



EUROPEAN CENTRAL BANK

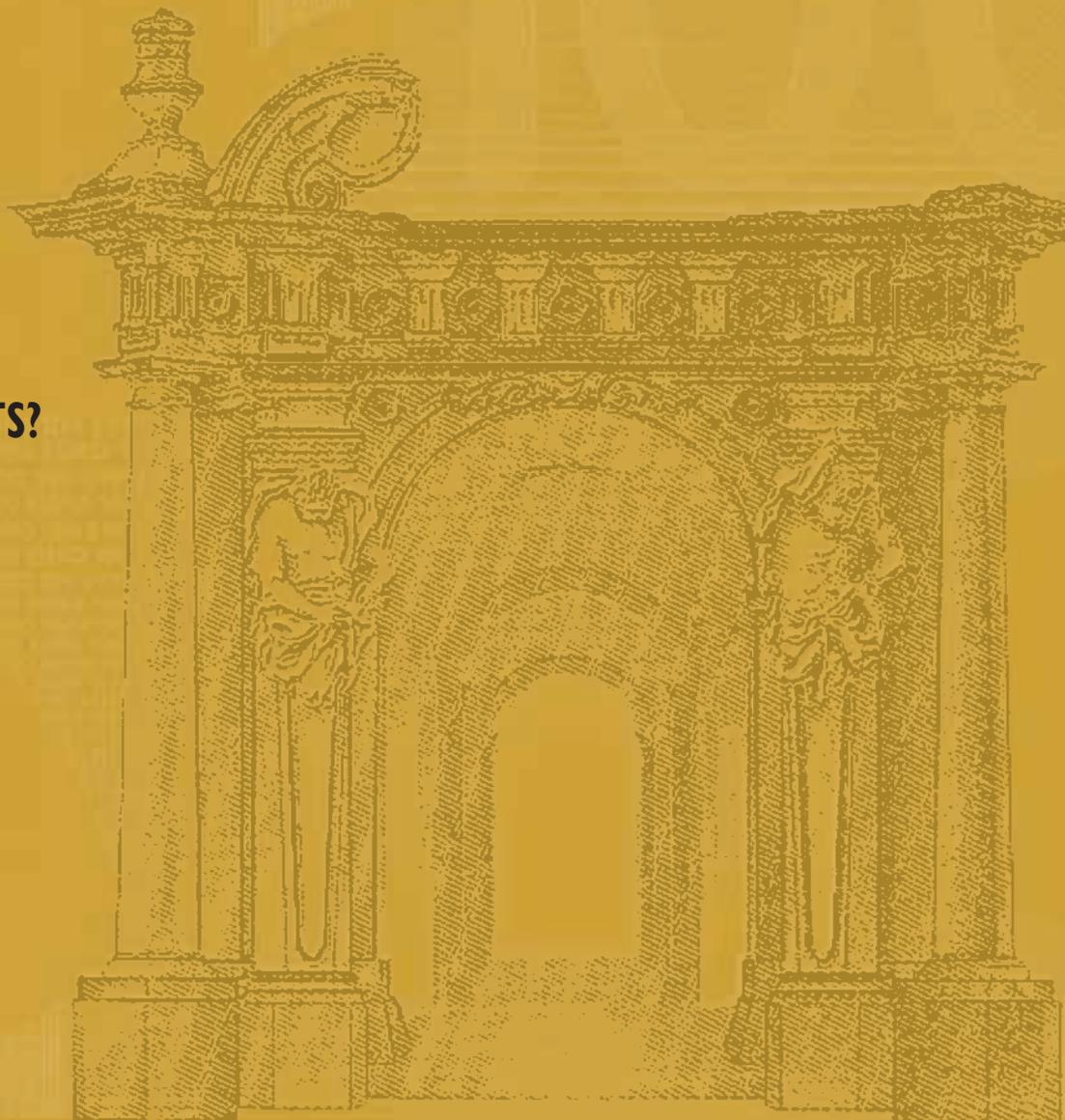
WORKING PAPER SERIES

NO. 371 / JUNE 2004

**EUROSYSTEM INFLATION
PERSISTENCE NETWORK**

**INFLATION
PERSISTENCE:
FACTS OR ARTEFACTS?**

by Carlos Robalo Marques





EUROPEAN CENTRAL BANK



WORKING PAPER SERIES

NO. 371 / JUNE 2004

EUROSYSTEM INFLATION
PERSISTENCE NETWORK

INFLATION PERSISTENCE: FACTS OR ARTEFACTS? ¹

by Carlos Robalo Marques ²

In 2004 all publications will carry a motif taken from the €100 banknote.

This paper can be downloaded without charge from <http://www.ecb.int> or from the Social Science Research Network electronic library at http://ssrn.com/abstract_id=533131.

¹ I especially thank without implicating Francisco Dias, Maximiano Pinheiro, Pedro Neves, Nuno Alves and José Maria Brandão de Brito for helpful discussions. Useful suggestions from Benoît Mojon, Andrew Levin, Jordi Gali and other members of the Inflation Persistence Network (IPN) are also acknowledged. The usual disclaimer applies.

² Banco de Portugal.

© European Central Bank, 2004

Address

Kaiserstrasse 29
60311 Frankfurt am Main, Germany

Postal address

Postfach 16 03 19
60066 Frankfurt am Main, Germany

Telephone

+49 69 1344 0

Internet

<http://www.ecb.int>

Fax

+49 69 1344 6000

Telex

411 144 ecb d

All rights reserved.

Reproduction for educational and non-commercial purposes is permitted provided that the source is acknowledged.

The views expressed in this paper do not necessarily reflect those of the European Central Bank.

The statement of purpose for the ECB Working Paper Series is available from the ECB website, <http://www.ecb.int>.

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

CONTENTS

Abstract	4
Non-technical summary	5
1. Introduction	6
2. Defining and measuring inflation persistence	7
2.1. Defining inflation persistence	7
2.2. Measures of inflation persistence	10
3. Persistence and mean reversion	14
4. An alternative measure of persistence	19
5. Persistence and mean reversion: re-evaluating inflation persistence in the United States and the euro area	20
6. Conclusions	31
References	32
Appendices	35
Graphics and tables	38
European Central Bank working paper series	48

Abstract

This paper addresses some issues concerning the definition and measurement of inflation persistence in the context of the univariate approach. First, it is stressed that any estimate of persistence should be seen as conditional on the given assumption for the long run level of inflation and that such long run level should be allowed to vary through time. Second, a non-parametric measure of persistence is suggested which explores the relation between persistence and mean reversion. Third, inflation persistence in the U.S. and the Euro Area is re-evaluated allowing for a time varying mean and it is found that estimates of persistence crucially depend on the function used to proxy the mean of inflation. In particular, the widespread belief that inflation has been more persistent in the sixties and seventies than in the last twenty years is shown to obtain only for the U.S. and for the special case of a constant mean.

JEL Classification: E31, C22, E52;

Keywords: Inflation persistence; univariate approach; time varying mean; mean reversion;

NON-TECHNICAL SUMMARY

This paper deals with some issues concerning inflation persistence in the context of the univariate approach. First, the definition and measures of inflation persistence are reviewed. It is argued that the mean of inflation should be seen as playing a crucial role in the definition and measurement of persistence. In particular, it follows from the definition of persistence that any estimate of persistence is to be seen as conditional on a given assumption for the mean of inflation.

Second, it is argued that rather than assuming a constant mean or simply testing for the possibility of some structural breaks in the mean of inflation, as it is customary in the literature, it is more natural to assume an exogenous time varying mean, as the starting null hypothesis.

Third, based on the correspondence between persistence and mean reversion, a non-parametric measure of persistence is suggested, which has the advantage of not requiring specifying and estimating a model for the inflation process.

Finally, inflation persistence in the U.S. and the Euro Area is reevaluated allowing for a time varying mean. Several types of means are considered ranging from the simplest case of a constant mean to pure time varying means computed using the well-known HP filter or a simple centred moving average of inflation. The general conclusion is that the estimates of inflation persistence crucially depend on the assumed mean, and that the more flexible the assumed mean is the less persistence we get. In particular, the empirical evidence shows that the widespread accepted wisdom that inflation has been more persistent in the sixties and seventies than in the last twenty years only obtains for the U.S. and for the special case of a constant mean, which however, appears to be a counterfactual assumption.

1. INTRODUCTION

Inflation persistence is usually discussed in the literature assuming basically two distinct approaches. One defines and evaluates inflation persistence in the context of a simple univariate time-series representation of inflation while the other uses a structural econometric model that aims at explaining inflation behaviour. For ease of presentation we shall denote the first as the “univariate” approach and the second as the “multivariate” approach. Persistence is usually seen as referring to the duration of shocks hitting inflation. Under the univariate approach a simple autoregressive model for inflation is usually assumed and the shocks are measured in the white noise component of the autoregressive process. The multivariate approach implicitly or explicitly assumes a causal economic relationship between inflation and its determinants (usually a Phillips curve or a structural VAR model) and sees inflation persistence as referring to the duration of the effects on inflation of the shocks to its determinants. What basically distinguishes the two approaches is the fact that in the univariate approach, shocks to inflation are not identified in the sense that they cannot be given an economic interpretation, i.e., these shocks are commonly seen as a summary measure of all shocks affecting inflation in a given period (monetary policy shocks, productivity shocks, external oil price shocks, etc.). On the contrary, under the multivariate approach an attempt is made (or may be made) to identify the different shocks hitting inflation and thus a shock-specific persistence analysis is possible.

This paper deals with some issues concerning the definition and measurement of inflation persistence in the context of the univariate approach. With some few exceptions, the bulk of the empirical literature evaluates inflation persistence assuming (implicitly or explicitly) that the mean of inflation is constant throughout the period under analysis. Even though some recent papers acknowledge that this might be a potential problem for the resulting estimates of persistence, the issue is addressed by simply allowing for the possibility of some (sometimes a single one) discrete structural breaks in the mean of inflation. This paper to some extent departs from this approach. First, it is argued that the mean of inflation should be seen as playing a crucial role in the definition and measurement of persistence. Second, it is

suggested that rather than starting by assuming a constant mean or simply testing for the possibility of some structural breaks in the mean of inflation, as has been done in most of the empirical literature, it is more natural to assume an exogenous time varying mean, as the null hypothesis. Third, based on the correspondence between persistence and mean reversion, a non-parametric measure of persistence is suggested, which does not require specifying and estimating a model for the inflation process. Finally this new methodology is applied to inflation in the U.S. and the Euro Area. It is shown that the evidence on inflation persistence dramatically changes with the assumption on the mean of inflation. In particular, the widespread accepted wisdom that inflation has been more persistent in the sixties and seventies than in the last twenty years only obtains for the U.S. and for the special case of a constant mean, which however, appears to be a counterfactual assumption.

The rest of the paper is organised as follows. Section 2 discusses the definition and measures of inflation persistence that have been presented in the literature to compute inflation persistence in the univariate context. Section 3 shows that there is a simple relation between mean reversion and persistence and makes the case for a time varying mean. Section 4 suggests an alternative simple and intuitive measure of inflation persistence. Section 5 re-evaluates the evidence on inflation persistence for the U.S. allowing for a time varying mean and section 6 concludes.

2. DEFINING AND MEASURING INFLATION PERSISTENCE

In this section we present the formal definition of persistence and discuss the different statistics suggested in the literature to measure inflation persistence.

2.1- Defining inflation persistence

There are now several definitions of inflation persistence available in the literature. For instance Batini and Nelson (2002) and Batini (2002) distinguish three different types of persistence: (1) “positive serial correlation in inflation”, 2) “lags between *systematic* monetary policy actions and their (peak) effect on inflation”; and (3) “lagged responses of inflation to *non-systematic* policy actions (i.e. policy shocks)”. In turn, Willis (2003) defines persistence as the “speed with which inflation returns to

baseline after a shock”. In what follows we shall adopt a modified version of Willis’s definition and define persistence as the “speed with which inflation converges to equilibrium after a shock”¹. The reason for such modification will become apparent from the discussion that follows.

With the exception of persistence of type (1) in Nelson and Batini (2002) and Batini (2002), which does not appear to be an acceptable definition of persistence, the other definitions deal with the idea of speed, i.e., the speed of the response of inflation to a shock. If the speed is low we say that inflation is (highly) persistent while if the speed is high we say that inflation is not (very) persistent.

An important implication of the above definition of persistence that seems worth stressing is the fact that any estimate of inflation persistence is conditional on the assumed long-run inflation path. Putting it slightly differently, in order to be able to tell whether inflation is moving slowly or quickly in response to a shock we need information on the likely path inflation would have followed had the shock not occurred as well as on the level inflation is expected to be once the effect of the shock has died off. And this information is given by the long run equilibrium level of inflation, which thus, plays the role of a metric². Strangely enough this implication of the definition of persistence seems to have been overlooked in the empirical literature. Virtually, so far, the empirical literature on the univariate approach has assumed (more implicitly than explicitly) a constant long run equilibrium level of inflation, when computing estimates of persistence³. Assuming a constant long run level of inflation might be a realistic assumption under some circumstances, but is not a satisfactory approach in most cases. However, it is important to bear in mind that any given estimate of persistence crucially depends on the specific long run level of inflation assumed in its computation and that, as a consequence, the reliability of such estimate intimately depends on how realistic the assumed long run inflation path is. As we shall see below there is a trade-off between persistence and the degree of

¹ For similar definitions see, for instance, Andrews and Chen (1994) and Pivetta and Reis (2001).

² If we assume that in the medium to long run inflation is determined by monetary policy, we can see the “long run level of inflation” as corresponding to the “central bank (implicit) inflation target”. Thus in what follows the expressions “long run level of inflation” and the “central bank inflation target” would be used interchangeably.

³ Exceptions are, for instance, Burdekin and Syklos (1999), Bleaney (2001), Levin and Piger (2003), which allow for the possibility of breaks in the mean of inflation.

flexibility of the assumed long run equilibrium level of inflation: for a given series of inflation, we obtain the maximum level of persistence under the assumption of a constant long run level of inflation, but we can make persistence to converge to zero if we allow enough flexibility to enter into our measure of the long run level of inflation.

Another point worth discussing when computing inflation persistence regards whether one should assume that the long run inflation path is exogenous or endogenous to the hypothesised shock to inflation. Within the context of the multivariate approach, with a structural model we can, at least in theory, account for the possibility of some shocks to affect the long run level of inflation⁴. However in the univariate context when computing inflation persistence we must assume that the shocks do not affect the “exogenous” long run inflation path or the “exogenous” central bank inflation target. Thus, in this framework, evaluating inflation persistence amounts to find an answer to the following question: how slowly does inflation converge for the (exogenous) central bank inflation target, in response to a shock?

A remaining aspect concerning the definition of inflation persistence that seems worth stressing concerns the idea that “a moving inflation target” may be a source of inflation persistence. For instance, if the central bank changes its target, it might take time for people to learn about the new target and thus inflation will take longer to converge to the target, than otherwise. This potential source of persistence can, at least in theory, be dealt with in the context of a structural model, as in such case it is possible to simulate different inflation trajectories for different inflation targets. However, such an analysis is not possible in the context of the univariate approach as we have only a single realization of the inflation process. As we argued above, in the context of the univariate approach, allowing for a “moving inflation target” reduces the estimated persistence, but this regards persistence obtained under the same inflation trajectory for two different assumptions on the long run level of inflation and thus, should not be seen as a claim against the idea that “a moving inflation target” might be a source of persistence⁵.

⁴ If we assume that, in the long run, inflation is solely determined by monetary policy, changes in the inflation target, by the central bank, would be the only “shocks” capable of affecting the long run equilibrium level of inflation.

⁵ We note that this claim is specific to our definition of persistence and might not carry to alternative definitions. For a somewhat different view on this issue see Kozicki and Tinsley (2002) and Kieler (2003). For instance, Kieler (2003) defines persistence as “the tendency of inflation to be a slow-

2.2- Measures of inflation persistence

Let us now briefly review the most common measures of inflation persistence that have been suggested in the literature. Under the univariate approach persistence is investigated by looking at the univariate time series representation of inflation. As it is customary in this strand of literature, in what follows we shall assume that inflation follows a stationary autoregressive process of order p (AR(p)), which we write as

$$y_t = \alpha + \sum_{j=1}^p \beta_j y_{t-j} + \varepsilon_t \quad (2.1)$$

In order to facilitate the discussion that follows we first note that model (2.1) may be reparameterised as:

$$\Delta y_t = \alpha + \sum_{j=1}^{p-1} \delta_j \Delta y_{t-j} + (\rho - 1)y_{t-1} + \varepsilon_t \quad (2.2)$$

where

$$\rho = \sum_{j=1}^p \beta_j \quad (2.3)$$

$$\delta_j = - \sum_{i=1+j}^p \beta_i \quad (2.4)$$

In the context of model (2.1) 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?

The concept of persistence is therefore intimately linked to the impulse response function (IRF) of the AR(p) process. However, the impulse response function is not a useful measure of persistence as it is an infinite-length vector. So, to overcome this difficulty, several scalar statistics have been proposed in the literature to measure

moving inertial variable with autocorrelations fairly close to one". Given this definition of persistence (which, as it will become apparent from the discussion further below, obtains as special case of our definition when a constant long-run equilibrium level of inflation is assumed) the authors are able to claim that part of the observed inflation persistence may be due to "shifts in the nominal anchor" i.e., to changes in the long run level of inflation, because "persistence of inflation exceeds persistence of deviations of inflation from the estimated nominal anchor" (Kozicki and Tinsley (2002, page 17).

inflation persistence. These include the “sum of the autoregressive coefficients” the “spectrum at zero frequency”, the “largest autoregressive root” and the “half-life”.

Andrews and Chen (1994) present a good discussion of the first three of these measures. They basically argue that the cumulative impulse response function (CIRF) is generally a good way of summarizing the information contained in the impulse response function (IRF) and as such a good scalar measure of persistence. In a simple AR(p) process, the cumulative impulse response function is simply given by
$$\text{CIRF} = \frac{1}{1-\rho}$$
 where ρ is the “sum of the autoregressive coefficients”, as defined in

(2.3). As there is a monotonic relation between the CIRF and ρ it follows that one can simply rely on the “sum of the autoregressive coefficients” as a measure of persistence. That is why sometimes persistence is also loosely defined as “positive serial correlation” or “high autocorrelation” of inflation.

Andrews and Chen (1994) discuss several situations in which the cumulative impulse response (CIRF) and thus also ρ , the sum of the autoregressive coefficients, might not be sufficient to fully capture the existence of different shapes in the impulse response functions. For instance, this could be the case when two series have the same CIRF but one exhibits an every-where positive IRF while the other has an IRF that oscillates between positive and negative values. The authors also note that in general the CIRF and thus ρ , as measures of inflation persistence, 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.

We notice that these criticisms apply in general to all measures of persistence surveyed in this section, as they are all a function of ρ . In general, the above limitations just mean that any scalar measure of persistence should be seen as giving an estimate of the “average speed” with which inflation converges to equilibrium after a shock. The more uniform is the speed of convergence throughout the convergence period the more reliable will be these scalar measures of persistence. In those cases where we suspect that the convergence process can display different speeds over time we will probably need to resort to different measures of persistence.



The “spectrum at zero frequency”, is a well-known measure of the low-frequency autocovariance of the series and, for the AR(p) process it is given by $h(0) = \frac{\sigma_\varepsilon^2}{(1-\rho)^2}$ where σ_ε^2 stands for the variance of ε_t . Again, for a fixed σ_ε^2 , there is a simple correspondence between this concept, the CIRF and ρ , and so they can be seen as equivalent measures of persistence⁶. However the two measures can deliver different results if one wants to test for changes in persistence over time. In such a situation the use of the “spectrum at zero frequency” may become problematic because changes in persistence will be brought about not only by changes in ρ but also by changes in σ_ε^2 . An additional advantage of ρ over $h(0)$ as a measure of persistence is that it is more intuitive and has a small and clearly defined range of potential variation (for a stationary process it varies between -1 and 1), which is not the case of the “spectrum at frequency zero”.

The “largest autoregressive root” of model (2.1) has also been used in the literature as a measure of persistence (see, for instance Stock, 2001). The use of this statistic as a measure of persistence is criticised both in Andrews and Chen (1994) and in Pivetta and Reis (2001). The main point against this statistic is that it is a very poor summary measure of the IRF because the shape of this function depends also on the other roots and not only on the largest one. For instance, an AR(2) process with roots equal to 0.8 and 0.7 is obviously more persistent than an AR(2) with roots of 0.8 and 0.2, but they will be undistinguishable if we use this measure of persistence. On the positive side, an important argument favouring the use of the largest autoregressive root as a measure of inflation persistence is the fact that an asymptotic theory has been developed and appropriate software is available so that it becomes ease to compute asymptotically valid confidence intervals for the corresponding estimates (see, Stock, 1991 and 2001).

⁶ We note that all these measures are only defined provided the series is stationary, i.e., $|\rho| < 1$. If the series is integrated of order 1, i.e., $\rho = 1$, the CIRF and $h(0)$ cannot be computed. However one would like to think of an integrated process as having persistence equal to one and of a white noise process as having zero persistence. That is why Cat, Garcia and Perron (1999) measure persistence in a modified way, using the normalized spectral density at frequency zero of the first-differences of the series, $f_{\Delta y}(0) = h_{\Delta y}(0) / \sigma_{\Delta y}^2$ where $h_{\Delta y}(0)$ is the spectral density function at frequency zero of Δy_t and $\sigma_{\Delta y}^2$ is the variance of Δy_t .

Finally, the “half-life” is a very popular measure of persistence especially in the literature that tries to evaluate the persistence of deviations from the “purchasing power parity equilibrium” (see, for instance, Murray and Papell (2002) and Rossi, (2001)). The “half-life” is defined as the number of periods for which the effect of a unit shock to inflation remains above 0.5. In the case of an AR(1) process given by $y_t = \rho y_{t-1} + \varepsilon_t$ it is easy to show that the half-life may be computed as $h = \frac{\ln(1/2)}{\ln(\rho)}$ ⁷.

The use of the “half-life” has been criticised on several grounds (see, for instance Pivetta and Reis, 2001). First, if the IRF is oscillating the half-life can understate the persistence of the process. Second, even for monotonically decaying processes this measure will not be adequate to compare two different series if one exhibits a faster initial decrease and then a subsequent slower decrease in the IRF than the other. Third, it may also be argued that for highly persistent processes the half-life is always very large and thus makes it difficult to distinguish changes in persistence over time. On the positive side, the half-life has the attractive feature that persistence is measured in units of time, which is not the case of any of the other three above mentioned measures of inflation persistence, and thus may be preferable for communication purposes. This probably explains why, despite the above criticisms, it still remains the most popular measure in the literature that investigates the persistence of deviations from PPP.

For the AR(p) process the exact computation of the “half-life” is more complex and for this reason, the simple expression above is usually used as an approximation to the true half-life. However Murray and Papell (2002) argue that this expression might not be a good approximation to the true “half-life” if the effect of the shock does not converge to zero monotonically. For that reason these authors choose to compute the half-life directly from the IRF⁸.

A potential problem that may arise with the computation of these measures stems from the fact that ordinary least squares estimators applied to (2.1) or (2.2) are not

⁷ In the case of the AR(1) the effect of a unit shock after h periods is ρ^h . The half-life is the number of periods h required for the effect to be reduced to half, so that we must have $\rho^h = 1/2$, from which the formula above follows.

⁸ Rossi (2001) derives an asymptotically correct formula for the half-life of an AR(p) process with a root close to unity.

free from finite sample biases. To deal with this problem, Andrews and Chen (1994) developed a “median unbiased estimator”, which is now of widespread use in empirical applications. This estimation procedure is used not only to obtain median unbiased estimates but also to compute median unbiased confidence intervals for ρ , (see, for instance, Murray and Papell, 2002 and Levin and Piger, 2003).

In summary, from the four measures of persistence just discussed, two of them, the “sum of autoregressive coefficients “ and the “spectrum at zero frequency” can be seen as close substitutes as they will tend to deliver the same conclusion for a fixed sample period. They also appear to be able to deliver the best estimates of inflation persistence. The “half-life” despite some limitations has the nice property of delivering persistence in units of time, which can be useful for communication purposes. In turn, the largest autoregressive root appears as the measure that can deviate the most from the true persistence of inflation.

In the following sections we focus mainly in ρ , the “sum of the autoregressive coefficients” as besides being a good measure of inflation persistence it also directly relates to the mean reversion coefficient of the series, which allows us to propose an alternative measure of persistence.

3. PERSISTENCE AND MEAN REVERSION

In this section we investigate the close relationship between persistence and mean reversion. Highlighting such a relationship has some obvious advantages. First, it allows a deeper understanding of what persistence implies in terms of the time path for any given stationary time series. Second, helps to emphasise the fact that we cannot measure persistence without previously addressing the issue of how to measure the mean of the series. Finally allows us to introduce an alternative simple and intuitive measure of inflation persistence.

In order to better understand the relationship between persistence and mean reversion we start by noting that equation (2.2) can be further reparameterised as:

$$\Delta y_t = \sum_{j=1}^{p-1} \delta_j \Delta y_{t-j} + (\rho - 1)[y_{t-1} - \mu] + \varepsilon_t \quad (3.1)$$

where

$$\mu = \frac{\alpha}{1-\rho} \quad (3.2)$$

We note that μ is the “unconditional mean” of the y_t series. As is well-known our AR(p) process in (2.1) and (2.2) may also be equivalently written as:

$$(y_t - \mu) = \sum_{j=1}^p \beta_j (y_{t-j} - \mu) + \varepsilon_t$$

or as

$$(y_t - \mu) = \sum_{j=1}^{p-1} \delta_j \Delta(y_{t-j} - \mu) + \rho(y_{t-1} - \mu) + \varepsilon_t \quad (3.3)$$

which shows that ρ , “the sum of the autoregressive coefficients”, can be obtained directly by estimating the model for the series of the “deviations from the mean”, $(y_t - \mu)$.

Let us now assume that y_t is a stationary series with $0 < \rho < 1$ ⁹. One identifying characteristic of any stationary time series is that it must exhibit the mean-reversion property¹⁰. In equation (3.1) the presence of mean reversion is reflected in the term $(\rho-1)[y_{t-1} - \mu]$. This implies that if in period $(t-1)$ the series y is above (below) the mean, the deviation $[y_{t-1} - \mu]$ will contribute as a “driving force” to a negative (positive) change of the series in the following period, through the coefficient $(\rho-1)$, thus bringing it closer to the mean. Of course mean reversion is stronger the larger (in absolute terms) the coefficient $\lambda = (\rho-1)$. Once we measure persistence by ρ and mean reversion by $\lambda = (\rho-1)$ we conclude that mean reversion and persistence are inversely related: high persistence implies low mean reversion and vice-versa.

This correspondence between persistence and mean reversion allows us to carry out a simple preliminary evaluation of persistence by visual inspection of two different series: in a graph with two stationary series the one exhibiting the lowest mean reversion, that is the one that crosses the mean less frequently, is the one exhibiting more persistence.

⁹ We shall assume that ρ is positive, because only under such a possibility does inflation persistence constitute an interesting issue.

¹⁰ This is true even for the so-called trend-stationary processes, as we shall see below. It is also well known that unit root processes, by definition, do not display this property.

To illustrate how important is the mean for the process of persistence evaluation, let us assume, for illustrative purposes that y_t follows a trend stationary process given by

$$y_t = \alpha_0 + \alpha_1 t + \varepsilon_t \quad (3.4)$$

In the simplest case ε_t might be a white noise process, and in this case persistence is zero. However to get a value of zero for our measures of persistence we need to properly account for the fact that the series has a time varying mean given by $E[y_t] = \mu_t = \alpha_0 + \alpha_1 t$. In other words, in order to get a zero value for our measures of persistence we have to think of the persistence of the white noise series, ε_t , that is the persistence of the deviations from the mean: $\varepsilon_t = (y_t - \alpha_0 - \alpha_1 t)$. Of course, if in empirical applications, we fail to take due account of the fact that the mean of the series is time varying and mistakenly assume it as constant over time, we are bound to conclude that the series is highly persistent when in fact it has no persistence at all. In general, for an assumed constant mean, any change in level of inflation will show up as higher persistence. On the contrary, a time varying mean will imply lower persistence (higher mean reversion), other things equal. In the limit, by assuming a constant mean we can turn a zero persistence series into a highly persistent one, or the other way round, by assuming a very flexible mean for inflation.

Some literature has to some extent recognized the liaison between persistence and the way the mean of the series is treated, and has tried to deal with the problem by identifying some “structural breaks in the level” of the series (see for instance Burdekin and Syklos (1999), Bleaney (2001), and Levin and Piger, (2003)). For instance, Levin and Piger (2003) investigate inflation persistence for 12 countries and 4 measures of inflation, in the period 1984-2002¹¹. In a first step the analysis is conducted under the assumption of a constant mean of the series for the whole period and the general conclusion is that inflation appears to be highly persistent, in most cases. In a second step the authors allow for the possibility of a structural break in the mean of the series and the general conclusion changes dramatically, the new global picture being one of low inflation persistence. Moreover, the reduction in estimated persistence is especially large for the countries for which the evidence of a structural

¹¹ The countries analysed are: Australia, Canada, France, Germany, Italy, Japan, The Netherlands, New Zealand, Sweden, Switzerland, United Kingdom and United States. For each country four different measures of inflation are investigated: GDP deflator, CPI, Core CPI and PCE deflator.

break is stronger¹². Countries for which evidence of a structural break is weaker are also the ones where remaining inflation persistence is higher¹³ (even though the evidence changes somewhat according to inflation measures). However, a natural remaining question regarding the work by Levin and Piger is whether the higher persistence found for these latter countries is a real feature of the data or rather a spurious result brought about by the assumption of a constant mean with a single break during the sample period. At least for some countries, allowing for a time varying mean appears as a reasonable alternative that may significantly change the conclusions about persistence.

In our opinion investigating inflation persistence under the univariate approach requires much more than simply accounting for the possibility of some potential discrete structural breaks in the mean of the series. In fact, it is unclear why one should test for breaks in the intercept when evaluating persistence. Testing for breaks in the intercept appears as a natural way to proceed in the context of the unit root literature. In such a context, we may wish to decide whether the data are better described by a model with a single intercept or by a model with two or more different intercepts. This of course also may have important consequences for the estimated persistence (the ρ parameter). However, in the context of persistence evaluation it is unclear why we should expect the second model to deliver a better estimate of persistence, as there is no reason why we should expect the mean which underlies the model with breaks in the intercept to be a better proxy for the unknown “long run level of inflation”¹⁴.

Given that, under the univariate times series representation of inflation, the mean of inflation is the level to which inflation returns after a shock, we see the mean of the series as playing the role of the long run level of inflation, the importance of which was discussed in the previous section. Thus, unless we have a theory or a model that allow us to reasonably assume that the long run equilibrium level of inflation can be

¹² These are: Australia, Canada, Italy, Sweden, The United Kingdom and the United States.

¹³ These are: France, Netherlands, New Zealand, Germany, Japan and Switzerland.

¹⁴ Moreover, it can be argued that testing for breaks implies endogeneising the mean because the outcome of such tests is conditional on a given estimated model. In other words, rather than computing persistence conditional on a given exogenous mean, as seems the natural thing to do given the exogeneity of the central inflation target, this approach computes the mean conditional on (or simultaneously with) the estimated persistence.

treated as a constant over the period under investigation, it seems more natural to assume a time varying mean, as the null hypothesis. Of course, under such a framework, the question of how to deal with an exogenous time varying mean naturally follows.

One can argue that without a theoretical model for the long run level of inflation we cannot expect to give the univariate approach a meaningful interpretation. However, specifying a theoretical model for the long run level of inflation will drive us away from the univariate framework into the multivariate approach. Thus, in order to stay within the univariate approach, we must use a pure statistical model to extract the mean of inflation. In this regard, the Hodrik-Prescott (HP) filter, the Baxter and King “band-pass filter” or simple “centred moving averages” appear as obvious candidates. We can also think of alternative measures of core inflation, provided these meet some required statistical criteria, as the ones suggested in Marques *et al.* (2002 and 2003). But of course by following such a an approach one is assuming that no matter what the truelong run driving forces of inflation are, the “long run level” of inflation can be well approximated by such statistical devices. For countries in which a credible inflation-targeting monetary policy has been followed we can also use the “exogenously announced inflation target” and for countries, where they are available, survey inflation-expectations can also be used¹⁵.

In concluding this section, we may summarize the above discussion in two main points. First, when evaluating the persistence of the series what really matters is the persistence of deviations from the mean. Second, we should not address inflation persistence without a previous discussion of how we expect the mean of the series, i.e., the “long run level” of inflation to have evolved over time, as failure to properly account for changes in the mean of the series will show up as (spurious) higher persistence.

¹⁵ See, for instance, Kozicki and Tinsley (2003) or Kieler (2003)).

4. AN ALTERNATIVE MEASURE OF PERSISTENCE

Given the monotonic relationship between the “sum of the autoregressive coefficients” (ρ) and the coefficient of mean reversion (λ) it appears natural to define the ratio

$$\gamma = 1 - \frac{n}{T} \quad (4.1)$$

as a measure of inflation persistence, where n stands for the number of times the series crosses the mean during a time interval with $T+1$ observations.

The γ statistic has the advantage of not requiring the researcher to specify and estimate a model for the inflation process. For this reason it can be expected to be a robust statistic against model misspecifications.

We note that γ , by construction, is always between zero and one. However, it can be shown (see Appendix A) that for a symmetric zero mean white noise process we have $E[\gamma] = 0.5$, so that values of γ close to 0.5 signal the absence of any significant persistence (white noise behaviour) while figures significantly above 0.5 signal significant persistence. On the other hand, figures below 0.5 signal a negative ρ , that is, negative long-run autocorrelation. It is also shown in Appendix A that under the assumption of a symmetric white noise process for inflation (zero persistence) the following result holds:

$$\frac{\gamma - 0.5}{0.5 / \sqrt{T}} \overset{\Delta}{\sim} N(0;1) \quad (4.2)$$

Result (4.2) allows us to carry out some simple tests on the statistical significance of the estimated persistence (i.e., $\gamma=0.5$)¹⁶. We note however that result (4.2) is valid only under the assumption of a pure white noise process and that if the null of $\gamma=0.5$ is rejected, we should expect γ to have a more complicated distribution, which, in particular, may depend on the characteristics of the data generating process.

An additional interesting property of γ is that there is a simple relation between the estimate of γ for a given period with $T+1$ observations and the estimated γ 's for two

¹⁶ For instance for a sample with $T=100$ the null of $\gamma=0.5$ (zero persistence) will be rejected for any estimated γ larger than 0.60.

non-overlapping consecutive sub-periods with T_1+1 and T_2+1 observations such that $T+1 = (T_1+1) + (T_2+1)$. In fact we have

$$1 - \gamma = \frac{n}{T} \approx \frac{n_1 + n_2}{T_1 + T_2} = \frac{n_1}{T_1} \frac{T_1}{T_1 + T_2} + \frac{n_2}{T_2} \frac{T_2}{T_1 + T_2} = \alpha(1 - \gamma_1) + (1 - \alpha)(1 - \gamma_2)$$

or simply

$$\gamma \approx \alpha\gamma_1 + (1 - \alpha)\gamma_2 \quad (4.3)$$

so that persistence for the whole period is (approximately) a weighted average of the persistence for the two consecutive periods.

Below we will consider the possibility of a pure time varying mean for inflation. In such case we measure persistence of the deviations from the time varying mean and our model may be written as

$$y_t = \alpha_t + \sum_{j=1}^p \beta_j y_{t-j} + \varepsilon_t \quad (4.4)$$

or equivalently as

$$(y_t - \mu_t) = \sum_{j=1}^p \beta_j (y_{t-j} - \mu_{t-j}) + \varepsilon_t \quad (4.5)$$

or further as

$$(y_t - \mu_t) = \sum_{j=1}^p \delta_j \Delta(y_{t-j} - \mu_{t-j}) + \rho(y_{t-1} - \mu_{t-1}) + \varepsilon_t \quad (4.6)$$

which corresponds to the general model used in section 5.

5. PERSISTENCE AND MEAN REVERSION: RE-EVALUATING INFLATION PERSISTENCE IN THE UNITED STATES AND THE EURO AREA

In this section we illustrate the issues discussed above, by re-evaluating the evidence on inflation persistence for the United States (U.S.) and the Euro Area (E.A.). For the U.S. both the GDP deflator and the consumer price index are analysed while for the Euro Area, for reasons of data availability, only the consumer price index is

investigated¹⁷. For reasons of space the analysis will mainly focus on the U.S. GDP deflator, so that results on the consumer price indices for the U.S. and E.A. are only explicitly mentioned when they are thought to add to the conclusions. However, all the results for the three series are equally presented in Appendix B. As measures of persistence we mainly use ρ , the “sum of the autoregressive coefficients” and γ the “the proportion of mean crossings”, suggested in the previous section.

There is now a widely accepted view in the literature that inflation has been more persistent during the sixties and seventies than thereafter. For instance, Levin and Piger (2003) write, “there is widespread agreement that inflation persistence was very high over the period extending from 1965 to the disinflation of the early 1980s. However, there is substantial debate regarding whether inflation persistence continued to be high since the early 1980s, or has declined”. In the same vein see Cogley and Sargent (2001), Willis (2003) and Guerrieri (2002)¹⁸.

Graph No.1 displays quarterly inflation in the U.S. as from 1960q2 to 2002q4 using the GDP deflator. This series has been analysed among others by Taylor (2000), Cogley and Sargent (2001), Pivetta and Reis (2001) and Levin and Piger (2003).

Let us start by focussing on the mean of inflation. Simple visual inspection of Graph No.1 suggests that we can basically distinguish three distinct periods. The first period stretches from the beginning of the sample until roughly the end of 1980. During this period, inflation exhibits a clear upward trend. Thus, if anything, the data suggest that we should not embark in a persistence evaluation exercise without accounting for the possibility of a time varying mean. Clearly assuming a constant mean as has been done in some literature does not appear a realistic approach.

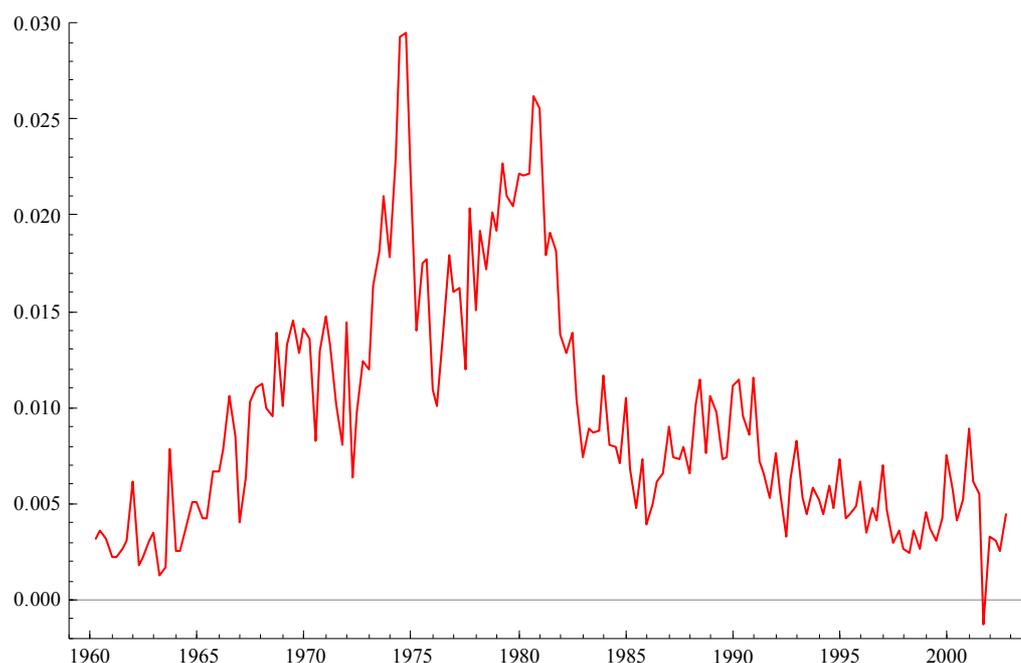
¹⁷ For the Euro Area the official data on the GDP price deflator are available only after 1992q1, which motivated not including this series in the analysis. Also the aggregate consumer price index for the twelve countries of the euro area only starts in 1967q1, which conditioned the final sample period used in the analysis. The original data for the consumer price index in the U.S. refers to the series of “consumer prices, all items, all urban consumers, seasonally adjusted” for the period 1967q1 to 2002q4 (IMF series) while the series for the Euro Area corresponds to the original 12 euro area countries (with fixed weights), for the same period. In turn, the original data for the quarterly GDP price deflator were downloaded from the Bureau of Economic Analysis website and refers to a somewhat longer period (1960q1 to 2002q4), in order to allow comparability with other empirical studies. In all cases, the inflation rate is obtained as the first difference of logged price indices.

¹⁸ Against this view see, however, Pivetta and Reis (2001) and Stock (2001). These authors argue that there is not enough evidence to conclude for a change in persistence.

The second period is composed of a very pronounced downward trend that took place during roughly 1981 and 1982. Finally, a third period from 1983 onwards, in which inflation seems not to have exhibited a clear increasing or decreasing trend. We note that this last period (1983-2002) basically corresponds to the sample period analysed in Levin and Piger (2003). Similarly to what these authors have done, this latter period can further be decomposed into two sub-periods according to the two different average levels of inflation: the first starting in 1983 and ending in mid 1991, (which corresponds to a higher average inflation) and the second, starting in mid 1991 to the end of the sample (with a lower average inflation rate)¹⁹.

Graph No.1

Quarter-on-quarter U. S. inflation – GDP deflator



Graph No. 2 displays the mean of inflation for each of these sub-periods, where two simple linear time trends during the first two sub-periods and a constant with a break in 1991q3, during the third sub-period, were used to proxy the time varying mean.

¹⁹ Actually Levin and Piger (2003) analyse the period 1984q1-2002q3. Using a formal testing procedure they found a structural break in the mean of inflation occurring in 1991q2. In our case we set the break in 1991q3 as this delivers a higher R^2 in the equation below.

Specifically the mean of inflation in Graph No.2 is obtained as the fitted values of the regression model:

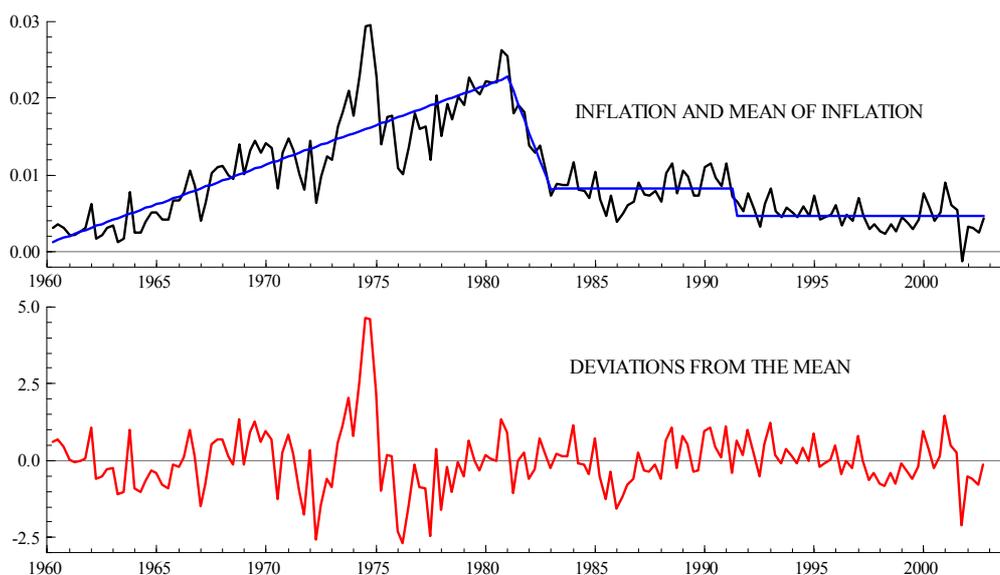
$$\pi_t = 0.0008 + 0.0003t_1 + 0.1792d_2 - 0.0018t_2 + 0.0075d_3 - 0.0036d_4$$

(1.30) (19.5) (5.43) (-4.99) (9.15) (-5.44)

estimated for the period 1960q2 to 2002q4²⁰. The lower panel of Graph No.2 displays the residuals of the regression, i.e., the deviations from the mean of inflation. A similar decomposition for the consumer price indices in the U.S. and the E.A. is performed in Appendix B (see Graphs B.3 and B.8)²¹.

Graph No.2

Quarter-on-quarter U. S. inflation – GDP deflator



Some of the analyses carried out for the U.S. as regards how the mean of inflation is treated, can be seen as special cases of Graph No.2. For instance, Taylor (2000)

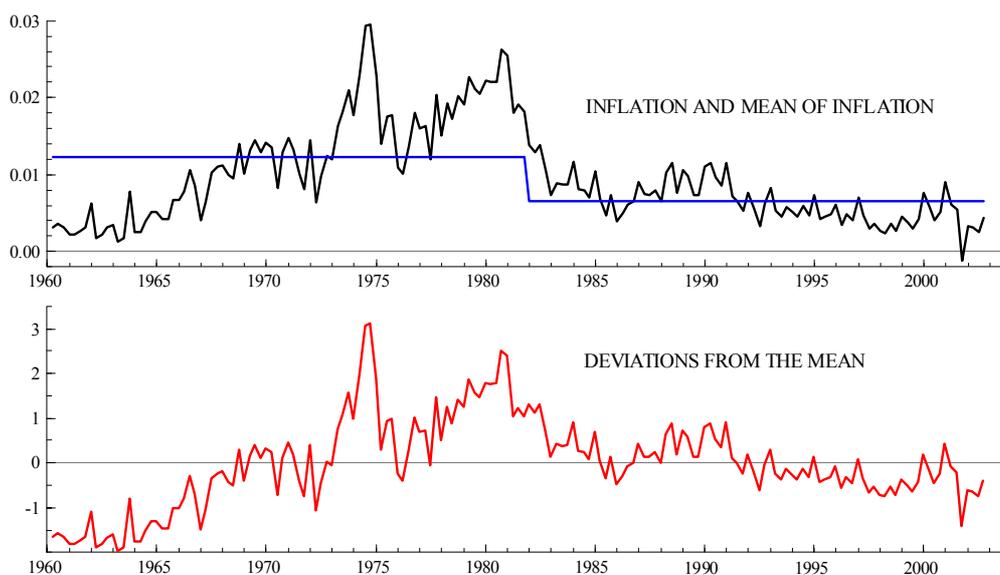
²⁰ The variables are defined as follows: t_1 = time trend for the period 1960q2 to 1980q4; t_2 = time trend for the period 1981q1 to 1983q1; d_2 = constant for the period 1981q1 to 1983q1; d_3 = constant for the period 1983q2 to 2002q4; d_4 = constant for the period 1991q3 to 2002q4. As expected this static regression exhibits some autocorrelation. However all the coefficients remain significant (except the global constant) when we allow for six lags of inflation to account for serial correlation. This can be seen as evidence that the assumed (deterministic) time profile for the mean in Graph No.2 is consistent with the data.

²¹ We note that the specific dates used to define the different sub-periods for each series were identified after eyeballing the series and are such that the resulting mean fits the data in the smoothest possible way.

basically assumes two different sub-periods: the first covering the sixties and seventies and the second covering basically the second half of the eighties to the end of the sample period. For each sub-period, the mean of inflation is assumed constant. The upper panel of Graph No.3 displays inflation as well as the average of inflation rates for two different sub-periods: 1960q2-1981q4 and 1982q1-2002q4. The lower panel displays the deviations of the series from these two different means. It is the persistence of these series that is analysed in Taylor (2000), with minor differences due to slightly different dates for the cut-off of the series. The conclusion of Taylor (2000) is that persistence has been larger during the first part of the sample²².

Graph No.3

Quarter-on-quarter U. S. inflation – GDP deflator



At first sight, by looking at the lower panel of Graph No.3 it appears that persistence is higher during the period 1960q2-1981q4. In fact for this period we get $\rho=0.92$, while for the period 1982q1-2002q4 we get $\rho=0.73$, thus apparently confirming our first guess (see Table 1 in the Appendix B). However, when we take a closer look at the graph we realise that in fact (average) mean reversion in the two periods is probably not significantly different in the two periods. In fact, we get $\gamma=0.83$ for the

²² Specifically Taylor (2000) considers the periods 1960q2-1979q1 and 1982q1-1999q3, so that the years 1980 and 1981 are excluded from the analysis. The author obtains $\rho=0.94$ for the first sub-period and $\rho=0.74$ for the second.

first sub-period and $\gamma=0.80$ for the second sub-period ($\gamma=0.81$ for the whole period) suggesting that there may not be a strong evidence of a change in persistence²³.

In formal terms we tested the change in persistence by estimating models (B.1) to (B.4) which are described in Appendix B. According to model (B.1) and (B.3) we would conclude that there is not a strong evidence favouring the idea of a significant change in persistence between the two periods (see Table 1 in Appendix B). However the conclusion is reversed if we rather retain the results of models (B.2) and (B.4). According to these models, which are not likely to suffer from over-parameterisation and thus allow more efficient inference the null of equal ρ s for the two sub-periods can be rejected²⁴.

A similar conclusion can be drawn for the consumer price index in the U.S. even though the evidence of a change in persistence between the two sub-periods is not as strong as in the case of the GDP deflator. However, for the E.A., even though the point estimates of ρ and γ suggest that we still are in the presence of a significantly persistent process (we get $\rho=0.85$ and $\gamma=0.79$ for the sub-period 1967/2-1983/4 and $\rho=0.80$ and $\gamma=0.74$ for the sub-period 1984/1-2002/4) there is no evidence of a significant decline between these two sub-periods (see Graphs B.1 and B.6 and Table 1 in Appendix B for details). So, from the situation depicted in Graph No.3 (and similarly in Graphs B.1 and B.6), which basically corresponds to the conventional analysis carried out in the literature that assumes a constant mean in each sub-period, we conclude that 1) inflation in the U.S. and the E.A. appears to have been highly persistent in the sixties and seventies (first sub-period) 2) inflation persistence in the

²³ We note that we do not have a test statistic to formally discuss whether the two estimates of γ are statistically different or not, so that strictly speaking, we cannot be sure whether these two magnitudes are statistically equivalent.

A potential explanation for the fact that the estimated ρ s differ a lot between the two periods while γ does not is that the estimated ρ in the first period is probably biased upwards due to the fact that mean reversion rather than being spread out all over the sample period is highly concentrated in the middle of the period (1968-1972). This also suggests that, if we assume a constant mean, then the period 1960-1981 is not homogenous in what regards inflation persistence. In terms of mean reversion we can distinguish three different sub-periods in Graph No.3: a first sub-period that goes from the beginning of sample (1960) until 1967 in which there is no mean reversion at all; a second sub-period in which mean reversion is high (1968-1973) and again a sub-period with very high persistence (1973-1981).

²⁴ We note that the structural break tests conducted in Appendix B correspond to the classical Chow tests, in which the break date is assumed to be fixed and known, rather than allowing for a break at an unknown date as in the methodology developed by Andrews (1993).

U.S has declined during the last twenty years or so (second sub-period) and 3) there is not a strong evidence that inflation persistence in the E.A has declined during the last two decades or so.

The previous approach to persistence evaluation has as its main limitation the fact that it assumes a constant mean for inflation during each sub-period. Most likely, many econometricians would argue that during the first sub-period (1960-1981), rather than exhibiting mean reversion, the GDP inflation series in Graph No.3 is more likely to be non-stationary. In fact an ADF test for this period (assuming a constant mean) reveals that the null of a unit root cannot be rejected casting strong doubts on the usefulness of measuring inflation persistence for the U.S. during this period assuming a constant mean²⁵. Of course, the above test on the statistical significance for the difference in the estimated ρ s is not valid if the series is not stationary.

To see how things can change let us now assume that the mean of inflation during the first two sub-periods (1960q2-1980q4 and 1981q1-1983q1) may be approximated by two linear time trends as in Graph No.2. This new possibility is displayed in Graph No.4 (upper panel), which differs from Graph No.2 in that it assumes a constant mean with no break for the whole sub-period 1983q2-2002q4. The ADF unit root test suggests that assuming a linear time trend to measure the mean of inflation in the sub-period 1960q2 to 1980q4 is a reasonable alternative (statistically speaking), as in such case, the null of a unit root is rejected in favour of a trend stationary process for inflation.

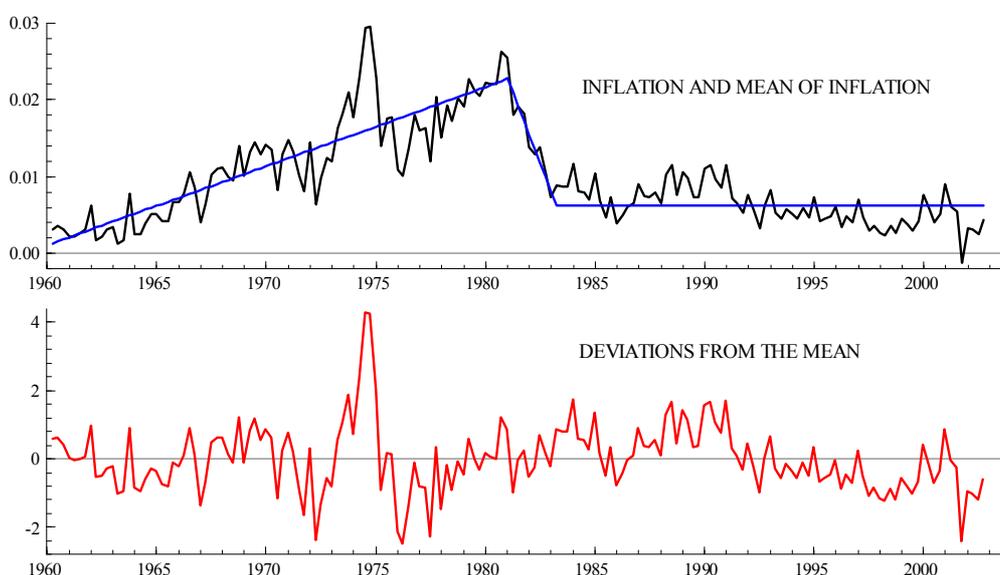
Now we have a different picture. Looking at the lower panel of Graph No.4, it is no longer so obvious that persistence for the period 1960-1980 has been higher than persistence in the period 1981- 2002. In fact, if anything, the results are now the other way round. First, for the whole period we now get $\rho=0.58$ and $\gamma=0.70$ suggesting the absence of any significant persistence. Second, we get estimates of persistence for the first sub-period which are lower (though not significantly so) than the ones for the second sub-period, in contrast with the previous situation. In fact, for the sub-period 1960q2-1980q4 we now have $\rho=0.45$ and $\gamma=0.66$ while for the sub-period 1981q1-2002q4 we have $\rho=0.79$ and $\gamma=0.74$. Thus, once we allow for a time varying mean

²⁵ The ADF test for the U.S. GDP deflator can be computed from Table 1 as $(0.92-1)/0.052 = -1.53$, so that the null of a unit root in inflation for the sub-period 1960q2-1981q4 cannot be rejected even for a 10% test.

(proxied by a time trend) as a more sensible approach, we get inflation less persistent in the sixties and seventies than in eighties and nineties. This conclusion does not change if instead we define the two sub-periods as from 1960q2-1983q1 and 1983q2-2002q4 or even if we exclude from the analysis the sub-period 1981q1-1983q1 – during which inflation exhibited a strong downward trend – and compare the sub-periods 1960q2-1980q4 and 1983q2-2002q4 (see Table 2 in Appendix B for details).

Graph No.4

Quarter-on-quarter U. S. inflation – GDP deflator



It is important to stress this result because it runs against the above-cited widely accepted idea that inflation in the U.S. has been more persistent in the sixties and seventies, than in the last twenty years. Put differently, the so-called widespread evidence claiming that inflation was more persistent in the sixties and seventies crucially depends on the implicit assumption of a time invariant mean for inflation in this period, which appears to be a counterfactual assumption.

Interestingly enough the results for the consumer price indices are not so clear-cut. The similar case for the Euro Area (see Graph B.7 and Table 2) delivers estimates of persistence that are basically equivalent for the sub-periods considered (for instance, we have $\rho=0.81$ and $\gamma=0.75$ for the sub-period 1967q2-1980q4 and $\rho=0.88$ and $\gamma=0.75$ for the sub-period 1986q2-2002q4). Also there is no statistical evidence of a

change in persistence between the two sub-periods. However for the U.S. consumer price index the conclusion very much depends on the sub-periods considered. If we compare the sub-periods 1967q2-1980q2 and 1980q3-2002q4 we conclude (using models B.2 and B.4) that persistence is higher during the first sub-period. However, if we rather take the two sub-periods 1967q2-1982q4 and 1983q1-2002q4 we get no evidence of a change in persistence. The reason for such a different conclusion stems from the effect of the sub-period 1980q3-1982q4 during which the estimated persistence is very low. If we exclude this sub-period from the analysis we conclude that persistence during the sub-period 1967q2-1980q4 and 1983q1-2002q4 is basically the same when measured by ρ .

Of course this is not the end of the story since by looking at the inflation series we can think of many other reasonable possibilities to measure the mean of inflation. For instance, if we now also assume two different means for the sub-period 1983-2002, as in Levin and Piger (2003) we end up with the situation described in Graph No.2, with the residuals (deviations from the mean) depicted in the corresponding lower panel. Now again we have a different picture. For the U.S. GDP deflator we get estimates for ρ which display an impressive constancy (see Table 3 in Appendix B). For all the sub-periods considered we have $\rho=0.45$ and thus the idea we get from the analysis of Graph No.2 is that the persistent process has now evaporated. This conclusion is to some extent confirmed by the statistics γ (which varies between 0.60 and 0.66)²⁶.

The results of a similar treatment for the consumer price indices in the U.S. and the E.A. can be seen in Graphs B.3 and B.8. and Table 3 in Appendix B. For the U.S. allowing for a break in the mean during the last sub-period (1983q1-2002q4) does not change the results in any significant way (vis-à-vis the previous situation). In particular the γ statistic does not change at all. The reason is that in contrast to the GDP series there seems to be no significant evidence of a break in the mean of the U.S. CPI inflation (compare Graphs B.2 and B.3). For the E.A. allowing for a break in the mean during the last sub-period reduces the estimates of persistence for this sub-period (as well as for the whole period), as expected. Now there is some (weak) evidence of a change in persistence when we compare the sub-periods 1967q2-1980q4

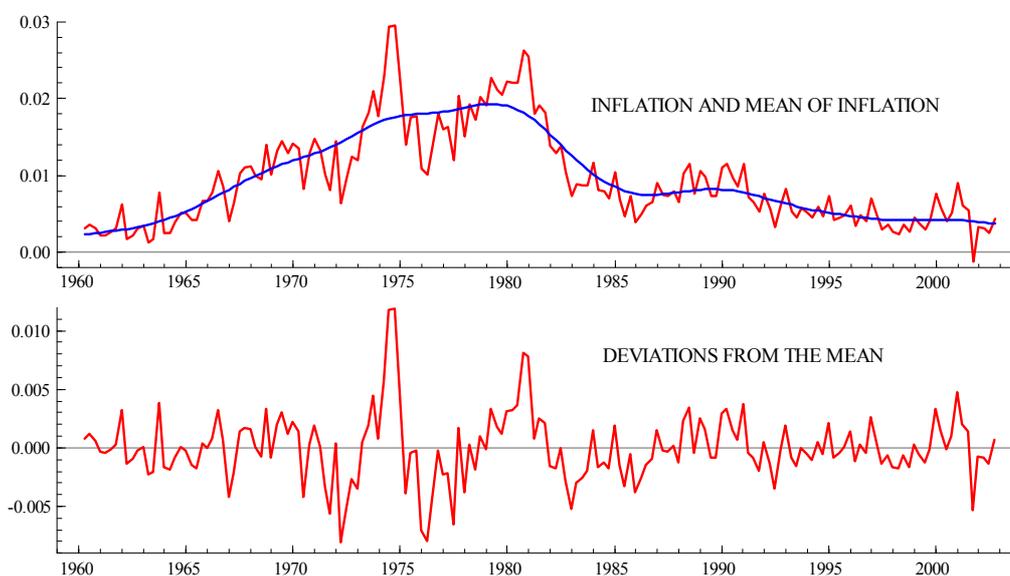
²⁶ We note that $\rho=0.50$ implies a half-life equal to 1 and thus absence of a significant persistence. Also it is easy to see that $\gamma=0.60$ is close to being not significantly different from 0.50 (zero persistence).

and 1981q1-2002q4 (model B.2) even though such evidence does not stand when we compare the sub-periods 1967q2-1986q1 and 1986q2-2002q4.

Of course, one may argue that there are no theoretical reasons why the mean of inflation should evolve over time as assumed in Graph No.2. A less subjective solution (in the sense that it is not defined after looking at the data) can be obtained by entertaining the possibility of a pure time varying mean and see what happens to inflation persistence under such circumstances. We consider two different possibilities for the mean of inflation: the widely used HP filter (with $\lambda=1600$) which is depicted in Graph No. 5 and the 13 terms centred moving average, which is displayed in Chart No.6. We note that the “moving average mean” is more flexible than the “HP mean” and that this will show up in lower persistence estimates.

Graph No.5

Quarter-on-quarter U. S. inflation – GDP deflator



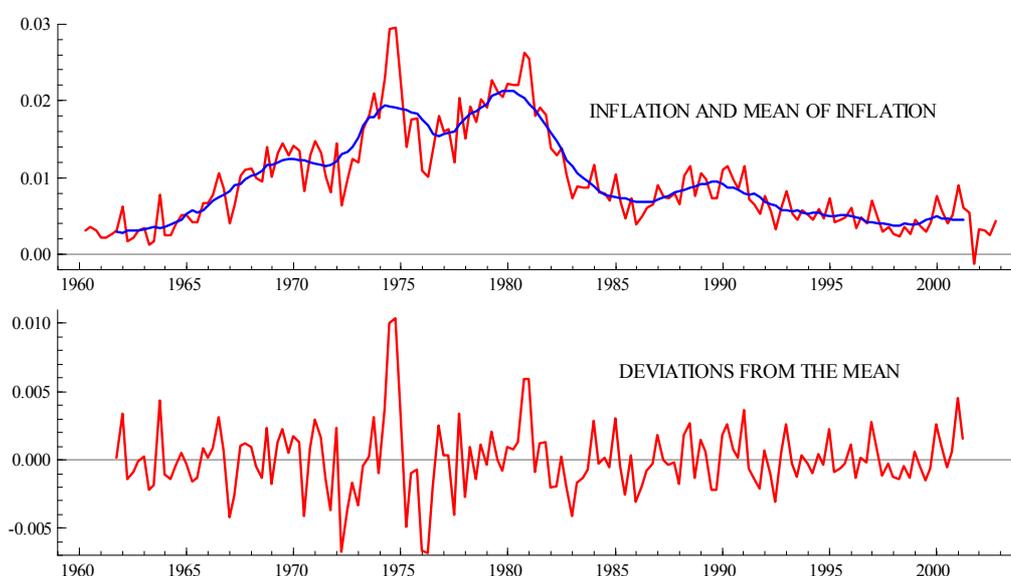
Now we see that while there seems to be still some residual (even though not significant) inflation persistence under the “HP mean” (we get $\rho=0.44$ and $\gamma=0.60$ for the U.S. GDP deflator), the “moving average mean” has basically removed all the persistence in the inflation series (we have $\rho=-0.03$ and $\gamma=0.52$). Moreover, once again there seems to be no strong evidence of a difference in persistence for the two

periods under analysis, i.e., there seems to be no change in inflation persistence through time. These conjectures are formally tested and confirmed in Tables 4 and 5.

These conclusions also stand for the consumer price indices in the U.S and the E.A. (see Graphs B.4 and B.5 for the U.S. and Graphs B.9 and B.10 for the E.A. and Tables 4 and 5)²⁷.

Graph No.6

Quarter-on-quarter U. S. inflation – GDP deflator



A noteworthy final remark regards the use of ρ as a measure of inflation persistence. In several cases the estimates for ρ turn out to be very sensitive to the number of lags of the selected model. For instance, in Table 3 the estimate $\rho=0.45$ for the U.S: GDP deflator during the sub-periods 1981q1-2002q4 or 1983q2-2002q4 is obtained for a model with three lags²⁸. However if a model with a single lag were chosen, we would get $\rho=0.25$ for the period 1981q1-2002q4 and $\rho=0.30$ for the sub-period 1983q2-

²⁷ As regards the U.S CPI we can see from Tables 4 and 5 that there seems to be some evidence of a decrease in persistence when we compare the periods (1967q2-1980q2) with the period (1980q3-2002q4), but once again such evidence disappears when we compare the period (1967q2-1982q4) with the period (1983q1-2002q4). The important point however is that the estimates of persistence for any sub-period are not statistically different from zero (i.e., γ is not statistically different from 0.5 or ρ is such that the implied half-life is less than 1).

²⁸ Such cases are marked ** in Tables 1 to 5 in Appendix B.

2002q4. In such cases γ may be seen as an interesting alternative measure of persistence as it does not require specifying an estimating a model to inflation.

Summing up, this section shows that the evidence on inflation persistence dramatically changes with the assumption on the mean of inflation. In particular, the evidence on whether inflation persistence was higher in the sixties and seventies than in the two last decades or whether inflation is persistent at all, ultimately hinges on the type of mean assumed when computing persistence. This section considers some statistical approaches to proxy the (time varying) mean of inflation, but, of course, other alternatives, as the ones discussed in section 3, could have been entertained. However, the real issue is that the reliability of any estimate of inflation persistence ultimately depends on how realistic the assumed long run inflation path is.

6. CONCLUSIONS

The main conclusions of this paper, which addresses some inflation persistence issues in the context of the univariate approach, may be summarized as follows.

First, it is stressed that any estimate of inflation persistence is conditional on a given assumption for the long run equilibrium level of inflation, which in the context of the univariate approach is proxied by the mean of inflation. Moreover, it is seen that there is a trade off between persistence and flexibility of the assumed long run level of inflation. In particular, persistence is maximised by assuming a time invariant mean for inflation.

Second, it is argued that the commonly followed empirical approach of computing inflation persistence under the assumption of a constant mean or of a piecewise constant mean, i.e., allowing for some structural breaks in the intercept of the estimated model, does not constitute a promising way to deal with the problem.

Third, exploring the relationship between persistence and mean reversion an alternative statistic to measure inflation persistence is suggested, which has the advantage of not requiring specifying and estimating a model for inflation.

Finally, estimates of inflation persistence for the U.S. and the Euro Area using quarterly GDP deflator and CPI are computed. Several sub-periods as well as different ways of proxying a time varying mean are considered. From this exercise a major

conclusion emerges: the evidence on whether inflation persistence was higher in the sixties and seventies than in the two last decades or whether inflation is persistent at all, ultimately hinges on the type of mean assumed when computing persistence.

The crucial dependence of the results on the assumed long run level of inflation obviously puts into question the usefulness of the univariate approach to investigate inflation persistence, unless we can find an acceptable proxy for the time varying mean of inflation. For countries for which a credible inflation-targeting monetary policy has been implemented using the exogenously announced inflation target to proxy the mean of inflation seems to be the natural solution. However, a problem remains for countries (or sample periods) for which it is not reasonable to assume a constant inflation target (for instance, most European countries in the sixties and the seventies or even in the nineties during the convergence period, before the launching of the euro). For such cases, before we are able to draw robust conclusions on inflation persistence, in the context of the univariate analysis, more work needs to be done in order to identify reliable measures for the long run level of inflation. A way out could be for researchers to agree on a small number of ways to compute a (potentially) time varying mean. This will allow obtaining comparable estimates for different countries and for different time periods.

REFERENCES

- Andrews, D.W.K., 1993, "Tests for parameter instability and structural change with unknown change point", *Econometrica*, 61, 821-856;
- Andrews, D.W.K., Chen H-Y, 1994, "Approximately median-unbiased estimation of autoregressive models", *Journal of Business & Economic Statistics*, Vol.12, No.2, 187-204;
- Batini, N., 2002, "Euro area inflation persistence", ECB, WP. No.201;
- Batini, N., Nelson, E., 2002, "The lag from monetary policy actions to inflation: Friedman revisited", Bank of England, Discussion Paper No.6;
- Bleaney, M., 2001, "Exchange rate regimes and inflation persistence", *IMF Staff Papers*, Vol. 47, No.3;

- Burdekin R.C.K., Syklos P.L., 1999, "Exchange rate regimes and shifts in inflation persistence: does nothing else matter?", *Journal of Money, Credit, and Banking*, Vol. 31, No.2, 235-247;
- Cati R.C., Garcia M.G.P., Perron P., 1999, "Unit roots in the presence of abrupt governmental intervention with an application to brazilian data", *Journal of Applied Econometrics*, 14, 27-56;
- Cogley T., Sargent, T., 2001, "Evolving post-war II U.S. inflation dynamics", NBER, *Macroeconomics Annual* edited by Ben S. Bernanke and Kenneth Rogoff;
- Guerrieri, L., 2002, "The inflation persistence of staggered contracts", Board of Governors of the Federal Reserve System;
- Kieler, M., 2003, "Is inflation higher in the euro area than in the United States?", IMF country Report No.03/298;
- Kozicki, S., Tinsley, P.A., 2002, "Alternative sources of the lag dynamics of inflation", RWP 02-12, Federal Reserve Bank of Kansas City;
- Levin A. T., Piger J. M., 2003, "Is inflation persistence intrinsic in industrial economies"? mimeo
- Marques C., R., Neves, P. D., Silva, A.G., 2002, "Why should central banks avoid the use of the underlying inflation indicator?", *Economics Letters*, Vol. 75, 17-23;
- Marques C., R., Neves, P. D., Sarmiento L.M., 2003, "Evaluating core inflation indicators", *Economic Modelling*, Vol.20/4, 765-775;
- Murray C. J., and Papell D. H., 2002, "The purchasing power parity persistence paradigm", *Journal of International Economics*, 56, 1-19;
- Pivetta F., Reis, R., 2002, "The persistence of inflation in the United States", mimeo;
- Rossi B., 2001, "Confidence intervals for half-life deviations from purchasing power parity", mimeo;
- Stock, J., 1991, "Confidence intervals for the largest autoregressive root in the US macroeconomic time series". *Journal of Monetary Economics*, 28, 435-459;
- Stock, J., 2001, "Comment", NBER, *Macroeconomics Annual*, edited by Ben S. Bernanke and Kenneth Rogoff;
- Taylor, J.B., 2000, "Low inflation, pass-through, and the pricing power of firms", *European Economic Review*, 44, 1389-1408;

Willis, J., L., 2003, “Implications of structural changes in the U.S. economy for pricing behavior and inflation dynamics”, Economic Review, First Quarter 2003, Federal Reserve Bank of Kansas City;

APPENDIX A – PERFORMING STATISTICAL TESTS ON THE γ STATISTIC

In this appendix we derive equations (4.2), which allows us to carry out the test of $\gamma=0.5$.

Derivation of equation (4.2)

Let ε_t stand for a zero mean white noise process, such that ε_t will assume positive and negative values with equal probability, and define x_t as a random variable such that $x_t=1$ if the series crosses the mean, i.e., if $\varepsilon_t \cdot \varepsilon_{t-1} < 0$ and $x_t=0$ if $\varepsilon_t \cdot \varepsilon_{t-1} > 0$. Then our measure of persistence can be written as

$$\gamma = 1 - \sum_1^T x_t / T = 1 - \bar{x} \quad (\text{A.1})$$

where x_t is a random variable with a Bernoulli distribution in which the probability of “success” equals to the probability of “failure” i.e., $p=1-p=0.5$. Thus, we have $E[x_t]=0.5$ and $\text{Var}[x_t]=p(1-p)=0.25$ which implies that $E[\gamma]=0.5$ and $\text{Var}[\gamma]=p(1-p)/T=0.25/T^{29}$. By the central limit theorem it follows that under the assumption of a white noise process for inflation (zero persistence process) we have

$$\gamma \hat{\sim} N(0.5; 0.25 / T) \quad (\text{A.2})$$

that is

$$\frac{\gamma - 0.5}{0.5 / \sqrt{T}} \hat{\sim} N(0; 1) \quad (\text{A.3})$$

which is equation (4.2) in section 4. This result allows us to carry out some simple tests on the statistical significance of γ . For instance for a sample with $T=100$ the null of $\gamma=0.5$ (zero persistence) will be rejected for any estimated γ larger than 0.60.

²⁹ It is possible to show that $\text{cov}[x_t, x_{t-j}] = 0$, for $j \neq 0$. For instance, note that $w_t = x_t \cdot x_{t-1}$ is a random variable with $E[w_t] = 0 \cdot \frac{6}{8} + 1 \cdot \frac{2}{8} = 0.25$ so that $\text{cov}[x_t, x_{t-1}] = E[x_t \cdot x_{t-1}] - E[x_t]E[x_{t-1}] = 0.25 - 0.5 \times 0.5 = 0$.

APPENDIX B – TESTING FOR CHANGES IN PERSISTENCE

To test for a change in persistence we assume the general autoregressive model

$$z_t = \sum_{j=1}^p \beta_j z_{t-j} + \varepsilon_t$$

reparameterised as

$$z_t = \sum_{j=1}^{p-1} \delta_j \Delta z_{t-j} + \rho z_{t-1} + \varepsilon_t$$

with

$$\rho = \sum_{j=1}^p \beta_j, \quad \delta_j = - \sum_{i=1+j}^p \beta_i$$

and where z_t is the series of deviations from the mean. The following four models were estimated:

$$z_t = \sum_{j=1}^{p-1} \delta_j \Delta z_{t-j} + \sum_{j=1}^{p-1} \phi_j d_t \cdot \Delta z_{t-j} + \rho_1 z_{t-1} + \rho_2 d_t \cdot z_{t-1} + \varepsilon_t \quad (\text{B.1})$$

$$z_t = \sum_{j=1}^{p-1} \delta_j \Delta z_{t-j} + \rho_1 z_{t-1} + \rho_2 d_t \cdot z_{t-1} + \varepsilon_t \quad (\text{B.2})$$

$$z_t = \sum_{j=0}^{p-1} \theta_j \Delta d_{t-j} + \sum_{j=1}^{p-1} \delta_j \Delta z_{t-j} + \sum_{j=1}^{p-1} \phi_j d_t \cdot \Delta z_{t-j} + \rho_1 z_{t-1} + \rho_2 d_t \cdot z_{t-1} + \varepsilon_t \quad (\text{B.3})$$

$$z_t = \sum_{j=0}^{p-1} \theta_j \Delta d_{t-j} + \sum_{j=1}^{p-1} \delta_j \Delta z_{t-j} + \rho_1 z_{t-1} + \rho_2 d_t \cdot z_{t-1} + \varepsilon_t \quad (\text{B.4})$$

where d_t is a dummy variable which is zero before the date of the break ($t < s$) and equals 1 thereafter ($t \geq s$) and Δd_t is a dummy variable which is one for the date of the break ($t = s$) and zero otherwise.

We note that while models (B.1) and (B.3) allow for the possibility of a break in every autoregressive coefficient, models (B.2) and (B.4) by assuming that $\phi_1 = \phi_2 = \dots = \phi_{p-1} = 0$ basically impose that the change in the persistence parameter (the sum of the autoregressive parameters) stems solely from a change in the first autoregressive parameter, i.e., β_1 . Even though this might appear a very restrictive

assumption the fact is that models (B.1) and (B.3) turned out also to deliver too many insignificant ϕ_j coefficients suggesting that they might be over-parameterised thus, raising concerns about the power of the test.

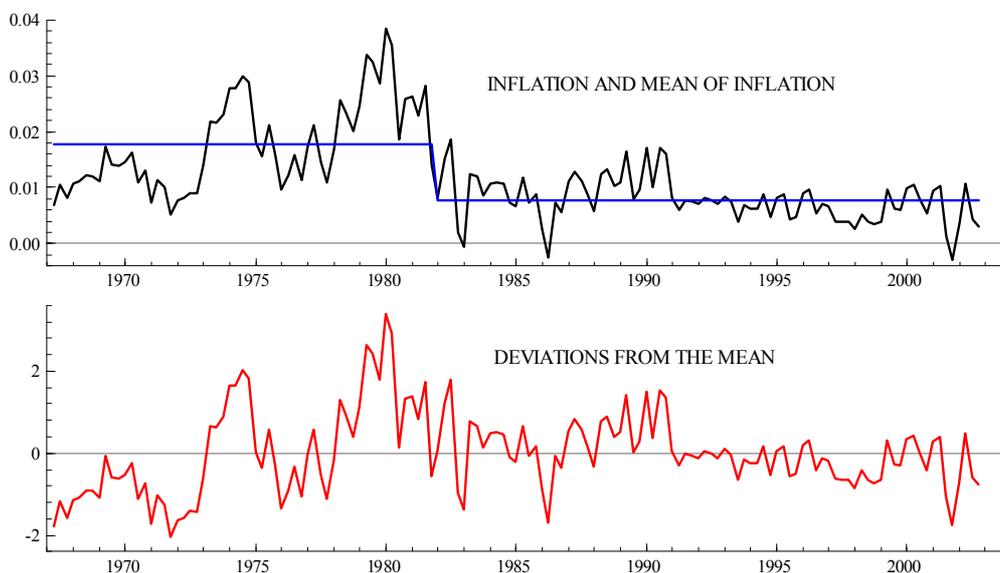
We note that models (B.1) and (B.2) are misspecified (even though they appear as corresponding to the conventional specification used in the literature to carry out the tests for a change in ρ). This misspecification comes from the fact that in models (B.1) and (B.2) data occurring before the break ($t = s$) are being used to estimate the parameters of the model, which is assumed to be valid only for the data after the break (i.e. $t \geq s$). In other words, lagged data [from period $(s - p)$ to period $(s - 1)$], that were generated by a model which is assumed to be valid only until period $(s - 1)$ i.e., for $t < s$, are being used to estimate the parameters of a model which is assumed to be valid only for $t \geq s$. So, we can think of these $p-1$ observations as if they were “outliers” for the parameters of the model assumed for $t \geq s$. And, in order to prevent these “outliers” to have damaging consequences on the estimated parameters of this model we need to introduce the dummy variables Δd_{t-j} . Thus, introducing these dummy variables is basically equivalent to run two independent regressions in which due account is taken of fact that the second model should only be estimated using data generated after the break has taken place.

Whether it is relevant to account for this problem and estimate models (B.3) and (B.4) rather than models (B.1) and (B.2) is basically an empirical issue. In our case it turned out to be important as the conclusions for the test sometimes change according to the type of model. Estimating type (B.3) and (B.4) equations appears to be especially important in models that (also) test for changes in the intercept as in such a case the “outlier” problem is likely to be more serious. Strangely enough this issue seems to have been overlooked in the empirical literature.

By looking at the Graphs in the main text we realise that heteroscedasticity across sub-periods might be a problem (even though not within sub-periods). For this reason the t-statistics in the tables, which refer to coefficient ρ_2 in the different models above, were computed using heteroscedastic consistent standard errors.

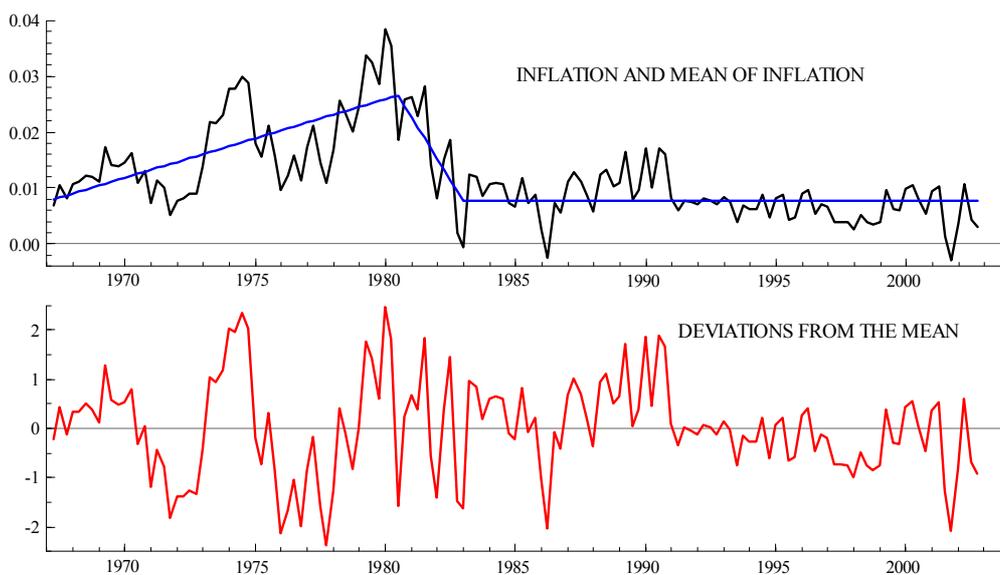
Finally, we note that our tests are conditional on the assumed time varying mean for each case, as we are estimating models for the deviations from the mean. That is also why the models were estimated without an intercept.

Graph B.1
Inflation in the U.S.- Consumer price index



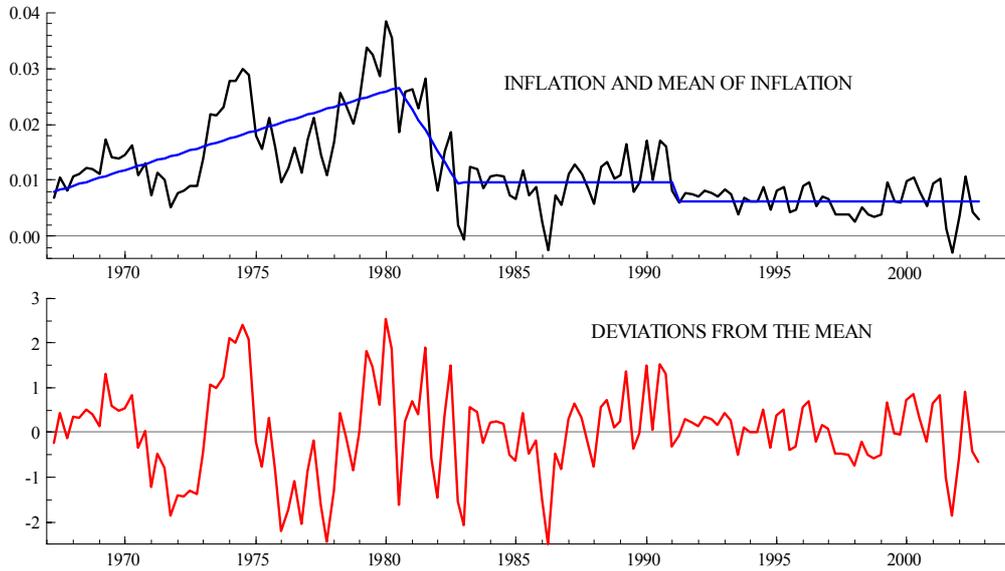
As in Graph No.3 in the text a constant mean is assumed for the two sub-periods: 1967q2-1981q4 and 1982q1-2002q4;

Graph B.2
Inflation in the U.S. – Consumer price index



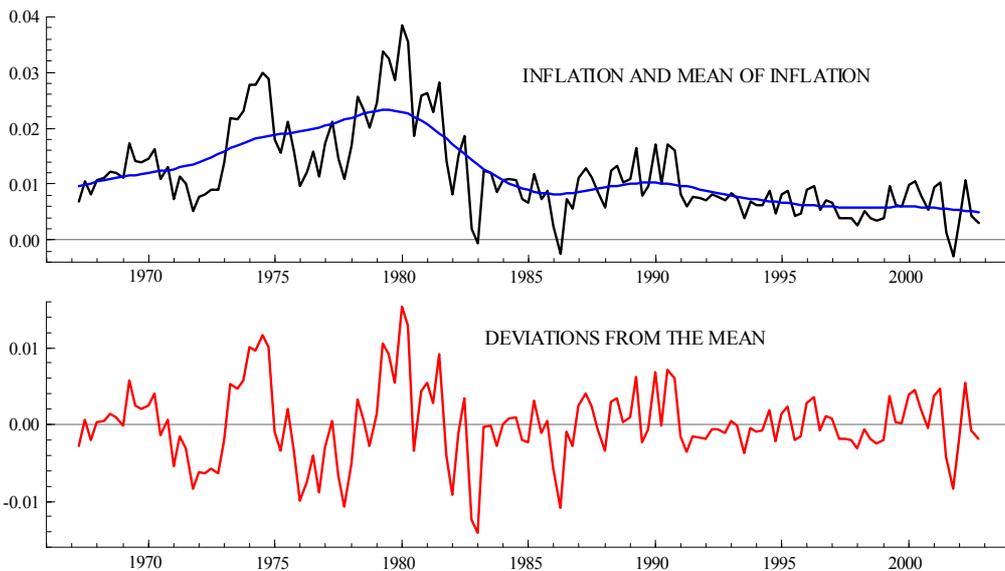
As in Graph No. 4 in the text the mean is proxied by two linear time trends for the sub-periods 1967q2-1980q2 and 1980q3-1982q4 and by a constant for the period 1983q1-2002q4.

Graph B.3
Inflation in the U.S. – Consumer price index



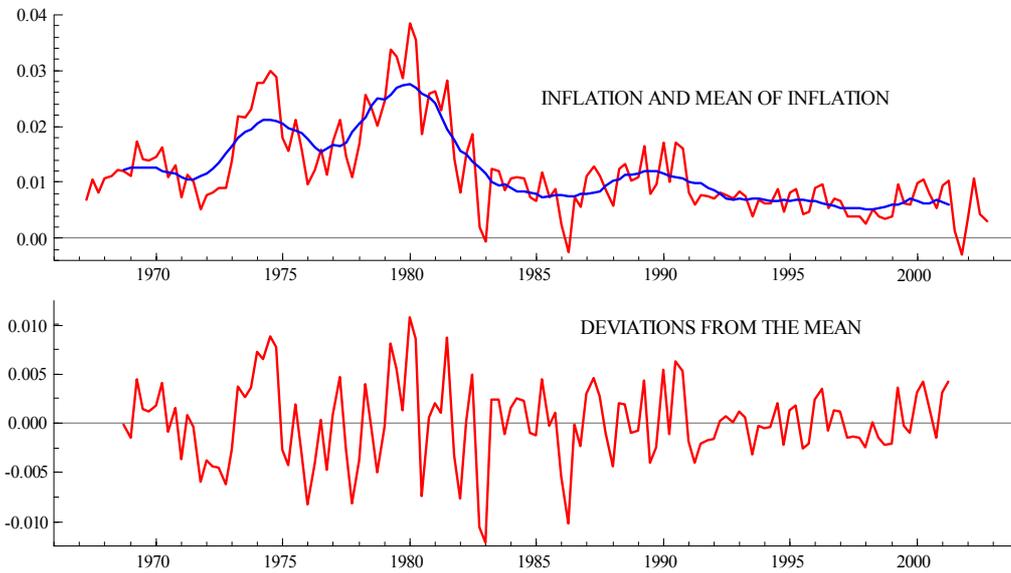
As in Graph No. 2 in the text the mean is proxied by two linear time trends for the two sub-periods 1967q2-1980q2 and 1980q3-1982q4 and by a constant for the period 1983q1-2002q4 with a break in 1991q2.

Graph B.4
Inflation in the U.S. – Consumer price index



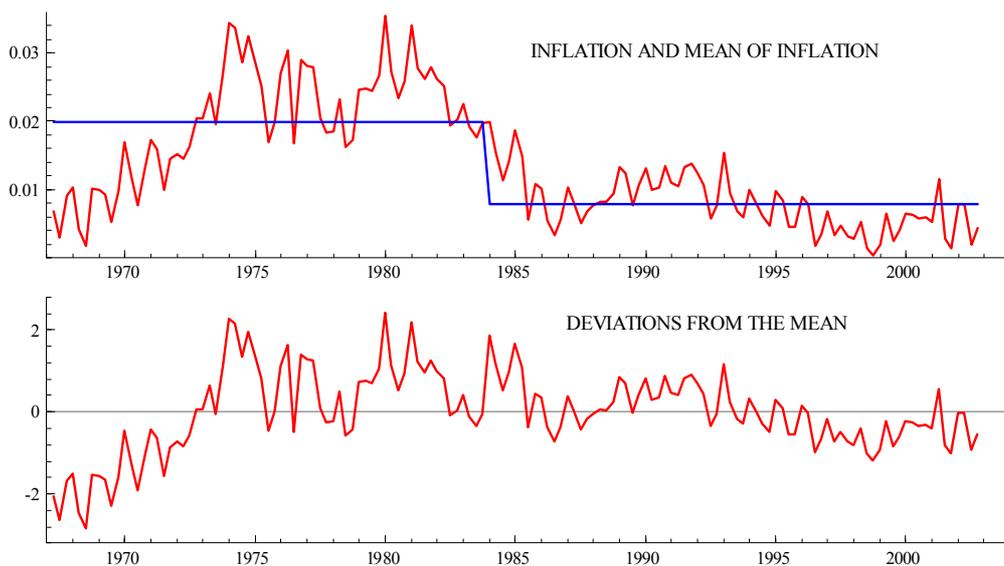
As in Graph No. 5 in the text the mean is proxied by the HP filtered series (with $\lambda = 1600$).

Graph B.5
Inflation in the U.S. – Consumer price index



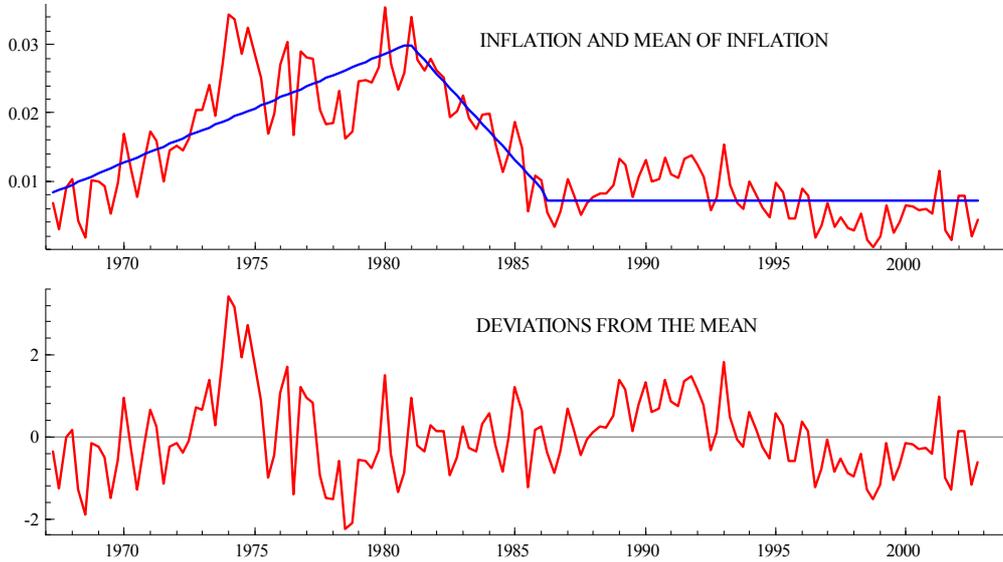
As in Graph No. 6 in the text the mean is proxied by the 13 terms centred moving average.

Graph B.6
Inflation in the E.A. – Consumer price index



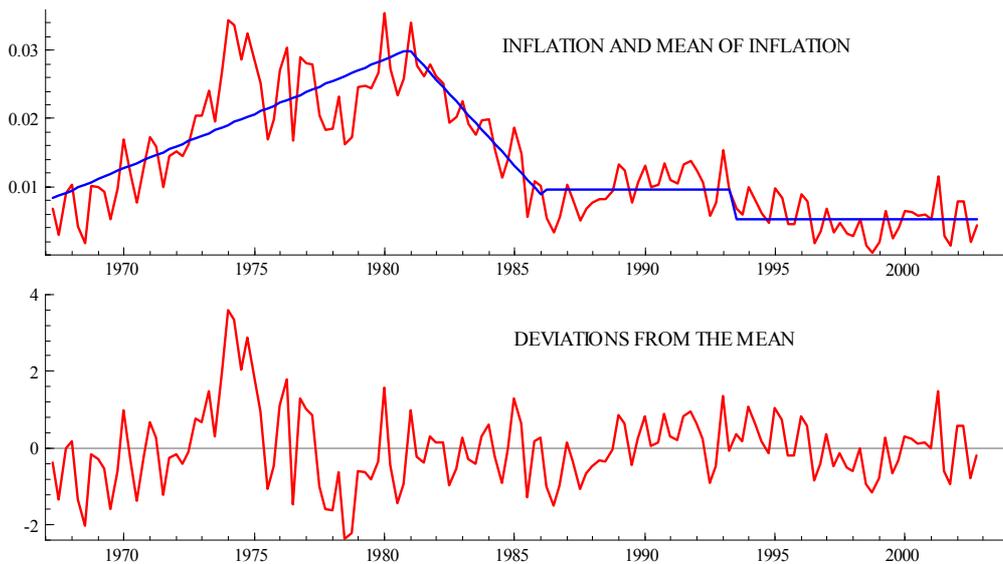
As in Graph No. 3 in the text a constant mean is assumed for the two sub-periods: 1967q2-1983q4 and 1984q1-2002q4;

Graph B.7
Inflation in the E.A. – Consumer price index



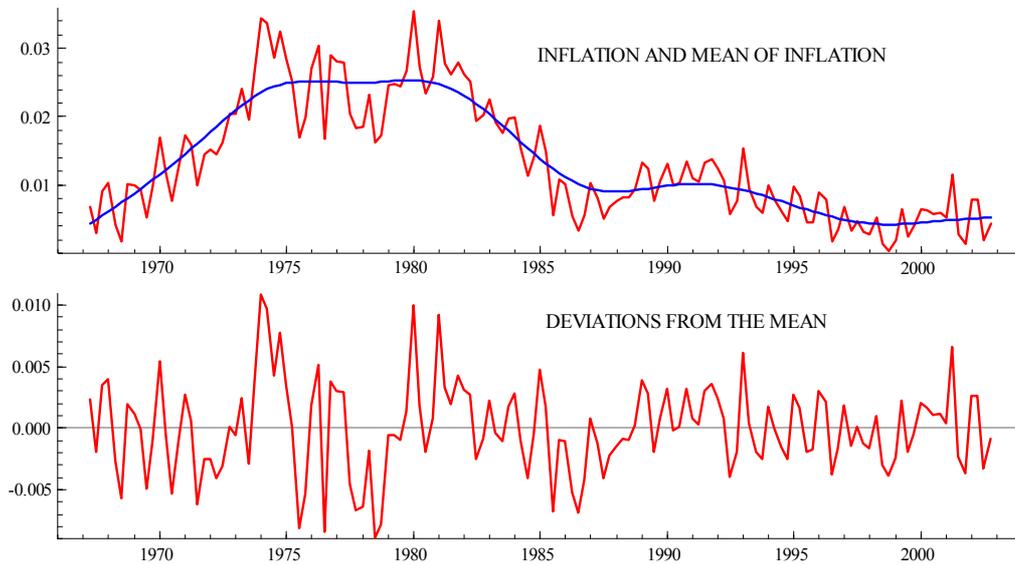
As in Graph No. 4 in the text the mean is proxied by two linear time trends for the sub-periods 1967q2-1980q4 and 1981q1-1986q1 and by a constant for the period 1986q2-2002q4.

Graph B.8
Inflation in the E.A. – Consumer price index



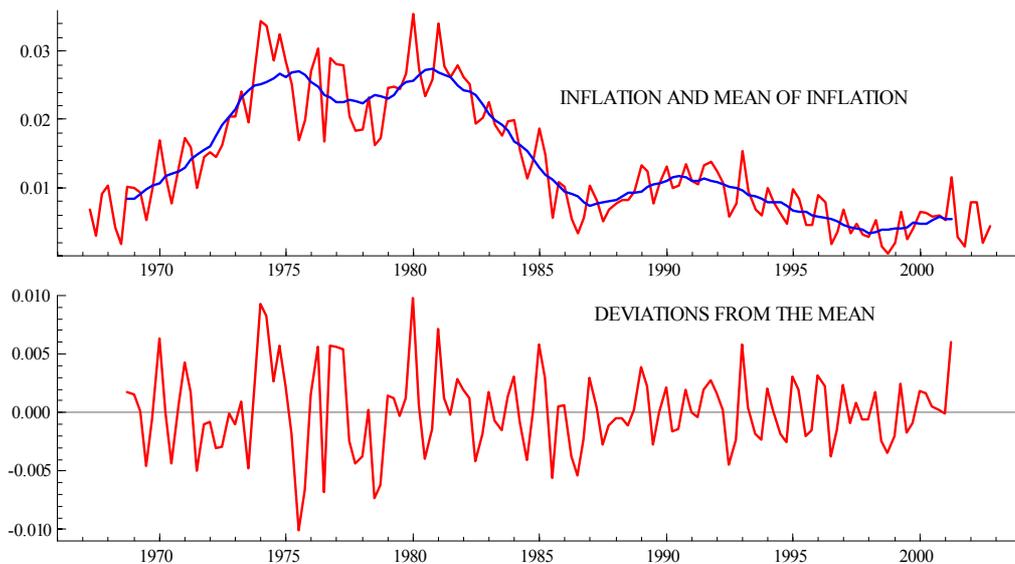
As in Graph No. 2 in the text the mean is proxied by two linear time trends for the two sub-periods 1967q2-1980q4 and 1981q1-1986q1 and by a constant for the period 1986q2-2002q4 with a break in 1993q3.

Graph B.9
Inflation in the E.A. – Consumer price index



As in Graph No. 5 in the text the mean is proxied by the HP filtered series (with $\lambda = 1600$).

Graph No.B.10
Inflation in the E.A. – Consumer price index



As in Graph No. 6 in the text the mean is proxied by the 13 terms centred moving average.

TABLE 1- Inflation persistence in the U.S. and the Euro Area ^(a)
(Case of Graphs No.3 in the text and B.1 and B.6 in Appendix B)

U.S.A. (GDP deflator)				
1960q2-2002q4	1960q2-1981q4		1982q1-2002q4	
$\rho=0.91$ (0.040) (4 lags) $\gamma=0.81$	$\rho=0.92$ (0.052) (3 lags) $\gamma=0.83$		$\rho=0.73$ (0.089) (3 lags) $\gamma=0.80$	
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (60/2-81/4) to the period (82/1-02/4)	No change (t=-1.27)*	Change in persistence (t=-1.82)*	No change (t=-1.54)*	Change in persistence (t=-2.04)*
U.S.A. (Consumer price index)				
1967/2-2002/4	1967/2-1981/4		1982/1-2002/4	
$\rho=0.73$ (0.075) (6 lags) $\gamma=0.73$	$\rho=0.81$ (0.090) (4 lags) $\gamma=0.86$		$\rho=0.66^{**}$ (0.147) (5 lags) $\gamma=0.64$	
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (67/2-81/4) to the period (82/1-02/4)	No change (t=-0.56)*	No change (t=-1.48)*	No change (t=-0.56)*	Change in persistence (t=-1.79)*
EURO AREA (Consumer price index)				
1967/2-2002/4	1967/2-1983/4		1984/1-2002/4	
$\rho=0.84$ (0.058) (8 lags) $\gamma=0.76$	$\rho=0.85$ (0.079) (8 lags) $\gamma=0.79$		$\rho=0.80^{**}$ (0.094) (4 lags) $\gamma=0.74$	
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (67/2-83/4) to the period (84/1-02/4)	No change (t=-0.09)*	No change (t=-0.71)*	No change (t=-0.32)*	No change (t=-0.63)*

^(a) The estimated models refer to the deviations from the mean as computed in Graphs No.3, B.1 and B.6. In the table ρ stands for the “sum of the autoregressive coefficients”; below each ρ are the corresponding standard errors and the number of lags of the estimated autoregressive model for the series of the deviations from the mean; γ is the persistence measure suggested in section 4 which varies between 0.5 (zero persistence) and 1 (maximum persistence);

* Heteroscedastic consistent t-statistics for coefficient ρ_2 in the corresponding model

(**) Point estimates of ρ are very sensitive to the number of lags (i.e., to the exact date for the first observation).

TABLE 2 – Persistence in the U.S. and the Euro Area ^(a)
(Case of Graphs No.4 in the text and B.2 and B.7 in Appendix B)

U.S.A. (GDP deflator)				
1960/2-2002/4	1960/2-1980/4	1981/1-2002/4	1960/2-1983/1	1983/2-2002/4
$\rho=0.58$ (0.090) (6 lags) $\gamma=0.70$	$\rho=0.45$ (0.139) (6 lags) $\gamma=0.66$	$\rho=0.79$ (0.099) (3 lags) $\gamma=0.74$	$\rho=0.45$ (0.135) (6 lags) $\gamma=0.64$	$\rho=0.80$ (0.104) (4 lags) $\gamma=0.77$
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (60/2-80/4) to the period (81/1-02/4).	No change ($t=1.53$)*	No change ($t=0.20$)*	No change ($t=1.54$)*	No change ($t=0.43$)*
Change in ρ from the period (60/2-83/1) for the period (83/2-02/4).	No change ($t=1.57$)*	No change ($t=0.61$)*	No change ($t=1.47$)*	No change ($t=0.60$)*
U.S.A. (Consumer price index)				
1967/2-2002/4	1967/2-1980/2	1980/3-2002/4	1967/2-1982/4	1983/1-2002/4
$\rho=0.54$ (0.010) (6 lags) $\gamma=0.66$	$\rho=0.63^{**}$ (0.117) (5 lags) $\gamma=0.75$	$\rho=0.53$ (0.137) (3 lags) $\gamma=0.61$	$\rho=0.67^{**}$ (0.128) (4 lags) $\gamma=0.71$	$\rho=0.63$ (0.129) (3 lags) $\gamma=0.63$
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (67/2-80/2) to the period (80/3-02/4) ^(b) .	No change ($t=-0.28$)*	Change in persistence ($t=-2.46$)*	No change ($t=-0.10$)*	Change in persistence ($t=-1.79$)*
EURO AREA (Consumer price index)				
1967/2-2002/4	1967/2-1980/4	1981/1-2002/4	1967/2-1986/1	1986/2-2002/4
$\rho=0.80$ (0.089) (8 lags) $\gamma=0.71$	$\rho=0.81$ (0.155) (8 lags) $\gamma=0.75$	$\rho=0.85$ (0.102) (4 lags) $\gamma=0.68$	$\rho=0.76$ (0.136) (8 lags) $\gamma=0.67$	$\rho=0.88$ (0.105) (4 lags) $\gamma=0.75$
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (67/2-80/4) to the period (81/1-02/4) ^(c) .	No change ($t=0.19$)*	No change ($t=-0.78$)*	No change ($t=0.28$)*	No change ($t=-0.50$)*

^(a) See table 1 for explanations. ^(b) There is no change in persistence when we compare the periods (1967/2-1982/4) and (1983/1-2002/4); ^(c) There is also no change in persistence when we compare the periods (1967/2-1986/1) and (1986/2-2002/4);

TABLE 3 – Persistence in the U.S. and the Euro Area^(a)
(Case of Graphs No.2 in the text and B.3 and B.8 in Appendix B)

U.S.A. (GDP Deflator)				
1960/2-2002/4	1960/2-1980/4	1981/1-2002/4	1960/2-1983/1	1983/2-2002/4
$\rho=0.45$ (0.103) (6 lags) $\gamma=0.63$	$\rho=0.45$ (0.139) (6 lags) $\gamma=0.66$	$\rho=0.45^{**}$ (0.149) (3 lags) $\gamma=0.60$	$\rho=0.45$ (0.135) (6 lags) $\gamma=0.64$	$\rho=0.45^{**}$ (0.104) (3 lags) $\gamma=0.62$
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (60/2-80/4) to the period (81/1-02/4).	No change ($t=-0.06$)*	Change in persistence ($t=-1.76$)*	No change ($t=0.07$)*	No change ($t=-1.53$)*
Change in ρ from the period (60/2-83/1) for the period (83/2-02/4).	No change ($t=0.10$)*	No change ($t=-1.35$)*	No change ($t=0.05$)*	No change ($t=-1.23$)*
U.S.A. (Consumer price index)				
1967/2-2002/4	1967/2-1980/2	1980/3-2002/4	1967/2-1982/4	1983/1-2002/4
$\rho=0.32^{**}$ (0.122) (8 lags) $\gamma=0.66$	$\rho=0.63^{**}$ (0.117) (5 lags) $\gamma=0.75$	$\rho=0.34$ (0.158) (3 lags) $\gamma=0.61$	$\rho=0.67^{**}$ (0.128) (4 lags) $\gamma=0.71$	$\rho=0.45$ (0.153) (3 lags) $\gamma=0.63$
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (67/2-80/2) to the period (80/3-02/4) ^(b) .	No change ($t=-0.32$)*	Change in persistence ($t=-2.57$)*	No change ($t=-0.12$)*	Change in persistence ($t=-1.85$)*
EURO AREA (Consumer price index)				
1967/2-2002/4	1967/2-1980/4	1981/1-2002/4	1967/2-1986/1	1986/2-2002/4
$\rho=0.73$ (0.102) (8 lags) $\gamma=0.64$	$\rho=0.81$ (0.155) (8 lags) $\gamma=0.75$	$\rho=0.60$ (0.159) (4 lags) $\gamma=0.57$	$\rho=0.76$ (0.136) (8 lags) $\gamma=0.67$	$\rho=0.58$ (0.162) (4 lags) $\gamma=0.60$
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (67/2-80/4) to the period (81/1-02/4) ^(c) .	No change ($t=-1.10$)*	Change in persistence ($t=-1.86$)*	No change ($t=-0.82$)*	No change ($t=-1.51$)*

^(a) See Table 1 for explanations. ^(b) There is no change in persistence when we compare the periods (1967/2-1982/4) and (1983/1-2002/4); ^(c) There is no change in persistence when we compare the periods (1967/2-1986/1) and (1986/2-2002/4);

TABLE 4 – Persistence in the U.S. and the Euro Area^(a)
(Case of Graphs No.5 in the text and B.4 and B.9 in Appendix B)

U.S.A. (GDP Deflator)				
1960/2-2002/4	1960/2-1980/4	1981/1-2002/4	1960/2-1983/1	1983/2-2002/4
$\rho=0.42$ (0.103) (6 lags) $\gamma=0.60$	$\rho=0.41$ (0.158) (6 lags) $\gamma=0.61$	$\rho=0.30^{**}$ (0.093) (3 lags) $\gamma=0.59$	$\rho=0.43^{**}$ (0.118) (6 lags) $\gamma=0.64$	$\rho=0.27$ (0.108) (1 lag) $\gamma=0.56$
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (60/2-80/4) to the period (81/1-02/4).	No change ($t=0.04$)*	No change ($t=-0.90$)*	No change ($t=-0.05$)*	No change ($t=-1.37$)*
Change in ρ from the period (60/2-83/1) for the period (83/2-02/4).	No change ($t=-0.17$)*	No change ($t=-1.63$)*	No change ($t=-0.42$)*	No change ($t=-1.70$)*
U.S.A. (Consumer price index)				
1967/2-2002/4	1967/2-1980/2	1980/3-2002/4	1967/2-1982/4	1983/1-2002/4
$\rho=0.31$ (0.121) (8 lags) $\gamma=0.64$	$\rho=0.62^{**}$ (0.127) (5 lags) $\gamma=0.68$	$\rho=0.38$ (0.150) (3 lags) $\gamma=0.61$	$\rho=0.39^{**}$ (0.152) (7 lags) $\gamma=0.65$	$\rho=0.28^{**}$ (0.163) (3 lags) $\gamma=0.63$
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (67/2-80/2) to the period (80/3-02/4) ^(b) .	No change ($t=-0.26$)*	Change in Persistence ($t=-2.81$)*	No change ($t=-0.38$)*	Change in Persistence ($t=-2.48$)*
EURO AREA (Consumer price index)				
1967/2-2002/4	1967/2-1980/4	1981/1-2002/4	1967/2-1986/1	1986/2-2002/4
$\rho=0.49$ (0.147) (8 lags) $\gamma=0.60$	$\rho=0.46$ (0.270) (8 lags) $\gamma=0.60$	$\rho=0.46$ (0.157) (4 lags) $\gamma=0.60$	$\rho=0.50$ (0.211) (8 lags) $\gamma=0.62$	$\rho=0.34$ (0.203) (4 lags) $\gamma=0.58$
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (67/2-80/4) to the period (81/1-02/4) ^(c) .	No change ($t=0.49$)*	No change ($t=-0.51$)*	No change ($t=0.25$)*	No change ($t=-0.77$)*

^(a) See Table 1 for explanations. ^(b) There is no change in persistence when we compare the periods (1967/2-1982/4) and (1983/1-2002/4); ^(c) There is also no change in persistence when we compare the periods (1967/2-1986/1) and (1986/2-2002/4);

TABLE 5 – Persistence in the U.S. and the Euro Area^(a)
(Case of Graphs No.6 in the text and B.5 and B.10 in Appendix B)

U.S.A. (GDP Deflator)				
1961/4-2001/2	1961/4-1980/4	1981/1-2001/2	1961/4-1983/1	1983/2-2001/2
$\rho=-0.03$ (0.152) (6 lags) $\gamma=0.52$	$\rho=-0.04$ (0.226) (6 lags) $\gamma=0.56$	$\rho=-0.14^{**}$ (0.267) (6 lags) $\gamma=0.49$	$\rho=0.01$ (0.205) (6 lags) $\gamma=0.55$	$\rho=-0.46$ (0.331) (6 lags) $\gamma=0.49$
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (61/4-80/4) to the period (81/1-01/2).	No change ($t=0.09$)*	No change ($t=-0.76$)*	No change ($t=-0.28$)*	No change ($t=-1.23$)*
Change in ρ from the period (61/4-83/1) for the period (83/2-01/2).	No change ($t=-0.71$)*	No change ($t=-1.41$)*	No change ($t=-1.26$)*	No change ($t=-1.49$)*
U.S.A. (Consumer price index)				
1968/4-2001/2	1968/4-1980/2	1980/3-2001/2	1968/4-1982/4	1983/1-2001/2
$\rho=0.42^{**}$ (0.122) (3 lags) $\gamma=0.56$	$\rho=0.43$ (0.190) (5 lags) $\gamma=0.64$	$\rho=-0.12$ (0.139) (2 lags) $\gamma=0.52$	$\rho=0.55$ (0.181) (3 lags) $\gamma=0.61$	$\rho=-0.10$ (0.218) (4 lags) $\gamma=0.53$
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (67/2-80/2) to the period (80/3-02/4) ^(b) .	Change in persistence ($t=-2.59$)*	Change in persistence ($t=-2.79$)*	Change in persistence ($t=-2.24$)*	Change in persistence ($t=-2.31$)*
EURO AREA (Consumer price index)				
1968/4-2001/2	1968/4-1980/4	1981/1-2001/2	1968/4-1986/1	1986/2-2001/2
$\rho=-0.14$ (0.256) (8 lags) $\gamma=0.56$	$\rho=-0.25^{**}$ (0.471) (8 lags) $\gamma=0.61$	$\rho=-0.37^{**}$ (0.131) (2 lags) $\gamma=0.52$	$\rho=-0.12^{**}$ (0.358) (8 lags) $\gamma=0.57$	$\rho=-0.40^{**}$ (0.151) (2 lags) $\gamma=0.54$
	Model (B.1)	Model (B.2)	Model (B.3)	Model (B.4)
Change in ρ from the period (67/2-80/4) to the period (81/1-02/4) ^(c) .	No change ($t=-1.25$)*	No change ($t=-0.82$)*	No change ($t=-1.21$)*	No change ($t=-0.75$)*

^(a) See Table 1 for explanations. ^(b) There is no change in persistence when we compare the periods (1967/2-1982/4) and (1983/1-2002/4); ^(c) There is also no change in persistence when we compare the periods (1967/2-1986/1) and (1986/2-2002/4);

European Central Bank working paper series

For a complete list of Working Papers published by the ECB, please visit the ECB's website (<http://www.ecb.int>).

- 314 "Exchange rate risks and asset prices in a small open economy" by A. Derviz, March 2004.
- 315 "Option-implied asymmetries in bond market expectations around monetary policy actions of the ECB" by S. Vähämaa, March 2004.
- 316 "Cooperation in international banking supervision" by C. Holthausen and T. Rønde, March 2004.
- 317 "Fiscal policy and inflation volatility" by P. C. Rother, March 2004.
- 318 "Gross job flows and institutions in Europe" by R. Gómez-Salvador, J. Messina and G. Vallanti, March 2004.
- 319 "Risk sharing through financial markets with endogenous enforcement of trades" by T. V. Köppl, March 2004.
- 320 "Institutions and service employment: a panel study for OECD countries" by J. Messina, March 2004.
- 321 "Frequency domain principal components estimation of fractionally cointegrated processes" by C. Morana, March 2004.
- 322 "Modelling inflation in the euro area" by E. S. Jansen, March 2004.
- 323 "On the indeterminacy of New-Keynesian economics" by A. Beyer and R. E. A. Farmer, March 2004.
- 324 "Fundamentals and joint currency crises" by P. Hartmann, S. Straetmans and C. G. de Vries, March 2004.
- 325 "What are the spill-overs from fiscal shocks in Europe? An empirical analysis" by M. Giuliadori and R. Beetsma, March 2004.
- 326 "The great depression and the Friedman-Schwartz hypothesis" by L. Christiano, R. Motto and M. Rostagno, March 2004.
- 327 "Diversification in euro area stock markets: country versus industry" by G. A. Moerman, April 2004.
- 328 "Non-fundamental exchange rate volatility and welfare" by R. Straub and I. Tchakarov, April 2004.
- 329 "On the determinants of euro area FDI to the United States: the knowledge-capital-Tobin's Q framework," by R. A. De Santis, R. Anderton and A. Hijzen, April 2004.
- 330 "The demand for euro area currencies: past, present and future" by B. Fischer, P. Köhler and F. Seitz, April 2004.
- 331 "How frequently do prices change? evidence based on the micro data underlying the Belgian CPI" by L. Aucremanne and E. Dhyne, April 2004.
- 332 "Stylised features of price setting behaviour in Portugal: 1992-2001" by M. Dias, D. Dias and P. D. Neves, April 2004.
- 333 "The pricing behaviour of Italian firms: New survey evidence on price stickiness" by S. Fabiani, A. Gattulli and R. Sabbatini, April 2004.

- 334 “Is inflation persistence intrinsic in industrial economies?” by A. T. Levin and J. M. Piger, April 2004.
- 335 “Has eura-area inflation persistence changed over time?” by G. O’Reilly and K. Whelan, April 2004.
- 336 “The great inflation of the 1970s” by F. Collard and H. Dellas, April 2004.
- 337 “The decline of activist stabilization policy: Natural rate misperceptions, learning and expectations” by A. Orphanides and J. C. Williams, April 2004.
- 338 “The optimal degree of discretion in monetary policy” by S. Athey, A. Atkeson and P. J. Kehoe, April 2004.
- 339 “Understanding the effects of government spending on consumption” by J. Galí, J. D. López-Salido and J. Vallés, April 2004.
- 340 “Indeterminacy with inflation-forecast-based rules in a two-bloc model” by N. Batini, P. Levine and J. Pearlman, April 2004.
- 341 “Benefits and spillovers of greater competition in Europe: A macroeconomic assessment” by T. Bayoumi, D. Laxton and P. Pesenti, April 2004.
- 342 “Equal size, equal role? Interest rate interdependence between the euro area and the United States” by M. Ehrmann and M. Fratzscher, April 2004.
- 343 “Monetary discretion, pricing complementarity and dynamic multiple equilibria” by R. G. King and A. L. Wolman, April 2004.
- 344 “Ramsey monetary policy and international relative prices” by E. Faia and T. Monacelli, April 2004.
- 345 “Optimal monetary and fiscal policy: A linear-quadratic approach” by P. Benigno and M. Woodford, April 2004.
- 346 “Perpetual youth and endogenous labour supply: a problem and a possible solution” by G. Ascari and N. Rankin, April 2004.
- 347 “Firms’ investment decisions in response to demand and price uncertainty” by C. Fuss and P. Vermeulen, April 2004.
- 348 “Financial openness and growth: Short-run gain, long-run pain?” by M. Fratzscher and M. Bussiere, April 2004.
- 349 “Estimating the rank of the spectral density matrix” by G. Camba-Mendez and G. Kapetanios, April 2004.
- 350 “Exchange-rate policy and the zero bound on nominal interest rates” by G. Camba-Mendez and G. Kapetanios, April 2004.
- 351 “Interest rate determination in the interbank market” by V. Gaspar, G. P. Quirós and H. R. Mendizábal, April 2004.
- 352 “Forecasting inflation with thick models and neural networks” by P. McNelis and P. McAdam, April 2004.

- 353 "Towards the estimation of equilibrium exchange rates for CEE acceding countries: methodological issues and a panel cointegration perspective" by F. Maeso-Fernandez, C. Osbat and B. Schnatz, April 2004.
- 354 "Taking stock: monetary policy transmission to equity markets" by M. Ehrmann and M. Fratzscher, May 2004.
- 355 "Production interdependence and welfare" by K. X. D. Huang and Z. Liu, May 2004.
- 356 "Developing a euro area accounting matrix: issues and applications" by T. Jellema, S. Keuning, P. McAdam and R. Mink, May 2004.
- 357 "Seasonal adjustment and the detection of business cycle phases" by A. M. Mir and D. R. Osborn, May 2004.
- 358 "Did the pattern of aggregate employment growth change in the euro area in the late 1990s?" by G. Mourre, May 2004.
- 359 "The longer term refinancing operations of the ECB" by T. Linzert, D. Nautz and U. Bindseil, May 2004.
- 360 "Optimal monetary policy rules for the euro area: an analysis using the area wide model" by A. Dieppe, K. Küster and P. McAdam, May 2004.
- 361 "Excess reserves and the implementation of monetary policy of the ECB" by U. Bindseil, G. Camba-Mendez, A. Hirsch and B. Weller, May 2004.
- 362 "Oil price shocks and real GDP growth: empirical evidence for some OECD countries" by R. Jiménez-Rodríguez and M. Sánchez, May 2004.
- 363 "Communication and exchange rate policy" by M. Fratzscher, May 2004.
- 364 "Asset price booms and monetary policy" by C. Detken and F. Smets, May 2004.
- 365 "Exchange rates and fundamentals: new evidence from real-time data" by M. Ehrmann and M. Fratzscher, May 2004.
- 366 "The informational content of over-the-counter currency options" by P. Christoffersen and S. Mazzotta, June 2004.
- 367 "Factor substitution and factor augmenting technical: progress in the US: a normalized supply-side system approach" by R Klump, P. McAdam and A. Willman, June 2004.
- 368 "Capital quality improvement and the sources of growth in the euro area" by P. Sakellaris and F. W. Vijselaar, June 2004.
- 369 "Sovereign risk premia in the European government bond market" by K. Bernoth, J. von Hagen and L. Schuknecht, June 2004.
- 370 "Inflation persistence during periods of structural change: an assessment using Greek data" by G. Hondroyannis and S. Lazaretou, June 2004.
- 371 "Inflation persistence: facts or artefacts?" by C. R. Marques, June 2004.

