IMF Working Paper

WP/97/131

INTERNATIONAL MONETARY FUND

Research Department

Can Switching Between Inflationary Regimes Explain Fluctuations in Real Interest Rates?

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October 1997

Abstract

It has recently been suggested that allowing for switches between different inflationary regimes produces a much better fit for the Fisher relationship between interest rates and inflation, at least for U.S. data. The paper assesses the merits of the regime-switching theory as an explanation for the apparent fluctuations in real interest rates in Australia, Canada, Germany, the United Kingdom, and the United States.

JEL Classification Numbers: E43

Keywords: Inflation, interest rates

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[1]Part of the work for this paper was done while the author was a Visiting Scholar in the Research Department. I thank the Research Department for its warm hospitality, and participants in seminars at the IMF and the University of Nottingham for helpful comments on earlier versions of the paper. Any errors that remain are of course the author's responsibility.

CONTENTS

SUMMARY

Ex post real interest rates have shown marked fluctuations in the postwar period, being particularly low in 1973-80 and particularly high since 1981. It has proved difficult to explain such fluctuations as changes in ex ante real interest rates. This paper explores the hypothesis that switching between different inflationary regimes has caused a type of "peso problem" to appear in long-term real interest rates, whereby ex post rates differ systematically from ex ante rates over a long period because of the possibility of a switch to the alternative regime. A model is estimated in which the standard model of interest determination, based on the Fisher hypothesis, can be augmented by a variable that catches the regime-switching effect. This effect turns out to be highly statistically significant.

Data from five industrial countries are used (Australia, Canada, Germany, the United Kingdom, and the United States). Two inflationary regimes are assumed: a low-inflation regime up to 1969 and after 1983, and a high-inflation regime associated with the period of oil price shocks in 1970-82. It is shown that, with this specification, inflation tends to be stationary within regimes, reverting toward the regime mean rather than following a random-walk process. With only two regime changes over a 40-year period, this model has virtually no capacity to explain fluctuations in short-term real interest rates, since the probability of a regime switch over the life of a short-maturity bond is too small. For long-term rates, the model explains the actual pattern of ex post real rates rather well. The low ex post rates of the 1970s can be explained more or less entirely by this model. For the high rates of the post-1982 period, the results are more mixed. The model works better for Germany and the United Kingdom than for Australia, Canada, and the United States.

I. INTRODUCTION

One of the unsolved puzzles of monetary economics is why real interest rates in the major OECD countries have been so high since the early 1980s (see Ciocca and Nardozzi, 1996, for an extended discussion). As Howe and Pigott (1992) note, this is an international phenomenon which has no obvious explanation (see Table 1). Atkinson and Chouraqui (1985) review various possibilities, including tax effects, higher demand for investment funds, and fiscal and monetary policy, and can come up with no convincing story. Mishkin (1988) dismisses a number of hypotheses and attributes high real interest rates to a shift in monetary policy after 1979 – but it requires either an implausible degree of price stickiness or *continuing* unexpected contractionary shifts in monetary policy to explain high real interest rates for over a decade afterwards. Barro and Sala-i-Martin (1990) suggest a rise in the demand for investment funds stimulated by rising company profitability combined with high oil prices, but this explanation is clearly much less plausible for the period since the oil price collapse in 1986 (there is also the point that the OECD ratio of investment to GDP was in fact lower in the 1980s than the 1970s). Perhaps the most likely candidate is the rise in world public debt (Ford and Laxton, 1995), and this is a point to which I return towards the end of the paper.

Fluctuations in real interest rates conflict with the strong form of the Fisher hypothesis that the *ex ante* real interest rate is constant. Recently, Evans and Lewis (1995) have suggested the new idea that recent history has been characterized by switches between inflationary regimes, and they claim that this resolves the apparent inconsistency of US short-term interest rates with the Fisher hypothesis. They use a two-regime Markov switching model in which inflation is the sum of stationary and non-stationary components, and show that a regression of Treasury Bill rates on expected inflation, as estimated from this model, produces a coefficient very close to unity. This is an interesting result – but how much does it help us to explain the fluctuations in *ex post* real interest rates observed over the past 40 years? To address this issue, I consider data from five industrial countries, rather than just the US, and estimate regime-switching models that allow for learning by agents about the relative frequency of different inflation regimes.

The paper is designed to explore the potential of the regime-switching hypothesis as an explanation of the basic features of the data rather than to present a complete model of real interest rates. Consequently, the model of the learning process is rather rudimentary (although not implausible) and the estimating equation involves some simplifications. There are many ways in which the model might be developed, but to present a more complex model at this stage would have obscured the main point, which is to judge the principal strengths and weaknesses of the regime-switching idea.

My principal findings are as follows:

(1) The data tend to support the regime-switching model of the inflationary process, but not in the form preferred by Evans and Lewis (1995). Inflation appears to be stationary within a regime, but to differ markedly in mean across regimes.
(2) The frequency of regime changes is too low for regime-switching to account for movements in *short-term* real interest rates.
(3) The regime-switching hypothesis explains the apparently low *long-term* real interest rates of the 1970s rather well, but only partially accounts for the high long-term rates observed since 1981.
(4) The predictions of the regime-switching hypothesis with respect to the yield curve are not supported by the data.
(5) After allowing for regime-switching, *ex ante* real interest rates are not correlated with the ratio of world public debt to GDP.

Section II summarizes the relevant theory and the evidence for, and implications for interest rates of, regime switching in the inflation process. The empirical results are presented in Section III, and Section IV concludes.

II. Theory

The Fisher hypothesis states that the nominal interest rate (i) is related to the expected inflation rate (π^e) in the following manner:

$$(1+i) = (1+r)\,(1+\pi^e) \tag{1}$$

where r is the real interest rate. Equation (1) is often written as $i=r+\pi^e$, implicitly ignoring the term in $r\pi^e$, an approximation which is valid only if π^e is small. Empirical tests of the Fisher hypothesis generally make the parsimonious assumption that r is a constant, and use actual inflation over an appropriate period as a proxy for expected inflation (typically, if the data do not fit this simple model, then secondary hypotheses about the determinants of r are introduced). Pre-war data do not appear to support the Fisher hypothesis according to this test, but this is not surprising since inflation at that time was essentially a zero-mean white-noise process, at least in the absence of major wars, so that the rational expectation of inflation was zero (Barsky, 1987).

In the post-war period, it became obvious fairly quickly that the inflationary process was no longer characterized by a zero mean. Consequently, agents were faced with the problem of learning about a new inflationary regime. Evans and Lewis (1995) argue that this learning process has been complicated by significant structural breaks corresponding to switches between regimes. It would be natural to think of the switch of regimes as occurring before and after the oil price shocks of the 1970s, when inflation temporarily reached double-digit levels in most industrial countries. This presumes that inflationary regimes differ in mean, which in turn implies that inflation is stationary within a regime, since non-stationary processes do not have a defined mean. Evans and Lewis choose the alternative route of estimating a model in which inflation always has a non-stationary component, with regimes differing in the variance of both the non-stationary and the stationary component. This non-stationary model has less clear implications for the *ex post* real interest rate than the stationary model. It also produces quite a surprising periodization of regimes for the US, with the low-variance regime lasting only from 1962 to 1974, and the high-variance regime covering 1953-61 and 1975-90. There is little evidence that such a periodization would be reproduced in other countries: indeed Ricketts and Rose (1995), in a study of the G-7 economies, estimate multi-state models with an autoregressive process for each economy, and find that the data typically support either two-state or three-state models, with only one of these states approximating to a non-stationary process.

Evans and Lewis (1995) do not report the results of any tests designed to discriminate between stationary and non-stationary switching-regime models of inflation. Table 1 presents such a test for five industrial countries, based on the prior identification of the candidate high-inflation period as 1970-82 (this coincides with the first and last years in which consumer price inflation in the industrial countries exceeded 5.5% p.a.). The test is a standard Augmented Dickey-Fuller (ADF) test except that it allows for a shift in mean in the 1970-82 period. The idea is to test for reversion towards a mean which differs between high-inflation and low-inflation periods. The mean for 1983-95 is constrained to be the same as that for 1955-69. As Table 1 shows, without shifts in regime, both interest rates and inflation appear to be variables that are integrated of order one (I(1)); only for German interest rates is non-stationarity rejected at the 5% level. The perception that these variables are I(1) has dominated recent research on the Fisher hypothesis, motivating tests of cointegration between interest rates and inflation (e.g. Mishkin, 1992). If, however, we allow for a shift of mean by including a dummy variable for the period 1970-82 in the ADF regression, the results alter dramatically. The null of non-stationarity can be rejected at or close to the 1% significance level in four out of the five cases. Only for the United States is the null not rejected at the 5% level (although it is rejected at the 10% level).[2]

These results suggest strongly that, if we accept the idea of regime switches in the inflationary process in the industrial countries, we should also proceed on the assumption that inflation is stationary within regimes, and this is the route which is followed here. Rather than allow the data to choose the regime periodization for each country, I select the 1970-82 period as the high-inflation state and impose this assumption on all countries. This simplifies the analysis and is also consistent with the idea that regime shifts were associated with unexpected oil price shocks.

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[2] The critical values were calculated by Monte Carlo methods described in the notes to Table 1. They are much closer to zero than those reported by Perron (1989) for a single structural break, because of the constraint that the mean of the process is the same at the end of the period as at the beginning. This does not entirely deal with the problem of detecting spurious structural breaks by biasing results in favor of rejection of the null. This can occur because the break point which is tested for is selected after examination of the data; this is a particular issue in the Perron case, but here the imposition of identical break points over all five series helps to reduce the problem (Nunes *et al.*, 1995). The choice of 1970-82 is a little arbitrary. The important feature is that the same periodization is used for all five countries.

Suppose that the inflation rate alternates between two stationary regimes, characterized by mean inflation rates π_1 and π_2.[3] If the long-run (i.e. unconditional) probabilities of these regimes are respectively p and $1-p$, then the expected future inflation rate converges at an infinite horizon to

$$\pi^{e\infty} = p\pi_1 + (1-p)\pi_2 \tag{2}$$

The notation $\pi^{e\infty}$ is used to distinguish this unconditional expected inflation from the inflation expected over the life of a bond of given maturity, π^e. Short-run expectations, however, will depend on the nature of the current inflationary regime and (if inflation is serially correlated within each regime) on the inflation rate currently observed. Ignoring the possible serial correlation element, the average inflation rate expected over the life of a particular bond will be a weighted average of $\pi^{e\infty}$ as given in equation (2) and the estimated mean inflation rate for the current regime (π_r):

$$\pi^e = q_r\pi_r + (1-q_r)\pi^{e\infty} \qquad 0<q_r<1 \tag{3}$$

The weights vary with the maturity of the bond and (except in the special case p=0.5) according to the regime, because the probability of a switch to the other regime within any given period will be regime-specific (hence the subscript r for q). For longer maturities, the probability of a regime switch within the life of the bond is obviously greater, so that q_r is a decreasing function of maturity.[4] In conjunction with (2), this implies that, in the higher-inflation regime, inflationary expectations will tend to be below the current inflation rate, whereas in the lower-inflation regime inflationary expectations will tend to be above the current rate. Consequently real interest rates which are calculated *ex post* (by deflating interest rates by current inflation) will tend to look high in low-inflation regimes and low in high-inflation regimes. As we shall see below, this pattern is broadly confirmed by the data.

It seems unlikely that p would have been the same before 1970, when the high-inflation regime had not yet been experienced, as after 1970, when it had. A fair test of the regime-switching hypothesis seems to require the inclusion of a plausible model of how agents learnt about regime frequencies. This must have been a slow process, since regime shifts were so infrequent. Learning introduces new complications into the estimation of the Fisher relationship, because it implies that the parameters of equations (2) and (3) are not constant over the data set. Both the estimated regime means (π_1 and π_2) and the long-run regime frequencies (p and $1-p$) will evolve through learning, and the weights (q_r) in (3) will also be affected.

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[3] The estimation method proposed here works equally well if there are in fact more than two regimes.

[4] The ratio of the probability of a switch *to* regime 1 to the probability of a switch *from* regime 1 per time period must equal $p/(1-p)$. Within this constraint, the switch probabilities may take any value between 0 and 1, and the higher they are, the lower q_r will tend to be.

The procedure which I follow is to set up an estimating equation in which the standard test of the Fisher relationship can be nested within the regime-switching hypothesis. In standard tests for short-term interest rates, the nominal interest rate is regressed on the inflation rate over the life of the bond (Mishkin, 1992). This becomes problematic for long-term rates, because it implies that data for bonds that have not yet matured cannot be included, thus eliminating much recent data. In addition, the inflation series would be strongly smoothed, with very high autocorrelation. Accordingly I use the current inflation rate (measured either over the past four or over the next four quarters) as a proxy both for the expected inflation rate in the standard approach and for the estimated regime mean (π_r) in equation (3). Using the same variable for the estimated regime mean is a simple way of nesting the single-regime Fisher hypothesis within the regime-switching model.

The next problem is how to approximate $\pi^{e\infty}$, given that it is a function of the estimated regime means and of p, which is assumed to evolve through learning. A convenient simplification is available here. If, at each moment, p is assumed to be equal to the relative frequency of the low-inflation regime up to that date, then $\pi^{e\infty}$ may be approximated by the mean inflation rate up to the same date (hereafter called the running mean).

The final problem concerns the weights in equation (3). They are regime-specific and (because of learning) likely to change over time. Regime-dependency can be dealt with by including a shift dummy for the high-inflation period to the coefficients. Time-variation has no obvious solution, and I simplify by treating the coefficients as constant within regimes. Accordingly, I estimate the following equation for long-term interest rates:

$$\ln(1+i_t) = a + b\ln(1+\pi_{t,\,t+4}) + c\ln(1+\Omega_t) \qquad (4)$$

where Ω represents the running mean of inflation since the beginning of 1955, time (t) is measured in quarters, and the parameters b and c are allowed to vary across regimes by applying shift dummies for the 1970-82 period. The Fisher hypothesis implies that $b+c=1$, whilst a represents the logarithmic real interest rate. The regime-switching hypothesis predicts that $c>0$.

In estimating equation (4), there is the fundamental issue of whether the variables should be treated as stationary or non-stationary. I have argued that the inflation data are consistent with switching between stationary regimes. In combination with learning about regime frequency, however, this implies that interest rates are likely to look non-stationary, as is shown by Table 1. In the restricted form of (4), in which $c=0$, the equation reduces to a standard test of the Fisher hypothesis. Since $c=0$ corresponds to no regime switching, it seems appropriate that in this case the variables should be treated as non-stationary and cointegration methods applied in estimation. I then test the regime-switching hypothesis by showing that this cointegration relationship fits the data significantly better if the restriction that $c=0$ is dropped. Finally, I consider what happens when b and c are allowed to vary across regimes.

III. EMPIRICAL EVIDENCE

A. Main Features of the Data

Table 2 presents some basic data about inflation rates and real long-term interest rates in Australia, Canada, Germany, the United Kingdom and the United States. Table 2A demonstrates that mean quarterly inflation rates were at least twice as high in 1970-82 as previously, but fell most of the way back to pre-1970 levels after 1983. Table 2B shows the *t*-statistics for differences in mean inflation rates relative to 1955-69. The differences are highly significant for 1970-82, but only significant for 1983-95 for two countries (Australia and the US). Finally, Table 2C shows that these different inflationary regimes were characterized by marked shift in measured real interest rates. Real rates were exceptionally low in 1970-82 and exceptionally high after 1983.[5]

Figure 1 is a graph of this measure of real long-term interest rates for the five countries. Figure 2 shows true *ex post* real interest rates for ten-year bonds plotted against the year of maturity. There is a similar pattern of low real interest rates in the period of oil price shocks and exceptionally high rates since the early 1980s, whichever measure is used.

B. Cointegration Analysis

I begin by investigating the relationship between long-term interest rates and actual inflation. The choice of 1955 as a starting point for the data set reflects a number of factors: the unraveling of post-war controls, the end of the Korean War, and the completion of the transition period marked by the Marshall Plan and the US occupation of Japan. Recent recognition that inflation and interest rates may be non-stationary variables has led investigators to use cointegration methods to test the relationship between them, with mixed results. Although MacDonald and Murphy (1989) failed to reject non-cointegration between three-month Treasury Bill rates and consumer price inflation for the four countries which they investigated (Belgium, Canada, the UK and the US), other investigators have generally found in favor of cointegration. For short-term interest rates and inflation, cointegration has been found by Atkinson (1989), Mishkin (1992) and Moazzami (1990) for the US, and by Atkinson (1989) and Mishkin and Simon (1995) for Australia. Wallace and Warner (1993) find US long-term interest rates and inflation rates to be cointegrated.

Table 3 presents the results of some cointegration tests on long-term interest rates and inflation in five countries. Data were obtained from *International Financial Statistics*. Inflation data refer

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[5] Measured real interest rates have been constructed using inflation over the previous four quarters rather than as truly *ex post* (i.e. over the life of the bond), which would result in the loss of many observations. Most previous studies of real long-term interest rates have used a similar proxy for expected inflation (Baxter, 1994; Edison and Pauls, 1993; Meese and Rogoff, 1988). Figures 1 and 2 compare the two measures graphically.

to the consumer price index, and interest rate data to long-term government bond yields (the maturity used is not the same in all five countries). In the upper half of the table, inflation from quarter *t–4* to quarter *t* is used, and in the lower half, inflation from quarter *t* to quarter *t+4* (the use of immediate future inflation is designed to reflect evidence that short-term interest rates do carry some information about future inflation – see Mishkin, 1992). In only two countries (Germany and the UK) do the Johansen test statistics reject the null of no cointegrating vector at the 5% level in both tests, and the coefficient is always significantly less than one. For Australia, Canada and the US, cointegration is accepted at the 5% level in only one of the tests (past inflation for the US; immediate future inflation for Australia and Canada), but when it is accepted, the coefficients are fairly close to one. Overall, these results are only weakly supportive of the Fisher hypothesis, which implies a coefficient of at least one, and possibly rather more than one if tax on interest payments is allowed for.

C. Allowing for Regime Switches

The test results reported in Table 3 are based on the assumption that inflation is an I(1) variable. As shown above, the dynamics of inflation appear to be better described as a broken stationary process. Accordingly Table 4 presents the results of tests for cointegration between long-term interest rates, current (or immediate future) inflation and mean inflation since the end of 1954, which is a proxy for long-run inflationary expectations. This new "regime-switch" variable is highly significant in virtually every case. Current (or immediate future) inflation always has a coefficient of less than 0.5, and mean inflation since the end of 1954 always has a larger estimated coefficient than current inflation. For Australia, Canada and the US, this coefficient is always greater than one, and only for Germany and the UK do the two coefficients sum to something close to one. The results are therefore mixed with respect to the predictions of the Fisher hypothesis about coefficients, but the results do suggest support for the inclusion of the "regime-switch" variable in the regression.

D. Robustness to Choice of Start Date

Table 5 presents the results of similar tests, but using mean inflation from the end of 1958 instead of mean inflation from the end of 1954. This is simply a test of the robustness of the findings to a different choice of start-date. The results do not differ greatly from those presented in Table 4. Except in the case of the UK, the estimated coefficients of the running mean of inflation are lower than in Table 4. Overall, however, the results shown in Table 5 confirm the findings of Table 4.

E. Regime Effects

According to the theory, the weight attached to current inflation, as opposed to long-run average expected inflation, should depend on the perceived long-run frequency of the current regime (see equation (3)). This implies that current inflation should have less weight in the less frequent high-inflation regime than in the more frequent low-inflation regime, because of the higher probability (per unit of time) of a regime switch in the former case. This is tested in Table 6 by allowing the parameters to vary across regimes. The results are rather negative. Only in two out of the five cases (Australia and the UK) do the dummy variables have the expected sign, with a transfer of weight from current inflation to the running mean in the less frequent high-inflation regime. Taking Tables 5 and 6 together, we are forced to conclude that, although the data support the inclusion of a regime-switch variable in the relationship between long-term interest rates and inflation, the parameter values are not in close accord with the predictions of the Fisher hypothesis.

F. Adjusted Measures of Real Interest Rates

On the basis of the above analysis, we can calculate adjusted real interest rates which take account of the probability of a regime switch. These adjusted real interest rates are shown in Table 7, and are calculated by deflating nominal long-term rates by an average of inflation from quarter t to $t+4$ and of mean inflation since the end of 1954.[6] For the period 1955-69, adjusted real interest rates are close to the conventionally measured real interest rates shown in Table 2 – inevitably, because the high-inflation regime had not yet been observed. For the high-inflation period of 1970-82, adjusted real interest rates no longer look low, as unadjusted rates do, and in four of the five countries are in fact slightly above the 1955-69 average. For the low-inflation period since 1982, adjusted real interest rates are below actual rates (with the exception of Australia), but remain more than 2% above their 1955-69 averages for Canada and the US, and more than 3% above for Australia. For the two European countries, however, adjusted real interest rates in 1983-95 are either within 0.5% of their 1955-69 average (Germany) or only just over 1% above it (the UK). Thus the hypothesis seems to be only a partial explanation of why real interest rates have been so high since 1982, although it explains well why they were low in the 1970s. It may be, of course, that it is the secondary hypothesis about the determination of the long-run probabilities of the two regimes, rather than the main hypothesis, that is at fault here. In other words, bond-holders may have attached a higher probability to a return to high inflation than was implied by its frequency since the end of 1954, but this cannot be tested independently of the main hypothesis.

G. The Term Structure of Interest Rates

The Fisher hypothesis has been tested for short-term rates in previous research, with generally negative results in the sense of coefficients significantly less than unity (e.g. Evans and Lewis, 1995). Garcia and Perron (1996) have recently shown that US short-term real interest rates display significant shifts in mean. These shifts mirror those discussed here for long-term rates. Whether the regime-switching hypothesis predicts shifts in short-term as well as long-term real interest rates depends on the frequency of regime switches. If regime switches are very infrequent, the impact on short-term rates is likely to be too small to be observable. A better test of the regime-switching hypothesis is to examine the behavior of the yield gap, since this

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[6] This choice of coefficients reflects the values of the parameters for Germany and the UK, which were each close to 0.5 when the coefficients were constrained to sum to unity.

should display a regime-switching pattern whatever the frequency of regime changes. The possibility of a regime switch should make the yield gap (the difference between long-term and short-term interest rates) high in low-inflation periods and low in high-inflation periods (i.e. it should display a similar pattern to the real long-term interest rate), because the likelihood of a regime switch is so much greater over the life of a long rather than a short bond.

Table 8 shows that this prediction is not supported by the data. The average yield gap has varied little over different inflationary regimes – a finding which is also reflected in an easy rejection of the null of non-stationarity for the yield gap in an Augmented Dickey-Fuller test. It is interesting to note, however, that within periods of a given inflationary regime there is a consistent negative correlation of the yield gap with the inflation rate (this effect is particularly strong in the US).

H. The Role of Public Debt

The previous sections have explored how far one can go in explaining *ex post* long-term real interest rates whilst assuming that *ex ante* real interest rates were constant, but allowing for "peso problem" effects from regime-switching. One direction in which the model might be developed is to allow for fluctuations in *ex ante* rates. In this section, I introduce an estimate of world net public debt (as a percentage of GDP) as an additional regressor in equation (4), along the lines suggested by Ford and Laxton (1995). This is equivalent to assuming that debt influences *ex ante* real interest rates. The debt series is obtained from *OECD Economic Outlook* (December 1996) back to 1980. For 1960-79 I use a weighted average of eight countries.[7] The argument for using a world debt series rather than a national series is that, in a world of integrated capital markets, the *ex ante* real interest rate should be equalized across countries. Consequently, if the debt story is correct, each country's real interest rate should be affected by rising debt in the world as a whole.

The results of this exercise are presented in Table 9. Real interest rates do not display the expected positive correlation with net debt. Indeed, for four out of the five countries the estimated coefficient is negative; for Canada it is positive but not at all statistically significant. I have also investigated possible non-linearities in the relationship between debt and real interest rates, on the basis that changes in the debt ratio may have more effect at higher levels of debt. The data do not support this hypothesis either, since the square of the debt ratio tends to have a negative coefficient, implying smaller effects at higher debt levels (these results are not shown).

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[7] The countries are Belgium, Canada, Germany, Japan, Netherlands, the UK and the US, and the national ratios are weighted by current GDP at current exchange rates. I am grateful to Thomas Helbling for supplying the data.

The failure of debt to emerge as a significant determinant of interest rates is in many ways surprising, since the debt ratio has undergone some quite dramatic movements over the period, falling from about 39% of OECD GDP in 1960 to 16% in 1973, and then rising steadily to 44% in 1995. It is possible that recent evidence of increasing labor market flexibility and adoption of official inflation targets has offset the impact of rising debt on inflationary expectations.

IV. Conclusions

Recent work on the Fisher hypothesis has been dominated by the perception of inflation as an I(1) process. In reality, the data are more consistent with a stationary process subject to periodic but rather infrequent shifts in mean. Under such circumstances, the Fisher hypothesis would predict significant shifts in *ex post* long-term real interest rates that coincide with regime shifts in the inflationary process, whilst short-term real interest rates would be more or less constant (because the probability of a regime shift is so small over the life of a short bond).

This regime-switching hypothesis can only be tested in conjunction with an auxiliary hypothesis about the perceived probability of a regime switch, and this probability was assumed to be based on the relative frequency with which alternative regimes had been observed since the mid-1950s. The results for five countries strongly support the inclusion of the "regime switch" variable in the Fisher relation, since it considerably improves the fit in standard tests of the Fisher hypothesis. However, for Australia, Canada and the US (but not the UK and Germany), the estimated relationships suggest a Fisher coefficient considerably higher than one, and the predicted pattern of coefficient variation across regimes does not appear in the data.

On the plus side, the regime-switch hypothesis explains well why long-term real interest rates appeared to be low in the 1970s, and why they have fluctuated much less in Germany than in other countries, since Germany was characterized by the smallest difference in inflation rates between regimes. It is significantly less good at explaining why real interest rates have been so high in the 1980s and 1990s. The hypothesis works rather well in this respect for Germany and the UK, only very partially for the US and Canada, and not at all for Australia. A major minus for the regime-switching theory is the failure of the yield gap to follow the predicted pattern. Short-term real interest rates have behaved far more like long-term rates than the theory would predict.

All this implies that the regime-switching hypothesis falls some way short of a complete explanation of the puzzle of post-war fluctuations in real interest rates. The results presented here, however, do suggest some empirical support for the idea. It is likely that "peso problem" effects from regime-switching have played a significant part in observed movements in *ex post* long-term real interest rates. As monetary authorities become increasingly committed to the target of low inflation, so that the experience of high inflation becomes a more distant memory, this model would predict *ex post* real interest rates to approach *ex ante* rates more closely.

Table 1. Tests of the Order of Integration of Long-term Interest Rates and Inflation 1955Q1-1995Q1
Augmented Dickey-Fuller statistics (based on four lags of the dependent variable)

	Australia	Canada	Germany	UK	US
Interest rates	–1.40	–1.88	–1.92	–1.72	–3.17*
Inflation					
without dummy	–2.69	–2.46	–2.31	–2.29	–2.63
with dummy	–4.33**	–3.78*	–4.45**	–4.17**	–3.12

Notes:
Dummy variable =1 1970Q1-1982Q4, = 0 otherwise.
* significant at the 5% level.
** significant at the 1% level.
Critical values without dummy, as given by W.A. Fuller, *Introduction to Statistical Time Series* (New York: John Wiley, 1976, p.373), are respectively –2.58 (10%), –2.89 (5%) and –3.50 (1%). Critical values with dummy are respectively –2.90 (10%), –3.23 (5%) and –3.83 (1%). These values were obtained using 20,000 replications for T=150 and a dummy variable = 1 for observations 51–100, = 0 otherwise.

Table 2. Real Long-term Interest Rates and Inflation 1955-95

2A. Mean Inflation Rates (quarterly rate; in logs)

Period	Australia	Canada	Germany	UK	US
1955Q1-1969Q4	0.0070	0.0065	0.0060	0.0085	0.0057
1970Q1-1982Q4	0.0234	0.0200	0.0124	0.0296	0.0183
1983Q1-1995Q1	0.0139	0.0088	0.0060	0.0117	0.0088

2B. Student's *t*-statistics of Difference in Mean Inflation Relative to 1955Q1-1969Q4

Period	Australia	Canada	Germany	UK	US
1970Q1-1982Q4	8.91	6.56	7.70	5.43	6.76
1983Q1-1995Q1	3.69	1.56	–0.07	1.36	2.54

2C. Mean Real Interest Rates (in logs)

Period	Australia	Canada	Germany	UK	US
1955Q1-1969Q4	0.0215	0.0249	0.0371	0.0256	0.0190
1970Q1-1982Q4	0.0002	0.0141	0.0300	–0.0019	0.0063
1983Q1-1995Q1	0.0561	0.0591	0.0449	0.0449	0.0476

Note:
"Real interest rates" are defined as the mean annualised long-term government bond yield in quarter t deflated by inflation over the four quarters t–4 to t..

Table 3. Estimated Cointegrating Relationship Between Nominal Interest Rates and Inflation

Dependent variable: long-term nominal yield on government bonds (annual; in logs)
Quarterly data 1955Q1-1995Q1

Indep't variable	**Australia**	**Canada**	**Germany**	**UK**	**US**
Constant	0.0422	0.0453	0.0541	0.0575	0.0290
	(1.83)	(3.31)	(15.71)	(6.86)	(2.41)
Inflation t–4 to t	0.709	0.711	0.479	0.469	0.872
	(2.17)	(2.97)	(5.12)	(4.64)	(3.82)
LR statistic	16.24*	11.69¶	20.09	21.95	18.09
Trace statistic	18.84*	15.21¶	27.60	25.46	21.79

Indep't variable	**Australia**	**Canada**	**Germany**	**UK**	**US**
Constant	0.0269	0.0342	0.0517	0.0453	0.0190
	(1.29)	(2.55)	(6.25)	(5.65)	(1.06)
Inflation t to t+4	0.949	0.912	0.533	0.637	1.070
	(3.20)	(3.89)	(5.14)	(6.59)	(3.16)
LR statistic	20.83	19.33	26.42	22.19	15.10*
Trace statistic	23.28	22.80	35.96	25.42	17.78¶

Notes:

"LR statistic" and "Trace statistic" refer to the results of Johansen tests for the null of zero cointegrating vectors versus the alternative of at least one cointegrating vector, using non-trended variables and a VAR with a maximum lag of four. The 5% critical values are respectively 16.43 and 20.93, and the 10% critical values are respectively 14.41 and 18.72 (the critical values are adjusted for finite sample size using the method of Cheung and Lai, 1993). * denotes significant at the 10% level only, and not at the 5% level. ¶ denotes not significant at the 10% level. Figures in parentheses are t-statistics. Cointegrating vectors and t-statistics are estimated using the Engle-Yoo method as described in Engle and Granger (1991, p. 56).

Table 4. Estimated Cointegrating Relationship Between Nominal Interest Rates, Current Inflation and Cumulative Mean Inflation 1955-95

Dependent variable: long-term nominal yield on government bonds (annual; in logs)
Quarterly data 1955Q1-1995Q1

Indep't variable	**Australia**	**Canada**	**Germany**	**UK**	**US**
Constant	–0.0175	0.0209	0.0370	0.0430	0.0121
	(–1.19)	(3.43)	(4.67)	(3.84)	(1.12)
Inflation t–4 to t	0.179	0.328	0.453	0.374	0.388
	(1.47)	(4.22)	(5.55)	(4.82)	(2.70)
Mean inflation from	1.600	1.256	0.615	0.401	1.227
end-1954 to date	(4.65)	(7.12)	(2.20)	(1.85)	(3.54)
Indep't variable	**Australia**	**Canada**	**Germany**	**UK**	**US**
Constant	–0.0037	0.0175	0.0345	0.0317	0.0053
	(–0.24)	(2.40)	(3.81)	(3.68)	(0.36)
Inflation t to t+4	0.337	0.339	0.410	0.392	0.425
	(2.84)	(3.68)	(4.63)	(6.95)	(2.18)
Mean inflation from	1.530	1.344	0.747	0.589	1.402
end-1954 to date	(4.53)	(6.72)	(2.49)	(3.73)	(3.10)

Notes:
"Mean inflation from end-1954 to date" is defined as $4(\ln p_t - \ln p_0)/t$ where t=0 in 1954Q4. * denotes significant at the 10% level only. Cointegrating vectors and t-statistics are estimated using the Engle-Yoo method as described in Engle and Granger (1991, p. 56).

Table 5. Alternative Estimates Using Mean Inflation since the End of 1958

Dependent variable: long-term nominal yield on government bonds (annual; in logs)

Indep't variable	**Australia**	**Canada**	**Germany**	**UK**	**US**
Constant	0.0093	0.0312	0.0467	0.0421	0.0199
	(0.62)	(7.86)	(6.64)	(4.73)	(2.06)
Inflation t–4 to t	0.265	0.282	0.430	0.344	0.393
	(1.89)	(3.09)	(5.14)	(4.19)	(2.65)
Mean inflation from	1.298	0.990	0.320	0.498	0.957
end-1958 to date	(3.94)	(5.82)	(1.37)	(3.05)	(3.29)
Indep't variable	**Australia**	**Canada**	**Germany**	**UK**	**US**
Constant	0.0104	0.0225	0.0385	0.0337	0.0150
	(0.59)	(2.46)	(3.49)	(5.62)	(0.93)
Inflation t to t+4	0.298	0.268	0.430	0.367	0.271
	(1.99)	(2.39)	(4.46)	(7.89)	(1.25)
Mean inflation from	1.236	1.236	0.579	0.622	1.266
end-1958 to date	(3.50)	(5.78)	(1.75)	(6.42)	(2.91)

Notes:
"Mean inflation from end-1958 to date" is defined as $4(\ln p_t - \ln p_0)/t$ where t=0 in 1958Q4.. * denotes significant at the 10% level only. Cointegrating vectors and t-statistics are estimated using the Engle-Yoo method as described in Engle and Granger (1991, p. 56).

Table 6. Allowing for Regime Effects on the Parameters

Dependent variable: long-term nominal yield on government bonds (annual; in logs)
Quarterly data 1955Q1-1995Q1

Indep't variable	**Australia**	**Canada**	**Germany**	**UK**	**US**
Constant	–0.0086	0.0248	0.0402	0.0546	0.0137
	(0.45)	(2.89)	(2.98)	(3.34)	(0.90)
Inflation t–4 to t	0.438	0.283	0.461	0.315	0.524
	(1.58)	(1.25)	(2.15)	(0.97)	(0.99)
Mean inflation from end-1954 to date	1.028	1.139	0.507	0.153	0.909
	(2.02)	(4.53)	(1.09)	(0.45)	(1.61)
Dummy X inflation t–4 to t	–0.503	0.388	0.363	–0.102	0.427
	(–1.20)	(1.01)	(1.07)	(–0.27)	(0.64)
Dummy X running mean inflation	1.252	–0.642	–0.594	0.503	–1.112
	(1.74)	(0.92)	(–1.26)	(1.02)	(–1.07)

Notes:
"Mean inflation from end-1954 to date" is defined as $4(\ln p_t - \ln p_0)/t$ where t=0 in 1954Q4. "Dummy" = 1 from 1970 to 1982; = 0 otherwise. * denotes significant at the 10% level only. Cointegrating vectors and t-statistics are estimated using the Engle-Yoo method as described in Engle and Granger (1991, p. 56).

Table 7. Adjusted Measures of Long-term Real Interest Rates 1955-95

Adjusted real interest rates (nominal interest rates deflated by 0.5 times inflation rate from *t* to *t+4* plus 0.5 times mean inflation rate since the end of 1954)

Period	**Australia**	**Canada**	**Germany**	**UK**	**US**
1955Q1-1969Q4	0.0202	0.0283	0.0364	0.0240	0.0202
1970Q1-1982Q4	0.0202	0.0338	0.0387	0.0296	0.0268
1983Q1-1995Q1	0.0593	0.0546	0.0410	0.0348	0.0441

Table 8. The Yield Gap Between Long-term and Short-term Interest Rates 1955-95

Long-term bond yields minus Treasury bill rates (in logs)
Average

Period	Australia	Canada	Germany	UK	US
1955Q1-1969Q4	0.0052	0.0109	0.0245	0.0082	0.0058
1970Q1-1982Q4	0.0052	0.0090	0.0135	0.0224	0.0065
1983Q1-1995Q1	0.0053	0.0108	0.0097	0.0188	0.0089

Correlation with quarterly inflation rates

Period	Australia	Canada	Germany	UK	US
1955Q1-1969Q4	–0.42	–0.49	–0.39	–0.44	–0.30
1970Q1-1982Q4	–0.09	–0.53	–0.16	–0.04	-0.56
1983Q1-1995Q1	–0.18	–0.14	–0.00	–0.14	–0.48

Augmented Dickey-Fuller statistic (estimated with one lag of the dependent variable)

Period	Australia	Canada	Germany	UK	US
1955Q1-1995Q1	–4.02**	–4.14**	–3.51**	–3.38*	–3.73**

Notes:
* significant at the 5% level.
** significant at the 1% level.
Critical values, as given by W.A. Fuller, *Introduction to Statistical Time Series* (New York: John Wiley, 1976, p.373), are respectively –2.58 (10%), –2.89 (5%) and –3.50 (1%).

Table 9. Testing for Debt Effects 1960-95

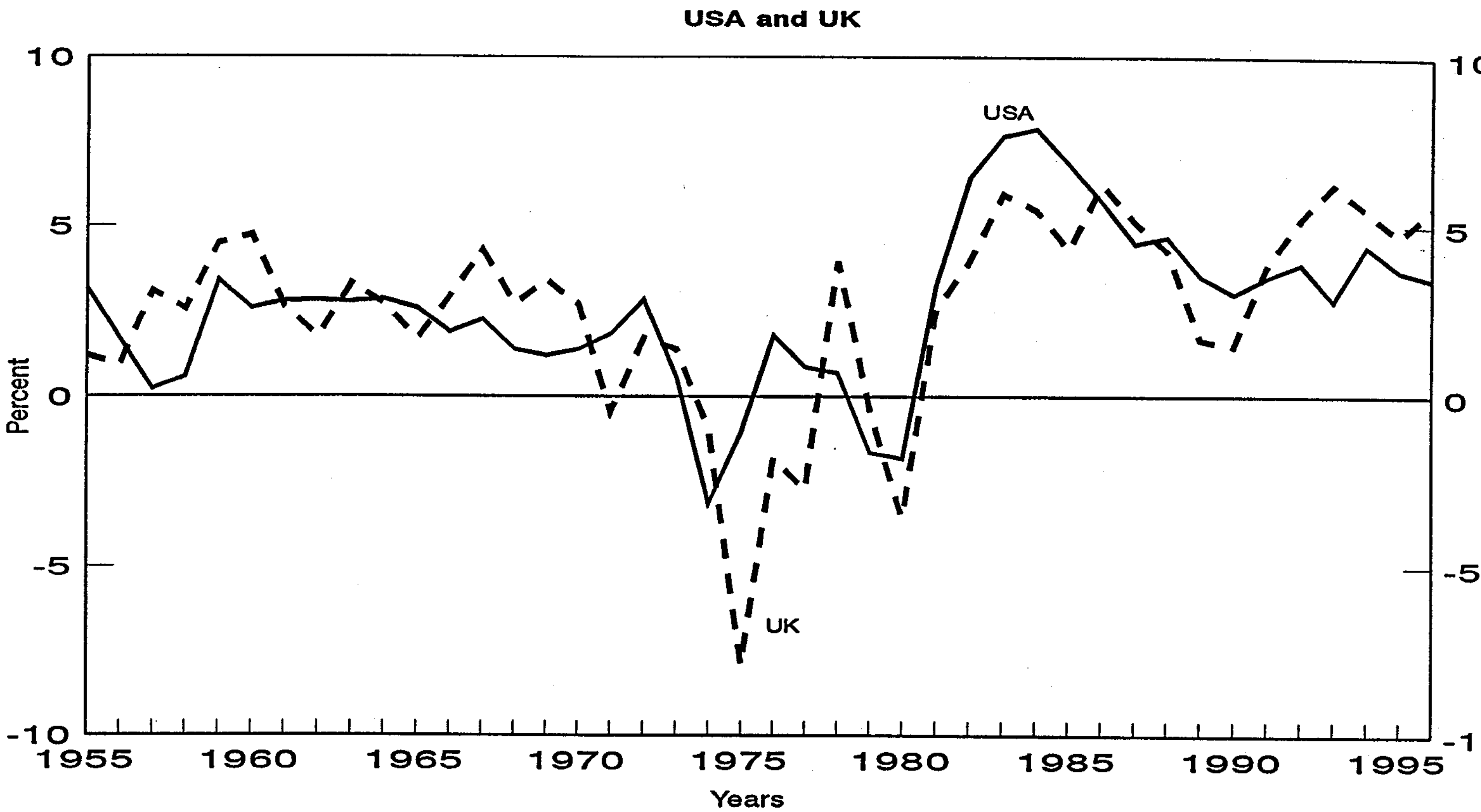
Dependent Variable: Long-term Nominal Yield on Government Bonds (annual; in logs)

Indep't variable	**Australia**	**Canada**	**Germany**	**UK**	**US**
Constant	0.0417	-0.0235	0.0422	0.0653	0.0646
	(0.65)	(-0.55)	(1.07)	(5.63)	(0.91)
Inflation t to t+4	0.344	0.588	0.689	0.252	0.673
	(0.95)	(2.11)	(3.61)	(5.44)	(0.39)
Mean inflation from	1.456	1.486	0.419	0.803	2.287
end-1954 to date	(1.89)	(3.94)	(0.76)	(9.32)	(2.41)
World net debt	-0.152	0.087	-0.021	-0.119	-0.250
(fraction of GDP)	(-0.71)	(0.70)	(-0.44)	(-3.59)	(-1.19)

Notes:
"Mean inflation from end-1954 to date" is defined as $4(\ln p_t - \ln p_0)/t$ where $t = 0$ in 1954Q4. * denotes significant at the 10% level only. Cointegrating vectors and t-statistics are estimated using the Engle-Yoo method as described in Engle and Granger (1991, p. 56).

World net debt is taken from *OECD Economic Outlook*, December 1996, and for 1960-79 from figures for eight countries supplied by Thomas Helbling. These data are GDP-weighted. The eight countries are Belgium, Canada, Germany, Japan, the Netherlands, Switzerland, the UK, and the US.

Figure 1. Long-term interest rates deflated by current inflation



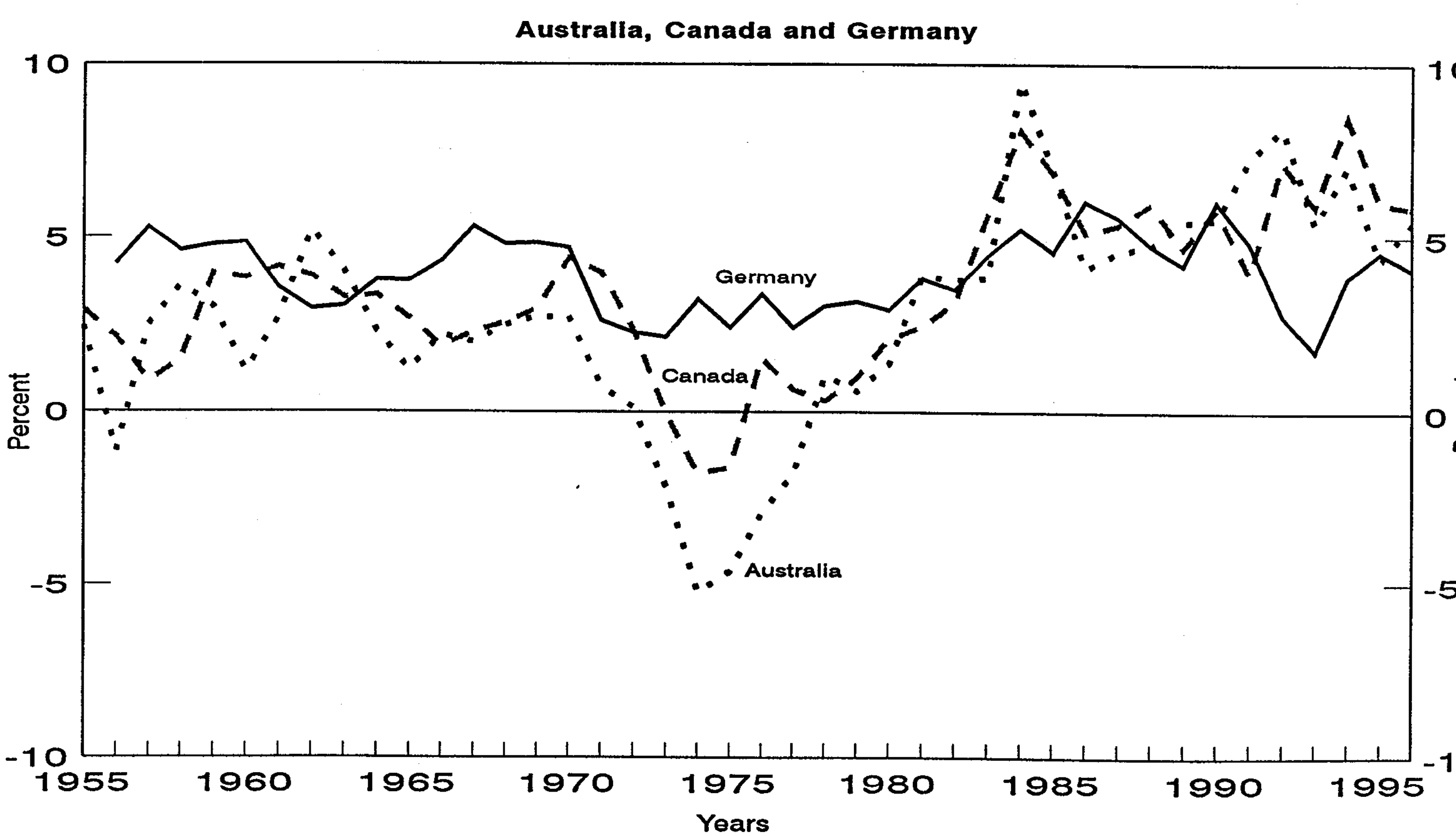
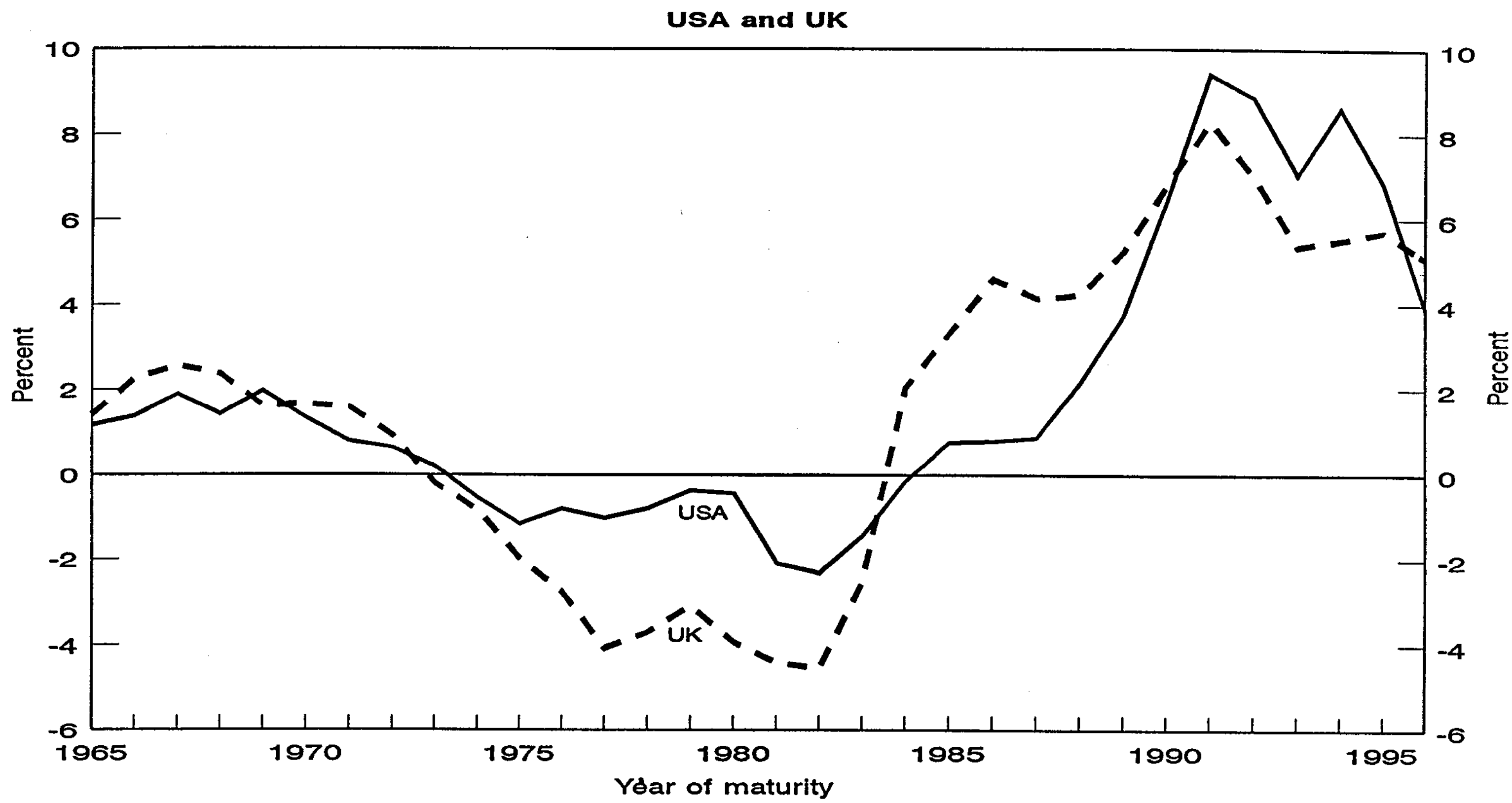
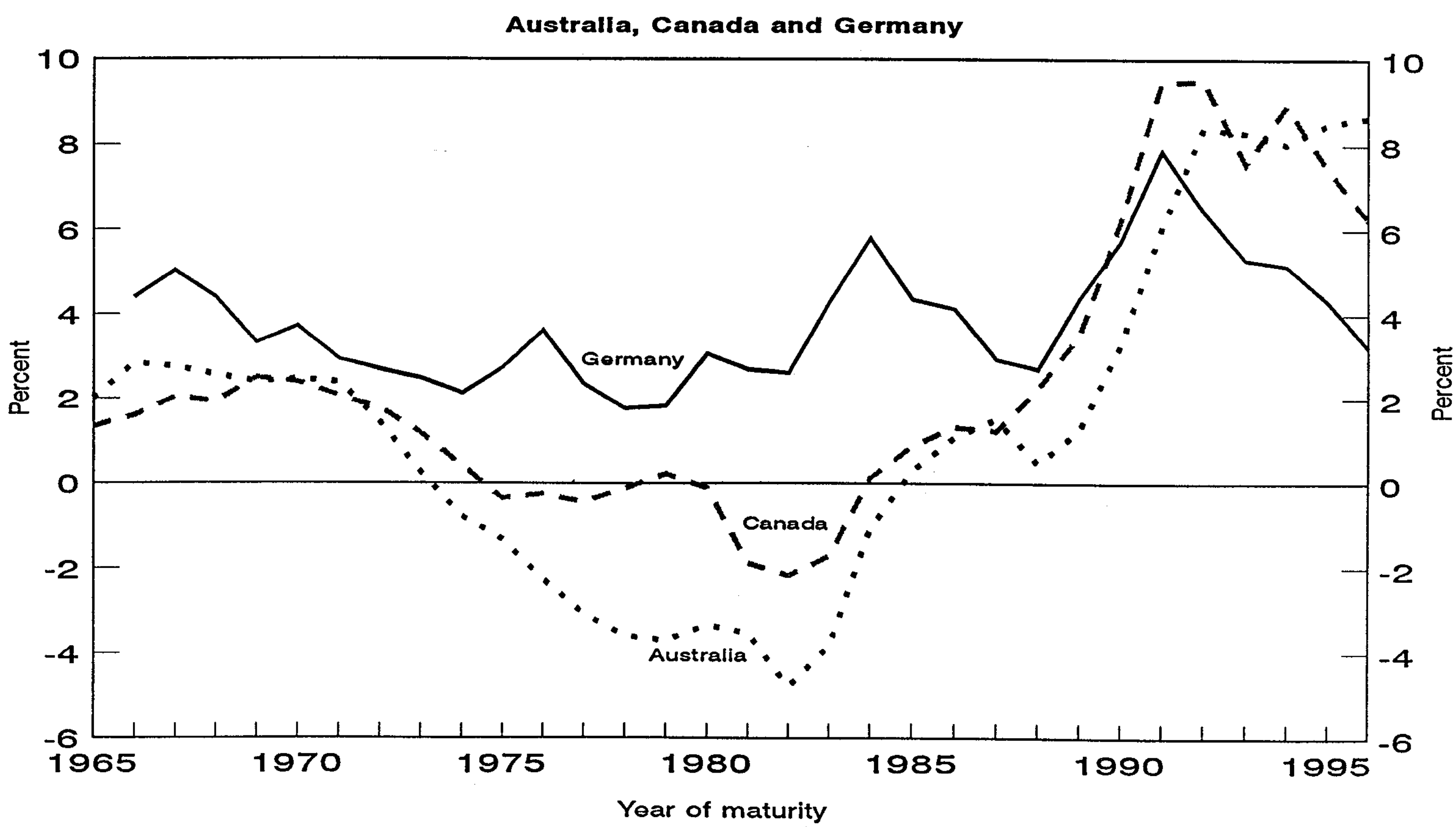


Figure 2. Ex post real interest rates for ten year bonds





REFERENCES

Atkins, F.J. (1980), "Cointegration, Error Correction and the Fisher effect," *Applied Economics*, 47, 1611-20.

Atkinson, P. and J.-C. Chouraqui (1985), "The Origins of High Real Interest Rates,"*OECD Economic Studies*, 2, 1-36.

Barro, R.J., and X. Sala -i-Martin (1990), "World Real Interest Rates," in Blanchard and Fischer (1990), 15-74.

Barsky, R.B. (1987), "The Fisher Hypothesis and the Forecastability and Persistence of Inflation," *Journal of Monetary Economics*, 19, 3-24.

Baxter, M., "Real Exchange Rates and Real Interest Differentials: Have We Missed the Business-cycle Relationship?" *Journal of Monetary Economics*, 33 (1994), 5-37.

Blanchard, O.J., and S. Fischer (eds) (1990), *NBER Macroeconomics Annual*, Cambridge, Mass.: MIT Press.

Brown, R., J. Durbin and J.M. Evans (1975), "Techniques for Testing the Constancy of Regression Relationships over Time." *Journal of the Royal Statistical Society Series B*, 37, 149-163.

Cheung, Y.W., and K.S. Lai (1993), "Finite-Sample Sizes of Johansen's Likelihood RatioTests for Cointegration." *Oxford Bulletin of Economics and Statistics*, 55, 313-28.

Ciocca, P., and G. Nardozzi (1996), *The High Price of Money: An Interpretation of World Interest Rates*, Oxford: Clarendon Press.

Edison, J.H. and B.D. Pauls, "A Re-assessment of the Relationship Between Real Exchange Rates and Real Interset Rates: 1974-1990," *Journal of Monetary Economics*, 31 (1993), 149-64.

Engle, R.F., and C.W.J. Granger (eds) (1991), *Long-run Economic Relationships*, Oxford: Oxford University Press.

Evans, M.D.D., and K.K. Lewis (1995), "Do Expected Shifts in Inflation Affect Estimates of the Long-run Fisher Relation?" *Journal of Finance*, 50, 225-53.

Ford, D., and Laxton, D. (1995), "World Public Debt and Real Interest Rates," *IMF Working Paper* no. 95/30.