ON THE PERSISTENCE OF UK INFLATION: A LONG-RANGE DEPENDENCE APPROACH

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We use long-memory techniques, based on fractional integration, as well as a method to distinguish between permanent and transitory components (UCSVO), to analyse UK inflation over a long period of time, from 1660 to 2016

STRUCTURE OF THE PRESENTATION

1. INTRODUCTION

The aim of the paper is to provide further evidence on the stochastic behaviour of inflation by using long-memory (fractional integration) techniques to analyse the UK experience.

The historical data for inflation in this country span a much longer time period than those for others, and therefore the UK experience is particularly suitable to examine persistence with long-memory methods.

In particular, our sample includes more than 350 annual observations, from the Restoration of the English monarchy in the second half of the 17th century until 2016.

The advantage of using long-range dependence methods is that they do not require imposing the assumption of a unit root or a simple AR process, and therefore are much more general and flexible than the autoregressive-moving average (AR(I)MA) models most commonly used in the literature.

In addition, in order to examine any possible changes in persistence, we also test for breaks and estimate persistence in the corresponding subsamples, and then we apply rolling- and recursive-window methods to capture other forms of time variation. Finally, we estimate the unobserved-components stochastic volatility outlier-adjusted (UCSVO) model of Stock and Watson (2016).

2. LITERATURE REVIEW

The period following WWII has been characterised in many countries by high persistence.

Numerous empirical studies have analysed inflation persistence using different approaches, but mainly estimating ARMA models.

Papers on US inflation initially focused on point estimates, and found that inflation persistence had declined after the 1980s (Cogley and Sargent, 2002).

Subsequent studies allowing for uncertainty around point estimates concluded that it had remained stable (Pivetta and Reis, 2007). More recently, Stock and Watson (2007, 2010) have suggested a method to separate transitory and permanent components of inflation and reconcile the previous two findings. Stock and Watson (2016) refined this method further by including a model-based adjustment for large inflationary spikes (i.e., outliers).

As for UK inflation in particular, some studies have focused on nonlinearities (Clements and Sensier, 2003; Arghyrou et al., 2005), whilst others have analysed its behaviour under different monetary regimes (e.g., Nelson, 2001, 2009; and Nelson and Nikolov, 2004).

Benati (2008) examined inflation both in the UK (from 1718 to 2006) and in other countries. His results, based on both reduced-form and structural New-Keynesian models, do not support a structural interpretation of persistence, which is measured by estimating AR models as in much of the existing literature.

Miles et al. (2017) argue that UK inflation has behaved rather similarly to US inflation. Specifically, both their level and volatility were initially rather high, but went down over time, especially during the Great Moderation (in the 1990s). Inflation volatility then increased again during the Great Recession brought about by the global financial crisis of 2007-8, when it reached values similar to those of the Great Depression of 1929. The only difference between the experience of these two countries is that, in the UK, the period of low volatility that characterised the 1990s had actually started with the end of the Bretton Woods monetary system, whilst this occurred much later in the case of US inflation.

3. ECONOMETRIC METHODOLOGY

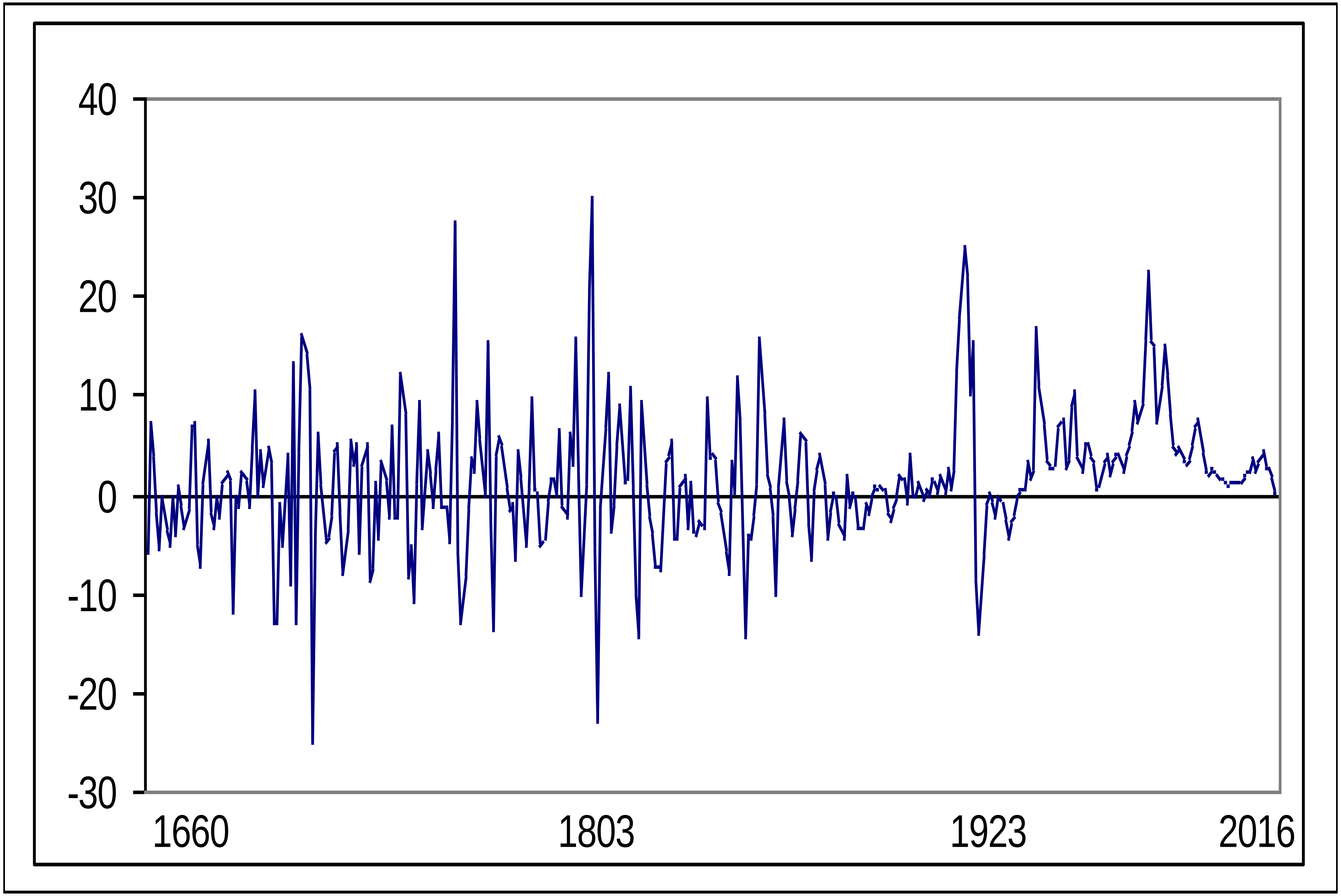
The econometric methodology is based on the concept of FRACTIONAL INTEGRATION, allowing for more flexible specifications that the standard ones based on stationarity I(0) and nonstationarity I(1).

The possibility of structural breaks in the context of I(d) models is also investigated.

4. DATA DESCRIPTION

The series examined is annual headline CPI inflation; the source is the Bank of England’s historical macroeconomic dataset (1660-2016).

Following Miles et al. (2017), we start in 1660, which is the year of the Restoration of the British monarchy and precedes by a few decades the *de facto* adoption of the Gold Standard monetary regime in 1717.


40
30
20
10
0
-10
-20
-30
1660
1803
1923
2016

5. EMPIRICAL RESULTS

The first model estimated:

$$y_t = \beta_0 + \beta_1 t + x_t, \qquad t = 1, 2, ...$$

$$(1 - L)^{d_1} x_t = u_t, \quad t = 1, 2, ...$$

assuming that the error u_t is:

a) White noise

b) Autocorrelated

	No regressors	An intercept	A linear time trend
White noise	0.24 (0.16, 0.36)	0.25 (0.17, 0.35)	0.22 (0.13, 0.35)
Bloomfield	0.02 (-0.04, 0.09)	0.02 (-0.04, 0.10)	-0.08 (-0.16, 0.02)

	No regressors	An intercept	A linear time trend
White noise	0.22 (0.13, 0.35)	-0.96071 (-2.56)	0.01405 (1.77)
Bloomfield	-0.08 (-0.16, 0.02)	-1.10705 (-2.41)	0.01482 (6.49)

The results indicate that a time trend is required regardless of the specification adopted for the error term. Under white noise residuals**,** the estimated value of *d* is 0.22, which is significantly higher than 0 and implies long-memory behaviour. When assuming that u_t is autocorrelated, the estimated value of *d* is approximately equal to -0.08 and the I(0) null hypothesis (short memory) cannot be rejected, namely a lower degree of persistence is found in this case.

Next we examine the possibility of structural breaks. We use first the Bai and Perron (2003) approach, and then the methods proposed by Gil-Alana (2008) and Hassler and Meller (2014), both specifically designed for the case of fractional integration.

The results indicate that there is a single break in the series around 1933. Therefore, we split the sample into the two corresponding subsamples, and estimate the differencing parameter for each of them.

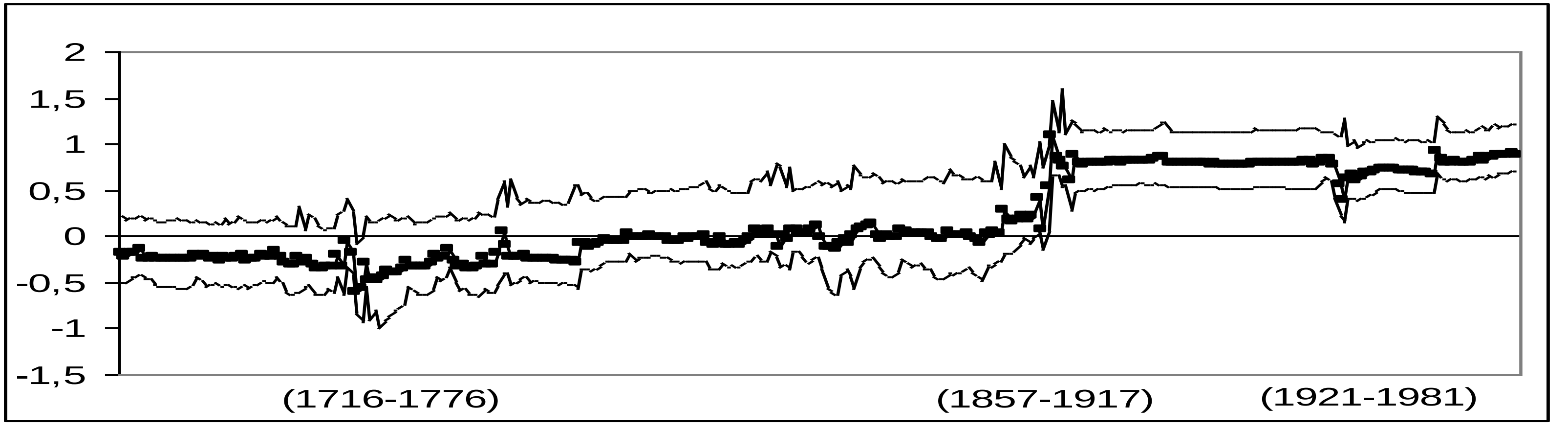
i) White noise errors			
	No regressors	An intercept	A linear time trend
(1660 - 1933)	0.12 (0.00, 0.29)	0.12 (0.00, 0.29)	0.12 (-0.01, 0.29)
(1934 - 2016)	0.74 (0.57, 1.00)	0.73 (0.57, 1.00)	0.73 (0.56, 1.00)

ii) Autocorrelated errors			
	No regressors	An intercept	A linear time trend
(1660 - 1933)	-0.27 (-0.35, -0.16)	-0.29 (-0.39, -0.15)	-0.32 (-0.42, -0.18)
(1934 - 2016)	0.37 (0.13, 0.65)	0.34 (0.13, 0.65)	0.34 (0.11, 0.65)

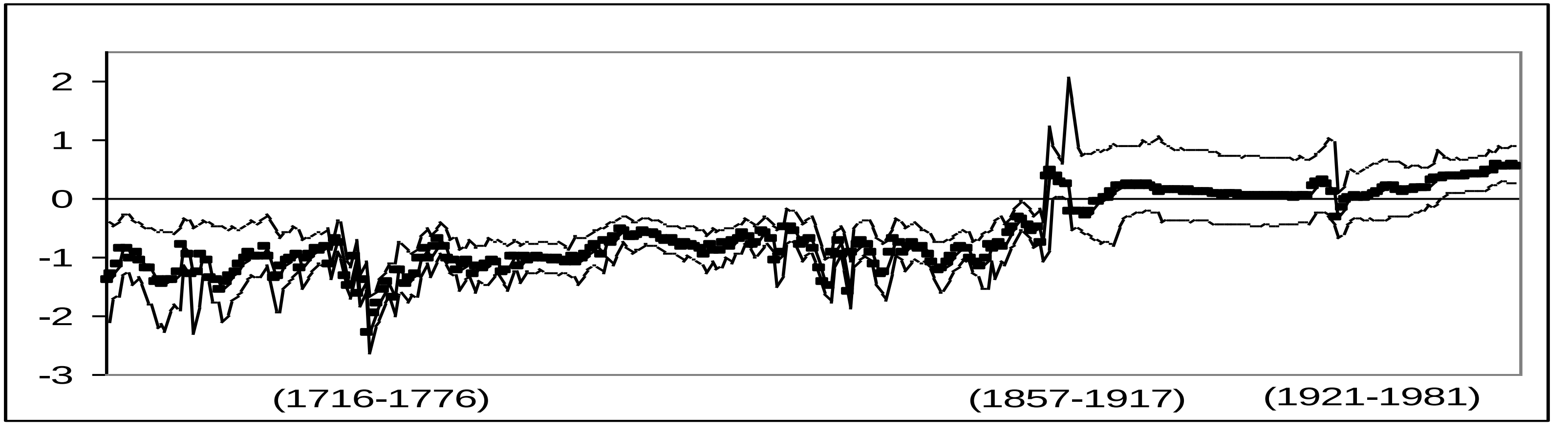
- There appears to be a significant increase in the degree of persistence after the break. In particular, under white noise errors, the value of *d* increases from 0.12 in the first subsample to 0.73 in the second one. When allowing for autocorrelation, the estimates are much smaller, but there is once again a sharp increase from 0.29 in the first subsample to 0.34 in the second one.

Next, we investigate whether or not the differencing parameter has remained stable over the whole sample as well as the subsamples considered. In Figure 3, we display the 60-year rolling window estimates of d, once again for the two cases of uncorrelated and autocorrelated errors.

i) No autocorrelation (white noise)



ii) Autocorrelation (Bloomfield)



The results are broadly consistent: inflation persistence was rather stable from 1660 till approximately 1776**.** Then, there was a slight increase till 1917-18, followed by a sharp jump to a stable higher level, and a further slight increase from 1981**.**

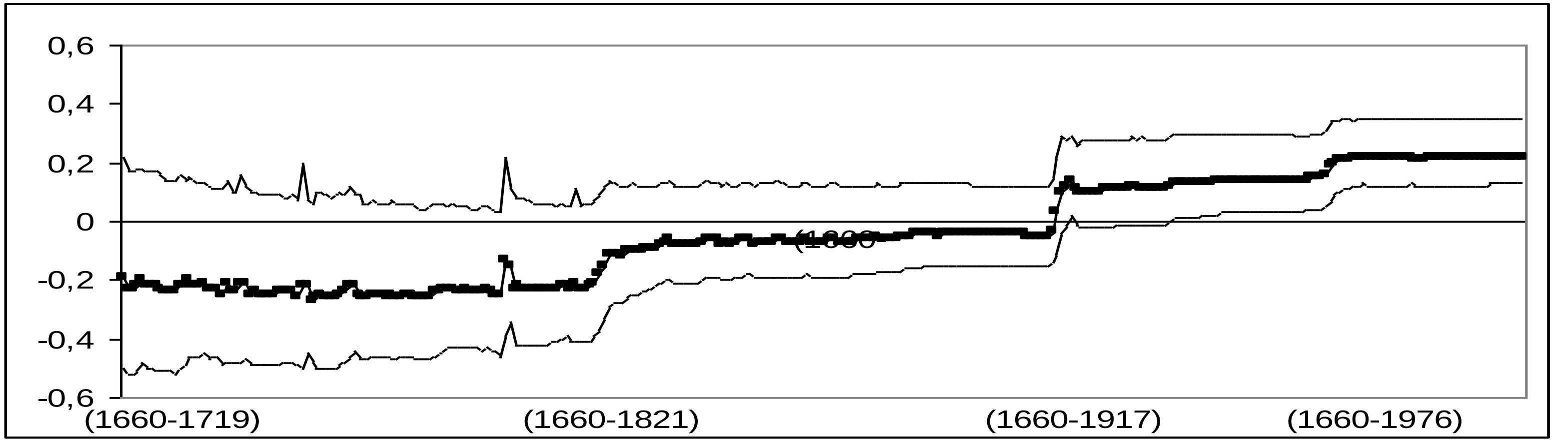
Given these results, we use once again Gil-Alana's (2008) method to test for breaks in the rolling-window estimates. The results are conclusively in favour of three breaks in these series, specifically, in 1776, 1917 and 1980.

i) White noise errors				
Period	*Dates*	*No regressors*	*An intercept*	*A linear trend*
1st subsample	1660 – 1776	-0.14 (-0.28, 0.10)	-0.13 (-0.30, 0.10)	**-0.25** **(-0.46, 0.07)**
2nd subsample	1777 – 1917	0.13 (-0.06, 0.47)	**0.13** **(-0.06, 0.45)**	0.13 (-0.07, 0.46)
3rd subsample	1918 – 1980	0.63 (0.42, 1.00)	**0.84** **(0.55, 1.11)**	0.85 (0.61, 1.11)
4th subsample	1981 – 2016	1.03 (0.57, 1.84)	**0.99** **(0.50, 1.63)**	0.99 (0.71, 1.84)
ii) Autocorrelated errors				
Period	*Dates*	*No regressors*	*An intercept*	*A linear trend*
2nd subsample	1777 – 1917	-0.47 (-0.64, 0.28)	-0.39 (-0.50, 0.23)	**-0.48** **(-0.62, 0.33)**
3rd subsample	1918 - 1980	0.13 (0.06, 0.44)	0.20 (-0.09, 1.08)	**-0.06** **(-0.39, 1.09)**
4th subsample	1981 - 2016	-0.47 (-0.97, 0.35)	-0.13 (-0.42, 0.21)	**0.00** **(-0.38, 0.95)**

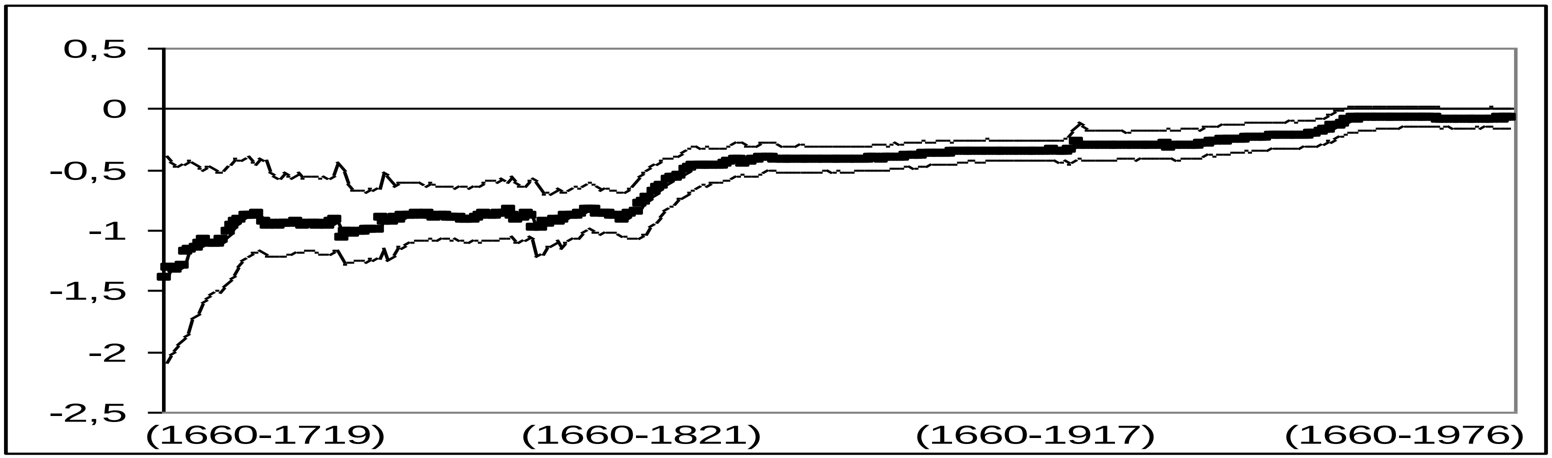
- The degree of persistence appears to have increased monotonically over time. With uncorrelated errors, the estimated value of *d* increases from -0.25 in the first subsample to 0.13 in the second, 0.84 in the third and 0.99 in the fourth one, and the I(1) null hypothesis cannot be rejected in the last two subsamples. With autocorrelation, d is initially equal to -0.89, and then moves over time to -0.48, -0.06 and finally 0.00; however, the corresponding confidence intervals are very wide and the differences between the estimated parameters are not statistically significant.

To complete the fractional integration analysis, we re-estimate *d,* this time recursively, starting with a sample of 60 observations, (1660-1719) and adding one observation at a time.

i) No autocorrelation (white noise)



ii) Autocorrelation (Bloomfield)



- The estimate of *d* remains around -0.2 from the first subsample till the one incorporating the year 1822; then it jumps, and remains stable (slightly below 0) till the subsample ending in 1917. Subsequently it increases, and it remains significantly above 0 thereafter.
- The recursive estimation under the assumption of autocorrelated disturbances yields a similar picture, although the estimated values of *d* are about 0.20 smaller in all cases

i) White noise errors				
Period	Dates	No regressors	An intercept	A linear trend
1st subsample	1660 – 1822	-0.05 (-0.16, 0.15)	-0.05 (-0.17, 0.16)	-0.11 (-0.29, 0.14)
2nd subsample	1823 – 1917	0.54 (0.27, 0.85)	0.51 (0.26, 0.81)	0.53 (0.30, 0.82)
3rd subsample	1918 – 1975	0.70 (0.45, 1.04)	0.77 (0.50, 1.07)	0.77 (0.48, 1.07)
4th subsample	1976 – 2016	0.71 (0.49, 1.13)	0.60 (0.40, 1.18)	0.78 (0.54, 1.16)
ii) Autocorrelated errors				
Period	Dates	No regressors	An intercept	A linear trend
1st subsample	1660 – 1822	-0.32 (-0.40, -0.22)	-0.37 (-0.45, -0.25)	-0.87 (-1.04, -0.57)
2nd subsample	1823 – 1917	-0.40 (-0.93, 0.37)	-0.34 (-0.74, 0.33)	-0.25 (-0.69, 0.40)
3rd subsample	1918 – 1975	0.12 (-0.28, 0.70)	0.13 (-0.32, 0.76)	-0.06 (-0.49, 0.75)
4th subsample	1976 – 2016	-0.04 (-0.38, 0.49)	-0.02 (-0.31, 0.32)	-0.05 (-0.32, 0.59)

The Gil-Alana (2008) tests on the recursive estimates of *d* imply that the break dates are 1822, 1917 and 1975. It can be seen that *d* increases from the first to the second and then the third subsample, whilst it remains stable in the last one. In particular, with uncorrelated disturbances, the estimates of *d* for the four subsamples are -0.05, 0.51, 0.77 and 0.78, respectively; therefore there is evidence of long memory ($d > 0$) in the last three subsample. Under the assumption of autocorrelation, the corresponding values are -0.87, -0.25, -0.06 and -0.05, and the I(0) null hypothesis cannot be rejected for any of the last three subsamples.

To summarise, our results suggest that UK inflation has been highly persistent since the end of WWI. The rolling- and recursive-window estimates of the fractional degree of integration *d* imply that the null hypothesis of a stable degree of persistence since WWI cannot be rejected. The slight increase in inflation persistence detected for the years after the 1980s by the rolling-window estimation is likely to reflect the fact that this method tends to overestimate the effects of the last regime change detected by the break tests.

UCSVO Analysis

Our findings for the postwar era imply stable persistence and are consistent with those of Pivetta and Reis (2006) and Stock and Watson (2007, 2010), who focus on the US.

The advantage of the Stock and Watson’s (2007, 2010) methodology is that it distinguishes between permanent and transitory shocks.

We apply the most recent version of their model (Stock and Watson, 2016) to UK data. This estimates the transitory component also including a correction for outliers.

Periods:

1. 1918-2016 (our break tests)
2. 1950-2016 (in line with literature)

Model:

- $y_t = \tau_t + \varepsilon_{y,t}$
- $\tau_t = \tau_{t-1} + \sigma_{\Delta\tau,t}\eta_t$
- $\varepsilon_{y,t} = \sigma_{y,t} s_t \zeta_t$
- $\Delta \ln \sigma_{y,t} = \gamma_y u_{y,t}$
- $\Delta \ln \sigma_{\Delta\tau,t} = \gamma_{\Delta\tau} u_{\Delta\tau,t}$,

where τ_t is a martingale trend, s_t generates outliers and ($u_{y,t}$, $u_{\Delta\tau,t}$) imply that (ζ_t , η_t, $u_{y,t}$, $u_{\Delta\tau,t}$)~*iidN*(0, I_4).

Bayesian estimation: we use an analogous strategy as Stock and Watson (2016), for Miles et al. (2016) show significant similarities between US and UK inflation.

- Priors

p: $B(\alpha, \beta)$, outliers occurring every 2 years;

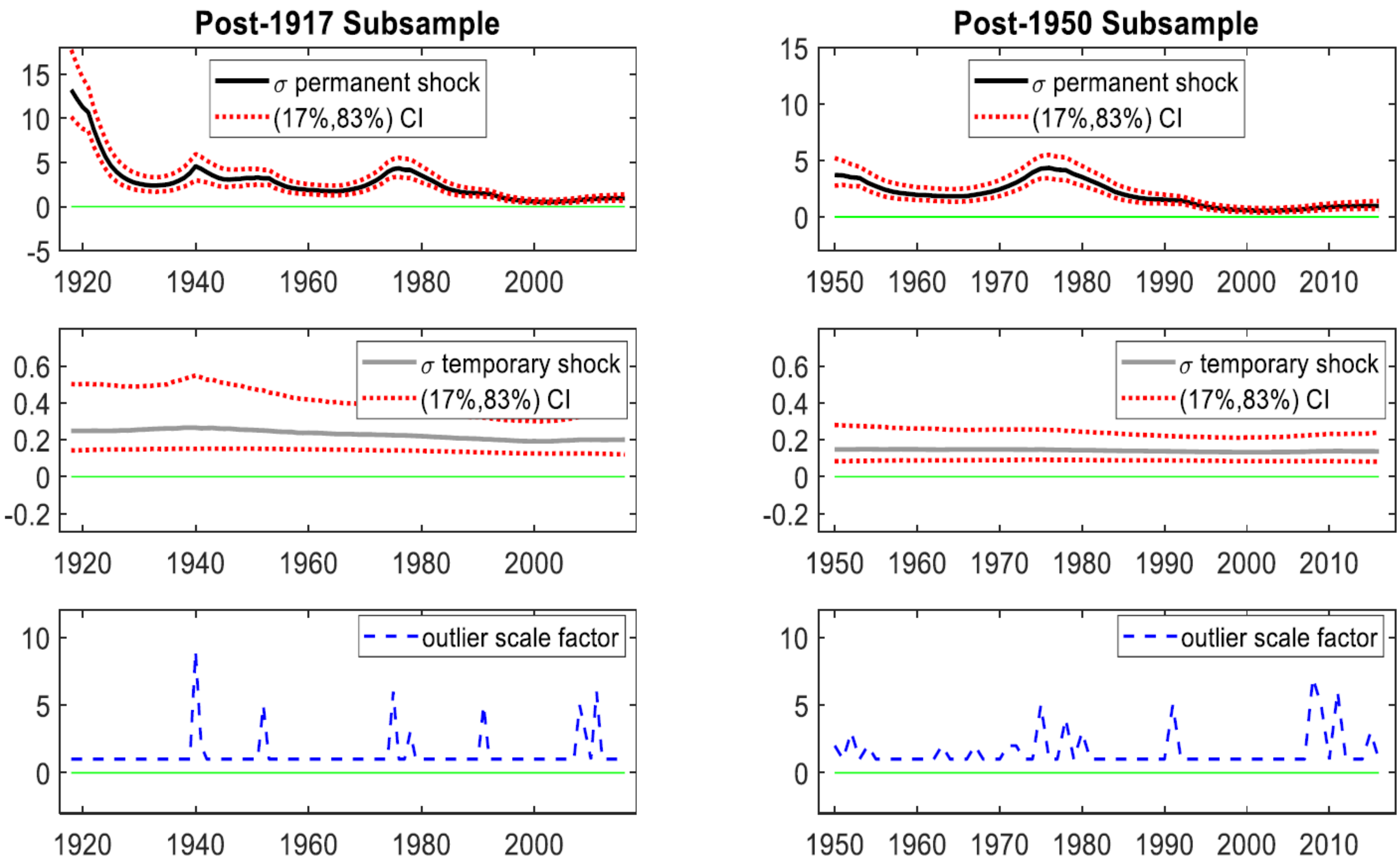
s: U[2,10];

γ_y, $\gamma_{\Delta\tau}$: uninformative uniform priors ($\ln\sigma_{y,t}$, $\ln\sigma_{\Delta\tau,t} \sim$ U[0,0.4]);

τ_0, $\Delta\ln\sigma_{y,0}$, $\Delta\ln\sigma_{\Delta\tau,0}$: independent diffuse priors.

- Posteriors

MCMC approximation with $\ln\eta_t^2$, $\ln\zeta_t^2 \sim \ln\chi_t^2$.


Post-1917 Subsample
Post-1950 Subsample
σ permanent shock
(17%,83%) CI
σ temporary shock
(17%,83%) CI
outlier scale factor
1920 1940 1960 1980 2000
1950 1960 1970 1980 1990 2000 2010

- The main change appears to have been the decline in the volatility of permanent shocks rather than in their persistence, which is consistent with our previous finding that the degree of fractional integration remained more or less the same after 1917.
- Thus, there is evidence of a reduction in the impact of permanent shocks on UK inflation during the inflation-targeting era. Transitory shocks have played a bigger role but their effects are difficult to manage .

6. CONCLUSIONS

- This paper uses historical data spanning the period from 1660 to 2016 to examine the degree of persistence in UK inflation. We use long-range dependence (parametric and non-parametric) techniques, more specifically fractional integration models. In addition we carry out break tests to detect any shifts in the degree of persistence and also run rolling-window and recursive regressions to examine its evolution over time. Finally, we estimate a UCSVO model to distinguish between permanent and transitory shocks to inflation.

- On the whole, the evidence suggests that UK inflation can be characterised as a long-memory stationary process with a relatively stable degree of persistence in the period following the Bretton Woods period, despite the adoption of different monetary regimes. In particular, there is no clear evidence that inflation targeting has brought about a lower degree of inflation persistence, contrary to what claimed in other studies, such as Osborn and Sensier (2009)

- The fact that these and related studies are based on relatively standard ARMA models and analyse a much shorter time series might account for the different findings. The UCSVO estimates suggest that inflation targeting might have reduced to some extent the impact of permanent shocks on inflation; however, it is their lower volatility as well as the presence of some sizeable outliers that appear to account for the break detected in the early 1980s.
- Future work will aim to investigate possible nonlinearities, for instance applying the method of Cuestas and Gil-Alana (2016) based on Chebyshev polynomials in time.