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ABSTRACT

UK Inflation Persistence: Policy or Nature?*

A large econometric literature has found that post-war US inflation exhibits very high persistence, approaching that of a random walk process. Given similar evidence for other OECD countries, many macroeconomists have concluded that high inflation persistence is a 'stylized fact'. The objective of this paper is to show that degree of inflation persistence is not an inherent structural characteristic of an economy, but in fact a function of the stability and transparency of monetary policy regime in place. We begin by estimating univariate processes for inflation across different periods, allowing for structural breaks based on a priori knowledge of the UK economy. Then we examine whether, a rather straightforward model, easily micro-founded in a standard classical set-up can generate the facts such as we find them. We calibrate our structural model for each of the regimes and solve it analytically for the implied persistence in the inflation process. We compare this theoretical prediction with the estimated persistence for each regime. Finally we bootstrap our model to generate pseudo inflation series and check whether the actual persistence coefficients lie within the 95 percent confidence limits implied by the bootstraps. As a robustness exercise we do the same for the Liverpool model.

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1 Introduction

Inflation persistence has been widely noted in the post-war period. Many have concluded that it was a 'stylised fact' and drawn the further conclusion that the key inflation-generating equation, the Phillips Curve, must be the source of this persistence, through inflation stickiness: this has in turn been used to rationalise a backward-looking ('persistent') element in the Calvo contract Phillips Curve. This paper questions all these points in the argument, using UK experience as our empirical focus. First we do not find that inflation persistence is a stylised fact; it appears to disappear at various points in the post-war UK, notably most recently; we suggest that this is connected to changes in monetary regime at frequent intervals. Second, we find that there is no need for the persistence, when it occurred, to originate in the Phillips Curve. Finally, by direct implication there is no necessary case here for a backward-looking element in the Phillips Curve.

We begin by looking at the empirical evidence on UK inflation, carefully separating the data into periods of different regimes. Then we examine whether a rather straightforward model, easily micro-founded in a standard classical set-up, can generate the facts such as we find them; we are not particularly committed to this model in detail, but rather use it as a benchmark in which a minimal number of special assumptions are made- such as particular forms of 'nominal rigidity' and 'adjustment'. We note that in any such model omitted variables will create error processes, and it is perfectly reasonable to find that these are themselves autocorrelated. These processes will propagate themselves through all the endogenous variables and be a natural source of persistence. However, if the monetary authorities are so determined, they may partly suppress this persistence through their monetary reactions; arguably just such a determination was observed when inflation targeting was instituted by the Treasury in 1992 after the UK's forced exit from the ERM.

Such was our sceptical starting point in this paper. However, nothing necessarily works out as expected. In what follows we report the results of applying this null hypothesis in an extremely 'stripped-down' form to our UK data- viz that in a basically bare-bones-classical model persistence is the product of exogenous processes interacting with the monetary regime.

We begin by noting that 'persistence' is not entirely a clear concept. A (stationary) time-series will typically consist of AR and MA (we confine ourselves to linear processes since the role of non-linearity seems to be basically secondary in this context). Persistence could naturally refer to the AR roots, ignoring the MA, which by construction must end sharply. however, the MA component can be inverted and turned into an infinite-order AR; this property is of course exploited in forming the widely-used VAR representation. For a single time-series we then have a pure AR of infinite order which can be truncated at some point empirically; this AR process can be used to measure persistence- in effect of all elements driving the variable. (Alternatively, one could invert the AR part and turn the process into the pure MA form of the Wold decomposition; this is the natural form for the impulse reaction function, which contains the same information in principle as the AR; but it is not so widely used and is non-parsimonious in estimation ,especially here with few degrees of freedom in several regimes; here therefore we use the AR in preference as a summary measure of 'net persistence'.). Call the latter (AR form) 'net persistence' and the former (the AR roots of the $ARMA$ form) 'gross persistence' for convenience. It is plain that the same variable can be grossly persistent (have high AR roots) and yet the MA part can somehow eliminate the shock after a period or two thus giving the roots nothing to 'work on', so resulting in little or no 'net persistence'. Such appears to be the case with inflation in at least some of the periods we deal with.

Furthermore according to our null-hypothesis model within which we organise our thinking, the inflation process invariably has at least one very high AR root (contributed by the exogenous error processes), as well as a voluminous MA remainder, which is in general too complex to analyse easily. The latter seems to be critical in determining the extent of net persistence; the monetary regime effectively operates in this MA part, dampening or not the direct effect of shocks on inflation. Thus basically the AR roots in our model reflect the more-or-less constant persistence of exogenous error processes, while the MA part reflects the activity of monetary reactions in 'closing down' such persistence in inflation, or not, as the regime dictates.

Ultimately we can only settle whether our model could be consistent with the facts by asking whether it could have generated the patterns of gross and net persistence we find in the actual data. To do this we generate the sampling variability within the model under each regime by the method of bootstrapping the model's estimated residuals; this permits us to find the 95% confidence limits around the inflation regression parameters, both gross $ARMA$ and net AR. This tells us what the standard errors of these regressions are *under the null hypothesis of our model*- the relevant standard errors. for us, rather than the usual ones which tell us whether the regression, viewed atheoretically, can reject a zero null hypothesis, a fairly uninteresting one for an economist. In what follows, to anticipate, we find that our very basic model 'tells quite a good story' but cannot strictly generate the facts of inflation persistence; this is in a way rather reassuring because it is merely a classroom model with calibrated parameters; the rejection does not seem so bad that some dynamic enrichment could not fix it.

1.1 Inflation persistence- some recent work

A large econometric literature has found that post-war US inflation exhibits very high persistence, approaching that of a random walk process [1] Given similar evidence for other OECD countries, many macroeconomists have concluded that high inflation persistence is a 'stylized fact' and have proposed varied microeconomic interpretations . Roberts (1998), Ball (2000), Ireland (2000), Mankiw and Reis (2001), Sims (2000), Woodford (2001) assume that private agents face information-processing constraints. Buiter and Jewitt (1989), Fuhrer and Moore (1995), Fuhrer (2000), Calvo et al. (2001), Christiano et al. (2001) assume that high inflation persistence results from the structure of nominal contracts. Others like Rotemberg and Woodford (1997), Dittmar, Gavin and Kydland (2001), Ireland (2003) generate the persistence through data generating process for the structural shocks hitting the economy. However, an alternative view is that the degree of inflation persistence is not an inherent structural characteristic of industrial economies, but in fact a function of the stability and transparency of monetary policy regime .[2]

Over the past decade we have observed substantial shifts in the monetary policy of a number of countries, particularly the widespread adoption of explicit inflation targets.[3] There is a growing body of research supporting the view that the monetary regime in place has an impact on the persistence properties of inflation or in other words inflation persistence is not an inherent characteristic of industrial economies.[4]. Brainard and Perry (2000), Taylor (2000) and Kim et al. (2001) find evidence that US. inflation persistence during the Volcker-Greenspan era has been substantially lower than during the previous two decades; Ravenna (2000) documents a large post-1990 drop in Canadian inflation persistence; Batini (2002) finds that U.K. and US. inflation had no persistence during the metallic-standard era (prior to 1914), highest persistence during the 1970s and markedly lower persistence during the last decade.

As Nelson (2001) points out monetary policy in the U.K. has undergone several regime changes over the last 50 years: from a fixed exchange rate with foreign exchange controls until 1972; to free-floating incomes policy with no domestic nominal anchor until 1978, followed by a system of monetary targeting until the mid-1980s; then back to exchange rate management, the period of 'shadowing' the Deutsche Mark, which finally culminated in the membership of the Exchange Rate Mechanism (ERM) from 1990-1992[5]. Since, 1992 inflation targeting has been the official regime governing U.K. monetary policy, with interest rate decisions made by the Treasury up to May 1997, after which the Bank of England received its independence. Monetary

[1] See Nelson and Plosser (1982), Fuhrer and Moore (1995), Pivetta and Reis (2001), Stock (2001)

[2] See Bordo and Schwartz (1999), Sargent (1999), Erceg and Levin (2002), Goodfriend and King (2001).

[3] See Bernanke et al. (1999), Johnson (2002), Mishkin and Schmidt-Hebbel (2002).

[4] See Levin and Piger (2002) and others as well...

[5] For the first seven years of floating exchange rates foreign exchange controls continued, but were finally abolished in 1979. Thus, the absence of controls in the ERM period gave little room for monetary policy to differ, even in the short run, from that consistent with the exchange rate target.

Policy and interest rate decisions ever since have been made by the Monetary Policy Committee (MPC) of the Bank.

For the period as a whole, there have been large swings both in inflation and economic growth. Inflation was continuously in double digits during most of the 1970s, and returned there in the early 1980s and 1990s. Nelson (2001) documents that economic growth, which was already lower in the U.K. in comparison to its major trading partners in the 1960s, underwent a further slowdown after 1973, with partial recovery beginning only in the 1980s. There were recessions in 1972, 1974-75, 1979-81 and 1990-92. However, the disinflation of the early 1990s has been followed by a period of low and stable inflation and reasonably stable real GDP growth.

In the current paper we investigate the impact of monetary regimes on inflation persistence using a structural micro-founded model, without nominal rigidities; thus there is no source of inflation persistence built into the model's structure, though persistence in the model generally comes from exogenous variables and errors which follow estimated univariate processes.

We begin in section I by establishing the facts of inflation persistence in the UK, allowing for breaks in monetary regimes. We estimate univariate processes for inflation across different time periods where these periods are carefully defined according to *a priori* knowledge of the U.K. economy; it is well-known that a failure to account for such breaks could yield spuriously high estimates of the degree of persistence.[6] Our initial results clearly indicate that inflation persistence is different in different regimes, with persistence being lowest in the inflation targeting regime as one would expect *a priori*. Bretton Woods era comes in second; *a priori* one would expect monetary targeting to come in second; however during the money targeting regime in the UK the policy makers were constantly changing what they were targeting and the targets themselves, leading to higher persistence. Persistence tends to be higher during the DM shadowing period as the government's primary aim then was to defend the peg. During the 1970s when the government introduced incomes policy as a means of controlling the inflation, there was no nominal anchor other than the price/wage control laws hence we get the highest persistence parameters.

In section II we use our structural model suitably calibrated for each of the regimes incorporating all available information about monetary policy behaviour during those periods; we solve it analytically for the implied persistence in the inflation final form equation, in order to compare this theoretical prediction with the estimated persistence for each regime. The aim in this section is essentially qualitative: to see whether a basic classical model, calibrated in a standard way, can generate predictions that persistence will depend on the monetary regime in the direction of the stylised facts. On the whole we find that this is so. In truth this is probably all one could expect from such a basic model.

In section III we make this comparison more formally and test statistically whether our calibrated model is seriously consistent with the inflation data, using a bootstrapping procedure: we generate bootstrap data for inflation under each regime and compute the implied sampling distribution of its AR and $ARMA$ coefficients. We then check for each regime whether the coefficients of the actual inflation series lies within 95% confidence interval of the AR coefficient distribution generated by our model. This is an ambitious test for such a basic model; and perhaps unsurprisingly the data pretty systematically reject the model. (In an epilogue we hope to provide, we carry out the same exercise on the Liverpool Model, which is an elaborated version of the same classical structure, with results to be reported.)

In section IV we conclude that the facts of inflation persistence are inconsistent with the common practice of building persistence into the Phillips Curve; this is because persistence clearly varies with the monetary regime..On the other hand a simple classical model with a non-persistent Phillips Curve is capable of replicating this regime-dependence qualitatively, generating substantially higher persistence in fixed-exchange-rate and monetary-targeting regimes than in inflation-targeting regimes. Persistence comes 'naturally' into a macro model and into the AR roots of the inflation $ARMA$ process through the persistence of exogenous error processes; monetary regimes can however 'close this down' for inflation if they choose, this closing-down

[6] Perron (1990)

showing in the MA part of the process. Our basic model is strictly rejected at the 95% confidence level by the inflation facts but one would hope that a more elaborate model along the same lines would do better.

2 Initial ARMA and AR

We begin by estimating univariate processes for inflation across different time periods. A key aspect of our approach is to allow for structural breaks based on *a priori* knowledge of the UK economy, since a failure to account for such breaks could yield spuriously to high estimates of the degree of persistence.[7] Our initial results clearly indicate that inflation persistence is different in different regimes, with persistence being lowest in the inflation targeting regime as one would expect *a priori*. The fixed exchange rate regime during the Bretton Woods era comes in second, providing some respite to the believers of fixed exchange rate regimes. *A priori* one would expect monetary targeting to come in second; however during the money targeting regime in the UK the policy makers were constantly changing what they were targeting and the targets themselves, leading to higher persistence. Persistence tends to be higher during the DM shadowing period as the government's primary aim then was to defend the peg. During the 1970s when the government introduced incomes policy as a means of controlling inflation, there was no nominal anchor hence we get the highest persistence parameters.

As is customary in this strand of literature we shall assume that inflation follows a stationary autoregressive process of order p $AR(p)$), which we write as:

$$\pi_t = \mu + \sum_{j=1}^{p} \alpha_j \pi_{t-j} + \varepsilon_t$$

where ε_t is a serially uncorrelated but possibly heteroscedastic random error term. In order to facilitate the discussion that follows we first note that the above model may be reparameterised as:

$$\Delta\pi_t = \mu + \sum_{j=1}^{p-1} \delta_j \Delta\pi_{t-j} + (\rho - 1)\pi_{t-1} + \varepsilon_t$$

where

$$\rho = \sum_{j=1}^{p} \alpha_j$$

and

$$\delta_j = -\sum_{i=1+j}^{p} \alpha_i$$

In the context of the above model persistence can be defined as the speed with which inflation converges to equilibrium after a shock in the disturbance term: given a shock that raises inflation today by 1% how long does it take for the effect of the shock to die off?

As Marques (2004) states "the concept of persistence is intimately linked to the impulse response function (IRF) of the $AR(p)$ process." However, being an infinite-length vector the IRF is not a useful measure

[7] See Perron (1990) for discussion.

of persistence. In the literature several scalar statistics have been proposed to measure inflation persistence. These include the "sum of autoregressive coefficients", the "spectrum at zero frequency", the "largest autoregressive root" and the "half life".

Andrews and Chen (1994) argue that the cumulative impulse response function (CIRF) is a good way of summarising the information contained in the impulse response function (IRF)[8], and hence a good scalar measure of persistence. In a simple $AR(p)$ process, the CIRF is given by

$$CIRF = \frac{1}{1-\rho}$$

where ρ is the "sum of autoregressive coefficients". As there exists a monotonic relationship between CIRF and ρ it follows that one can simply rely on the sum of AR coefficients, $\rho = \sum \alpha_j$, as the best scalar measure of persistence.[9] We must point out that all scalar measures of persistence should be seen as giving an estimate of the 'average speed' with which inflation converges to equilibrium after a shock to the system. The reliability of the measure would receive a boost if the speed of convergence is more uniform throughout the convergence period.

An alternative measure of persistence widely used in the literature is given by the largest AR root γ, that is, the largest root of the characteristic equation[10]

$$\lambda^K - \sum \alpha_j \lambda^{K-j} = 0$$

It is easy to show that in the distant future, the impulse response of inflation to a shock becomes increasingly dominated by the largest root, so the size of γ is a key determinant of how long the effects of the shock will persist. When $\gamma = 1$, the process is infinitely persistent since, given a shock, we expect inflation never to revert to its initial value. When $\gamma = 0$, inflation is white noise and there is no persistence. In between, $0 < \gamma < 1$, the higher is γ, then the longer (to first approximation) it will take for inflation to come back to the original level, after a shock.

However, Phillips (1991), Andrews (1993a) and Andrews and Chen (1994), criticise this measure of persistence. The main point of criticism is that the shape of the IRF depends on all the roots of the equation, not just the largest one. Hence, this statistic is a very poor summary of the impulse response function. According to Andrews and Chen (1994) and Marques (2004) ρ is more informative than the largest AR root as a measure of overall persistence. Despite this drawback, the largest AR root is still widely used as a measure of persistence. According to Levin, Natalucci and Piger (2004) the largest AR root has intuitive appeal as a measure of inflation persistence, as it determines the size of the impulse response, $\frac{\delta \pi_{t+j}}{\delta \varepsilon_t}$, as j grows large. The other reason being that an asymptotic theory has been developed and appropriate software is available so that it is quite easy to compute asymptotically valid confidence intervals for the corresponding estimates. [11]

Levin, Natalucci and Piger (2004) show how the volatility of inflation can be decomposed into two sources: one due to the variance of the shocks to the autoregression and the other due to the propagation of shocks through autoregressive dynamics. The measure they use is the ratio of the total variance of inflation series to the variance of shocks to the autoregression:

[8] Impulse Response Functions are an intuitive way to interpret measures of inflation persistence. IRF gives the response of inflation at various future dates to a shock that occurs today.

[9] The authors note that that CIRF and thus ρ may not be sufficient to fully capture all the shapes in the impulse response functions. For e.g.CIRF and ρ will not be able to distinguish between two series in which one exhibits a large initial increase and then a subsequent quick decrease in the IRF while the other exhibits a relatively small initial increase followed by a subsequent slow decrease in the IRF.

[10] See, for instance Stock (2001).

[11] See Stock (1991 and 2001).

$$\frac{Var(\pi_t)}{Var(\varepsilon_t)}$$

When the ratio is only slightly above unity, then that is consistent with a white noise process for the inflation series. If the ratio is nearer or above 2.0 then it means that the volatility of inflation contains a substantial propagation component. We have not used this measure however as we have felt able to interpret the time-series equation coefficients themselves adequately.

In the analysis below we measure the degree of persistence of the inflation process in terms of the sum of the AR coefficients, ρ (henceforth referred to as the 'persistence parameter'). We also calculate the largest AR root so that our results are comparable with others in the literature.

To obtain an estimate of ρ , an AR lag order K must be chosen for each inflation series. For this purpose, we utilize AIC, the information criterion proposed by Akaike (1973), with a maximum lag order of K = 4 considered. The lag order chosen for each series is reported in Table 1. While not reported here, we have found that using SIC (the criterion proposed by Schwarz 1978) does not alter any of the conclusions reached in this paper.

Table 1. Lag Order

Monetary Regime	Lag Order
Fixed Exchange Rate: US (1956:1 to 1970:4)	1
Incomes Policy (1971:1 to 1978:4)	1
Money Targeting (1979:1 to 1985:4)	1
Fixed Exchange Rate: Germany (1986:1 to 1992:3)	1
Flexible/Strict Inflation Targeting (RPI) (1992:4 to 2003:3)	1
Flexible/Strict Inflation Targeting (RPIX) (1992:4 to 2003:3)	1

Initially we ran ARs on annual inflation (year-on-year) for different regimes. However, that gave us high autoregression due to the presence of a moving average component. In the current paper inflation is calculated as quarter-on-quarter inflation annualised. See below Fig.1, the plot of inflation series. Further, as inflation is quarter-on-quarter one has to take into account seasonality, which we have done by using seasonal dummies.

We have estimated both 'gross' as well as 'net' persistence as explained in the introduction. To capture the 'gross persistence' we estimated $ARMA$s for the different regimes.[12] They are reported in Table 2 below.[13] If one were to look at the AR coefficient in these results, one can be mislead about the degree of persistence. It is important to evaluate the persistence taking into account both the autoregressive as well as moving average effects that are working on inflation. In many of the regimes the MA process works against the AR process thus leading to low 'net' persistence. Compare for example the $ARMA$ and AR results for Inflation targeting. Using RPI the best fitting $ARMA$ is of order $(3,3)$, with the AR coefficient with quite high values, a surprising result for this regime. However, this regime also has a strong MA process working on it. The 'net' persistence that we get is 0.20 and that too not significant at conventional levels of significance. The bottom line is that persistence should be inferred from the ARs, however to 'understand' what is going on in the inflation time series it is imperative to analyse the $ARMA$s.

Table 2. Best Fitting ARMAs

[12] Seasonal dummies have been taken into account.
[13] Details can be found in the Appendix Figure 1-6.

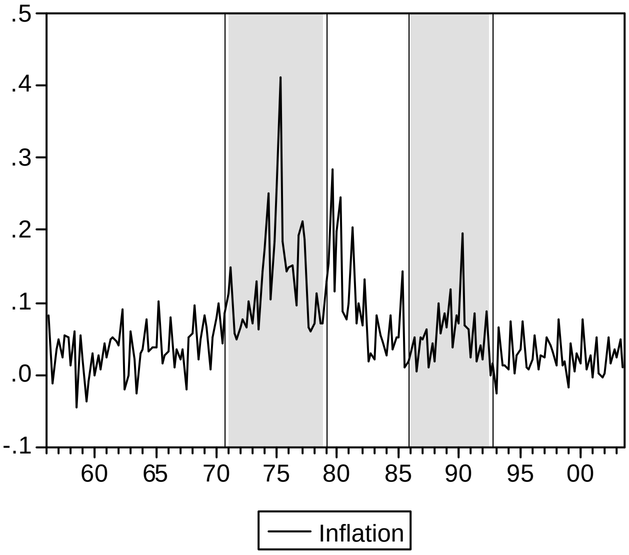

Figure 1:

	Different Monetary Regimes					
	FUS/Bretton Woods	IP	MT	FGR/ERM	FIT/SIT (RPI)	FIT/SIT (RPIX
AR(1)	0.414439 (0.0093)	1.720229 (0.0000)	0.925756 (0.0000)	0.629426 (0.0009)	0.720498 (0.0000)	−0.743549 (0.0000)
AR(2)	−0.353781 (0.0221)	−1.707837 (0.0000)			0.514976 (0.0021)	
AR(3)		0.722245 (0.0001)			−0.835545 (0.0000)	
MA(1)	−0.137642 (0.1966)	−0.968766 (0.0000)	−0.997379 (0.0000)		−0.761763 (0.0000)	0.683187 (0.0001)
MA(2)	0.227487 (0.0269)	0.984350 (0.0000)			−0.701631 (0.0000)	−0.359680 (0.0561)
MA(3)	0.759041 (0.0000)				0.971221 (0.0000)	0.000744 (0.9971)
MA(4)						0.594662 (0.0010)

N.B. Figures in brackets are the *p values*.

To evaluate the 'net' persistence we have estimated pure ARs with seasonal dummies. The ARs are reported in the Table 3 below. [14]As the lag order chosen for all the regimes is 1, both the measures of inflation persistence, ρ the sum of AR coefficients and γ the largest AR root will give us the same persistence. As noted in the opening paragraph of this section inflation targeting is the least persistent regime, in fact the lag is insignificant using both the RPI and RPIX. The period of the Bretton Woods era comes in second,

[14]Detailed results can be found in the Appendix Figure 7-13.

the lag being significant only at 10 percent. Money targeting comes in third with an AR coefficient of 0.52. The period of DM shadowing culminating in U.K. joining the ERM comes in fourth with an AR coefficient of 0.63. The period with highest persistence is of course the incomes policy regime.

Table 3. Best Fitting AR and Regression on a Constant

Regime	Best Fitting Autoregression		Regression on a Constant	
	Estimated Coefficient for $AR(1)$	*p value*	Estimated Constant	S.E. of Regression
FUS/Bretton Woods	0.252211	0.0676	0.036213	0.033687
IP	0.735547	0.0000	0.131845	0.077915
MT	0.516666	0.0090	0.093772	0.071213
FGR/ERM	0.629426	0.0009	0.056810	0.041171
FIT/SIT (RPI)	0.202199	0.1999	0.024828	0.024938
FIT/SIT (RPIX)	-0.152273	0.3380	0.025481	0.022338
Full Sample	0.743048	0.0000	0.061092	0.062856

N.B. The best fitting AR has been run taking into account seasonal dummies.

As demonstrated by Perron (1990), the degree of persistence of a given time series will be exaggerated if one fails to recognise the presence of a break in the mean of the process. It is therefore important to obtain formal econometric evidence about the presence or absence of structural breaks in the inflation series. This can be done using classical and Bayesian methods used to evaluate the evidence for structural breaks.[15] However, if one possesses *a priori* knowledge of the break date, then one can simply estimate the univariate AR process for the inflation series over the sub-samples and then apply the breakpoint test of Chow (1960). The Chow breakpoint test partitions data in two or more sub-samples. The test compares the sum of squared residuals obtained by fitting a single equation to the entire sample with the sum of squared residuals obtained when separate equations are fit to each sub-sample of data. Significant differences in the estimated equations indicate a structural change in the relationship. We conducted a Chow breakpoint test to check if there were in fact structural changes in the economy. The results are reported in the Table 4 below. We do not accept the null of no structural change.

Table 4. Chow Stability Test

Chow Breakpoint Test: 1971:1 1979:1 1986:1 1992:4			
F-statistic	2.983189	Probability	0.000067
Log likelihood ratio	58.64247	Probability	0.000012

Following Batini (2002), we have also estimated a regression of inflation on a constant for each of the sub-samples[16]. The regression on a constant provides very useful summary statistics: its estimated parameter corresponds to the sample mean of inflation, while the residual standard error corresponds to inflation's standard deviation. If the mean of inflation has gone down, this may explain also why the variance of inflation has dropped over time. There is considerable evidence that inflation variability and the level of inflation are positively related across countries. David and Kanago (2000) review this evidence for OECD countries.

In case of the U.K. we observe a clear drop in mean inflation from the high value of 13.18 during the 1970s to the low and stable value of 2.5 during the last decade. The variance of inflation has also fallen during this period. The mean inflation during the Bretton Woods era was 3.62 and DM shadowing was 5.68. During the early 80s it was 9.4 along with a standard error of 0.0134.

[15] See Levin and Piger (2002).
[16] See Table 3 above.

3 A Basic Structural Model

In this section we use our basic benchmark model to characterise each UK monetary regime of the post-war period. Nelson (2000) provides estimates for the U.K. of the Taylor rule for several different monetary regimes in the period 1972-97; prior to the Bank of England receiving operational independence.[17] His results suggest that prior to 1992, it is difficult to characterise U.K. monetary policy using a standard Taylor rule. During these regimes policy makers were constantly changing the rules, what they were targeting and the targets themselves.

In this paper in contrast we impose the restrictions that we think existed in those periods.[18] Thus our models can be thought of as simple approximations of actual policy behaviour during each regime.

To ensure stationarity of output we detrend it (by a Hodrick-Prescott filter). See Fig 2 and 3 below. We assume the other variables to be stationary within each regime period: thus either they are assumed in the case of real variables to have constant equilibria (e.g. the real exchange rate) or the monetary policy regime is assumed to be aiming for some constant nominal equilibria on inflation, hence on interest rates.

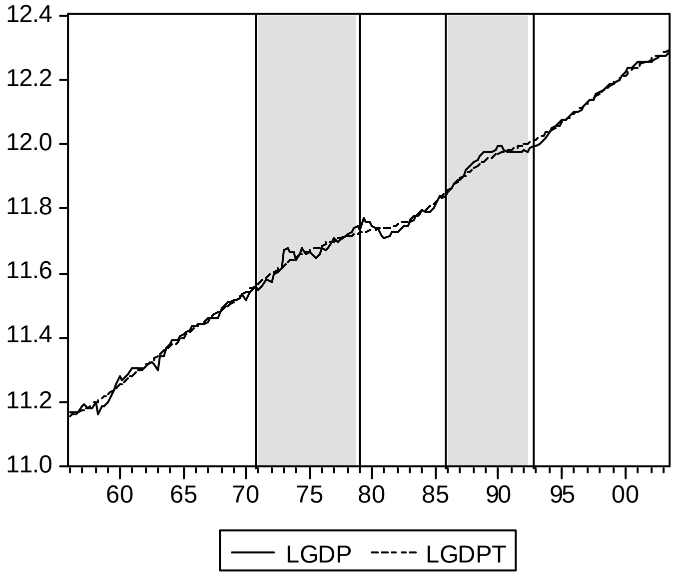

Figure 2:

In all the models the first equation is the optimising IS function as in McCallum and Nelson (1998)- as they note this can be regarded as a transformation of the structural consumption Euler equation, with the market-clearing condition for output substituted into it; the error term captures stochastic movements in government spending, exports etc. In the case of fixed exchange rate regimes we have an additional expenditure switching effect in the IS curve- which routinely emerges from both Old and New Open Economy Models.. The second equation in the models is the New Classical Phillips curve- this can be regarded as

[17] In a famous paper, Taylor (1993) showed that US monetary policy after 1986 is well characterised by a rule for the Federal Funds rate whereby the interest rate responds to output gap and inflation deviation from target. There has subsequently been an explosion of theoretical and empirical work in this area. See for example Clarida et al. (2000)

[18] For our choice of regime dates see Minford (1998), Nelson (2000) and Budd (2002).

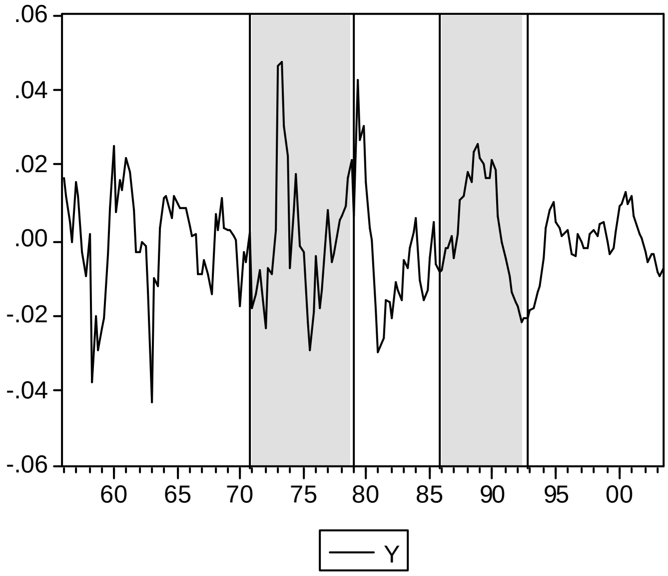

Figure 3:

the reduced form of the flex-price supply equations, assuming a one-period information lag. Finally under inflation targeting regimes where policy makers respond to the output gap: we take account of Orphanides (1998)-style output gap forecast errors as well.

3.1 Fixed Exchange Rate Regime (US) or Bretton Woods (1956:1 TO 1970:4)

Our first regime is the Bretton Woods fixed exchange rate system. This is not easy to model because of its progressive deterioration in the 1960s when 'one-off' exchange rate changes became commonplace means of adjustment. Another important factor causing change was the progressive dismantling of direct controls - including a relaxation of controls on international capital flows - which, while certainly adding to the potential macro-economic benefits from international economic activity, undoubtedly made fixed exchange rates inherently more difficult to sustain. Furthermore, countries within the system came to attach different priorities to inflation and unemployment as the immediate objective of policy. There was also disagreement about how the burden of domestic policy adjustment should be shared between surplus and deficit countries, including the US, the country of the anchor currency. The system eventually collapsed under the weight of the outflows from the US dollar, which, under the parity system, had to be taken into other countries' official reserves, on such a scale that the dollar's official convertibility into gold had eventually to be formally suspended in 1971.

Here we have made drastic simplifications, ignoring parity changes and assuming a high degree of capital mobility throughout. Equations 1 and 3-7 are when put together the IS or demand side of the model; the errors entering here from a variety of exogenous shocks, apart from R_{FUSt}, are aggregated into u_{FUSt}.

$$\widetilde{y}_t = \gamma(E_t \widetilde{y}_{t+1}) - \alpha(R_t - E_t P_{t+1} + P_t) + \lambda(E_t NX_{t+1}) + u_{FUS_t} \quad (1)$$

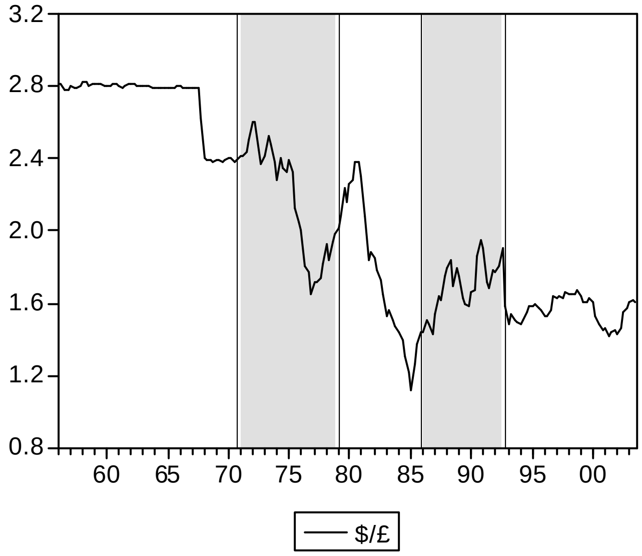

Figure 4:

$$\widetilde{y}_t = \delta(P_t - E_{t-1}P_t) + v_{FUS_t} \tag{2}$$

$$NX_t = a_{FUS_0}Q_{FUS_t} + a_{FUS_1}y^F_{FUS_t} \tag{3}$$

$$Q_{FUS_t} = P_t - (S_{FUS_t} + P^f_{FUS_t}) \tag{4}$$

$$R_t = R^F_{FUS_t} + (E_tS_{FUS_{t+1}} - S_{FUS_t}) \tag{5}$$

$$S_{FUS_t} = \overline{S}_{FUS} \tag{6}$$

$$R^F_{FUS_t} = \rho_{FUS}R^F_{FUS_{t-1}} + \eta_{FUS_t} \tag{7}$$

$$u_{FUS_t} = \rho_{FUS_0}u_{FUS_{t-1}} + \varepsilon_{FUS_t} \tag{8}$$

$$v_{FUS_t} = \rho_{FUS_1} v_{FUS_{t-1}} + x_{FUS_t} \tag{9}$$

In the equations above, $\widetilde{y}_t$is the output gap defined as log GDP - log GDP trend, R_t the nominal interest rate is the Bank of England base rate, P_t is the price level, NX_t is net exports, Q_{FUS_t} is the real exchange rate, S_{FUS_t} is the nominal exchange rate defined as \$/£, $P^f_{FUS_t}$ is the US price level (CPI) and $R^F_{FUS_t}$ is the US. federal funds rate (nominal). Equations (1) and (2) are based on aggregate demand and supply specifications that are designed to reflect rational optimising behaviour on the part of the economy's private actors. Equation (1) is a forward looking open economy IS curve. The error term u_{FUS_t}can be interpreted as the demand shock to the economy which we have modeled as an $AR(1)$ process. Equation (2) is a standard Phillips Curve where v_t is the productivity shock modeled as an $AR(1)$. Equation (3) simply puts forth the idea that the net exports of a country is a function of the real exchange rate and the world income. If the real exchange rate appreciates or the world income is higher, then there would be a greater demand for the domestic exports. Equation (4) is the definition of real exchange rate and equation (5) is the Uncovered Interest Rate Parity (UIP) condition. Equation (6) simply states that the nominal exchange rate is fixed, as we are in a fixed exchange rate regime. We have modeled the world interest rate as an $AR(1)$ process. The error terms in equation (7), (8) and (9), are all $i.i.d.$

Now substituting equation (6) in (5) yields:

$$R_t = R^F_{FUS_t} \tag{10}$$

Leading equation (3) and (4) forward one-period and taking expectations yields:

$$E_t NX_{t+1} = a_{FUS_0}(E_t Q_{FUS_{t+1}}) + a_{FUS_1}(E_t y^F_{FUS_{t+1}}) \tag{11}$$

$$E_t Q_{FUS_{t+1}} = E_t P_{t+1} - (\overline{S}_{FUS} + E_t P^f_{FUS_t}) \tag{12}$$

Substituting equation (12) in (11) for $E_t Q_{FUS_{t+1}}$yields:

$$E_t NX_{t+1} = a_{FUS_0} E_t P_{t+1} - a_{FUS_0}\overline{S}_{FUS} - a_{FUS_0} E_t P^f_{FUS_t} + a_{FUS_1}(E_t y^F_{FUS_{t+1}}) \tag{13}$$

Substituting equation (13) for $E_t NX_{t+1}$, and equation (2) for $\widetilde{y}_t$in equation (1) yields:

$$\begin{aligned}\delta(P_t - E_{t-1}P_t) + v_{FUS_t} = {} & \gamma(E_t \widetilde{y}_{t+1}) - \alpha(R_t - E_t \pi_{t+1}) + \lambda a_{FUS_0} E_t P_{t+1} \\ & - \lambda a_{FUS_0}\overline{S}_{FUS} - \lambda a_{FUS_0} E_t P^f_{FUS_t} + \lambda a_{FUS_1}(E_t y^F_{FUS_{t+1}}) + u_{FUS_t}\end{aligned} \tag{14}$$

Furthermore for simplicity we assume that $y^F_{FUS_t}$ and $P^f_{FUS_t}$ do not explicitly affect $\widetilde{y}_t$. Their influence shall be captured as a part of the stochastic disturbance term u_{FUS_t}.

Finally substituting $E_t \widetilde{y}_{t+1} = \rho_{FUS_1} v_{FUS_t}$, equation (10) for R_t and equation (7) for $R^F_{FUS_t}$ in equation (14) yields the semi-reduced form solution for P_t:

$$\delta(P_t - E_{t-1}P_t) + v_{FUS_t} = \gamma\rho_{FUS_1}v_{FUS_t} - \alpha(\rho_{FUS}R^F_{FUS_{t-1}} + \eta_{FUS_t}) \\ + (\alpha + \lambda a_{FUS_0})E_t P_{t+1} - \alpha P_t - \lambda a_{FUS_0}\overline{S}_{FUS} + u_{FUS_t} \quad (15)$$

Now the Minimum-State-Variable (MSV) conjectured solution for P_t in this model is:

$$P_t = \phi_{FUS_0} + \phi_{FUS_1}R^F_{FUS_{t-1}} + \phi_{FUS_2}u_{FUS_t} + \phi_{FUS_3}v_{FUS_t} + \phi_{FUS_4}\eta_{FUS_t} \quad (16)$$

Substituting the conjectured solution in equation (15) and substituting out for $R^F_{FUS_{t-1}}$ the solution for inflation under fixed exchange rate regime is:

$$\pi_t = (\rho_{FUS} + \rho_{FUS_0} + \rho_{FUS_1})\pi_{t-1} - \{\rho_{FUS}(\rho_{FUS_0} + \rho_{FUS_1}) + \rho_{FUS_0}\rho_{FUS_1}\}\pi_{t-2} + (\rho_{FUS}\rho_{FUS_0}\rho_{FUS_1})\pi_{t-3} \\ + \phi_{FUS_1}\Delta\eta_{FUS_{t-1}} - \phi_{FUS_1}(\rho_{FUS_0} + \rho_{FUS_1})\Delta\eta_{FUS_{t-2}} + (\phi_{FUS_1}\rho_{FUS_0}\rho_{FUS_1})\Delta\eta_{FUS_{t-3}} + \phi_{FUS_2}\Delta\varepsilon_{FUS_t}(1 - \rho_{FU} \\ - \phi_{FUS_2}\rho_{FUS_1}\Delta\varepsilon_{FUS_{t-1}}(1 - \rho_{FUS}L) + \phi_{FUS_3}\Delta x_{FUS_t}(1 - \rho_{FUS}L) - \phi_{FUS_3}\rho_{FUS_0}\Delta x_{FUS_{t-1}}(1 - \rho_{FUS}L) \\ + \phi_{FUS_4}\Delta\eta_{FUS_t}(1 - \rho L) - \phi_{FUS_4}(\rho_{FUS_0} + \rho_{FUS_1})\Delta\eta_{FUS_{t-1}}(1 - \rho_{FUS}L) + \phi_{FUS_4}(\rho_{FUS_0}\rho_{FUS_1})\Delta\eta_{FUS_{t-2}}(1 - \rho_{F} \quad (1)$$

Thus the inflation equation is an $ARMA(3, 4)$.

3.2 Incomes Policy Regime (1971:1 to 1978:4)

Sterling was floated in June 1972[19]. 1972 was also the year of the Heath government's 'U-turn' in macroeconomic policy. The view of the government was that it could stimulate output and employment through expansionary monetary and fiscal policies, while at the same time keeping inflation under control through statutory wage and price controls[20]. The opinion of the day was that the break-out of inflation in the 1970s largely reflected autonomous wage and price movements, and that the appropriate policy response was to take actions that exerted downward pressure on specific products, rather than to concentrate on a monetary policy response. Examples of non-monetary attempts to control inflation included statutory incomes policy announced in November 1972 and the voluntary incomes policy pursued by the Labour government from 1974; the extension of food subsidies in March 1974 budget; and the cuts in indirect taxation in the July 1974 mini-Budget (Bank of England (1974a, 1974b)).

From late 1973 policy makers did start paying heed to the growing criticism of rapid money growth that they had permitted. However, there was an unwillingness to make the politically unpopular decision of raising nominal interest rates. The Bank of England was given instructions from the Government that the growth of broad money (the Sterling M3 aggregate) was to be reduced - however, the nominal interest rates must not be increased. The result was the 'Corset', the introduction of direct quantitative control on £M3, which imposed heavy marginal reserve requirements if increases in banks' deposits exceeded a limit. While this control did result in a reduction in the observed £M3 growth, it did so largely by encouraging the growth of deposit substitutes, distorting £M3 as a monetary indicator and weakening its relationship with

[19] The float of the exchange rate was announced on the 23 June 1972 (Bank of England (1972, page 310)).

[20] From 1973 to 1980, the government periodically used the Supplementary Special Deposits Scheme, called the 'corset', as a quantitative control on the expansion of the banks' balance sheets and therefore of the £M3 monetary aggregate. As Nelson (2000) points out it is likely that this served prinicipally as a device for restricting artificially the measured growth of £M3 without changing the monetary base or interest rates, rather than as a genuinely restrictive monetary policy measure. See also Minfoed (1993, page 423).

future inflation.[21] For the rest of the 1970s monetary policy often looked restrictive as measured by £M3 growth, but loose as measured by interest rates or monetary base growth.

In July 1976 targets were announced for £M3 monetary aggregate[22]. From then on UK had a monetary policy that reacted to monetary growth and to the exchange rate[23]. Depreciation of the exchange rate in 1976 was a major factor that triggered a tighter monetary policy during 1976-1979. However, we must not over emphasise the monetary tightness as the nominal interest rate was cut aggressively (by more than 900 basis points from late 1976 to early 1978) ahead of the fall in inflation from mid-1977 to late 1978. Reflecting the easier monetary policy, money base (M0) growth, which had been reduced to single digits in the late 1977, rose sharply and peaked at more than 18% in July 1978; inflation troughed at 7.6% in October 1978 and continued to rise until May 1980, when it was 21%. Furthermore, the nominal Treasury bill rate from July 1976 to April 1979 averaged 9.32%. In real terms it was well below zero, indicating the continued tendency of the policy makers until 1978 to hold nominal interest rates well below the actual and prospective inflation rate[24].

Nelson (2000) finds that the estimated long-run response of the nominal interest rate to inflation was well below unity during the 1970s. Moreover, the real interest rate was permitted to be negative for most of the period. These results suggest that UK monetary policy failed to provide a nominal anchor in the 1970s. However, we note that there was a determinate inflation rate during this period, even though there was clearly no orthodox monetary anchor. What we have chosen to do from a modelling viewpoint is treat incomes policy as the determinant of inflation. and to assume that interest rates 'fitted in' with what the model dictated was necessary to achieve that inflation rate and the accompanying output rate. Plainly this is a drastic over-simplification since interest rates were independently set at quite inappropriate levels; however, introducing such contradictory monetary policy poses too much of a modelling challenge for this exercise- it could well be that there was such monetary indeterminacy, and incomes policy so incredible, that we were here in a 'non-Ricardian' period where fiscal policy was left to determine inflation. However exploring such possibilities lies well beyond the scope of this paper.

$$\widetilde{y}_t = \gamma(E_t\widetilde{y}_{t+1}) - \alpha(R_t - E_t\pi_{t+1}) + u_{IP_t} \tag{18}$$

$$\widetilde{y}_t = \delta(\pi_t - E_{t-1}\pi_t) + v_{IP_t} \tag{19}$$

$$\pi_t = \pi_{t-1}(1-c) + \tau_t \tag{20}$$

$$u_{IP_t} = \rho_{IP_0} u_{IP_{t-1}} + \varepsilon_{IP_t} \tag{21}$$

[21] As Nelson (2000) points out it is likely that this served prinicipally as a device for restricting artificially the measured growth of £M3 without changing the monetary base or interest rates, rather than as a genuinely restrictive monetary policy measure. See also Minford (1993, page 423).

[22] The value of this target was 11% from May 1976 to April 1978 and 10% from May 1978 to April 1970. These are the mid-points of the successive targets announced for the annual £M3 growth.

[23] For discussions of the development of UK monetary policy in the 1970s, see Goodhart (1989), Minford (1993), and Bank of England (1984).

[24] Judd and Rudebusch (1998) report average real interest rate for the US for the period 1970-78 to be 2 basis points. Hence, the phenomenon of low or negative real interest rates in the 1970s was more pronounced in the UK.

$$v_{IP_t} = \rho_{IP_1} v_{IP_{t-1}} + x_{IP_t} \quad (22)$$

$$\tau_t = \rho_3 \tau_{t-1} + \zeta_t \quad (23)$$

In the equations above, π_t is the inflation quarter-on-quarter annualised and c is the incomes policy restraint. As before equation (18) is a forward looking IS curve and equation (19) is a neoclassical Phillips curve. Equation (20) states that inflation at time t is set by incomes policy at some fraction of the actual inflation in period $t-1$ but subject to an error (the 'break-down' of policy) which we have modeled as an $AR(1)$. During this period there was a serious credibility problem. So, if the government came along and announced that it would cut inflation by 80 percent that simply would not be believable. However, if the government announced that it would cut inflation by say 20 percent then that would definitely be more credible and policy makers would be in a position to gradually get inflation expectations and hence inflation under control. Furthermore, it should be remembered that during this period there were no explicit targets. However, from policy makers' behaviour we do know that there existed implicit targets, and c helps us operationalise that. We have modeled the IS and PP forecast error as $AR(1)$ processes. ε_{IP_t}, $\zeta_t$and x_{IP_t} are all *i.i.d.*

Substituting equation (23) in (20) the solution for π_t in this regime is:

$$\pi_t = \{\rho_3 + 1 - c\}\pi_{t-1} - \rho_3(1-c)\pi_{t-2} + \zeta_t \quad (24)$$

The theoretical implied form for inflation is an $AR(2)$.

3.3 Money Targeting Regime (1979:1 to 1985:4)

In 1979 inflation was rising rapidly from an initial rate of over 10 percent. The policy of wage controls that had been used to hold down inflation in 1978 had crumbled in the 'winter of discontent' of that year when graves went undug and rubbish piled up in the streets. The budget was in crisis, the deficit already up to 5 percent of GDP and headed to get worse due to large public sector pay increases promised by the previous government. Milton Friedman (1980) advised a gradual reduction in the money supply growth rate and a cut in taxes in order to stimulate output. The first part was accepted, but the opinion was that tax rates needed to remain high to try and reduce the deficit which was important in conditioning financial confidence.

As mentioned earlier monetary aggregate targeting was introduced in the UK in 1976 in conjunction with the International Monetary Fund (IMF) support arrangement. The previous government was quite successful in shrinking the Public Sector Borrowing Requirement (PSBR) from 10 percent in 1975 to less than 4 percent in 1977. However, the policies lacked long-term durability. To achieve durability policy was cast in the form of a Medium Term Financial Strategy (MTFS), a monetary and fiscal policy programme announced by the Conservative Government in its annual budget in 1980. This strategy consisted first of a commitment to a five-year rolling target for gradually decelerating £M3. Second, controls were removed, including the 'Corset', exchange controls and incomes policy. Third, the monetary commitment was backed up by a parallel reduction in the PSBR/GDP ratio.

Large misses of the £M3 target were permitted as early as mid-1980, with the MTFS being heavily revised in 1982. In October 1985 £M3 targeting was abandoned. It was however clear prior to the abandonment that key policy makers did not regard overshoots of the £M3 target as intolerable, as long as other measures of monetary conditions, such as interest rates or monetary base growth, were not indicating that monetary

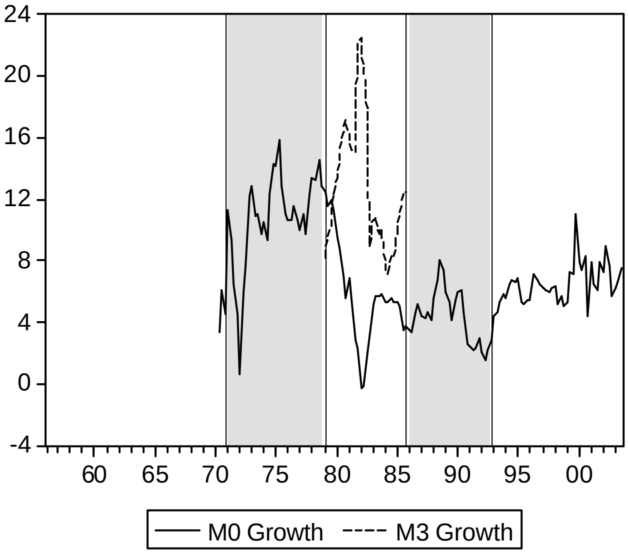

Figure 5:

policy was loose.[25] Formally, monetary targets continued to be a part of the MTFS right until 1996. However, by 1988, the targets had been so de-emphasised in monetary policy formation that Nigel Lawson, the Chancellor of the Exchequer could say "*As far as monetary policy is concerned, the two things perhaps to look at are the interest rate and the exchange rate*"[26].

Even though the logic behind the MTFS was well developed, it failed not only to command credibility, but also to be carried out in its own literal terms. Policy turned out to be more fiercely contractionary than gradualism had intended. The paradox was: tougher yet less credible policies, apparently the worst of both worlds.

$$\widetilde{y}_t = \gamma(E_t\widetilde{y}_{t+1}) - \alpha r_t + u_{MT_t} \tag{32}$$

$$\widetilde{y}_t = \delta(P_t - E_{t-1}P_t) + v_{MT_t} \tag{33}$$

$$M_t = P_t - \beta_4 R_t + \beta_5(E_t\widetilde{y}_{t+1}) + \xi_{0_t} \tag{34}$$

$$\Delta M_t = \overline{M} + \xi_{1_t} \tag{35}$$

[25] See Goodhart (1989, pg. 303) and Minford (1993, pg. 409-12)

[26] Testimony, 30 November 1988, in Treasury and Civil Service Committee, 1988, pg. 36.

$$R_t = r_t + E_t P_{t+1} - P_t \tag{36}$$

$$u_{MT_t} = \rho_{MT_0} u_{MT_{t-1}} + \varepsilon_{MT_t} \tag{37}$$

$$v_{MT_t} = \rho_{MT_1} v_{MT_{t-1}} + x_{MT_t} \tag{38}$$

$$\xi_{0_t} = \rho_4 \xi_{0_{t-1}} + \epsilon_t \tag{39}$$

In the equations above, r_t is the real interest rate and M_t is the money demand (or supply). Equation (32) and (33) are the IS and Phillips curve, respectively. Equation (34) the LM curve sets out a standard money demand schedule. Growth in money supply equals a exogenously specified target $\overline{M}$ [27] and a random shock (equation (35)). Equation (36) is the definition of nominal interest rate in the model. As before the IS and PP curve shocks have been modelled as $AR(1)$ processes. ε_{MT_t}, x_{MT_t} and ϵ_t are all $i.i.d.$

Leading equation (33) one period and taking expectations yields:

$$E_t \widetilde{y}_{t+1} = \rho_{MT_1} v_{MT_t} \tag{40}$$

Substituting equation (40) and (36) in equation (32) yields:

$$\widetilde{y}_t = \gamma \rho_{MT_1} v_{MT_t} - \alpha[R_t - (E_t P_{t+1} - P_t)] + u_{MT_t} \tag{41}$$

Further, substituting equation (35) in (34) yields:

$$R_t = \left(\frac{1}{\beta_4}\right) P_t + \left(\frac{\beta_5}{\beta_4}\right) E_t \widetilde{y}_{t+1} - \left(\frac{1}{\beta_4}\right) M_{t-1} + \left(\frac{1}{\beta_4}\right) \xi_{0_t} - \left(\frac{1}{\beta_4}\right) \xi_{1_t} \tag{42}$$

Now, substituting equation (33) and (42) in equation (41) yields the semi-reduced form solution for P_t:

$$\begin{aligned} \delta(P_t - E_{t-1}P_t) + v_{MT_t} = \gamma \rho_{MT_1} v_{MT_t} - \alpha \left[\left(\frac{1}{\beta_4}\right) P_t + \left(\frac{\beta_5}{\beta_4}\right) E_t \widetilde{y}_{t+1} - \left(\frac{1}{\beta_4}\right) M_{t-1} + \left(\frac{1}{\beta_4}\right) \xi_{0_t} - \left(\frac{1}{\beta_4}\right) \xi_{1_t}\right] \\ + \alpha(E_t P_{t+1} - P_t) + u_{MT_t} \end{aligned} \tag{43}$$

The MSV conjectured solution for P_t is:

$$P_t = \phi_{MT_0} + \phi_{MT_1} M_{t-1} + \phi_{MT_2} u_{MT_t} + \phi_{MT_3} v_{MT_t} + \phi_{MT_4} \xi_{0_t} + \phi_{MT_5} \xi_{1_t} \tag{44}$$

Substituting the conjectured solution in equation (43) and substituting out for M_{t-1} yields the solution for π_t under money targeting regime:

[27] We assume $\overline{M} = 0$ for convenience.

$$\pi_t = [\rho_4 + (\rho_{MT_0} + \rho_{MT_1})]\pi_{t-1} - [\rho_4(\rho_{MT_0} + \rho_{MT_1}) + \rho_{MT_0}\rho_{MT_1}\}\pi_{t-2} + (\rho_{MT_0}\rho_{MT_1}\rho_4)\pi_{t-3}$$
$$+ \Delta\xi_{1_{t-1}} - \{\rho_4 + (\rho_{MT_0} + \rho_{MT_1})\}\Delta\xi_{1_{t-2}} + \{\rho_{MT_0}\rho_{MT_1} + \rho_4(\rho_{MT_0} + \rho_{MT_1})\}\Delta\xi_{1_{t-3}}$$
$$- (\rho_{MT_0}\rho_{MT_1}\rho_4)\Delta\xi_{1_{t-4}} + \phi_{MT_2}\Delta\varepsilon_{MT_t} - \phi_{MT_2}(\rho_{MT_1} + \rho_4)\Delta\varepsilon_{MT_{t-1}} + \phi_{MT_2}(\rho_{MT_1}\rho_4)$$
$$\Delta\varepsilon_{MT_{t-2}} + \phi_{MT_3}\Delta x_{MT_t} - \phi_{MT_3}(\rho_{MT_0} + \rho_4)\Delta x_{MT_{t-1}} + \phi_{MT_3}(\rho_{MT_0}\rho_4)\Delta x_{MT_{t-2}} + \phi_{MT_4}\Delta\epsilon_t -$$
$$\phi_{MT_4}(\rho_{MT_0} + \rho_{MT_1})\Delta\epsilon_{t-1} + \phi_{MT_4}(\rho_{MT_0}\rho_{MT_1})\Delta\epsilon_{t-2} + \phi_{MT_5}\Delta\xi_{1_t} - \phi_{MT_5}\{\rho_4 + (\rho_{MT_0} + \rho_{MT_1})\}$$
$$\Delta\xi_{1_{t-1}} + \phi_{MT_5}\{\rho_{MT_0}\rho_{MT_1} + \rho_4(\rho_{MT_0} + \rho_{MT_1})\}\Delta\xi_{1_{t-2}} - \phi_{MT_5}(\rho_{MT_0}\rho_{MT_1}\rho_4)\Delta\xi_{1_{t-3}} \quad (45)$$

The theoretical implied form for inflation is an $ARMA(3,5)$.

3.4 Fixed Exchange Rate Regime (Germany) or ERM (1986:1 to 1992:3)

The next regime largely consists of informal linking of the Sterling to the Deutsche Mark. This includes not only the 'shadowing' of the Mark in 1986-88, but also the period from 1989-1990 during which UK was a formal member of the Exchange Rate Mechanism. The idea essentially was that, just as the other major European currencies were successfully aiming to hold inflation down by anchoring their currencies to the DM within the ERM, the U.K. too could lock in to Germany's enviable record of sustained low inflation even without actually joining the mechanism. The approach was never formally announced, but it became clear in practice that the Sterling DM exchange rate, which had depreciated very sharply from DM 4 in July 1985 to DM 2.74 in early 1987, was not subsequently allowed to appreciate above DM 3 even though this meant a massive increase in U.K. foreign exchange reserves, and a reduction of interest rates from 11 percent to a trough of 7 percent during 1987 to prevent the appreciation. This had the effect of accommodating and aggravating the inflationary consequences of the earlier depreciation.

In the Spring of 1988, the exchange rate cap was lifted but by then the boom was already entrenched. Interest rates were pushed up - to 15 percent by the Autumn of 1989 - to bring the situation under control. A year later the UK also formally joined the ERM.. The episode produced a painful recession in which inflation which had risen to over 7% fell back sharply. According to Nelson (2000) from 1987-1990, the Bundesbank's monetary policy, rather than a domestic variable, served as U.K. monetary policy's nominal anchor.

At the time of ERM entry UK policy needs appeared to coincide with those of its partners. In principle it seemed possible that with the enhanced policy credibility that ERM membership was expected to bring, U.K. could hope to complete the domestic economic stabilisation programme with lower interest rates than otherwise, and so at less cost in terms of loss of output. There was also a very strong non-monetary consideration, that the UK would have little influence on the outcome of the European Inter-Government Conference if it was not in the ERM.

However, things did not go as planned. German reunification meant that Germany needed to maintain a tight monetary policy at a time when the domestic situation in a number of ERM countries, including the UK,. required monetary easing. Parity adjustment was against the ERM rules and seemed inconsistent with maintaining policy credibility. The UK was then confronted with a situation where tightening policy by raising rates made no economic sense in terms of domestic conditions. It then sought to maintain the parity through intervention in the hope that the pressures in Germany would abate. In reality those pressures did not ease soon enough and after heavy intervention, and a last bout of interest rate increases, the U.K. had no choice but to withdraw from the ERM on September 1992.

The model we use here is the same as the Bretton Woods model with the exception that Germany replaces the US throughout.

$$\widetilde{y}_t = \gamma(E_t\widetilde{y}_{t+1}) - \alpha(R_t - E_tP_{t+1} + P_t) + \lambda(E_tNX_{t+1}) + u_{FGR_t} \quad (46)$$

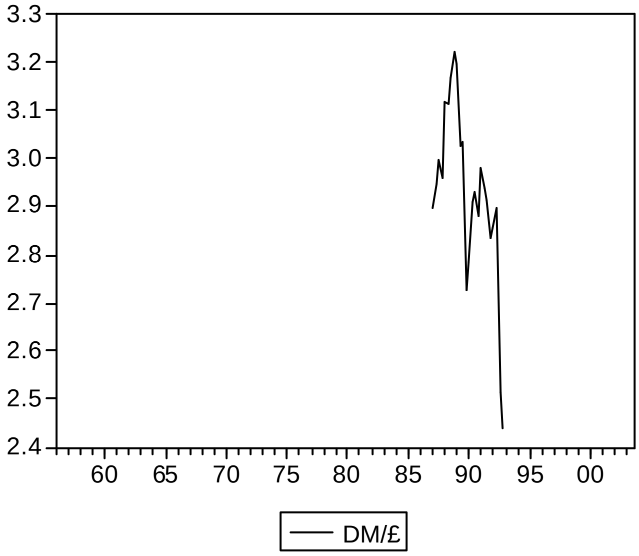

Figure 6:

$$\widetilde{y}_t = \delta(P_t - E_{t-1}P_t) + v_{FGR_t} \tag{47}$$

$$NX_t = a_{FGR_0}Q_{FGR_t} + a_{FGR_1}y^F_{FGR_t} \tag{48}$$

$$Q_{FGR_t} = P_t - (S_{FGR_t} + P^f_{FGR_t}) \tag{49}$$

$$R_t = R^F_{FGR_t} + (E_tS_{FGR_{t+1}} - S_{FGR_t}) \tag{50}$$

$$S_{FGR_t} = \overline{S}_{FGR} \tag{51}$$

$$R^F_{FGR_t} = \rho_{FGR}R^F_{FGR_{t-1}} + \eta_{FGR_t} \tag{52}$$

$$u_{FGR_t} = \rho_{FGR_0}u_{FGR_{t-1}} + \varepsilon_{FGR_t} \tag{53}$$

$$v_{FGR_t} = \rho_{FGR_1} v_{FGR_{t-1}} + x_{FGR_t} \tag{54}$$

Here S_{FGR_t} is the nominal exchange rate $DM/£$, $R^F_{FGR_t}$ is the German nominal interest rate (day-to-day money rate) and $P^f_{FGR_t}$ is the German price level (CPI).

Solving the model like earlier the semi-reduced form solution for P_t is:

$$\begin{aligned}\delta(P_t - E_{t-1}P_t) + v_{FGR_t} &= \gamma\rho_{FGR_1} v_{FGR_t} - \alpha(\rho_{FGR} R^F_{FGR_{t-1}} + \eta_{FGR_t}) \\ &+ (\alpha + \lambda a_{FGR_0}) E_t P_{t+1} - \alpha P_t - \lambda a_{FGR_0} \overline{S}_{FGR} + u_{FGR_t}\end{aligned} \tag{55}$$

Now the Minimum-State-Variable (MSV) conjectured solution for P_t in this model is:

$$P_t = \phi_{FGR_0} + \phi_{FGR_1} R^F_{FGR_{t-1}} + \phi_{FGR_2} u_{FGR_t} + \phi_{FGR_3} v_{FGR_t} + \phi_{FGR_4} \eta_{FGR_t} \tag{56}$$

Substituting the conjectured solution in equation (55) and substituting put for $R^F_{FGR_{t-1}}$ the solution for inflation under fixed exchange rate regime against Germany is:

$$\begin{aligned}\pi_t &= (\rho_{FGR} + \rho_{FGR_0} + \rho_{FGR_1})\pi_{t-1} - \{\rho_{FGR}(\rho_{FGR_0} + \rho_{FGR_1}) + (\rho_{FGR_0}\rho_{FGR_1})\}\pi_{t-2} + \rho_{FGR}\rho_{FGR_0}\rho_{FGR_1}\pi_{t-3} \\ &+ \phi_{FGR_1}\Delta\eta_{FGR_{t-1}} - \phi_{FGR_1}(\rho_{FGR_0} + \rho_{FGR_1})\Delta\eta_{FGR_{t-2}} + (\phi_{FGR_1}\rho_{FGR_0}\rho_{FGR_1})\Delta\eta_{FGR_{t-3}} \\ &+ \phi_{FGR_2}\Delta\varepsilon_{FGR_t}(1-\rho_{FGR}L) - \phi_{FGR_2}\rho_{FGR_1}\Delta\varepsilon_{FGR_{t-1}}(1-\rho_{FGR}L) + \phi_{FGR_3}\Delta x_{FGR_t}(1-\rho_{FGR}L) - \\ &\phi_{FGR_3}\rho_{FGR_0}\Delta x_{FGR_{t-1}}(1-\rho_{FGR}L) + \phi_{FGR_4}\Delta\eta_{FGR_t}(1-\rho_{FGR}L) - \phi_{FGR_4}(\rho_{FGR_0} + \rho_{FGR_1})\Delta\eta_{FGR_{t-1}} \\ &(1-\rho_{FGR}L) + \phi_{FGR_4}(\rho_{FGR_0}\rho_{FGR_1})\Delta\eta_{FGR_{t-2}}(1-\rho_{FGR}L)\end{aligned} \tag{57}$$

The theoretical implied form for inflation is as with Bretton Woods an $ARMA(3,4)$.

3.5 Inflation Targeting Regime (1992:4 to 2003:3)

Immediately following the U.K.'s exit from the Exchange Rate Mechanism (ERM) in September 1992, inflation expectations were between 5 percent and 7 percent at maturities 10 to 20 years ahead - well above the inflation target of 1-4 percent at the time. Five years into the regime, by April 1997, inflation expectations had ratcheted down to just over 4 percent. A credibility gap still remained but it had narrowed markedly. The announcement of operational independence for the Bank of England in May 1997[28] caused a further decline in inflation expectations by around 50 basis points across all maturities. By the end of 1998, inflation expectations were around the U.K.'s 2.5 percent inflation target, at all maturities along the inflation term structure. They have remained at that level since then.

Using the inflation target as a reference point for expectations is important during the transition to low inflation as the target then serves as a means of guiding inflation expectations downwards over time. It is widely thought, though not a feature of our models here, that lags in policy mean that inflation-targeting needs to have a forward-looking dimension.(according to Haldane (2000) a successful inflation-targeting regime must have "ghostbusting" as an underlying theme; by which he means that policy makers take seriously the need to be pre-emptive in setting monetary policy, offsetting incipient inflationary pressures.)

[28]Autonomy of the Bank is enshrined in the Bank of England Act of 1998. This act confers instrument-independence on the Bank, though the government still sets the goals of policy. In the jargon, there is goal-dependence but instrument independence.

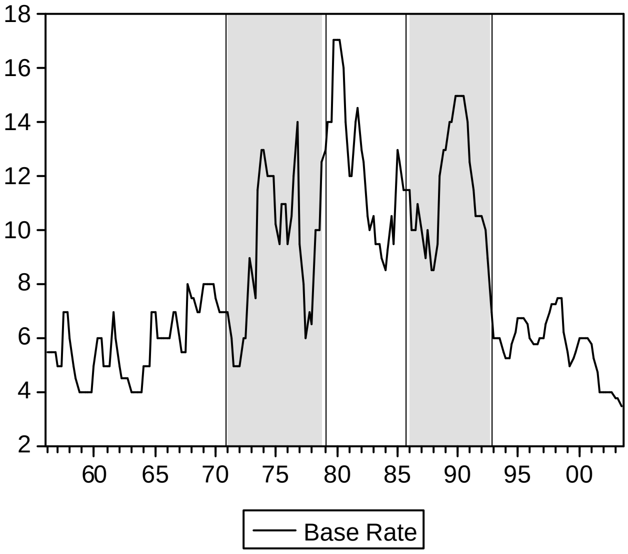

Figure 7:

Nevertheless within our model here a forward element makes no sense and in fact causes indeterminacy; so we have framed interest rate policy in terms of current inflation and output[29]

$$\widetilde{y}_t = \gamma(E_t \widetilde{y}_{t+1}) - \alpha(R_t - E_t \pi_{t+1}) + u_{FIT_t} \tag{58}$$

$$\widetilde{y}_t = \delta(\pi_t - E_{t-1}\pi_t) + v_{FIT_t} \tag{59}$$

$$R_t = \beta_{FIT_0} + \beta_{FIT_1} R_{t-1} + \beta_{FIT_2}(\pi_t - \pi^*) + \beta_{FIT_3}(\widetilde{y}_t) - \beta_{FIT_3}(w_{FIT_t}) \tag{60}$$

$$u_{FIT_t} = \rho_{FIT_0} u_{FIT_{t-1}} + \varepsilon_{FIT_t} \tag{61}$$

$$v_{FIT_t} = \rho_{FIT_1} v_{FIT_{t-1}} + x_{FIT_t} \tag{62}$$

$$w_{FIT_t} = \rho_{FIT_2} w_{FIT_{t-1}} + z_{FIT_t} \tag{63}$$

[29] Haldane (2000) goes on to say ‘Like ghosts, these pressures will be invisible to the general public at the time policy measures need to be taken. Claims of sightings will be met with widespread derision and disbelief. But the central bank’s job is to spot the ghosts and to exorcise them early. A successful monetary policy framework is ultimately one in which the general public is not haunted by inflationary shocks.’

In the equations above all variables are as defined earlier, with the exception of inflation where we use RPIX rather than the RPI since the regime is defined in terms of this variable; π^* is the inflation target of the Bank of England. As before equation (58) and (59) are the IS and Phillips curve, respectively. Equation (60) is a Taylor rule with interest rate smoothing. We also take into account Orphanides (1998) style output gap forecast error. As before the IS, PP and output gap forecast error have all been modelled as $AR(1)$ processes. ε_{FIT_t}, x_{FIT_t} and z_{FIT_t} are all *i.i.d.*

Leading equation (59) one period and taking expectations yields:

$$E_t\widetilde{y}_{t+1} = \rho_{FIT_1} v_{FIT_t} \tag{64}$$

The MSV conjectured solution for π_t is:

$$\pi_t = \phi_{FIT_0} + \phi_{FIT_1} R_{t-1} + \phi_{FIT_2} u_{FIT_t} + \phi_{FIT_3} v_{FIT_t} + \phi_{FIT_4} w_{FIT_t} \tag{65}$$

Substituting equation (64) and (65) in equation (58) yields:

$$\widetilde{y}_t = \gamma\rho_{FIT_1} v_{FIT_t} - \alpha(1-\phi_{FIT_1})R_t + \alpha\phi_{FIT_0} + u_{FIT_t} \tag{66}$$

Now, substituting equation (60) for R_t in equation (66) yields:

$$\begin{aligned}\widetilde{y}_t &= \gamma\rho_{FIT_1} v_{FIT_t} - \alpha(1-\phi_{FIT_1})[\beta_{FIT_0} + \beta_{FIT_1} R_{t-1} + \beta_{FIT_2}(\pi_t - \pi^*) + \beta_{FIT_3}(\widetilde{y}_t) \\ &\quad - \beta_{FIT_3}(w_{FIT_t})] + \alpha\phi_{FIT_0} + u_{FIT_t}\end{aligned} \tag{67}$$

Further, substituting equation (59) for $\widetilde{y}_t$yields:

$$\begin{aligned}[1-\alpha\beta_{FIT_3}(\phi_{FIT_1}-1)][\delta(\pi_t - E_{t-1}\pi_t) + v_{FIT_t}] &= \gamma\rho_{FIT_1} v_{FIT_t} + \alpha(\phi_{FIT_1}-1)\beta_{FIT_0} \\ &\quad + \alpha\beta_{FIT_1}(\phi_{FIT_1}-1)R_{t-1} + \alpha\beta_{FIT_2}(\phi_{FIT_1}-1)(\pi_t-\pi^*) \\ &\quad - \alpha\beta_{FIT_3}(\phi_{FIT_1}-1)w_{FIT_t} + \alpha\phi_{FIT_0} + u_{FIT_t}\end{aligned} \tag{68}$$

Finally, substituting the conjecture equation (65) in equation (68) and also substituting out for R_{t-1} the solution for π_t under flexible inflation targeting regime is:

$$\begin{aligned}\pi_t &= [\rho_{FIT_2} + (\rho_{FIT_0} + \rho_{FIT_1})]\pi_{t-1} - \{\rho_{FIT_2}(\rho_{FIT_0} + \rho_{FIT_1}) + \rho_{FIT_0}\rho_{FIT_1}\}\pi_{t-2} \\ &+ (\rho_{FIT_0}\rho_{FIT_1}\rho_{FIT_2})\pi_{t-3} + \phi_{FIT_0}(1-\rho_{FIT_0})(1-\rho_{FIT_1})(1-\rho_{FIT_2}) \\ &+ \phi_{FIT_1}\{A + B\ u_{FIT_{t-1}} + C\ v_{FIT_{t-1}} + D\ w_{FIT_{t-1}}\} - \phi_{FIT_1}\{\rho_{FIT_2} + (\rho_{FIT_0} + \rho_{FIT_1})\} \\ &\{A + B\ u_{FIT_{t-2}} + C\ v_{FIT_{t-2}} + D\ w_{FIT_{t-2}}\} \\ &+ \phi_{FIT_1}\{\rho_{FIT_2}(\rho_{FIT_0} + \rho_{FIT_1}) + \rho_{FIT_0}\rho_{FIT_1}\}\{A + B\ u_{FIT_{t-3}} + C\ v_{FIT_{t-3}} + D\ w_{FIT_{t-3}}\} \\ &- \phi_{FIT_1}\rho_{FIT_0}\rho_{FIT_1}\rho_{FIT_2}\{A + B\ u_{t-4} + C\ v_{t-4} + D\ w_{t-4}\} \\ &+ \phi_{FIT_2}\varepsilon_{FIT_t} - \phi_{FIT_2}(\rho_{FIT_1} + \rho_{FIT_2})\varepsilon_{FIT_{t-1}} \\ &+ \phi_{FIT_2}\rho_{FIT_1}\rho_{FIT_2}\varepsilon_{FIT_{t-2}} + \phi_{FIT_3}x_{FIT_t} - \phi_{FIT_3}(\rho_{FIT_0} + \rho_{FIT_2})x_{FIT_{t-1}} \\ &+ (\phi_{FIT_3}\rho_{FIT_0}\rho_{FIT_2})x_{FIT_{t-2}} + \phi_{FIT_4}z_{FIT_t} \\ &- \phi_{FIT_4}(\rho_{FIT_0} + \rho_{FIT_1})z_{FIT_{t-1}} + \phi_{FIT_4}\rho_{FIT_0}\rho_{FIT_1}z_{FIT_{t-2}}\end{aligned} \tag{69}$$

where

$$A = \beta_{FIT_0} + \beta_{FIT_2}\phi_{FIT_0} - \beta_{FIT_2}\pi^*$$

$$B = \phi_{FIT_2}(\beta_{FIT_2} + \delta\beta_{FIT_3})$$

$$C = \beta_{FIT_2}\phi_{FIT_3} + \beta_{FIT_3}(1 + \delta\phi_{FIT_3})$$

$$D = \beta_{FIT_2}\phi_{FIT_4} - \beta_{FIT_3}(1 - \delta\phi_{FIT_4})$$

The theoretical implied form for inflation under flexible inflation targeting is an $ARMA(3,4)$.

One can analyse a strict inflation targeting regime by simply changing equation (60) to:

$$R_t = \beta_{SIT_0} + \beta_{SIT_1}R_{t-1} + \beta_{SIT_2}(\pi_t - \pi^*) \tag{70}$$

Now the Central Bank, in the words of Mervyn King, is an 'Inflation nutter'. Using this interest rate rule the reduced form for π_t is:

$$\begin{aligned}\pi_t = {} & (\rho_{SIT_0} + \rho_{SIT_1})\pi_{t-1} - \rho_{SIT_0}\rho_{SIT_1}\pi_{t-2} + \phi_{SIT_0}(1-\rho_{SIT_0})(1-\rho_{SIT_1}) + \phi_{SIT_1}\{A + B\ u_{SIT_{t-1}} + C\ v_{SIT_{t-1}}\} \\ & - \phi_{SIT_1}(\rho_{SIT_0} + \rho_{SIT_1})\{A + B\ u_{SIT_{t-2}} + C\ v_{SIT_{t-2}}\} + \phi_{SIT_1}\rho_{SIT_0}\rho_{SIT_1}\{A + B\ u_{SIT_{t-3}} + C\ v_{SIT_{t-3}}\} + \phi_{SIT_2}\varepsilon_{SI} \\ & - \phi_{SIT_2}\rho_{SIT_1}\varepsilon_{SIT_{t-1}} + \phi_{SIT_3}x_{SIT_t} - \phi_{SIT_3}\rho_{SIT_0}x_{SIT_{t-1}}\end{aligned} \tag{71}$$

where

$$A = \beta_{SIT_0} + \beta_{SIT_2}\phi_{SIT_0} - \beta_{SIT_2}\pi^*$$

$$B = \beta_{SIT_2}\phi_{SIT_2}$$

$$C = \beta_{SIT_2}\phi_{SIT_3}$$

The theoretical implied form for inflation under strict inflation targeting is an $ARMA(2,3)$.

3.6 Comparing Model and Data

As Section 3 shows, the analytical solution for inflation in each of the regimes (except for the incomes policy regime) has an $ARMA$ (p, q) representation. In case of incomes policy (IP) the solution for inflation has a pure $AR(2)$ representation as the demand and supply shocks (u_t and v_t) do not enter the solution for inflation. It is clear from the reduced-form solution for inflation that, under all these regimes persistence is the product of the forcing processes interacting with the monetary regime in place.

3.6.1 Calibration

In order to operationalise the models described in the previous section we use calibrated values of various parameters. Several of these values are borrowed from (closed economy) models in Orphanides (1998), Dittmar et al. (1999), McCallum and Nelson (1999a, 1999b), McCallum (2001), and Rudebusch and Svensson (1999) or are based on evidence discussed there. For the open economy we use parameter values reported in Ball (1999) and Batini and Haldane (1999).The calibrated parameter values can be found in the Appendix Table 7.

We also estimate some of the parameters in the models. The estimated parameters can be found in the Appendix Table 8. In each of the models we estimate the AR coefficients of the IS and PP shocks. In doing so we use the solution implied by the model for y_t, P_t or π_t. This means that the expectation of a variable is model derived rather than being simply the realised value. The first step is to get the shock data by simply plugging in the calibrated parameter values along with the data in the IS/PP curve equation. Once we have the shock data we run $AR(1)$ on it, to get ρ_0 and $\rho_1$in the various models.[30]

Further, the foreign interest rate in the fixed exchange rate regimes, money supply and money demand shock in the money targeting regime are modeled as $AR(1)$'s. We estimated the coefficients, ρ[31], ρ_3 and ρ_4 by running an $AR(1)$ on the foreign interest rate, money supply and money demand shock data. Money demand shock data can be obtained by simply plugging in the calibrated parameters and data in equation (34).

We also have the Orphanides (1998) forecast error in the incomes policy and inflation targeting regime. We can work out the forecast error by making use of the MSV conjecture for y_t.Once we have the forecast error we estimate an $AR(1)$ to get ρ_2.[32]

4 Bootstrapping

Comparison of our models with the ARs and $ARMA$s we have estimated on the actual data cannot be done via deterministic simulation because the estimated equations depend on the distributions of all the shocks, each of them with rather different impulse response functions because of different MA processes. What we wish to do is to replicate the stochastic environment to see whether within it our estimated AR and $ARMA$ equations could have been generated. This we do via bootstrapping the models above with their error processes.

The idea is to create pseudo data samples (here 1000) for inflation. Within each regime we draw the vectors of iid shocks in our error processes with replacement (by drawing vectors for the same time period we preserve their contemporaneous cross-correlations); we then input them into their error processes and these in turn into the model to solve for the implied path of inflation over the sample period. We then run AR and $ARMA$ regressions on all the samples to derive the implied 95% confidence intervals for all the coefficients. Finally we compare the AR and $ARMA$ coefficients estimated from the actual data to see whether they lie within these 95% confidence intervals The comparison both guides us on whether our models are moving the parameters in the right direction; and informs us more formally whether the data rejects the models. The Table below summarises the results of this exercise. In it we shall refer to the AR (invariably an $AR(1)$) as the measure of net persistence that interests us most; the $ARMA$ parameters, hard to interpret as they are in terms of their net effect, we refer to in the context of the formal rejection test.

[30] Please note that we have omitted the subscripts specific to each regime. eg. ρ_{FUS_0}etc
[31] Again we have omitted subscripts for specific regimes.
[32] We ommit regime specific subscripts.

Table 5. Confidence Limits from our models

Fixed Exchange Rate (US)- Bretton Woods			
AutoRegression Moving Average (ARMA)			
ARMA(2,3)		95% Confidence Interval	
	Estimated	Lower	Upper
AR(1)	0.414439	-1.23062	1.499227
AR(2)	-0.353781	-1.02463	0.715851
MA(1)	-0.137642	-1.327915	1.721431
MA(2)	0.227487	-0.904292	1.430455
MA(3)	0.759041	-0.419199	0.682204
Autoregression			
AR(1)	0.252211	-0.011184	0.493779

Incomes Policy			
AutoRegression Moving Average (ARM			
ARMA(3,2)		95% Confidence Interval	
	Estimated	Lower	Upper
AR(1)	1.720229	-0.772099	1.456237
AR(2)	-1.707837	-0.775096	0.95824
AR(3)	0.722245	-0.331869	0.69187
MA(1)	-0.968766	-1.673696	1.266874
MA(2)	0.98435	-1.25814	0.994991
Autoregression			
AR(1)	0.735547	0.102834	0.626665

Money Targeting			
Autoregressive Moving Average (ARMA)			
ARMA(1,1)		95% Confidence Interval	
	Estimated	Lower	Upper
AR(1)	0.925756	-0.943254	0.800196
MA(1)	-0.997379	-1.437889	1.003879
Autoregression			
AR(1)	0.516666	-0.443949	0.114045

Fixed Exchange Rate (Germany)-ERM			
Autoregressive Moving Average (ARMA)			
ARMA(1,0)		95% Confidence Interval	
	Estimated	Lower	Upper
AR(1)	0.629426	-0.295087	0.343463
Autoregression			
AR(1)	0.629426	-0.295087	0.343463

Flexible Inflation Targeting (RPIX)			
Autoregressive Moving Average (ARMA)			
ARMA(1,4)		95% Confidence Interval	
	Estimated	Lower	Upper
AR(1)	-0.743549	-0.913662	1.014348
MA(1)	0.683187	-2.064438	0.911997
MA(2)	-0.35968	-0.344124	1.215575
MA(3)	0.000744	-0.604194	0.93342
MA(4)	0.594662	-0.547243	0.937894
Autoregression			
AR(1)	-0.152273	-0.312357	0.139256

Strict Inflation Targeting (RPIX)			
Autoregressive Moving Average (ARMA)			
ARMA(1,4)		95% Confidence Interval	
	Estimated	Lower	Upper
AR(1)	-0.743549	-0.887745	1.009078
MA(1)	0.683187	-2.202045	0.905415
MA(2)	-0.35968	-0.31248	1.466678
MA(3)	0.000744	-0.709148	0.947983
MA(4)	0.594662	-0.571813	0.940871
Autoregression			
AR(1)	-0.152273	-0.305537	0.139316

Flexible Inflation Targeting (RPI)			
Autoregressive Moving Average (ARMA)			
ARMA(3,3)		95% Confidence Interval	
	Estimated	Lower	Upper
AR(1)	0.720498	-0.535779	1.028335
AR(2)	0.514976	-0.35913	0.953655
AR(3)	-0.835545	-0.207415	0.868657
MA(1)	-0.761763	-1.717227	0.276406
MA(2)	-0.701631	-0.99985	0.902502
MA(3)	0.971221	-0.95622	0.960893
Autoregression			
AR(1)	0.202199	-0.321649	0.121946

Strict Inflation Targeting (RPI)			
Autoregressive Moving Average (ARMA)			
ARMA(3,2)		95% Confidence Interval	
	Estimated	Lower	Upper
AR(1)	0.720498	-0.440764	0.963478
AR(2)	0.514976	-0.272451	0.946504
AR(3)	-0.835545	-0.154489	0.863422
MA(1)	-0.761763	-1.829207	0.16466
MA(2)	-0.701631	-0.987876	0.81029
MA(3)	0.971221	-0.934857	0.955036
Autoregression			
AR(1)	0.202199	-0.312724	0.125578

Taking each regime in turn, we find that the model has some success under the Bretton Woods regime. Here it predicts that net persistence, the $AR(1)$ parameter, will be moderate (within a range of -0.01 and 0.49) against an actual estimate of 0.25. Of the five $ARMA$ parameters, four lie comfortably within the 95% confidence intervals and the fifth is only marginally outside.

With the Incomes Policy period net persistence rose substantially in the actual data; from 0.25 to 0.74. The model's net persistence range similarly moves upwards to a range of 0.10 to 0.63. Three out of the five $ARMA$ parameters also lie outside the 95% confidence interval, two of them quite a lot outside. Thus the data formally rejects the model of this period but does at least get the direction of change right; it is perhaps not surprising the model fails given our discussion of its inadequacies above.

Where the model fails worst is in the Money Targeting, MT, and the Fixed Exchange Rate (Germany) or ERM, regimes. For these it fails even to get the direction of change in net persistence right. For both the model implies that the range of net persistence (the $AR(1)$ parameter) should fall to below that of Bretton Woods. However the data tell us that net persistence remained high at similar levels to the Incomes Policy period; viz 0.52 for MT and 0.62 for FGR. Under MT one of the two $ARMA$ parameters also lies outside the 95% interval; under ERM the form is AR and so the net persistence equation applies. So the model is not merely plainly rejected by the data for these two regimes but also fails even to establish the correct direction. Again perhaps, given the turbulence of these two periods with repeated changes of tack in the emerging formulation of monetary policy, and also the fitful progress in inflation itself towards the official targets, the model's failure is not surprising.

Interestingly, when we turn to Inflation targeting (it makes little difference whether it is strict or not), the model does considerably better, at least if one uses RPIX as the inflation measure. It predicts that the range of net persistence ($AR(1)$ again) falls to -0.31 to 0.14. The actual $AR(1)$ parameter falls to -0.15, comfortably in the middle of this range. Of the five $ARMA$ coefficients four are well within the 95% confidence intervals and the fifth is only marginally outside. Thus the model is not rejected by the data.

(It should be mentioned that if we apply the model to the RPI, its success is less. The RPI's persistence only falls to 0.2, much the same as Bretton Woods; but the model predicts it should fall rather more. The model is also formally rejected for the RPI- with two out of the five $ARMA$ coefficients and also the $AR(1)$ coefficient outside their 95% confidence intervals. However, it seems right to concentrate on RPIX for this period, since with interest rate targeting the RPI itself became highly influenced by monetary policy in a misleading way. Certainly the persistent movements of interest rates would have imparted spurious persistence to RPI inflation.)

What we find therefore is that the model does capture some directional characteristics of the data. The latter say that both Bretton Woods and the Inflation targeting regimes generated quite low persistence, while the Incomes Policy, Money Targeting and ERM periods all exhibited quite high persistence. The model also says that Bretton Woods and Inflation Targeting should exhibit low persistence, while Incomes Policy should exhibit high persistence; so far so good. But it also predicts low persistence under Money Targeting and ERM, where it goes seriously wrong. In formal terms the model is rejected for three out of the five regimes, representing the extensive period from 1971 to1992 when UK inflation went through its wildest gyrations; plainly and not surprisingly the model needs more careful dynamic specification for these periods.

4.1 Substituting a fully-specified version of the basic model- bootstrapping the Liverpool Model

It seemed worthwhile to test our conclusion from the results with this basic model by running the same regimes on a fully-specified model derived from the same micro-foundations, viz the Liverpool Model of the UK (Appendix 2 carries some details of the model). Plainly considerable efforts have been made in this 20-year-old model to address the dynamic issues that appear to lie behind the stochastic failure of our benchmark model. In Table 6 that follows we report the results of applying the regimes above to the equivalent Liverpool versions of the model set out above. We are unable to run the model over the 1956-71 period as the errors used below relate to the period 1986-2002; however, we have assumed these could be applied to the 1971-86 period as well, as this was similarly turbulent (oil price and dollar shocks etc);.though strictly we should of course use shocks from these periods, at this stage we have been unable to gather them up.

Table 6. Confidence Limits from the Liverpool Model

	Incomes Policy		
	Autoregressive Moving Average (ARMA)		
ARMA(3,2)		95% Confidence Interval	
	Estimated	Lower	Upper
AR(1)	1.720229	-0.380451	2.098515
AR(2)	-1.707837	-1.66239	0.899277
AR(3)	0.722245	-0.642377	0.849375
MA(1)	-0.968766	-1.257318	1.310988
MA(2)	0.98435	-0.969748	0.994694
Autoregression			
AR(1)	0.735547	0.7024	0.96358

	Money Targeting				**Fixed Exchange Rate (Germany)-ERM**		
Autoregressive Moving Average (ARMA)					Autoregressive Moving Average (ARMA)		
ARMA(1,1)		95% Confidence Interval		ARMA(1,0)		95% Confidence Interval	
	Estimated	Lower	Upper		Estimated	Lower	Upper
AR(1)	0.925756	-0.66046	1.022038	AR(1)	0.629426	0.826362	0.985212
MA(1)	-0.997379	-0.988756	0.997495				
Autoregression				Autoregression			
AR(1)	0.516666	0.035179	0.593107	AR(1)	0.629426	0.826362	0.985212

	Flexible Inflation Targeting (RPIX)		
Autoregressive Moving Average (ARMA)			
ARMA(1,4)		95% Confidence Interval	
	Estimated	Lower	Upper
AR(1)	-0.743549	-1.001816	0.993012
MA(1)	0.683187	-1.645765	0.624049
MA(2)	-0.35968	-0.631137	0.863117
MA(3)	0.000744	-0.34802	0.445033
MA(4)	0.594662	-0.19635	0.54215
Autoregression			
AR(1)	-0.152273	-0.558027	-0.199794

In fact the Liverpool Model is still formally rejected by the data in two regimes- at least when shocks are applied form the 1986-2002 period; strictly we should apply to each regime the shocks from that regime only. The model slightly overpredicts persistence for the ERM regime. It also slightly under-predicts the persistence under inflation targeting. However, it is fairly close in both these cases, as well as being formally within the confidence intervals for Money Targeting and Incomes Policy. It also firmly predicts the collapse of persistence as one moves into inflation targeting.. As with the benchmark model, the same message comes through: that changes in persistence come about through regime changes.

5 Conclusions

The facts of UK inflation persistence appear to be inconsistent with the common practice of building persistence into the Phillips Curve; this is because persistence clearly varies across the post-war sample. Our suggestion here is that, as suggested by a basic New Classical model of the economy as well as by a more elaborate version in practical use, it varies mainly with the monetary regime; the roots of the inflation $ARMA$ process may not alter too much over time as they depend in this model on the autoregressive coefficients of the exogenous error processes. Monetary regimes can however 'close this persistence down' for inflation if they choose, this closing-down showing in the MA part of the process. Our benchmark and also our full New Classical model with a non-persistent Phillips Curve are both capable of replicating a fair amount of this regime-dependence qualitatively, generating higher persistence in the earlier regimes than under inflation-targeting regimes; they each strictly fail to capture the dynamics of particular periods. Nevertheless the rejections do not seem to invalidate the basic conclusion that persistence is likely to depend on the monetary regime. We conclude in short that inflation persistence is a phenomenon of policy not of nature.

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6 Appendix 1: Calibrated Parameters, Estimated Parameters, ARMA and Autoregressions on Inflation

Table 7. Calibrated Parameters

Parameter	Calibrated Value
α	0.4
δ	0.5
λ	0.2
γ	1
$a_{FUS,0}$	-2
$a_{FUS,1}$	0.65
$a_{FGR,1}$	-2
$a_{FGR,1}$	0.65
c	0.2
β_{IT_0}	0.025
β_{IT_1}	0.85
β_{IT_2}	1.5
β_{IT_3}	0.5
β_4	0.15
β_5	1

Table 8. Estimated Parameters

Regime	Estimated Parameters					
	ρ	ρ_0	ρ_1	ρ_2	ρ_3	ρ_4
Fixed Exchange Rate: US (FUS)	0.958062	0.991000	0.952826			
Incomes Policy (IP)		0.576917	-0.058496		-0.211389	
Money Targeting (MT)		0.783269	0.813735			0.922729
Fixed Exchange Rate: Germany (FGR)	0.990000	0.80459	0.813998			
Flexible Inflation Targeting (FIT) RPI		0.84942	-0.107643	0.278439		
Flexible Inflation Targeting (FIT) RPIX		0.878123	-0.021416	0.458199		
Strict Inflation Targeting (SIT) RPI		0.84942	-0.107643			
Strict Inflation Targeting (SIT) RPIX		0.878123	-0.021416			

ARMA for Fixed Exchange Rate (FUS) 1956:1 till 1970:4

Dependent Variable: PI
Method: Least Squares
Date: 09/08/04 Time: 16:39
Sample(adjusted): 1956:4 1970:4
Included observations: 57 after adjusting endpoints
Convergence achieved after 15 iterations
Backcast: 1956:1 1956:3

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PI(-1)	0.414439	0.152948	2.709681	0.0093
PI(-2)	-0.353781	0.149547	-2.365678	0.0221
@SEAS(1)	0.025780	0.010441	2.469116	0.0172
@SEAS(2)	0.055665	0.010987	5.066490	0.0000
@SEAS(3)	0.000535	0.011954	0.044778	0.9645
@SEAS(4)	0.060960	0.011561	5.273132	0.0000
MA(1)	-0.137642	0.105100	-1.309629	0.1966
MA(2)	0.227487	0.099649	2.282876	0.0269
MA(3)	0.759041	0.100356	7.563482	0.0000

R-squared	0.522354	Mean dependent var	0.036269
Adjusted R-squared	0.442746	S.D. dependent var	0.033037
S.E. of regression	0.024662	Akaike info criterion	-4.423199
Sum squared resid	0.029193	Schwarz criterion	-4.100612
Log likelihood	135.0612	Durbin-Watson stat	2.000008

Inverted MA Roots	.46+.86i	.46 -.86i	-.79

Figure 8:

ARMA for Incomes Policy (IP) 1971:1 till 1978:4

Dependent Variable: PI
Method: Least Squares
Date: 09/08/04 Time: 16:42
Sample: 1971:1 1978:4
Included observations: 32
Convergence achieved after 27 iterations
Backcast: 1970:3 1970:4

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PI(-1)	1.720229	0.151073	11.38676	0.0000
PI(-2)	-1.707837	0.175883	-9.710096	0.0000
PI(-3)	0.722245	0.151923	4.754016	0.0001
@SEAS(1)	-0.039412	0.042245	-0.932942	0.3605
@SEAS(2)	0.087505	0.033672	2.598759	0.0161
@SEAS(3)	-0.068058	0.037884	-1.796495	0.0856
@SEAS(4)	0.165460	0.031062	5.326690	0.0000
MA(1)	-0.968766	0.055369	-17.49659	0.0000
MA(2)	0.984350	0.060160	16.36220	0.0000

R-squared	0.695404	Mean dependent var	0.131845
Adjusted R-squared	0.589457	S.D. dependent var	0.077915
S.E. of regression	0.049923	Akaike info criterion	-2.924423
Sum squared resid	0.057322	Schwarz criterion	-2.512185
Log likelihood	55.79077	Durbin-Watson stat	1.940594
Inverted MA Roots	.48+.87i	.48 -.87i	

Figure 9:

ARMA for Money Targeting Regime (MT) 1979:1 till 1985:4

Dependent Variable: PI
Method: Least Squares
Date: 09/08/04 Time: 16:46
Sample: 1979:1 1985:4
Included observations: 28
Convergence achieved after 17 iterations
Backcast: 1978:4

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PI(-1)	0.925756	0.037742	24.52848	0.0000
@SEAS(1)	0.006995	0.024678	0.283463	0.7795
@SEAS(2)	0.071150	0.024233	2.936038	0.0076
@SEAS(3)	-0.057870	0.024673	-2.345483	0.0284
@SEAS(4)	-0.014601	0.023397	-0.624055	0.5390
MA(1)	-0.997379	0.056516	-17.64775	0.0000

R-squared	0.674493	Mean dependent var	0.093772
Adjusted R-squared	0.600514	S.D. dependent var	0.071213
S.E. of regression	0.045010	Akaike info criterion	-3.176442
Sum squared resid	0.044570	Schwarz criterion	-2.890969
Log likelihood	50.47018	Durbin-Watson stat	2.120261
Inverted MA Roots	1.00		

Figure 10:

ARMA for Fixed Exchange Rate: Germany (FGR) 1986:1 till 1992:3

Dependent Variable: PI
Method: Least Squares
Date: 09/08/04 Time: 18:06
Sample: 1986:1 1992:3
Included observations: 27

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PI(-1)	0.629426	0.163175	3.857369	0.0009
@SEAS(1)	0.005575	0.012960	0.430193	0.6712
@SEAS(2)	0.074814	0.011437	6.541602	0.0000
@SEAS(3)	-0.035922	0.018827	-1.907968	0.0695
@SEAS(4)	0.040522	0.011404	3.553183	0.0018

R-squared	0.692220	Mean dependent var	0.056810
Adjusted R-squared	0.636260	S.D. dependent var	0.041171
S.E. of regression	0.024831	Akaike info criterion	-4.387909
Sum squared resid	0.013564	Schwarz criterion	-4.147939
Log likelihood	64.23676	Durbin-Watson stat	1.933567

Figure 11:

7 Appendix 2: The Liverpool Model – Listing of equations

7.1 Behavioural equations

$$\log(EG_t) = \log(EGSTAR_t) + A39\log(Y_t/YSTAR_t) \tag{1}$$

$$\begin{aligned} XVOL_t = {} & A40YSTAR_t\{A27\log(WT_t) + A28\log(Y_t) + A47 + \\ & A29\{ESTAR_t + 0.6\{RXR_t - ESTAR_t\}\} + \\ & A30\{XVOL_t - 1/\{A40YSTAR_t - 1\}\}\} \end{aligned} \tag{2}$$

$$\begin{aligned} XVAL_t = {} & XVAL_{t-4} + \{XVOL_t - XVOL_{t-4}\} + A31 \\ & \{0.32YSTAR_t\{RXR_t - RXR_{t-4} - ESTAR_t + ESTAR_{t-4}\}\} + \\ & A32XVALres_{t-1} \end{aligned} \tag{3}$$

$$\begin{aligned} \log(M0_t) = {} & A44 + A13\log(M0_{t-1}) + A14\{\log(Y_t) + \\ & \log(1 - TAX_{t-1})\} + A16TREND_t + A17NRS_t + A18VAT_t \end{aligned} \tag{4}$$

$$\begin{aligned} \log(U_t) = {} & A42 + A3\log(Y_t) + A4\{\log(RW_t) + \log(1.0 + BO_t) + \\ & \log(1.0 + VAT_t)\} + A5TREND_t + A6\log(U_{t-1}) + A36Ures_{t-1} \end{aligned} \tag{5}$$

$$\begin{aligned} \log(G_t) = {} & A45 + A19RL_t + A20\{\log(G_{t-1}) - \log(FIN_{t-1})\} + \\ & A21\{\log(G_{t-1}) - \log(Gt - 2)\} + \log(G_{t-1}) \end{aligned} \tag{6}$$

$$\begin{aligned} \log(CON_t) = {} & A46 + A22RL_t + A23\log(W_t) + A24QEXP_t + \\ & A25\log(CON_{t-1}) \end{aligned} \tag{7}$$

$$\begin{aligned} \log(RW_t) = {} & A43 + A7UNR_t + A8\{\log(UB_t) + \log(1.0 + LO_t)\} + \\ & A9\log(U_t) + A37\log(RW_{t-1}) + \{.095\}UNR_t\{-A10\} + \\ & A10\log(RW_{t-2}) + A11ETA_t + A12ETA_{t-1} \end{aligned} \tag{8}$$

$$\begin{aligned} RXR_t = {} & A41 + 0.000 + A1\{\log(RW_t) + \log(1.0 + BO_t)\} + \\ & A53\{\log(P_t) - \log(P_{t-4})\} + \{1. + A1\}\log(1. + VAT_t) + \\ & A2TREND_t + A35RXRres_{t-1} \end{aligned} \tag{9}$$

ARMA for FIT/SIT (RPI) 1992:4 till 2003:3

Dependent Variable: PI
Method: Least Squares
Date: 09/08/04 Time: 18:28
Sample: 1992:4 2003:3
Included observations: 44
Convergence achieved after 21 iterations
Backcast: 1992:1 1992:3

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PI(-1)	0.720498	0.091068	7.911688	0.0000
PI(-2)	0.514976	0.154413	3.335048	0.0021
PI(-3)	-0.835545	0.099350	-8.410095	0.0000
@SEAS(1)	0.040859	0.008304	4.920215	0.0000
@SEAS(2)	0.051110	0.006453	7.919977	0.0000
@SEAS(3)	-0.021042	0.008841	-2.379918	0.0231
@SEAS(4)	-0.009923	0.009699	-1.023069	0.3135
MA(1)	-0.761763	0.047080	-16.18010	0.0000
MA(2)	-0.701631	0.040454	-17.34373	0.0000
MA(3)	0.971221	0.071546	13.57482	0.0000

R-squared	0.814881	Mean dependent var	0.024828
Adjusted R-squared	0.765879	S.D. dependent var	0.024938
S.E. of regression	0.012066	Akaike info criterion	-5.800076
Sum squared resid	0.004950	Schwarz criterion	-5.394578
Log likelihood	137.6017	Durbin-Watson stat	1.976813

Inverted MA Roots	.87+.49i	.87 -.49i	-.98

Figure 12:

ARMA for FIT/SIT (RPIX) 1992:4 till 2003:3

Dependent Variable: PIRPIX
Method: Least Squares
Date: 09/08/04 Time: 18:43
Sample: 1992:4 2003:3
Included observations: 44
Convergence achieved after 24 iterations
Backcast: 1991:4 1992:3

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PIRPIX(-1)	-0.743549	0.115369	-6.444947	0.0000
@SEAS(1)	0.030704	0.004857	6.321113	0.0000
@SEAS(2)	0.070139	0.004781	14.66911	0.0000
@SEAS(3)	0.051468	0.007977	6.451915	0.0000
@SEAS(4)	0.025297	0.004343	5.825121	0.0000
MA(1)	0.683187	0.152514	4.479513	0.0001
MA(2)	-0.359680	0.182014	-1.976107	0.0561
MA(3)	0.000744	0.203009	0.003664	0.9971
MA(4)	0.594662	0.165544	3.592169	0.0010

R-squared	0.891576	Mean dependent var	0.025481
Adjusted R-squared	0.866794	S.D. dependent var	0.022338
S.E. of regression	0.008153	Akaike info criterion	-6.600668
Sum squared resid	0.002326	Schwarz criterion	-6.235720
Log likelihood	154.2147	Durbin-Watson stat	1.986331

Inverted MA Roots	.55 -.55i	.55+.55i	-.89 -.44i	-.89+.44i

Figure 13:

AR for Fixed Exchange Rate (FUS) 1956:1 till 1970:4

PI is inflation calculated qtr-on-qtr and then annualised using the formula ((1+qtr-on-qtr pi)^4)-1

Dependent Variable: PI
Method: Least Squares
Date: 08/31/04 Time: 15:17
Sample(adjusted): 1956:3 1970:4
Included observations: 58 after adjusting endpoints
PI = C(1)*PI(-1) + C(2)*(@SEAS(1)) + C(3)*(@SEAS(2)) + C(4)
(@SEAS(3)) + C(5)(@SEAS(4))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.252211	0.135162	1.865989	0.0676
C(2)	0.029167	0.009141	3.190735	0.0024
C(3)	0.046141	0.009181	5.025728	0.0000
C(4)	-0.007564	0.010671	-0.708814	0.4815
C(5)	0.039690	0.007339	5.408416	0.0000

R-squared	0.337852	Mean dependent var	0.035406
Adjusted R-squared	0.287879	S.D. dependent var	0.033400
S.E. of regression	0.028185	Akaike info criterion	-4.217785
Sum squared resid	0.042103	Schwarz criterion	-4.040161
Log likelihood	127.3158	Durbin-Watson stat	1.947207

A regression on just the constant can provide us with some very useful summary stats. The coefficient on the constant can be interpreted as the mean value of inflation during the period and the std error of regression as the std deviation of inflation. (Batini & Nelson 2001)

Dependent Variable: PI
Method: Least Squares
Date: 06/24/04 Time: 17:03
Sample(adjusted): 1956:2 1970:4
Included observations: 59 after adjusting endpoints
PI = C(1)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.036213	0.004386	8.257234	0.0000

R-squared	0.000000	Mean dependent var	0.036213
Adjusted R-squared	0.000000	S.D. dependent var	0.033687
S.E. of regression	0.033687	Akaike info criterion	-3.926611
Sum squared resid	0.065819	Schwarz criterion	-3.891399
Log likelihood	116.8350	Durbin-Watson stat	1.928770

Figure 14:

AR for Incomes Policy (IP) 1971:1 till 1978:4

Dependent Variable: PI
Method: Least Squares
Date: 08/31/04 Time: 15:21
Sample: 1971:1 1978:4
Included observations: 32
PI = C(1)*PI(-1) + C(2)*(@SEAS(1)) + C(3)*(@SEAS(2)) + C(4)
(@SEAS(3)) + C(5)(@SEAS(4))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.735547	0.131656	5.586884	0.0000
C(2)	0.050085	0.023863	2.098825	0.0453
C(3)	0.081931	0.025531	3.209159	0.0034
C(4)	-0.047070	0.030082	-1.564702	0.1293
C(5)	0.053034	0.021331	2.486279	0.0194

R-squared	0.631629	Mean dependent var	0.131845
Adjusted R-squared	0.577056	S.D. dependent var	0.077915
S.E. of regression	0.050671	Akaike info criterion	-2.984320
Sum squared resid	0.069324	Schwarz criterion	-2.755299
Log likelihood	52.74912	Durbin-Watson stat	1.734798

Dependent Variable: PI
Method: Least Squares
Date: 06/24/04 Time: 17:09
Sample: 1971:1 1978:4
Included observations: 32
PI = C(1)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.131845	0.013773	9.572342	0.0000

R-squared	0.000000	Mean dependent var	0.131845
Adjusted R-squared	0.000000	S.D. dependent var	0.077915
S.E. of regression	0.077915	Akaike info criterion	-2.235655
Sum squared resid	0.188191	Schwarz criterion	-2.189851
Log likelihood	36.77048	Durbin-Watson stat	0.947912

Figure 15:

AR for Money Targeting Regime (MT) 1979:1 till 1985:4

Dependent Variable: PI
Method: Least Squares
Date: 09/02/04 Time: 15:51
Sample: 1979:1 1985:4
Included observations: 28
PI = C(1)*PI(-1) + C(3)*(@SEAS(1)) + C(4)*(@SEAS(2)) + C(5)
(@SEAS(3)) + C(6)(@SEAS(4))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.516666	0.181012	2.854314	0.0090
C(3)	0.047971	0.025441	1.885575	0.0720
C(4)	0.105603	0.026826	3.936580	0.0007
C(5)	0.003096	0.034871	0.088779	0.9300
C(6)	0.020941	0.026443	0.791924	0.4365

R-squared	0.424630	Mean dependent var	0.093772
Adjusted R-squared	0.324566	S.D. dependent var	0.071213
S.E. of regression	0.058526	Akaike info criterion	-2.678242
Sum squared resid	0.078783	Schwarz criterion	-2.440349
Log likelihood	42.49539	Durbin-Watson stat	2.464990

Dependent Variable: PI
Method: Least Squares
Date: 06/24/04 Time: 17:17
Sample: 1979:1 1985:4
Included observations: 28
PI = C(1)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.093772	0.013458	6.967741	0.0000

R-squared	0.000000	Mean dependent var	0.093772
Adjusted R-squared	0.000000	S.D. dependent var	0.071213
S.E. of regression	0.071213	Akaike info criterion	-2.411214
Sum squared resid	0.136926	Schwarz criterion	-2.363635
Log likelihood	34.75699	Durbin-Watson stat	1.214665

Figure 16:

AR for Fixed Exchange Rate: Germany (FGR) 1986:1 till 1992:3

Dependent Variable: PI
Method: Least Squares
Date: 08/31/04 Time: 15:14
Sample: 1986:1 1992:3
Included observations: 27
PI = C(2)*PI(-1) + C(3)*(@SEAS(1))+ C(4)*(@SEAS(2)) + C(5)
(@SEAS(3)) + C(6)(@SEAS(4))

	Coefficient	Std. Error	t-Statistic	Prob.
C(2)	0.629426	0.163175	3.857369	0.0009
C(3)	0.005575	0.012960	0.430193	0.6712
C(4)	0.074814	0.011437	6.541602	0.0000
C(5)	-0.035922	0.018827	-1.907968	0.0695
C(6)	0.040522	0.011404	3.553183	0.0018

R-squared	0.692220	Mean dependent var	0.056810
Adjusted R-squared	0.636260	S.D. dependent var	0.041171
S.E. of regression	0.024831	Akaike info criterion	-4.387909
Sum squared resid	0.013564	Schwarz criterion	-4.147939
Log likelihood	64.23676	Durbin-Watson stat	1.933567

Dependent Variable: PI
Method: Least Squares
Date: 06/24/04 Time: 17:21
Sample: 1986:1 1992:3
Included observations: 27
PI = C(1)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.056810	0.007923	7.169895	0.0000

R-squared	0.000000	Mean dependent var	0.056810
Adjusted R-squared	0.000000	S.D. dependent var	0.041171
S.E. of regression	0.041171	Akaike info criterion	-3.505836
Sum squared resid	0.044071	Schwarz criterion	-3.457842
Log likelihood	48.32878	Durbin-Watson stat	1.941648

Figure 17:

IT (RPI) 1992:4 till 2003:3

Dependent Variable: PI
Method: Least Squares
Date: 09/02/04 Time: 14:16
Sample: 1992:4 2003:3
Included observations: 44
PI = C(1)*PI(-1) + C(2)*(@SEAS(1)) + C(3)*(@SEAS(2)) + C(4)
(@SEAS(3)) + C(5)(@SEAS(4))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.202199	0.155057	1.304028	0.1999
C(2)	0.004205	0.005202	0.808372	0.4238
C(3)	0.058344	0.004341	13.44163	0.0000
C(4)	-0.001419	0.010188	-0.139242	0.8900
C(5)	0.018345	0.004400	4.169527	0.0002

R-squared	0.724339	Mean dependent var	0.024828
Adjusted R-squared	0.696066	S.D. dependent var	0.024938
S.E. of regression	0.013748	Akaike info criterion	-5.629174
Sum squared resid	0.007371	Schwarz criterion	-5.426425
Log likelihood	128.8418	Durbin-Watson stat	2.044634

Method: Least Squares
Date: 06/24/04 Time: 17:23
Sample: 1992:4 2003:3
Included observations: 44
PI = C(1)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.024828	0.003759	6.604149	0.0000

R-squared	0.000000	Mean dependent var	0.024828
Adjusted R-squared	0.000000	S.D. dependent var	0.024938
S.E. of regression	0.024938	Akaike info criterion	-4.522409
Sum squared resid	0.026741	Schwarz criterion	-4.481859
Log likelihood	100.4930	Durbin-Watson stat	2.655625

Figure 18:

IT (RPIX) 1992:4 till 2003:3

Dependent Variable: PIRPIX
Method: Least Squares
Date: 09/02/04 Time: 14:18
Sample: 1992:4 2003:3
Included observations: 44
PIRPIX= C(1)*PIRPIX(-1) +C(2)*(@SEAS(1)) + C(3)*(@SEAS(2)) +
C(4)*(@SEAS(3)) + C(5)*(@SEAS(4))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.152273	0.156983	-0.969998	0.3380
C(2)	0.016681	0.004178	3.992304	0.0003
C(3)	0.062099	0.003347	18.55519	0.0000
C(4)	0.016641	0.009775	1.702345	0.0967
C(5)	0.021902	0.002795	7.836655	0.0000

R-squared	0.865861	Mean dependent var	0.025481
Adjusted R-squared	0.852103	S.D. dependent var	0.022338
S.E. of regression	0.008591	Akaike info criterion	-6.569658
Sum squared resid	0.002878	Schwarz criterion	-6.366909
Log likelihood	149.5325	Durbin-Watson stat	2.008503

Method: Least Squares
Date: 06/25/04 Time: 16:27
Sample: 1992:4 2003:3
Included observations: 44
PIRPIX = C(1)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.025481	0.003368	7.566689	0.0000

R-squared	0.000000	Mean dependent var	0.025481
Adjusted R-squared	0.000000	S.D. dependent var	0.022338
S.E. of regression	0.022338	Akaike info criterion	-4.742597
Sum squared resid	0.021456	Schwarz criterion	-4.702047
Log likelihood	105.3371	Durbin-Watson stat	2.944162

Figure 19:

AR for Full Sample 1956:1 till 2003:3

Dependent Variable: PI
Method: Least Squares
Date: 09/02/04 Time: 16:34
Sample(adjusted): 1956:3 2003:3
Included observations: 189 after adjusting endpoints
PI = C(1)*PI(-1) + C(2)*(@SEAS(1)) + C(3)*(@SEAS(2)) +C(4)
(@SEAS(3)) +C(5)(@SEAS(4))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.743048	0.049368	15.05116	0.0000
C(2)	0.014584	0.006378	2.286650	0.0234
C(3)	0.057806	0.006387	9.049966	0.0000
C(4)	-0.038421	0.007506	-5.118435	0.0000
C(5)	0.028704	0.006030	4.760292	0.0000

R-squared	0.614112	Mean dependent var	0.060976
Adjusted R-squared	0.605723	S.D. dependent var	0.063003
S.E. of regression	0.039560	Akaike info criterion	-3.595887
Sum squared resid	0.287962	Schwarz criterion	-3.510127
Log likelihood	344.8114	Durbin-Watson stat	2.318469

Chow Breakpoint Test: 1971:1 1979:1 1986:1 1992:4

F-statistic	2.983189	Probability	0.000067
Log likelihood ratio	58.64247	Probability	0.000012

We do not accept the null of no structural change.

Figure 20:

7.2 Identities and calibrated relationships

$$RS_t = \{RXR_t - EEX_t\} + RSUS_t \quad (10)$$
$$NRSt = P\exp_t + RS_t \quad (11)$$
$$RL_t = \{RXR_t - EEXL_t\}/5.0 + RLUS_t) \quad (12)$$
$$NRL_t = RL_t + PEXL_t \quad (13)$$
$$Y_t = GINV_t + CON_t + EG_t + XVOL_t - AFC_t \quad (14)$$
$$INFL_t = \log(MON_t) - \log(MON_{t-4}) - \log(M0_t) + \log(M0_{t-4}) \quad (15)$$
$$\log(P_t) = \log(P_{t-4}) + INFL_t \quad (16)$$
$$W_t = FIN_t + G_t \quad (17)$$
$$BDEF_t = EG_t - 2.0 \times TAX_t \times Y_t + TAX_0 \times Y_0 \quad (18)$$
$$AFC_t = Y_t\{0.6588318\{AFC_{t-1}/Y_{t-1}\} + 0.1966416\{AFC_{t-3}/Y_{t-3}\} + 0.1454006\{AFC_{t-4}/Y_{t-4}\}+\} \quad (19)$$
$$PSBR_t = BDEF_t + RDI_t \quad (20)$$
$$RDI_t = -.5\{NRL_{t-1}/4.0\}FIN_{t-1}\{\{\{Pt/P_{t-1}\}^{0.66}\} - 1.0\} + PSBR_t\{.32\{NRS_t/4.0\} + .5\{NRL_t/4.0\}\} + 0.32\{NRS_t/4.\}FIN_{t-1} - .32\{NRS_{t-1}/4.\}FIN_{t-1} + RDI_{t-1} \quad (21)$$
$$GINV_t = G_t - G_{t-1} + A38G_{t-1} \quad (22)$$
$$FIN_t = EG_t - Y_t * \{TAX_t\} + XVAL_t + A54 * FIN_{t-1} + \{1. - A54\} * \{FIN_{t-1} * \{\{P_{t-1}/P_t\}^{0.66}\}\} \{1.0 - 0.155 * \{\{NRL_t/NRL_{t-1}\} - 1.0\}\} + res\_FIN_t + RDI_t \quad (23)$$

7.3 Equilibrium variables (-star):

The -star variables YSTAR, USTAR, ESTAR and WSTAR are the equilibrium values of Y, U, RXR and RW respectively, found by solving equations 2,5,8 and 9 under the conditions that XVOL=0 and exogenous variables maintain their current values; EGSTAR is the value of EG that would produce a constant debt/GDP ratio with Y=YSTAR.

7.4 Coefficient values in order A1–56:

1.528 -0.003 -2.150 0.792 0.010 0.804 0.470 0.210 -0.018 -0.224
-0.290 0.189 0.870 0.150 0.000 -0.002 -0.349 0.839 -0.016 -0.004
0.640 -0.215 0.056 0.153 0.870 0.000 0.529 -1.205 -0.388 0.429
0.103 0.193 0.000 0.000 0.931 0.271 1.000 0.012 -0.125 0.320
0.170 25.262 0.102 -0.337 0.013 0.666 11.503 -0.016 -0.011 0.017
0.011 0.750 -0.750 0.300 -1.000 -1.000

(Exogenous variables- e= error term)
RSUS = c + 0.899RSUS(-1) +e
EUNRS = c + 0.977EUNRS(-1) +e
DlogWT = c + e

DBO = c + e
DVAT = c - 0.286 DVAT(-1) + e
DUNR = c + 0.869 DUNR(-1) + e
DUB = c + e
DLO =c + e
DTAX = c -0.365 DTAX(-1) +e
DlogEURXR = c + 0.235 DlogEURXR(-1) + e
DlogEUCPI = c + 0.503 DlogEUCPI(-1) + e

Model notation:

Endogenous Variables	
Y	GDP at factor cost
P	Consumer Price Level
INFL	Percentage growth rate of P (year-on-year)
MON	Nominal Money Stock (M0)
RW	Real wages (Average Earnings/Price)
U	Unemployment
Q	Output deviation from trend (Y/YSTAR)
AFC	Adjustment to factor cost
EG	real government spending on goods and services
BDEF	interest-exclusive budget deficit (deflated by CPI)
PSBR	public sector borrowing requirement (deflated by CPI)
XVAL	real current account of balance of payments
XVOL	same, at constant terms of trade
RS(RL)	real short term (log term) interest rate
NRS (NRL)	nominal short term (long term) interest rate
M0	real money balances (M0)
G	real private stock of durable goods, including inventories
W	real private stock of wealth
FIN	real private stock of financial assets (net)
CON	real private non-durable consumption
RXR	real exchange rate (relative CPI, UK v. ROW)
RDI	real debt interest
GINV	gross private investment in durables plus stockbuilding
Exogenous Variables	
MTEM	Temporary growth of money supply
PEQ	Growth of money supply
BO	Employers national insurance contributions
UNR	Trade Unionisation rate
LO	Average amount lost in taxes and national insurance
TREND	Time trend
WT	World Trade
TAX	Overall tax rate
UB	Unemployment benefit rate (in constant pounds)
EUNRS............................	Euro nominal short-term interest rates
EURXR............................	Euro real exchange rate index
EUCPI	Euro CPI
RSUS	US real short-term interest rate

The Liverpool Model of the UK

The model (an account can be found in Minford, 1980) has been used in forecasting continuously since 1979, and is now one of only two in that category. The other is the NIESR model, which however has been frequently changed in that 20-year period: the only changes in the Liverpool Model were the introduction in the early 1980s of supply-side equations (to estimate underlying or equilibrium values of unemployment, output and the exchange rate) and the shift from annual data to a quarterly version in the mid-1980s.

The Liverpool Model of the UK is an open economy version of a rational expectations IS-LM model, such as can be derived from a micro-founded model by suitable approximations (McCallum and Nelson, 1999)- thus for example the Liverpool Model IS curve has the expectation of future output in it, the hallmark of this approximation. The model's Phillips or Supply curve assumes overlapping 4-quarter wage contracts- thus real wages are affected by the 4-quarter-moving average of inflation surprises. The labour market underpinning it is explicit and the model solves for equilibrium or natural rates of output, unemployment and relative prices. In recent work a new FIML algorithm developed in Cardiff University (Minford and Webb, 2000) has been used to reestimate the model parameters: it turns out that the new estimates are little different from the model's original ones, based partly on single-equation estimates, partly on calibration from simulation properties.

The model has been used in forecasting continuously since 1979, and is now one of only two in that category. The other is the NIESR model, which however has been frequently changed in that 20-year period: the only changes in the Liverpool Model were the introduction of the explicit natural rate supply-side equations in the early 1980s and the shift from annual data to a quarterly version in the mid-1980s. In an exhaustive comparative test of forecasting ability over the 1980s, Andrews et al (1996) showed that out of three models extant in that decade- Liverpool, NIESR, and LBS- the forecasting performance of none of them could 'reject' that of the others in non-nested tests, suggesting that the Liverpool Model during this period was, though a newcomer, at least now worse than the major models of that time. For 1990s forecasts no formal test is available, but the LBS model stopped forecasts and in annual forecasting post-mortem contests the NIESR came top in two years, Liverpool in three. In terms of major UK episodes, Liverpool model forecasts successfully predicted the sharp drop in inflation and the good growth recovery of the early 1980s. From the mid-1980s they rightly predicted that the underlying rate of unemployment was coming down because of supply-side reforms and that unemployment would in time fall steadily in consequence. Then they identified the weakness of UK membership of the ERM and its likely departure because of the clash between the needs of the UK economy and those of Germany leading the ERM at the time of German Reunification. After leaving the ERM they forecast that inflation would stay low and that unemployment would fall steadily from its ERM-recession peak back into line with the low underlying rate - as indeed was the case. Thus the Liverpool Model has a reasonable forecasting record; its capacity to replicate the dynamics of the data is currently being examined, in work similar to this.