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# FIVE WEEKS IN THE LIFE OF THE POUND: INTEREST RATES, EXPECTATIONS AND STERLING'S EXIT FROM THE ERM

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**ABSTRACT**

Yields to maturity of a set of nominal and index linked gilts are used to obtain estimates of the term structures of nominal and real interest rates. These also allow calculation of expected inflation. The estimation is performed for a period of five weeks including the date of sterling's exit from the ERM. We look at the macroeconomic consequences of the shift in the exchange rate regime as implied by the behaviour of financial markets, and how those markets incorporate new information.

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## Introduction

On Wednesday 16th September 1992, after a rise of two percentage points in interest rates and the announcement of a further three percentage point rise for the following day had failed to stem heavy selling pressure on sterling against the currencies of the ERM, sterling's membership of the ERM was suspended with no firm indication of a return date. This paper looks at the behaviour of interest rates and expected inflation implied by the prices of conventional and index linked government securities for a period of five weeks including that Wednesday. This allows us to judge the macroeconomic consequences of the shift in the exchange rate regime as implied by the behaviour of financial markets, and how those markets incorporate new information.

## Uncovering the term structure of real and nominal interest rates

Since 1981 the British government has issued index linked debt. Although the indexing is imperfect, the prices or yields to maturity of these bonds allow us to infer a term structure of real interest rates, where by "term structure" we mean the path of future expected short (here one quarter) interest rates. Many, perhaps most, of the

important propositions of macroeconomic theory are statements about the real interest rate. For example, purchasing power parity, together with capital mobility, implies equalisation of domestic and foreign real interest rates; unanticipated permanent
increases in government spending, or changes in lump sum taxes, should have no effect on the real interest rate; and many others. The problem so far has been that only *ex post* measures are available, so that the failure of tests of these propositions has allowed the alibi that the *ex ante* real interest rate is inaccurately measured, being distorted by errors in estimates of expectations. Woodward (1990) notes that "series on real interest rates derived from such estimates basically amount to conjecture". Index linked gilts allow a direct measure of the real interest rate and should be extremely useful in assessing the predictions of neoclassical macroeconomics. So far they have not been extensively used for this purpose. Barro (1987), in his macroeconomic textbook, tabulates some yields to maturity as evidence of the relative stability of the *ex ante* real interest rate. Arak and Kreicher (1985) use index linked gilts to generate a path of expected inflation for the U.K. and note a rapid fall in 1982. Beyond this most discussion has been in the financial literature, with no macroeconomic content. This paper will use real interest rates derived from index linked gilts to study a major shift in monetary regime, from a fixed to a floating exchange rate.

For such analyses, one is interested in the path of future expected short term or instantaneous real interest rates. Unfortunately most studies of U.K. index linked gilts have constructed only variants of the yield to maturity, which will be some weighted average of future expected rates. Woodward (*op. cit.*), Arak and Kreicher (*op. cit.*) and Levin and Copeland (1992) fall into this category. Brown (1988) does compute the expected path of *ex ante* real interest rates implicit in the price of index linked gilts. The imperfection of indexation of these securities implies that their real return is not completely invariant to inflation expectations. Previous studies differ in how this problem is tackled. Arak and Kreicher (*op. cit.*) and Woodward (*op. cit.*) use the nominal term structure to discount the nominal element of indexed gilts. Brown (*op. cit.*) and Levine and Copeland (*op. cit.*) make essentially *ad hoc* assumptions about these expectations. It seems to us that the former approach is to be preferred, since the attraction of indexed gilts is to allow an escape from *ad hoc* assumptions. Thus in our view none of the previous studies has got it quite right.

The major part of the stock of index linked debt is held by tax exempt institutions so that the derived real term structure can be viewed as the gross or zero tax real term structure. Even for tax payers, since the coupons are low, the majority of the returns are in tax free capital gains. See Robertson and Symons (1992) and Brown (*op. cit.*) for a more lengthy discussion of this issue. For the five week period studied there are between twelve and fourteen such bonds with a maximum maturity of 2030. These bonds therefore contain information about the real term structure to a horizon of approximately 150 quarters from sterling's exit from the ERM. We use a subset of the available conventional nominal gilts both in the derivation of the real term structure (since the imperfect indexing of the index linked bonds means that part of their return is discounted at the nominal interest rate) and to generate the nominal term structure. The subset chosen consists of high coupon nominal gilts with maturities that roughly match the index linked bonds. Since high coupon bonds generate a sizeable proportion of their return as coupon income they will not appeal to income tax payers, who will tend to hold low coupon bonds at each horizon where more of the return occurs via untaxed capital gains; tax exempt institutions on the other hand will be the overwhelming holders of high coupon bonds. Unfortunately the longest dated (non-convertible) nominal gilt matures in 2017, thirteen years earlier than the longest dated index linked. We shall calculate the nominal term structure up to 2017 and extend it to 2030 by the method described below. This allows us to calculate zero tax real and nominal term structures as a quarterly series to a horizon of 150 quarters from the five weeks in September and October 1992. Note that as we move through the five weeks the horizon of the longest dated bond reduces by five weeks, approximately half a quarter. In principle this should be allowed for in estimation, but for a period of this length changes in the calculated term structure would be trivial. The derivation of the term structure from a set of bonds chosen is described fully in Robertson and Symons (*op. cit.*). Here we shall only sketch the procedure. Table 1 reports the full set of bonds we shall use. We calculate the term structures daily from Monday 7th September 1992 (Day 1) to Friday 9th October 1992 (Day 25). Yields to maturity for the bonds were collected from the *Financial Times* of each following morning.

Given yields to maturity for the set of bonds, the term structure is calculated as follows. We assume that, due to arbitrage in the bond market, the price of a bond equals the present discounted value of the stream of coupon payments. For nominal bonds the appropriate discount rates are the nominal term structure. For bonds where the coupon and face value are indexed to the *current* price level (perfect indexation) the appropriate discount rates are the real term structure. Say there are n bonds and let the price of a particular bond be $p=p(\mathbf{r})$ where $\mathbf{r}=(r_1,r_2,.....,r_m)$ is the (real or nominal as appropriate) term structure to the maturity date of that bond. Here $r_i$ is the short (one quarter) interest rate expected to hold in i quarter's time. The yield to maturity y of the bond as conventionally calculated (and as published in, say, the *Financial Times*) is the constant future rate that generates the observed bond price i.e. y is the solution to $p=p(y\mathbf{1})$, where $\mathbf{1}$ is a vector of ones. Expanding the price function as a Taylor series about the yield to maturity we obtain:

$$(1) \qquad p(\mathbf{r}) = p(y\mathbf{1}) + (\partial p/\partial \mathbf{r})'(\mathbf{r} - y\mathbf{1})$$

where $\partial p/\partial \mathbf{r} = (\partial p/\partial r_1, \partial p/\partial r_2, .....\partial p/\partial r_m)'$ calculated at some vector lying between $\mathbf{r}$ and $y\mathbf{1}$. We take an approximation to (1) by calculating $\partial p/\partial \mathbf{r}$ at $y\mathbf{1}$. Now by definition of y, $p(\mathbf{r})=p(y\mathbf{1})$ so (1) reduces to

$$(2) \qquad (\partial p/\partial \mathbf{r})'(\mathbf{r} - y\mathbf{1}) = 0$$

where $\partial p/\partial \mathbf{r}$ can easily be calculated from the present value formula. It thus follows that

$$(3) \qquad y = (1/(\partial p/\partial \mathbf{r})'\mathbf{1})(\partial p/\partial \mathbf{r})'\mathbf{r}$$

which expresses the yield to maturity as a weighted average of expected future short rates. It is easy to see by examination of $\partial p/\partial \mathbf{r}$ that these weights on $r_i$ i=1,...m decline with i. One such equation holds for each bond, so we have a matrix equation

$$(4) \qquad A\,\mathbf{r} = \mathbf{y}$$

where $\mathbf{y}$ is the vector of yields to maturity and each row of A is the normalised $\partial p/\partial \mathbf{r}'$ for a particular bond. Thus the number of columns of A is the maximum duration of the longest bond and the number of rows is the number of bonds i.e. dim(A)=nxm. Of course the number of bonds is generally very much lower than the maximum duration of the set of bonds so (4) cannot be solved for $\mathbf{r}$ without further restrictions on the vector $\mathbf{r}$.

We proceed in two steps. First we construct the piecewise flat term structure consistent with the observed prices and yields: that is, if the maturities of the set of n bonds are $m_1$ $m_2$ ....$m_n$ in ascending order (so that $m_n$ =m above), we calculate the term structure that takes n discrete values; one on $(0,m_1)$, one on $(m_1, m_2)$, one on $(m_2,m_3)$ and so on. The intuition behind this procedure is as follows. Say we have bonds maturing in four and eight quarters. The first yield to maturity tells us the average rate over the first four quarters, the second yield to maturity gives the average rate over the first eight quarters. Thus one may compute the average rate from four to eight quarters. This structure represents in a sense the limit of the information in the set of bond prices or yields. The second step is to smooth these underlying averages onto functions of time. The justification for smoothing is that the term structures of both real and nominal rates represent expectations of future events about which typically there is no precise information on timing. The choice of smoothing functions is arbitrary and there are several candidate families that can approximate piecewise continuous functions accurately. We choose to smooth onto Hermite polynomials $\{t^n \exp(-t^2/2)\}$ (plus a constant) and select the first three (n=0,1,2). Our strong prior on the term structures is that one period future rates eventually become constant as the horizon increases. The use of Hermite polynomials guarantees this feature. We choose the first three Hermite polynomials since this seems to give a good balance between overfitting in the sense of allowing too many interior turning points and underfitting in the sense of removing too much of the detail of the term structure[1]. Robertson and Symons (*op. cit.*) discuss further the choice of functions for smoothing the term structure.

The above assumes perfectly indexed gilts. The indexation in the UK is imperfect in the sense that adjustment of coupons and face value is made according to the retail price index *eight months lagged.* This introduces an element of the nominal term structure into the bond price. This can be handled, and the reader is referred to Robertson and Symons (*op. cit.*) for details.

Two applications of this procedure, one for the nominal bonds and one for index linked give estimates of the nominal and real term structure. The differences between these define market expectations of inflation plus any risk premia associated with the different types of bonds, likely to be mainly an inflation risk premium attached to nominal bonds. If the inflation risk premium tends to be small in magnitude then we may interpret this surface directly as market expectations of future inflation rates measured daily over the five week period. Available evidence is that risk premia tend to be small. Levin and Copeland (*op. cit.*) attempt estimation of the inflation risk premium for UK gilts and find that it is typically one tenth or less of the value of the real interest rate. Of course it may have changed after the ERM exit. Woodward (*op. cit.*) finds similarly, by different methods. We present these results with the proviso that movements in risk premia may be a modest component of the expected inflation series we derive.

**Results**

Figures 1 to 4 show the term structures of real and nominal interest rates (expressed annually) from day 1 (7th Sept) to day 25 (9th Oct) implied by the index-linked and nominal bonds. Wednesday 16th September is day 8. Figure 1 shows the underlying averages i.e. the piecewise flat function as described above for our set of nominal bonds. Note that the horizon is only 100 quarters. Figure 2 shows the same structure smoothed onto Hermite polynomials and extrapolated to 150 quarters. Figures 3 and 4 give the corresponding surfaces for the real term structure. One can detect in these diagrams a sharp rise in the long nominal interest rate after day 8 and a fall in the short nominal rate. There seems to be very little movement in the long real rate, while the short real rate falls substantially.

These movements become clearer by graphing sections through the surfaces. Figure 5 graphs the short (defined as the average of expected real interest rates for the next four quarters, i.e. 92q4 to 93q3), the medium (defined analogously at an horizon of five years), and the long (defined as the average of the last four quarters into 2030) for each day of the five week period. The constancy of the long interest rate is striking. The short rate on the other hand dropped sharply on days 8 to 11 and then remained fairly constant. It seems difficult to conclude other than that the monetary squeeze imposed by the Government due to sterling's membership of the ERM was keeping the short real interest rate artificially high in early September. The announcement of sterling's exit allowed a strong reduction in the short term real interest rate of about one percentage point. Medium term rates, in the judgement of the financial markets, also fell by just under one percentage point, though more slowly than the short rate. Whilst it seems clear that monetary policy can have strong effects on the short real interest rate, the movements in the medium rate (i.e. the short rate in five years time) presumably reflect the markets' discounting the possibility of sterling's re-entry into the ERM with an attendant monetary squeeze. Indeed if we take a short rate of 4.8% as the ERM squeeze value (taken from Figure 5) and the long rate as 3.8%, then the medium rate value of 4.2% is consistent with a market view of a 40% chance of an ERM (or other) induced squeeze at that horizon.

Market perception is that the long run real interest rate was not affected by sterling's membership of the ERM. This is consistent with a market view that the exchange rate regime is immaterial to the setting of long run real interest rates. That said, it is also consistent with a view that has monetary policy affecting even long rates, but that the market had already fully discounted sterling's exit by early September.

Turning to the market expectations of inflation, we graph in Figure 6 the surface giving the expected inflation rates at horizons up to 150 quarters daily for the five week period. The extreme movements in this graph suggest that changes in risk premia are interfering with the pure expected inflation component. In Figure 7 sections through this surface give expected short and long rates. The long rate clearly shows a steep rise in inflation expectations at the time of sterling's exit from the ERM. The expected long rate rises from some 4.2% with sterling in the ERM to 6% outside the ERM. The short rate moves erratically with no obvious trend. In the short run the RPI could increase in virtue of an increase in the price of imports, though the extent of the transmission to domestic prices may be limited in the short run in a depressed economy. The RPI should fall offsettingly in virtue of falls in home mortgage rates: the net effect is unclear. Robertson (1992) has found that market forecasts of inflation based on the term structure have considerable predictive power up to five years, so there are grounds for taking these forecasts seriously.

## Conclusions

We have used the prices of bonds to infer the term structure of real and nominal interest rates for the period containing sterling's exit from the ERM. We also use these to derive market expectations of inflation under the assumption of a negligible inflation risk premium. We assume that prices of these bonds are set by arbitrage allowing us to write the price of a bond as the discounted value of future coupon payments. These formulae are then inverted and, with the addition of a smoothness prior, a term structure surface derived. For the set of bonds we have chosen, tax distortions are likely to be minor and the term structures can be interpreted as zero tax. We then use this term structure to examine market behaviour through sterling's exit from the ERM, and in particular to infer market expectations of the consequences of this event. A number of points about market behaviour are immediately apparent. Firstly it is clear that monetary policy has significant effects on short *ex ante* real interest rates. Secondly the financial markets appear to have rapidly assimilated the new information and to have responded in line with conventional macroeconomic theory, without panics or fads. Thirdly the inflationary consequences of the change in regime are clearly demonstrated: inflation is expected not to change in the short term, but to rise in the long term to about 6%. Thus the markets appear to view that Wednesday as marking a sea-change in the prospects for UK inflation. Fourthly the high short term real interest rate has been reduced to about the level of the long run real interest rate. Medium rates also fell but by less than short rates. Finally the long run real interest rate was not greatly affected by the events of 16th September.

## ENDNOTES

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1 In fitting a small number of Hermite polynomials it is desirable to scale the independent variable, here time measured in quarters, to obtain good approximations. Experimentation showed that a re-scaling factor of 0.03 gave good results.

**TABLE 1**

Index Linked and High Coupon Conventional Bonds 7th September - 9th October 1992

(a) Index Linked

| Bond | | Maturity Date | |
|---|---|---|---|
| 2pc | 1994 | 16th May | (not used in estimation) |
| 2pc | 1996 | 16th Sep | |
| $4\frac{5}{8}$pc | 1998 | 27th Apr | (available from day 11) |
| $2\frac{1}{2}$pc | 2001 | 24th Sep | |
| $2\frac{1}{2}$pc | 2003 | 20th May | |
| $4\frac{3}{8}$pc | 2004 | 20th Oct | (available from day 13) |
| 2pc | 2006 | 19th Jul | |
| $2\frac{1}{2}$pc | 2009 | 20th May | |
| $2\frac{1}{2}$pc | 2011 | 23rd Aug | |
| $2\frac{1}{2}$pc | 2013 | 16th Aug | |
| $2\frac{1}{2}$pc | 2016 | 26th Jul | |
| $2\frac{1}{2}$pc | 2020 | 16th Apr | |
| $2\frac{1}{2}$pc | 2024 | 17th Jul | |
| $4\frac{1}{8}$pc | 2030 | 22nd Jul | |

(b) Conventional

| Bond | | Maturity Date |
|---|---|---|
| $14\frac{1}{2}$pc 1994 | | 1st Mar |
| $15\frac{1}{4}$pc 1996 | | 3rd May |
| $15\frac{1}{2}$pc 1998 | | 30th Sep |
| 13pc | 2000 | 14th Jul |
| 10pc | 2003 | 8th Sep |
| $9\frac{1}{2}$pc | 2005 | 18th Apr |
| 9pc | 2008 | 13th Oct |
| 9pc | 2012 | 6th Aug |
| $8\frac{3}{4}$pc | 2017 | 25th Aug |

Notes (i) The IL 1994 bond was not used in estimation because of the short time to maturity and consequent possibility of distortion in the pricing of this bond due to its imminent redemption and the peculiarity introduced by the lack of indexation for eight months of its remaining life.

(ii) Two IL bonds were issued during the five week period and are introduced into the estimation as soon as quoted yields appeared.

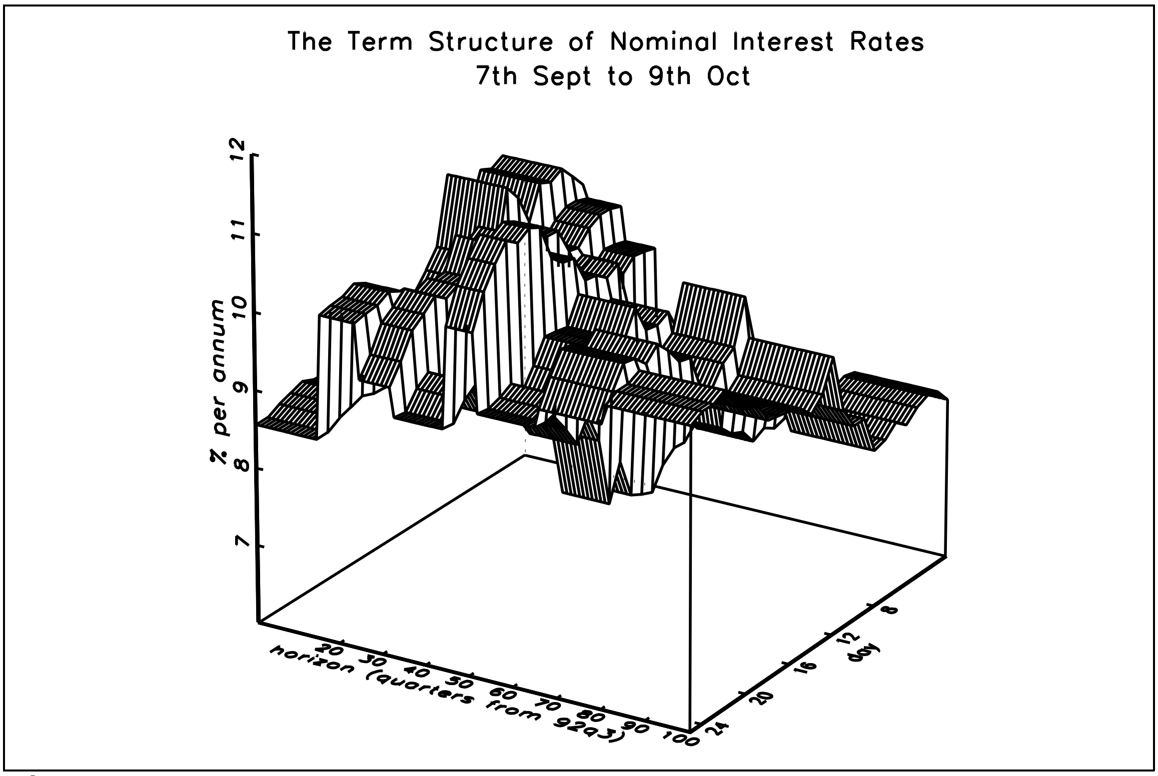



Figure 1

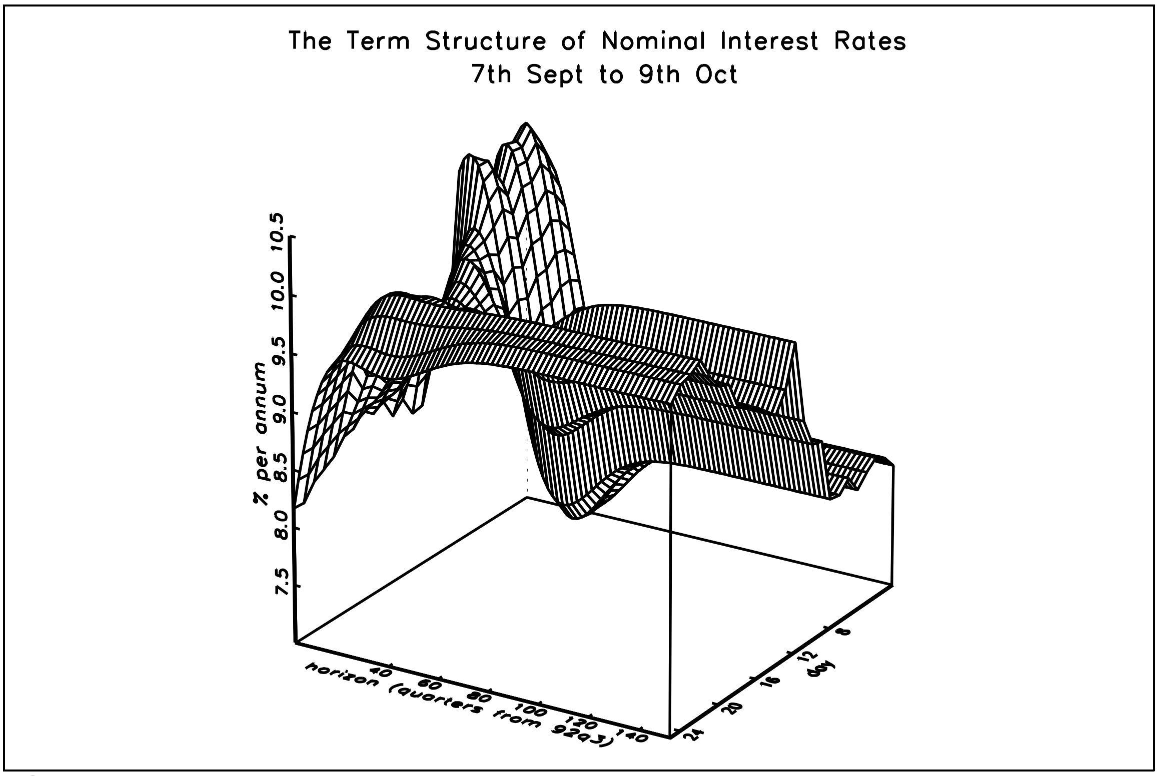



Figure 2

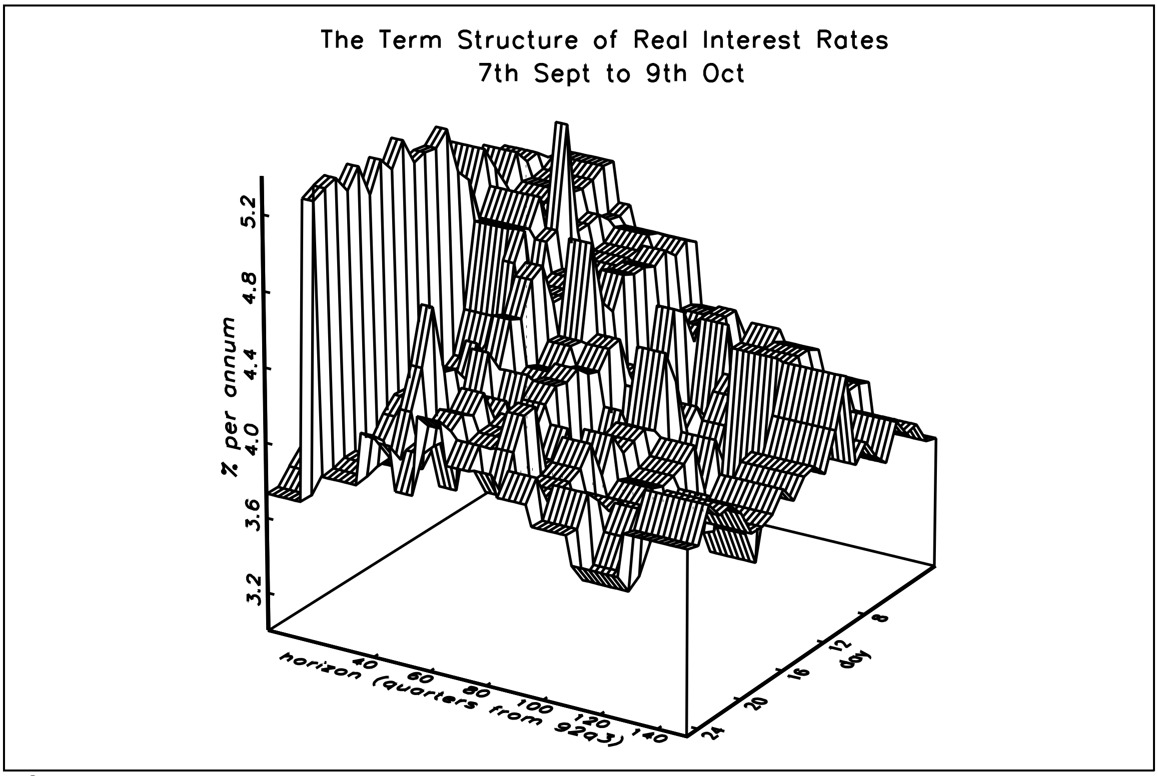


Figure 3

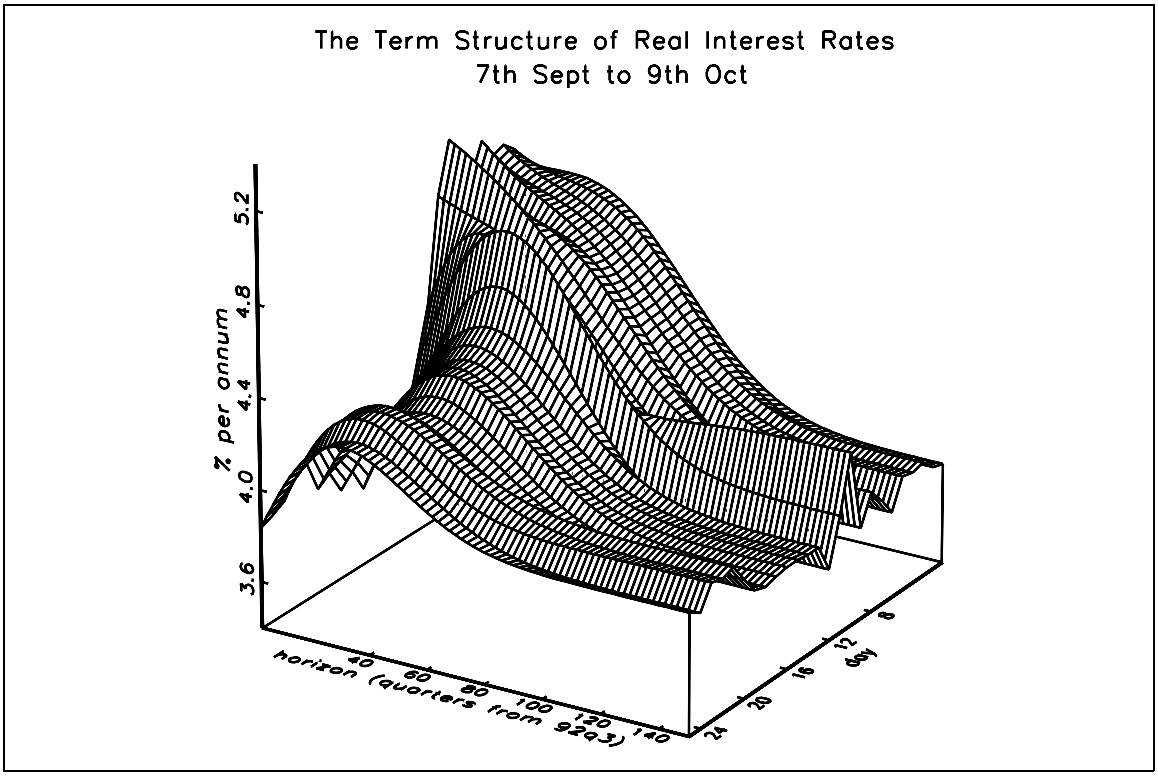
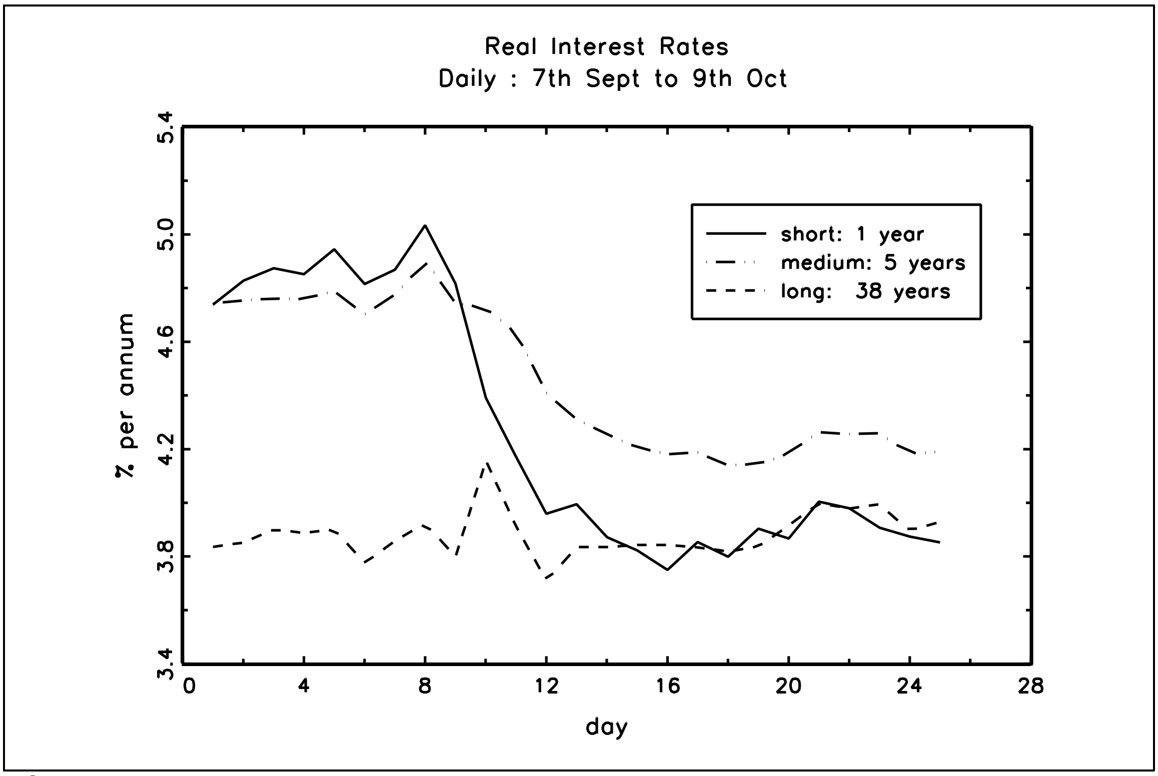


Figure 4


Real Interest Rates
Daily : 7th Sept to 9th Oct
% per annum
day
short: 1 year
medium: 5 years
long: 38 years
5.4
5.0
4.6
4.2
3.8
3.4
0
4
8
12
16
20
24
28
Figure 5

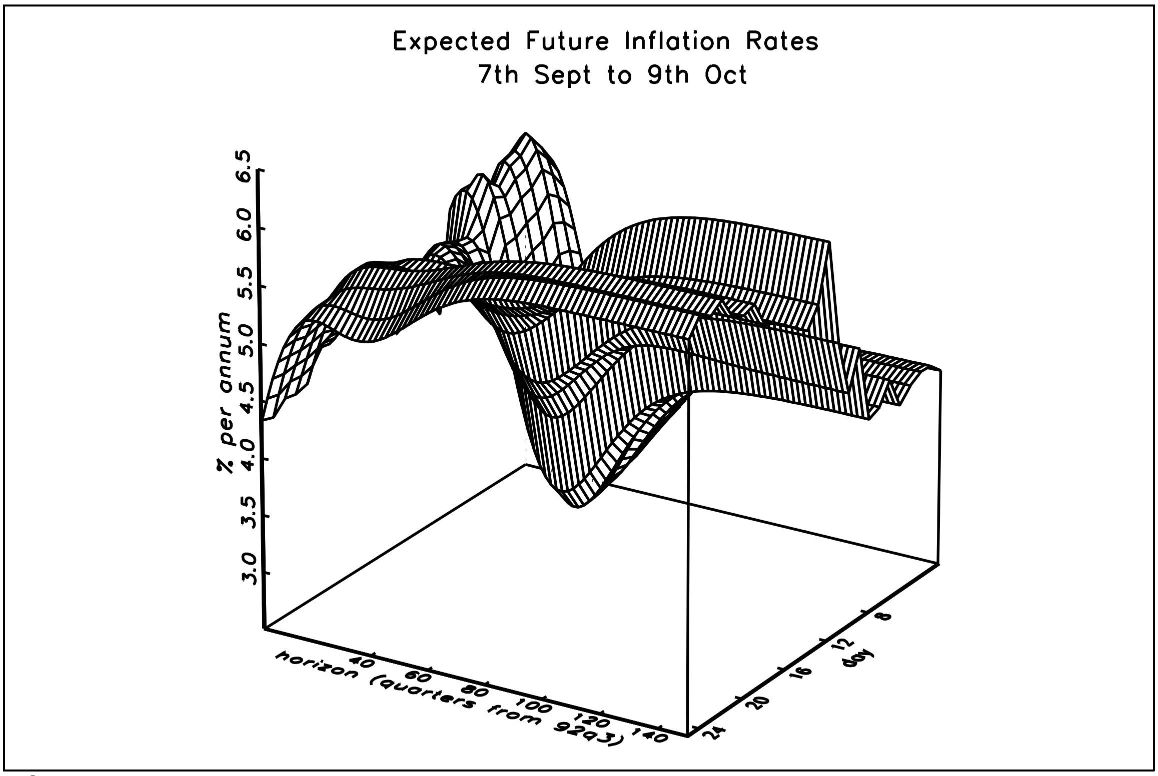



Figure 6

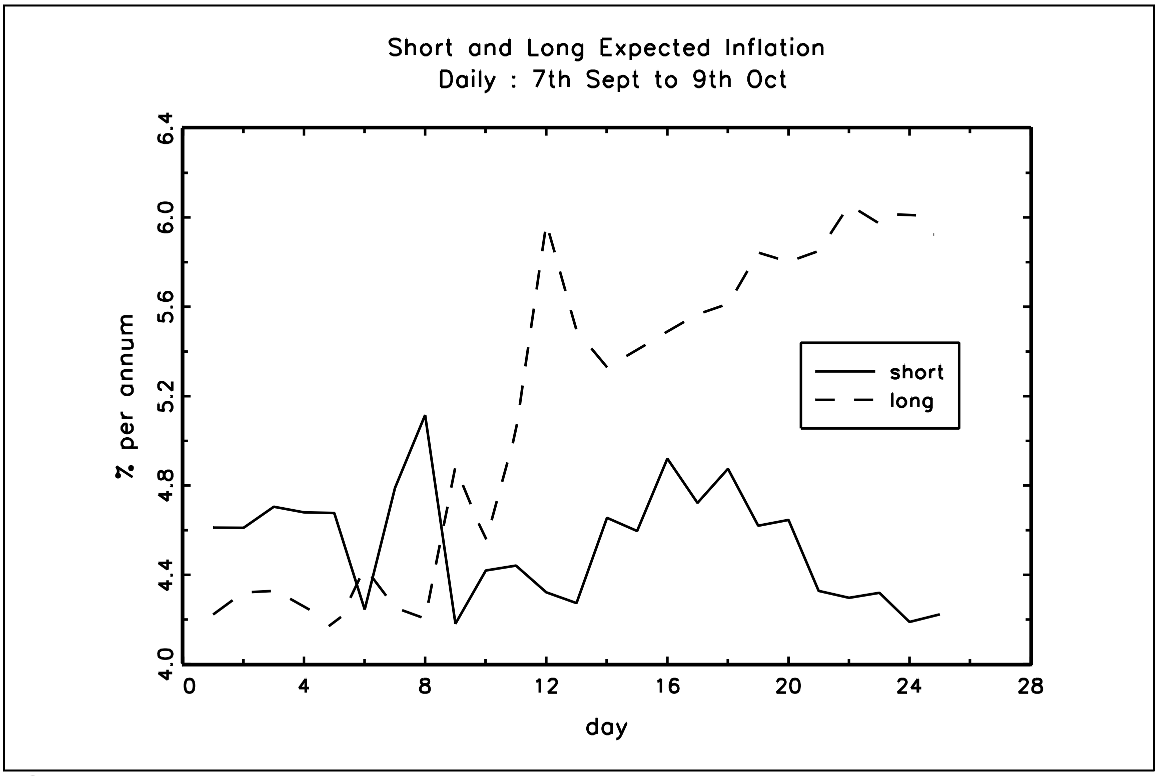



Figure 7

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