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A Nonparametric Approach to Evaluating Inflation-Targeting Regimes

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Abstract

We use a variety of nonparametric test statistics to evaluate the inflation-targeting regimes of Australia, Canada, New Zealand, Sweden and the UK. We argue that a sensible approach of evaluation must rely on a variety of methods, among them nonparametric econometric methods, for robustness and completeness. Our evaluation strategy is based on examining three possible policy implications of inflation targeting: First, a welfare implication; second, a real variability implication. The welfare implication involves evaluating consumption and leisure per person by testing whether their distributions of levels and the growth rates remained unchanged under inflation targeting. Then we introduce nonparametric univariate and multivariate statistical methods to test whether the conditional variance of a variety of real variables, such as the real exchange rate depreciation rate, real GDP per capita growth rate in addition to private consumption per capita and leisure per capita growth rates, remained unchanged under inflation targeting, decreased or increased significantly. Third, we examine whether inflation-targeting policies eliminated boom-bust housing cycles. For control we also examine the US data during periods of high and low inflation before and after 1984.

JEL Classification C02, C12, C14,E31

Key Words: distributional dominance, sudden shift in conditional variance, inflation targeting, great moderation, boom-bust housing cycles.

1. Introduction

Australia, Canada, New Zealand, Sweden and the UK adopted inflation-targeting policy and successfully maintained relatively low and stable inflation rates from the early 1990s to-date. This paper provides a nonparametric approach to evaluating inflation targeting. We argue that a sensible approach of evaluation must rely on a variety of methods, among them nonparametric econometric methods, and even non econometric methods, for robustness and completeness.

Policy evaluation requires evaluating the costs and the benefits of the policy. The evaluation of inflation targeting as a monetary policy regime in this paper is based on examining three possible implications of the policy: First is a relative welfare implication, i.e. the benefits, and second is a relative real variability implication, i.e., the costs. For the benefits, we examine the level and the growth rate of consumption and leisure per person of working age, which are the basic arguments in the utility function. And for the costs, we will examine the conditional variability of real GDP per person of working age, consumption per person of working age, leisure per person of working age and the real exchange rate depreciation rate. We also examine the effects of the policy on boom-bust cycles in the housing markets.

Monetary policy does not have a real effect in the long run, i.e., the neutrality proposition. Inflation is independent of real output in the long run, i.e., the Phillips curve is vertical. However, monetary policy can have a real effect in the short run and over the business cycle frequencies for a variety of, debatable, reasons. Among those are price stickiness, menu cost, and misperception, etc.

There is no argument, however, that inflation raises the cost of living. It adversely affects the consumption of goods and services. Wage inflation does the same for leisure. Wage inflation makes leisure expensive. Central banks tell more stories about how inflation affects aggregate demand, consumption and investment. There are a few channels. Most obvious is the interest rate channel, which affects the demand for goods and services. Higher interest rates normally induce lower household's consumption and more savings. In other words, it lowers current consumption relative to future consumption, i.e., the intertemporal substitution. Consumption also falls because existing loans cost more in terms of interest payments. Finally, higher interest rates mean that the price of both financial and real assets - shares, bonds, property, etc. - falls in that the present value of future returns drops when interest rates rise. Households are less willing to consume when faced with declining wealth. The question is whether low and stable price and wage inflation increase the levels and the growth rates of consumption and leisure per capita, over the period of the policy horizon.

The relative variability implication stems from the possibility that certain monetary regimes such as inflation targeting may induce real changes in the short run. Stabilization of inflation might be achieved on the expense of making other variables unstable.

Mussa (1986) and Backus *et al.* (1995) among others suggest that the exchange rate regime is not neutral. In other words, the distributions of real variables may differ across monetary regimes. Monacell (2004), for example, provides different views. Milton Friedman, in his "Inflation and Unemployment," Nobel Memorial Lecture, December 13, 1976, said that the increase in the variability of inflation or expected inflation may raise the natural level of unemployment maybe through reducing the efficiency of the prices to carry information to economic agents. The point is that inflation and the variability of inflation could have a short-run real effect.

Initial inspection of the data suggest that the distributions of real variables changed. Table 1 reports descriptive statistics for key real variables before and after inflation targeting for the five countries in our sample. These statistics show that the mean and the variance have changed. Similarly, both the means and the standard deviations seem to have changed in the US even though the US did not adopt an explicit inflation-targeting policy. Note, however, that these changes do not constitute *test* statistics.

We test the welfare and the real variability implications for periods before and after inflation-targeting regimes for the five countries mentioned above. We compare the results to the US, which experienced periods of low inflation and high inflation. Bernanke (2004) identified two different monetary policy regimes in the US, a high inflation regime before 1984 and a low inflation regime 1984 onwards. He attributed these outcomes to differences policies, which contributed, according to Bernanke, to the so called the Great Moderation.

For the welfare implications we use a variety of nonparametric tests to test for the equality of distributions of different policy regimes, i.e., before and after inflation targeting. We find low inflation periods are associated with welfare improvement. The level of real private consumption per person has significantly increased during the periods of low and stable inflation. The same happened in the US. Leisure, however, declined in all countries, except for Sweden. Households seem to have substituted more consumption for leisure.

For the variability implication, we test whether real variables exhibited statistically significant sudden large shifts in their conditional variances after inflation targeting. We find no significant change in the real variability across regimes, except at points when the regime changes, e.g., Sweden's real GDP and consumption per capita growth rates and Canada's leisure per person growth rate. Our test statistics cast some doubt about the Great Moderation phenomena; i.e., changes in the variability of real data over time are not *statistically* significant.

Finally, we examined boom-bust cycles by examining the relationship between real interest rates and house price cycles during the periods of inflation targeting. In all countries, except New Zealand which maintained positive real interest rates, there exists a negative relationship between real interest rates and house prices at the business cycle frequencies. This negative relationship is usually associated with bubbles in housing markets, e.g., Japan in the 1980s and Hong Kong in the 1990s.

Our evaluation suggests that inflation targeting as a policy *per se* is not different from a policy that aims at keeping inflation low and stable such as the fed's policy after 1984. Low and stable inflation periods are associated with increased consumption levels, and growth rates in some countries, most likely due to lower costs of living and low interest rates. Except at the points of regime changes, *real* outcomes during the periods of low and stable inflation are not more or less variable than real outcomes during the periods of high inflation. And, except for central banks that kept positive real interest rates such as New Zealand, inflation targeting countries share with the US a negative correlation between real interest rate and house prices at the business cycle frequency, which is typically associated with bubbles.

Next we will present three nonparametric tests from the theory of permutation and rank tests. In section 3 we present a multivariate test statistics for sudden and large shifts in the conditional variance of a system of variables, along with a univariate test of the same effect. In section 4 we describe the data. In 5.1, implement the ranking tests. We will compare the entire distributions of two real variables before and after inflation targeting. In section 5.2 we apply the univariate and multivariate tests to the data. In section 5.3 we examine boom-bust cycles and monetary policy. Section 6 is a conclusion.

2. The welfare implication

We begin with evaluating the welfare implication of inflation targeting. Households under a policy regime A (low and stable inflation) are better off than households under a policy regime B (high and variable inflation) if the distribution of some real outcomes of regime A dominates the distribution of the same real outcomes of regime B. From the welfare implication point of view, the vector of outcomes of the regime, could be real consumption and leisure per capita, which are the usual arguments in the utility function.

Throughout this paper we maintain that regime A is independent of regime B from policy standpoint (no Lucas critique) even though we rely on nonparametric test statistics from the theory of permutation and rank tests. In a related field, the literature of stochastic dominance provides a variety of tests that also aim at ranking of distributions; they differ in the null hypothesis. Common tests were derived under the null hypothesis of dominance. For example, McFadden (1989), Klecan *et al.* (1991) use the Kolmogorov-Smirnov goodness of fit test, and Anderson (1996) uses the Pearson test. Davidson and Duclos (2000) derive the test under the null of equality of the two distributions.

We choose three tests from this theory. The first test is the Wilcoxon (1945) Rank Sum test, which is also known as the Mann-Whitney (1947) two-sample statistic. It is a test for assessing whether two samples come from the same distribution. The null hypothesis is that the two samples are drawn from a single population, and therefore their probability distributions are equal. It requires the two samples to be independent, and the observations to be ordinal or continuous measurements, i.e. one can at least say, of any two observations, which is the greater. This test is one of the best-known non-parametric significance tests. It was proposed initially by Wilcoxon (1945), for equal sample sizes, and extended to arbitrary sample sizes and in other ways by Mann and Whitney (1947). MWW is virtually identical to performing an ordinary parametric two-sample *t* test on the data after ranking over the combined samples.[i] In general, let $X_1, \cdots X_m$ be iid with any distribution function $F(x)$, and $Y_1 \cdots Y_m$ are iid with any distribution function $G(x)$. The null hypothesis is $H_0 : F(x) = G(x), each\ x \in (-\infty, \infty)$. However, it is trickier when it comes to the alternative hypothesis just like the literature on stochastic dominance because the alternative hypothesis could take different forms. One possible and common form is to assume a shift model like $G(x) = F(x - \Delta)$, and then the alternative hypothesis is written in terms of Δ, as $H_1 : \Delta > 0$. Another version is $H_2 : F(x) \geq G(x), each\ x \in (-\infty, \infty)$ and with a strict inequality for at least one x. G is said to be stochastically larger than F. H_2 is a larger class of alternatives because $(F, G) \in H_1$ implies $(F, G) \in H_2$. The other alternative in terms of Mann – Whitney statistic is $H_3 : \theta_{XY} > \frac{1}{2}$. These *large alternatives* regarding the Wilcoxon Rank Sum test are well-documented in the literature, see Randles and Wolfe (1979, p. 130-132).

The second test is the Pearson test, Anderson (1996). It is a nonparametric K-sample test for the equality of median. It tests the null hypothesis that K samples were drawn from populations with the same median. In the case of two samples, the test statistic is distributed chi-squared and calculated with and without a continuity correction. We report only one statistic; fewer more statistics are calculated, but they are not reported because they have the same p values.

The third test is the Kolmogorov-Smirnov, which is a well known non-parametric test to test for the equality of distributions. Non rejection of the null by this test is probably an indication of the weakness of this test in cases where there are differences in the tail of the distributions. However, it is very powerful for the alternatives that involve clustering in the data.[ii]

Wagner (2006) and Razzak (2009) use these methods to test for first-order stochastic dominance. However, we are really interested in rejecting the null hypothesis of equality of the distributions of consumption and leisure before and after the implementation of the inflation targeting policy.

3. The variability implication: testing for large shifts in the distribution

Firstly, for the univariate straightforward case, we test the hypothesis that the conditional variance of a single real variable, e.g., real GDP per person, has not changed versus the alternative hypothesis that it has suddenly shifted.

We compute the followings, in the order shown, to arrive at a statistic for the conditional variance:

1 $V_i = (n_i - 1)S_i^2 / \sigma^2$;

2 $\eta_i = H_{n_i - 1}(V_i)$; and

3 $R_i(S_i^2) = \Phi^{-1}(\eta_i)$

Where V_i is the statistic for a sudden shift in the variance, which is distributed chi-squared, S_i^2 is the sample variance, n_i is the number of observation or the window for which the variance is computed; σ^2 is a pooled or overall variance calculated as $(n_i - 1)S_i^2 / \sum_{i=1}^{m} n_i - m$, where i is the number of samples $= 1, 2, \cdots m$. We map V_i onto a standard normal distribution to make the presentation of the results easy. $H(.)$ is the distribution function of the chi-squared random variable with $n_i - 1$ degrees-of-freedom and Φ^{-1} is the inverse of the standard normal distribution function.

We plot $R_i(S_i^2)$, which is distributed standard normal, with upper and lower control limits. The limits usually take the value $\pm 3\sigma$. These limits, under a standard normal distribution function, are *prediction* or *tolerance* limits for the distributions of $R_i(S_i^2)$. A $\pm 3\sigma$ control limit constitutes a band of 0.99730 prediction intervals for future values of the $R_i(S_i^2)$ according to the Tchebysheff's theorem[iii] Values that fall in the tails of the standard normal curve are significantly different from values elsewhere under the bell-shaped curve, and constitute large and sudden jumps.

This chart is designed to function as alarm system. It signals cases where deviations of observations from the mean, for example, are greater than $\delta\sigma$. They are also designed so that the probability of false alarm is small if the process is in statistical control. The probability of a false alarm is equal to $\beta(\delta)$, which is a type II error. This is the probability of a shift equal to $\delta\sigma$ that will not be detected. The probability of detecting such a shift is $1 - \beta(\delta)$, which is the power of the test:

4 $\beta(\delta) = \Phi\left(Z_{\alpha/2} - |\delta| \sqrt{n_i}\right),$

Where Φ is the cumulative standard normal distribution function. We can calculate the power of the test for detecting sudden large shifts in the moments, so for example, with $n_i \geq 5$ and $\delta = 1.5$ the power is $1 - \beta = 1 - \{\Phi(3 - 1.5\sqrt{5}) - \Phi(-3 - 1.5\sqrt{5})\} = 0.638$. For an economic application of these control statistics see Razzak (1991). For other similar test statistics that are used in economic literature see Inclan and Tiao (1994) who use CUSUM tests and Chen and Gupta (1997).

Secondly, we provide a multivariate test for the equality of the variance for P variables. For a multivariate normal variable $X^T = [X_1, X_2 \cdots X_{\mathrm{P}}]^T$, where each X is iid, the superscript T denotes transpose, and the variance (of the population) is a *function* called the *Generalized Variance*, which is the determinant of a matrix, Σ.

The determinant of the sample variance matrix S^2 is called the *Sample Generalized Variance,* where S^2 is the sample covariance matrix based on sample of size n.[iv]

Anderson (1958) shows that a convenient statistic for the generalized variance is the following form of the Sample Generalized Variance:

$$5 \quad D_k = (n-1)\mathrm{P}\left[\frac{|S_k^2|}{|\Sigma|}\right]^{1/\mathrm{P}} > 0$$

And $k = 1, 2 \cdots m$.

The matrix S^2 is computed by:

$$6 \quad S_{ij}^2 = \frac{1}{n-1}\sum_{k=1}^{m}(X_{ki} - \overline{X}_i)(X_{kj} - \overline{X}_j)$$

And Σ is approximately:

$$7 \quad \overline{S}^2 = \frac{1}{N-m}\sum_{k=1}^{m}(n-1)S_k^2$$

Which is the mean of S^2.

Unfortunately, for $\mathrm{P} \geq 3$, the statistic D_k has no exact distribution so we cannot test for the significance level. Ganadesikan and Gupta (1970) approximated the distribution by a Γ (Gamma) distribution with two parameters, a shape and a scale parameter,. They showed that the Γ distribution is best approximated when $n = 10$.

The shape parameter is:

$$8 \quad h = \frac{\mathrm{P}(n-\mathrm{P})}{2}$$

And the scale parameter is:

$$9 \quad \mathrm{A} = \frac{\mathrm{P}}{2}\left[1 - \frac{(\mathrm{P}-1)(\mathrm{P}-2)}{2n}\right]^{1/\mathrm{P}}$$

Just like what we have done earlier to simplify the interpretation and the presentation of the results, we transform the Γ distribution into a standard normal by computing the following:

$$10 \quad u_k = G_{h,\mathrm{A}}(D_k)$$

Where G is the distribution function of the Gamma distribution with the two parameters above, and then the inverse of u_k

$$11 \quad R_i(D_k) = \Phi^{-1}(u_k)$$

$R_i(D_k)$ and $R_i(S_i^2)$ are distributed standard normal and therefore the values could be $R(.) < 0 < R(.)$. In this case $R_i(D_k)$ will take positive and negative values.

Just like the previous univariate statistics, a significant increase implies values of $R(D_k)$ > $\pm 3\sigma$ ..[v]

4. The data

See data appendix for definitions and sources. We choose Australia, Canada, New Zealand, Sweden and the UK because These countries adopted inflation targeting earlier than other countries, thus they have a longer span of data. The data cover the period March 1980 to December 2007. New Zealand data are shorter, from 1987 to 2007. In addition, we examine the US data from June 1975 to December 2007. We use private consumption, leisure, GDP, and the real effective exchange rate. We plot the log level of private consumption per person of working age in figure 1; and in figure 2 log leisure, which we define 100 – hours worked assuming that households have 100 hours of possible work time a week. Figure 3 plots the first difference of the log of real GDP per person of working age. The real exchange depreciation rates are plotted in figure 4. These data will be used in sections 5.1 and 5.2 to examine the first and second implications of the policy, i.e., the welfare and real variability implications. All log levels have trend. We test the data for unit root and we could not reject it.[vi] In section 5.3 we examine the boom-bust cycles in the housing markets. The data will be described later.

5. Results

Testing the welfare implications of the policy

We test whether real private consumption and leisure per person of working age in levels and in growth rates (first difference of the log level) have equal distributions during periods prior and during inflation targeting.[vii]

The periods before inflation targeting are: March 1980 to December 1992 for Australia; March 1980 to December 1990 for Canada; June 1987 to December 1988 for New Zealand; March 1980 to December 1992 for Sweden and March 1980 to December 1991 for the UK. For the US, the data for the period of high inflation rate are from June 1975 to March 1983 and the period of low inflation are from March 1984 to December 2007.

Table 2 reports the p values of the statistics for three tests described in section 2. The table has six columns. The first column reports the countries, the second reports the variables, the third reports the p values for the Wilcoxon Rank Sum test (the Mann and Whitney test), the fourth column reports the *probability* that distributions in regime B (before inflation targeting) are greater than those in regime A. In column five we report the p value for testing whether the medians are equal across the two regimes. Finally we report the p value for the Kolmogorov-Smirnov test.

For all countries, there is a strong rejection to the hypothesis that log private consumption per person is equal across regimes, the p values are zero. The probability that the PDF is greater before inflation targeting is also small. The medians are unequal and the Kolomogrov-Smirnov also rejects the equality with zero p values. Distributions of the levels of consumption are significantly larger and dominant under inflation targeting. The same is true for the US under low inflation regime.

Not so with the log leisure, Australia's log leisure per person declined during inflation targeting. The equality hypothesis is rejected in favour of regime B. The probability that leisure in regime B is greater than that in regime A is 0.897. The medians are unequal and the Kolmogorov-Smirnov p value is zero, which also rejects equality. The same is true for the UK and the US. Canada’s distribution of leisure before inflation targeting and after inflation targeting seem equal; the p value for the Rank Sum test is 0.981. The probability that leisure before inflation targeting dominates is about half. The medians of the two distributions are equal; the p value is 0.847. The p value for the Kolmogorov-Smirnov is 0.966. Thus, Canada’s level of leisure per capita has not significantly changed under inflation targeting. For New Zealand, the equality of distributions of leisure is rejected with a p value of the Wilcoxon Rank Sum test equal to 0.045. The probability that leisure in regime B is greater than that under inflation targeting is 0.339. The hypotheses of the equality of the medians has a p value of 0.167. The Kolmogorov-Smirnov test statistic has p value of 0.138. Leisure most probably declined in New Zealand under inflation targeting. The level of leisure per person has significantly statistically increased in Sweden under regime A of inflation targeting. P values of all tests are zero. Sweden is the only country with significant increase in the log of leisure per capita under inflation targeting.

Because the log levels might have unit roots and that could render the P values of the test statistics invalid, we also examine the growth rates of consumption and leisure per capital.

For Australia, there is a significant evidence that the growth rate of consumption under inflation targeting dominates. The same is true in New Zealand and Sweden. Consumption growth is dominant under inflation targeting regimes in three out of five countries. We still cannot reject the equality in Canada. The probability that consumption growth before inflation targeting is > growth after inflation targeting is 0.57. And, consumption growth has probably remained unchanged in the UK and the US.

Because the US is not an explicit inflation targeting country and our results for consumption growth are 3 out of 6 countries, our results may imply that low inflation, not necessarily inflation targeting, has positive welfare implications, whether inflation is targeted or not. We interpret the results as being largely supportive of a policy of low inflation, although they vary only slightly across countries.

Testing the variability of the real variables

We apply the univariate and multivariate tests for sudden change in the variance to the first difference of log: real effective exchange rate (the real depreciation rate), real GDP per person, real private consumption per person and leisure per person.

We choose a sample size of 8 quarters for the window to compute the statistic $R(S_i^2)$ in equation (3), which is consistent with the medium term horizon used for policy by central banks. We plot the test statistics in figures 5-8.[viii]

Each figure includes the statistic $R_i(S_i^2)$ before inflation targeting (regime B) represented by black dots and after inflation targeting (regime A) represented by white dots. The plots denote standard normal distribution with control limits $\pm 3\sigma$. Points that exceed the $\pm 3\sigma$ represent statistically significant sudden shifts in the conditional variance.

Central banks have been wary about excess variability. The Reserve Bank of New Zealand Policy Targets Agreement with the minister of finance signed in December 16, 1999 added the following clause to the original 1989 Agreement, *"(c) In pursuing its price stability objective, the Bank shall implement monetary policy in a sustainable, consistent and transparent manner and shall seek to avoid unnecessary instability in output, interest rates and the exchange rate."* There is also a reasonably large literature on the Great Moderation, see the cited papers in Bernanke (2004). This literature suggests that macroeconomic (i.e., real GDP) volatility have declined in the 1990s, thus the Great Moderation, and attempts to explain why. Many different reasons where advanced such as structural microeconomic changes and better monetary policy. Stock and Watson (2002) for example argued that there favourable shocks played a big role in all that.

In figure 5, we plot the univariate $R_i(S_i^2)$ statistics for GDP per person growth rates for all countries. All the black dots which represent the pre inflation targeting periods are inside the $\pm 3\sigma$, meaning that the conditional variance is stable for all countries including the US. There is one white dot outside the $\pm 3\sigma$ limit. Sweden experienced a statistically significant sudden jump in the conditional variance of real GDP per person in 1993-1994 right at the point of regime change.[ix]

Figure 6 plots the univariate statistics for consumption per person growth rates. No significant shifts in the conditional variance is found during the period before inflation targeting. Sweden alone experienced significant shifts in 1993-1994 at the change of regime point, and another in 2005-2006. For the US, the two regimes, low and high inflation, are statistically stable.

Most of the instability is found in leisure. Signals of large and sudden shifts in the conditional variance occurred in Canada, New Zealand, Sweden and the UK. Figure 7 shows that the UK is most unstable with multiple jumps under both regimes, before and after inflation targeting. Canada experienced instability in the first year of inflation targeting. The labour supply seems most affected, which is something central banks do not seem to discuss often. Again, the US is most stable.[x]

Figure 8 plots the *real* exchange rate depreciation rates. Australia and Canada's variability is unchanged across regimes, and largely stable. New Zealand's variability is much improved under inflation targeting. All the instability in New Zealand are found during the period before inflation targeting. Sweden too, has a stable real exchange rate under inflation targeting. The UK experienced a jolt at the first two years of the adoption on inflation-targeting regime. We find no evidence of instability in the US data. We would like to emphasize that the samples we use for defining inflation targeting regimes overlap with some changes in the exchange rate regimes in the UK and Sweden. Both left the European Exchange Rate Mechanism at the same time, floated, and adopted inflation-targeting policy.

Figure 9 plots the multivariate conditional *Sample Generalized Variance* $R_i(D_k)$. The samples are slightly different from previous ones. In a few cases we had to choose 7 quarters instead of 8. The results are reported in table 3. The US has one large jump in the variance in the years 1984-1985. Many studies have identified a break in the conditional variance of the US real GDP data around that point (see for example, Bernanke (2004) for more references and Stock and Watson (2002) among many studies on the Great Moderation). New Zealand also experienced a sudden shift in 1988-1990 the year inflation targeting was adopted officially. Sweden experienced two large shifts, one is in the same year of adopting inflation targeting in 1993-1994, and one in the year just before. Australia also had a jolt in 1994-1995, early at inflation targeting. Canada is the only country that experienced a large shift in the multivariate Sample Generalized Variance in 1980-1982, and we have no explanation for it.

In summary and across all tests, the number of black dots (before inflation targeting) that lie outside the $\pm 3\sigma$ prediction intervals is equal to the number of white dots (during inflation targeting). There is no strong evidence that inflation targeting increased or decreased real variability. However, uncertainty increases sharply during in the year immediately after changing the regime or at the beginning of the sample, whether before or after inflation targeting. The US which is not an inflation targeting country exhibited no significant real variability in both periods of low and high inflation, either. Our tests do not lend a lot of support to the Great Moderation story. Perhaps there is a moderation, but not great moderation. Variability changed both visually (see figure 3) and (table 1), but the changes are statistically insignificant.

5.3 Housing boom-bust cycles

Taylor (2007) argued that the decline that occurred in the average size of the fluctuations in residential constructions in the US in the early 1980s measured by standard deviations was due to improved monetary policy. Similar arguments for improved monetary policy are made in Bernanke (2004) and in Blanchard and Riggi (2009). Stabilizing inflation at low levels and anchoring inflation expectations are the good reasons for the Great Moderation.

Central banks in inflation-targeting countries do not follow systematic ways, e.g., the Taylor rule, in setting short-term interest rates, rather they enjoy full discretion in setting the interest rates on quarterly basis. They also adjust interest rates in-between quarters. They produce forecasts on quarterly basis, and along with other information, they assess the nature and the permanency of the shocks and then discuss policy setting. The process produces policy errors from time to time either because of forecasts errors or bad judgments, or both. These errors could be serially correlated and highly persistent. Eventually, these policy errors could adversely affect the formation of inflation expectations, hence the real interest rate.

High inflation expectations over the business cycle frequency can push real interest rates down for long periods of time or into negative territories. All countries have episodes of negative real interest rates, except New Zealand, which remained positive all the times.

Negative real interest rate stimulates the demand for housing. If the supply of land and housing is inelastic, see for example Glaeser *et al.* (2008), shifts in the demand fuel housing price inflation. Taylor (2007) finds episodes similar to these in the US. In effect monetary policy can still create boom-bust cycles in the housing market. Thus, the covariance of the real interest rate and the house price over the short-term business cycle is expected to be negative.

We compute the short – term real interest rate $r_t = i_t - \pi_{t-1}$, where i_t is the nominal interest rate, π_{t-1} is the CPI annualized inflation rate as a proxy for expected inflation. Housing prices are also in real terms. We remove the trend (fluctuations occur at frequency > 32 quarters) and the noise (fluctuations occur at frequencies < 6 quarters) from the data and focus on the business cycle frequency in between using Christiano – Fitzgerald's (2003) time-varying asymmetric Band-Pass filter. Figures 10 and 11 plot the levels and the de-trended real interest rates and house prices.

Figure 12 includes confidence ellipse for lagged de-trended real interest rates and de-trended house price. The real interest rates are up to 8 quarters lag. We use the sample over the periods of inflation targeting, and for the US over the period from 1984. The relationships are significantly negative, except for New Zealand and Australia, where real interest rate is uncorrelated with real house prices over the cycle. New Zealand had some mild increase in house prices during 2005–2007, but not as significant as it is in other countries. As shown in figure 10, New Zealand had run most tight monetary policy among all other central banks, hence real interest rates were among the highest in Western countries (the means are 3.7, 3.3, 5.6, 3.4, 3.4 and 2.1 for Australia, Canada, New Zealand, Sweden, the UK and the US respectively). Australia has only a few quarters of negative real interest rates in September 2000-June 2001, and in the first three quarters of 2008. The housing markets, especially in New Zealand, has been relatively calm. Higher real interest rates could have been beneficial in that regard, but not without a cost. There is no free lunch in economics and trade-offs exist. The cost of capital has been high in New Zealand, which could explain some of the relatively low productivity growth, see Prescott (2002), Hall and Hall and Scobie (2005), and Razzak (2007).

These plots seem to suggest that monetary policy of low and stable inflation did not prevent boom-bust cycles in the housing markets. Obviously none of the central banks in our sample targets asset prices. There is a significant negative correlation between the real interest rates and housing price at the business cycle frequency. There is no evidence of any correlation between real interest rates and house prices at the business cycle in both New Zealand and Australia.

6. Conclusions

Our objective was to provide a nonparametric methodology to evaluating inflation-targeting regimes in Australia, Canada, New Zealand, Sweden and the UK. We believe that evaluators ought to use variety of methods instead of relying on one particular approach, for completeness and robustness. In particular, we tested three possible implications of inflation targeting as a policy. First is a welfare implication and second is a real variability implication. Successful inflation targeting reduces inflation, which in turns reduces the cost of living and perhaps increase welfare in the short to medium runs.

We used a variety of methods to test whether distributions remained unchanged or not under two different policy regimes. We found that the distribution of the level of consumption per person is dominant under inflation targeting, and in all five countries, and also when inflation was low in the US, which is not an inflation targeting regime, after March 1984. Similarly, the growth rate of consumption per capita is dominant under inflation targeting in three out of the five inflation targeting countries.

The level of leisure per person, however, did not increase under inflation targeting, except for Sweden. And it did not increase in the US during the period of low inflation rate. People seem to have been working longer hours in all other countries over the period of inflation targeting and decided to substitute consumption for leisure. We would only speculate that low interest rates and stable macroeconomic conditions encourage more consumption in the short run. Lower wage inflation also means higher real wages and less consumption of leisure.

The second implication of inflation targeting is real variability. We tested whether the conditional variability of consumption per person, leisure per person, real GDP per person and the exchange rate depreciation rate remained unchanged across policy regimes or have experienced statistically significant large, and sudden shifts. In addition to the commonly used univariate test for equality of the variance, we introduced a multivariate test, where the Sample Generalized Variance is computed and a test statistic is derived.

We found that, real consumption per person, real leisure per person and the real depreciation rate exhibited more or less a similar variability under inflation-targeting regimes and earlier regimes. Across all countries and the real variables above, we identified a similar number of incidents of statistically significant large and sudden jumps in the conditional variance during various periods of pre and during inflation targeting regimes.

We identified, however, as expected, variability increases at the regimes' switching periods. Some variables are more variable than others such as GDP per and leisure per person growth rates. And, some countries experienced more variability in some variables than others such as Sweden and the UK while others like Canada and New Zealand seem to have less variability under inflation targeting. For the US, we found no significant variability in either period, except at the point of the regime shift in 1984, consistent with Stock and Watson (2002).

Finally, we examine the boom-bust cycles under inflation targeting and compare that with the US. We found incidents of low and negative real interest rates in all countries, except for New Zealand. Australia had five quarters of negative real interest rates in the entire sample. For these two countries, there is no correlation between real interest rates and housing prices at the business cycles. The correlation between the real interest rates and house prices are significantly negative over the business cycle, which is typically associated with bubbles.

We conclude that inflation targeting *per se* does not lead to welfare improvement, less or more real variability (more stability), or prevent boom-bust cycles in housing markets, but regimes of low and stable inflation generally do experience higher levels of consumption per person and maybe higher growth rates of consumption. We found no evidence of statistically significant shift in the conditional variance of real variables, which does not lend a lot of support to the Great Moderation story. Boom-bust cycles in housing markets cannot be prevented by inflation targeting regimes unless the real interest rates are kept reasonably and systematically high.

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Data Appendix

The main sources of the data are:

OECD.stat: OECD online data base www.oecd.org
IFS: International Financial Statistics database, August 2008 (CD-ROM) IMF
ILO: Statistics and databases on line www.ilo.org

$\hat{c}$: is the natural logarithm of private consumption per person in the working age 15-64 years old. Quarterly frequency and seasonally adjusted. Source: OECD
$\hat{h}$: is the natural logarithm of average weekly hours worked per person in the working age 15-64 years old. Quarterly frequency. Annual total hours worked per worker extracted from OECD then we divided it by 52 weeks to get average weekly hours worked per worker. Source: OECD
$\hat{l}$: is the logarithm of average weekly leisure hours per person in the working age 15-64 years old. $\hat{l} = \log(100 - H)$ the assumption is that the population of working age 15-64 has 100 productive hours per week. Quarterly frequency. Source: OECD

Output is the natural logarithm of real GDP per person in the working age 15-64 years old. Quarterly frequency and seasonally adjusted. Source: OECD

Population is the population at working age 15-64 years old. Quarterly frequency. Source: OECD

The real effective exchange rate is quarterly frequency and the source is the IFS

The consumer price index, quarterly frequency and the source is the IFS

The nominal interest rates are short term rates from the IFS. For the US we use the federal fund rate; for Australia we use short-term rate from OECD; for New Zealand we use 3-month bill rate; for Canada we use the treasury bill rate from the IFS and the same is for the UK. For Sweden we use the 3-month treasury discount notes.

The house price index for the US is from the Freddie Mac and Fannie Mae; for Australia is from Australian Bureau of Statistics; for Canada is from Stat Canada; for New Zealand is from the Reserve Bank of New Zealand; for Sweden is from Sweden bureau of statistics; and for the UK is from is from a website called Nationwide. All data are seasonally adjusted.

Code to calculate the multivariate statistics for sudden shifts in the moments SAS-IML

```
%macro razzak(dataset=name , Variables= name, name, name…, K=number,
S=number);
proc iml;
use &dataset;
read all into x var {&variables};
k=&k;/*-number of samples-*/
s=&s; /*- sample size-*/
p=ncol(x); /*-number of variables-*/
n=nrow(x); /*-total number of observation=k*s -*/
b=j(s,1,1);
j=(p-1)*(p-2)/(2*s);
scale=(p/2)*(1-j)##(1/p);
shape= p*(s-p)/2 ;
start qc;
do h=s to n by s;
gp=x(|(h-s+1):h,|);
mgp=gp(|:,|);

 if h=s then xb=mgp; else xb=xb//mgp;
 cssg=gp-(mgp@b);
 ssg=(cssg`*cssg);
 covg=(cssg`*cssg)/((s)-1);
 dcovg=det(covg);
 if h=s then do ;
ssp=ssg;;dcov=dcovg ;  end;

 else do ;ssp=ssp+ssg;dcov=dcov//dcovg; end;
 end;
xdb=x(|:,|)@b;
b=j(k,1,1);
cov=ssp/(n-k); /* this is a S bar matrix*/
 dsbar=det(cov);
 gamma=((s-1)*p)*(dcov/dsbar)##(1/p);
y=gamma/scale;
gamma=probgam(y,shape);
xdb=x(|:,|)@b;
t2=(s*diag((xb-xdb)*inv(cov)*(xb-xdb)`))(|,+|);
sample=(1:k);
colchr={'Z1' 'Z2' 'Z3' 'Z4' 'Z5' 'Z6' 'Z7' 'Z8' };

/* q1 is the standard normal for the variance R(D) in the paper*/

u=probchi(t2,p);
q=probit(u);
u1=probgam(y,shape);
q1=probit(u1);
output2=output2//(sample`||gamma||u1||q1);
```

```
colchr2={'Sample' 'Gam' 'u1' 'Q1'};
output=output//(sample`||t2||u||q||dcov);
colchr1={'SAMPLE' 'T SQUARE' 'U' 'Q' 'DET S'};
*print cov(|colname=colchr rowname=colchr|);
* print output(|colname=colchr1|);
* print output2(|colname=colchr2|) ;
create p0 from  output(|colname=colchr1|);
append from output;
close p0;
create p1  from  output2(|colname=colchr2|);
append from output2;
close p1;
finish ;
start main;
run qc;
finish;
run  main ;
quit;
proc print data=p0;
title "Country=&dataset";
title2'IML OUTPUT Dataset=P0';
run;
proc print data=p1;
title2'IML OUTPUT Dataset=P1';
run;
%mend;
data name;
 input Year$  GDP  RER   Consumption  Leisure….;
```

Table 1: Descriptive Statistics

	Before Inflation Targeting B		After Inflation Targeting A	
Australia	Mean	Standard Deviation	Mean	Standard Deviation
Inflation	7.36	3.06	2.60↓	1.44↓
Leisure	-0.006	0.74	-0.23↑	1.24↑
Consumption	-0.41	1.51	2.41↑	1.24↓
GDP	1.05	2.67	1.81↑	1.00↓
Real Exchange Rate	-1.58	9.83	1.27	6.83↓
Canada				
Inflation	6.35	3.10	2.10↓	1.21↓
Leisure	-0.10	0.85	-0.02↑	0.58↓
Consumption	1.52	2.46	1.67↑	1.54↓
GDP	1.16	2.31	1.19 (?)	1.46↓
Real Exchange Rate	1.47	5.64	0.09	6.16↑
New Zealand				
Inflation	11.88	5.12	2.32↓	1.44↓
Leisure	0.74	0.55	-0.13↓	0.49↓
Consumption	1.02	2.102	1.80↑	2.04↓
GDP	0.26	1.36	1.27↑	1.76↑
Real Exchange Rate	1.25	9.16	0.59	8.06 (?)
Sweden				
Inflation	7.81	3.22	1.50↓	1.30↓
Leisure	0.02	0.55	0.06(?)	0.65↓
Consumption	1.00	2.69	1.73↑	1.61↓
GDP*	0.84	1.90	1.86↑	1.56↓
Real Exchange Rate	0.42	5.76	-0.64	5.44↓
UK				
Inflation	7.49	4.19	2.77↓	0.86↓
Leisure	-0.001	1.00	-0.13↑	0.66↓
Consumption	2.62	2.87	2.45(?)	1.18↓
GDP	1.36	1.85	1.68↑	0.72↓
Real Exchange Rate	1.16	8.70	0.94	6.39↓
USA				
Inflation	8.34	2.7	3.00↓	1.01↓
Leisure	-0.11	0.5	-0.07↑	0.43↓
Consumption	0.18	2.7	1.76↑	1.23↓
GDP	1.22	2.6	1.85↑	1.26↓
Real Exchange Rate	1.13	8.0	-2.40	7.68↓

Inflation-targeting regime is defined over the period March 1993 – December 2007 in Australia; March 1991 – December 2007 in Canada; March 1990-December 2007 in New Zealand; March 1993 – December 2007 in Sweden; and March 1992 – December 2007 in the UK. For the US, the period of high inflation is June 1975 to March 1983 and the period of low inflation is March 1984 to December 2007. The data are annualized growth rates defines as $(\ln x_t - \ln x_{t-4})*100$ .Inflation is CPI inflation. Leisure is $100 - h_t$ and h_t is average weekly hours-worked per person (15-64). Consumption is per capita (per person of working age (15-64)). GDP is real GDP per capita growth. The real exchange rate depreciation rate is $(\ln q_t - \ln q_{t-4})*100$ where q_t is the effective real exchange rate. The OECD GDP for Sweden has a very clear downward shift in the level around 1990, which must be interpreted carefully.

Table 2 : Tests for distributions

	Wilcoxon Rank Sum Test Probability		Continuity corrected Pearson χ_1^{2} *	Kolomogrov-Simrnov
	P value $A = B$	Prob value $B > A$	P $median \quad A = median \quad B$	P value $A = B$
$\ln \hat{c}_t$ i				
Australia	0.000	0.004	0.000	0.000
Canada	0.000	0.048	0.000	0.000
NZ	0.001	0.200	0.001	0.000
Sweden	0.000	0.083	0.000	0.000
UK	0.000	0.009	0.000	0.000
USA	0.000	0.000	0.000	0.000
$\ln(100-\hat{h}_t)$ ii				
Australia	0.000	0.897	0.000	0.000
Canada	0.981	0.499	0.847	0.966
NZ	0.045	0.339	0.167	0.138
Sweden	0.000	0.001	0.000	0.000
UK	0.000	0.836	0.000	0.000
USA	0.000	0.997	0.000	0.000
$\Delta \ln \hat{c}_t$				
Australia	0.000	0.252	0.000	0.000
Canada	0.212	0.572	0.319	0.006
NZ	0.275	0.374	0.428	0.416
Sweden	0.026	0.375	0.033	0.001
UK	0.990	0.501	0.845	0.027
USA	0.954	0.509	0.642	0.083
$\Delta \ln(1-\hat{h}_t)$				
Australia	0.397	0.548	0.561	0.281
Canada	0.151	0.417	0.550	0.043
NZ	0.000	0.880	0.001	0.000
Sweden	0.299	0.442	0.175	0.332
UK	0.712	0.479	0.557	0.103
USA	0.856	0.490	0.818	0.238

A denotes period under inflation-targeting regime and B is the period before inflation targeting. The periods before inflation targeting are: March 1980 to December 1992 for Australia; March 1980 to December 1990 for Canada; March 1980 to December 1989 for New Zealand; March 1980 to December 1992 for Sweden and March 1980 to December 1991 for the UK. For the US, the period of high inflation B is from June 1975 to March 1983 and the period of low inflation policy A is March 1984 to December 2007.

In column 3 H0 is that $A = B$ and the p value is for $prob >| Z |= 0$

In column 4 we report $p\{B\} > \{A\}$

i $\ln \hat{c}_t$ denotes consumption per capita.

ii $\ln(100-\hat{h}_t)$ denotes leisure per capita.

* The test is in Hope, A. C. A. (1968). We calculate Pearson, Fisher's exact and one-sided Fisher's exact p values but do not report them because the values are identical to the one we reported here.

Table 3 Multivariate Statistics for Sudden Shift in the Conditional Sample Generalized Variance

Australia			
Before Inflation Targeting		After Inflation Targeting	
Sample	$R_i(D_k)$	Sample	$R_i(D_k)$
81-82	-0.90	94-95	3.05*
83-84	0.81	96-97	2.04#
85-86	2.17#	98-99	0.77
87-88	-1.40	00-01	1.09
89-90	1.28	02-03	1.64
91-92	0.33	04-05	0.91
		06-07	-1.04

Asterisk denotes significant shift beyond the 3σ tolerance limits.
The fact that the first observation of the inflation-targeting regime is significant may be due to a change in the regime, thus economically predicted.
# denotes significant at the 2σ tolerance level.

Canada			
Before Inflation Targeting		After Inflation Targeting	
Sample[i]	$R_i(D_k)$	Sample	$R_i(D_k)$
Sep80-Mar82	4.97*	92-93	-0.42
Jun82-Dec83	0.69	94-95	1.41
Mar84-Sep85	-0.18	96-97	1.30
Dec85-Jun87	2.25#	98-99	1.04
Sep87-Mar89	-1.16	00-01	1.40
Jun89-Dec90	-1.85	02-03	1.05
		04-05	-0.25
		05-07	0.55

i The sample size is 7.
Asterisk denotes significant shift beyond the 3σ tolerance limits.
# denotes significant at the 2σ tolerance level.

New Zealand	
Sample	$R_i(D_k)$
87-88[i]	2.47
89-90	3.12*
91-92	0.60
93-94	-0.32
95-96	-0.21
97-98	-0.15
99-00	1.05
01-02	-0.92
03-04	-0.35
05-07[ii]	-0.30

i Sample is from September 1987.
ii Sample ends in June 2007.
Asterisk denotes significant shift beyond the 3σ tolerance limits. # denotes significant at the 2σ tolerance level.

Sweden			
Before Inflation Targeting		After Inflation Targeting	
Sample[i]	$R_i(D_k)$	Sample[ii]	$R_i(D_k)$
81-82	-0.14	Mar93-Jun94	6.27*
83-84	-1.08	Sep94-Dec95	1.12
85-86	-2.44#	Mar96-Jun97	-0.18
87-88	-0.45	Sep97-Dec98	-1.07
89-90	-1.18	Mar99-Jun00	-0.18
91-92	4.61*	Sep00-Dec01	-1.55
		Mar02-Jun03	-1.09
		Sep03-Dec04	-1.77
		Mar05-Jun06	-1.00
		Sep06-Dec07	-2.59#

i The sample is 8 observations.
ii The sample is 6 observations.
Asterisk denotes significant shift beyond the 3σ tolerance limits.
The fact that the first observation of the inflation-targeting regime is significant may be due to a change in the regime, thus economically predicted.
# denotes significant at the 2σ tolerance level.

UK			
Before Inflation Targeting		After Inflation Targeting	
Sample[i]	$R_i(D_k)$	Sample[ii]	$R_i(D_k)$
80-82	1.92	Jun92-Dec93	0.54
83-84	-0.70	Mar94-Sep95	1.47
85-86	1.08	Dec95-Jun97	0.61
87-88	0.42	Sep97-Mar99	-0.53
89-90	-1.80	Jun99-Dec00	0.17
91-92	-0.06	Mar01-Sep02	0.15
		Dec02-Jun04	-0.10
		Sep05-Mar06	-2.06#
		Jun06-Dec07	-2.84#

i The sample size is 8 and from June 1980 to March 1992.
ii The sample size is 7.
Asterisk denotes significant shift beyond the 3σ tolerance limits.
# denotes significant at the 2σ tolerance level.

US			
Period of High Inflation		Period of Low Inflation	
	$R_i(D_k)$	Sample	$R_i(D_k)$
Jun75-Mar77	-1.87	84-85	3.53*
Jun77-Mar79	1.36	86-87	1.90
Jun80-Mar81	1.88	88-89	1.18
Jun81-Mar83	2.42#	90-91	0.83
		92-93	1.53
		94-95	0.07
		96-97	-0.81
		98-99	-1.47
		00-01	0.90
		02-03	0.55
		04-05	-0.54
		06-07	1.01

The sample size is 8 and from June 1980 to March 1992.
Asterisk denotes significant shift beyond the 3σ tolerance limits.
# denotes significant at the 2σ tolerance level.

Figure 1: Log Consumption Per Person of Working Age Population

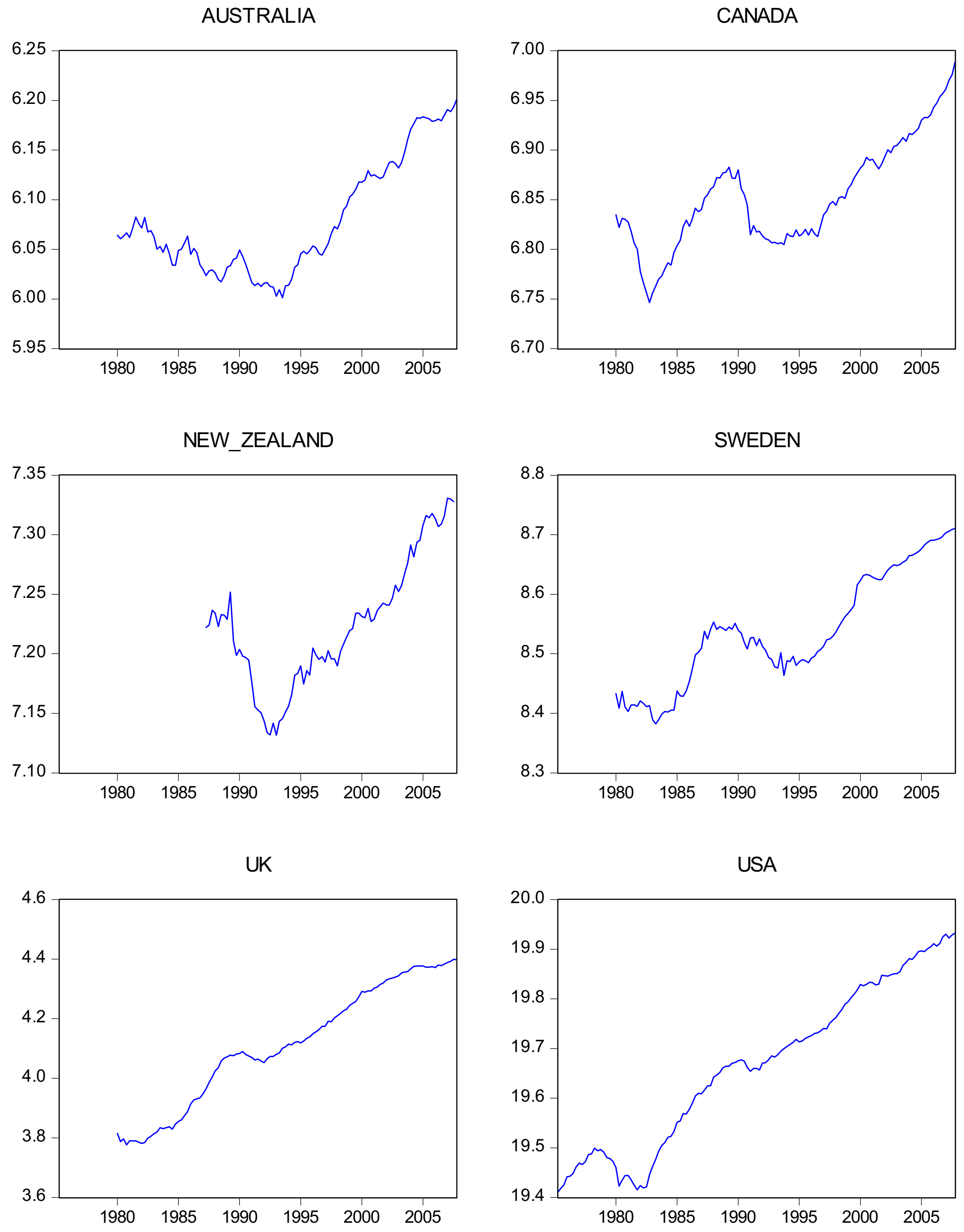


Figure 2: Log Leisure Per Person of Working Age Population

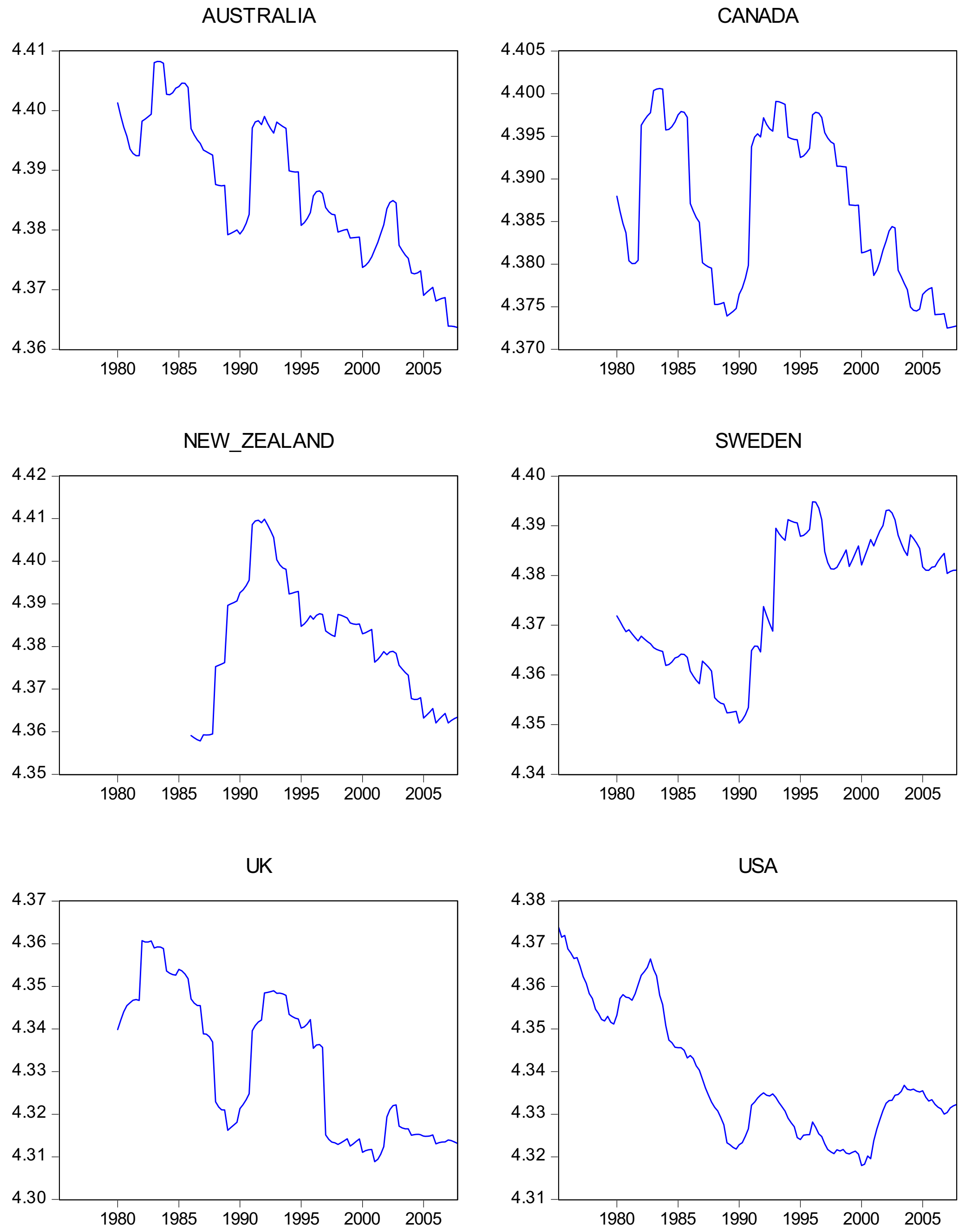


Figure 3: First-Differenced Log Quarterly Real GDP Per Person of Working Age

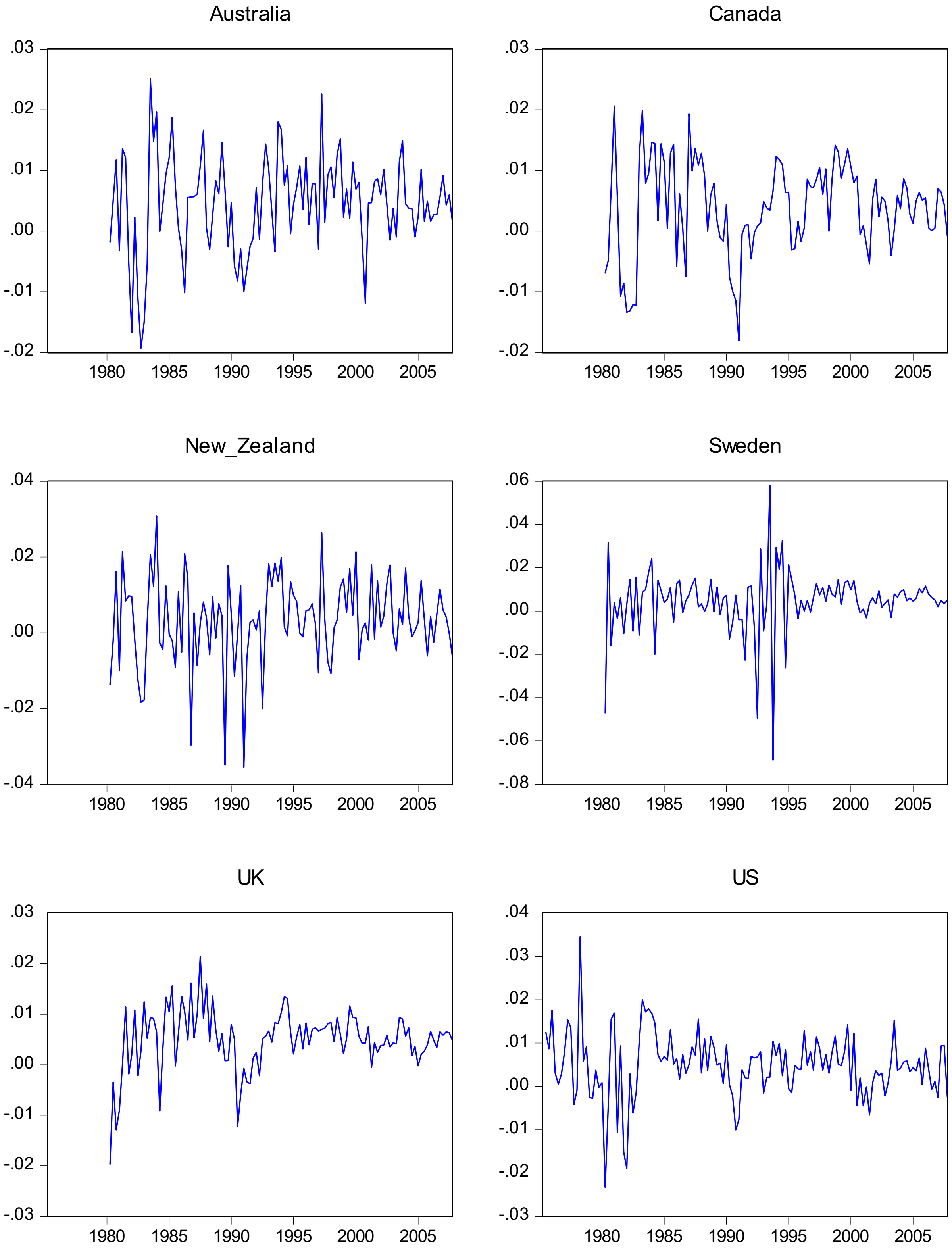


Figure 4: The Real Exchange Depreciation Rates

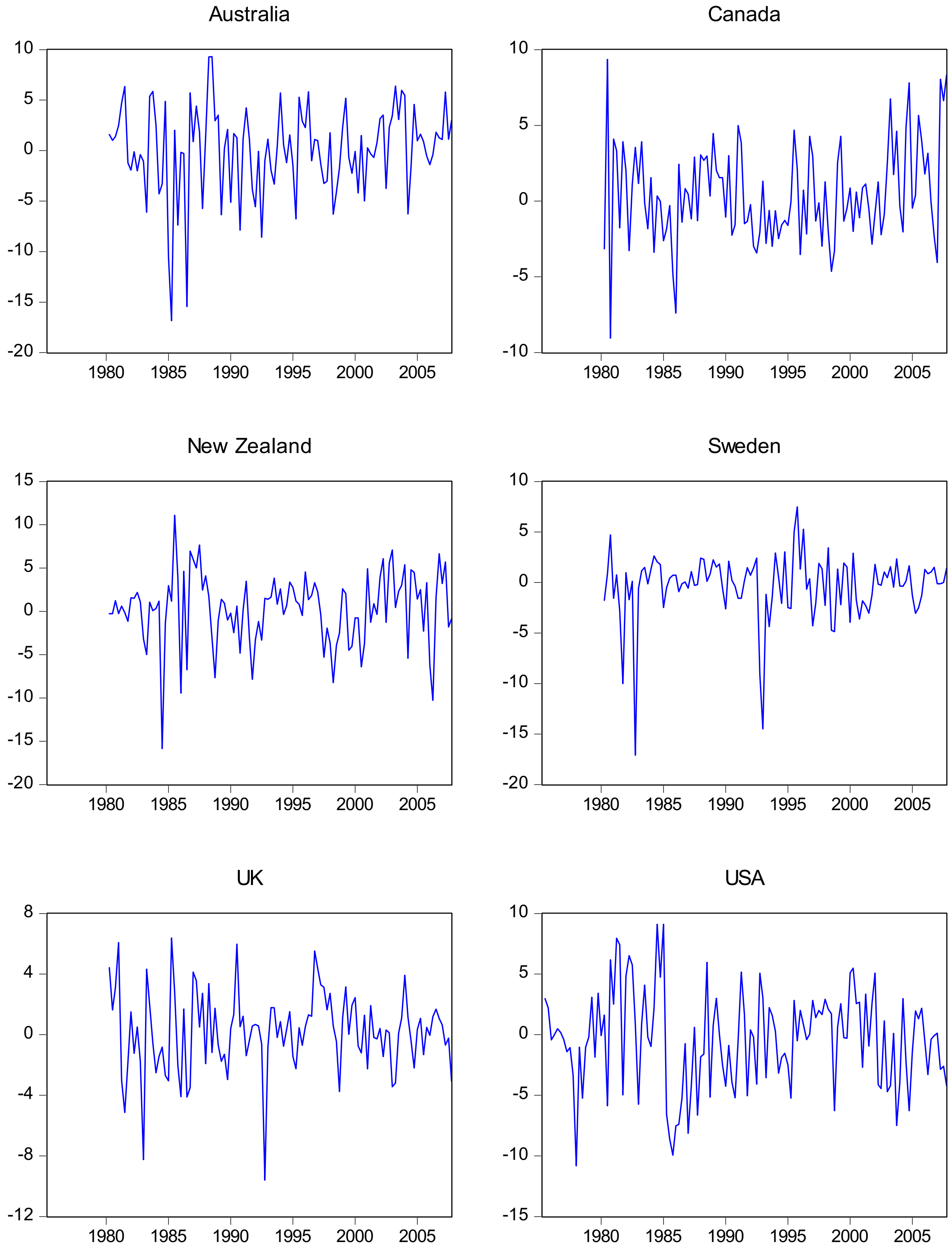
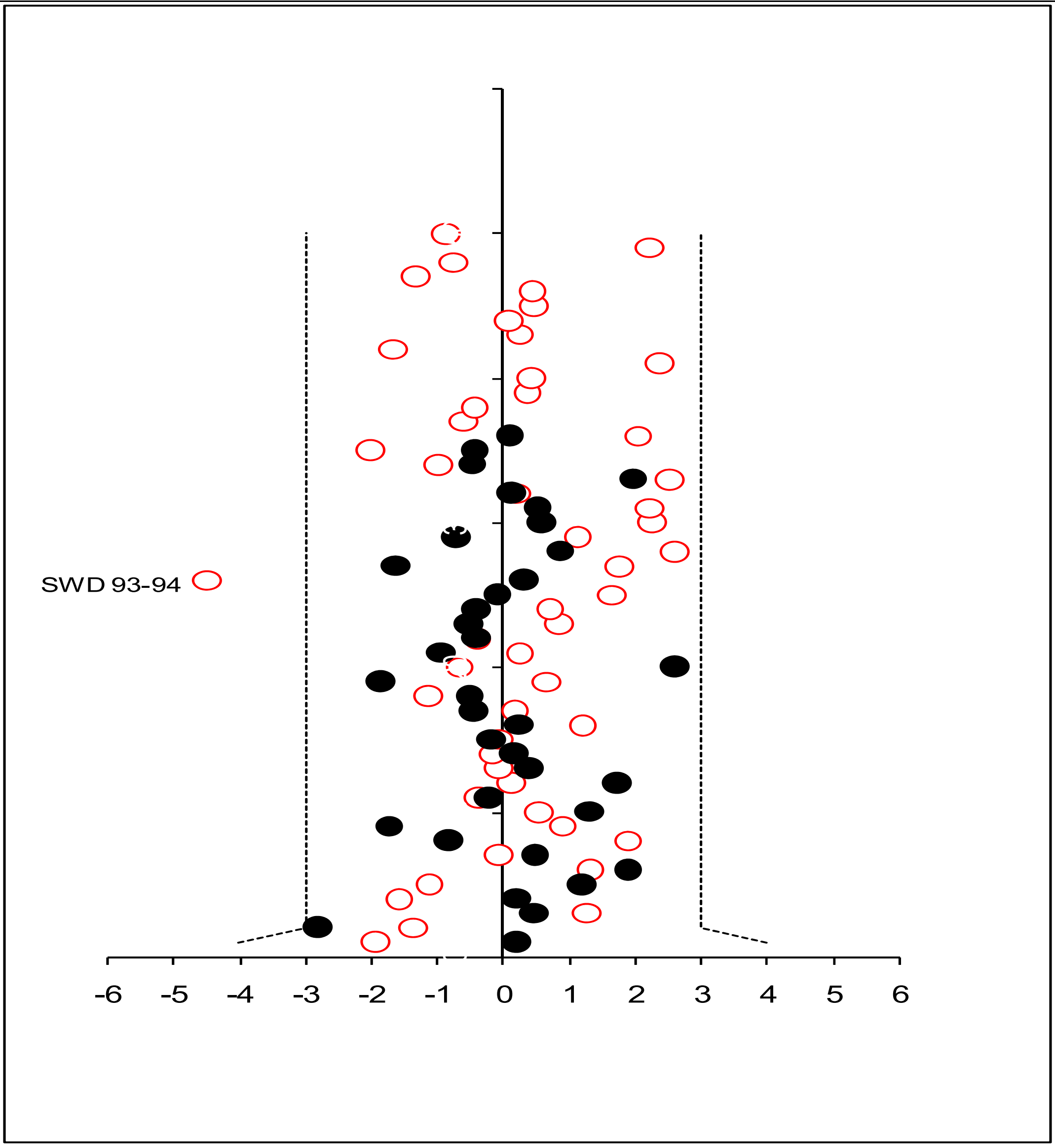
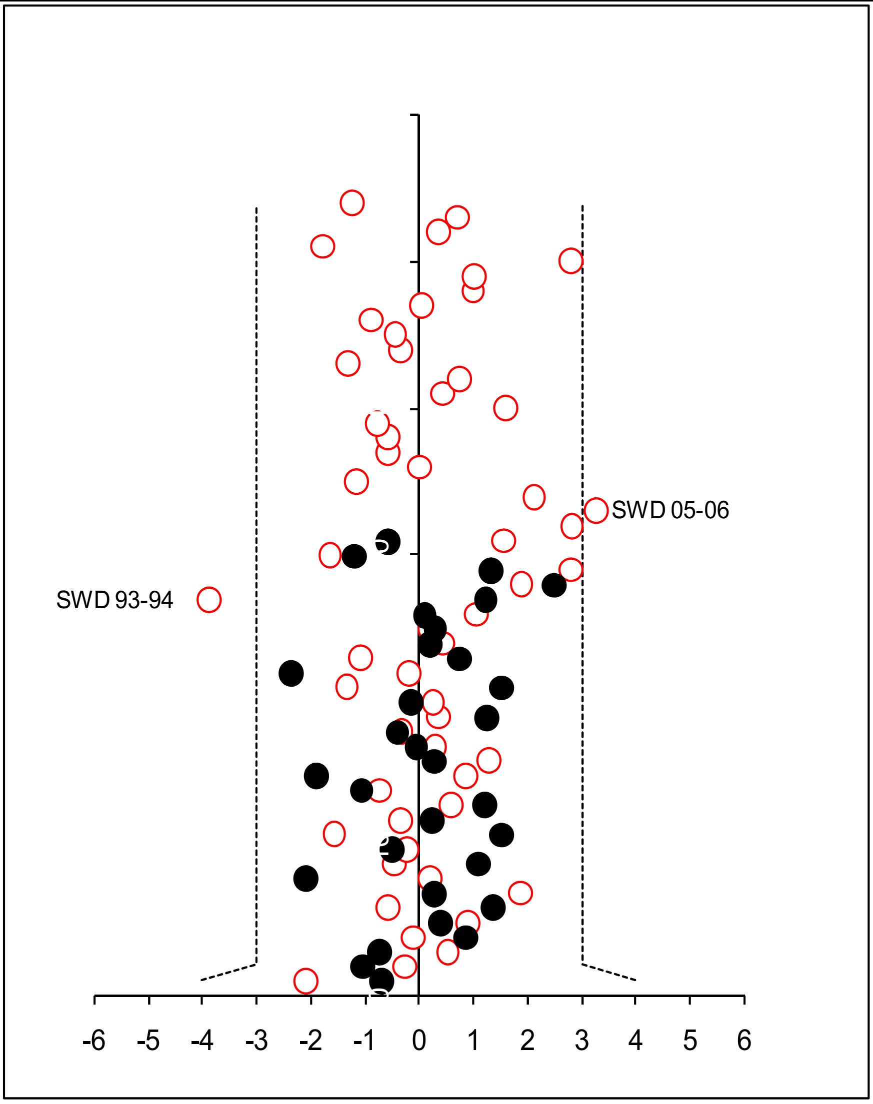


Figure 5: Univariate Statistics For Sudden Change in The Variance GDP Per Capita Growth



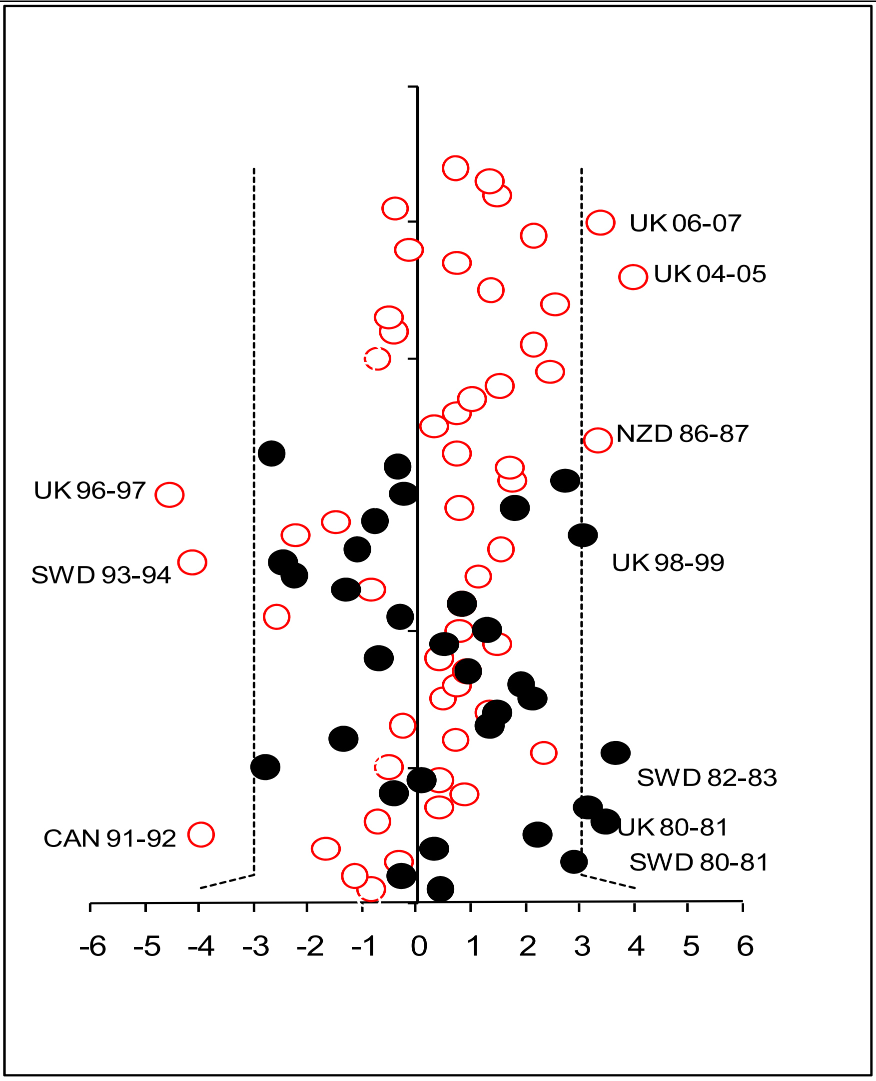
●	**Before Inflation Targeting**	○	**After Inflation Targeting**

Figure 6:Univariate Statistics For Sudden Change in The Variance Consumption Growth



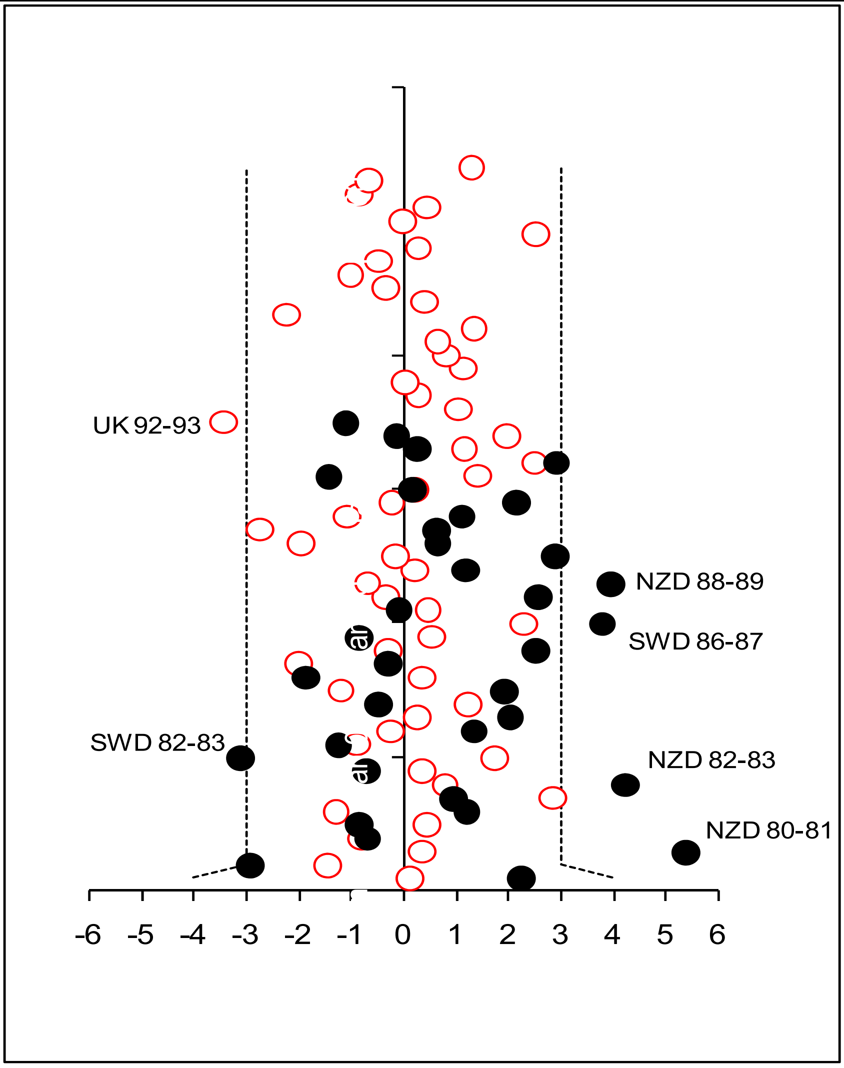
●	**Before Inflation Targeting**	○	**After Inflation Targeting**

Figure 7:Univariate Statistics For Sudden Change in The Variance Leisure Growth



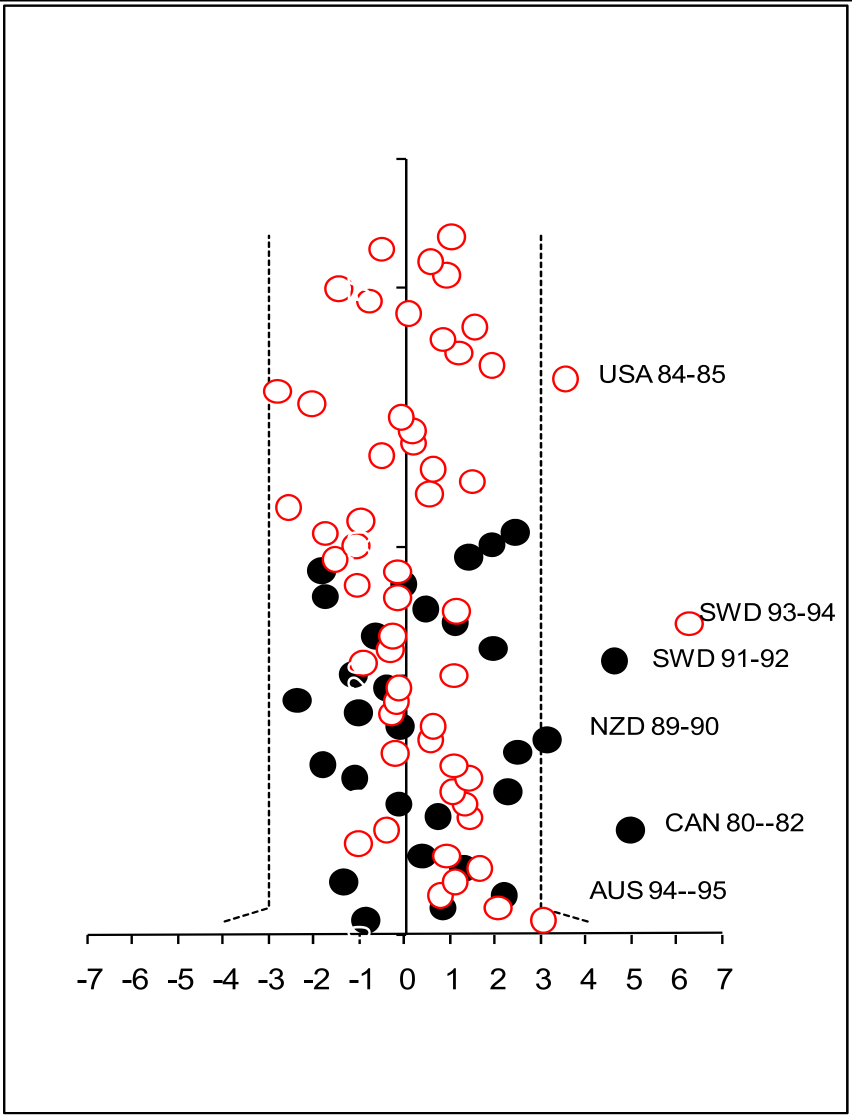
	Before Inflation Targeting		After Inflation Targeting
●	**Before Inflation Targeting**	○	**After Inflation Targeting**

Figure 8:Univariate Statistics For Sudden Change in The Variance
Real Exchange Rate Depreciation



	Before Inflation Targeting		After Inflation Targeting
●	**Before Inflation Targeting**	○	**After Inflation Targeting**

Figure 9 Multivariate Statistics For Sudden Change in The Variance



●	**Before Inflation Targeting**	○	**After Inflation Targeting**

Figure 10
Level and De-trended Real Interest Rates

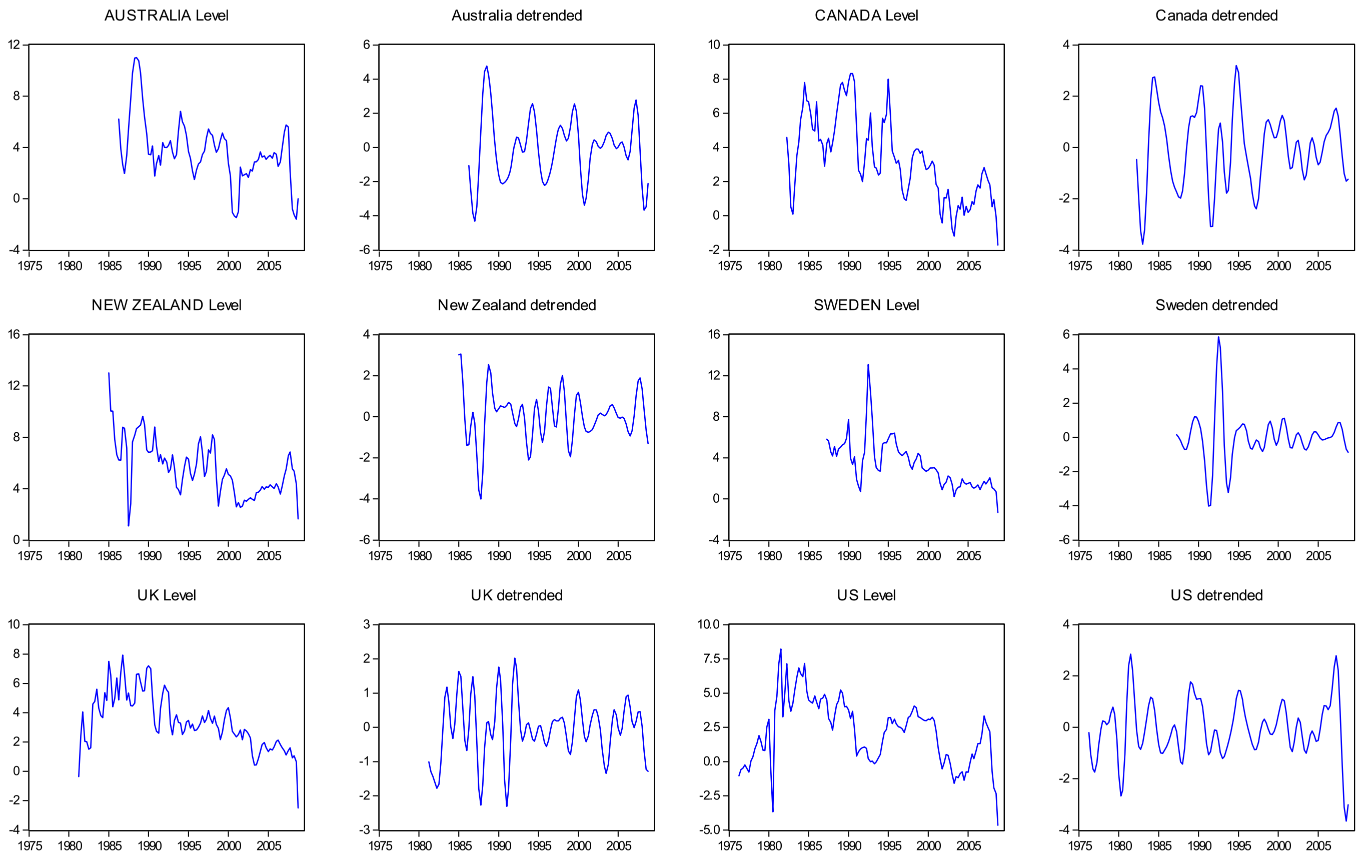


Figure 11
Level and De-trended House Prices

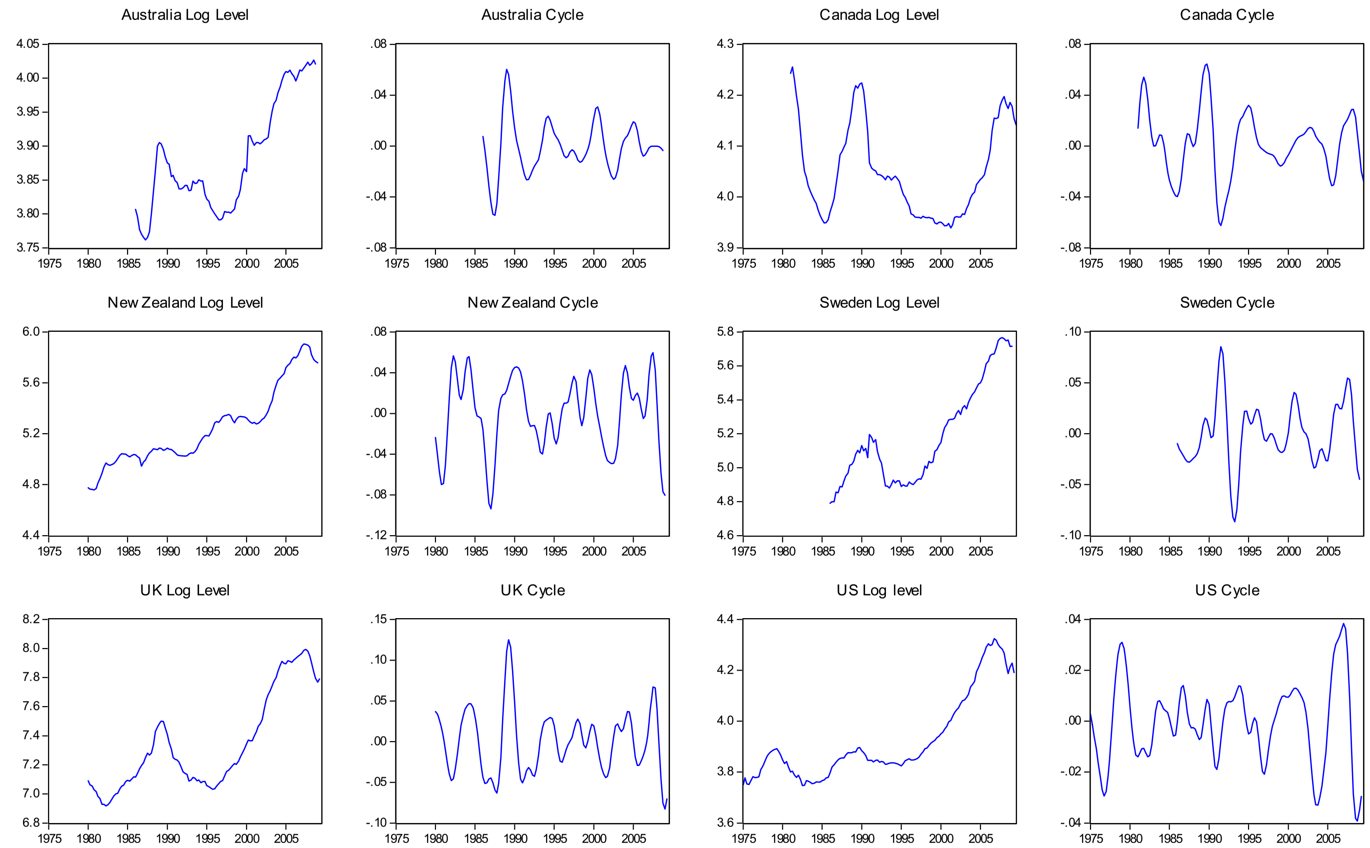
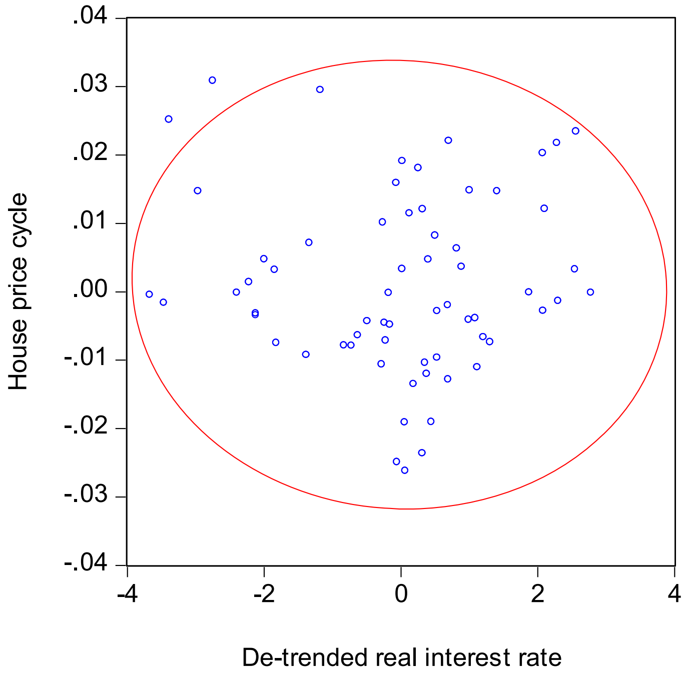
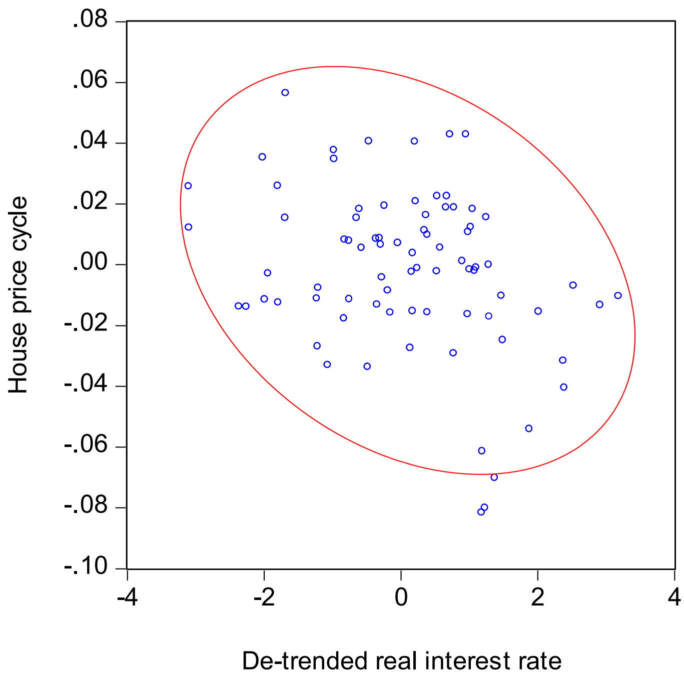


Figure 12
Real Interest Rate and House Price at Business Cycle Frequencies

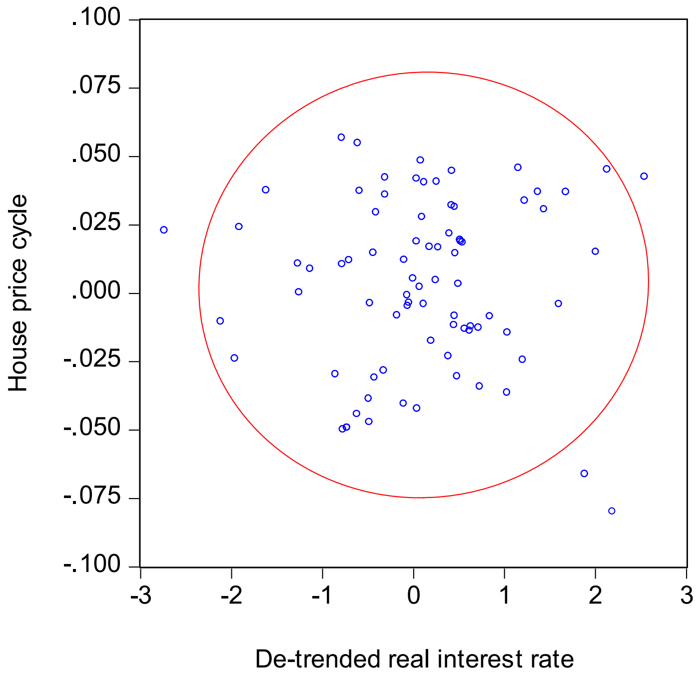
Australia (1993-2008)



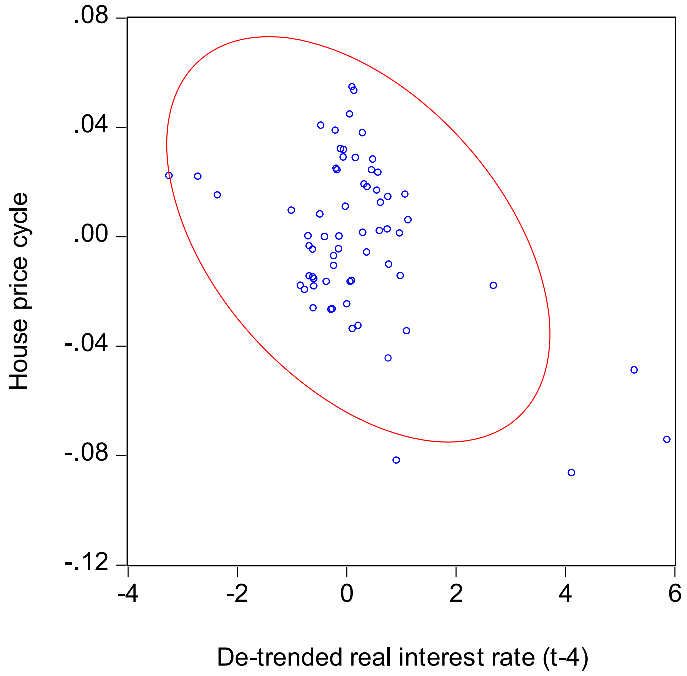
Canada (1990-2009)



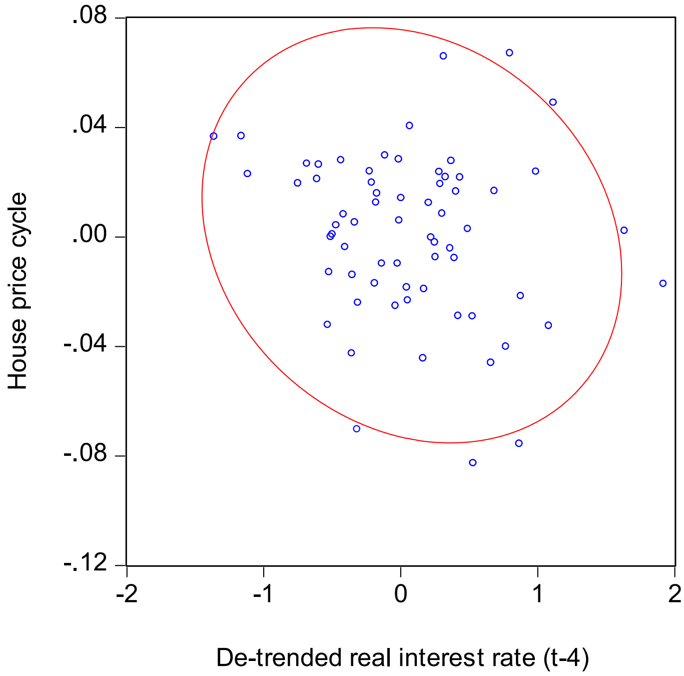
New Zealand (1989-2008)



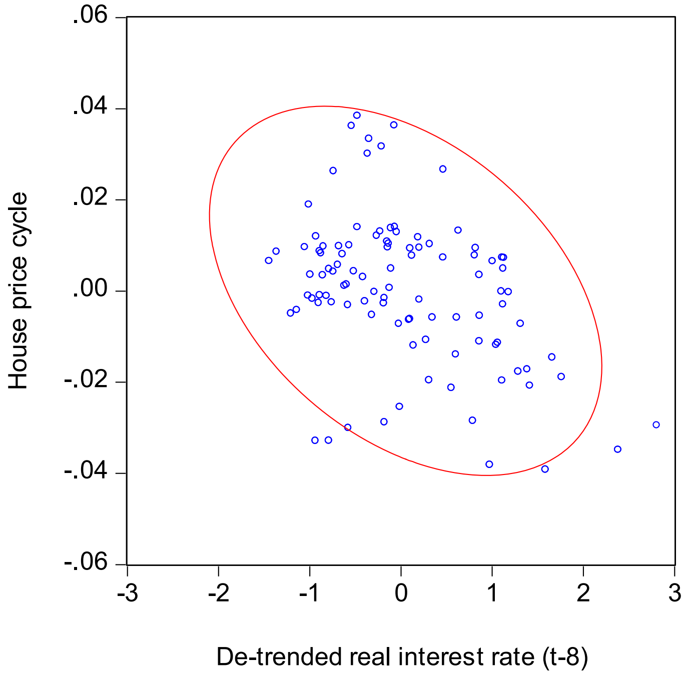
Sweden (1993 - 2009)



United Kingdom (1993-2009)



United State (1984-2009)



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[i] For two independent samples $X_1,\cdots X_m$ and $Y_1\cdots Y_n$, Wilcoxon (1945) introduced the linear rank statistic $W=\sum_{i=m+1}^{N}R_i$ where $R_1\cdots R_N$ are the joint rankings of $Z=(X_1\cdots X_m,Y_1\cdots Y_n)'$ and $N=m+n$. Mann and Whitney (1947) proposed the equivalent statistic $W_{YX}=\sum_{i=1}^{m}\sum_{j=1}^{n}I(Y_j<X_i)$, where I is the indicator function. When there are no ties, $W_{YX}=mn+n(n+1)/2-W$. There are other versions such as $W_{XY}=\sum_{i=1}^{m}\sum_{j=1}^{n}I(Y_j>X_i)$, where $W_{XY}=W-n(n+1)/2$. Using this latter version, the U statistic estimator $\theta_{XY}=P(Y_1>X_1)$ is $\theta_{XY}=\frac{W_{XY}}{mn}=\frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}I(Y_j>X_i)$. In the presence of ties, the U statistic is modified by adding $I(Y_j=X_i)/2$.

[ii] The **Kolmogorov-Smirnov statistics is** (Kolmogorov (1933) and Smirnov (1939), Conover (1999) is not very powerful against differences in the tails of the distributions. It is, however, very powerful for alternative hypotheses that involve clustering in the data. The statistics to evaluate directional hypotheses are $D^+=\max_x\{F(x)-G(x)\}$ and $D^-=\min_x\{F(x)-G(x)\}$, where $F(x)$ and $G(x)$ are the empirical distribution functions for the sample that we are comparing. The combined statistic is $D=\max(|D^+|,|D^-|)$. The p value for this statistic can be obtained by evaluating the asymptotic limiting distribution. Let n_1 be the sample size for the first sample and n_2 is the sample for the second sample. Smirnov (1939) shows that $\lim_{n_1,n_2\to\infty}\Pr\left\{\sqrt{n_1n_2/(n_1+n_2}D_{n_1n_2}\le z\right\}=1-2\sum_{i=1}^{\infty}(-1)^{i-1}\exp(-2i^2z^2)$. The first five terms form the approximation P_a used in the calculation (see STATA reference book). The exact p value is calculated by a counting algorithm (Gibbons (1971, p. 27-131). A corrected p value was obtained by modifying the asymptotic p value using a numerical approximation technique $Z=\Phi^{-1}(P_a)+1.04/\min(n_1,n_2)+2.09/\max(n_1,n_2)-1.35\sqrt{n_1n_2/(n_1+n_2)}$ and p value = $\Phi(Z)$, where Φ is the cumulative normal distribution function.

[iii] Chebyshev's inequality (also known as Tchebysheff's inequality, Chebyshev's theorem, or the Bienaymé-Chebyshev inequality) states that in any data sample or probability distribution, nearly all the values are close to the mean value, and provides a quantitative description of *nearly all* and *close to,* For any $k>1$, the following example (where $\sigma=1/k$) meets the bounds exactly. So $\Pr(X=1)=1/2k^2$; $\Pr(x=0)=1-1/k^2$ and $\Pr(X=-1)=1/2k^2$ for that distribution $\Pr(|X-\mu|)\ge k\sigma=1/k^2$. Equality holds exactly for any distribution that is a linear transformation of this one. Inequality holds for any distribution that is not a linear transformation of this one.

[iv] Anderson (1958) shows that the determinant of S^2 is proportional to the sum of squares of the volumes of all *parallelopes* formed by using as principle edges P vectors of $X_1,X_2,\cdots X_{\mathrm{P}}$ as one set of end points, and the mean of X as the other with $\frac{1}{(n-1)^{\mathrm{P}}}$ as the factor of proportionality.

[v] A SAS – IML code to calculate the multivariate statistics for the case of three and more variables is in the appendix.

[vi] we tested all variables for unit root using a variety of common unit root tests with different specifications and lag specifications. We tested these lags thoroughly using a variety of common information criteria (Dickey and Fuller (1979, 1981), Said and Dickey (1984), Dickey and Pentula (2002), Perron (1990, 1988, 1989 and 1997), Phillips (1987), and Elliott (1999)). We could not reject the unit root hypothesis. These results may reflect the weak powers of these tests. We tested the data again for a shorter samples, after inflation targeting to avoid *potential* the break in the data. We still could not reject the unit root hypothesis. Sweden seems to have a break around 1990. Non rejection of the unit root for GDP per person, consumption per person, and leisure per person for Sweden could well be due to the break in the data, but the Perron test still does not reject the null. It is well understood that all common unit root tests lack power.

[vii] Changes in hours and leisure are small for long periods then they increase suddenly.

[viii] All calculations are available upon requests.

[ix] The early version of this paper which is a working paper at the Arab Planning Institute and the Economics and Econometrics Institute report wrong results for the UK. We found a bug in the code and fixed it.

[x] That said, monetary policy is not the only effect on the supply of labour. Fiscal policy, namely tax policy, also has an intratemporal effect on the level of hours worked. Taxes distort the relative price of consumption and leisure. In the neoclassical model, an expected increase in the tax rate reduces the supply of labour. Hence, increases leisure. Sweden has the largest tax rate among the countries in the sample. Nickell (2003), p 12 table 2, computes the tax wedge for some of the countries in our sample over intervals from 1960 to 2000. The tax wedge in Sweden has increased from 34 percent in 1960-1964 to 77 percent in 1996-2000, which should explain why leisure increased (literature on labour supply that suggest Sweden home production is high, Olovsson (2009)). In New Zealand, the opposite happened. New Zealanders tax rates declined substantially after the economic reforms in 1984 and during the period of inflation targeting from 1989, which might explain why Kiwis work longer hours.