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Has a Structural Break Affected New Zealand Business Cycles?

Dr Amal Sanyal
Bert Ward

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Department of Economics and Marketing
PO Box 84
Lincoln University
CANTERBURY

Telephone No: (64) (3) 325 2811
Fax No: (64) (3) 325 3847

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Abstract

By international standards, New Zealand's recent business cycle fluctuations are remarkably volatile. Some bivariate regularities observed in developed economies are weak and sometime uncertain. Are these features endemic to New Zealand's economy or the result of structural disturbances of the seventies? The paper reports that there are distinct signs of some structural break in the seventies, but the qualitative features of the business cycle are similar before and after any possible break. The reasons of these peculiarities then are to be sought in New Zealand's own economic institutions.

Both authors are Senior Lecturers at the Department of Economics and Marketing, Lincoln University, New Zealand.

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Introduction

Interest in the analysis of aggregate economic time series of New Zealand has been recently revived by Kim et al.,1994 (KBH), which analyses bivariate regularities of the cyclical components of various economic series. Given the history of major disturbances in the New Zealand economy, e.g. the commodity boom, the oil shock and the loss of UK markets in the seventies, and the reform and liberalisation since 1984, a relevant question is whether the series used display any structural breaks during the sample period. Secondly, if there are structural breaks, whether that has influenced the cyclical behaviour of economic variables. Since we have *a priori* reasons for expecting some structural break in the New Zealand series, these two questions need consideration.

This paper explores these two questions using the Bank of New Zealand Model XII data base for 1967:1 to 1991:4. It finds evidence of structural breaks in the seventies. Alternative specifications of the trend function produce different possible dates for the break; but they all fall between 1974:2 to 1977:2. Secondly bivariate cyclical relations between real GDP and other aggregates of interest were studied for the period since each structural break. They produced results not significantly different for different breaking dates, and qualitatively very similar to those reported by KBH for the period 1966:4 to 1990:1. The tentative conclusion is that the qualitative properties of the cyclical relations have not been affected by the structural break of the seventies.

Section 1 reports on the results of the exercises that explore structural break points. In Section 2 we report on the temporal cross correlation between real GDP and other variables. Since these results are not significantly different for the period up to 1991:4 beginning from alternative break points, we report only one set starting 1975:1, the earliest date in the range for which unbroken series are available for all our variables.

1. Search for Break Points and Stationarity Status of the Series

Potentially, the existence of a structural break raises two related but separate problems. The first and more obvious one is that if the economy was following two distinct trajectories before and after a date T_b, the regularities derived from a sample including periods both before and after it fail to display either of them adequately. The second one, related to methodology, is that the presence of structural breaks may interfere with the statistical tests for determining the status of the data regarding stationarity. Perron 1989, 1994, for example, has argued that the Augmented Dicky Fuller (ADF) procedure is biased towards the non-rejection of the null hypothesis of a stochastic trend, if the sample period contains a structural break. This might therefore lead to an inappropriate detrending method resulting in spurious conclusions in further analysis.

In fact exercises done with the unbroken real GDP series from 1967:1 to 1991:4 show that it is difficult to conclude if the series is difference stationary or trend stationary. If anything, the evidences are somewhat more loaded towards the possibility of difference stationarity[1] . Fortunately, the location of statistically significant break points, as we will discuss below, also deliver at the same time a detrended stationary series, which we could subject to temporal correlation analysis for exploring bivariate economic relations.

Perron developed a procedure for testing the null hypothesis that a series is difference stationary allowing for a one-time break at a time T_b against the alternative hypothesis that the series is trend stationary about a breaking trend. The rejection of this null hypothesis indicates that the series is best characterised as having stationary fluctuations around a deterministic trend, once allowance has been made for the shift in the intercept and/or the slope of the trend function. This family of tests can be conducted around an exogenously supplied break point, as also an "endogenous" break point which may be identified by a recursive routine related to the procedure.

Breaking-trend processes can be expressed as either an Additive Outlier(AO) model where the effect of a break is instantaneous, or as an Innovational Outlier(IO) model where the effect is

gradual. Tests using the AO model are based on results obtained from the OLS estimation of the following equation (details for the IO specification are given in Perron, 1994):

$$Y_t = \alpha Y_{t-1} + \mu + \beta t + \theta DU_t + \gamma DT_t + \delta D(T_b)_t + \sum_1^k \eta_i \Delta(Y_{t-i}) + e_t \qquad (1)$$

In equation (1) DU_t, DT_t and $D(T_b)_t$ are dummy variables where DU_t =1 and DT_t = (t-T_b) if $t>T_b$ (0 otherwise), and $D(T_b)_t$ = 1 if $t=T_b+1$ (0 otherwise). In addition, e_t is assumed to be independently distributed with zero mean and constant variance.

Equation (1) is the general expression for a process that is stationary around a trend function with a break in (i) both its level and slope if none of β, θ and γ is equal to zero, (ii) in just its level if only γ = 0, or (iii) in just its slope if only θ = 0. In each of these three different versions of the alternative hypothesis we expect $\alpha < 1$ and $\delta \approx 0$.

The null hypothesis to which each version of equation (1) is the alternative may be expressed as:

$$Y_t = \alpha Y_{t-1} + \mu + \delta D(T_b)_t + \sum_1^k \eta_i \Delta(Y_{t-i}) + e_t \qquad (2)$$

where $\alpha = 1$ and $\delta \neq 0$.

Equation (1) is estimated with OLS and H_o: $\alpha = 1$ is tested against H_a: $\alpha < 1$. Because the distribution of the $t(\hat{\alpha})$ statistic is non-standard under H_o, $t(\hat{\alpha})$ must be referred to the asymptotic critical values tabulated in Perron(1994). However, if Ho: $\alpha = 1$ is rejected, then the distributions of the t and F statistics are standard and so the zero restrictions on β, θ and γ may then be tested in the usual way in order to identify just which of the three types of breaking-trend alternative is most consistent with the sample data.

The estimation of equation (1) requires the determination of two parameters, namely T_b (break-point dates) and k (truncation-lag parameter). Values of T_b were generated endogenously by estimating (1) recursively[2] and then choosing the T_b value that minimises the estimate of $t(\hat{\alpha})$. Since this procedure leads to tests of H_o: $\alpha = 1$ with the lowest power (Perron, 1994), its actual rejection may be taken as strong evidence against the null hypothesis of a difference-stationary process. For the IO specification of (1), T_b may also be selected by

the min $t(\hat{\alpha})$ criterion as well as the criterion of minimising the *t*-statistic for γ, the parameter for the DT_t dummy variable.

Under each criterion for choosing T_b the value of the truncation parameter *k* was selected by two different criteria. Firstly, *k* was selected as the value that minimised AIC, and secondly as the longest lag length for which the $t(\hat{\eta})$ statistic was significant. In all cases, the resulting OLS residuals were tested for departure from a 'white noise' process.

Tests of the null hypothesis that (log) real GDP is a difference stationary process with a one-time break in its trend were carried out with the AO model using the min $t(\hat{\alpha})$ criterion and then with the IO model using both the min $t(\hat{\alpha})$ and the min $t(\hat{\gamma})$ criteria with the following summary results. For the AO model, break-points were selected at 1975:2 when *k* was chosen with the *t*-significance criterion and at 1977:2 when the min-AIC criterion was used.

Table 1
Empirical Results of Perron Test: Real GDP Series, 1967:1 to 1991:4
(Equation 1 with $k = 0$)

Variable	**Coefficient**	**Standard Error**	***t* - value**	***p* - value**
Constant	5.2291	0.7965	6.565	0.000
RGDP(-1)	0.3924	0.0925	4.242	0.0001
DU	0.0549	0.0258	2.127	0.0361
DT	-0.0032	0.0007	-4.428	0.000
$D(T_b)$	0.0321	0.0379	0.845	0.4003
Trend	0.0059	0.0010	5.900	0.000

Residual Diagnostic Tests:

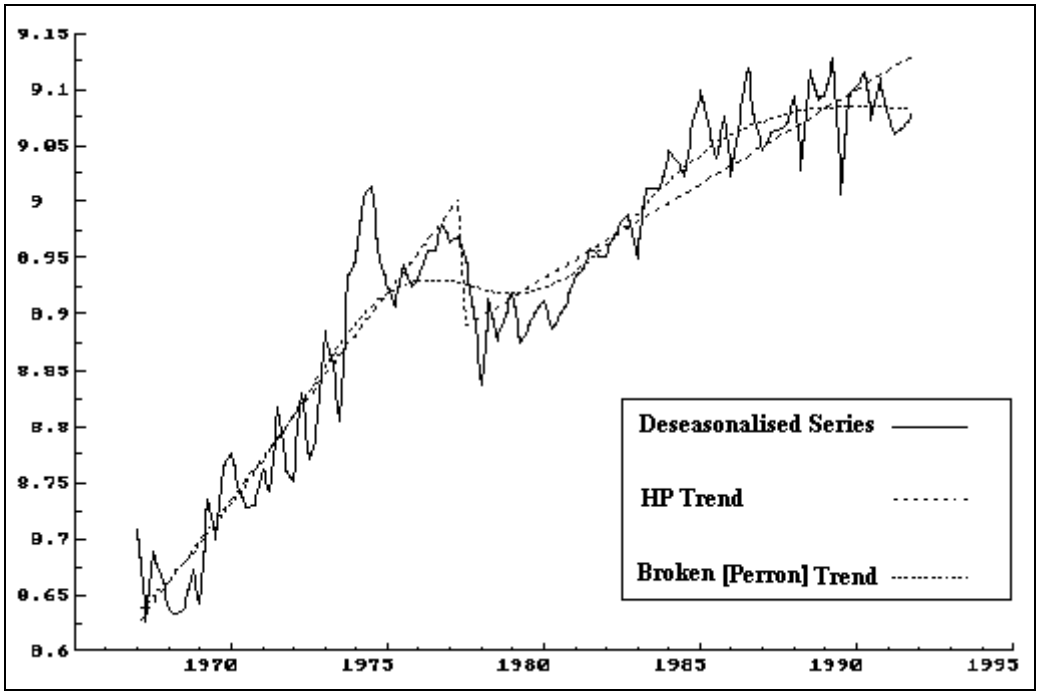
AR/MA 1-5 ~ F (5, 88) = 1.6742 [0.1492]
ARCH4 ~ F (4,85) = 1.2106 [0.3123]
Normality ~ Chi^2 (2) = 1.1500 [0.5627]
RESET ~ F (1, 92) = 2.8084 [0.0972]

(Values in square brackets are *p*-values.)

For the IO model, the overall results were quite similar. When the min $t(\hat{\alpha})$ criterion was used to select T_b, break points were selected at 1977:2 regardless of the criterion used to choose *k*. Using the min $t(\hat{\gamma})$ criterion for selecting T_b, break points were selected at 1974:2 and 1977:2 under the *t*-significance and the min-AIC criteria for choosing *k*, respectively. Moreover, the remaining empirical results obtained for the six versions of the test were so similar that it was extremely difficult to statistically discriminate amongst the six models. Consequently, only the detailed results obtained for the AO version of equation (3) with T_b=1977:2 are reported below[3] .

Since none of the four residual diagnostic tests provides any strong evidence against the assumption that the error term in (1) is a 'white noise' process, we proceed to test the null hypothesis of a unit root in real GDP, ie $H_0 : \alpha = 1$ against H_A $\alpha < 1$.The Perron test statistic is (0.3924-1)/0.0925 = - 6.5686, which, according to the Perron procedure, has a *p*-value of less than 0.01. Hence the null hypothesis is safely rejected in favour of the alternative that real GDP is stationary around a deterministic trend having a structural break in its level and slope at 1977:2.

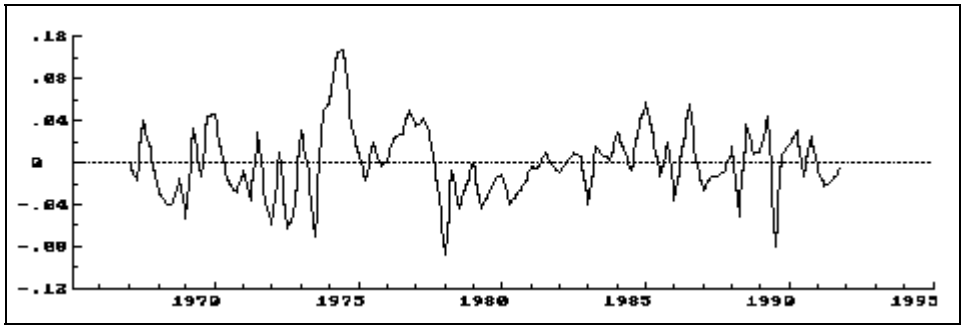
Having rejected the unit root hypothesis, tests of zero restrictions on the coefficients of the DU, DT and trend variables may be tested with the standard *t* and *F*-ratio statistics. The very small *p*-values for these three coefficients indicate that each is statistically significant and this is confirmed by a joint test where the value of F(3,93) = 13.13 had a *p*-value less than 0.01. Moreover, the results in Table 1 also show that the value of the δ coefficient (0.0321) is approximately zero.



Data Source: Bank of New Zealand.

Figure 1
Real GDP, the HP Trend and the Perron Breaking Trend

Deviations from the Breaking Trend



Deviations from the HP Trend

Figure 2
Cyclical components generated by the
Perron Breaking Trend Method and the HP Filter

The computed broken trend function is displayed along with the HP trend and the sample observations on real GDP in Figure 1. Figure 2 produces the cyclical components derived using the HP filter and the broken trend function.

2. Temporal Bivariate Regularities

As reported above, structural breaks have been identified variously between 1974:2 and 1977:2. Since the identification of the breaks by the above method at the same time ascertains that the series starting from the break point describes a trend stationary process, we can generate the cyclical components by using the Hodrick and Prescott (HP)[4] filter on the deseasonalised series. Temporal cross correlation between the cyclical components of real GDP and other relevant series were carried out for the period starting at each break point till 1991:4. The quantitative results were not significantly different. We therefore report on one set of exercises with the first sample point at 1975:1, which is the earliest date within the range of identified structural break points, from where continuous series are available for all variables of interest.

We have grouped the variables other than GDP into three classes: those related to expenditure, those related to inputs and those related to the money market and rest-of-the-world factors. In Tables 4 to 6, the first column reports the volatility of each series measured as percent standard deviation from the HP trend values. Other columns present the correlation of the cyclical component of real GDP with other variables over eleven consecutive quarters, including the contemporaneous correlation in the central column. A significant positive (negative) number in the central column indicates that the variable is pro(anti)-cyclical. If the highest numerical value in a row occurs at a cell other than the central one, it implies a phase shift in the relation between the corresponding variable and real GDP. Finally small values and erratic signs denote unstable or statistically inconclusive relations.

Volatility:

The volatility of real GDP at 2.80 is significantly higher than the corresponding figure of 1.38 for the world GDP, or 1.71 for real GNP of USA reported by Kydland and Prescott (1990)[5] . This is in line with the observation of KBH regarding the volatility of real GDP of New Zealand. Their sample period contained the relatively more volatile period from 1967 to 1974, which we have discarded. Thus the high value of 3.64 reported by them has expectedly come down, but this is still significantly higher than that of either the world GDP or the GDP of

other advanced economies reported in the literature. It appears that the volatility is endemic in the series and is not the contribution of the structural break.

The volatility is contributed by most of the expenditure side variables. Exports, total investment, both private and government, and within private investment, dwelling and other investments, and durable consumption have volatility much higher than that of GDP. Total government expenditure and its central and local government components also display high volatility.

Table 2
Cyclical Behaviour of Output and Income
Cross Correlations of Variables with Real GDP
Quarterly, 1975:1-1991:4

Variable x	Volatility (%Std.Dev)	x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
GDP	2.80	0.01	-0.09	0.10	0.10	0.16	1.00	0.16	0.10	0.10	-0.09	0.01
Private Consumption	1.83	0.01	0.08	0.18	0.03	0.09	0.36	-0.06	-0.18	-0.06	-0.33	-0.14
Consumption Durables	4.23	0.08	0.17	0.15	0.12	0.13	0.38	-0.03	-0.12	-0.07	-0.34	-0.08
Private Investment	8.93	0.04	0.11	0.13	0.19	0.37	0.40	0.17	0.17	-0.04	-0.11	-0.17
Private Dwellings	9.78	0.03	0.16	0.20	0.23	0.48	0.55	0.33	0.10	-0.07	-0.22	-0.17
Other Private Investment	9.40	0.03	0.09	0.09	0.14	0.29	0.30	0.10	0.18	-0.03	-0.05	-0.15
Government Investment	10.19	-0.01	0.08	-0.03	0.00	0.00	0.09	-0.05	0.05	0.30	0.14	0.38
Total Investment	6.47	0.04	0.14	0.12	0.17	.034	0.39	0.15	0.18	0.14	0.00	0.03
Total Exports	4.19	0.05	0.06	0.04	0.02	0.19	0.50	0.14	-0.12	-0.01	-0.15	-0.01
Total Imports	5.69	0.01	-0.03	-0.08	-0.04	0.08	0.13	0.16	0.09	-0.09	-0.19	-0.21
Government Expenditure	3.45	0.04	0.05	-0.03	0.02	-0.07	0.04	-0.13	0.03	0.08	0.17	0.40

Data Source :Reserve Bank of New Zealand.

The only important stabilising influence on the expenditure side are private consumption (which implies private non-durable consumption is very stable) and government consumption expenditure (not reported here).

On the other hand input uses are remarkably more stable than the real GDP series. Total employment shows a volatility of 1.00 per cent compared to 2.80 for real GDP. While employment in the government is generally stable in many countries, in New Zealand, private sector employment at 1.39 and market employment at 1.07 are almost equally stable. Hours worked in the private sector are more volatile than the real GDP, though as we will discuss below, lacks any significant correlation with real GDP. Capacity utilisation also has a low volatility of 1.75. Table 5 summarises the relation between the volatility of different groups of variables and that of real GDP.

Table 3
Cyclical Behaviour of New Zealand Production Inputs
Cross Correlations of Variables with Real GDP
Quarterly, 1975:1-1991:4

Variable x	Volatility (%Std.Dev)	x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
GDP	2.80	0.01	-0.09	0.10	0.10	0.16	1.00	0.16	0.10	0.10	-0.09	0.01
Employment Total	1.00	0.20	0.00	-0.04	-0.01	0.01	-0.08	-0.07	-0.08	-0.13	0.01	0.14
Employment (Private)	1.39	-0.04	0.00	-0.03	-0.11	0.03	0.05	0.16	0.08	0.22	0.16	0.11
Hours (Private)	3.55	0.03	0.06	0.02	-0.14	-0.08	0.10	0.07	0.08	0.02	0.01	-0.11
Total Productivity	3.65	0.03	-0.05	0.17	0.30	0.14	0.71	0.11	0.02	0.17	-0.01	-0.06
Productivity (Private)*	4.97	-0.01	0.02	0.06	0.16	0.18	0.43	0.38	-0.05	0.04	-0.01	-0.06
Real Wage Rate (Private)**	1.98	-0.02	-0.11	-0.08	0.02	0.15	0.08	-0.18	-0.32	-0.27	-0.26	-0.17
Capacity Utilisation	1.75	-0.03	-0.02	0.00	0.13	0.26	0.27	0.28	0.12	-0.01	-0.08	-0.18
Business Inventory	2.91	-0.04	-0.21	-0.26	-0.30	-0.28	0.08	0.18	0.33	0.36	0.29	0.28
Final Domestic Sales	1.90	0.07	0.15	0.17	0.12	0.30	0.64	0.11	-0.03	0.00	-0.21	-0.02

Data Source: Reserve Bank of New Zealand.

Capacity Utilisation is not transformed into natural logarithms

*Real Private Output divided by Private Sector Total Hours Paid Per Quarter

**Deflated by GDP Deflator

Pro(counter)- cyclicity and Phase Shifts:

The nature of the cyclical relationship of selected variables with real GDP and of phase shifts are summarily presented in Table 6. Here we discuss some of the important attributes.

All important real expenditure variables, except imports, are procyclical. This includes exports and various components of consumption and investment. Private investment, consumption and their components all have significant contemporaneous procyclicity, while government investment appears to lag behind GDP by five quarters. Government expenditure as a whole is procyclical, but like government investment, lags real GDP by five quarters, mainly because the consumption component of government expenditure (not reported here) is not significantly correlated with real GDP.

A noticeable feature is that the components of investment and consumption, though significantly correlated with real GDP, have a much lower order of correlation than in the US economy as reported in Kydland and Prescott(1990). This is a feature reported by KBH as well. Interestingly most of these values in our finding are further below the KBH paper. This is consistent with KBH moving window cross-correlation observations that these correlations were falling off through the periods (KBH, Figure 3).

The behaviour of imports and exports merits separate statement. In contrast with the KBH paper that reported strong contemporaneous procyclicity of imports, our study finds a weak anticyclical behaviour lagging by five quarters. However the correlation of five-quarter lagged imports over the sample period (-0.21) is not significant at 1 per cent level and is significant only at 5 per cent. KBH had pointed out the unstable behaviour of imports revealed by their moving window analysis, and commented that the full sample correlations might be of limited value. We also feel that our own full sample findings are themselves not very revealing, and no generalisation can be made on the correlation between real GDP and imports.

Exports show marked procyclicity with contemporaneous correlation at 0.50. There is no indication of a phase shift. This contrasts with observations made in KBH over the longer period. The conjecture made by them about the more recent behaviour of exports on the basis of moving windows appears to be upheld by the more recent period used by us. When taken

in conjunction with other open economy variables discussed below, it appears that the relation of those factors to the domestic cycle is uncertain.

Table 4
Cyclical Behaviour of New Zealand Monetary and Open Economy Variables
Cross Correlations of Variables with Real GDP
Quarterly, 1975:1-1991:4

Variable x	Volatility (%Std.Dev)	x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
GDP	2.80	0.01	-0.09	0.10	0.10	0.16	1.00	0.16	0.10	0.10	-0.09	0.01
M1	6.24	0.13	0.06	0.07	0.08	-0.01	-0.05	-0.18	-0.12	-0.32	-0.21	-0.23
M3	3.55	-0.09	-0.14	-0.15	-0.11	-0.15	-0.13	-0.04	-0.02	-0.13	-0.14	-0.06
Velocity M1	9.84	-0.19	0.10	-0.13	-0.01	0.11	0.35	0.18	0.13	-0.01	0.02	0.31
Velocity M3	7.99	-0.07	0.19	-0.01	0.08	0.19	0.42	0.11	0.07	-0.17	-0.08	0.20
Private Mortgage Rate*	3.10	0.02	0.02	0.05	0.05	0.17	0.12	-0.08	-0.13	-0.09	-0.11	0.11
Bank Bill Rate*	2.46	-0.14	-0.15	-0.10	-0.14	0.03	0.12	0.12	0.19	0.18	-0.03	0.11
Trading Bank Lending Rate*	2.72	-0.03	-0.04	0.00	0.00	0.09	0.01	-0.12	-0.15	-0.07	-0.10	0.12
Government Security Rate*	2.72	-0.09	-0.07	0.00	0.03	0.14	0.13	-0.01	-0.05	-0.02	-0.07	0.12
GDP Deflator	3.42	0.05	-0.02	-0.15	-0.08	0.03	-0.30	0.01	-0.11	-0.21	-0.11	-0.13
Consumer Price Index	2.60	0.06	0.00	-0.05	-0.08	-0.11	-0.10	0.04	0.06	-0.03	-0.02	-0.08
Nominal Exchange Rate	4.33	-0.03	0.11	0.06	-0.18	-0.31	-0.31	-0.27	-0.15	-0.12	-0.15	-0.15
Real Exchange Rate	4.55	-0.18	-0.04	-0.01	-0.16	-0.18	-0.17	-0.12	0.00	-0.04	-0.02	-0.01
World GDP	1.38	-0.21	-0.08	-0.05	-0.07	0.00	0.07	0.11	0.16	0.14	0.07	-0.02
World Inflation	1.43	0.14	0.16	0.15	0.12	0.19	0.20	0.20	0.17	0.04	0.00	-0.08

Data Source: Reserve Bank of New Zealand. *Interest rates are not transformed into natural logarithms

The Labour Market:

Total employment has very little variation over the sample period, as we noted earlier. The temporal cross correlations with real GDP also move erratically across periods. This may be due to the near invariability of government employment. Private employment shows more variability, is procyclic, but lags the cycle by three quarters. Also the correlation at its highest

(0.22) is poor compared to very high values for the US labour market reported by Kydland and Prescott(1990). The reason may be institutional, and the alleged widespread tendency to labour hoarding in the economy. The number of hours worked in the private sector, though much more volatile, also shows erratic and poor correlation with GDP.

As a result of poor correlation between employment or hours with real GDP, both total and private sector productivity show strong procyclical tendency. Real wage rate behaves anticyclically, following the GDP with a lag of two quarters. In view of the fact that the GDP deflator and the Consumer Price Index are both anticyclical, it implies that nominal wages are sticky and do not respond well to the rise in GDP. Capacity utilisation is procyclic and is virtually contemporaneous with GDP. Business inventories are expectedly anticyclical and contemporaneous. The overall picture of the New Zealand production system that emerges from these observations on the input side variables, is a system that carries a stock of employed labour (like industrial capacity) and uses it more or less intensively in face of differing economic activity. The effect of increased activity thus does not spill into the labour market either generating significantly increased employment or increased nominal wages. The recent reforms in the economy and the labour market, particularly the State Sector Act, 1988 and the Employment Contracts Act, 1991 are expected to change some of these features in the near future.

Monetary Variables:

Money stock M1 has a much larger variability than real GDP and shows systematic countercyclicality with a lag of three quarters. M3 has consistently negative correlation coefficients but none significant at 5 per cent level. It is more stable than M1. Monetary velocities are better correlated with real GDP. Both M1 and M3 velocities are procyclical and contemporaneous.

Nominal interest rates on the principal loan instruments do not display any systematic relation with real GDP. Even the somewhat weak regularity displayed by trading bank lending rate reported in KBH is absent for the full sample period examined by us.

Table 5
Comparison of Volatility of Real GDP and other Variables

More Volatile than Real GDP	Real GDP	Less Volatile than Real GDP
Private Dwelling Investment: 9.78 Other Private Investment: 9.40 Total Investment: 6.47 Consumption Durables: 9.40 Total Exports: 4.19 Total Imports: 5.69	Volatility: 2.80	Private Consumption: 1.83 Total Employment : 1.00 Private Sector Employment 1.39 Market Employment: 1.07 Capacity Utilisation: 1.75 Final Sales: 1.90 World GDP: 1.38

Table 6
Cyclical Relations and Phase Shifts

Pro-cyclic		Counter-cyclic	
Contemporaneous	Total Investment Private Investment Investment in Dwellings Consumption of Durables Total Consumption Aggregate Productivity Private Sector Productivity Capacity Utilisation M1 Velocity M3 Velocity	Contemporaneous	Business Inventory GDP Deflator Nominal Exchange Rate Real Exchange Rate* World Inflation Rate*
Lagged	Government Investment Government Expenditure	Lagged	Private Employment* Real Wages M1

GDP deflator is contemporaneously countercyclical. For Consumer Price Index, though showing negative correlations, these correlation values are insignificant at any reasonable level.

Nominal exchange rate shows distinct contemporaneous anticyclicity. In the case of real exchange rate though, the coefficients are consistently negative, and the numerically largest of them is significant only at above 5 per cent level. The world inflation rate seems to be

procyclical. The effect of real GDP of the world as a whole is somewhat dubious. Though the largest correlation value is significant at 5 per cent level, the behaviour of lagged and led correlation is erratic. We are persuaded by the moving window analysis of this variable that the relation is not statistically stable.

The tentative conclusion we draw from these exercises is that, firstly, there is evidence of a structural break in the seventies, and secondly, that this break has not altered the qualitative nature of the cyclical relations reported in KBH.

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FOOTNOTES

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[1] We conducted a series of tests for difference stationarity using the ADF procedure, setting the lag length by both the min.AIC and the longest significant lag length criterion. The only case where, according to this set of tests, the null of difference stationarity can be rejected is that of no trend and k = 0, with the Min AIC criterion. In the other cases there is not enough statistical evidence to reject the null. The details of these exercises are available on request.

[2] The assistance of Professors S. Ng and P. Perron in providing a RATS procedure for carrying out these tests is gratefully acknowledged.

[3] The other five sets of results are available on request.

[4] It extracts a nonlinear trend which is stochastic but moves smoothly over time and is uncorrelated with the cyclical component. This involves choosing a trend that minimises the following:

$$\sum_{t=1}^{T}(y_t - y^{*}{}_t)^2 + \lambda\sum_{t=2}^{T-1}[(y_{t+1}{}^{*} - y_t) - (y_t{}^{*} - y_{t-1}{}^{*})]^2$$

where y_t is the original series, $y^{*}{}_t$ is the trend component of y_t , $y_t - y^{*}{}_t$ is the residual cyclical component and λ is a smoothing parameter. See Hodrick and Prescott, 1980.

[5] Note that volatility is measured here as a percentage (and not additive) deviation concept.