EUROPEAN CENTRAL BANK

WORKING PAPER SERIES

NO. 414 / NOVEMBER 2004

EUROSYSTEM INFLATION PERSISTENCE NETWORK

INFLATION PERSISTENCE IN THE EUROPEAN UNION, THE EURO AREA, AND THE UNITED STATES

by Gregory Gadzinski
and Fabrice Orlandi

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INFLATION PERSISTENCE IN THE EUROPEAN UNION, THE EURO AREA, AND THE UNITED STATES [1]

by Gregory Gadzinski [2]
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In 2004 all publications will carry a motif taken from the €100 banknote.

1 This paper was prepared as part of the works of the Eurosystem Inflation Persistence Network (IPN). We are grateful to the IPN participants for useful discussions. The paper also benefited from comments by J-L. Diaz del Hoyo, F. Engels, E. Girardin, N. Vidalis, seminar participants at the ESSIM 2004 conference and an anonymous referee. The views expressed in this paper are those of the authors and do not necessarily reflect those of the European Central Bank (ECB).
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The Eurosystem Inflation Persistence Network

This paper reflects research conducted within the Inflation Persistence Network (IPN), a team of Eurosystem economists undertaking joint research on inflation persistence in the euro area and in its member countries. The research of the IPN combines theoretical and empirical analyses using three data sources: individual consumer and producer prices; surveys on firms' price-setting practices; aggregated sectoral, national and area-wide price indices. Patterns, causes and policy implications of inflation persistence are addressed.

The IPN is chaired by Ignazio Angeloni; Stephen Cecchetti (Brandeis University), Jordi Galí (CREI, Universitat Pompeu Fabra) and Andrew Levin (Board of Governors of the Federal Reserve System) act as external consultants and Michael Ehrmann as Secretary.

The refereeing process is co-ordinated by a team composed of Vítor Gaspar (Chairman), Stephen Cecchetti, Silvia Fabiani, Jordi Galí, Andrew Levin, and Philip Vermeulen. The paper is released in order to make the results of IPN research generally available, in preliminary form, to encourage comments and suggestions prior to final publication. The views expressed in the paper are the author's own and do not necessarily reflect those of the Eurosystem.

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ISSN 1561-0810 (print)
ISSN 1725-2806 (online)

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Abstract:

In this paper we report results on inflation persistence using 79 inflation series covering the EU countries, the euro area and the US for five different inflation variables. The picture that emerges is one of moderate inflation persistence across the board. In particular we find euro area inflation persistence to be broadly in line with US inflation persistence. The issue of allowing for intercept dummies in the underlying inflation models is found to be of paramount importance to avoid overestimation of the level of persistence. The use of alternative measures of persistence is found to be commendable on the grounds that they complement each other in practice.

Keywords: Inflation dynamics; structural change; median unbiased estimates

JEL classification: E31 E52 C22 C12

NON-TECHNICAL SUMMARY

The study of inflation is of fundamental importance since this variable can have far-reaching implications for the economy both in terms of economic efficiency and wealth distribution. At a practical level, this is reflected in the mandate of many monetary authorities to maintain price stability. In relation to their objective, such institutions pay special attention to the development of tools enabling them to better understand and monitor the properties of inflation dynamics. The present paper adds to a recent literature committed to the study of one such property, namely the persistence of inflation.

Inflation persistence can be defined as the tendency of inflation to converge slowly (or sluggishly) towards the central bank's inflation objective, following changes in the objective or various other shocks. Documenting this property of inflation is important for a number of reasons such as its relevance for forecasting. Following a shock to the inflation process, the forecasting performance can rest heavily on the forecaster's ability to adequately predict the pattern of absorption of that shock. The study of inflation persistence can also provide a useful input into the analysis of cross-country inflation differentials by helping distinguish between structural and shock-induced inflation differentials and provide tools to gauge the likely duration of episodes of inflation differentials.

Our approach produces measures of persistence that are based on univariate models of inflation. Accordingly, the origin of the shock cannot be taken into account. Rather, the persistence results relate to the absorption of a 'typical shock'. This framework is however conveniently consistent with most of the related empirical literature. It also has the merit of providing concise results on persistence and constitutes a useful initial step in the gathering of information on the persistence of inflation series. To be precise, we construct two different measures of persistence on the basis of these univariate models, namely the sum of the autoregressive coefficients and the half-life indicator. These two indicators can offer complementary information under certain circumstances. Our univariate models feature structural breaks in order to avoid spurious overestimation of the persistence parameter. Importantly, such univariate dynamic models with break are shown to be adequate tools to accommodate trending patterns such as a period of desinflation.

This paper provides empirical results on the level of inflation persistence for the EU countries, the euro area and the US using five different inflation series. The dataset comprises 79 quarterly inflation series covering the following countries and variables:

* Belgium, Germany, Denmark, Greece, Spain, France, Ireland, Italy, Luxembourg, Netherlands, Austria, Portugal, Finland, Sweden, United Kingdom, Euro Area, United States

* GDP inflation, CPI inflation, Core inflation, HICP inflation, private consumption inflation, services inflation

Our general finding points to a low level of inflation persistence across the board over our sample period, 1984:1 onwards. Differences across variables are generally non-negligible with Core inflation usually displaying higher persistence than the other variables and, at the other extreme, GDP inflation showing low levels of persistence for most countries. The analysis also suggests that the euro area and the US inflation series display a comparable level of persistence. In addition, our results point to the need to account for a structural break in the inflation series in most cases. The break typically occurs at the beginning of the 90s and entails a structural decline in the average level of inflation. The omission of such breaks is shown to affect substantially the results leading to substantially higher levels of measured persistence.

1. Introduction

The study of inflation is of fundamental importance since this variable can have far-reaching implications for the economy both in terms of economic efficiency and wealth distribution. At a practical level, this is reflected in the mandate of many monetary authorities to maintain price stability. In relation to their objective, such institutions pay special attention to the development of tools enabling them to better understand and monitor the properties of inflation dynamics. The present paper adds to a recent literature committed to the study of one such property, namely the persistence of inflation.

Inflation persistence can be defined as the tendency of inflation to converge slowly (or sluggishly) towards the central bank's inflation objective, following changes in the objective or various other shocks. Documenting this property of inflation is important for a number of reasons such as its relevance for forecasting. Following a shock to the inflation process, the forecasting performance can rest heavily on the forecaster's ability to adequately predict the pattern of absorption of that shock. The study of inflation persistence can also provide a useful input into the analysis of cross-country inflation differentials by helping distinguish between structural and shock-induced inflation differentials and provide tools to gauge the likely duration of episodes of inflation differentials.

In the field of the analysis of inflation persistence, recent developments have challenged the view that it should be conceived as a time-invariant phenomenon. Authors have argued that changes in the level of credibility of the central bank's commitment to attain their objective, should have an effect on the relative importance of forward-looking and backward-looking terms in inflation models such as the New-Keynesian-Phillips-Curve (see Taylor (1998), Sargent (1999)). This in turn could have an impact on the level of inflation persistence. Relaxing the assumption of inflation persistence time-invariance implies that high inflation persistence, as witnessed over the period 1965-85 in many countries, need not be an intrinsic feature of these economies (see Bordo and Schwartz (1999), Erceg and Levin (2002), Goodfriend and King (2001), Benati (2003)).

Thus in practice, such theories being correct, some variation in the level of inflation persistence should be present in the data given the monetary policy changes witnessed over history. A growing literature has emerged accumulating empirical evidence to test the hypothesis of inflation persistence time-variance. Supporting empirical evidence for this claim has been gathered (see Barsky (1987), Evans and Wachtel (1993), Brainard and Perry (2000), Taylor (2000), Kim et al. (2001), Cogley and Sargent (2001), Ravenna (2000), Benati (2003), Levin and Piger (2004)). However, a debate surfaced following conflicting results pointing to a constancy of inflation persistence over the more recent past notwithstanding the existence of changes in the monetary policy environment over that same period (see Pivetta and Reis (2004), Stock (2001), O'Reilly and Whelan (2004)).

The present paper adds to this empirical literature by providing further results on the level of inflation persistence for the EU countries, the euro area and the US using six different inflation series (GDP deflator, CPI deflator, Core inflation, HICP inflation, Private consumption inflation and Services inflation). The analysis follows the "classical" approach as laid down in Levin and Piger (2004). In particular, we pay special attention to the occurrence of a structural break in the series to avoid spurious overestimation of the persistence level (see Perron (1989) and Levin and Piger (2004)). This approach produces measures of persistence that are based on univariate models of inflation. Accordingly, the origin of the shock cannot be taken into account. Rather, the persistence results relate to the absorption of a 'typical shock'. This framework is however conveniently consistent with most of the related empirical literature. It also has the merit of providing concise results on persistence and constitutes a useful initial step in the gathering of information on the persistence of inflation series. To be precise, we construct two different measures of persistence on the basis of these univariate models, namely the sum of the autoregressive coefficients and the half-life indicator. These two indicators can offer complementary information under certain circumstances.

Our general finding points to a low level of inflation persistence across the board over our sample period, 1984:1 onwards. The results display a fair amount of diversity across countries and across variables. Anecdotally, for GDP inflation series the hypothesis of absence of persistence altogether cannot be rejected in many cases. Overall, the analysis suggests that the euro area and the US inflation series display comparable level of persistence.

The paper is organised as follows. In section 2 we provide methodological details on the approach used to produce all the results reported in the paper. Section 3 then proceeds to the presentation of the results with a special focus on euro area and US results being the subject of section 4. The annex reports additional tables and charts and provides preliminary results for the euro area and the US for an extended sample spanning the period 1970-2003.

2. Defining and Measuring Inflation Persistence

Our two measures of persistence are based on the following equation.

$$\pi_t = \mu_0 + \mu_1 \cdot D_t + \rho \cdot \pi_{t-1} + \sum_{i=1}^{k-1} \alpha_i \cdot \Delta\pi_{t-i} + \varepsilon_t \qquad (1)$$

The variable D_t allows for the presence of a structural break in the intercept to avoid spurious overestimation of the persistence level (see Perron (1989) and Levin and Piger (2004)). Such breaks are assumed to take the form of permanent shifts so that, assuming a break occurs at date T, then D_t equals zero for $t<T$ and 1 for $t\geq T$.

The choice of a particular deterministic component can have a strong bearing on the result of the persistence analysis (see Marques (2004)). As such, it is important to emphasise that in the present analysis this deterministic component is not treated as a free variable. Instead, its inclusion in the specification of Eq.1 is based on a formal procedure that tests for the existence of such an event. It is also important to stress that the form of the deterministic component considered in the present analysis, i.e. a permanent shift dummy, displays features that are useful to accommodate the relevant events. To illustrate this, note that following the occurrence of an intercept break, the process does not jump to its new unconditional mean instantly. Rather, the process moves towards it in a sluggish manner, which is a reflection of the dynamics embedded in the equation. Practically, in a dynamic equation, a shift in the mean can be pictured as a permanent shock to the inflation process. As such, the pattern of its impact on the inflation process can be formally obtained from the first row of the F^j matrix in:

$$\xi_t = F\xi_{t-1} + v_t \qquad (2)$$

where F is constructed out of the autoregressive coefficients of the AR process corresponding to the ADF Eq.1, ξ_t is a vector comprising contemporary inflation and its (k-1) lags and v_t is a vector formed with ε_t and a set of (k-1) zeroes.

The total impact of the change in the mean is described as follows:

$$\sum_{j=0}^{\infty} \frac{\partial \pi_{t+j}}{\partial x_t} = \frac{\partial x_t}{1-\rho} \qquad (3)$$

where ∂x_t is the permanent shock to the process (i.e., the shift in the mean as measured by the dummy D_t in Eq.1) and ρ is as in Eq.1.

Interestingly, Eq.2 and Eq.3 imply that the swiftness of the movement to reach the new mean following the occurrence of a break is a function of the parameter ρ, namely of the degree of persistence of the process itself. This feature of auto-regressive processes bears some useful resemblance with theoretical models positing a sluggish adjustment to permanent shifts in the monetary objective (see e.g., Erceg and Levin (2000)). In addition, this feature also makes auto-regressive models that feature intercept breaks adequate tools to model temporary trending patterns observed in some inflation series such as periods of desinflation.

Our first measure of persistence is the parameter ρ in the above equation. Note that this parameter also corresponds to the sum of the coefficients on the lagged dependant variables when the equation is recast in AR form.[1] The parameter ρ is chosen as a measure of persistence as it captures important features of the impulse response function (IRF), which itself characterises the pattern of absorption of shocks hitting the inflation process over time. In particular, the cumulative effect of a shock on inflation, i.e. the sum of the deviations of inflation in each period following a shock, is given by $1/(1-\rho)^2$. Thus, the larger the ρ, the larger the cumulative impact of the shock will be on inflation. Assuming that the patterns of the shock absorption are broadly similar for all countries then a higher cumulative impact implies a longer lasting shock. If however, the countries display very different patterns of shock dynamics, such a conclusion can not be drawn. In that case, a country could absorb shocks more rapidly and still display a higher level of cumulative impact due to high impacts taking place in the early periods following the occurrence of a shock. In such circumstances, our measure of persistence should be understood as referring more generally to the relative size across countries of the overall effect of a shock on inflation, rather than providing information on the relative timing of shock absorption across countries.

In view of the potential limitations of the parameter ρ, we report a second persistence indicator, namely the half-life indicator (HL). This indicator measures the number of periods during which a temporary shock displays more than half of its initial impact to the process. Clearly, this measure is related to the IRF of Eq.1. However, it focuses on a different characteristic of the IRF, compared to the ρ parameter. In other words, both measures attempt at summarising the information contained in the IRF. Formally the HL indicator can be described as in Eq.4 below. In words, the formula implies that we check whether the IRF is below 0.5 at period j=30; if so, we continue decrementing j until we find the point at which the IRF is higher than 0.5; that value of j defines the half-life of the series.

$$HL_{0.5} = \underset{j \in J}{Sup}\left(\frac{\partial \pi_{t+j}}{\partial e_t}\right) \geq 0.5 \text{ or equals J if the previous set is empty} \qquad (4)$$

where $HL_{0.5}$ is our HL indicator, ∂e_t is a temporary shock to the inflation process and J is arbitrarily set to 30 in the empirical part of our analysis.

[1] For discussions and illustrations on that approach see, for instance, Andrews and Chen (1994), Batini (2002), Kim et al. (2001), Levin and Piger (2004), Pivetta and Reis (2002), Taylor (2000).

[2] The concept of cumulative impact of a shock is usually referred to as the cumulative impulse response function (CIRF) and is well documented in Hamilton (1994).

The explicit reference to the timing of the absorption of shocks in the HL indicator can provide useful complementary information to the results provided by the ρ parameter, especially in the event of stark differences in the shape of the IRFs across countries. Indeed, though the HL cannot totally offset the drawbacks of the ρ parameter measure (see Pivetta and Reis (2002)) combining the two indicators can reduce the risk of foregoing entirely all relevant information pertaining to the differences in the shape of the IRFs across countries.

Concerning the estimation of Eq.1, it proceeds as follows. An initial regression is estimated, which excludes any intercept break. Lag length is fixed according to the AIC results. This regression is used to perform the intercept break analysis. In case a break is detected a new regression is specified, which includes that break, and the lag length selection procedure is repeated for that regression. The Quandt (1960) test statistic is used to detect the presence of a break in the intercept, using a 10% significance threshold relying on p-values generated using the fixed-regressor bootstrap approach as in Hansen (2000 and 2001) and allowing for heteroscedasticity under the null. The latter approach was chosen on the basis of its improved performance compared to the non-bootstrap version of the test in small samples, (for a discussion see Hansen (2000, 2001)). The search procedure for the break-date discarded the initial 15% of the sample and the final 15% of the sample.[3] Furthermore, we test for the presence of a break on all parameters of the models, conditional on a break in the intercept. This test uses a 10% significance threshold, follows the procedure described in Hansen (2000) and allows for heteroscedasticity under the null.[4]

From there, we obtain a median-unbiased estimate for ρ using the grid-bootstrap procedure by Hansen (1999). We allow for heteroscedasticity in the bootstrap procedure by using the De Haan and Levin (1997) heteroscedastic-consistent standard error estimator and scaling the bootstrap residuals by the actual residuals from the OLS equation. The HL indicator requires the IRF to be generated together

---

[3] Note that in addition to allowing for a break in the series, inflation series have also been treated for the presence of outliers as described in Table 7.

[4] Clark (2003) performed a simulation study and found that the bootstrap method of Diebold and Chen (1996) provided somewhat better finite sample properties than the fixed-regressor bootstrap of Hansen (2000); however, Levin and Piger (2004) found that the two methods yielded essentially identical results in practice.

with its confidence interval. The latter can be computed in different ways. The traditional methods include the asymptotic interval (see Lütkepohl (1990)), the Monte Carlo integration method (see Sims and Zha (1995)) and the bootstrap interval (see Runkle (1987)). However, generating confidence intervals using nonlinear re-parameterisations of AR processes can produce very erratic behaviours (see Berkowitz and Kilian (2000)). To circumvent this problem, we use the relevant estimates from the grid-bootstrap technique and project these onto the impulse responses by means of the nonlinear function defining the impulse at each date. This procedure is based on the percentile bootstrap method, which has been shown to be transformation-respecting (see Hall (1992)).

3. The results

This section reports on the estimation of the two persistence measures described above: the ρ parameter and the HL indicator. The dataset comprises 79 quarterly inflation series covering the following countries and variables[5]:

* Belgium, Germany, Denmark, Greece, Spain, France, Ireland, Italy, Luxembourg, Netherlands, Austria, Portugal, Finland, Sweden, United Kingdom, Euro Area, United States
* GDP inflation, CPI inflation, Core inflation, HICP inflation, private consumption inflation, services inflation

The sample period for each series is reported in Table 9 in the Annex. Series have been treated for the presence of outliers as described in Table 10 in the Annex.

3.1 Estimation of the univariate inflation models

The lag structure adopted for Eq.1 for each series is reported in Table 11 in the Annex. The results of the structural break analysis for the case of a break in the intercept are summarised in Table 1 below, which reports the date of any significant break. In most cases these results point to the need to account for a break in the intercept. The break typically occurs at the beginning of the 90s and appears to correspond, loosely speaking, with the adoption of inflation targeting in the case of the UK, Finland, and Sweden. In the case of Spain, it could be argued that the identified break occurs at a date relatively early compared with the announcement of inflation targeting. All in all, the break dates appear to be fairly comparable across series. A notable exception is when a country does not uniformly display a break for all its variables but only for a subset of them. This inconsistency could potentially lead to the questioning of the validity of ascribing a monetary interpretation to the occurrence of such breaks given that they are not detected in all variables. Alternatively, this could be interpreted as evidence against the use of a purely statistical approach for the detection of structural breaks. Possibly, the use

[5] See Table 8 in the Annex for further details on the data.

of ad hoc information to assist inference or the recourse to multivariate analysis is needed to rid the analysis of such inconsistencies. Puzzling results also relate to the breaks identified for Dutch CPI inflation, HICP inflation, Core inflation and Private consumption inflation (n.b. similar breaks for the Netherlands, at the end of the 1980s, are reported in Benati (2003) and Levin and Piger (2004)). The break found for Dutch GDP in 1999:2 is puzzling as well to the extent that an 'EMU effect' would have required finding a similar break for a greater number of series. To summarise, though intuitively meaningful in most cases, some breaks remain difficult to explain at this stage. In that respect, it is worth recalling that the primary aim of allowing for such a break is a very practical one, namely avoiding overestimation of the persistence parameter in the event of such a break being present in the data, whatever its origin.

Table 1: Structural Break in intercept

	GDP INFLATION	CPI INFLATION	CORE INFLATION	HICP INFLATION	PRIV. CONS. INFLATION	SERVICES INFLATION
Belgium	1994:3**	--	--	--	--	--
Germany[a]	1994:4**	--	--	--	--	NA
Denmark	1990:2**	1990:1**	1990:1**	1990:1**	NA	--
Greece	1993:3**	1993:2**	NA	1992:4**	NA	NA
Spain	1992:2**	--	1993:3**	--	1992:1*	1993:4**
France	--	1992:2**	1992:2**	1992:2**	1993:3**	1992:4*
Ireland	--	--	--	--	NA	NA
Italy	1991:2**	1995:3**	--	1995:3**	1995:3**	1993:1**
Luxembourg	NA	--	--	--	NA	NA
Netherlands	1999:2*	1988:4*	1988:1**	1988:4*	1988:2**	NA
Austria	1995:3**	--	--	--	--	NA
Portugal	NA	1992:2**	1992:3**	1991:3*	NA	NA
Finland	1990:4*	1991:2**	1991:2**	1993:2**	1993:2	NA
Sweden	1993:2**	1993:2**	1993:3**	1990:4**	1991:3**	NA
United Kingdom	1992:1**	1990:4**	1990:4**	1990:4**	1991:1**	NA
Euro area	1993:2**	1993:2**	1993:2**	1995:4**	NA	NA
United States	1991:2**	1991:1**	1991:2**	NA	1991:3	NA

Notes: Results in the table refer to the implementation of the Hansen (2000) break-test procedure (see Section 2 for further details). NA, --, * and ** respectively stand for: non-available data, non-detection of a significant intercept break, significant intercept break at 10% level and significant intercept break at 5% level. (a) Use of an alternative series for German CPI, i.e. West German and Pan German data spliced in 1995 (instead of 1991), in an attempt to correct for a series of rent control interventions implemented over the period 1991-1995, does not alter the result for German CPI (no intercept break).

Table 2 below reports the annualised change in the mean of inflation implied by the structural break in the intercept. The size of the change is generally remarkably similar across inflation series. In all cases, the break in the intercept implies a decline in average inflation. The exceptions turn out to be the "anomalous" breaks referred to in the previous paragraph concerning the Dutch series.

Table 2: Change in mean inflation (annualised) after structural break in intercept

	GDP INFLATION	CPI INFLATION	CORE INFLATION	HICP INFLATION	PRIV. CONS. INFLATION	SERVICES INFLATION
Belgium	-1.83	--	--	--	--	--
Germany	-1.66	--	--	--	--	NA
Denmark	-2.40	-2.04	-2.64	-2.19	NA	--
Greece	-10.55	-13.00	NA	-12.75	NA	NA
Spain	-3.67	--	-3.75	--	-1.09	-1.24
France	--	-1.78	-2.04	-2.05	-1.86	-0.59
Ireland	NA	--	--	--	NA	NA
Italy	-4.07	-3.04	--	-3.16	-3.80	-1.08
Luxembourg	NA	--	--	--	NA	NA
Netherlands	+1.91	+2.67	+2.77	+2.59	+3.84	NA
Austria	-1.99	--	--	--	--	NA
Portugal	NA	-7.71	-7.57	-7.96	NA	NA
Finland	-4.08	-3.45	-4.13	-2.88	-0.74	NA
Sweden	-4.90	-4.29	-4.32	-4.17	-5.63	NA
United Kingdom	-3.20	-3.38	-3.61	-3.85	-9.53	NA
Euro area	-2.61	-2.00	-2.56	-1.48	NA	NA
United States	-1.40	-1.80	-2.58	NA	-2.75	NA

Notes: Results reported in the table compute the change in the unconditional mean implied by the change in the intercept reported in Table 1 (see section 2 for further details). NA, --, * and ** respectively stand for: non-available data, non-detection of a significant intercept break, significant intercept break at 10% level and significant intercept break at 5% level.

Tests for the existence of a break in the ρ parameters (at an unknown date), conditional on the existence of a break in the intercept, are reported in Table 3 below.[6] It is important to realise that any uncovered variation in the level of persistence could be related to a vast array of phenomenon as the univartiate framework used in this paper does not control for all such events. Extending the framework to allow for multivariate analysis appears particularly warranted for studying issues of persistence time-variance.

For a number of series, the ρ parameter appears to break at the end of the 1990s. It is tempting to interpret this as a first evidence of an EMU effect. At this stage, this interpretation is tentative as further work would be needed to confirm these preliminary findings. Note, for instance, that the break at the end of the 1990s is missing for many series. Also, some authors (see Hendry (2000)) have signalled that such breaks entailing a change in the dynamic of a process are typically less straightforwardly detectable than breaks unambiguously involving a change in the unconditional mean, such as a break in the intercept.

[6] Note that these results are not required to for the estimation of Eq.1 since the specification solely allows for the presence of a break in the intercept.

Table 3: Structural break in the ρ parameters conditional on a break in intercept

	GDP INFLATION	CPI INFLATION	CORE INFLATION	HICP INFLATION	PRIV. CONS. INFLATION	SERVICES INFLATION
Belgium	--	--	--	--	2000:2*	--
Germany[a]	--	--	--	--	1999:1*	NA
Denmark	--	--	--	--	NA	--
Greece	1988:3**	--	NA	--	NA	NA
Spain	--	--	1999:2**	--	--	--
France	--	--	--	--	--	1998:2*
Ireland	--	--	--	--	NA	NA
Italy	1999:4*	--	--	1998:2**	1999:1**	--
Luxembourg	NA	--	--	2000:2*	NA	NA
Netherlands	--	--	--	--	1998:1**	NA
Austria	--	--	--	--	--	NA
Portugal	NA	--	--	1990:1*	NA	NA
Finland	--	--	1989:2*	--	--	NA
Sweden	--	--	1993:3*	--	--	NA
United Kingdom	--	1999:3**	--	--	--	NA
Euro area	--	--	2001:1*	2000:4**	NA	NA
United States	--	--	2000:4*	NA	--	NA

Notes: Results in the table refer to the implementation of the Hansen (2000) break-test procedure (see Section 2 for further details). NA, --, * and ** respectively stand for: non-available data, non-detection of a significant break in the ρ parameter, significant break in the ρ parameter at 10% level and significant break in the ρ parameter at 5% level. (a) Use of an alternative series for German CPI, i.e. West German and Pan German data spliced in 1995 (instead of 1991), in an attempt to correct for a series of rent control interventions implemented over the period 1991-1995, does not alter the result for German CPI (no break in the ρ parameter).

Finally, a joint test for the existence of a break in all the parameters of the equation (at an unknown date), conditional on the existence of a break in the intercept, is reported in Table 4 below. Such a test can be seen as an overall stability check. All in all, the results do not point to the need to account for such instability. Note that, in the course of the analysis it appeared that adjusting for the presence of outliers (e.g., in the event of a VAT change, see details in Table 10) enhanced the stability of the inflation equations.

Table 4: Structural break in all AR parameters conditional on a break in intercept

	GDP INFLATION	CPI INFLATION	CORE INFLATION	HICP INFLATION	PRIV. CONS. INFLATION	SERVICES INFLATION
Belgium	1991:4**	--	--	--	1989:1**	--
Germany[a]	--	--	1999:2**	--	1999:2**	NA
Denmark	--	--	--	--	NA	--
Greece	1991:3**	--	NA	--	NA	NA
Spain	--	--	1999:3**	--	--	--
France	--	--	--	1988:2**	--	--
Ireland	NA	--	--	--	NA	NA
Italy	--	--	--	--	--	--
Luxembourg	NA	--	--	2000:3*	NA	NA
Netherlands	--	--	--	--	--	NA
Austria	--	--	--	--	--	NA
Portugal	NA	--	1993:1**	1990:1*	NA	NA
Finland	--	--	--	--	--	NA
Sweden	--	--	--	--	--	NA
United Kingdom	--	1995:4**	--	1989:3**	--	NA
Euro area	--	--	--	--	NA	NA
United States	--	--	--	NA	--	NA

Notes: Results in the table refer to the implementation of the Hansen (2000) break-test procedure (see Section 2 for further details). NA, --, * and ** respectively stand for: non-available data, non-detection of a significant break in the AR parameters, significant break in the AR parameters at 10% level and significant break in the AR parameters at 5% level. (a) Use of an alternative series for German CPI, i.e. West German and Pan German data spliced in 1995 (instead of 1991), in an attempt to correct for a series of rent control interventions implemented over the period 1991-1995, does not alter the result for German CPI (no break in the AR parameters).

3.2 Results for the ρ parameter

The specification of Eq.1 for each country is based on the intercept break analysis presented in the previous sub-section. Results for the persistence parameter ρ, based on the estimation of Eq.1, are reported in Table 12 in the annex. They point to a relatively low level of persistence, as the ρ parameter median value is less than 0.7 in most cases (i.e., 55 out of the 79 series) and the random walk hypothesis is rejected for 57 out of the 79 series. Differences across variables are generally non-negligible. Core inflation usually displays higher persistence than the other variables. This could point to lower persistence of the components (i.e., energy and unprocessed food) of CPI that are excluded from its computation. At the other extreme, GDP inflation shows very low levels of persistence for most countries. In half the cases, absence of persistence cannot be ruled out, as the ρ parameter estimate is insignificantly different from zero (see also Figure 1 below). For a number of countries the median estimate is virtually at zero implying instantaneous absorption of shocks. The results available for a few Services inflation series point to levels of persistence broadly in line with the other inflation variables (see also **Figure 7** below). For the euro area and the US the level of persistence is more stable across variables than for most other countries (see also Figure 2 below). Finally, estimates also show noticeable differences across countries (see Figure 1-Figure 7 below). In addition, the ranking of countries by their level of persistence changes from one variable to another.

Figure 1: GDP Inflation, Estimated ρ persistence (90% interval), conditional on break in intercept

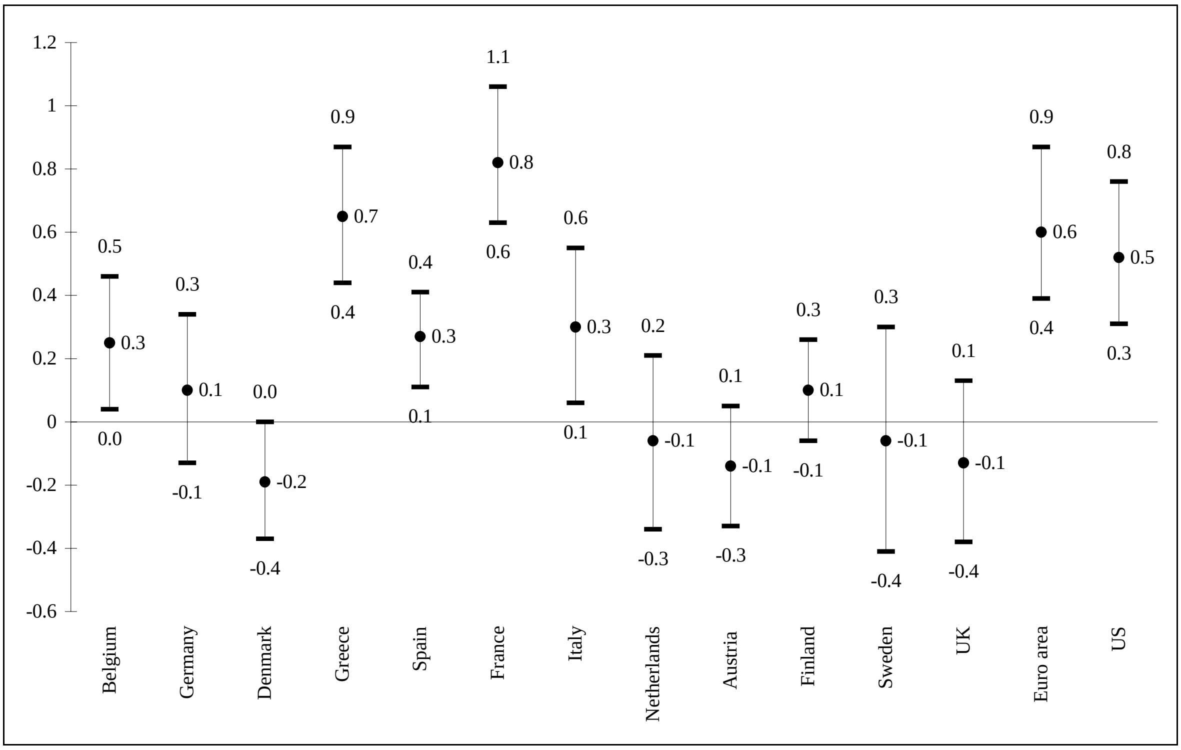


Figure 2: Estimated ρ persistence (90% interval), conditional on break in intercept, for the euro area and the United States

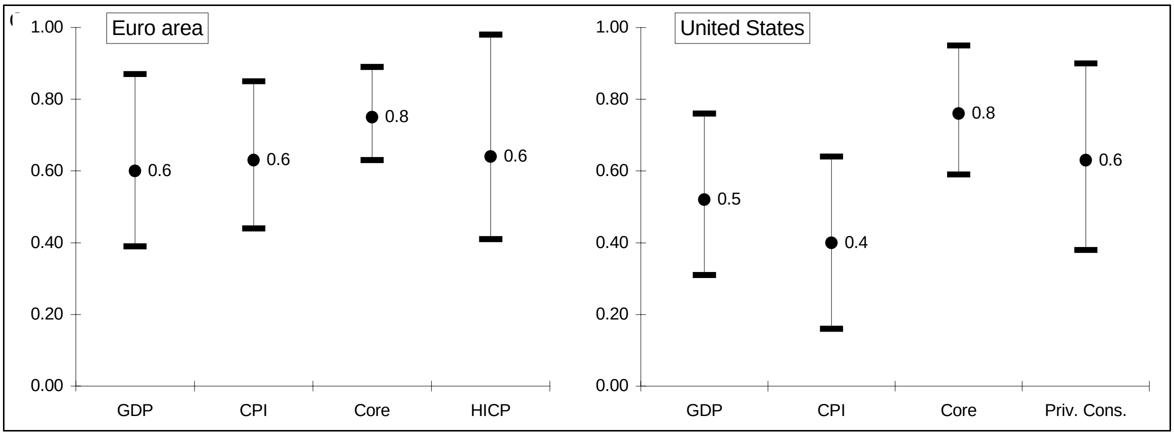


Figure 3: CPI Inflation, Estimated ρ persistence (90% interval), conditional on break in intercept

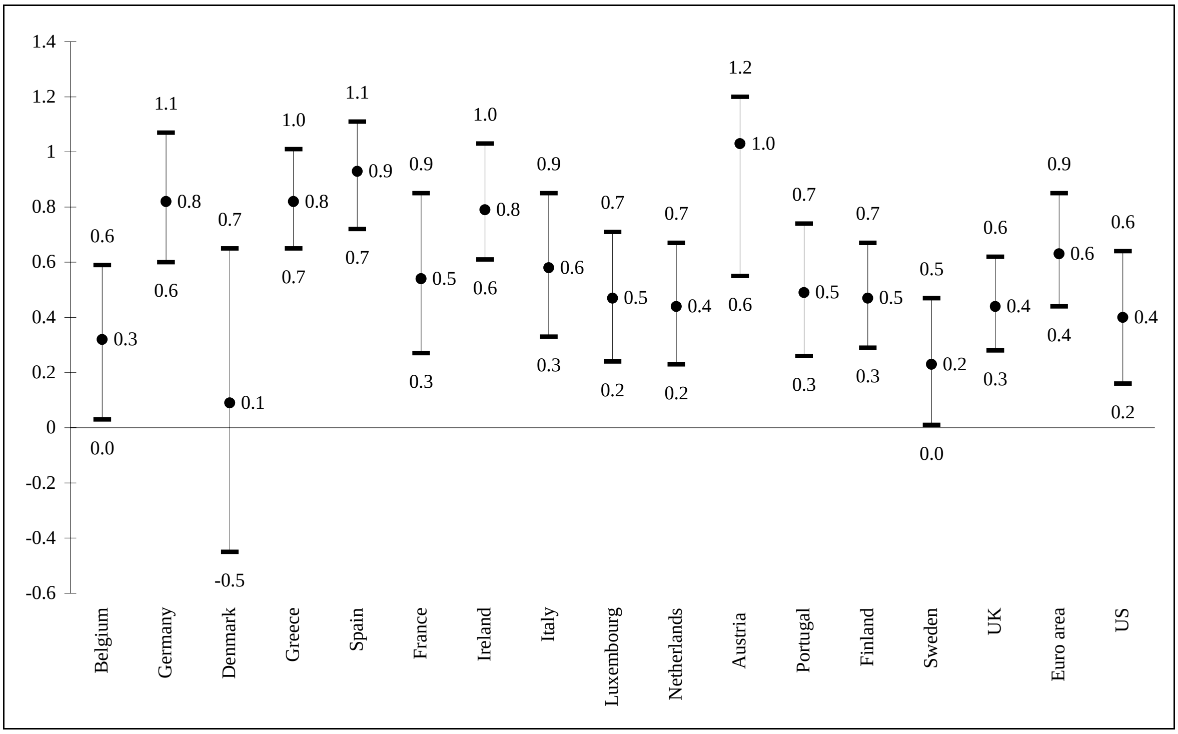


Figure 4: CORE Inflation, Estimated ρ persistence (90% interval), conditional on break in intercept

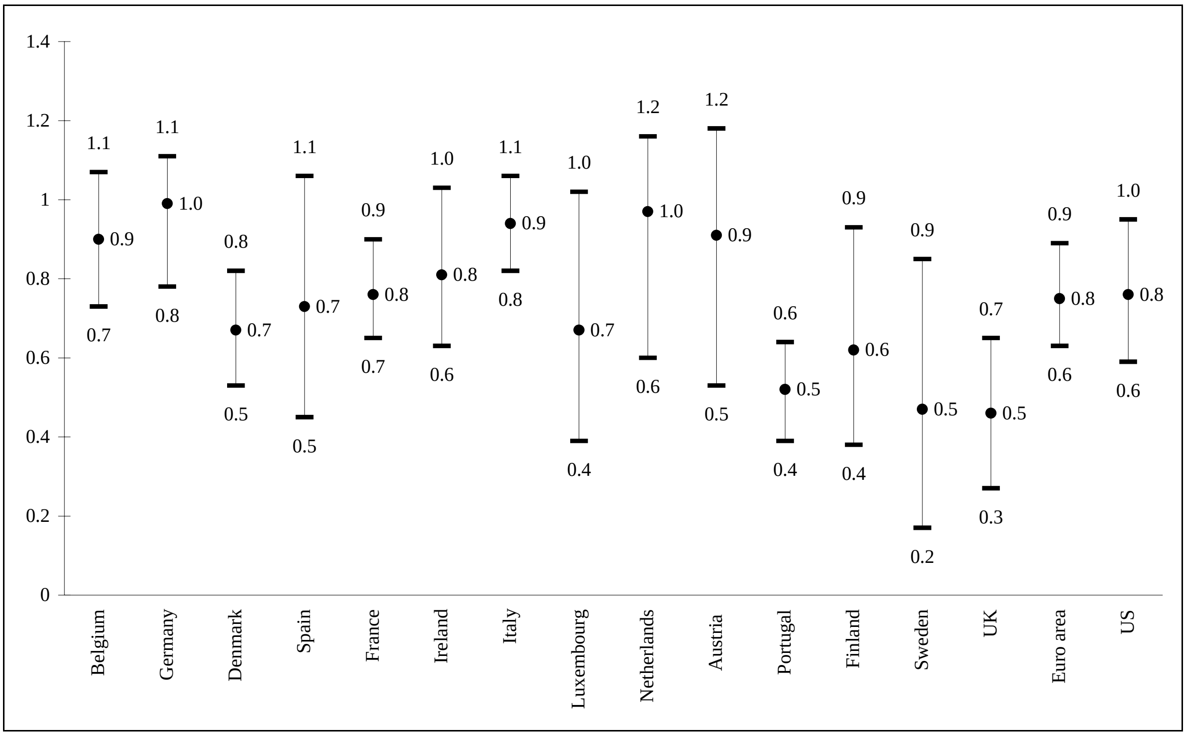


Figure 5: HICP Inflation, Estimated ρ persistence (90% interval), conditional on break in intercept

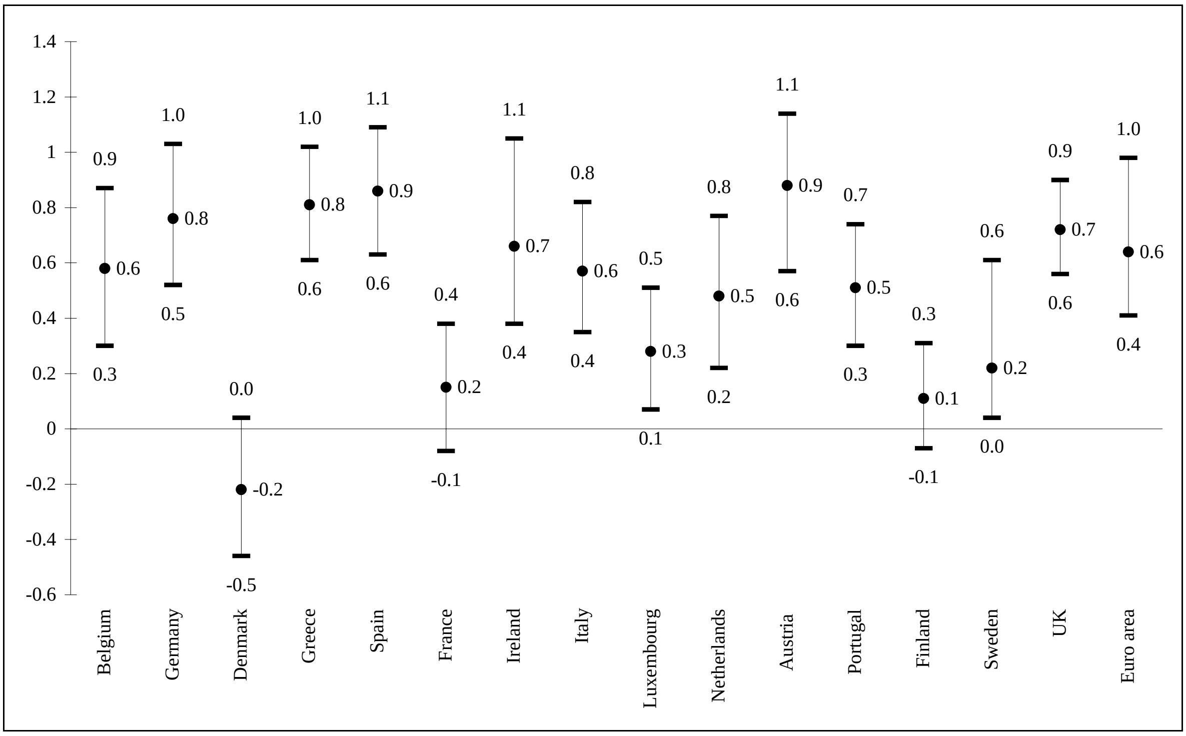


Figure 6: Private Consumption Inflation, Estimated ρ persistence (90% interval), conditional on break in intercept

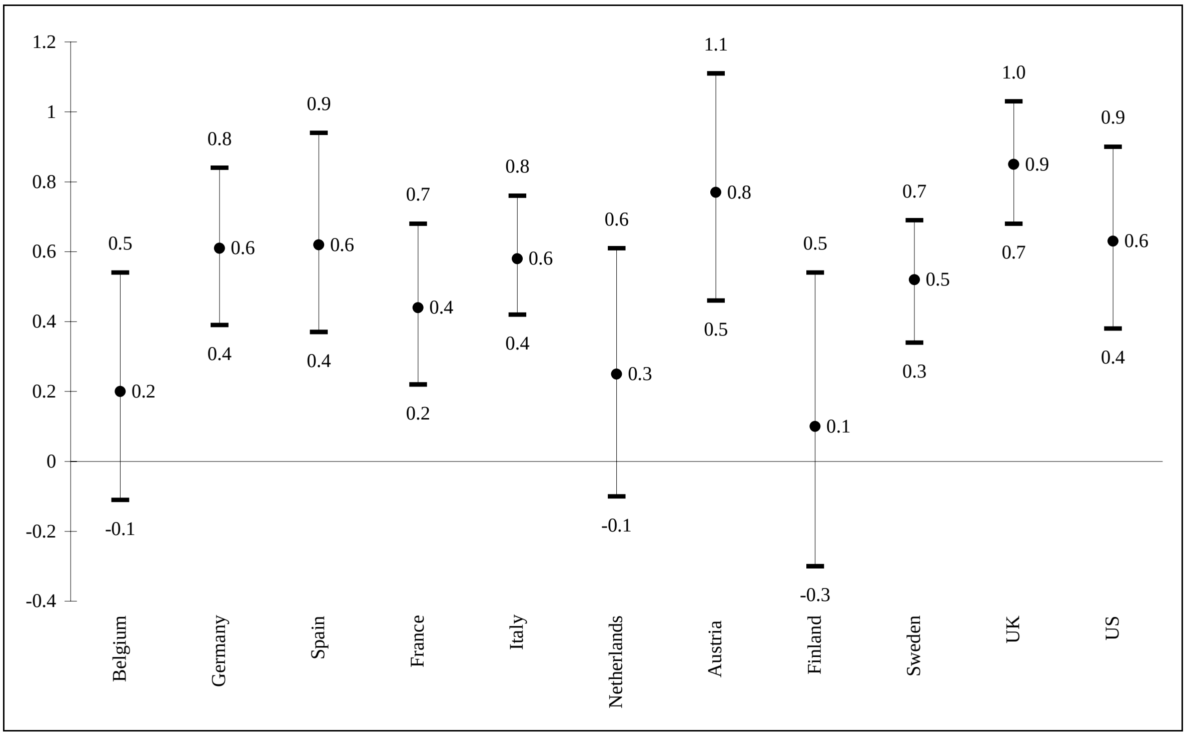
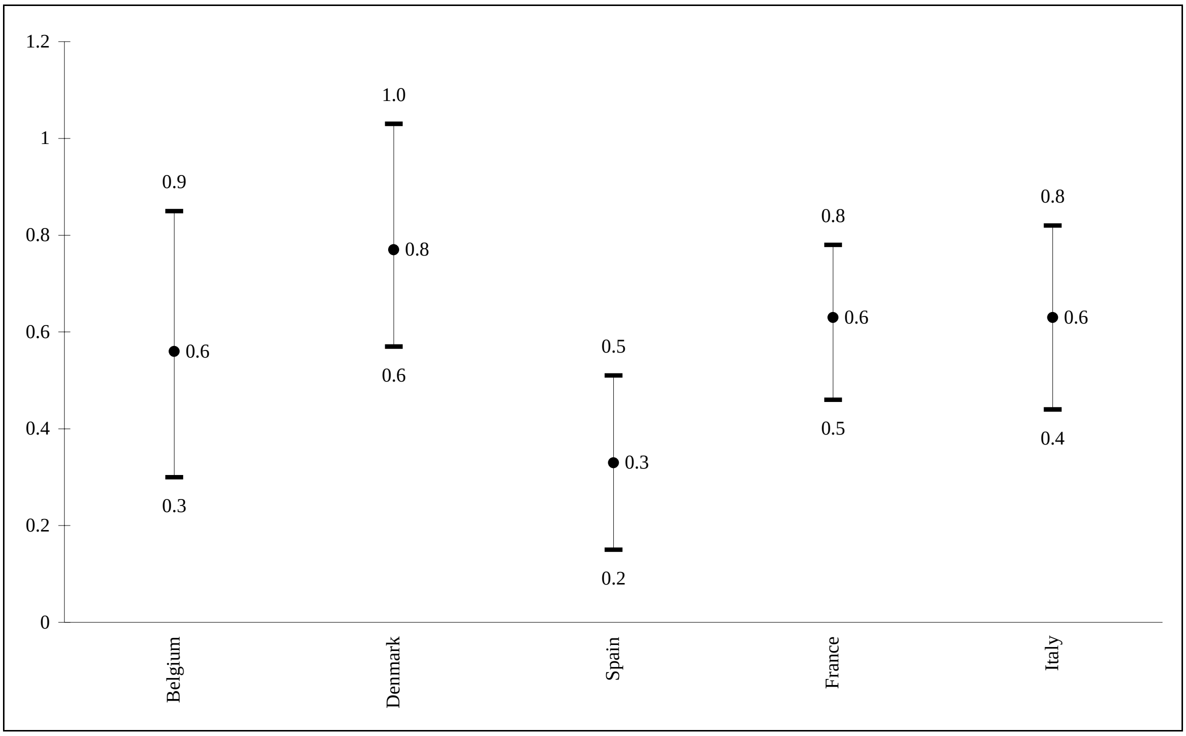


Figure 7: Services Inflation, Estimated ρ persistence (90% interval), conditional on break in intercept



3.3 Results for the half-life indicator

Computing the IRF based on the estimation of the Eq.1 we obtain HL indicator measures for each country and each variable as reported in Table 13 in the annex. The picture that emerges is again one of low inflation persistence across the board with HL measures showing that the impact of a shock to the inflation process is already halved within the first quarter (i.e., the indicator takes a value of one), in most cases. As was the case for the ρ parameter, results for the HL indicator suggest that inflation persistence is usually lowest when using GDP inflation data and highest when using Core inflation data. Noteworthy is the fact that some processes that appear to have a random walk (i.e., ρ close or above 1) display finite half-lives measures nonetheless, suggesting they still have a substantial mean-reverting component bringing down their IRF below the 0.5 mark rapidly, though the shock never dies out completely.

A close correspondence between the two indicators (the ρ parameter and the HL indicator) should however not be expected a priori, as already discussed in Section 2. In practise, the degree of correspondence between the two measures of persistence depends on the degree of similarity of the shapes of the IRFs across series. Formally, the relationship between the ρ and the HL indicator can be described as follows, where F is as in Eq.3 above.

$$F^{HL} \cdot \begin{pmatrix} 1 \\ 1 \\ . \\ . \\ . \\ 1 \end{pmatrix} = \begin{pmatrix} 0.5 \\ . \\ . \\ . \\ . \\ . \end{pmatrix} \tag{5}$$

To be more specific, in the case of an inflation process with three lags the formula would read as follows.

Assuming the following inflation process:

$$\pi_t = \mu_0 + \sum_{i=1}^{3} \beta_i \cdot \pi_{t-i} + \varepsilon_t \tag{6}$$

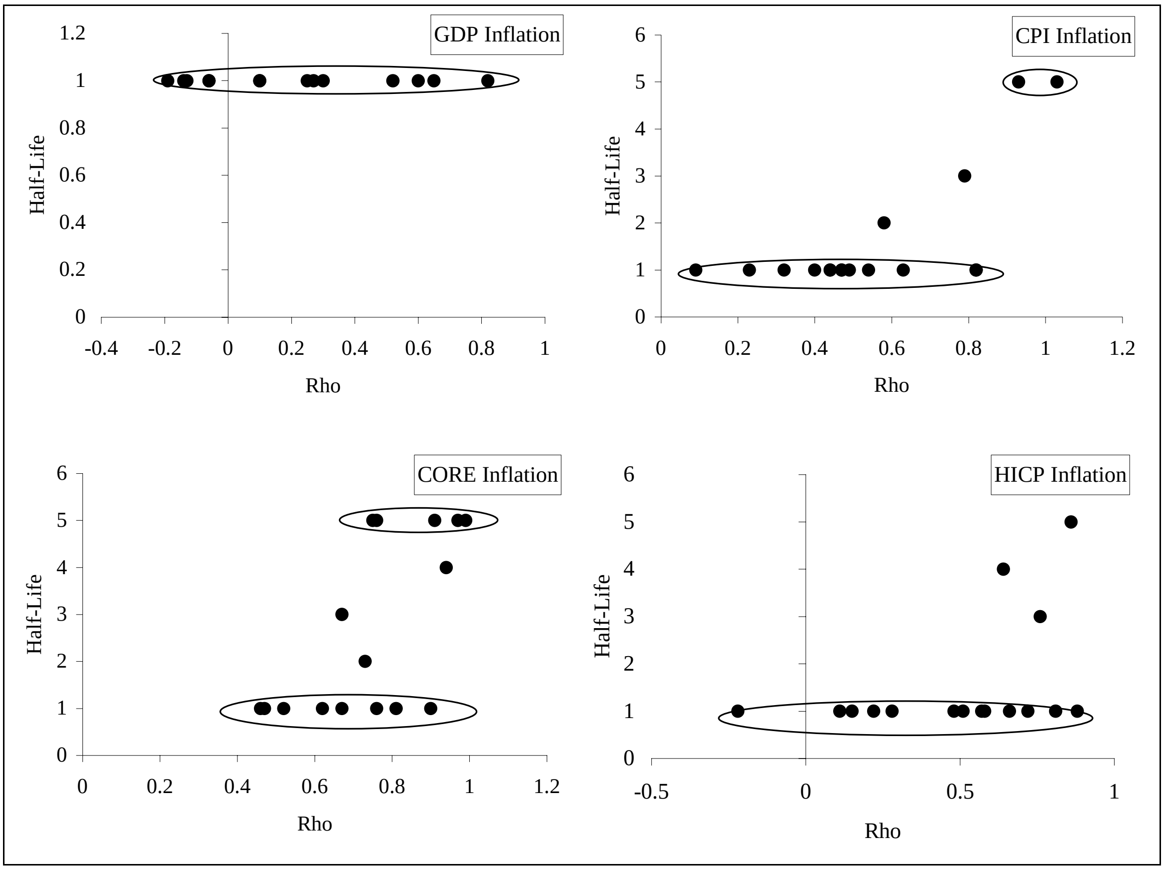
Then the relationship between HL and ρ reads:

$$\begin{pmatrix} (\rho - \beta_2 - \beta_3) & (\rho - \beta_1 - \beta_3) & (\rho - \beta_1 - \beta_2) \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix}^{HL} \cdot \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 0.5 \\ . \\ . \end{pmatrix} \tag{7}$$

Note that in the case of a lag order of one the above formula reduces to a simpler relationship between HL and ρ, namely $\rho^{HL} = 0.5$. This can be seen by the fact that in such a case $\beta_1 = \rho$ and $\beta_2 = \beta_3 = 0$. In all other cases, the relationship is more complex and involves other terms beside HL and ρ, namely all the autoregressive terms.

Figure 8 below analyses the degree of correspondence between these two indicators by presenting some scatter plots. These scatter plots point to the absence of a clear-cut positive linear relationship between the two indicators. Instead, an entirely different picture emerges. Clearly, the observations in the plots seem to cluster at different levels on the HL axis. Within each cluster there seems to be no relationship between HL and ρ whatsoever. To be fair, it should be mentioned that when deliberately ignoring the group-clustering effect a loose positive relationship between HL and ρ emerges (see Figure 11 in the Annex). However, the point made here with Figure 8 is that this relationship is far from perfect and appears to be highly non-linear, which is in line with algebraic derivations presented above.

Figure 8: Relationship between the Half-Life indicator and the ρ parameter, excluding outliers



To summarise, in this section we noted that the ranking of the persistence of these series according to the HL indicator does not correspond perfectly to the ranking obtained with the ρ parameter. To echo the discussion provided in section 2, this needs to be interpreted as evidence that the IRFs display different shapes across series. Consequently, the ρ needs to be interpreted restrictively as solely providing information on the relative size of the cumulative impact of a shock across series but cannot be relied upon to get information on the relative timing of the absorption of a shock. To get information on the latter, one needs to rely on the HL indicator instead though it should be borne in mind that the HL provides only a rough summarisation of the full timing information contained in the entire IRF.

4. Further results on euro area and US inflation persistence

In this section, we provide further results for the euro area and the US. We provide some sensitivity analysis to check the robustness of the result with respect to the starting date of the sample. We then summarise the analysis by comparing the level of inflation persistence obtained for the euro area and the US.

4.1 Some sensitivity analysis for the euro area and the US

The sensitivity analysis reported in Table 14 and Table 15 provides further useful practical information. For instance, it shows that the outcome for euro area CPI inflation using the sample starting in 1984:1 is not representative of the typical outcome obtained using samples starting around that period. It seems according to Table 14 that a higher level of persistence for euro area CPI inflation would be more representative of such a typical outcome, as evidenced by the fact that the average of the outcomes is higher than the reading for the sample starting in 1984:1. **Figure 9** below confirms that finding by showing that the outcome of the sample starting in 1984:1 is lower than most other outcomes. The same appears to be true for Euro area HICP inflation. For US CPI and Core inflation, the outcome of the sample starting in 1984:1 lays above the average of the outcomes and, thus, does not appear to be a good representation of the typical outcome for sample starting in the mid-80s. In this case however, **Figure 10** tends to invalidate that point by showing that the sample starting in 1984:1 is in line with the typical outcome. Indeed, the picture shows that the average of the outcomes in the case of the US would not be very representative because it is affected by unrepresentative events affecting the samples starting before 1982. Finally, comparing **Figure 9** and **Figure 10**, it appears that the outcomes based on samples starting around 1984:1 are less stable for the euro area than for the US. This calls for a heightened level of caution when analysing results for the euro area based on samples running from around the mid-80s. To be fair, it is important to stress that in many cases the variations depicted in **Figure 9** or in **Figure 10** are not statistically significant as can be seen from observing the confidence bands reported in Table 14 and in Table 15. Recalling the sensitivity of the median estimate however still appears worthwhile as in some cases the discussion focuses on this statistic rather than on the entire confidence interval of the persistence parameter.

Figure 9: Euro area inflation ρ persistence sensitivity with respect to start of the sample

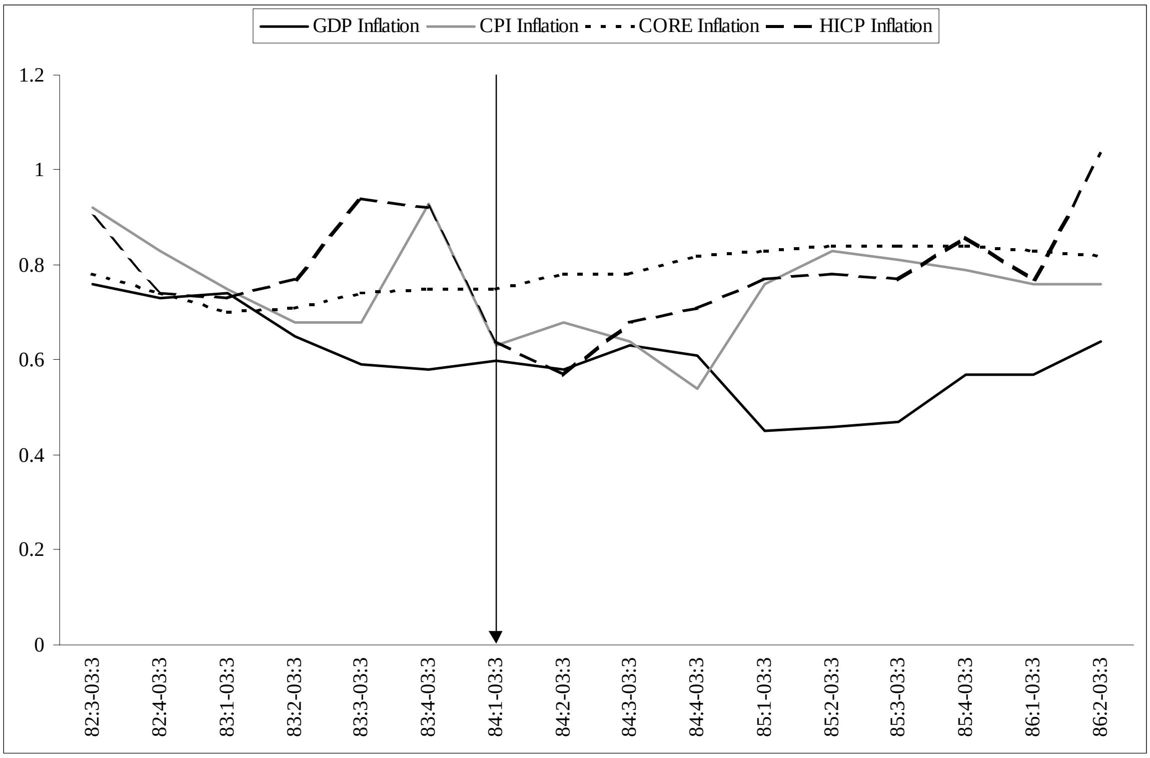
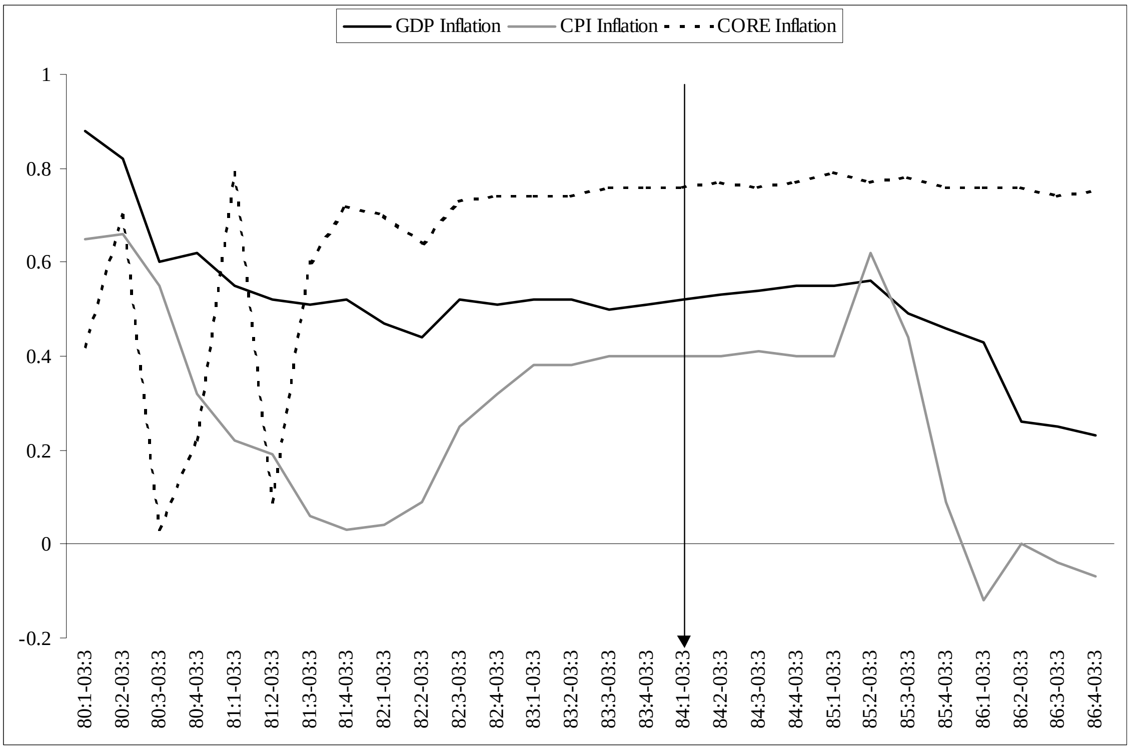


Figure 10: United States inflation ρ persistence sensitivity with respect to start of the sample



4.2 Rolling regressions

Beyond the reporting of a single measure for an entire sample, some authors have advocated the use of rolling regressions. Such regressions, it is argued, offer maximum flexibility to identify the level of the ρ parameter. Intuitively, it is also often perceived as a good way of gauging the degree of variation in the level of persistence over time. However, it is important to realise that these rolling regressions do not offer a direct formal testing of the hypothesis of a structural change in the level of persistence. In addition, these rolling regressions will suffer the omission of structural break dummies as any other regression. We illustrate this last point in the Figure **12**-Figure 14. In each of these Figures we show that once the rolling regression starts using data that includes a date at which a break took place the omission of the corresponding dummy starts to bite in the sense that it biases the persistence parameter rolling estimate.[7] The omission of the dummies does indeed have an impact on the profile of the

[7] For further details on these breaks see: Annex – Preliminary results on the sample including the 1970s.

rolling regression results. Alternatively, this point can be illustrated by showing the sensitivity of those rolling-windows experiments with respect to the size of the windows. Once the size of the windows is chosen so as to allow for some windows not to be affected by structural changes it is possible to visualise the consequences of omitting such structural changes in the specification of the equations.

As far as the degree of variation of the persistence parameter is concerned, the somewhat erratic behaviour of these rolling regressions should not be taken at face value, as they do not constitute a formal test on that issue. Indeed, we even refrain from reporting confidence bands for rolling regression considering them uninformative in line with the point made by other authors that such confidence bands are unrealistically wide given the data limitation implied by these techniques. Instead, the formal test reported in Table 3 should be relied upon to assess the instability in the ρ parameter.

4.3 Euro area and US inflation persistence compared

In this section, we summarise with a set of tables the results for the euro area and compare them to the ones obtained for the US. The similarity between the euro area and the US is evident, both in terms of the structural breaks uncovered and in terms of the level of the estimates for inflation persistence.

Table 5: Comparing intercept breaks for the euro area and the US

	GDP INFLATION	CPI INFLATION	CORE INFLATION	HICP INFLATION
Sample 1984:1-2003:3				
EURO AREA	1993:2	1993:2	1993:2	1995:4
US	1991:2	1991:1	1991:2	NA

Note: NA stands for non-available data

Table 6: Comparing ρ parameter breaks for the euro area and the US

	GDP INFLATION	CPI INFLATION	CORE INFLATION	HICP INFLATION
Sample 1984:1-2003:3				
EURO AREA	--	--	2001:1	2000:4
US	--	--	2000:4	NA

Note: NA stands for non-available data

Table 7: Comparing the ρ parameter value for the euro area and the US

	GDP INFLATION	CPI INFLATION	CORE INFLATION	HICP INFLATION
Sample 1984:1 2003:3				
EURO AREA	0.60	0.63	0.75	0.64
US	0.52	0.40	0.76	NA

Note: NA stands for non-available data

5. Concluding remarks

This paper gathers empirical results on the level of persistence using 79 inflation series covering the EU countries, the euro area and the US for five different inflation variables, relying on two persistence indicators (the sum of the autoregressive coefficient and the half-life indicator) based on the estimation of univariate inflation models. The results suggest that the euro area and the US inflation series display comparable levels of persistence. Also, the picture that emerges is one of moderate persistence across the board. Preliminary results presented in the annex suggest that such results can be reconciled with other results elsewhere in the literature that point to a higher level of persistence on account of the fact that the latter omit the inclusion of intercept dummies in their model for inflation. The omission of such dummies is shown to be potentially responsible for all of the difference between the set of results presented here and the type of results presented elsewhere.

At the methodological level, the recourse to two different types of persistence measures appears warranted as evidenced by the fact the two sets of results do not perfectly correspond to each other. Technically, this relates to the existence of some discrepancies in the shape of the IRFs across series. It implies that the ρ parameter should be construed more restrictively as providing information solely on the relative cumulative impact of a shock across series while the half-life remains the only provider of information on the relative timing of the absorption of shocks.

A number of extensions could be envisaged. First, extending the framework to a multivariate analysis appears warranted as it could enhance the robustness of the results by controlling for a number of events. Extending the analysis to allow for multiple breaks in the inflation equations may yield further valuable empirical insights.

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Annex - Tables

Table 8: Description of the data

VARIABLE	SOURCE	FURTHER DETAILS
GDP Inflation series	Eurostat	ECB calculation based on Eurostat data (see Fagan et al. (2001)).
CPI Inflation series	OECD (MEI)	Seasonal adj. based on the Tramo/Seats procedure.
Core Inflation series	Eurostat	HICP excluding unprocessed food and energy. Seasonal adj. based on the Tramo/Seats procedure.
HICP Inflation series	Eurostat	ECB calculation based on Eurostat data (see Fagan et al. (2001)).
Priv. Consumption Inflation	OECD (QNA)	Item: "Deflator – private final consumption expenditure". Seasonal adj. based on the X12 procedure.
Services Inflation	OECD (MEI)	Item: "CPI Services less Rent" Seasonal adj. based on the X12 procedure.

Note: NA stands for non-available data

Table 9: Sample periods

	GDP INFLATION	CPI INFLATION	CORE INFLATION	HICP INFLATION	PRIV. CONS. INFLATION	SERVICES INFLATION
Belgium	1984:1-2003:2	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	1984:1-2003:1	1984:1-2003:2
Germany	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	1984:1-2002:3	NA
Denmark	1984:1-2003:2	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	NA	1984:1-2003:2
Greece	1984:1-2003:2	1984:1-2003:2	NA	1984:1-2003:2	NA	NA
Spain	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	1984:1-2003:2	1984:1-2003:2
France	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	1984:1-2002:3	1984:1-2003:2
Ireland	NA	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	NA	NA
Italy	1984:1-2003:2	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	1984:1-2002:2	1984:1-2003:2
Luxembourg	NA	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	NA	NA
Netherlands	1984:1-2003:2	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	1984:1-2002:2	NA
Austria	1988:1-2003:2	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	1984:1-2003:1	NA
Portugal	NA	1984:1-2003:3	1991:2-2003:2	1984:1-2003:3	NA	NA
Finland	1984:1-2003:2	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	1984:1-2003:1	NA
Sweden	1984:1-2002:2	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	1984:1-2002:2	NA
United Kingdom	1984:1-2003:2	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	1984:1-2002:3	NA
Euro area	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	NA	NA
United States	1984:1-2003:3	1984:1-2003:3	1984:1-2003:3	NA	1984:1-2002:3	NA

Note: NA stands for non-available data

Table 10: Outlier adjustment (based on standard VAT rate changes unless otherwise mentioned)

Belgium	1992:2, 1994:1, 1996:1
Germany	1991:1-1991:4 (reunification, these obs. have been omitted), 1993:1, 1996:2, 1998:2 (Adjustments for rent control changes in the CPI series: 1991:4, 1993:1, 1994:1, 1995:3)
Denmark	1992:1
Greece	1988:1, 1990:2, 1990:3
Spain	1992:1, 1992:3, 1992:4, 1995:1
France	1995:3, 1995:4, 2000:2
Ireland	1985:1, 1985:2, 1986:1, 1986:2, 1990:1, 1990:2, 1991:1, 1991:2, 2001:1, 2002:1, 2002:2
Italy	1988:3, 1988:4, 1997:4
Luxembourg	1992:1
Netherlands	1984:1, 1986:4, 1989:1, 1992:4, 2001:1
Austria	1984:1
Portugal	1988:1, 1988:2, 1992:2, 1995:1
Finland	-
United Kingdom	1990:2 (Poll Tax introduction), 1991:2
Sweden	1990:1, 1991:1, 1992:1

Source: European Commission.

Table 11: AIC Lag Order Selection

	GDP INFLATION		CPI INFLATION		CORE INFLATION		HICP INFLATION		PRIV. CONS. INFLATION		SERVICES INFLATION	
	No S.B.	S.B.	No S.B.	S.B.	No S.B.	S.B.	No S.B.	S.B.	No S.B.	S.B.	No S.B.	S.B.
Belgium	4	4	5	5	4	4	2	2	5	5	2	2
Germany[a]	5	5	4	4	4	4	2	2	2	2	NA	NA
Denmark	1	2	4	4	4	4	4	1	NA	NA	5	5
Greece	4	4	4	4	NA	NA	4	4	NA	NA	NA	NA
Spain	3	2	4	4	4	4	5	5	4	4	2	1
France	5	5	3	3	4	4	3	1	5	5	3	3
Ireland	NA	NA	2	2	3	3	5	5	NA	NA	NA	NA
Italy	5	5	3	5	3	3	3	2	3	5	5	5
Luxembourg	NA	NA	2	2	2	2	2	2	NA	NA	NA	NA
Netherlands	5	5	5	5	4	4	4	5	5	5	NA	NA
Austria	2	1	3	3	4	4	4	4	5	5	NA	NA
Portugal	NA	NA	5	5	3	3	5	5	NA	NA	NA	NA
Finland	2	2	3	2	4	4	4	1	5	5	NA	NA
Sweden	3	1	4	2	4	4	4	2	3	3	NA	NA
United Kingdom	2	1	3	1	3	1	4	4	5	5	NA	NA
Euro area	2	2	2	2	4	4	5	5	NA	NA	NA	NA
United States	3	3	3	3	4	4	NA	NA	3	3	NA	NA

Notes: Results in the table report the selected lag length for the inflation equations (see Section 2 for further details). S.B. and No S.B. stands for the equation allowing for the presence of an intercept structural break and the equation not allowing for such a break, respectively. (a) Use of an alternative series for German CPI, i.e. West German and Pan German data spliced in 1995 (instead of 1991), in an attempt to correct for a series of rent control interventions implemented over the period 1991-1995, we find a lag length of 5 (n.b., no intercept break had been identified for this variable).

Table 12: Estimated persistence ρ (90% interval), conditional on break in intercept

	GDP INFLATION			CPI INFLATION			CORE INFLATION			HICP INFLATION			PRIV. CONS. INFLATION			SERVICES INFLATION		
	05	**50**	**95**	**05**	**50**	**95**	**05**	**50**	**95**	**05**	**50**	**95**	**05**	**50**	**95**	**05**	**50**	**95**
Belgium	0.04	0.25	0.46	0.03	0.32	0.59	0.73	0.90	1.07	0.30	0.58	0.87	-0.11	0.20	0.54	0.30	0.56	0.85
Germany[a]	-0.13	0.10	0.34	0.60	0.82	1.07	0.78	0.99	1.11	0.52	0.76	1.03	0.39	0.61	0.84	NA	NA	NA
Denmark	-0.37	-0.19	0.00	-0.45	0.09	0.65	0.53	0.67	0.82	-0.46	-0.22	0.04	NA	NA	NA	0.57	0.77	1.03
Greece	0.44	0.65	0.87	0.65	0.82	1.01	NA	NA	NA	0.61	0.81	1.02	NA	NA	NA	NA	NA	NA
Spain	0.11	0.27	0.41	0.72	0.93	1.11	0.45	0.73	1.06	0.63	0.86	1.09	0.37	0.62	0.94	0.15	0.33	0.51
France	0.63	0.82	1.06	0.27	0.54	0.85	0.65	0.76	0.90	-0.08	0.15	0.38	0.22	0.44	0.68	0.46	0.63	0.78
Ireland	NA	NA	NA	0.61	0.79	1.03	0.63	0.81	1.03	0.38	0.66	1.05	NA	NA	NA	NA	NA	NA
Italy	0.06	0.30	0.55	0.33	0.58	0.85	0.82	0.94	1.06	0.35	0.57	0.82	0.42	0.58	0.76	0.44	0.63	0.82
Luxembourg	NA	NA	NA	0.24	0.47	0.71	0.39	0.67	1.02	0.07	0.28	0.51	NA	NA	NA	NA	NA	NA
Netherlands	-0.34	-0.06	0.21	0.23	0.44	0.67	0.60	0.97	1.16	0.22	0.48	0.77	-0.10	0.25	0.61	NA	NA	NA
Austria	-0.33	-0.14	0.05	0.55	1.03	1.20	0.53	0.91	1.18	0.57	0.88	1.14	0.46	0.77	1.11	NA	NA	NA
Portugal	NA	NA	NA	0.26	0.49	0.74	0.39	0.52	0.64	0.30	0.51	0.74	NA	NA	NA	NA	NA	NA
Finland	-0.06	0.10	0.26	0.29	0.47	0.67	0.38	0.62	0.93	-0.07	0.11	0.31	-0.30	0.10	0.54	NA	NA	NA
Sweden	-0.41	-0.06	0.30	0.01	0.23	0.47	0.17	0.47	0.85	0.04	0.22	0.61	0.34	0.52	0.69	NA	NA	NA
United Kingdom	-0.38	-0.13	0.13	0.28	0.44	0.62	0.27	0.46	0.65	0.56	0.72	0.90	0.68	0.85	1.03	NA	NA	NA
Euro area	0.39	0.60	0.87	0.44	0.63	0.85	0.63	0.75	0.89	0.41	0.64	0.98	NA	NA	NA	NA	NA	NA
United States	0.31	0.52	0.76	0.16	0.40	0.64	0.59	0.76	0.95	NA	NA	NA	0.38	0.63	0.90	NA	NA	NA

Notes: Results in the table report the grid-bootsrtap estimator (see Hansen (1999)) of the persistence parameter rho (see Section 2 for further details). NA stands for non-available data. (a) Use of an alternative series for German CPI, i.e. West German and Pan German data spliced in 1995 (instead of 1991), in an attempt to correct for a series of rent control interventions implemented over the period 1991-1995, produces the following interval (i.e., 05, 50, 95) for the German CPI persistence parameter: 0.31, 0.69, 1.12.

Table 13: Half-life results

	GDP INFLATION			CPI INFLATION			CORE INFLATION			HICP INFLATION			PRIV. CONS. INFLATION			SERVICES INFLATION		
	05	**50**	**95**	**05**	**50**	**95**	**05**	**50**	**95**	**05**	**50**	**95**	**05**	**50**	**95**	**05**	**50**	**95**
Belgium	1	1	1	1	1	1	1	1	30	1	1	3	1	1	2	1	1	3
Germany	1	1	1	1	1	30	1	5	30	1	3	30	1	1	3	NA	NA	NA
Denmark	1	1	1	1	1	1	1	1	1	1	1	1	NA	NA	NA	4	4	30
Greece	1	1	1	1	1	5	NA	NA	NA	1	1	30	NA	NA	NA	NA	NA	NA
Spain	1	1	1	5	5	30	1	2	30	5	5	30	1	1	6	1	1	2
France	1	1	30	1	1	1	1	1	1	1	1	1	1	1	4	1	1	1
Ireland	NA	NA	NA	1	3	30	1	1	30	1	1	30	NA	NA	NA	NA	NA	NA
Italy	1	1	1	1	2	7	1	4	30	1	1	3	2	2	3	1	1	1
Luxembourg	NA	NA	NA	1	1	1	1	3	30	1	1	1	NA	NA	NA	NA	NA	NA
Netherlands	1	1	1	1	1	30	1	5	30	1	1	5	1	1	5	NA	NA	NA
Austria	1	1	1	1	1	30	5	5	30	1	1	30	1	1	30	NA	NA	NA
Portugal	NA	NA	NA	1	1	5	1	1	1	1	1	1	NA	NA	NA	NA	NA	NA
Finland	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	NA	NA	NA
Sweden	1	1	2	1	1	1	1	1	5	1	1	1	1	1	4	NA	NA	NA
United Kingdom	1	1	1	1	1	2	1	1	2	1	1	1	1	1	1	NA	NA	NA
Euro area	1	1	4	1	1	1	1	5	5	1	4	30	NA	NA	NA	NA	NA	NA
United States	1	1	1	1	1	1	2	5	5	NA	NA	NA	1	1	4	NA	NA	NA

Notes: Results in the table report the number of periods, in quarters, during which an initial shock to the inflation process continues to display at least ½ of its initial impact. A formal definition of the Half-life indicator is provided in Eq.2. NA stands for non-available data.

Table 14: Equations for the euro area – sub-sample sensitivity analysis for e ρ parameter

GDP INFLATION					
Sample period	Break-date	Persistence parameter interval			Lag length
		05	50	95	
82:3-03:3	93:2	0.61	0.76	0.99	2
82:4-03:3	93:2	0.56	0.73	0.94	2
83:1-03:3	93:2	0.55	0.74	1.02	2
83:2-03:3	93:2	0.48	0.65	0.83	2
83:3-03:3	93:2	0.42	0.59	0.76	2
83:4-03:3	92:1	0.39	0.58	0.79	2
84:1-03:3	**93:2**	**0.39**	**0.60**	**0.87**	**2**
84:2-03:3	93:2	0.35	0.58	0.85	2
84:3-03:3	92:1	0.40	0.63	0.94	2
84:4-03:3	92:1	0.38	0.61	0.89	2
85:1-03:3	93:2	0.28	0.45	0.63	1
85:2-03:3	93:2	0.27	0.46	0.66	1
85:3-03:3	93:2	0.27	0.47	0.68	1
85:4-03:3	93:2	0.27	0.57	1.03	3
86:1-03:3	93:2	0.30	0.57	1.02	3
86:2-03:3	93:2	0.36	0.64	1.05	3
Average		**0.39**	**0.60**	**0.87**	

CORE INFLATION					
Sample period	Break-date	Persistence parameter interval			Lag length
		05	50	95	
82:3-03:3	93:2	0.68	0.78	0.90	4
82:4-03:3	93:2	0.64	0.74	0.85	4
83:1-03:3	93:2	0.61	0.70	0.80	4
83:2-03:3	93:2	0.60	0.71	0.82	4
83:3-03:3	93:2	0.63	0.74	0.86	4
83:4-03:3	93:2	0.64	0.75	0.88	4
84:1-03:3	**93:2**	**0.63**	**0.75**	**0.89**	**4**
84:2-03:3	93:2	0.65	0.78	0.92	4
84:3-03:3	93:2	0.65	0.78	0.93	4
84:4-03:3	93:2	0.69	0.82	0.97	4
85:1-03:3	93:2	0.70	0.83	0.98	4
85:2-03:3	93:2	0.71	0.84	0.99	4
85:3-03:3	93:2	0.71	0.84	0.99	4
85:4-03:3	93:2	0.71	0.84	0.99	4
86:1-03:3	93:2	0.71	0.83	0.98	4
86:2-03:3	92:2	0.69	0.82	0.97	4
Average		**0.67**	**0.78**	**0.92**	

CPI INFLATION					
Sample period	Break-date	Persistence parameter interval			Lag length
		05	50	95	
82:3-03:3	--	0.79	0.92	1.06	4
82:4-03:3	93:2	0.65	0.83	1.05	3
83:1-03:3	87:1	0.59	0.75	0.96	3
83:2-03:3	96.2	0.54	0.68	0.84	3
83:3-03:3	93.2	0.48	0.68	0.94	4
83:4-03:3	--	0.75	0.93	1.09	4
84:1-03:3	**93:2**	**0.44**	**0.63**	**0.85**	**2**
84:2-03:3	93.2	0.47	0.68	0.99	2
84:3-03:3	93.2	0.43	0.64	0.89	2
84:4-03:3	93.2	0.38	0.54	0.72	2
85:1-03:3	93.2	0.57	0.76	1.00	4
85:2-03:3	93.2	0.64	0.83	1.04	4
85:3-03:3	93.2	0.63	0.81	1.03	4
85:4-03:3	93.2	0.61	0.79	1.01	4
86:1-03:3	93.2	0.58	0.76	0.98	4
86:2-03:3	93.2	0.57	0.76	0.99	4
Average		**0.57**	**0.75**	**0.97**	

HICP INFLATION					
Sample period	Break-date	Persistence parameter interval			Lag length
		05	50	95	
82:3-03:3	--	0.80	0.90	1.03	3
82:4-03:3	93:4	0.60	0.74	0.89	5
83:1-03:3	93:4	0.56	0.73	0.92	5
83:2-03:3	93:4	0.57	0.77	1.03	5
83:3-03:3	--	0.76	0.94	1.06	5
83:4-03:3	--	0.73	0.92	1.06	5
84:1-03:3	95:4	**0.41**	**0.64**	**0.98**	**5**
84:2-03:3	95:4	0.34	0.57	0.85	5
84:3-03:3	95:4	0.48	0.68	0.92	5
84:4-03:3	95:4	0.50	0.71	1.00	5
85:1-03:3	93:4	0.56	0.77	1.04	5
85:2-03:3	93:4	0.57	0.78	1.04	5
85:3-03:3	93:4	0.57	0.77	1.04	5
85:4-03:3	91.4	0.72	0.86	1.04	5
86:1-03:3	93:4	0.57	0.77	1.04	5
86:2-03:3	--	0.84	1.03	1.09	5
Average		**0.60**	**0.79**	**1.00**	

Table 15: Equations for the U.S. – sub-sample sensitivity analysis for ρ parameter

GDP INFLATION

Sample period	Break-date	Persistence parameter interval			Lag length
		05	50	95	
80:1-03:3	--	0.73	0.88	1.06	3
80:2-03:3	--	0.67	0.82	1.02	3
80:3-03:3	91:2	0.51	0.60	0.71	3
80:4-03:3	91:2	0.49	0.62	0.75	3
81:1-03:3	91:2	0.43	0.55	0.67	3
81:2-03:3	91:2	0.38	0.52	0.69	3
81:3-03:3	91:2	0.33	0.51	0.69	3
81:4-03:3	91:2	0.31	0.52	0.75	3
82:1-03:3	91:2	0.26	0.47	0.70	3
82:2-03:3	91:2	0.21	0.44	0.68	3
82:3-03:3	91:2	0.32	0.52	0.74	3
82:4-03:3	91:2	0.30	0.51	0.74	3
83:1-03:3	91:2	0.31	0.52	0.76	3
83:2-03:3	91:2	0.31	0.52	0.75	3
83:3-03:3	91:2	0.29	0.50	0.73	3
83:4-03:3	91:2	0.30	0.51	0.74	3
84:1-03:3	**91:2**	**0.31**	**0.52**	**0.76**	**3**
84:2-03:3	91:2	0.32	0.53	0.77	3
84:3-03:3	91:2	0.33	0.54	0.78	3
84:4-03:3	91:2	0.33	0.55	0.78	3
85:1-03:3	91:2	0.3 3	0.55	0.78	3
85:2-03:3	91:2	0.34	0.56	0.80	4
85:3-03:3	91:2	0.29	0.49	0.70	4
85:4-03:3	91:2	0.27	0.46	0.69	4
86:1-03:3	91:2	0.22	0.43	0.66	4
86:2-03:3	91:2	0.16	0.26	0.37	1
86:3-03:3	91:2	0.13	0.25	0.36	1
86:4-03:3	91:2	0.12	0.23	0.35	1
Average		**0.33**	**0.51**	**0.71**	

CPI INFLATION

Sample period	Break-date	Persistence parameter interval			Lag length
		05	50	95	
80:1-03:3	--	0.39	0.65	1.01	4
80:2-03:3	--	0.40	0.66	0.99	3
80:3-03:3	--	0.24	0.55	0.92	4
80:4-03:3	91:2	0.09	0.32	0.56	1
81:1-03:3	91:1	-0.11	0.22	0.58	4
81:2-03:3	93:2	-0.07	0.19	0.44	1
81:3-03:3	93:2	-0.14	0.06	0.24	1
81:4-03:3	91:1	-0.18	0.03	0.25	1
82:1-03:3	91:1	-0.17	0.04	0.25	1
82:2-03:3	91:1	-0.10	0.09	0.28	1
82:3-03:3	91:1	-0.00	0.25	0.50	3
82:4-03:3	91:1	0.09	0.32	0.55	3
83:1-03:3	91:1	0.15	0.38	0.60	3
83:2-03:3	91:1	0.16	0.38	0.60	3
83:3-03:3	91:1	0.17	0.40	0.64	3
83:4-03:3	91:1	0.16	0.40	0.64	3
84:1-03:3	91:1	**0.16**	**0.40**	**0.64**	**3**
84:2-03:3	91:1	0.16	0.40	0.64	3
84:3-03:3	91:1	0.16	0.41	0.63	3
84:4-03:3	91:1	0.16	0.40	0.64	3
85:1-03:3	91:1	0.15	0.40	0.63	3
85:2-03:3	--	0.33	0.62	0.97	3
85:3-03:3	90:4	0.19	0.44	0.70	3
85:4-03:3	91:1	-0.13	0.09	0.31	1
86:1-03:3	91:1	-0.11	-0.12	0.35	1
86:2-03:3	91:1	-0.21	0.00	0.22	1
86:3-03:3	91:1	-0.25	-0.04	0.18	1
86:4-03:3	91:1	-0.28	-0.07	0.14	1
Average		**0.05**	**0.28**	**0.55**	

CORE INFLATION

Sample period	Break-date	Persistence parameter interval			Lag length
		05	50	95	
80:1-03:3	91:2	0.04	0.42	1.11	4
80:2-03:3	--	0.35	0.70	1.19	4
80:3-03:3	92:3	-0.32	0.03	0.36	5
80:4-03:3	93:2	-0.24	0.22	1.20	5
81:1-03:3	--	0.46	0.79	1.20	5
81:2-03:3	93:1	-0.08	0.09	0.26	1
81:3-03:3	91:4	0.33	0.60	0.94	5
81:4-03:3	91:1	0.50	0.72	1.01	5
82:1-03:3	91:1	0.49	0.70	0.95	5
82:2-03:3	91:1	0.41	0.64	0.91	4
82:3-03:3	91:1	0.53	0.73	0.95	4
82:4-03:3	91:1	0.57	0.74	0.93	4
83:1-03:3	91:1	0.56	0.74	0.93	4
83:2-03:3	91:1	0.56	0.74	0.93	4
83:3-03:3	91:1	0.59	0.76	0.95	4
83:4-03:3	91:1	0.59	0.76	0.95	4
84:1-03:3	**91:1**	**0.59**	**0.76**	**0.95**	**4**
84:2-03:3	91:1	0.60	0.77	0.96	4
84:3-03:3	91:1	0.59	0.76	0.95	4
84:4-03:3	91:1	0.60	0.77	0.96	4
85:1-03:3	91:1	0.61	0.79	0.98	4
85:2-03:3	91:1	0.60	0.77	0.95	4
85:3-03:3	91:1	0.60	0.78	0.97	4
85:4-03:3	91:1	0.59	0.76	0.96	4
86:1-03:3	91:1	0.59	0.76	0.97	4
86:2-03:3	91:1	0.58	0.76	0.97	4
86:3-03:3	91:1	0.56	0.74	0.94	4
86:4-03:3	91:1	0.57	0.75	0.96	4
Average		**0.44**	**0.66**	**0.94**	

Annex – Figures

Figure 11: Relationship between the Half-Life indicator and the ρ parameter

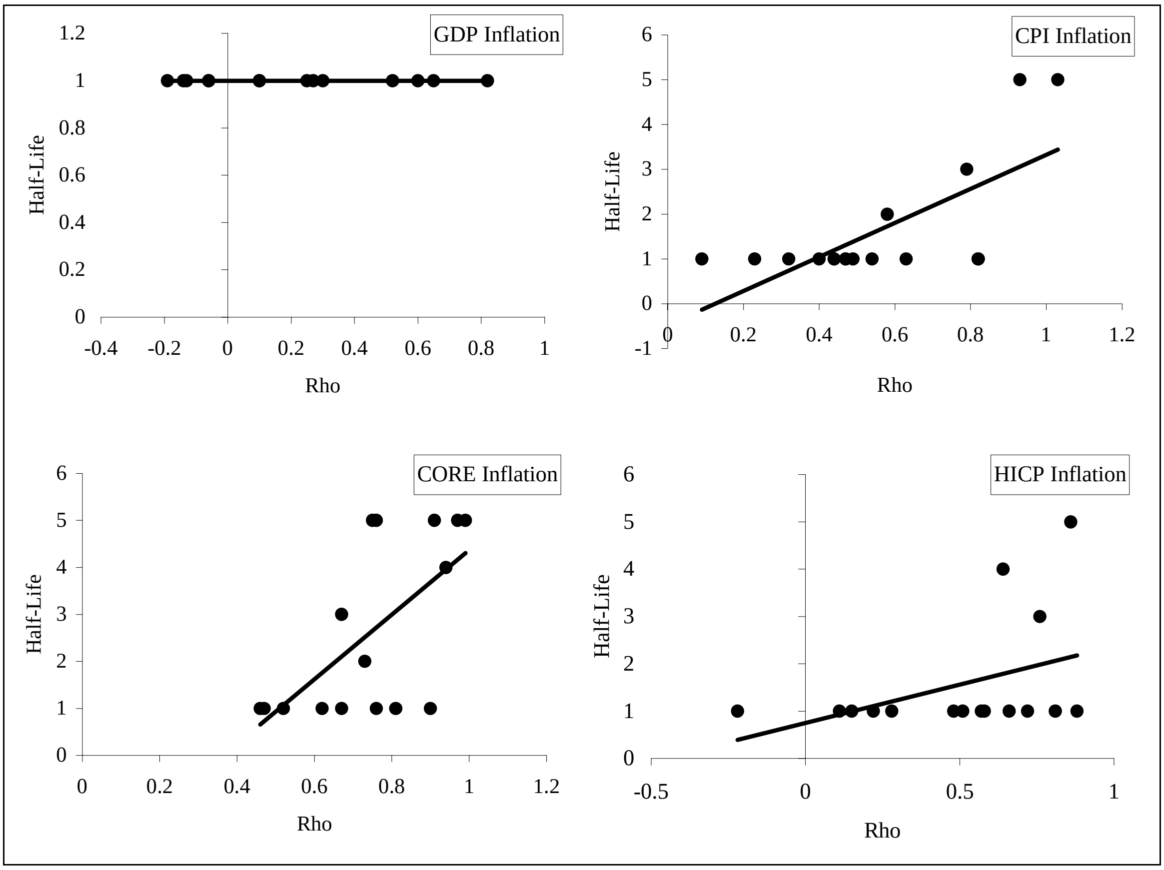


Figure 12: Estimated ρ persistence, euro area GDP inflation, 12-years rolling regressions – The impact of the break 1982:3

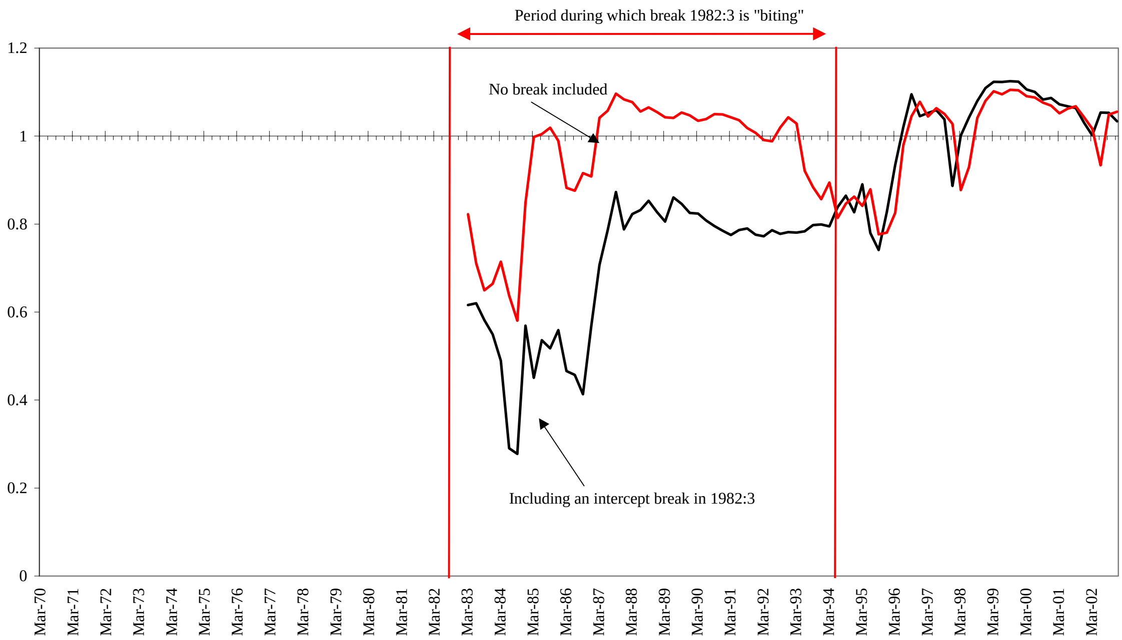


Figure 13: Estimated ρ persistence, euro area CPI inflation, 12-years rolling regressions – The impact of the break 1982:1

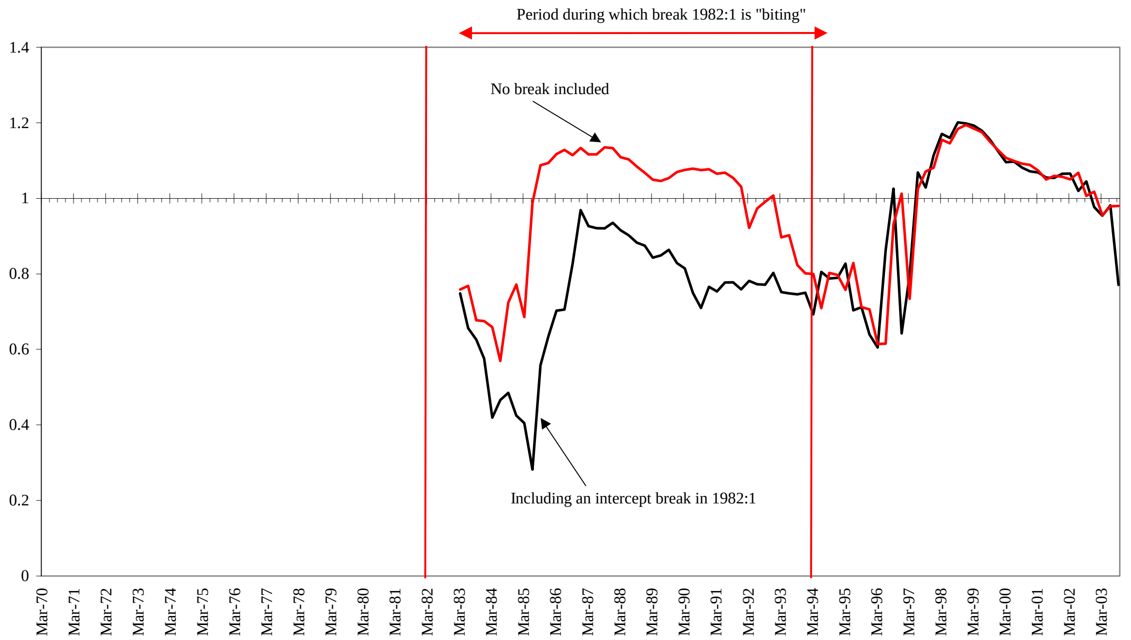
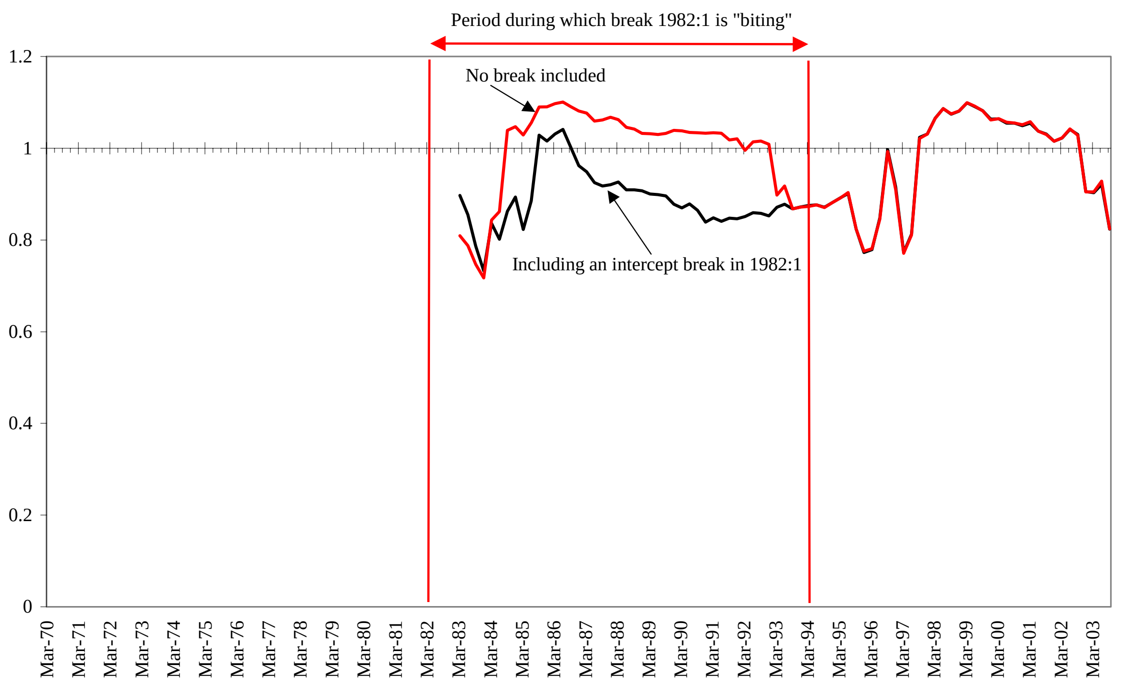


Figure 14: Estimated ρ persistence, euro area HICP inflation, 12-years rolling regressions – The impact of the break 1982:1



Annex - Preliminary results on the sample including the 1970s

In an attempt at reconciling our findings, which point to a low level of inflation persistence for the euro area and the US since the mid-80s, with other results in the literature that point to a higher level of persistence since (at least) the 1970s (see Pivetta and Reis (2004), Stock (2001), O'Reilly and Whelan (2004)), we extend our analysis by recalculating the value for the ρ parameter on an extended sample that includes the 1970s. For the estimation, we follow the same procedure as described in section 2. In particular, we test for the presence of an intercept break over that extended sample. Results in Table 16 and Table 17 below unambiguously point to the presence of such breaks both in the euro area and in the US inflation series. The timing of the breaks both for the euro area and the US are strikingly similar across variables.

Table 16: Structural Break in intercept for the euro area, 1970:1-2003:3

	GDP INFLATION		CPI INFLATION		CORE INFLATION		HICP INFLATION	
	SupW	**ExpW**	**SupW**	**ExpW**	**SupW**	**ExpW**	**SupW**	**ExpW**
Breakdate	1982:3	1982:3	1982:1	1982:1	1982:2	1982:2	1982:1	1982:1
Asymptotic p-value	0.009	0.006	0.001	0.000	0.001	0.001	0.000	0.000
Fixed-regressor-bootstrapped p-value	0.025	0.012	0.005	0.005	0.002	0.003	0.000	0.000

Notes: Results in the table refer to the implementation of the Hansen (2000) break-test procedure (see Section 2 for further details).

Table 17: Structural Break in intercept for the U.S., 1970:1-2003:3

	GDP INFLATION		CPI INFLATION		CORE INFLATION	
	SupW	**ExpW**	**SupW**	**ExpW**	**SupW**	**ExpW**
Breakdate	1981:2	1981:2	1981:4	1981:4	1981:4	1981:4
Asymptotic p-value	0.002	0.003	0.019	0.025	0.056	0.045
Fixed-regressor-bootstrapped p-value	0.004	0.007	0.017	0.020	0.059	0.056

Notes: Results in the table refer to the implementation of the Hansen (2000) break-test procedure (see Section 2 for further details).

Adding these breaks to the specification of the inflation equations goes some way to reducing the persistence parameter (see Table 18 and Table 19 below). Note that we find all these intercept shift-dummies to be significant, at the 5% level, in all equations. Interestingly, the inclusion of this dummy is sufficient for being able to reject the random walk hypothesis in all cases, except for US CPI and Core inflation. Hence, adding a single intercept dummy in each of these equations allows for a substantial portion of the discrepancy between our findings and the findings of others that point to a higher level of persistence to be accounted for.

Table 18: Alternative equations for the euro area

	GDP INFLATION			
Sample period	Dummies included in the equation	Persistence parameter ρ (90%)		
		05	**50**	**95**
1970:2-2003:3	no break	0.94	1.02	1.05
1970:2-2003:3	82:3**	0.73	0.83	0.93
1984:1-2003:3	93:2**	0.39	0.60	0.87
	CPI INFLATION			
Sample period	Dummies included in the equation	Persistence parameter ρ (90%)		
		05	**50**	**95**
1970:2-2003:3	no break	0.97	1.02	1.06
1970:2-2003:3	82:1**	0.79	0.87	0.96
1984:1-2003:3	93:2**	0.44	0.63	0.85
	CORE INFLATION			
Sample period	Dummies included in the equation	Persistence parameter ρ (90%)		
		05	**50**	**95**
1970:2-2003:3	no break	0.95	1.02	1.05
1970:2-2003:3	82:2**	0.83	0.88	0.94
1984:1-2003:3	93:2**	0.63	0.75	0.89
	HICP INFLATION			
Sample period	Dummies included in the equation	Persistence parameter ρ (90%)		
		05	**50**	**95**
1970:2-2003:3	no break	0.96	1.02	1.05
1970:2-2003:3	82:1**	0.81	0.88	0.96
1984:1-2003:3	95:4**	0.41	0.64	0.98

Notes: * significant dummy in the equation at 10% level, ** significant dummy in the equation at 5% level. The detection of breaks is based on tests for breaks at an unknown date following the methodology developed in Hansen (2000).

Table 19: Alternative equations for the U.S.

	GDP INFLATION			
Sample period	Dummies included in the equation	Persistence parameter ρ (90%)		
		05	**50**	**95**
1970:2-2003:3	no break	0.85	1.00	1.26
1970:2-2003:3	81:2**	0.66	0.78	0.90
1984:1-2003:3	91:2**	0.31	0.52	0.76
	CPI INFLATION			
Sample period	Dummies included in the equation	Persistence parameter ρ (90%)		
		05	**50**	**95**
1970:2-2003:3	no break	0.78	0.96	1.20
1970:2-2003:3	81:4**	0.56	0.75	1.02
1984:1-2003:3	91:1**	0.16	0.40	0.64
	CORE INFLATION			
Sample period	Dummies included in the equation	Persistence parameter ρ (90%)		
		05	**50**	**95**
1970:2-2003:3	no break	0.76	0.76	1.20
1970:2-2003:3	81:4**	0.60	0.60	1.20
1984:1-2003:3	91:2**	0.59	0.76	0.95

Notes: * significant dummy in the equation at 10% level, ** significant dummy in the equation at 5% level. The detection of breaks is based on tests for breaks at an unknown date following the methodology developed in Hansen (2000).

Some differences between the long and the short sample (including dummies) outcome however remain. Further work would thus be required to fully reconcile the results obtained for the small sample with the results obtained for the long sample. It could be argued that the remaining discrepancy between the outcome of the long and the small sample might be again related to an issue of intercept break. Indeed, the fact that the breaks uncovered for the long sample (i.e. a break in the beginning of the 1980s, see Table 16 and Table 17) do not coincide with the ones uncovered for the small sample (i.e. a break in the beginning of the 1990s, see Table 1) clearly points to the possible need to account for more than one break. Allowing for multiple breaks in the long sample could potentially further reduce the level of persistence.

Alternatively, the remaining discrepancy between level of persistence obtained for the long sample and the level obtained for the small sample could be seen as a sign of a change in the level of persistence over time. A formal test for the existence of such a change in the level of persistence over time (based on the Hansen (2001) procedure) is reported in Table 20 and Table 21 below. The results of the test do not identify any break in the level of persistence for the euro area inflation series. It reports a statistically significant change in the level of persistence for the US CPI and Core inflation in 1980:2. Looking at Figure 10 above, it appears that the break in the level of persistence in 1980:2 for US CPI and Core inflation is of a rather temporary nature.[8]

Returning to the result pointing to the absence of persistence variation for the euro area series, over the period 1970-2003, a note of caution should be drawn. It should be emphasised that some authors (see Hendry (2000)) have signalled that breaks entailing a change in the dynamic of a process are typically less straightforwardly detectable than breaks unambiguously involving a change in the unconditional mean, such as a break in the intercept. Accordingly, we argue that the apparent absence of persistence instability would require further work to be established more firmly. Possibly, such extensions could entail the use of alternative structural break tests and/or extending the framework to a multivariate analysis. The latter in particular could help controlling for a wider spectrum of events, which at the moment might be blurring the picture regarding the evolution of the persistence level parameter.

[8] Note that these results on the stability of the ρ parameter are broadly in line with those reported for the small sample (see Table 3) as the break in ρ parameter detected for US CPI and Core inflation do not concern the small sample.

Table 20: Structural Break in ρ persistence parameter, conditional on detected breaks in the intercept, for the euro area, 1970:1-2003:3

	GDP INFLATION		CPI INFLATION		CORE INFLATION		HICP INFLATION	
	SupW	**ExpW**	**SupW**	**ExpW**	**SupW**	**ExpW**	**SupW**	**ExpW**
Breakdate	1982:4	1982:4	1980:3	1980:3	1982:3	1982:3	1980:3	1980:3
Asymptotic p-value	0.563	0.330	0.803	0.547	0.639	0.698	0.879	0.712
Fixed-regressor-bootstrapped p-value	0.430	0.360	0.768	0.588	0.739	0.758	0.787	0.744

Note: NA stands for non-available data

Table 21: Structural Break in ρ persistence parameter, conditional on detected breaks in the intercept, for the U.S., 1970:1-2003:3

	GDP INFLATION		CPI INFLATION		CORE INFLATION	
	SupW	**ExpW**	**SupW**	**ExpW**	**SupW**	**ExpW**
Breakdate	1982:4	1982:4	1980:1	1980:1	1980:2	1980:2
Asymptotic p-value	0.929	0.900	0.040	0.083	0.060	0.170
Fixed-regressor-bootstrapped p-value	0.841	0.865	0.024	0.073	0.071	0.210

Note: NA stands for non-available data

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