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Business Cycle Asymmetries and the Nominal Exchange Rate Regimes

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Abstract

This paper investigates differences in time series behaviour of real output and the price levels in seven countries (the United States, the United Kingdom, Germany, Japan, Canada, Australia, and New Zealand) under alternative exchange rate systems. Quarterly data spanning the Bretton-Woods and the subsequent floating exchange rate regimes are used to test whether or not the cyclical fluctuations of output and price levels are symmetric. It is shown that the evidence of asymmetries depends on the prevailing nominal exchange rate regime and the method used to de-trend the data.

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1. Introduction

Studying the differences in the characteristics of expansions and contractions of output has been an important part of the research on business cycle fluctuations. Mitchell (1927) and Keynes (1936) noted that although contractions are briefer than expansions, they are also more sudden and violent. In other words, the business cycle is asymmetric.

Empirically, the literature on business cycles provides ample evidence of asymmetry in the cyclical fluctuations of unemployment and industrial production time series. However, evidence of asymmetry in real GDP is weak or does not exist (Folk, 1986).[2] Different techniques have been used to test for symmetry in the literature. Most of the studies have been concerned with comparing periods of contractions with expansions. Only a few of these studies were concerned with identifying different types of asymmetry (for example, see Sichel (1993), Beaudry and Koop (1993), McQueen and Thorley (1993) and Verbrugge (1997)). Ramsey and Rothman (1996) and Verbrugge (1997) tested for symmetry in prices. None of these studies, however, has explicitly tested for symmetry under different exchange rate regimes.

Tests for symmetry of data spanning different monetary regimes may be subject to the Lucas critique. Kydland and Prescott (1990) argue that changes in institutional arrangements can lead to changes in the nature of economic shocks. Mussa (1986) provides evidence of non-neutrality of nominal exchange rate regimes. He shows that the distribution of the price level is different across fixed versus floating nominal exchange rate regimes. Backus, Kehoe, and Kydland (1994) test the changes in the mean and standard deviation of macroeconomic time series (including the price level) in different countries and across different exchange rate regimes and confirm Mussa's earlier conclusion regarding the non-neutrality of nominal exchange rate regimes. Baxter and Stockman (1989) also study the statistical behaviour of some macroeconomic time series (the price level was not included) for twenty-one OECD countries during the Bretton-Woods and the floating exchange rate regimes and confirm Mussa's findings, but find no systematic evidence of differences in the behaviour of the data across exchange rate regimes. There is evidence that the behaviour of the general price level depends on the exchange rate regime. Klein (1976) argues that the formation of price expectations depends on the prevalent type of monetary regime. Nadal De Simone (1997) shows that the behaviour of the price level and the nominal exchange rate is different in an inflation targeting regime than in a monetary targeting regime.

The objective of this paper is to answer the following questions: (1) how does the prevailing monetary arrangement such as different nominal exchange rate regimes affect the business cycles? This is accomplished by testing the null hypotheses that cyclical fluctuations of real output and the price levels are symmetric during (a) the fixed exchange rate system (i.e., Bretton-Woods); (b) the floating exchange rate system. The alternative hypothesis is asymmetry. Two types of symmetries will be investigated, i.e., steepness and deepness. (2) do stylised facts of the business cycles vary across countries as well as across exchange rate regimes? (3) do methods of de-trending the data affect the results?

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2 For empirical testing and evidence on asymmetry see, for example, Granger and Anderson (1978), Neftci (1984), Falk (1986), Chan and Tong (1986), DeLong and Summers (1986), Sichel (1989, 1993), Neftci and McNevin (1986), Tsay (1989), Hamilton (1989), Westland and Ohlen (1991), Rothman (1991), Tiao and Tsay (1991), Geweke and Terui (1991), Burgess (1992), Mittnik (1991), Hussey (1992), McQueen and Thorley (1993), Bradley and McClelland (1996), Ramsey and Rothman (1996), and Verbrugge (1997).

The types of asymmetry I am investigating in this paper are those described in Sichel (1993), Ramsey and Rothman (1996) and Verbrugge (1997), namely, steepness and deepness. The first type of asymmetry, "steepness," occurs when contractions are *steeper* than expansions. The second type of asymmetry, "deepness," occurs when troughs are *deeper* than peaks are tall.[3]

Figures 1 and 2 illustrate the difference between the two types of cyclical asymmetries. Let me start with steepness. Figure 1 shows a cycle exhibiting steepness, which pertains to relative *slopes* or *rate of change* and compares mirror images across an imaginary *vertical axis* placed at peaks and troughs (Sichel, 1993). Ramsey and Rothman (1996) use the notion "longitudinal" asymmetry to describe steep time series. Longitudinal asymmetry means asymmetry in the direction of movement of the business cycle. Alternatively, a time series is said to be steep if its *first difference* exhibits skewness. This means that sharp decreases in the series should be larger (smaller), but less frequent than the more moderate increases.

Figure 2 shows a cycle exhibiting deepness, which pertains to relative levels and compares mirror images across a *horizontal axis* (Sichel, 1993). Deepness occurs when the range from the mean to the peak is not equal to the range from the mean to the trough. This type of asymmetry is called "transversal" asymmetry in Ramsey and Rothman (1996). Alternatively, a time series that exhibits deepness should also exhibits skewness; that is, it should have fewer observations below (above) its mean or trend than above (below), but the average deviation of observations below (above) the mean or trend should exceed the average deviation of observations above (below). Note that if a time series exhibits either type of asymmetry, steepness or deepness, it is considered asymmetric.

The paper is organised as follows. Some of the implications of asymmetry are discussed next. A description of the non-parametric test statistic used in this paper is presented in section 3. In section 4, I test for steepness and deepness in real GDP and the CPI using quarterly data (1960q3-1997q3) for the US, UK, Germany, Japan, Canada, Australia and New Zealand.

It will be shown that the evidence of any type of asymmetry depends on the prevalent exchange rate regime. It also depends on the de-trending method used to de-trend the data. Further, asymmetries of business cycles are different across countries. Section 5 is a summary.

2. Implications of asymmetry

Stylised facts about business cycle fluctuations have been an important issue in economic literature. Whether GDP and CPI cyclical fluctuations are symmetric or not matters for macroeconomic modelling because linear models with Gaussian innovations cannot generate asymmetric fluctuations. Kim, Mittnik and Rachev (1996) show that the characteristic of the cyclical component of time series like GDP or the CPI depends on the properties of the transmission mechanism and the innovations. If either the transmission mechanism is non-linear or the innovations are asymmetric, the Data Generating Process (DGP) of GDP or the CPI will be asymmetric. Recently, Acemoglu and Scott (1997) offer a theory of economic fluctuations where they explain the asymmetrical behaviour of aggregate output even when the innovations are symmetric.

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[3] McQueen and Thorley (1993) test for another type of asymmetry; that is sharpness.

Evidence of asymmetry in the shocks, or non-linearity of the transmission mechanism implies that non-linear models are more appropriate to model time series than linear ones (e.g., Hamilton's (1989)). Non-linear models have important implications for estimation, calibration, forecasting, policy-simulation experiments and eventually, policy making. For example, the Reserve Bank of New Zealand and the Bank of Canada use calibrated models with asymmetrical transmission mechanisms. These models have been used for forecasting and policy in recent years.

An example of models that generate asymmetries is found in Ball and Mankiw (1994), where prices rise rapidly above their expected levels when output is above its potential level but fall relatively slowly when output is below its potential level. This has some interesting policy implications because positive demand shocks raise prices but have a relatively small impact on output while negative demand shocks have a relatively larger effect on output than prices. Sichel (1993) suggests that this type of model is consistent with deepness.[4] Chetty and Heckman (1986) and Baldwin and Krugman (1989) also provide models with asymmetrical behaviour, where exit from an industry is less costly for firms than entry, which implies production can fall rapidly but it rises more slowly. This type of model generates steepness in time series (Sichel, 1993).

3. Testing procedure

Economic theory provides few restrictions on the distributions of observable variables while most econometric analyses are based on tightly specified parametric models and likelihood-based methods. Maximum likelihood estimators are used to estimate the unknown parameters of the likelihood function given some regularity conditions (Cramer, 1946). These estimators are only asymptotically normal. The estimators will be inefficient and perhaps inconsistent if the parametric model is not true or is misspecified. Therefore, the cost of imposing strong restrictions that are required for parametric estimation and testing can be substantial. Non-parametric methods, on the other hand, are more attractive for identifying stylised facts because they are model-independent, do not require a specific functional-form and some are distribution-free. For these reasons, we use a non-parametric technique to test for symmetry.

DeLong and Summers (1989) use a test based on the skewness statistic. Sichel (1993) provides a test based on skewness but uses regression analysis. In this paper, the Triples test of Randles *et al* (1980) is used to test for symmetry in the cyclical fluctuations of real output and the price levels. I use the Triples test following Verbrugge (1997) approach. He tests for symmetry in a number of US macroeconomic time series.

The idea of the test is to examine all possible triples from a sample of size N (i.e., $\binom{N}{3}$ combinations) to test the null hypothesis that a given distribution is symmetric about some unknown median against a very broad class of asymmetric alternatives. For example, if all of these triples are right-skewed, then it is true for the whole underlying distribution. The test has some attractive features that it is independent of the moments of the distribution of the variable being tested, therefore it is not sensitive to outliers (e.g., skewness). Randles *et al* (1980) show that the test is superior to other tests of symmetries such as the U-statistic

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4 I tend to disagree with Sichel on this point. The notion of *rapid* and *slow* changes in prices seem to be indicative of *relative slope changes*, i.e., steepness.

(Davis, Clarence and Quade, 1978), The Sign test of Gastwirth (1971) and Gupta (1967). Eubank *et al* (1992) suggest that the test is the test of choice against unimodel alternatives to symmetry found in Granger and Anderson (1978).

The test is described as follows:[5]

Let $x_1,\ldots,x_N$ denote a random sample from a continuous population with cdf $F(x-\theta)$, where θ is an unknown median. If $i, j, and\ k$ are three distinct integers such that $1 \le i,\ j, k \le N$, the Triples of observations (x_i, x_j, x_k) forms a right Triples (skewed to the right) if the middle observation is closer to the smallest observation than it is to the largest one.

Let

$$g(x_i, x_j, x_k) = \frac{1}{3}[sign(x_i + x_j - 2x_k) + sign(x_i + x_k - 2x_j) + sign(x_j + x_k - 2x_i)] \quad (1)$$

The range of *g* is $[-\frac{1}{3}, 0, \frac{1}{3}]$. A right Triples is a Triples that maps into $\frac{1}{3}$ and a left Triples that which maps into $-\frac{1}{3}$. The Triples test is given by:

$$U = \frac{\hat{\eta} - \eta}{\sqrt{\sigma^2_{\hat{\eta}} / N}} \approx N(0,1) \quad (2)$$

where

$$\hat{\eta} = \binom{N}{3}^{-1} \sum_{i<j<k} g(.) \quad (3)$$

This implies that $\hat{\eta}$ is the (number of right Triples - number of left Triples)/ $3\binom{N}{3}$

$E(\hat{\eta}) = \eta = pr\{x_1 + x_2 - 2x_3 > 0\} - pr\{x_1 + x_2 - 2x_3 < 0\}$, with

$$\sigma^2_{\hat{\eta}} \big/ N = \binom{N}{3}^{-1} \sum_{c=1}^{3} \binom{3}{c} \binom{N-3}{3-c} \hat{\zeta}\, c \quad (4)$$

where

$$\hat{\zeta}_1 = \frac{1}{N} \sum_{i=1}^{N} (g_1(x_i - \hat{\eta})^2 \quad (5)$$

and

$$g_1(x_i) = \binom{N-1}{2}^{-1} \sum_{\substack{j<k \\ i \ne j,\, i \ne k}} \sum g(x_i, x_j, x_k) \quad (6)$$

[5] I thank Randal Verbrugge for providing his code to compute the statistics.

$$\hat{\zeta}_2 = \binom{N}{2}^{-1} \sum_{j<k} \sum g_2 \, [(x_j, x_k) - \hat{\eta}]^2 \tag{7}$$

and

$$g_2(x_j, x_k) = \frac{1}{N-2} \sum \sum_{\substack{i=1 \\ i \neq j \neq k}} g(x_i, x_j, x_k) \tag{8}$$

and

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

We test

$H_0 : \hat{\eta} = 0$ versus $H_1 : \hat{\eta} \neq 0$

4. Results and analysis

The data for real GDP are quarterly from 1960q3 to 1997q2 and those for the CPI are from 1960q3 1997q3.[6] The sample includes the United States (USA), the United Kingdom (UK), Germany, Japan, Canada, Australia, and New Zealand.

Nelson and Plosser (1982) show that the natural logarithms of GDP and the CPI are approximately unit root processes. We use the ADF and the Phillips-Perron tests to test the null hypothesis that the logarithms of real output and the price levels are unit root processes under both the fixed and the floating exchange rates regimes. We cannot reject the null hypothesis that the two series contain unit roots.[7]

Testing the null hypothesis that the cyclical components of real output and the price levels are symmetric across the exchange rate regimes involves testing for (1) steepness and (2) deepness. To test for steepness, the natural logarithms of real GDP ($\ln y_t$) and CPI ($\ln P_t$) are de-trended using the first difference operator. To test for deepness, the natural logarithms are de-trended using four filters. The first filter is the Hodrick-Prescott (1997) filter, HP1.[8] The second filter is a variate of the HP filter, HP2 (Razzak, 1997). This filter is computed by recursively solving the minimisation problem of the Hodrick and Prescott loss function. The

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[6] The source of the data is Datastream except for Canada which is the International Financial Statistics, and New Zealand, which is Statistics New Zealand. Examination of the data shows some seasonal pattern in the CPI for the UK and Japan. Because methods of seasonal adjustment are controversial, I decided to use the data the way the are published. Evidence of asymmetry in the UK and Japanese data might be biased and results should be interpreted with care.

[7] We do not report the results but they are available from the author. However, there is a controversy about the power of these tests against stationary alternatives but it is well accepted that these two series contain unit roots. Phillips (1991) uses a Bayesian method to test the Nelson-Plosser data and confirmed that most of them contain unit roots (see the Journal of Applied Econometrics (1991, p. 333-374) special issue on this matter). Johansen (1992) provides a discussion of ARIMA models with an I(2) representation; it contains two unit roots. From an economic perspective, Granger (1997, P. 173) casts some doubt on the plausibility of I(2) characterisation. I follow Granger and assume that the two series are I(1).

[8] The HP filter is well known and widely used. Properties of the HP filter are criticized in the literature (See Nelson and Kang (1981), Harvey and Jaeger (1991), King and Rebelo (1993), and Cogley and Nason (1995).

third filter is the non-parametric filter of Coe and McDermott (1997), NP, which is a statistical procedure, where the trend is estimated using the non-parametric regression estimation method known as the Nadaraya-Watson method. This method does not require the researcher to specify a particular functional form for the trend. It is shown that it is asymptotically optimal, in the sense that it minimises a global error criterion (cross validation) and ensures that the degree of smoothing is consistent with the cyclical properties of the data. Finally, the Baxter and King (1995) Band-Pass filter, BK, is used. All of them are linear so they satisfy the requirement for testing the null hypothesis, which is symmetry without inducing a bias. Sichel (1993) and Verbrugge (1997) provide evidence that the Nelson-Beveridge filter biases the test for symmetry, therefore it is not used in this paper.[9]

Here, I stress again that the de-trending method is the key to answering questions regarding business cycles asymmetries of the "deepness" type. The filters listed above represent a particular view on how the growth-cycle phenomenon is determined. There are other filters such as the deterministic linear trend, moving averages, and the Kalman filter (Kuttner, 1994), which I do not use in this paper.

In table 1, I report the correlation coefficients between all four cyclical measures of GDP, and for all countries. It seems obvious that there is little correlation between these different measures of the cycles. It will be shown that because of that the results of the test for symmetry in the business cycle vary substantially.

To test, we split the sample into two sub-samples: the Bretton-Woods period (1960q3 to 1973q2) and the floating period, where the sample starts in 1973q3.[10] The fixed exchange rate regime in New Zealand continued until March 1985 and in Australia until 1983q2.

Testing results for steepness are reported in tables 2 and 3. I report the Triples test, U, and P values. From table 2, the Triples tests indicate that the null hypothesis cannot be rejected under the fixed and the floating exchange rate regimes, except perhaps for the UK (P-value 0.0244). Real GDP data (i.e., $\Delta \ln y_t = \varepsilon_t$) seem to be symmetric across regimes. This result is consistent with the literature (for example, see DeLong and Summers (1989), Sichel (1993), and Verbrugge (1997)). The lack of steepness in GDP goes against the assertions of Mitchell and Keynes.

The results for testing $\Delta \ln P_t$ are reported in table 3. Under the fixed exchange rate regimes, the null hypothesis of symmetry is not rejected, except in the case of Australia. The CPI for Japan and New Zealand may exhibit some steepness. The null hypothesis of symmetry can be rejected with P-values 0.04 and 0.05 respectively. However, under the floating exchange rates regimes, significant evidence of steep asymmetry in the CPI (i.e., $\Delta \ln P_t = \zeta_t$) is found except for Australia. This type of asymmetry is consistent with Ramsey and Rothman (1996) and Verbrugge (1997) for the US data. Positive steepness indicates that the CPI increased rapidly for some time, and then it either increased at a slower rate, or fell.

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[9] It is very likely that the value of the smoothing parameter (λ) in the Hodrick-Prescott filter varies from one country to another. However, searching for the optimal value of (λ) for each country is beyond the scope of this paper. Therefore, a value of 1600 for all countries is maintained.

[10] I left out one quarter (three months) to avoid the volatility related to the transition from the fixed to the floating exchange rate regime.

This evidence is plausible because (1) most CPIs in the industrialised countries were subject to the same oil price shocks (1973 and 1979) and (2) more recently, most of these countries seem to have been pursuing similar price-stabilisation objectives. This result can be interpreted as evidence that the nature of the shocks to the price level has changed under the floating exchange rates regimes. Kydland and Prescott (1990) argue that changes and expected changes in institutions may alter the nature, magnitudes, and the volatility of economic shocks. The statistics for the UK and Japan are likely to be biased because both data exhibit some seasonal fluctuations (see footnote 5).

The test statistics for deepness in real GDP are presented in table 4. For each country, four different techniques to de-trend output are used. It has been shown that the correlation coefficients between these cyclical measures are small. In general, there is evidence of deepness in GDP. This evidence exists under both the fixed and the flexible exchange rate regimes. However, the evidence of asymmetry is dependent on the type of de-trending method used to generate the trend and, therefore, the cycle. Recall that the type of asymmetry in GDP that is consistent with the stylised facts of Mitchell (1927) and Keynes (1936) should be a negative-deep asymmetry; that is with troughs deeper than expansions.

The results of the test for deepness reported in tables 4 and 5 can be summarised as follows:

The evidence of asymmetry in real GDP depends on the filtering technique used to de-trend the data. The significance of the test statistics seems to follow no particular pattern across exchange rate regimes. Also, no pattern is found within a given regime across countries. Also, the finding of asymmetry in GDP is affected by nominal exchange rate regimes. Almost all significant evidence of negative deepness in GDP is found under the Bretton-woods system. This evidence of negative deepness is consistent with Mitchell (1927) and Keynes (1936). This type of asymmetry is found in the US and Canada under both exchange rate regimes. Under the floating regime, Germany, Japan, and New Zealand GDPs exhibit significant positive deepness that is not consistent with Mitchell (1927) and Keynes (1936). Similar qualitative results hold for the CPI. The evidence of deep-asymmetry is less significant than that found in real GDP.

5. Summary

Mitchell (1927) and Keynes (1936) noted that although contractions of economic activity are briefer than expansions; they are more sudden and violent. Hence, the business cycle is asymmetric. The notion that recessions are *deeper* (i.e., deepness) than expansions has been tested by a large number of researchers. The literature provides evidence of asymmetry in fluctuations of unemployment and industrial production. Very little evidence of asymmetry, however, is found in GDP fluctuations. To arrive at this result, researchers used different methods of testing. Most of the studies used US data. Very few studies examined the cyclical fluctuations of the price level. In all studies, researchers ignored the fact that the nominal exchange rate *regime* is non-neutral. By non-neutral we mean that the behaviour of macroeconomic variables is affected by the prevalent nominal exchange rate regimes (Klein, 1976 and Mussa, 1986).

Business cycles asymmetries have some interesting implications. Ball and Mankiw (1994), for example, provide a model that can generate asymmetry (i.e., deepness). Chetty and Heckman (1986) and Baldwin and Krugman (1994) provide models that can generate asymmetry (i.e., steepness). Whether GDP and CPI fluctuations are symmetric or not affects macroeconomic modelling, which in turn affects the estimation and the calibration of models. It follows that forecasts obtained from such non-linear models are different from those obtained from linear models. Policy simulation exercises are also influenced. Eventually, policy recommendations and policy-making will also be affected. The Ball and Mankiw (1994) model has some interesting policy implications because positive demand shocks raise prices but have a relatively small impact on output while negative demand shocks have a relatively larger effect on output than prices.

In this paper, I am not only testing for symmetry but I identify different types of asymmetries in the cyclical fluctuations of GDP and the CPI for a number of countries (US, UK, Germany, Japan, Canada, Australia and New Zealand). The two types of asymmetry are steepness and deepness. If a time series exhibits either type, it is said to be asymmetric. These types were identified in Sichel (1993), Ramsey and Rothman (1996) and Verbrugge (1997). A negative deep asymmetry in the cyclical fluctuations of GDP is consistent with Mitchell (1927) and Keynes (1936) observations.

To test for symmetry, I use the non-parametric Triples test of Randles *et al* (1980). This paper is different from the literature in the sense that I allow for exchange rate regime non-neutrality. I test the data under the fixed exchange rate regime (i.e., Bretton-Woods) and the recent floating exchange rate regime. I also test the data under the inflation targeting regimes in the UK, Canada, Australia and New Zealand. My main findings are:

(1) The finding of asymmetry is affected by the prevalent nominal exchange rate regime because of exchange rate regimes non-neutrality.

(2) The evidence of business cycles asymmetries varies from one country to another. Under both exchange rate regimes, the US and Canada share similar asymmetries that are consistent with Mitchell (1927) and Keynes (1936), i.e., negative-deepness. However, Germany, Japan and New Zealand business cycles under floating exchange rate regimes seem to exhibit positive-deepness.

(3) The evidence of asymmetry mentioned in (2) depends on the filtering method used to de-trend the data.

Specifically,

(4) I find no evidence of asymmetry in CPI during the period of fixed exchange rate regimes. However, a significant evidence of steepness in the CPI is found during the period of floating exchange rate regimes. This evidence is consistent with the fact that the CPI grew at a fast rate in the early 1970s then it either grew a slower rate or fell.

(5) Regardless of the exchange rate regime, no significant evidence of steepness in GDP is found.

(6) Regardless of the exchange rate regime, no significant evidence of deepness in CPI is found.

(7) Under both exchange rate regimes, a significant evidence of deepness in GDP is found.

Future research will attempt to provide a Monte-Carlo experiment to prove that the method of de-trending matters for testing business cycle symmetries.

References

Acemoglu, D and A Scott, “Asymmetric Business Cycles: Theory and Time Series Evidence,” *Journal of Monetary Economics* 40 (1997), 501-533.

Backus, D, P J Kehoe and F E Kydland, ”International Business Cycles: Theory and Evidence,” In Thomas F Cooley (ed.,) *Frontiers of Business Cycle Research.* Princeton University Press, Princeton New Jersey (1994), 331-356.

Ball, L and G Mankwi, “Asymmetric Price-Adjustment and Economic Fluctuations,” The Economic Journal 104 (1994), 247-262.

Baldwin, R and P Krugman, “Persistent Trade Effects of large Exchange Rate Shocks,” *Quarterly Journal of Economics* 104(4) (1989), 635-645.

Baxter, M and R King, ”Measuring Business Cycles: Approximate Band-Pass Filters for Economic Time Series,” *National Bureau of Economic Research*, Working Paper No. 5022: Cambridge, MA, (1995).

Baxter, M and A Stockman, “Business Cycles and the Exchange-Rate Regime,” *Journal of Monetary Economics* 23 (1989), 377-400.

Beaudry, P and G M Koop, “Do Recessions Permanently Change Output?” *Journal of Monetary Economics* 31 (1993), 149-163.

Bradley, R and R McClelland, “A Kernel Test for Neglected Nonlinearity,” *Studies in Nonlinear Dynamics and Econometrics* 1(2) (1996), 119-130.

Bowen, A, “British Experience with Inflation Targetry,” in Leiderman, L and L Svensson (eds.,) *Inflation Targets* . London, UK, Centre of Economic Policy Research, (1995), 53-68.

Burgess, S M, “Asymmetric Employment Cycles in Britain: Evidence and an Explanation,” *The Economic Journal* 102 (1992), 279-290.

Chan, K S and H Tong, “On Estimating Thresholds in Autoregressive Models,” *Journal of Time Series Analysis* 7 (1986), 179-190.

Chetty, V K and J J Heckman, “A Dynamic Model of Aggregate Supply, Factor Demand and Entry and Exit for a Competitive Industry with Heterogeneous Plants,” *Journal of Econometrics* (1986), 237-262.

Coe, D and J McDermott, “Does the Gap Model Work in Asia?” *International Monetary Fund Staff Papers* Vol. 44 No.1 (1997), 59-80.

Cogley, T and J Nason, “Effects of the Hodrick-Prescott Filter on Trend and Difference Stationary Time Series: Implications for Business Cycle Research,” *Journal of Economic Dynamics and Control* 19 (1995), 253-278.

Cramer, H, Mathematical Methods of Statistics, Princeton, N. J.: Princeton University Press (1946).

Davis, C, E Clarence and D Quade, "U-Statistics for Skewness or Symmetry," *Communications of Statistics-Theory and Methods* A7 (5), (1978), 413-418.

DeLong, G and L Summers, "Are Business Cycles Symmetrical?" In Robert Gordon (ed.,) *American Business Cycles: Continuity and Change.* Chicago, Illinois: National Bureau of Economic Research and the University of Chicago Press, (1986).

Eubank, R, V Lariccia and R Rosenstein, "Testing Symmetry about an Unknown Median, via Linear Rank Procedures," *Nonparametric Statistics* 1, (1992), 301-311.

Falk, B, "Further Evidence on the Asymmetric Behaviour of Economic Time Series Over the Business Cycle," *Journal of Political Economy* 94, (1986), 1096-1109.

Freedman, C, "The Canadian Experience with Targets for Reducing and Controlling Inflation," in Leiderman, L. and L. Svensson (eds.,) *Inflation Targets* . London, UK, Centre of Economic Policy Research, (1995), 19-31.

Gastwirth, J L, "On the Sign Test for Symmetry," *Journal of the American Statistical Association* 66, (1971), 821-823.

Geweke, J and N Terui, "Threshold Autoregressive Models for Macroeconomic Time Series: A Bayesian Approach," American Statistical Association (1991) Proceedings of the Business and economics Statistic Section, American Statistical Association.

Granger, C W J, "On Modelling the Long Run in Applied Economics," The Economic Journal Vol. 107 No. 440, (1997), 169-177.

Granger, C W J and A P Anderson, "An Introduction to Bilinear Time Series Models," Gottingen: Vandenhoek and Ruprecht, (1978).

Gupta, M K, "An Asymptotically Non parametric Test for Symmetry," Annals of Mathematical Statistics 38, (1967), 849-866.

Hamilton, J D, "A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle," Econometrica 57 (1989), 357-384.

Harvey A and A Jaeger, "Deterending , Stylized Facts and the Business Cycle," Journal of Applied Econometrics 8(3), (1993), 231-247.

Hussey, R, "Nonparametric Evidence on Asymmetry in Business Cycle Using Aggregate Employment Time Series," *Journal of Econometrics* 51 (1992), 217-231.

Johansen, S, "A Statistical Analysis of Cointegration for I(2) Variables," *Econometric Theory* 11(1) (1995), 25-29.

Keynes, J M, The General Theory of Employment, Interest and Money, (1936), London: Macmillan.

Kim, K, R A Buckle and V Hall, "Dating New Zealand Business Cycles," *New Zealand Economic Papers* 29(2) (1995), 143-141.

Kim, J, S Mittnik, and S Rachev, "Detecting Asymmetries in Observed Linear Time Series and Unobserved Disturbances," *Studies in Nonlinear Dynamics and Econometrics* 1(3), (1996), 131-143.

King, R and S Rebelo, "Low Frequency Filtering and the Real Business Cycle," *Journal of Economic Dynamics and Control* 17, (1993), 207-231.

Klein, B, "The Social Costs of the Recent Inflation: The Mirage of Steady, Anticipated Inflation," *Carnegie-Rochester Conference Series* 3 (1976), 185-212.

Kuttner, K N, "Estimating Potential Output as a Latent Variable," *Journal of Business & Economics Statistics* 12 (1994), 361-368.

Kydland, F and E Prescott, "Business Cycles: Real Facts and a Monetary Myth," *Federal Reserve Bank of Minneapolis Quarterly Review* (1990), 3-18.

McNevin, B and S Neftci, "Some Evidence on the Non-Linearity of Economic Time Series." In Jess Benhabib (ed.,) *Cycles and Chaos in Economic Equilibrium*, Princeton, New Jersey: Princeton University Press, (1992), 429-445.

McQueen, G and S R Thorley, "Asymmetric Business Cycle Turning Points," *Journal of Monetary Economics* 31 (1993), 341-362.

Mitchell, W, Business Cycles: The Problem and Its Setting, (1927), New York: National Bureau of Economic Research.

Mittnik, S and Z Niu, "Asymmetries in Business Cycles: Econometric Techniques and Empirical Evidence." In Willi Semmler (ed.,) *Business Cycles: theory and Empirical Methods*. Boston, Massachusetts: Kluwer, (1994), 331-350.

Mussa, M, "Nominal Exchange Rate Regimes and the Behaviour of Real exchange Rates," In K. Brunner and A. Meltzer (eds.,) Real Business Cycles, Real Exchange Rates, and Actual policies. Carnegie-Rochester Conference Series. Amsterdam: North-Holland Vol. (25) (1986), 117-214.

Nadal De Simone, F, "Inflation Targeting and Monetary Targeting in a Small Open Economy: The Behaviour of Price Levels," Reserve Bank of New Zealand Working Paper W96/4 (Wellington, New Zealand), (1996).

Neftci, S, "Are Economic Time Series Asymmetric Over the Business Cycle?" *Journal of Political Economy* 92 (1984), 307-328.

Phillips, P C B, "To Criticise the Critics: An Objective Bayesian Analysis of Stochastic Trends," Journal of Applied Econometrics Vol. 6 (1991), 333-364.

Ramsey, J and P Rothman, "Time Irreversibility and Business Cycle Asymmetry," *Journal of Money, Credit and Banking* 28 (1996), 1-21.

Randles R, M Flinger, G Policello and D Wolfe, “An Asymptotically Distribution-Free Test for Symmetry Versus Asymmetry,” *Journal of the American Statistical Association* 75 (1980), 168-172.

Razzak, W A, ”The Hodrick-Prescott Technique: A Smoother versus a Filter An Application to New Zealand GDP,” *Economics Letters* 56 (1997), 163-168.

Rothman, P, ”Further Evidence on the Asymmetric Behaviour of Unemployment Rates Over the Business Cycle,” *Journal of Macroeconomics* 13 (2) (1991), 291-298.

Sichel, D, “Business Cycle Asymmetry? A Deeper Look,” *Economic Inquiry* 31 (1993), 224-236.

Sichel, D, “Are Business Cycles Asymmetric? A Correction,” *Journal of Political Economy* 97(5) (1989), 1255-1260.

Tiao, G C and R S Tsay, “Some Advances in Nonlinear and Adaptive Modelling in Time Series Analysis,” University of Chicago Graduate School of Business and Statistics Research Centre Technical report No 118 (1991).

Tsay, R S, “Testing and Modelling Threshold Autoregressive Processes,” *Journal of the American Statistical Association* 84 (1989), 231-240.

Verbrugge, R, “Investigating Cyclical Asymmetries,” *Studies in Nonlinear Dynamics and Econometrics* 2(1) (1997), 15-22.

Westlund A and S Ohlen, “On Testing for Symmetry in Business Cycles,” *Empirical Economics* 16 (1991), 479-502.

Table 1
Correlation Coefficients of de-trended GDP measures

US	HP1	HP2	BK	NP
HP1	1.00000	0.55069	0.70489	0.52200
HP2	0.55069	1.00000	0.25318	0.61841
BK	0.70489	0.25318	1.00000	0.64771
NP	0.52218	0.61841	0.64771	1.00000
UK	HP1	HP2	BK	NP
HP1	1.00000	0.43598	0.46283	0.51583
HP2	0.43598	1.00000	-0.04687	0.38059
BK	0.46283	-0.04687	1.00000	0.59927
NP	0.51583	0.38059	0.59927	1.00000
Germany	HP1	HP2	BK	NP
HP1	1.00000	0.52653	0.50897	0.47289
HP2	0.52653	1.00000	0.05724	0.46292
BK	0.50897	0.05724	1.00000	0.60401
NP	0.47289	0.46292	0.60401	1.00000
Japan	HP1	HP2	BK	NP
HP1	1.00000	0.33306	0.59069	0.37561
HP2	0.33306	1.00000	-0.10159	0.33884
BK	0.59069	-0.10159	1.00000	0.51693
NP	0.37561	0.33884	0.51693	1.00000
Canada	HP1	HP2	BK	NP
HP1	1.00000	0.45669	0.63915	0.45086
HP2	0.45669	1.00000	0.08640	0.45539
BK	0.63915	0.08640	1.00000	0.60362
NP	0.45086	0.45539	0.60362	1.00000
Australia	HP1	HP2	BK	NP
HP1	1.00000	0.71164	0.03379	0.22358
HP2	0.71164	1.00000	-0.21562	0.34284
BK	0.03379	-0.21562	1.00000	0.38185
NP	0.22358	0.34284	0.38185	1.00000
New Zealand	HP1	HP2	BK	NP
HP1	1.00000	0.53964	0.39897	0.50413
HP2	0.53964	1.00000	-0.08172	0.41578
BK	0.39897	-0.08172	1.00000	0.59957
NP	0.50413	0.41578	0.59957	1.00000

HP1 is the Hodrick-Prescott (1997) filter with a smoothing parameter = 1600, HP2 is the modified HP filter (Razzak, 1997), BK is the Baxter-King (1995) Band-Pass filter, and NP is the non-parametric filter (Coe and McDermott, 1997).

Table 2
Test for Steepness ($\Delta \ln GDP_t$)

	Bretton-Woods(1960q3-1973q2)			Floating (1973q3-1997q32		
	$\hat{\eta}$	U	P value	$\hat{\eta}$	U	P Value
USA	-0.007550	-0.0998	0.4602	-0.018848	-0.9256	0.1773
UK	0.010442	0.3989	0.3449	-0.036547	-1.9694	0.0244
Germany	-0.018197	-0.7343	0.2314	0.026108	1.1786	0.1193
Japan	0.016633	0.5720	0.2836	-0.011726	-0.5528	0.2902
Canada	0.010748	0.4600	0.3227	-0.002891	-0.1732	0.4312
Australia [a]	0.017323	0.8088	0.2093	0.013627	0.5479	0.2918
New Zealand [b]	-0.006425	-0.2747	0.3917	-0.038891	-1.3628	0.0864

The null hypothesis H_0: Symmetry, and the alternative H_1: Asymmetry (steepness).
U is the Triples test statistic (Randles, Flinger, Policello and Wolfe, 1980), which is, asymptotically, distributed standard normal.

a: For Australia, the period of fixed exchange rate regime is 1960q3 to 1983q2, and the period of the float is 1983q3 to 1997q3.

b: For New Zealand, the period of fixed exchange rate regime is 1960q3 to 1985q1, and the period of the float is 1985q3-1997q3.

Table 3
Test for Steepness ($\Delta \ln CPI_t$)

	Bretton-Woods (1960q3-1973q2)			Floating (1973q3-1997q3)		
	$\hat{\eta}$	U	P value	$\hat{\eta}$	U	P Value
USA	-0.008371	-0.3200	0.3745	0.085251	6.2259*	0.0001
UK	0.011312	0.4435	0.3200	0.087006	6.4792*	0.0001
Germany	0.025309	1.0786	0.1400	0.035047	2.3526*	0.0090
Japan	0.042443	1.7509	0.0400	0.094971	6.5154*	0.0001
Canada	-0.002142	-0.0942	0.4625	0.037961	2.2584*	0.0119
Australia [a]	0.049752	2.6892*	0.0030	0.002221	0.0887	0.4646
New Zealand [b]	0.031228	1.6396	0.0500	0.105319	4.6086*	0.0001

The null hypothesis H_0: Symmetry, and the alternative H_1: Asymmetry (steepness).
U is the Triples test statistic (Randles, Flinger, Policello and Wolfe, 1980), which is, asymptotically, distributed standard normal.

a: For Australia, the period of fixed exchange rate regime is 1960q3 to 1983q2, and the period of the float is 1983q3 to 1997q3.

b: For New Zealand, the period of fixed exchange rate regime is 1960q3 to 1985q1, and the period of the float is 1985q3-1997q3.

Asterisk means significant at the 5% level.

Table 4

Test for Deepness ($\ln GDP_t - \ln GD\overline{P}$)

		Bretton Woods(1960q3-1973q2)			Floating (1973q3-1997q2)		
	Trend	$\hat{\eta}$	U	P value	$\hat{\eta}$	U	P Value
USA	HP1	0.017	0.6341	0.2630	-0.032	-1.9712	0.0243
	HP2	0.002	0.0697	0.4722	-0.033	-2.3576*	0.0091
	NP	-0.046	-1.6321	0.0513	-0.035	-2.1681*	0.0150
	BK	-0.071	-2.5736*	0.0050	-0.012	-0.7514	0.2262
UK	HP1	0.005	0.2258	0.4106	0.025	1.5615	0.0592
	HP2	0.001	1.3856	0.0829	-0.054	-3.1150*	0.0009
	NP	-0.058	-2.0669*	0.0193	0.016	0.9251	0.1774
	BK	0.017	0.6798	0.2483	0.044	2.7597*	0.0029
Germany	HP1	-0.067	-3.2118*	0.0006	0.045	2.6010*	0.0046
	HP2	0.004	0.1380	0.4451	-0.016	-0.7383	0.2301
	NP	-0.055	-2.4370*	0.0074	0.033	1.8299	0.0336
	BK	-0.076	-2.4257*	0.0076	0.047	2.6823*	0.0036
Japan	HP1	0.034	1.4629	0.0717	0.034	1.9990	0.0228
	HP2	-0.056	-2.0290*	0.0212	-0.064	-4.0042*	0.0001
	NP	-0.055	-2.3589*	0.0091	0.065	4.3624*	0.0001
	BK	-0.019	-0.5366	0.2957	0.048	3.1831*	0.0009
Canada	HP1	-0.016	-0.7346	0.2313	0.015	0.6885	0.2455
	HP2	-0.005	-0.2257	0.4107	-0.025	-1.6616	0.0483
	NP	-0.097	-5.6044*	0.0001	-0.050	-3.5588*	0.0002
	BK	-0.053	-2.0394*	0.0207	-0.029	-2.0499*	0.0218
Australia [a]	HP1	-0.043	-2.9180*	0.0017	0.040	1.8483	0.0323
	HP2	-0.034	-2.1843*	0.0144	-0.001	-0.0653	0.4739
	NP	-0.087	-5.9120*	0.0001	-0.008	-0.3227	0.0373
	BK	0.009	0.4860	0.3135	-0.038	-1.5133	0.0605
New Zealand [b]	HP1	0.004	0.2363	0.4066	-0.059	-2.9623*	0.0015
	HP2	-0.007	-0.3854	0.3499	0.098	6.1047*	0.0001
	NP	-0.003	-0.1242	0.4506	-0.058	-2.9680*	0.0015
	BK	0.025	1.3045	0.0960	-0.043	-1.5494	0.0606

The null hypothesis H_0: Symmetry, and the alternative H_1: Asymmetry (Deepness). U is the Triples test statistic (Randles, Flinger, Policello and Wolfe, 1980), which is, asymptotically, distributed standard normal.

a: For Australia, the period of fixed exchange rate regime is 1960q3 to 1983q2, and the period of the float is 1983q3 to 1997q3.

b: For New Zealand, the period of fixed exchange rate regime is 1960q3 to 1985q1, and the period of the float is 1985q3-1997q3.

HP1 is the HP filter with lambda=1600. HP2 is the HP filter (Razzak, 1997), where the sample is 1963q3-1997q2. NP is the non-parametric filter (Coe and McDermott, 1997) and BK is the Baxter and King (1995) Band-Pass filter, where the sample is 1964q3 to 1996q4. Asterisk means significant at the 5% level.

Table 5

Test for Deepness ($\ln CPI_t - \ln C\bar{PI}$)

		Bretton-Woods (1960q3 -973q2)			Floating (1973q3-1997q3)		
	Trend	$\hat{\eta}$	U	P value	$\hat{\eta}$	U	P Value
USA	HP1	-0.020	-0.674	0.2500	0.009	0.7015	0.2415
	HP2	0.331	1.293	0.0980	0.005	0.3681	0.3564
	NP	-0.027	-0.9928	0.1604	0.006	0.3575	0.3603
	BK	0.011	0.3341	0.3691	-0.002	-0.1257	0.4499
UK	HP1	-0.028	0.9450	0.1723	0.006	0.4550	0.3245
	HP2	0.028	0.9546	0.1698	0.055	3.8510*	0.0001
	NP	0.011	0.4237	0.3359	0.017	0.9755	0.1646
	BK	-0.052	-1.7048	0.0441	-0.017	-0.9131	0.1806
Germany	HP1	0.014	-0.5416	0.2949	-0.022	-1.0526	0.4580
	HP2	0.072	3.5711*	0.0001	0.021	1.0480	0.1473
	NP	-0.004	-0.1658	0.4341	-0.036	-2.1257*	0.0167
	BK	-0.012	-0.3850	0.3501	-0.021	-0.8665	0.1931
Japan	HP1	-0.071	-2.5030*	0.0061	-0.017	-0.8036	0.2108
	HP2	0.031	1.0382	0.1495	0.048	2.1464*	0.0159
	NP	-0.016	-0.6788	0.2486	0.005	0.2404	0.4050
	BK	-0.109	-4.7681*	0.0001	0.015	0.7022	0.2413
Canada	HP1	-0.032	-1.3904	0.0822	0.076	5.5346*	0.0001
	HP2	-0.024	-0.6298	0.2644	0.017	1.1449	0.1261
	NP	-0.009	-0.3980	0.3453	0.040	2.1683*	0.0150
	BK	-0.054	-1.7592	0.0392	0.030	1.6654	0.0479
Australia [a]	HP1	-0.001	-0.0899	0.4642	0.040	1.8483	0.0323
	HP2	0.045	2.6546*	0.0039	- 0.066	-2.6888*	0.0035
	NP	0.020	1.0600	0.1446	0.003	0.1183	0.4529
	BK	-0.005	-0.3421	0.3661	0.024	0.8941	0.1856
New Zealand [b]	HP1	-0.023	-1.1748	0.1200	0.048	2.1892*	0.0143
	HP2	-0.016	-0.7669	0.2216	0.036	1.0349	0.1503
	NP	-0.0005	-0.0300	0.4880	0.017	0.5506	0.2909
	BK	0.037	2.1043*	0.0176	-0.0446	-1.5898	0.4368

The null hypothesis H_0: Symmetry, and the alternative H_1: Asymmetry (Deepness). U is the Triples test statistic (Randles, Flinger, Policello and Wolfe, 1980), which is, asymptotically, distributed standard normal.

a: For Australia, the period of fixed exchange rate regime is 1960q3 to 1983q2, and the period of the float is 1983q3 to 1997q3.

b: For New Zealand, the period of fixed exchange rate regime is 1960q3 to 1985q1, and the period of the float is 1985q3-1997q3.

HP1 is the HP filter with lambda=1600. HP2 is the HP filter (Razzak, 1997), where the sample is 1963q3-1997q2. NP is the non-parametric filter (Coe and McDermott, 1997), and BK is the Baxter and King (1995) Band-Pass filter, where the sample is 1964q3-1996q4. Asterisk means significant at the 5% level.

Figure 1 A steep time series (a longitudinal asymmetry)

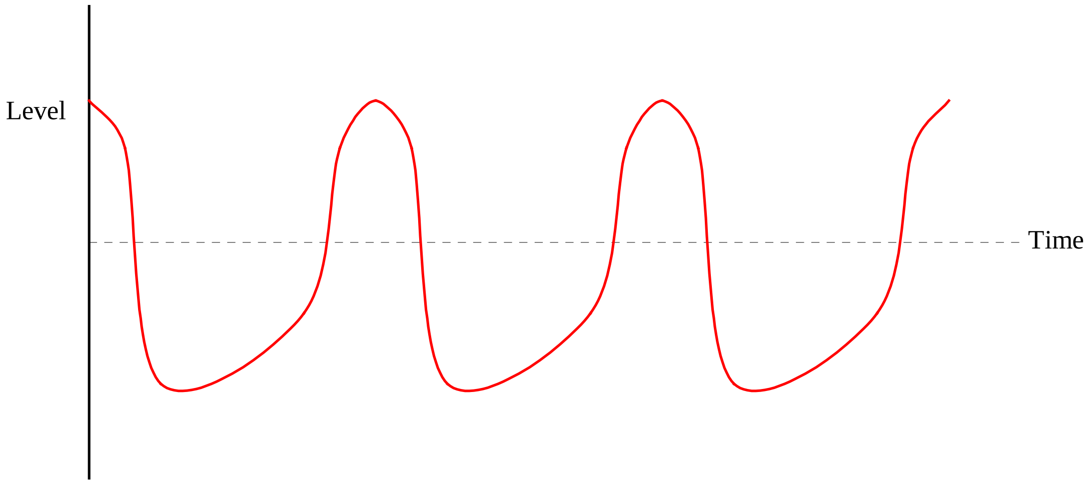

Figure 2 A deep time series (a transversal asymmetry)