	(1.302)	
R squared = 0.395				
SBC = 5.084				
Δu_t	0.727	-0.225	-0.081	0.104
	(0.217)	(0.058)	(0.094)	
R squared = 0.406				
SBC = 2.712				
Australia				
First Difference Model	$\hat{\beta}_0$	$\hat{\beta}_1^+$	$\hat{\beta}_1^-$	Wald Test
Δy_t	4.353	-2.029	-0.609	0.119
	(0.437)	(0.320)	(0.662)	
R squared = 0.604				
SBC = 3.490				
Δu_t	1.092	-0.282	-2.468	0.000
	(0.259)	(0.062)	0.515)	
R squared = 0.672				
SBC = 1.914				

For New Zealand, there is no evidence of asymmetry between the effects of positive and negative changes in unemployment on the GDP growth rate. The signs of the coefficients are in the expected direction and both types of shocks are significant, but the Wald test suggests the effects of unemployment changes are of equal magnitude whether they are positive or negative. Using unemployment as the dependent variable, however, does imply asymmetry in the effects of positive versus negative GDP growth movements. Whilst the Wald test suggests that the magnitude of the coefficients on positive GDP growth is not significantly different from that on negative GDP growth, the Okun coefficient is significantly different from 0 for positive GDP growth only. Positive growth in GDP lowers the unemployment rate whilst negative growth in GDP does not raise the unemployment rate significantly.

For Australia the evidence of asymmetry is even stronger. Using GDP growth as the dependent variable we find that increases in unemployment lower GDP growth significantly whilst decreases in unemployment have an effect of statistically similar magnitude in the opposite direction but this effect is not significant at conventional significance levels. Using unemployment changes as the dependent variable we find that both positive and negative GDP growth affects the unemployment rate but that the effects of negative growth are statistically much greater, around 9 times greater, than the effects of positive growth.

14.5 Does the Australian CDR ‘Cause’ the New Zealand CDR or Is It All the US?

One last question of potential interest addressed briefly here is the relationship between the depth of the New Zealand recessions (rather than the incidence of New Zealand recessions) and the depth of recessions in Australia. A related question is whether it is only the US depth of recession that actually matters for New Zealand recessions and not the state of the Australian economy.



This is examined using simple Granger causality analysis. The basic idea is to run regressions of the form:

$$CDR_t^{NZ} = \mu + \sum_{i=1}^2 \alpha_i CDR_{t-i}^{NZ} + \sum_{j=1}^2 \beta_j CDR_{t-j}^{AUS} + \sum_{k=1}^2 \gamma_k CDR_{t-k}^{US}$$

and test whether the CDR_{t-j}^{AUS} have an independent significant effect by testing the null hypothesis that $\beta_j = 0 \forall j$ using an F-test.

The preliminary results from this investigation are presented in Table A5.3 below.

Table A5.3
GDP CDR Granger Causality Tests

Null Hypothesis	p-value	
AUS CDR does not Granger Cause NZ CDR	0.038	$\sum_{j=1}^2 \beta_j > 0$
US CDR does not Granger Cause NZ CDR	0.137	$\sum_{k=1}^2 \gamma_k > 0$

Simple bivariate Granger causality tests (not reported) indicate that both the Australian and US CDR affect the New Zealand CDR. However, in the trivariate VAR specification as estimated here, the US CDR does not have a significant direct effect on the New Zealand CDR. It is the Australian CDR that helps determine the NZ CDR. Given that the US CDR does affect the AUS CDR significantly however, we can say that the US CDR will affect the NZ CDR indirectly through the Australian CDR.

15 Appendix 6 : Male versus Female Unemployment & Full-Time versus Part-Time Employment

The analysis in the body of the paper relies on aggregate Australian data for total employment and the unemployment rate for all persons. This appendix provides some preliminary evidence for Australia looking at male versus female unemployment rate and full-time versus part-time employment rates in order to gauge some possible driving factors in the findings of nonlinearities and asymmetries in the aggregate series.

First the linear ARIMA models and BDS tests:

Table A6A
BDS tests

	ADF(lags)	ARIMA(p,d,q)	GARCH(p,q)	BDS (p-value)
Male u_t	-2.614(1)	(1, 1, 0)	<i>ARCH</i> (1)	3.314(0.012)
Female u_t	-3.166(3)	(3, 1, 0)	<i>No</i>	0.753(0.452)
Full-time E_t	-1.362(1)	(1, 1, 0)	<i>No</i>	1.816(0.069)
Part-time E_t	-0.358(0)	(0, 1, 0)	<i>No</i>	0.813(0.379)

Note: appropriate lag length was chosen in the ADF tests and ARIMA models using the AIC and SBC and analysis of residuals. Critical values for the ADF tests were chosen according to whether a linear time trend or a constant was included in the test regression (See Enders (1995) for a rigorous methodology for performing these tests and modelling procedures. A bolded number indicates significance at the 5% level.

The evidence presented in Table 1B suggests that the male unemployment rate and the full-time employment rate both exhibit omitted nonlinearity not captured by linear models (even if ARCH or GARCH are allowed for). Female unemployment and part-time employment show no evidence of nonlinearity.

The test for deepness and steepness in HP filtered data are as follows:

Table A6B
Deepness and Steepness (triples) tests

	Deepness ($\hat{\eta}$)	(p-value)	steepness ($\hat{\eta}$)	(p-value)
Male u_t	0.009	(0.57)	0.032	(0.08)
Female u_t	-0.012	(0.42)	-0.001	(0.94)
Full-time E_t	0.013	(0.41)	-0.039	(0.02)
Part-time E_t	-0.022	(0.17)	-0.003	(0.89)

The deepness and steepness triples tests indicate that male unemployment exhibits positive steepness - it rises more rapidly than it falls over the cycle. Full-time employment exhibits strong evidence of negative steepness - it falls much faster than it rises over the cycle.

It would appear that the source of at least some of the asymmetric adjustment in the Australian labour market can be attributed to the adjustment in male, full-time employment.