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Asymmetric Adjustment of Unemployment and Output in New Zealand: Rediscovering Okun's Law

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Abstract

Okun's law - the relationship between unemployment and output - is one of the best known empirical regularities in macroeconomics. It is an important relationship because the way in which unemployment reacts to changes in output has implications for labour market and monetary policies and for forecasting. Most specifications of Okun's law assume a symmetric relationship: expansions and contractions in output have the same absolute effect on unemployment. In this paper, we test this assumption against the alternative view that the relationship is asymmetric. We use New Zealand data from 1978 to 1999 and contemporary econometric techniques including asymmetric modelling. Our main finding is that changes in unemployment and output in New Zealand are related in both the long run and the short run but only if an asymmetric approach is taken.

Key Words

Okun's law; asymmetric modelling; unemployment and output; New Zealand

JEL Codes

C22, E32

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1. Introduction

Okun’s law - the relationship between unemployment and output - is one of the best known empirical regularities in macroeconomics (Okun 1962). It is an important relationship because the way in which unemployment reacts to changes in output has implications for labour market and monetary policies and for forecasting. Okun equations have been estimated for many countries. (See, for example, Attfield and Silverstone 1998, Kaufman 1988, Moosa 1997, Palley 1993 and Prachowny 1993 and Weber 1995).

Most specifications of Okun's law assume a symmetric relationship, that is, expansions and contractions in output have the same absolute effect on unemployment. In this paper, we test this assumption against the alternative view that the relationship is asymmetric. We use New Zealand data from 1978 to 1999 and contemporary econometric techniques including asymmetric modelling. Our main finding is that changes in unemployment and output in New Zealand are related in both the long run and the short run but only if an asymmetric approach is taken. Sections 2 and 3 outline Okun’s law and its estimation, respectively. Section 4, 5 and 6 test for asymmetry, unit roots and cointegration while Section 7 provides estimates of the error-correction model. Section 8 concludes the paper.

2. Okun’s Law

A typical textbook presentation of Okun’s law is:

$$\Delta U = a + b\frac{\Delta Y}{Y} \qquad b < 0 \tag{1}$$

where

ΔU = annual percentage point change in the unemployment rate

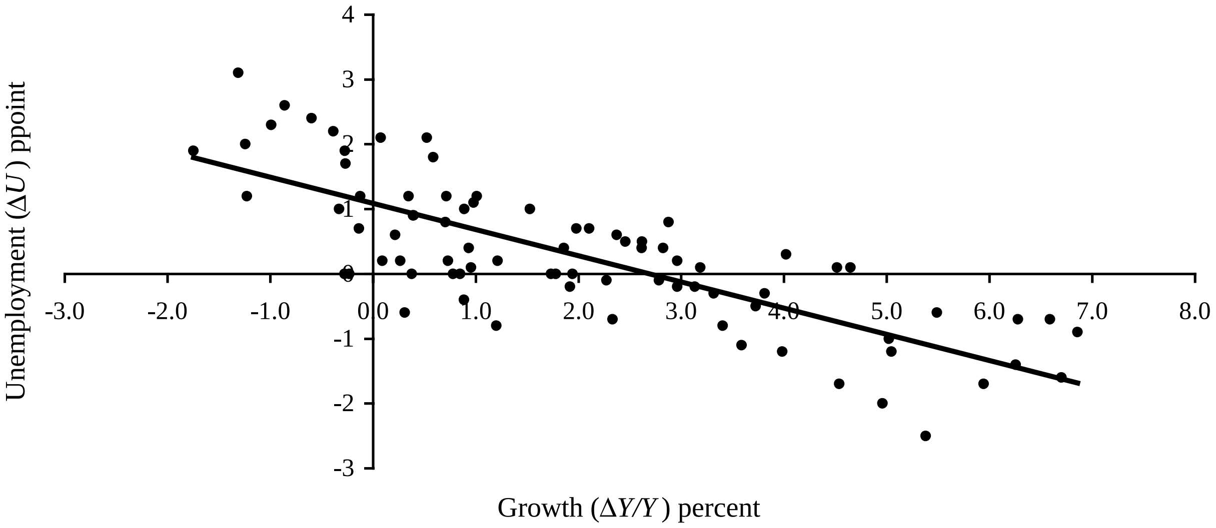
$\Delta Y/Y$ = annual percentage change in real output.

Figure 1 is a scatter plot of ΔU against $\Delta Y/Y$ using quarterly New Zealand data for the 20 year period from 1979:1 to 1999:1. Equation 2 is an OLS estimate of equation 1 (where the brackets enclose the *t*-statistic). It is illustrated as the trend line in Figure 1.

$$\Delta U = 1.1 - \underset{(11.2)}{0.4}\frac{\Delta Y}{Y} \qquad R^2 = 0.61 \tag{2}$$

Several insights are typically drawn from equation 2 and Figure 1. The most important insight relates to *b* or ‘Okun’s coefficient’. It says that a one percent change in output is associated inversely with a 0.4 percentage point change in unemployment. Equation 2 also indicates that in the absence of output growth, unemployment will increase around one percentage point, while the rate of growth required to prevent unemployment from rising is around 2.75 percent.

Figure 1. Unemployment and Output in New Zealand 1979-99
Annual Changes, Seasonally Adjusted



Source: Data Appendix.

The reason for the less than proportionate change in (un)employment, argued Okun, is that changes in output are also associated with changes in participation, labour hours and capital utilisation. Prachowny (1993), using a production function in natural logs, shows that Okun's argument can be derived from a production function whereby either employment or unemployment (the labour force divided by employment) enters the function. In particular, let

$$\begin{aligned} y_t &= \alpha(k_t + c_t) + \beta(\gamma n_t + \delta h_t) + \tau_t + \varepsilon_t \\ &= \alpha(k_t + c_t) + \beta[\gamma(l_t - u_t) + \delta h_t] + \tau_t + \varepsilon_t \end{aligned} \tag{3}$$

where

y = real output
k = capital input
c = capital utilisation
n = number of workers (labour force less number unemployed)
h = average hours worked
l = labour force
u = unemployment rate (l-n)
τ = disembodied technological progress
$\gamma, \delta, \alpha, \beta$ output elasticities
ε = error term.

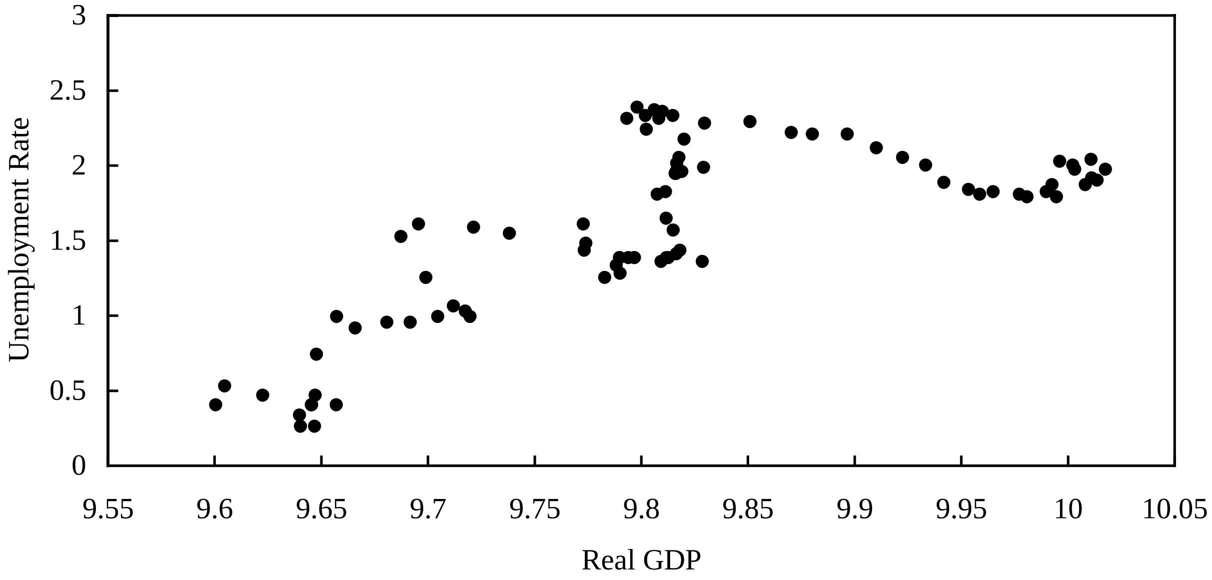
Equation 3 shows that labour services has three components: the labour force (l_t), the unemployment rate (u_t) and hours worked (h_t). The substance of Okun's law is to say that co-movements in output (y_t) and unemployment dominate any adjustment in capital and its utilisation ($k_t + c_t$), the labour force, hours worked and technological progress (τ_t). Okun's relationship, as specified by Prachowny, comprises a long run and a short run, while Attfield and Silverstone (1998) show that Okun's coefficient can be interpreted as the slope coefficient in the cointegrating regression between output and unemployment.

3. The Basic Approach to Estimation

Figure 2 shows the log of the quarterly unemployment rate (log u) against the log of real output (log y) between 1978 and 1999. The relationship is clearly non-linear.

Figure 2. Unemployment and Real Output in New Zealand 1978-99

Natural Log Scales, Quarterly, Seasonally Adjusted



Source: Data Appendix.

Since log u and log y (hereafter u and y) are potentially non-stationary variables, the relationship between them has to be estimated using the cointegration approach. This presupposes that there is a long-run and a short-run relationship between the variables which, given that n = 2, implies that there is, at most, a single long-run relationship between u and y, that is:

$$u_t = \beta_0 + \beta_1 y_t + \beta_2 t + \varepsilon_t \tag{4}$$

where the time trend (t) is included to take account of long-run linear growth which the model cannot explain. (One reason for putting u_t on the far left of equation 4 is that subsequent tests establish that y_t is weakly exogenous). Assuming u_t and y_t are both $I(1)$, then Engle and Granger (1987) show that cointegration exists if $\varepsilon_t \sim I(0)$. The long-run model set out in equation 4 is associated with a short-run error-correction model (ECM) based on symmetric adjustment, with the second-step Engle-Granger test for cointegration based on the OLS estimate of ρ in the following regression equation:

$$\Delta\hat{\varepsilon}_t = \rho\hat{\varepsilon}_{t-1} + \upsilon_t \qquad \upsilon_t \sim IID(0,\sigma^2) \tag{5}$$

If the null hypothesis of no cointegration H_0: $\rho = 0$ can be rejected in favour of H_1: $\rho < 0$, then equations 4 and 5 jointly imply the following ECMs:

$$A(L)\Delta u_t = B(L)\Delta y_{t-1} - (1-\alpha_1)ec_{t-1} + \omega_t \qquad \omega_t \sim IID(0,\sigma^2) \tag{6a}$$

$$A(L)\Delta y_t = B(L)\Delta u_{t-1} - (1-\alpha_2)ec_{t-1} + \omega_t^* \qquad \omega_t^* \sim IID(0,\sigma^2) \tag{6b}$$

where

$$ec_{t-1} = \hat{\varepsilon}_{t-1} = u_{t-1} - \hat{\beta}_0 - \hat{\beta}_1 y_{t-1} - \hat{\beta}_2 t$$

and $A(L)$ and $B(L)$ are polynomial lag operators.

Equation 6 implies that any short-run changes in unemployment and output due to disequilibrium ($1-\alpha_i$) are strictly proportional to the absolute value of the error-correction term. If, however, adjustment to disequilibrium is asymmetric, then Enders and Granger (1998) and Enders and Siklos (1999) show that an alternative specification for equation 4 - called the threshold autoregressive (TAR) model - can be written as:

$$\Delta\hat{\varepsilon}_t = I_t\rho_1\hat{\varepsilon}_{t-1} + (1-I_t)\rho_2\hat{\varepsilon}_{t-1} + \upsilon_t^* \qquad \upsilon_t^* \sim IID(0,\sigma^2) \tag{7}$$

where I_t is the Heaviside indicator function based on the threshold value τ:

$$I_t = \begin{cases} 1 & if \quad \hat{\varepsilon}_{t-1} \geq \tau \\ 0 & if \quad \hat{\varepsilon}_{t-1} < \tau \end{cases} \tag{8}$$

The asymmetric version of the ECM, then, replaces the single error-correction term in equation 6 (ec_{t-1}) with two error-correction terms multiplied by I_t and ($1-I_t$) respectively.

Before proceeding to estimate the model implied by equations 4, 7 and 8, it is useful to test formally to see if u_t and y_t adjust in an asymmetric pattern with respect to the business cycle.

If our tests show that they are asymmetric, this will provide further evidence in favour of using the threshold adjustment model of cointegration. It will also ensure that our approach to estimating Okun's law is not misspecified.

4. Testing for Asymmetries in u_t and y_t

The method used to test for asymmetries is based on Sichel (1993). He uses a form of the test for skewness to consider if the detrended component of a time series variable exhibits 'deepness' and/or 'steepness' as opposed to following a symmetric pattern over the cycle. With 'deepness' there is an expectation that business cycle troughs will be deeper than cyclical peaks are tall (although the opposite is possible and can be tested). 'Steepness' occurs when business cycle contractions are steeper than expansions, although the form of this asymmetry can again be tested to see if expansions are steeper than contractions.

The method used to detrend each series follows Speight and McMillan (1998). They use the structural times-series (STM) approach of Harvey (1985) to decompose u_t and y_t into trend and cycle(s). Denoting the trend as u_t^* and y_t^*, it is possible to test $(u_t - u_t^*)$ and $(y_t - y_t^*)$ for asymmetries. Following Harvey (1995) and Koopman *et al.* (1995), a univariate time-series y_t can be modelled as:

$$y_t = \mu_t + \varphi_t + \varepsilon_t; \qquad \varepsilon_t \sim NID(0, \sigma_\varepsilon^2) \tag{9}$$

where μ_t is the trend and φ_t is the cycle. The seasonal component and (potential) first-order autoregressive components are omitted, the former since the data are seasonally-adjusted. The trend is specified in stochastic form with slope β_t that also can vary stochastically.

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t \qquad \eta_t \sim NID(0, \sigma_\eta^2) \tag{10}$$

$$\beta_t = \beta_{t-1} + \zeta_t \qquad \zeta_t \sim NID(0, \sigma_\zeta^2) \tag{11}$$

The cycle is given by

$$\begin{bmatrix} \varphi_t \\ \varphi_t^* \end{bmatrix} = \rho_\varphi \begin{bmatrix} \cos\lambda_c & \sin\lambda_c \\ -\sin\lambda_c & \cos\lambda_c \end{bmatrix} \begin{bmatrix} \varphi_{t-1} \\ \varphi_{t-1}^* \end{bmatrix} + \begin{bmatrix} \kappa_t \\ \kappa_t^* \end{bmatrix} \tag{12}$$

where $0 < \rho_\varphi \leq 1$ is a damping factor, λ_c is the frequency of the cycle in radians (where $2\pi/\lambda_c$ defines the period of the cycle). κ_t and κ_t^* are two mutually uncorrelated NID disturbances with zero mean and common variance, σ_κ^2.

The model hyperparameters ($\sigma_{\varepsilon}^2, \sigma_{\eta}^2, \sigma_{\xi}^2, \sigma_{\kappa}^2, \rho_{\phi}, \lambda_c$) can be estimated with STAMP (see Koopman *et al.* 1995) using the Kalman filter, with associated state space form used to construct estimates of the unobserved components (μ_t, φ_t, and β_t). The results for u_t and y_t, based on imposing no prior restrictions and using seasonally adjusted data from 1978:1 to 1999:1, are presented in Table 1. Figures 3 and 4 show actual unemployment and real output, respectively, and their associated STM and Hodrick-Prescott trends.

Table 1. Structural Time Series Estimates

Hyperparameters	Log Unemployment Rate[a] (u_t)	Log Real GDP[b] (y_t)
σ_{ε}^2 (×100)	2.7124	0
σ_{η}^2 (×100)	0	0
σ_{ξ}^2 (×100)	0.6895	0
Cycle 1		
σ_{κ}^2 (×100)	1.2698	0.1169
ρ_{φ}	0.9896	0.9647
λ_c	0.6015	1.1550
$2\pi/4\lambda_c$ (in years)	2.6115	1.3600
Cycle 2		
σ_{κ}^2 (×100)	1.6666	0.2029
ρ_{φ}	0.9946	0.9677
λ_c	0.1896	0.5929
$2\pi/4\lambda_c$ (in years)	8.2866	2.6493
Cycle 3		
σ_{κ}^2 (×100)	–	0.5025
ρ_{φ}	–	0.9862
λ_c	–	0.1305
$2\pi/4\lambda_c$ (in years)	–	12.0398
Diagnostic Tests		
Standard error	0.0517	0.0069
Normality $\chi^2(2)$	1.0740	0.7122
Heteroskedasticity $F(26, 26)$	0.6690	0.7550
Durbin-Watson	1.885	1.751
Box-Ljung Q-statistic $\chi^2(6)$	10.74	7.400
R^2	0.992	0.996
R_d^2 (based on differences)	0.590	0.570

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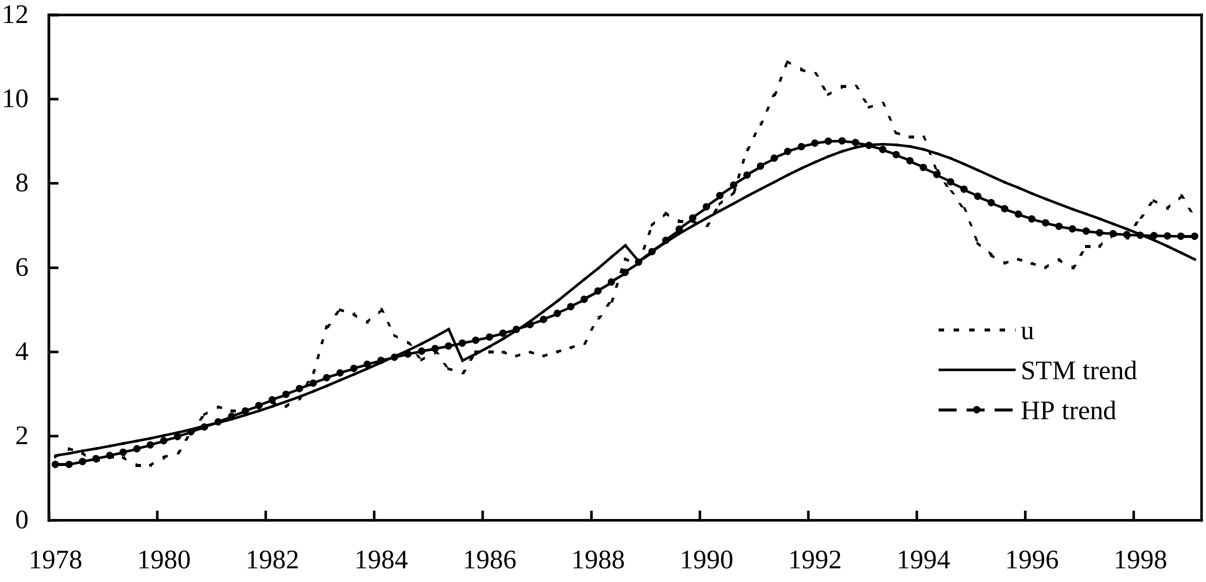
[a] Slope dummies starting in 1985.3 and 1988.4 and dummies for outliers in 1978.4, 1980.2, 1983.1, 1983.4 and 1985.2 were included.

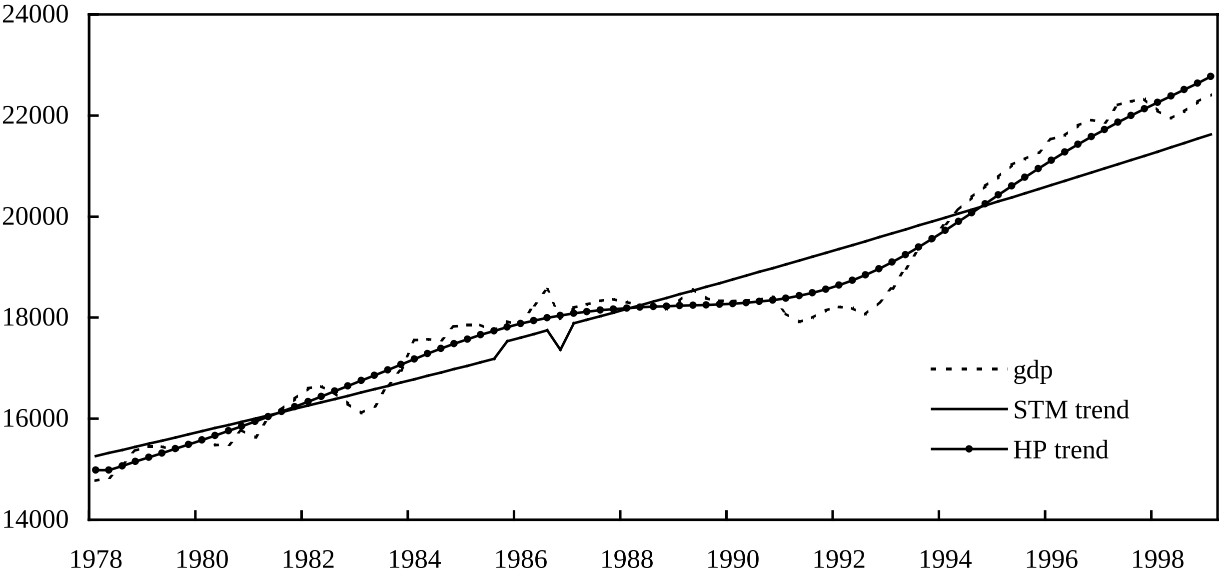
[b] A slope dummy starting in 1985.4 and outlier dummies for 1980.4, 1981.1, 1983.4, 1984.1 and 1986.4 were included.

Figure 3. Unemployment in New Zealand, Seasonally Adjusted, 1978-1999
Actual and STM and Hodrick-Prescott Trends, March Years, Percent



Source: Data Appendix.

Figure 4. Real GDP in New Zealand, Seasonally Adjusted, 1978-1999
Actual and STM and Hodrick-Prescott Trends, March Years, $billion



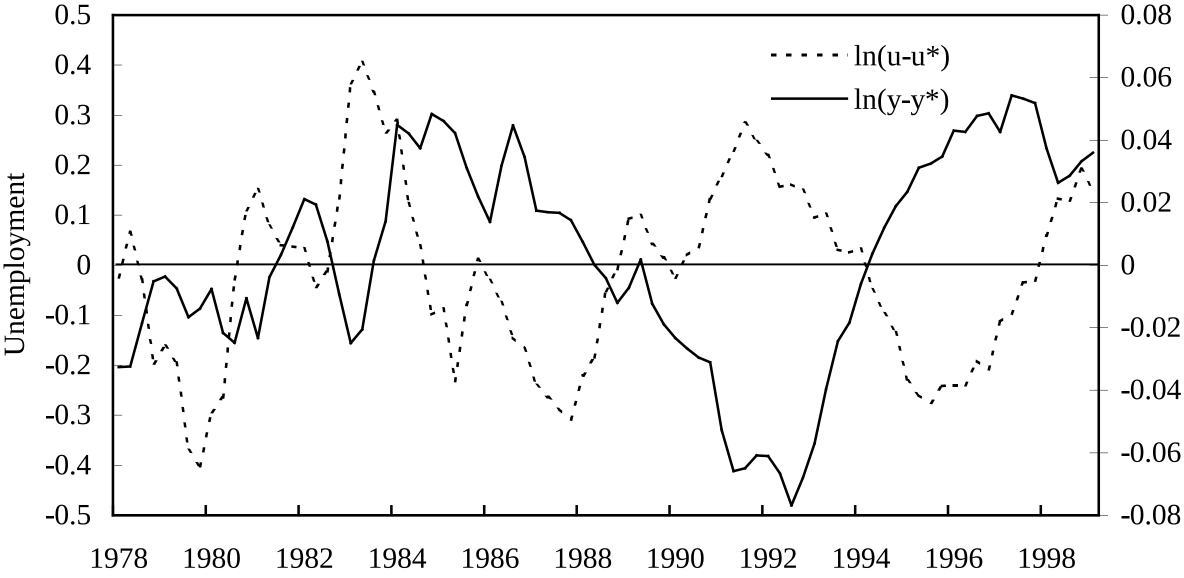
Source: Data Appendix

Table 1 shows that u_t has a fixed (rather than stochastic) level but a stochastic slope. Koopman *et al*. (1995) refer to this special case as a ‘smooth trend’. (See Figure 3). In contrast, the output series (y_t) has both a fixed level and slope and therefore the trend component in the model is deterministic. (See Figure 4). The variance of output, σ_ε^2, is zero.

In such cases it is possible to test if the corresponding trend and slope parameters in the state are zero. For the output model, both parameters are significantly different from zero. The trends obtained from the STM approach are shown in Figures 3 and 4 and compared to the corresponding trends obtained when using the Hodrick-Prescott (1980) filter. The latter is very close to fitting a natural cubic spline with bandwidth 1600.

In the unemployment model, two cycles were obtained with periods of 2.6 and 8.3 years. There are three cycles in the output series, one very short at 1.4 years, a second cycle at 2.6 years, and a much longer cycle of over 12 years. Both models are correctly specified as shown by the various diagnostic tests reported in Table 1. The resulting composite cycles for u_t and y_t, when detrended and expressed as $(u_t - u_t^*)$ and $(y_t - y_t^*)$, show a high degree of correspondence as indicated by Figure 5.

Figure 5. Cyclical Unemployment and Real GDP in New Zealand, 1978-99
Quarterly, March Years



Source: Data Appendix.

Having obtained detrended series for each of the variables being considered, and denoting such a series by x_t, we tested for asymmetry using a ‘deepness’ test. This involved regressing

$$z_t = (x_t - \bar{x})^3 / \sigma(x)^3 \tag{13}$$

on a constant and computing the Newey-West (1987) asymptotic heteroskedasticity and autocorrelation consistent standard error (using a ‘Parzen window’ of one third of the sample). Similarly, the 'steepness' test is the same as equation 13, but replacing x_t with Δx_t. The results obtained are presented in Table 2. These results suggest that the height and depth of the unemployment cycle is fairly symmetric, but that there is contractionary steepness (given that the unemployment cycle is negatively related to the output cycle). In contrast, the real GDP cycle is typified by negative skewness (hence the trough is deeper than the boom is tall) and expansionary steepness. Thus for both series, there is evidence of asymmetric adjustment across the business cycle.

Table 2. Asymmetric 'Deepness' and 'Steepness' Tests

Variable	log z_t	a.s.e	*p*-value	log Δz_t	a.s.e.	*p*-value
Unemployment Rate, u_t	0.063	0.062	0.16	0.364	0.042	0.00
Real GDP, y_t	-0.421	0.092	0.00	0.217	0.043	0.00

5. Testing for Unit Roots in u_t and y_t

Standard ADF-tests for unit roots are reported in Table 3. They are based on the sequential testing procedure outlined in Perron (1988) which tests down from the drift plus trend model to the no drift, no trend model. The results indicate that both unemployment and output are non-stationary $I(1)$ series.

Table 3. Augmented Dickey-Fuller Tests for Unit Roots
New Zealand Unemployment and Real GDP, 1978:1-1999:1, Seasonally Adjusted

Variable		Test statistic		
	lag length	τ_τ	τ_μ	τ
Unemployment rate, u_t	3	-1.85	-1.87	-0.10
Real GDP, y_t	3	-1.92	-0.22	2.45
Δu_t	3	-3.51^{*}	-3.40^{*}	-3.31^{**}
Δy_t	2	-4.82^{**}	-4.85^{**}	-3.71^{**}

Rejects the null hypothesis at ** 1 per cent and * 5 per cent levels, respectively.

Perron (1989) shows that a stationary series around a deterministic time trend that undergoes a permanent shift during the period under consideration is often mistaken by conventional ADF-tests as a persistent innovation to a stochastic trend. Thus the recursive, rolling and sequential approaches developed by Banerjee, Lumsdaine and Stock (1992) are used to test for unknown shifts in the trend and/or intercept in the ADF-test. The results are reported in Table 4. These show that even after allowing for structural breaks in the series, u_t and y_t are $I(1)$.

Table 4. Recursive, Rolling and Sequential Augmented Dickey-Fuller Tests of Unit Roots
New Zealand Unemployment and Real GDP, 1978:1-1999:1, Seasonally Adjusted

Variable	Recursive	Rolling	Mean-shift statistics		Trend-shift statistics	
	min τ_τ	min τ_τ	Min τ_τ	max F	min τ_τ	max F
u_t	-2.09	-2.74	-1.83	4.48	-2.11	4.83
y_t	-1.87	-3.15	-1.52	5.11	-1.77	4.59
5% critical value	-4.33	-5.01	-4.80	18.62	-4.48	16.30

6. Testing for Cointegration between u_t and y_t

We have established that the data are non-stationary and tested for structural breaks. Since u_t and y_t also follow asymmetric adjustment paths, equation 4 was estimated and the residuals used to estimate equations 7 and 8. As the threshold value τ in equation 8 is unknown (and there is no *a priori* reason to expect that it should be zero), the procedure suggested in Enders and Siklos (1999) was used to perform a grid-search. Specifically, the estimated residuals from equation 4 were sorted in ascending order and called $\hat{\varepsilon}_1^\tau < \hat{\varepsilon}_2^\tau < .... < \hat{\varepsilon}_T^\tau$ where T is the number of usable observations. The largest and smallest 15 percent of the $\{\hat{\varepsilon}_i^\tau\}$ values were discarded and the remainder considered as possible threshholds. Equations 7 and 8 were then estimated for each possible threshold. The model with the lowest residual sum of squares was chosen in order to obtain the preferred value of τ. Equation 7, with τ equal to 0.006, was then used to test for cointegration using the t-Max and F-test proposed in Enders and Siklos (1999).

The results obtained from estimation are as follows, where the brackets t-values. D84:1 is a dummy for 1984:1 to take account of an outlier. If the dummy is removed there is evidence of non-normality in the regression residuals.

$$u_t = \underset{(13.4)}{3.9193} - \underset{(-13.3)}{0.405}\, y_t + \underset{(18.6)}{0.003}\, t \tag{14}$$

$$\Delta\hat{\varepsilon}_t = -\underset{(-4.16)}{0.301}\, I_t \hat{\varepsilon}_{t-1} - \underset{(-0.73)}{0.054}(1 - I_t)\hat{\varepsilon}_{t-1} + \underset{(4.35)}{0.018}\, D84{:}1 + v_t \tag{15}$$

Diagnostics

AR 1-5 $F(4, 73) = 1.560$; DW = 1.98; ARCH 4 $F(4, 73) = 0.233$; Normality $\chi^2(2) = 0.116$

X^2_i $F(5, 75) = 0.826$; $X_i{*}X_i$ $F(5, 75) = 0.826$; RESET $F(1, 80) = 0.05$

cointegration t-Max = -4.16** (5% critical value -1.85, Enders and Siklos 1999, Table 6a)

cointegration F-test $\rho_1=\rho_2=0$ $F = 8.936$** (5% critical value 6.95 , Enders and Siklos 1999, Table 5a)

F-test $\rho_1 = \rho_2$ $F(1, 81) = 11.76$** (** rejects at 1% significance level).

Equation 14 shows that the long-run Okun coefficient for New Zealand is -0.41.[1] Equation 15 tests whether equation 14 represents a long-run stationary relationship. The t-Max and F-tests both reject the null hypothesis of no cointegration at better than the 1% significance level. Since the Enders and Siklos critical values are based on simulations with no trend in the long-run relationship (and no dummy for 1984:1 in the DF equation), a Monte Carlo experiment was conducted with the model structure set by equations 14 and 15, $\tau = 0.006$, and u_t and y_t replaced with two variables constrained to equal random walks. The simulation was performed 10,000 times using $N(0,1)$ serially uncorrelated pseudo-random numbers. In common with this type of Monte Carlo experiment, we set the initial values of the two random walks at zero, and discarded the first 50 observations generated before computing t- and F-values. The 5% critical value for the t-Max is -2.747, and the 5% critical value for the F-test is 5.650.

Thus, the model structure used here (especially involving the time trend) does have an important effect on the size properties of the model, although we are still able to reject at better than the 1% significance level. Lastly, having established that $\hat{\varepsilon}_{t-1}$ is stationary, it is possible to test if $\rho_1 = \rho_2$. This null is strongly rejected and asymmetry is again confirmed.

In comparison, the symmetric Engle-Granger test based on testing the residuals from equation 14, using equation 5, produced a t-statistic of -2.002 (the MacKinnon 1991, critical value at the 5% level is -3.898). The dynamic model single-equation test, using the approach given in Banerjee, Dolado and Mestre (1992), produced a cointegration t-statistic of -1.907 (the critical value at the 5% level is -3.98).[2] Lastly, the Johansen (1995) approach was used, with the time trend constrained to enter the cointegration space. The $\lambda_{\max}$ and λ_{trace} tests (that

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[1] Moosa (1997) provides estimates for the G7 countries ranging from -0.49 and -0.46 for Canada and the U.S. to -0.10 for Japan. Most countries had Okun coefficients between -0.38 and -0.49.

[2] This procedure is automated in PcGive (Version 9). See Harris (1995) for details. The long-run Okun coefficient obtained by solving the dynamic model is -0.330.

the rank $r = 0$) were 6.312 and 9.646, respectively.[3] Neither test can reject the null at better than the 50% significance level. Imposing the condition that y_t is weakly exogenous (by restricting the weightings matrix α) was accepted. Assuming that a cointegration vector exists, the Johansen approach produced a long-run Okun coefficient of -0.358 (with an associated asymptotic *t*-value of -2.64).

7. Asymmetric Error-Correction Model

Having established cointegration in the asymmetric model, it is now possible to estimate an asymmetric version of equation 6. The results obtained are as follows:

$$\Delta u_t = \underset{(3.14)}{0.002} - \underset{(-2.26)}{0.158}\, I_t\hat{\varepsilon}_{t-1} + \underset{(0.51)}{0.036}(1 - I_t)\hat{\varepsilon}_{t-1} - \underset{(-2.74)}{0.103}\, \Delta y_{t-1} + \underset{(2.41)}{0.248}\, \Delta u_{t-1} + \omega_t \tag{16a}$$

Diagnostics

$R^2 = 0.29$; AR 1-5 $F(5,73) = 2.026$; DW = 2.21; ARCH 4 $F(4, 70) = 0.286$

Normality $\chi^2(2) = 0.271$; X^2_i $F(8, 69) = 0.944$; $X_i{*}X_i$ $F(13, 64) = 0.847$; RESET $F(1, 77) = 0.729$

Chow $F(4, 74) = 1.642$; Chow $F(14, 64) = 0.975$; Chow $F(30, 48) = 1.360$; Chow $F(50, 28) = 1.688$.

$$\Delta y_t = \underset{(3.46)}{0.005} - \underset{(-0.89)}{0.190}\, I_t\hat{\varepsilon}_{t-1} + \underset{(0.22)}{0.047}(1 - I_t)\hat{\varepsilon}_{t-1} - \underset{(-1.23)}{0.382}\, \Delta u_{t-1} + \underset{(1.90)}{0.217}\, \Delta y_{t-1} - \underset{(-3.89)}{0.039}\, D86:4 + \omega_t^* \tag{16b}$$

Diagnostics

$R^2 = 0.23$; AR 1-5 $F(5, 72) = 1.656$; DW = 1.88; ARCH 4 $F(4, 69) = 0.651$

Normality $\chi^2(2) = 2.732$; X^2_i $F(9, 67) = 0.555$; $X_i{*}X_i$ $F(14, 62) = 0.627$; RESET $F(1, 76) = 1.264$

Chow $F(4, 73) = 0.215$; Chow $F(14, 63) = 0.507$; Chow $F(30, 47) = 0.432$; Chow $F(45, 32) = 0.399$.

Both equations are well-specified. The *t*-statistics on the error-correction terms show that real GDP is weakly exogenous, while the *t*-statistics on the Δu_{t-1} and Δy_{t-1} terms in equation 16 show that real GDP Granger-causes unemployment, but real GDP is not Granger-caused by unemployment. We therefore concentrate on equation 16a, which shows that the short-run Okun coefficient is -0.103 (about one-quarter the value of the estimated long-run coefficient). Unemployment adjusts asymmetrically to disequilibrium. Figure 6 illustrates the path of $\hat{\varepsilon}_{t-1}$. Positive values of $\hat{\varepsilon}_{t-1}$ are associated with short-run negative adjustments in the unemployment

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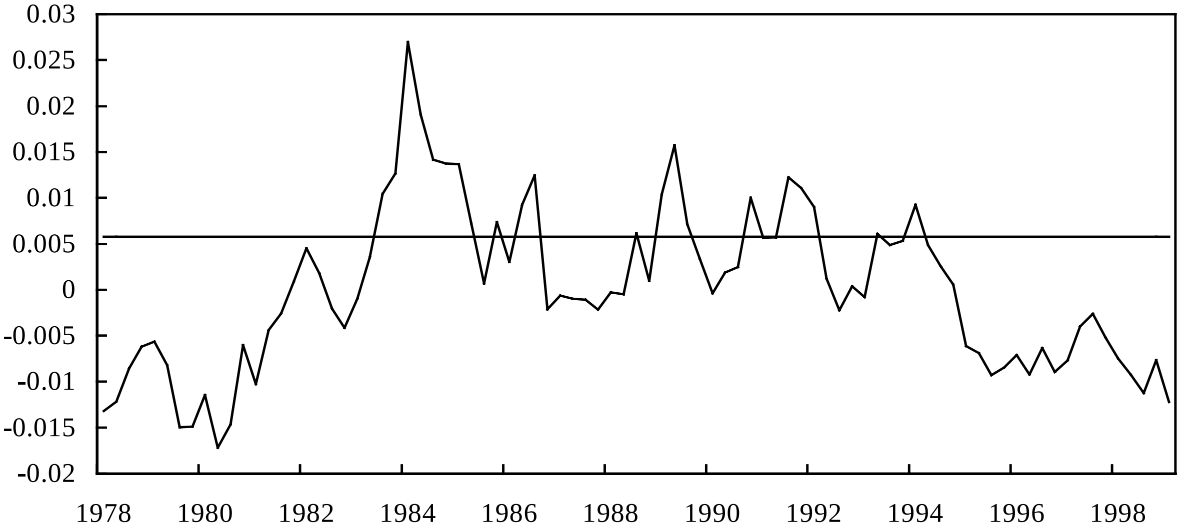
[3] The residuals from the VECM pass the various diagnostic tests available in PcFiml (v9), such as no autocorrelation, no ARCH processes, normality, and homoskedasticity (including vector tests and tests for stability based on 1-step ahead residuals and Chow tests).

rate. These values bring the long-run unemployment-output relationship back into equilibrium. Other things being equal, the speed of adjustment ($1-\alpha$) indicates that some 15.8% of the disequilibrium is removed each quarter; it would therefore take 1.58 years for the economy to return to its long-run trend.

Figure 6. Error Correction $\hat{\varepsilon}_{t-1}$

Quarterly, March Years



Source: Data Appendix.

In contrast, negative values of $\hat{\varepsilon}_{t-1}$ have no significant impact on short-run changes in unemployment. Thus, quantity adjustments in the output and labour market appear confined to downturns in the economic cycle. Upturns are presumably characterised by short-run adjustments in prices more than short-run adjustments in the real side of the economy.[4]

8. Summary and Conclusion

Failure to take account of asymmetries would result in a rejection of an Okun hypothesis that there exists a long-run relationship between unemployment and real GDP in New Zealand. Using an asymmetric approach, it is possible to establish cointegration and to show that short-run adjustment to disequilibrium is confined mostly to downturns in the business cycle. These results suggest that standard estimates of Okun's law will, at best, be understated due to misspecification of the adjustment process.

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[4] In the symmetric version of the model, the speed-of-adjustment coefficient, ($1-\alpha$) in equation 3a, is -0.080 (with an associated *t*-value of -1.90). In the Johansen version, ($1-\alpha$) equals -0.080 with a *t*-value of -2.36.

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Data Appendix

Figure 1

	ΔY/Y	*ΔU*
1978-1		
1978-2		
1978-3		
1978-4		
1979-1	0.4	0.0
1979-2	3.0	-0.2
1979-3	3.8	-0.3
1979-4	2.8	-0.1
1980-1	1.9	0.0
1980-2	1.0	0.1
1980-3	0.7	0.8
1980-4	1.0	1.2
1981-1	0.7	1.2
1981-2	1.5	1.0
1981-3	2.5	0.5
1981-4	3.0	0.2
1982-1	4.5	0.1
1982-2	4.6	0.1
1982-3	4.0	0.3
1982-4	2.9	0.8
1983-1	0.6	1.8
1983-2	-1.0	2.3
1983-3	-1.2	2.0
1983-4	-0.1	1.2
1984-1	2.8	0.4
1984-2	5.5	-0.6
1984-3	6.6	-0.7
1984-4	6.9	-0.9
1985-1	5.0	-1.0
1985-2	3.4	-0.8
1985-3	2.3	-0.7
1985-4	1.2	0.2
1986-1	0.8	0.0
1986-2	0.9	0.4
1986-3	1.9	0.4
1986-4	1.8	0.0
1987-1	2.3	-0.1
1987-2	1.7	0.0
1987-3	0.3	0.2
1987-4	0.7	0.2
1988-1	0.4	0.9
1988-2	0.3	1.2
1988-3	0.5	2.1
1988-4	-0.3	1.9

Figure 2

	gdp	*ln(gdp)*	*u*	*ln(u)*
1978-1	14773	9.600556	1.5	0.405465
1978-2	14834	9.604677	1.7	0.530628
1978-3	15102	9.622582	1.6	0.470004
1978-4	15365	9.639847	1.4	0.336472
1979-1	15450	9.645364	1.5	0.405465
1979-2	15452	9.645494	1.5	0.405465
1979-3	15371	9.640238	1.3	0.262364
1979-4	15474	9.646916	1.3	0.262364
1980-1	15633	9.657139	1.5	0.405465
1980-2	15477	9.647110	1.6	0.470004
1980-3	15488	9.647821	2.1	0.741937
1980-4	15772	9.665991	2.5	0.916291
1981-1	15635	9.657267	2.7	0.993252
1981-2	16006	9.680719	2.6	0.955511
1981-3	16184	9.691778	2.6	0.955511
1981-4	16392	9.704549	2.7	0.993252
1982-1	16606	9.717519	2.8	1.029619
1982-2	16643	9.719745	2.7	0.993252
1982-3	16514	9.711964	2.9	1.064711
1982-4	16302	9.699043	3.5	1.252763
1983-1	16112	9.687320	4.6	1.526056
1983-2	16246	9.695602	5.0	1.609438
1983-3	16672	9.721486	4.9	1.589235
1983-4	16953	9.738200	4.7	1.547563
1984-1	17552	9.772923	5.0	1.609438
1984-2	17573	9.774119	4.4	1.481605
1984-3	17559	9.773322	4.2	1.435085
1984-4	17824	9.788301	3.8	1.335001
1985-1	17853	9.789927	4.0	1.386294
1985-2	17855	9.790039	3.6	1.280934
1985-3	17728	9.782901	3.5	1.252763
1985-4	17927	9.794063	4.0	1.386294
1986-1	17852	9.789871	4.0	1.386294
1986-2	18248	9.811811	4.0	1.386294
1986-3	18557	9.828602	3.9	1.360977
1986-4	17976	9.796793	4.0	1.386294
1987-1	18202	9.809287	3.9	1.360977
1987-2	18264	9.812687	4.0	1.386294
1987-3	18334	9.816513	4.1	1.410987
1987-4	18363	9.818093	4.2	1.435085
1988-1	18307	9.815039	4.8	1.568616
1988-2	18247	9.811756	5.2	1.648659
1988-3	18240	9.811372	6.2	1.824549
1988-4	18169	9.807472	6.1	1.808289

Figure 1 *contd*

	ΔY/Y	*DU*
1989-1	-0.4	2.2
1989-2	0.1	2.1
1989-3	0.4	0.9
1989-4	0.9	1.0
1990-1	0.8	0.0
1990-2	0.1	0.2
1990-3	-0.1	0.7
1990-4	-0.3	1.7
1991-1	-0.6	2.4
1991-2	-0.9	2.6
1991-3	-1.3	3.1
1991-4	-1.7	1.9
1992-1	-1.2	1.2
1992-2	-0.3	0.0
1992-3	0.3	-0.6
1992-4	0.9	-0.4
1993-1	1.2	-0.8
1993-2	1.9	-0.2
1993-3	3.6	-1.1
1993-4	5.0	-1.2
1994-1	6.3	-0.7
1994-2	6.7	-1.6
1994-3	6.3	-1.4
1994-4	5.9	-1.7
1995-1	5.4	-2.5
1995-2	5.0	-2.0
1995-3	4.5	-1.7
1995-4	4.0	-1.2
1996-1	3.7	-0.5
1996-2	3.3	-0.3
1996-3	3.2	0.1
1996-4	3.1	-0.2
1997-1	2.6	0.4
1997-2	2.6	0.5
1997-3	2.4	0.6
1997-4	2.1	0.7
1998-1	2.0	0.7
1998-2	1.0	1.1
1998-3	0.2	0.6
1998-4	-0.3	1.0
1999-1	-0.2	0.0

Figure 2 *contd*

	gdp	*ln(gdp)*	*u*	*ln(u)*
1989-1	18330	9.816294	7.0	1.945910
1989-2	18568	9.829195	7.3	1.987874
1989-3	18381	9.819073	7.1	1.960095
1989-4	18332	9.816403	7.1	1.960095
1990-1	18324	9.815967	7.0	1.945910
1990-2	18336	9.816622	7.5	2.014903
1990-3	18355	9.817657	7.8	2.054124
1990-4	18399	9.820052	8.8	2.174752
1991-1	18076	9.802340	9.4	2.240710
1991-2	17912	9.793226	10.1	2.312535
1991-3	17999	9.798071	10.9	2.388763
1991-4	18145	9.806150	10.7	2.370244
1992-1	18213	9.809891	10.6	2.360854
1992-2	18184	9.808297	10.1	2.312535
1992-3	18069	9.801953	10.3	2.332144
1992-4	18304	9.814875	10.3	2.332144
1993-1	18577	9.829680	9.8	2.282382
1993-2	18978	9.851036	9.9	2.292535
1993-3	19347	9.870293	9.2	2.219203
1993-4	19541	9.880270	9.1	2.208274
1994-1	19861	9.896513	9.1	2.208274
1994-2	20136	9.910265	8.3	2.116256
1994-3	20384	9.922506	7.8	2.054124
1994-4	20606	9.933338	7.4	2.001480
1995-1	20782	9.941843	6.6	1.887070
1995-2	21025	9.953467	6.3	1.840550
1995-3	21136	9.958733	6.1	1.808289
1995-4	21269	9.965006	6.2	1.824549
1996-1	21530	9.977203	6.1	1.808289
1996-2	21608	9.980819	6.0	1.791759
1996-3	21803	9.989803	6.2	1.824549
1996-4	21908	9.994607	6.0	1.791759
1997-1	21864	9.992597	6.5	1.871802
1997-2	22208	10.008208	6.5	1.871802
1997-3	22275	10.011220	6.8	1.916923
1997-4	22330	10.013686	6.7	1.902108
1998-1	22096	10.003152	7.2	1.974081
1998-2	21941	9.996112	7.6	2.028148
1998-3	22079	10.002382	7.4	2.001480
1998-4	22268	10.010906	7.7	2.041220
1999-1	22418	10.017619	7.2	1.974081

Figure 3

	u	**STM trend**	**HP trend**
1978-1	1.5	1.536980	1.322863
1978-2	1.7	1.591535	1.322863
1978-3	1.6	1.646514	1.389074
1978-4	1.4	1.703786	1.458829
1979-1	1.5	1.762808	1.532702
1979-2	1.5	1.822950	1.611317
1979-3	1.3	1.881999	1.695365
1979-4	1.3	1.943912	1.785562
1980-1	1.5	2.011529	1.882408
1980-2	1.6	2.083929	1.986057
1980-3	2.1	2.160027	2.096325
1980-4	2.5	2.238554	2.212616
1981-1	2.7	2.318957	2.334135
1981-2	2.6	2.403762	2.460047
1981-3	2.6	2.497754	2.589543
1981-4	2.7	2.600432	2.721728
1982-1	2.8	2.708031	2.855545
1982-2	2.7	2.818407	2.989745
1982-3	2.9	2.936135	3.122869
1982-4	3.5	3.062843	3.253069
1983-1	4.6	3.195585	3.378144
1983-2	5.0	3.331037	3.495857
1983-3	4.9	3.465280	3.604532
1983-4	4.7	3.603169	3.703311
1984-1	5.0	3.744229	3.792164
1984-2	4.4	3.887908	3.871809
1984-3	4.2	4.038057	3.943845
1984-4	3.8	4.194075	4.010413
1985-1	4.0	4.362051	4.074016
1985-2	3.6	4.540768	4.137207
1985-3	3.5	3.790898	4.202660
1985-4	4.0	3.953202	4.272847
1986-1	4.0	4.122866	4.349915
1986-2	4.0	4.305775	4.435990
1986-3	3.9	4.506464	4.533153
1986-4	4.0	4.726066	4.643393
1987-1	3.9	4.960527	4.768484
1987-2	4.0	5.207783	4.909972
1987-3	4.1	5.462005	5.068984
1987-4	4.2	5.719762	5.246141
1988-1	4.8	5.984489	5.441421
1988-2	5.2	6.253112	5.653976
1988-3	6.2	6.526595	5.882292
1988-4	6.1	6.147086	6.124200
1989-1	7.0	6.383810	6.377282
1989-2	7.3	6.604867	6.638619
1989-3	7.1	6.807080	6.905153
1989-4	7.1	6.994713	7.173740

Figure 4

	gdp	**STM trend**	**HP trend**
1978-1	14773	15262.184	14981.85
1978-2	14834	15322.650	14981.85
1978-3	15102	15383.355	15065.68
1978-4	15365	15444.301	15149.89
1979-1	15450	15505.488	15234.40
1979-2	15452	15566.917	15319.27
1979-3	15371	15628.590	15404.72
1979-4	15474	15690.508	15491.02
1980-1	15633	15752.670	15578.45
1980-2	15477	15815.079	15667.27
1980-3	15488	15877.735	15757.80
1980-4	15772	15940.639	15850.22
1981-1	15635	16003.793	15944.57
1981-2	16006	16067.197	16040.83
1981-3	16184	16130.852	16138.76
1981-4	16392	16194.759	16238.14
1982-1	16606	16258.919	16338.72
1982-2	16643	16323.334	16440.39
1982-3	16514	16388.003	16543.15
1982-4	16302	16452.929	16647.19
1983-1	16112	16518.112	16752.63
1983-2	16246	16583.554	16859.40
1983-3	16672	16649.255	16967.02
1983-4	16953	16715.215	17074.59
1984-1	17552	16781.438	17180.99
1984-2	17573	16847.922	17285.02
1984-3	17559	16914.670	17385.67
1984-4	17824	16981.683	17482.08
1985-1	17853	17048.961	17573.51
1985-2	17855	17116.505	17659.40
1985-3	17728	17184.317	17739.38
1985-4	17927	17536.996	17813.18
1986-1	17852	17606.474	17880.55
1986-2	18248	17676.227	17941.30
1986-3	18557	17746.257	17995.23
1986-4	17976	17363.864	18042.35
1987-1	18202	17887.150	18083.00
1987-2	18264	17958.015	18117.52
1987-3	18334	18029.161	18146.31
1987-4	18363	18100.589	18169.89
1988-1	18307	18172.300	18188.88
1988-2	18247	18244.295	18204.05
1988-3	18240	18316.575	18216.23
1988-4	18169	18389.141	18226.29
1989-1	18330	18461.995	18235.13
1989-2	18568	18535.138	18243.60
1989-3	18381	18608.570	18252.61
1989-4	18332	18682.294	18263.28

Figure 3 *contd*

	u	**STM trend**	**HP trend**
1990-1	7.0	7.173418	7.4409045
1990-2	7.5	7.350479	7.7026769
1990-3	7.8	7.524172	7.9543561
1990-4	8.8	7.696329	8.1906824
1991-1	9.4	7.865056	8.4059315
1991-2	10.1	8.034298	8.594503
1991-3	10.9	8.201605	8.7513218
1991-4	10.7	8.357054	8.8723185
1992-1	10.6	8.503388	8.9549547
1992-2	10.1	8.639879	8.9981972
1992-3	10.3	8.763531	9.0024827
1992-4	10.3	8.856976	8.9694115
1993-1	9.8	8.911945	8.9017869
1993-2	9.9	8.932541	8.803519
1993-3	9.2	8.917231	8.6792392
1993-4	9.1	8.874876	8.5342523
1994-1	9.1	8.807042	8.3740551
1994-2	8.3	8.711132	8.2042359
1994-3	7.8	8.595305	8.0304611
1994-4	7.4	8.461297	7.8580364
1995-1	6.6	8.314200	7.6916955
1995-2	6.3	8.168814	7.5354917
1995-3	6.1	8.028920	7.3924435
1995-4	6.2	7.892851	7.2645407
1996-1	6.1	7.758039	7.1528102
1996-2	6.0	7.628429	7.0575715
1996-3	6.2	7.506637	6.9785044
1996-4	6.0	7.387584	6.914683
1997-1	6.5	7.275221	6.8647909
1997-2	6.5	7.159984	6.8270207
1997-3	6.8	7.040460	6.7994366
1997-4	6.7	6.913116	6.7799743
1998-1	7.2	6.784526	6.7666264
1998-2	7.6	6.650132	6.7573716
1998-3	7.4	6.505537	6.7504714
1998-4	7.7	6.354337	6.7446943
1999-1	7.2	6.197292	6.7392006

Figure 4 *contd*

	gdp	**STM trend**	**HP trend**
1990-1	18324	18756.309	18276.81
1990-2	18336	18830.618	18294.46
1990-3	18355	18905.221	18317.49
1990-4	18399	18980.119	18347.25
1991-1	18076	19055.315	18385.08
1991-2	17912	19130.808	18432.40
1991-3	17999	19206.600	18490.46
1991-4	18145	19282.693	18560.20
1992-1	18213	19359.087	18642.29
1992-2	18184	19435.784	18737.15
1992-3	18069	19512.785	18844.98
1992-4	18304	19590.090	18965.64
1993-1	18577	19667.702	19098.50
1993-2	18978	19745.622	19242.53
1993-3	19347	19823.850	19396.31
1993-4	19541	19902.388	19558.23
1994-1	19861	19981.237	19726.62
1994-2	20136	20060.398	19899.72
1994-3	20384	20139.874	20075.79
1994-4	20606	20219.664	20253.19
1995-1	20782	20299.770	20430.42
1995-2	21025	20380.193	20606.13
1995-3	21136	20460.936	20779.16
1995-4	21269	20541.998	20948.58
1996-1	21530	20623.381	21113.66
1996-2	21608	20705.086	21273.83
1996-3	21803	20787.116	21428.81
1996-4	21908	20869.470	21578.50
1997-1	21864	20952.151	21723.06
1997-2	22208	21035.159	21862.84
1997-3	22275	21118.496	21998.33
1997-4	22330	21202.163	22130.23
1998-1	22096	21286.162	22259.44
1998-2	21941	21370.493	22387.02
1998-3	22079	21455.159	22513.92
1998-4	22268	21540.160	22640.88
1999-1	22418	21625.497	22768.33

Figure 5

	ln(y-y)*	*ln(u-u*)*
1978-1	-0.032577	-0.024354
1978-2	-0.032410	0.065929
1978-3	-0.018459	-0.028657
1978-4	-0.005148	-0.196381
1979-1	-0.003585	-0.161443
1979-2	-0.007410	-0.194991
1979-3	-0.016619	-0.369970
1979-4	-0.013895	-0.402338
1980-1	-0.007626	-0.293430
1980-2	-0.021609	-0.264251
1980-3	-0.024852	-0.028183
1980-4	-0.010636	0.110461
1981-1	-0.023314	0.152134
1981-2	-0.003816	0.078477
1981-3	0.003289	0.040119
1981-4	0.012106	0.037574
1982-1	0.021122	0.033398
1982-2	0.019394	-0.042920
1982-3	0.007659	-0.012383
1982-4	-0.009216	0.133419
1983-1	-0.024893	0.364286
1983-2	-0.020565	0.406154
1983-3	0.001365	0.346442
1983-4	0.014125	0.265749
1984-1	0.044895	0.289222
1984-2	0.042136	0.123733
1984-3	0.037385	0.039321
1984-4	0.048411	-0.098672
1985-1	0.046082	-0.086648
1985-2	0.042240	-0.232162
1985-3	0.031148	-0.079840
1985-4	0.021995	0.011768
1986-1	0.013849	-0.030254
1986-2	0.031835	-0.073663
1986-3	0.044672	-0.144536
1986-4	0.034646	-0.166799
1987-1	0.017449	-0.240535
1987-2	0.016895	-0.263860
1987-3	0.016767	-0.286829
1987-4	0.014393	-0.308843
1988-1	0.007385	-0.220555
1988-2	0.000148	-0.184421
1988-3	-0.004189	-0.051336
1988-4	-0.012043	-0.007689
1989-1	-0.007175	0.092145
1989-2	0.001771	0.100068
1989-3	-0.012305	0.042132
1989-4	-0.018928	0.014940

Figure 6

	ec
1978-1	-0.013191
1978-2	-0.012204
1978-3	-0.008578
1978-4	-0.006199
1979-1	-0.005628
1979-2	-0.008228
1979-3	-0.014985
1979-4	-0.014929
1980-1	-0.011463
1980-2	-0.017198
1980-3	-0.014654
1980-4	-0.006026
1981-1	-0.010268
1981-2	-0.004383
1981-3	-0.002550
1981-4	0.000951
1982-1	0.004532
1982-2	0.001809
1982-3	-0.002054
1982-4	-0.004133
1983-1	-0.000969
1983-2	0.003555
1983-3	0.010447
1983-4	0.012665
1984-1	0.026957
1984-2	0.019059
1984-3	0.014165
1984-4	0.013742
1985-1	0.013674
1985-2	0.007213
1985-3	0.000699
1985-4	0.007393
1986-1	0.003040
1986-2	0.009286
1986-3	0.012482
1986-4	-0.002110
1987-1	-0.000657
1987-2	-0.000969
1987-3	-0.001109
1987-4	-0.002160
1988-1	-0.000310
1988-2	-0.000485
1988-3	0.006168
1988-4	0.000991
1989-1	0.010364
1989-2	0.015743
1989-3	0.007119
1989-4	0.003384

Figure 5 *contd*

	$\ln(y-y^*)$	$\ln(u-u^*)$
1990-1	-0.023319	-0.024472
1990-2	-0.026618	0.020138
1990-3	-0.029536	0.036003
1990-4	-0.031096	0.134008
1991-1	-0.052761	0.178280
1991-2	-0.065829	0.228816
1991-3	-0.064938	0.284433
1991-4	-0.060813	0.247138
1992-1	-0.061026	0.220389
1992-2	-0.066574	0.156147
1992-3	-0.076872	0.161545
1992-4	-0.067904	0.150939
1993-1	-0.057054	0.094990
1993-2	-0.039651	0.102834
1993-3	-0.024348	0.031218
1993-4	-0.018325	0.025050
1994-1	-0.006036	0.032723
1994-2	0.003762	-0.048346
1994-3	0.012049	-0.097092
1994-4	0.018927	-0.134023
1995-1	0.023478	-0.230895
1995-2	0.031149	-0.259774
1995-3	0.032460	-0.274761
1995-4	0.034779	-0.241408
1996-1	0.043022	-0.240441
1996-2	0.042684	-0.240122
1996-3	0.047714	-0.191238
1996-4	0.048565	-0.208041
1997-1	0.042600	-0.112672
1997-2	0.054257	-0.096706
1997-3	0.053316	-0.034751
1997-4	0.051828	-0.031313
1998-1	0.037339	0.059437
1998-2	0.026346	0.133512
1998-3	0.028662	0.128826
1998-4	0.033232	0.192083
1999-1	0.035991	0.149969

Figure 6 *contd*

	ec
1990-1	-0.00038
1990-2	0.001895
1990-3	0.002449
1990-4	0.010002
1991-1	0.005665
1991-2	0.005694
1991-3	0.012246
1991-4	0.011065
1992-1	0.009026
1992-2	0.001196
1992-3	-0.00221
1992-4	0.000373
1993-1	-0.00082
1993-2	0.006102
1993-3	0.004869
1993-4	0.005347
1994-1	0.009283
1994-2	0.004848
1994-3	0.002532
1994-4	0.000556
1995-1	-0.00612
1995-2	-0.00688
1995-3	-0.00928
1995-4	-0.00845
1996-1	-0.00709
1996-2	-0.00922
1996-3	-0.00635
1996-4	-0.00894
1997-1	-0.0077
1997-2	-0.00402
1997-3	-0.00264
1997-4	-0.00523
1998-1	-0.00748
1998-2	-0.00926
1998-3	-0.01123
1998-4	-0.00764
1999-1	-0.01222

Sources

GDP **Statistics New Zealand,** PC Infos SNBQ.S2SZT
Real GDP, quarterly, seasonally adjusted, millions of New Zealand dollars.
Note: For Figure 1, GDP is the four-quarter moving total of SNBQ.S2SZT.

U **Statistics New Zealand,** PC Infos HLFQ.S1F3S (post 1985-4)
Unemployment rate, males and females, all ages.
Chapple (1994) (pre 1985-4).