Inflation, Inflation Risks and Asset Returns

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Abstract

If low and stable inflation is maintained then the economic environment in the United Kingdom will be very different from any sustained period in the post-war era. This may have significant implications for financial markets: asset prices, the demand and supply for various types of financial contract, and the structure of financial intermediation are likely to be affected by a low inflationary environment. This paper examines the empirical evidence on the links between asset returns, inflation and inflation variability. We calculate the real returns on a range of financial and physical assets and develop a model of inflation expectations and inflation variability. We then estimate the impact of anticipated inflation, inflation shocks and the variability of inflation on asset values.

1. Introduction

This paper examines the empirical evidence on the links between asset returns, inflation and inflation variability. At the time of writing (July 1994) consumer and producer price inflation in the United Kingdom are running at close to the lowest rates in over 30 years. If low and stable inflation is maintained then the economic environment will be very different from any sustained period in the post-war era. This may have significant implications for financial markets: asset prices, the demand and supply for various types of financial contract, and the structure of financial intermediation are likely to be affected by a low inflationary environment. Therefore, an understanding of how perceptions of the level and conditional variability of inflation affect the relative returns on assets is important; and it is essential in interpreting changes in asset prices, especially at times when expectations about inflation and inflation variability are likely to have moved. For example, the yields on assets which are poor hedges against unanticipated inflation may be high relative to the yields on assets which are good hedges against price rises at times when inflation variability is high. Changes in inflation risk premia will affect the relative yields on these types of assets. Being able to isolate the contribution of changes in risk premia to the evolution of changes in relative returns makes it easier to extract any other information in asset prices about the future course of the economy. More generally, it is interesting to know which assets have proved to be a good hedge against inflation surprises and which assets have generated low real returns when inflation is unexpectedly high. [See Fama and Schwert (1977) for an earlier empirical analysis of the issues.]

The plan of this paper is as follows. In Section 2 we consider the likely links between asset prices and inflation. In Section 3 we turn to modelling the level and variability of inflation. In Section 4 we measure the average real returns on a range of assets over the post-war period. Section 5 describes our results on the links between asset returns, inflation shocks and inflation risks.

2. Theoretical evidence on the links between asset prices and inflation

In theory agents are only interested in the real returns from holding various assets, or the real costs of issuing liabilities. No assets generate a return whose real value is known in advance. The real returns on assets with known nominal returns - eg most government bonds (if held to maturity) and (effectively) many bank and building society deposits - are particularly sensitive to unexpected changes in the general price level, at least in the short term. The real returns on assets whose prices are more closely linked to the value of tangible assets - equities and, more directly, claims on industrial commodities, land and property - may be less vulnerable to unexpected general inflation, but are still likely to be affected by sudden changes in the value of money. To understand the links between returns on assets and prices of consumption goods, models have been developed in which rational, optimising agents allocate resources between current consumption and a range of financial and tangible assets, often with the aim of maximising an additive lifetime utility function. Such models imply that the relative returns on assets should depend upon the conditional covariability between the marginal utility of consumption and the asset value [see Rubinstein (1976) and Breeden (1979, 1986)]. This result suggests that a fruitful way to think about how inflation and inflation variability affect relative returns is to consider how the covariability between asset values and consumption is influenced by changes in the general level of prices and/or by changes in the conditional variability of prices. This idea is developed further below.

Consider an asset with a guaranteed nominal return (of £1) in period $t+k$. Assume there is a representative consumer who aims to maximise a time-separable, lifetime utility function which depends on real consumption in each period over the planning horizon. Let the money price of the asset at t be denoted by P_t and let an index of consumer goods prices at t be 1. The first-order condition (or Euler equation) for this optimisation implies that the asset price must satisfy:

$$P_t = \frac{1}{(1+\delta)^k} E_t \left[\frac{U'(C_{t+k})}{U'(C_t)} \frac{1}{PC_{t+k}} \right] \qquad (1)$$

where

δ is the discount rate applied to future flows of utility

$U'(C)$ is the marginal utility of consumption

PC_{t+k} is the index of consumer goods prices at $t+k$

Equation (1) says that the cost, in terms of foregone utility of current consumption, of buying a financial asset ($P_t . U'(C_t)$) must equal the expected product of the real value of the asset tomorrow and the marginal value of consumption then, adjusted for the discount applied to future expected utility ie

$$\left[\frac{1}{(1+\delta)^k} \right] \cdot \left[\frac{U'(C_{t+k})}{PC_{t+k}} \right]$$

If there is an asset which is perfectly indexed, and which pays 1 unit of the consumption good at $t+k$ whatever the price level, its money price (denoted P_t^I) must satisfy:

$$P_t^I = \frac{1}{(1+\delta)^k} E_t \left[\frac{U'(C_{t+k})}{U'(C_t)} \right] \qquad (2)$$

Equation (1) implies

$$P_t = \frac{1}{(1+\delta)^k} \left[E_t \left[\frac{U'(C_{t+k})}{U'(C_t)} \right] E_t \left[\frac{1}{1+\pi_k} \right] + \mathrm{cov}_t \left[\frac{U'(C_{t+k})}{U'(C_t)}, \frac{1}{(1+\pi_k)} \right] \right] \qquad (3)$$

Where π_k is the rate of increase of consumer prices between $t+k$ and t; $cov_t(x,y)$ is the covariance between x and y conditional on information available at t. Using (2) in (3) we can now write:

$$\left[\frac{P_t}{P_t^I}\right] = \frac{E_t\left[\frac{1}{1+\pi_k}\right] + cov_t\left[\frac{U'(C_{t+k})}{U'(C_t)}, \frac{1}{1+\pi_k}\right]}{E_t\left[\frac{U'(C_{t+k})}{U'(C_t)}\right]} \qquad (4)$$

If we assume that the representative utility function implies constant relative risk aversion,

$$U(C) = \frac{\beta C^{1-\alpha}}{1-\alpha}$$

then

$$\frac{U'(C_{t+k})}{U'(C_t)} = \frac{\beta(C_{t+k})^{-\alpha}}{\beta(C_t)^{-\alpha}} = \left[\frac{1}{1+g_k}\right]^{\alpha} \qquad (5)$$

Where g_k is the growth in real consumption between t and $t+k$.

We can now use (4) and (5) to write the relative value of non-indexed to indexed bonds:

$$\left[\frac{P_t^I}{P_t}\right] = \frac{E_t\left[\frac{1}{1+\pi_k}\right] + cov_t\left[\left[\frac{1}{1+g_k}\right]^{\alpha}, \frac{1}{1+\pi_k}\right]}{E_t\left[\left[\frac{1}{1+g_k}\right]^{\alpha}\right]} \qquad (6)$$

The second term on the right-hand side in (6) is the inflation risk premium; it depends upon the conditional covariability between inflation and the growth in consumption. If inflation and the growth in real consumption are negatively correlated, the final term is negative and non-indexed bonds trade at more of a discount to indexed bonds than if agents were risk neutral ($\alpha = 0$). The risk premium here depends upon the degree of risk aversion (α) and the covariance between π_k and g_k. The greater is risk aversion and the more negative the covariance the larger is the price discount on non-indexed assets and the higher is their expected return.

Equation (6) suggests that higher expected inflation may have two effects upon the relative returns of indexed and non-indexed assets. First, there is a direct impact reflected in the first term of (6); higher anticipated inflation reduces the price (increases the nominal yield) on the conventional bond. Second, there could be an effect if there is a link between higher expected inflation and a higher conditional covariance between inflation and consumption growth. If, for example, the conditional correlation between inflation and consumption growth were constant and negative, but the conditional variance of inflation was positively related to the level of inflation then the inflation risk premium on non-indexed bonds would increase with higher expected inflation.

The useful thing about developing an explicit relation between asset returns, expected inflation and inflation variability is that it makes precise how inflation risks should affect expected returns. In the model described above the key factor for risk is the covariance between unexpected price rises and real consumption. In the next section we look at both the conditional covariance between inflation and consumption growth and at the links between inflation and the conditional variance of inflation.

Before moving on to empirical evidence it is important to note one important feature of the consumption-based asset pricing model described here. The model is heavily dependent upon the assumption of a representative consumer; most empirical work based on the model makes a virtue of this by using it as a justification for taking aggregate consumption as the appropriate measure of c_t. But there is a tension between using the representative agent assumption in models to explain the pricing of assets which contribute to the net worth of one group of agents but are the liabilities of another. Companies issue bonds and take loans from banks, and persons are also major borrowers from building societies and banks; the assets corresponding to these liabilities - bank and building society deposits and bonds held on behalf of the household sector by institutions - are, ultimately, largely held by the personal sector. Inflation shocks may redistribute wealth between the issuers and the holders of these sorts of financial instrument but leave aggregate wealth and average consumption little changed; the representative agent model is ill-suited to modelling risk premia on such assets and empirical work based only on the covariance between total consumption and inflation may be unhelpful in revealing the determinants of risk premia on assets which are not held equally by all agents. With this in mind we will not confine our analysis of the links between inflation and asset returns to run through the channel of the impact upon aggregate consumption: because aggregate consumption may be independent of inflation, while inflation can have severe effects upon particular groups of consumers (the elderly, those with substantial financial assets etc), it would not be sensible to model inflation risk premia as dependent only upon the conditional covariance of total consumption with inflation. A more robust strategy, and one we follow below, is to allow the conditional variance of inflation to affect the risk premium on different assets without specifying an explicit asset pricing model requiring the representative agent assumption.

3. Modelling inflation and inflation variability

Chart 1 shows the monthly rate of change of the unadjusted RPI over the post-war period. In order to assess how expectations of inflation, perceptions of inflation variability and unanticipated changes in retail prices affect the real returns on assets we need to model how inflation is expected to evolve and how variability in inflation changes through time.(1) For this we require a model that is capable of accounting for the changing variance of inflation. The Autoregressive Conditional Heteroscedasticity (ARCH) model [see Engle (1982)] can be used to capture these characteristics: the model assumes that the size of the variance changes through time as a function of previously observed residuals and hence models both the mean and variance of a time series. [For other approaches to measuring the variance of inflation see Khan (1977) and Klein (1977).] We follow a simple, univariate approach in which the level of inflation is modelled as a simple function of past inflation and of seasonal (monthly) factors; the variability in the unanticipated shocks to inflation is assumed to be a function of past inflation shocks and of the level, and rates of change, of inflation. We estimate the processes for the level and for the conditional variability of inflation simultaneously by a maximum likelihood technique. For the monthly series,(2) the model we estimate can be written as:

$$\Delta log(RPI)_t = \alpha_0 + \sum_{i=1}^{12} \alpha_i \, \Delta log(RPI)_{t-i} + \sum_{i=1}^{11} \beta_i D_i + e_t \qquad (7)$$

$$E_t(e_t^2) = h_t$$

$$h_t = \delta_0 + \delta_1 h_{t-1} + \delta_2 e_{t-1}^2 + \sum_{i=1}^{12} \lambda_i \Delta log(RPI)_{t-i} \qquad (8)$$

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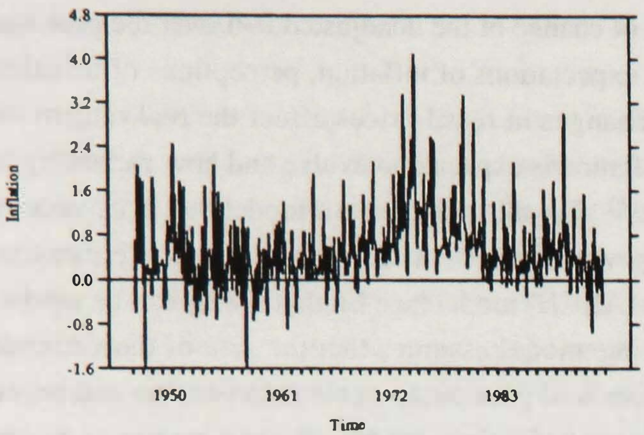
(1) For detailed analysis of the RPI and its components see Mizon, Safford and Thomas (1990).

(2) The monthly data was adjusted in July 1979 to take account of the VAT increase.

Chart 1: Monthly RPI inflation



(For the quarterly model four lags of variables were used.) Equation (7) is the process for mean inflation; D_i are month (or quarterly) dummies. Equation (8) is the generalised auto-regressive conditional heteroscedasticity (GARCH) model of inflation. Equation (8) is written as a GARCH 1,1 model which also allows for any impact of recent levels of inflation upon inflation variability. (We tested for more general models than a GARCH 1,1 but found that higher order processes were not justified.) On the assumption that e_t is normally distributed, maximising the log-likelihood for the model is equivalent to maximising:

$$- \Sigma_{t=0}^{T} \left\{ \log\ (\surd h_t) + \frac{e_t^2}{2h_t} \right\} \tag{9}$$

(9) is maximised with respect to the parameters of the model ($\alpha_0, \alpha_1, \ldots \alpha_{12}$, $\beta_1, \ldots \beta_{11}$, $\delta_0, \delta_1, \delta_2, \lambda_1, \ldots \lambda_{12}$).

The model was estimated using both monthly data and quarterly data. For the quarterly model, inflation is defined as the difference in the logarithm of the level of the RPI between the last months of successive quarters.

For both quarterly and monthly models, the sum of the coefficients on inflation in the conditional variance equation (8),

$$\left(\sum_{i=1}^{n} \lambda_i\right)$$

was close to zero, though individual coefficients were highly significant. This suggested that while the change in the rate of inflation might have a significant impact upon inflation variability, the level of inflation did not. This conjecture was tested by re-arranging equation (8) in the form of lags of second differences of log RPI in the conditional variance equations and one first difference term.

The estimation process is extremely non-linear and we encountered convergence problems in estimation. We found that when δ_1 had a starting value very close to 1 it did not move much between iterations and the results on convergence, a unit root and a negative coefficient on e_t^2 term, were not economically sensible. When δ_1 was started some way from 1 the parameters converged on more sensible values but the likelihood was significantly lower. When we started δ_1 at a value near to 1 but below it, eg 0.95, parameters converged to economically sensible values (positive coefficients on h_t and e_t^2) though the log likelihood remained slightly below the value when $\delta_1 = 1.0$ was the start point. We decided to opt for the economically sensible results. One important point emerged. When δ_1 was started at 0.95 (our preferred model) the results showed that the level of inflation had no effect on the conditional variance, but this result was not robust to the choice of starting point. In cases where some parameters converged on less plausible values, the level of inflation did appear to matter. Because of the convergence problems it is hard to conclude whether it is the level or the change in inflation which alters volatility of inflation. Nevertheless, the economically sensible model shows that the level of inflation is insignificant and hence gives some support to the conjecture that it is only the change in inflation that affects the volatility of inflation.

The models for monthly and quarterly inflation and inflation variability are shown in Tables 1 and 2. Several points emerge from the tables. First, many of the monthly and quarterly dummies (β's) are significant in the equations for the mean rate of inflation, implying that price rises - after allowance for the autocorrelations in the variables - are highly seasonal. Seasonality seems clearer with the quarterly series than with monthly inflation. Second, the rate of inflation displays substantial serial correlation: the sum of the coefficients on the first 12 lags of monthly inflation (the α's) is 0.83, as is the sum of the coefficients on the four lags of quarterly inflation. Third, the unanticipated components of inflation show no signs of being significantly correlated at any lags. This is a necessary - though certainly not a sufficient - condition for forecasts implied by the model to be efficient, ie to have the characteristics of rational expectations. Chart 2 shows the unanticipated element in monthly inflation implied by the model (e_t) and chart 3 shows the time series of the conditional variance (h_t); charts 4 and 5 show the analogous series from the quarterly model.

Table 1

Monthly model of inflation and inflation variability

Parameter Estimates from maximum likelihood estimation of equations (1) and (2) (asymptotic standard errors in parentheses)

(a)	Mean Equation for Inflation		(b)	Conditional Variance Equation	
α_0	.092	(.081)	δ_0	.001	(.001)+
α_1	.277	(.043)+	δ_1	.967	(.007)+
α_2	.054	(.057)	δ_2	.022	(.005)+
α_3	.109	(.046)+	*λ_1	-.038	(.015)+
α_4	.012	(.049)	λ_2	.035	(.024)
α_5	.124	(.050)+	λ_3	.034	(.021)
α_6	.084	(.048)	λ_4	.068	(.019)+
α_7	-.034	(.046)	λ_5	-.018	(.016)
α_8	.037	(.055)	λ_6	.054	(.020)+
α_9	.025	(.048)	λ_7	.004	(.011)
α_{10}	-.014	(.039)	λ_8	-.014	(.012)
α_{11}	-.038	(.043)	λ_9	-.003	(.015)
α_{12}	.195	(.041)+	λ_{10}	-.052	(.008)+
β_1	.070	(.108)	λ_{11}	-.001	(.017)
β_2	.041	(.121)			
β_3	.780	(.124)+			
β_4	-.315	(.133)+			
β_5	-.069	(.131)			
β_6	-.432	(.114)+			
β_7	-.103	(.113)			
β_8	-.156	(.098)			
β_9	.143	(.129)			
β_{10}	.077	(.106)			
β_{11}	-.062	(.128)			

Period: 1949:7 - 1994:3

log likelihood	203.59
number of observations	537

Ljung Box Q Statistics[1]

Q(4)	1.64
Q(8)	5.75
Q(12)	10.37
Q(16)	19.75

---

1 Distributed χ^2_k under the null hypothesis of no serial correlation up to order k in e_t.

* λ_i (i+1...11) are the coefficients on the change in monthly inflation in period t-i.

\+ significant at .05 level.

Table 2

Quarterly model of inflation and inflation variability

Parameter Estimates for maximum likelihood estimation of equation (1) and (2)

asymptotic standard errors in parenthesis ($^{+}$ = significant at 5%)

(a) mean equation for inflation

α_0	-.801	$(0.189)^{+}$
α_1	.542	$(0.065)^{+}$
α_2	.132	$(0.065)^{+}$
α_3	.025	(0.083)
α_4	.127	(0.069)
β_1	1.559	$(0.276)^{+}$
β_2	.880	$(0.218)^{+}$
β_3	1.759	$(0.319)^{+}$

(b) conditional variance equation

δ	.019	(0.014)
δ_1	.953	$(0.016)^{+}$
δ_2	.015	$(0.006)^{+}$
$^{*}\lambda_1$	.198	$(0.064)^{+}$
λ_2	.230	$(0.060)^{+}$
λ_3	-.027	(0.054)
λ_4	-.059	(0.056)

Period: 1950:3 - 1993:3

Number of observations: 174

log likelihood = -54.26

Ljung-Box Q Statistics

Q(1)	0.703	Q(4)	1.33
Q(2)	0.757	Q(8)	2.6
Q(3)	1.038	Q(12)	4.36

$^{*}\lambda_i$ (i=1...4) are coefficients on the change in quarterly inflation at lag *i*.

Chart 2: Unanticipated monthly RPI inflation

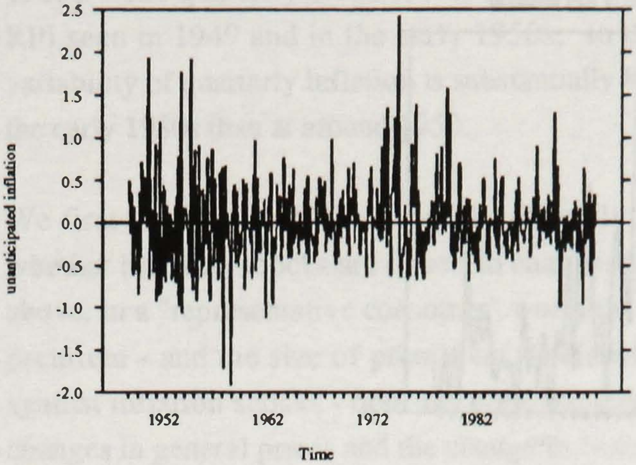


Chart 3: Conditional variance of monthly RPI inflation

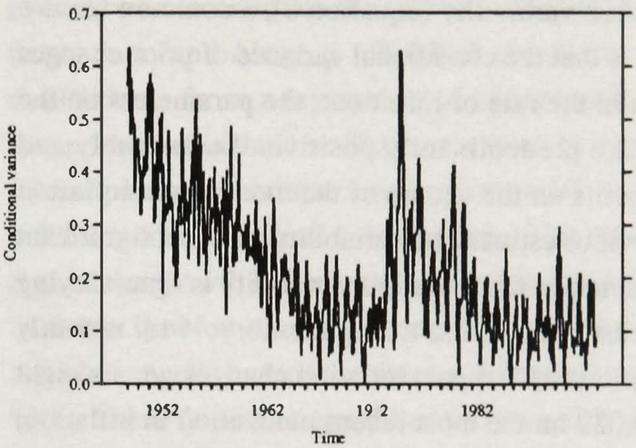


Chart 4: Unanticipated quarterly RPI inflation

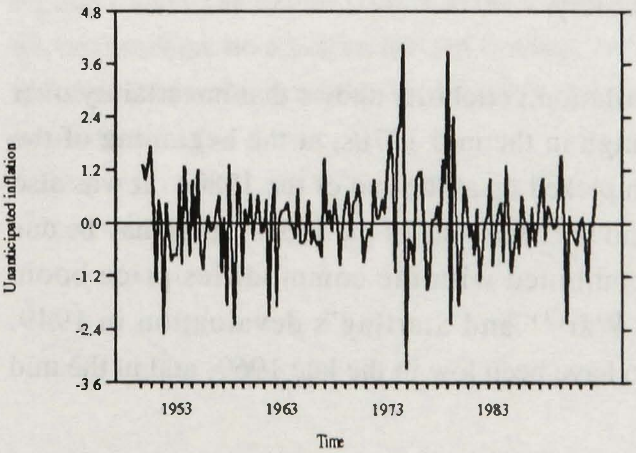
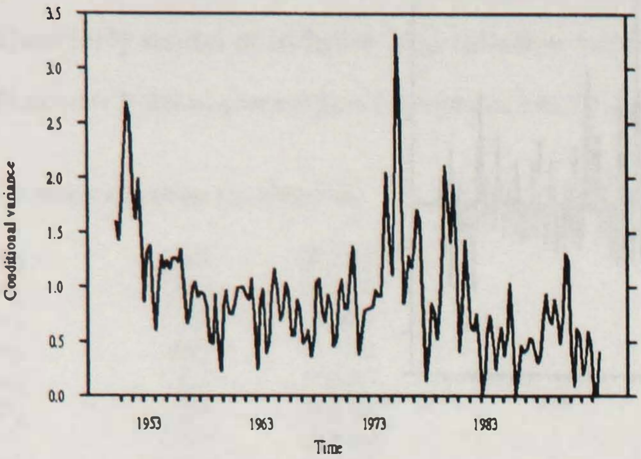


Chart 5: Conditional variance of quarterly RPI inflation



Turning to the models of inflation variability [equation 8], a common feature which emerges from the tables is that the conditional variance of price changes tends to rise with acceleration in the rate of inflation: the parameters on the second difference of log RPI are predominantly positive. For monthly and quarterly inflation the coefficients on the square of the most recent inflation innovation (δ_2) and on the previous estimate of variability (δ_1) are significant and positive: these coefficients imply that inflation variability is time-varying and is sensitive to recent shocks, but also has a long memory; with monthly data the history of past innovations and of past inflation changes get a weight of 0.967 against a weight of 0.022 on the most recent innovation in inflation; with quarterly data the weight on the recent innovation in inflation is 0.015, compared with 0.953 for past history.

The time series of monthly inflation variability shows that uncertainty over price rises was particularly high in the mid 1970s, at the beginning of the 1980s and also when inflation picked up at the end of the 1980s. It was also high at the end of the 1940s and the beginning of the 1950s. This may be due to the lifting of rationing combined with the commodities price boom associated with the Korean War[3] and Sterling's devaluation in 1949. Inflation variability appears to have been low in the late 1960s and in the mid

(3) Engle (1983) found a similar effect in US price data.

1980s. The quarterly series is less sensitive to some of the erratic jumps in RPI seen in 1949 and in the early 1950s; so the series for the conditional variability of quarterly inflation is substantially higher in the mid 1970s and in the early 1980s than at around 1950.

We first used the residuals from the monthly model of inflation to assess whether inflation shocks are linked to changes in consumption. As we noted above, in a "representative consumer" world the existence of an inflation risk premium - and the size of premia on assets which are imperfectly hedged against inflation shocks - depends upon the covariance between unexpected changes in general prices and the change in consumption. Assuming that real consumption would grow smoothly in the absence of unanticipated inflation events, we can estimate the relevant moment by calculating the covariance between e_t and $\Delta\log(c_t)$. Table 3 shows the covariance, along with the coefficients from a regression of consumption growth on the unexpected component of inflation. The covariance is negative and significant and the related parameter estimates suggest that a 1% inflation shock is associated with a 0.2% reduction in total consumption. This result is robust to the inclusion of lags of the growth in consumption and to lags of inflation shocks (lower panel of Table 3). Non-durable consumption appears to be slightly less sensitive to inflation shocks but still declines substantially when inflation is unexpectedly high. These findings suggest that inflation risk should be priced and that assets less well hedged against such risks should, other things equal, pay higher returns - and to an extent related to the conditional variability of inflation. In the next section we measure the real holding period returns of a range of assets and then assess the extent to which returns on a range of assets are affected by inflation.

Table 3

Inflation Shocks and Consumption

(a) Total Consumption

Covariance between e_t and $\Delta\log(c_t)$
= -.192 [1955:2 - 1993:2]

Regression of $\Delta\log(c_t)$ on:

CNST	0.614	(0.097)
e_t	-0.193	(0.098)
R^2	.025	
DW	2.144	
Ljung Box Statistics		
Q(1)	0.819	
Q(2)	3.15	
Q(3)	6.54	
Q(4)	8.03	
Q(8)	16.78	
Q(12)	24.28	

Regression of $\Delta\log(c_t)$ on:

CNST	0.505	(0.138)
e_t	-0.209	(0.099)
e_{t-1}	-0.207	(0.099)
e_{t-2}	-0.181	(0.100)
e_{t-3}	-0.197	(0.102)
e_{t-4}	0.036	(0.100)
$\Delta\log(c_{t-1})$	-0.111	(0.086)
$\Delta\log(c_{t-2})$	0.146	(0.083)
$\Delta\log(c_{t-3})$	0.206	(0.082)
$\Delta\log(c_{t-4})$	-0.031	(0.084)
R^2	0.15	
Ljung Box Statistics		
Q(1)	0.00	
Q(2)	0.49	
Q(3)	0.66	
Q(4)	0.83	
Q(8)	7.97	
Q(12)	12.39	

(b) Non Durable Consumption

Covariance between e_t and $\Delta\log(c_t)$
= -.116 [1955:2 - 1993:2]

Regression of $\Delta\log(c_t)$ on:

CNST	0.576	(0.072)
e_t	-0.117	(0.072)
R^2	.017	
DW	1.960	
Ljung Box Statistics		
Q(1)	0.05	
Q(2)	9.18	
Q(3)	10.05	
Q(4)	10.62	
Q(8)	17.82	
Q(12)	23.85	

Regression of $\Delta\log(c_t)$ on:

CNST	0.378	(0.109)
e_t	-0.156	(0.073)
e_{t-1}	-0.160	(0.073)
e_{t-2}	-0.079	(0.073)
e_{t-3}	-0.172	(0.073)
e_{t-4}	0.024	(0.073)
$\Delta\log(c_{t-1})$	-0.029	(0.085)
$\Delta\log(c_{t-2})$	0.232	(0.082)
$\Delta\log(c_{t-3})$	0.105	(0.083)
$\Delta\log(c_{t-4})$	0.064	(0.084)
R^2	.15	
Ljung Box Statistics		
Q(1)	0.02	
Q(2)	0.23	
Q(3)	1.05	
Q(4)	1.42	
Q(8)	8.17	
Q(12)	13.37	

Notes: standard errors in parentheses. Period for all estimation: 1955:2-1993:2

4. Measuring real asset returns

In this section we describe the real holding period returns on a range of assets in the post-war period. The assets whose returns we measure are:

UK Government bonds with 5 years to maturity
UK Government bonds with 10 years to maturity
UK Government bonds with 20 years to maturity
Deposits (or loans) paying base rate
Deposits paying the average building society share rate
Gold
Euro D Mark deposits (returns expressed in £ having been adjusted for exchange rate changes)
Euro dollar deposits (expressed in £ having been adjusted for exchange rate changes)
UK equities
Oil
Industrial commodities
Houses
Commercial property
Land

Exact definitions of how the returns were constructed are given in the appendix. For each asset we have made no adjustment for transactions costs, for real services provided by ownership of the asset or for maintenance costs and depreciation. With houses and commercial property these factors are certainly not trivial - although their real value is unlikely to change very much from month to month. Thus our measure for real estate should provide an adequate proxy for the variation of the total return but not the level of the total return. We measure returns pre-tax[4] to avoid distortions arising from changing tax regimes. For each asset we construct a measure of the logarithm of the inflation-adjusted holding period return. In most cases monthly holding

(4) Except for the building society share rate, which is post tax.

period returns could be calculated; but for many of the tangible assets (land, houses, commodities) only quarterly returns were calculated. Inflation adjustments were made using the unadjusted index of retail prices. The formula used to construct (monthly) real holding period returns is:

$$(\log ((1 + y_t)/((RPI_t/RPI_{t-1})^{12}))) \times 100$$

where y_t = the nominal holding period return for time t expressed at an annual rate.

RPI_t = the index of retail prices at the end of period t. This measure is used because the series is available back to the 1940s, unlike RPIX.

For equities and bonds, y_t reflects the percentage change in the value of the asset plus any dividends (or coupons) paid; for tangible assets, y_t is simply the percentage change in the asset price over the period; for bank and building society deposits or loans, y_t is simply the relevant nominal interest rate; and for US dollar and DM euro deposits, y_t takes account of currency changes against sterling during the month.

Table 4 shows average real returns for each asset over the longest post-war period for which data are available. Table 5 shows real returns, and average inflation rates, over several sub-periods. Several points are worth noting from the tables. First, inflation variability (as measured by the standard deviation of the log change in the unadjusted, all items monthly RPI) was slightly lower in the relatively low inflation periods (1947-1955 and 1955-1965) than in the period 1975-1985 (when average inflation was over 11.0%). Second, the tables reveal that tangible assets which are often thought to be a good hedge against unanticipated inflation - gold, oil and commodities - do not yield noticeably higher returns in the periods of higher inflation; in the decade 1975-85 the average real return on commodities and on oil was substantially negative. Third, the assets which emerge as generating the highest real returns over long periods are equities (average real holding period return of 7.4% over 1950-93) and land (average return of 5.2% over the shorter period 1964-93). Finally, assets whose returns are fixed in nominal terms - at least over short periods - appear to generate slightly lower average returns in the high inflation periods. Bonds, building society deposits and assets generating returns linked to banks' base rates all yielded returns in the high inflation period 1975-85 below their average for the post-war period. But in all cases the difference in yields was not very large. This does not mean that the returns on such assets are invariant to sudden shocks to inflation; rather that, over sustained periods of high inflation, the nominal yield on conventional bonds and on deposits does respond to inflation. How rapid that response is and how risk premia evolve over time are analysed in the next section.

Table 4

Real holding period returns

	Mean real holding period return[1]	Standard deviation	Period	Number of observations
(Monthly)				
bonds (5yr)	0.956	7.831	1947:6-93:11	557
bonds (10yr)	1.333	7.867	1947:6-93:11	557
bonds (20yr)	1.396	7.984	1947:6-93:11	557
base rate	1.002	7.815	1947:6-93:11	557
bsoc deposit	-1.056	7.816	1947:6-93:11	557
gold	0.436	58.419	1950:1-93:10	526
equities	7.391	53.779	1950:1-93:10	526
Euro$	1.932	33.394	1957:1-93:10	442
EuroDM	2.989	31.586	1963:7-93:10	364
ΔlogRPI[1]	6.347	8.143	1947:6-94:3	561
(Quarterly)				
oil	-3.951	65.959	1963:1-93:2	118
commodities	-2.575	25.201	1965:1-93:2	110
houses	2.468	13.393	1964:1-92:3	115
land	5.212	24.883	1964:2-92:3	114
ΔlogRPI	6.347	6.110	1947:3-94:1	186
(Annual)				
commercial properties	3.965	10.720	1969-1993	25
user cost of housing	-0.914[2]	7.983	1964-1992	29
ΔlogRPI (12 month change)	6.390	4.799	1949-1993	45

1 expressed at an annual rate.
2 the user cost of housing is constructed using the following formula:

usercost = $(\lambda\, r\,(1-t) + (1-\lambda)\, r + \alpha + m - \pi)$
r = building society mortgage
λ = average gearing rate
t = basic rate of tax
δ = depreciation rate (assumed = .01)
m = maintenance rate (assumed = .005)
π = percentage increase in mix adjusted house price index

Table 5

Real Holding Period Returns: Sub-periods

Monthly Series

	1947:7-1955:1		1955:1-1965:1		1965:1-1975:1		1975:1-1985:1		1985:1-1993:11	
	mean	s.dev	mean	s.dev	mean	s.dev	mean	s.dev	mean	s.dev
bonds (5yr)	-2.581	8.263	1.735	7.284	0.225	6.545	0.429	9.744	4.616	6.132
bonds (10yr)	-1.960	8.344	2.053	6.417	0.451	6.598	1.133	9.637	4.705	6.472
bonds (20yr)	-1.701	8.563	2.068	6.509	0.471	6.787	1.353	9.675	4.534	6.758
base rate	-2.328	8.295	1.900	6.278	-0.221	6.686	-0.121	9.369	5.507	5.911
bsoc deposit	-1.983	8.201	0.345	6.355	-2.596	6.939	-3.429	9.562	2.567	6.022
gold	-4.278	9.931	-2.987	7.234	10.158	64.302	1.731	87.615	-5.893	57.304
equities	10.018	40.721	6.977	45.065	-0.478	69.175	14.792	63.053	10.242	52.454
Euro$	-	-	1.088	5.952	0.996	22.717	6.663	39.175	-1.517	48.007
EuroDM	-	-	0.340	4.359	4.849	26.553	-0.656	37.723	5.226	31.515
ΔlogRPI	4.99	8.107	3.027	6.302	7.386	7.369	11.149	9.738	4.974	6.2519

Quarterly Series

	1965:1-1975:1		1975:1-1985:1		1985:1-1993:3	
	mean	s.dev	mean	s.dev	mean	s.dev
oil	-2.959	15.216	-5.621	30.674	-9.680	29.733
commodities	-0.959	26.506	-2.439	24.973	-6.912	25.251
houses	-3.306	6.586	0.843	17.896	6.421	10.414
land	4.925	30.457	1.529	23.809	7.882	23.639

5. Results on the links between asset returns and inflation

In this Section we report results from regressions which aim to measure the sensitivity of real holding period returns on a range of assets to unexpected inflation (e_t), and to our measures of perceived (or conditional) inflation volatility (h_t). This is in the spirit of the Arbitrage Pricing Theory [see Chen, Roll and Ross (1986)]. For each of the assets whose returns were described in Section 4 we regressed the ex-post, real holding period return on inflation shocks, anticipated inflation and the conditional variance of inflation. Lags of the inflation variables, and of the dependent variable, were included to pick up any dynamic adjustment of asset prices to changes in the inflation environment. The model we estimate for each asset can be written:

$$rr_t = \alpha + \sum_{i=0}^{k} \beta_i e_{t-i} + \lambda h_t + \sum_{i=0}^{k} \delta_i \dot{p}^e_{t-i} + \sum_{i=1}^{j} \gamma_i rr_{t-i} \qquad (10)$$

where rr_t is the ex-post, real return on the asset in period t; e_t is, as before, unexpected inflation in period t; h_t is the conditional variance of inflation (based on the models estimated and described in Section 2) at t; and $\dot{p}^e_t$ is the expected value of inflation at time t, based on past inflation and seasonal dummies, (it is the fitted value from the estimates of equation (7) above and can be seen as the expected values at the start of period t for inflation during period t).

Since aggregate consumption appears to be negatively related to inflation shocks, the model of risk premia derived in Section 2 implies that those assets whose real returns are not invariant to inflation shocks should have higher expected returns (ie risk premia), and that those premia should be greater the more volatile is inflation. In terms of equation (10) this implies that for assets with significantly negative β's - ie those whose real returns are reduced by inflation shocks - the average ex-post returns should rise with inflation variability (λ positive) as risk premia increase.

Table 6 summarises the results for assets whose returns we measure monthly. We report the impact effect of an inflation shock, and the impact response of a change in conditional inflation variability, upon real returns. The table also shows the long-run impact of these changes. The results are derived from asset-return equations with 12 lags of inflation shocks, of anticipated inflation and of past returns. Table 7 shows the results for assets where returns are measured quarterly; the models for real returns include the estimated current inflation shock and expected inflation, the conditional variability of inflation and four lags of the inflation terms and of the dependent variable. Since, in both tables, we include variables which are generated from other regressions (e_t, $\dot{p}_t^e$ and h_t) the normal standard errors on the associated coefficients are not unbiased [see Pagan (1984, 1986) and Oxley and McAleer (1993)]. With more than one generated regressor in the equations it is unclear in which direction the unadjusted OLS standard errors are biased. Parameter estimates are, however, consistent. So although estimation of equation (10) by OLS is not efficient, the parameter estimates are consistent and with large sample sizes (generally greater than 500 for monthly estimates) the efficiency loss is likely to be small.

Table 6

The Effects of Inflation Shocks (e_t) and Conditional Variability of Inflation (h_t) Upon Real Holding Period Returns.

[Monthly real yields and monthly inflation are expressed as annual rates.]

Period	Impact Effects		Long-Run Effects								Estimation
	e_t	h_t	e_t	π^A	h_t	R^2	Q1	Q4	Q8	Q12	
5-year bonds	-.941 (43.70)	-0.902 (4.13)	-1.501	-.252	-2.509	0.888	0.0	0.38	2.31	3.96	50.7-93:10
10-year bonds	-.939 (40.1)	-0.96 (4.26)	-1.353	-.213	-2.237	0.867	0.0	0.60	2.69	7.65	50:7-93:10
20-year bonds	-.957 (38.61)	-0.817 (3.42)	-1.407	-.108	-1.914	0.855	0.02	3.62	5.86	10.65	50:7-93:10
building society deposits	-.982 (55.47)	-0.56 (3.51)	-.298	-.367	-0.887	0.924	0.02	0.89	3.56	4.77	50:7-93:10
gold	-.036 (0.07)	-5.28 (1.52)	1.506	-.278	-4.999	0.013	0.05	0.19	4.91	19.88	51:1-93:10
equities	-.391 (0.82)	0.598 (0.21)	-5.01	.022	0.76	0.110	0.0	0.14	2.61	7.89	50:7-93:10
Euro $ deposits	-1.023 (3.11)	-2.09 (0.69)	-2.611	0.36	-2.24	0.058	0.0	0.03	0.74	10.5	58:1-93:10
Euro DM deposits	-0.369 (1.02)	-15.8 (2.19)	-1.42	1.29	-14.27	0.127	0.0	0.07	8.45	10.00	64:7-93.10
base rate loans	-.961 (51.53)	-0.52 (3.0)	-0.89	-.43	-2.33	0.92	0.0	0.2	1.85	3.94	48:7-93:10

Notes: Numbers in parentheses beneath impact effects are t statistics on parameter estimates from the OLS regression of real returns on inflation shocks, anticipated inflation and the conditional variability of inflation. The effect of a change in h_t is the impact of an increase in the conditional variability of inflation by one standard deviation. The mean of h_t over the period 1949:7-1993:11 is 0.214 and the standard deviation is 0.128. The coefficient beneath the impact effect of h_t is the t statistic on the OLS parameter estimate from the real yield regression. Long-run effects of both e_t and h_t are measured using the estimated coefficients on current and lagged inflation variables and on the dependent variables. The long-run impact of e_t shows the effect of a rise in inflation which, despite being sustained, does not alter expectations of inflation. The effect of a sustained rise in inflation which <u>does</u> eventually alter expectations is given by the column headed π^A.

Q_i is the Ljung-Box portmanteau statistic for testing for serial correlation of the error residual up to the i^{th} order (distributed χ_i^2 under null of no serial correlation).

Table 7

The Effects of Inflation Shocks (e_t) and Conditional Variability of Inflation (h_t) Upon Real Holding Period Returns. [Quarterly yields are expressed as annual rates of return.]

	Impact Effects		Long-Run Effects								Estimation Period
	e_t	h_t	e_t	π^A	h_t	R^2	Q1	Q2	Q4	Q8	
commodities	-1.134 (1.89)	2.12 (0.18)	13.75	-4.05	3.403	0.118	0.12	0.34	1.19	9.49	66:1-93:2
oil	-1.15 (1.97)	4.6 (0.49)	13.36	-4.1	5.39	0.083	0.13	0.31	0.59	8.76	64:1-93:2
houses	-1.315 (5.71)	-4.3 (1.05)	0.48	1.03	-11.08	0.495	0.015	.018	0.97	3.6	63:1-93:1
land	-0.957 (2.61)	-0.297 (0.04)	-17.69	1.33	-1.14	0.635	0.054	0.085	0.19	8.18	63:2-92:3

Notes: The footnotes to Table 6 apply. The impact of h_t is, once again, the effect of a one standard deviation rise in conditional variability; the mean of h_t for 1950:3-1993:3 is 0.902, the standard deviation is 0.53.

The tables show that the immediate impact of unexpected inflation upon the real returns on all assets is negative. But some assets appear to be fairly well insulated against erosion in real value, even in the short run. The real yields on equities, on Euro DM deposits and on gold are relatively insensitive to inflation shocks. In contrast, the real returns on bonds, on building society deposits and on assets generating returns linked to base rate are highly sensitive to inflation shocks; real yields fall pretty much one for one with unanticipated price rises. More surprisingly, the quarterly results suggest that tangible assets - commodities, oil, houses and land - are no better as inflation hedges in the very short term.

Assessing the longer-term impact of inflation shocks is somewhat problematic. The natural way to assess the long-run impact of a change is to solve a dynamic model for the long-run response to a sustained change in a driving variable. While this strategy certainly makes sense in looking at the long-term impact of permanently higher inflation variability, it is less plausible when looking at the longer-term effect of an inflation shock. We therefore show two "long-run impacts" for the rate of inflation in the tables. The first is the effect on the real return in the longer term of a rise in inflation which, although sustained, does not alter expectations. This is equivalent to calculating the long-run impact on real yields of a rise in e_t which is sustained. The second effect is the impact of a sustained rise in expected inflation (which we denote by a rise in π^A).

The long-run impacts suggest that assets that yield returns which are relatively well hedged against inflation shocks in the short run (gold, equities, Euro DM deposits) are also well protected against prolonged periods of higher expected inflation. Assets which are least well protected against short-run inflation shocks (bonds, bank deposits, Euro $ deposits, houses) are much better protected against sustained periods of higher inflation when higher price rises have come to be expected, but even so their pre-tax returns are generally a decreasing function of higher predicted inflation.

The conditional variability of inflation has a negative impact upon the real returns on most assets, though in many cases the parameter estimate is not very well defined. It is surprising that for assets revealed to be poor inflation hedges - conventional bonds, building society and bank deposits and assets with returns linked to base rate - the effect of higher conditional inflation variability is apparently to reduce real yields; evidently holders of these assets are not compensated for higher inflation risk with higher average returns. In theory we should expect these effects to be linked: assets whose real returns are significantly affected by actual inflation shocks should be influenced by changes in perceptions of the conditional variability of such shocks. We would expect that the future real returns on assets whose value is sensitive to inflation shocks should rise when inflation variability rises; ie, there should be a link between the longer-run effect of h_t upon returns and the impact of e_t upon returns.

This result is hard to square with the usual inflation risk premium story. But those assets whose returns fall most when conditional variability rises - gold and Euro DM deposits - are amongst the assets best hedged against inflation. This result is more consistent with the existence of time-varying inflation risk premia which we would expect to generate relatively low average returns on assets which are well-hedged when inflation variability rises.

One explanation for the poorly defined risk premia may be that we have not captured the full dynamics - the low R^2 values and insignificant t statistics on some of the assets suggest this may be the case. We have modelled how inflation variability affects returns on assets. However, it is possible that the volatility of asset returns affects the volatility of inflation. One way to test this would be to use a multivariate ARCH model.

The main conclusion from the tables is that few assets provide consistently good protection from inflation shocks and that higher inflation variability reduces the average real returns on most assets. Even when higher inflation has been sufficiently persistent to have become anticipated, it still appears to erode the real returns on the majority of assets. (The only exceptions to this are houses, land, equities and dollar and DM euro deposits.) These results are all based upon pre-tax real returns; given the non-indexation of the tax system the conclusion that higher inflation and higher inflation variability is bad for real returns on nearly all assets could only be strengthened by adjusting for tax.

6. Conclusions

This paper has shown that there is considerable variability in the conditional variance of inflation and that inflation shocks are negatively correlated with average real consumption. These results suggest that assets whose real returns are sensitive to inflation - in particular those whose real yields fall when prices of consumer goods rise faster than anticipated - should have inflation risk premia. Our results show that most assets are sensitive to inflation shocks, but that inflation risk premia are not very well defined. Indeed, most assets appear to generate lower average returns when inflation variability is high, a result which is hard to interpret in terms of inflation risk premia. Finally, the paper shows that there is significant variability across assets in the degree to which inflation shocks, and changes in anticipated inflation, affect real returns in both the short and long run.

Overall, the results suggest that in the United Kingdom inflation and inflation variability even when it is anticipated is bad for those who hold net assets.

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Data Annex

The returns on assets were calculated as follows:

(1) 5, 10 and 20 year bonds:

nominal holding period returns are based on the following approximation first developed by Campbell and Schiller:

$$y_{jt} = r_{jt+1} + \frac{\left[1 - \left[\frac{1}{(1+r_{jt})}\right]^{j}\right]\left(r_{jt} - r_{jt+1}\right)}{\left[1 - \left(\frac{1}{1+r_{jt}}\right)\right]}$$

where y_{jt} is the gross redemption yield at time t of a bond with j periods to maturity. r_{jt} are the average (par) yields on United Kingdom government bonds with j = 5, 10 or 20 years to maturity. (Source: Bank of England, reported in Financial Statistics, Table 7.1E.) Campbell (1986), Shiller, Campbell and Schoenholtz (1983) and Hall and Miles (1992) show that the approximation to holding period returns is very accurate.

y_{it} is then used to define the log real holding return (h_{jt}) using:

$$h_{jt} = (\log((1+y_{jt})/((RPI_t/RPI_{t-1})^{12}))) \times 100$$

(2) Building society deposit rates: the nominal holding period return in period t is the log of the current average building society share rate. (Source: Financial Statistics, Table 7.1K.)

(3) Base Rate: the nominal holding period return is the log of the base rate of large UK banks. (Source: Financial Statistics, Table 7.1O.)

(4) Gold: the nominal holding period return on gold is calculated as the change through the month in the log of the dollar gold price, adjusted for

the percentage change in the dollar sterling rate. (Source: Financial Statistics, Table 7.1C.)

(5) Equities: the nominal holding period return is the change in the log of the FT all share index plus the current dividend yield on the index. (Source: post-1963 Financial Statistics, Table 7.1G; pre-1963, Actuaries Investment Index, Institute of Actuaries.)

(6) Euro \$: the nominal holding period return is the log of the (last working day of month) Euro \$ deposit rate adjusted for £/\$ exchange rate changes. (Source: Financial Statistics, Table 7.1C and Table 7.1B.)

(7) Euro DM: the nominal holding period return is the log of the (last working day of month) Euro DM deposit rate adjusted for £/DM exchange rate changes. (Source: Bank of England (BIS), and Financial Statistics, Table 7.1B.)

(8) Oil: the nominal holding period return is the change in the log (dollar denominated) oil price index adjusted for the change in the £/\$ exchange rate. (Source: Financial Times; London spot markets - Dubai and Brent Blend.)

(9) Commodity prices: the nominal holding period return is the change in the log of the commodity prices index (metals and agricultural non-foods) adjusted for the change in the £/\$ exchange rate. (Source: UN Monthly Bulletin on Statistics.)

(10) Houses: the nominal holding period return is the change in the log of the Department of the Environment's UK mix-adjusted house price index.

(11) Land: nominal returns are the change in the log of the Department of Environment quarterly index of residential land prices with planning permission.

(12) Commercial property: the nominal return is the change in the log of the Jones, Lang and Wooton overall performance property index of commercial property values.

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