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Inflation Persistence in New EU Member States: Is It Different Than in the Euro Area Members?

Michal Franta, Branislav Saxa and Kateřina Šmídková *

Abstract

Is inflation persistence in the new EU Member States (NMS) comparable to that in the euro area countries? We argue that persistence may not be as different between the two country groups as one might expect. We confirm that one should work carefully with the usual estimation methods when analyzing the NMS, given the scope of the convergence process they went through. We show that due to frequent breaks in inflation time series in the NMS, parametric statistical measures assuming a constant mean deliver substantially higher persistence estimates for the NMS than for the euro area countries. Employing a time-varying mean leads to the reversal of this result and suggests similar or lower inflation persistence for the NMS compared to euro area countries. Structural measures show that backward-looking behavior may be a more important component in explaining inflation dynamics in the NMS than in the euro area countries.

JEL Codes: E31, C22, C11, C32.
Keywords: Inflation persistence, new hybrid Phillips curve, new member states, time-varying mean.

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Nontechnical Summary

According to our findings, inflation persistence in the group of new EU Member States (NMS) is not considerably different from inflation persistence in the current euro area countries. If it was significantly different, fulfillment of the Maastricht criteria could be complicated, for example, due to the asymmetric impact of common shocks, such as large changes in oil prices, on the two groups of countries. Moreover, differences in inflation persistence between the two groups could also suggest that the convergence of the NMS towards the current euro area countries might slow down after they adopt the euro.

Inflation persistence was put forward as one of the causes of divergence when persistent inflation differentials among the euro area countries were debated several years ago. During this debate, it was pointed out that once the NMS adopt the euro, they might also face the problem of inflation differentials. Subsequently, several studies presented estimates of inflation persistence in the NMS in order to see if high inflation persistence could be a matter of concern for the NMS. These studies work mostly with micro data. The few studies that take a macroeconomic approach focus solely on one country. As a result, the empirical studies available so far on the NMS do not provide sufficient information for a cross-country comparison.

Our empirical cross-country analysis takes the macroeconomic approach. It is built around the same definition of inflation persistence as that employed by the Eurosystem Inflation Persistence Network. According to this definition, the higher the inflation persistence is, the longer it takes for inflation to return to its equilibrium after a shock hits the economy. We argue that it must be checked carefully if the equilibrium value of inflation can be assumed constant for the NMS, which have gone through significant structural changes during the transformation process, including changes in monetary policy regimes, and which continue to converge toward the current euro area countries. It follows that out of the three sources of inflation persistence (extrinsic, intrinsic, and expectations-driven), expectations-driven persistence – which is closely connected to inflation targets perceived by public – should be distinguished from the other two sources. Therefore, we pay considerable attention to the choice of persistence measure.

We analyze the following statistical measures of inflation persistence: measures based on autoregressive models with constant means, autoregressive models with time-varying means, and autoregressive fractionally integrated moving average models. These models differ in their approach to the equilibrium value of inflation and the underlying value of the perceived inflation target. In addition to the statistical measures, we consider structural measures of inflation persistence. On the one hand, the results based on structural measures are more powerful because their estimates of inflation persistence in the NMS are relevant for both the pre-euro and euro period. On the other hand, it is a real challenge to obtain these results, given the relatively poor data availability and the small size of the available data samples.

We start our analysis by estimating autoregressive models with constant means for the GDP deflators of our two groups of countries: the NMS (the Czech Republic, Hungary, Poland, and Slovakia) and the current euro area countries (Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, and Spain). As suspected, the estimates of inflation persistence in the four NMS are higher than in the current euro area countries. This result is robust to the choice of estimation method used (the only exception being Greece if the Hansen method is used). However, we argue that these high estimates are biased upward due to the above-mentioned problem with the constant mean assumption. When the models with time-varying means are estimated, the inflation persistence in the four NMS is comparable to that in the current euro area countries. The remarkable estimated downward shift in perceived inflation targets in the NMS is the reason why the models with time-varying means are superior to the ones with constant means. These models are also superior to the autoregressive fractionally integrated moving average models, according to our findings.

The superiority of the time-varying mean models suggests that expectations have been an important source of inflation persistence in the NMS since 1993, the starting year of our data sample. Since that time, the perceived inflation targets in the NMS have converged from 3–7% to the levels common in the current euro area countries (1–3%), according to our estimates. However, the available estimates of the New Hybrid Phillips Curve, including ours for the Czech Republic, indicate that inflation behavior is still more backward-looking in the NMS than in the current euro area countries. To conclude, while inflation persistence due to nominal and real rigidities in the NMS is comparable to that in the current euro area countries, expectations-based persistence is higher. Anchoring of inflation expectations will therefore be an important component of the euro adoption process for the NMS.

1. Introduction

In this paper, we provide input into the discussion concerning the readiness of the new EU Member States (NMS) to adopt the euro. With regards to euro adoption, the NMS face two closely related challenges. First, they need to fulfill the Maastricht criteria, including the one on inflation. Second, they need to adapt their economies to life with the euro. Inflation persistence differences between the euro area countries and the NMS can represent an obstacle to dealing successfully with both challenges.

The issue of differences in inflation persistence was raised by various studies[1] in 2002, when inflation divergence among the current euro area members was observed. These studies show that the inflation convergence reached prior to adopting the euro has not been sustained among the current euro area members since 1998, and they point out that inflation persistence is one of the most prominent reasons. The euro adoption candidates therefore need to learn what their national inflation persistence is and, if it is high, try to reduce it in order to prevent inflation from exceeding the euro area average after euro adoption. Specifically, high estimates of inflation persistence may call for institutional and labor market reforms that typically improve the flexibility of the domestic economy and subsequently reduce inflation persistence.

Furthermore, inflation persistence can influence the fulfillment of the Maastricht criteria, which is an issue for the NMS before and even after euro adoption. High inflation persistence corresponds to the slow return of inflation to its long-run value after a shock (e.g. an oil shock) occurs. Therefore, NMS with high estimates of persistence could struggle to meet the inflation criterion should a common shock hit the European countries. They could struggle for two reasons. First, it would take them longer to combat the consequences of this common shock and reduce inflation to its long-run value. This decreases the probability of meeting the inflation criterion. Second, the Maastricht criterion on inflation stability says that the NMS must have inflation comparable to the best inflation performers. This inherently implies that in the case of common shocks, the benchmark will be set by countries with a high speed of inflation adjustment. If differences in national inflation persistence values across the EU are large, it will be very difficult to stay close to the benchmark for the NMS with relatively high persistence. It is therefore of crucial importance to have estimates of inflation persistence available for the NMS prior to euro adoption.

To our knowledge, there are only a few studies assessing inflation persistence in the NMS. The available results, mainly based on micro data, indicate that inflation persistence in the NMS could be higher than in the current euro area members, although in some countries it is decreasing slowly over time. Since disaggregate evidence makes international comparison problematic, we carry out our analysis using inflation aggregates.[2] On the other hand, inflation aggregates can suffer from an aggregation bias, i.e., inflation aggregates exhibit higher persistence than the particular components included.

In this paper, we use several approaches to define and estimate inflation persistence in order to discuss thoroughly the appropriateness of various measures for the measurement of inflation persistence in the NMS. Furthermore, we attempt to choose the measure that enables international comparison of the euro area countries and the NMS. The list of the inflation persistence measures employed in this study is depicted by the following scheme:

[1] Section 2 provides a literature overview of papers related to inflation persistence in this context.
[2] Aggregates are also relevant for conducting monetary policy.

Scheme of Inflation Persistence Measures Considered

Statistical measures – Parametric	i) Autoregressive model with constant mean (naïve estimates)
	ii) Autoregressive model with time-varying mean
	iii) Autoregressive fractionally integrated moving average model (ARFIMA)
Structural measures	iv) Estimates of the New Hybrid Phillips Curve (NHPC)

First of all we adopt a purely statistical approach and estimate several parametric measures based on the sum of the autoregressive coefficients and impulse response functions, before employing a structural approach that provides an estimate of inflation inertia based on structural parameters. These approaches have already been applied to the analysis of inflation persistence in the current euro area members. Hence, we can compare our results for this control group with those of previously published work.

The first group of parametric statistical measures of inflation persistence assumes a constant mean. The four NMS[3] in our sample score highly among the EU members as far as inflation persistence is concerned. The estimated inflation persistence for the NMS is close to one, once the confidence intervals have been taken into account. This finding is in line with the available micro studies on inflation persistence in the NMS and with previously published research on inflation persistence in the current euro area Member States.

Our second, more sophisticated, statistical measure of inflation persistence gives, however, another picture. It allows for a time-varying mean. We separate the impact of persistence in nominal contracts and persistence in the real economy factors influencing inflation (intrinsic and extrinsic persistence) from the impact of inflation expectations and monetary policy regime changes (the two being inseparable in our model). We find that according to this measure the estimates of inflation persistence in the NMS are comparable to those in the current euro area members.

In our third statistical measure, we focus on the measure that is built on the autoregressive fractionally integrated moving average (ARFIMA) representation of the inflation process. A stationary process with parameter instability and a fractionally integrated process can look very similar to each other (mean reversion). Nevertheless, the implications of the two representations of the inflation process for the measurement of inflation persistence differ. Values of the impulse response function based on ARFIMA suggest that persistence in some NMS is higher than in the rest of the sample. Additional statistical tests suggest that assuming a stationary process with breaks is a preferable assumption to fractionally integrated models for almost all the countries considered.

The various statistical measures of inflation persistence introduced so far provide a complex picture of the actual extent of inflation inertia in the NMS compared to the euro area. It is worth noting that these measures can mainly serve as inputs to the debate about the fulfillment of the Maastricht criteria. If the values are comparable for the two groups of countries (the euro area countries and the NMS), it could be less difficult for the NMS to fulfill the Maastricht criterion on

[3] In our analysis, the NMS are represented by four countries (the Czech Republic, Hungary, Poland, and Slovakia) since for these four NMS the complete data needed for the inflation persistence analysis are available.

inflation, for example. However, these measures cannot serve as a basis for inferences about the country-specific effects of common monetary policy in the euro area extended to the NMS. The argument draws on the Lucas critique, which views structural (deep) parameters as the only appropriate measure underlying the discussion on the consequences of unequal inflation persistence after the monetary policy regime switch.

Therefore, as a last approach to measuring inflation persistence, we introduce a model based on deep parameters that allows an international comparison of the extent of inflation inertia. We estimate the hybrid version of the new Phillips curve (NHPC) for the Czech Republic, Poland, and Slovakia, and we compare the estimation results with existing studies for Hungary and the euro area. The structural measure suggests that the influence of expected future inflation on current inflation does not predominate over the influence of past inflation in the Czech Republic and Hungary.

The structure of the paper is as follows. Section 2 reviews the available literature on the topic, placing special emphasis on the relevance of inflation persistence in the NMS. Section 3 describes the approaches adopted to measuring and estimating inflation persistence. Section 4 reports on and discusses the results of these alternative estimates. Section 5 concludes.

2. Related Literature

Inflation persistence is a crucial aspect of overall inflation dynamics. It is, therefore, important to compare the size of inflation persistence between countries, especially if they form a monetary union. For example, differences in inflation persistence among the euro area countries are blamed for the persisting inflation differentials in the euro area. Angeloni and Ehrmann (2004) set up an empirical model consisting of 12 countries that share the same nominal interest rate. Simulations based on the model estimated on quarterly panel data covering 1998–2003 suggest the relevance of differences in inflation persistence for preserving inflation differentials as well as other cyclical differentials.

Furthermore, the ECB targets price stability in the euro area as a whole, and the same nominal interest rate is prescribed for countries that can experience different levels of inflation and inflation persistence. Bjorksten (2002) and Ca'Zorzi and De Santis (2003) notice that inflation differences may prevail longer inside the euro area once the NMS introduce the euro. In order to avoid divergence, EC (2002, 2004), ECB (2003), OECD (2002), and IMF (2002) suggest that adequate national structural reforms should be adopted in countries with high inflation persistence.

Inflation persistence measures are usually based on univariate models (e.g. the sum of autoregressive coefficients, the largest autoregressive root, half-life and spectral density at frequency zero – see Marques (2004) for a summary). In univariate analysis, the mean of the inflation process is often assumed to be constant. However, some recent studies examine several economic reasons that question this assumption. First, Bilke (2005) and Dossche and Everaert (2005) discuss the role of monetary policy changes for the inflation mean. Second, Gadzinski and Orlandi (2004) and Levin and Piger (2004) focus on the influence of administrative price changes on the mean of inflation. In this paper we argue that the specific situation of the NMS (e.g. monetary policy regime change, administrative price regulation) can also have an impact on the mean of inflation and should be taken into account when measuring inflation persistence.

Not accounting for breaks in the inflation mean causes bias of inflation persistence measures (as shown for the autoregressive process by Perron, 1989). Some recent empirical studies have approached this problem by allowing for structural breaks in inflation series. Levin and Piger (2004) estimate an autoregressive model for several industrial countries during the period 1984–2003, first with the assumption of a constant mean, and subsequently allowing for one structural break in the mean of inflation. Cecchetti and Debelle (2006) go further and estimate inflation persistence allowing for no break or one, two or three breaks. These studies find evidence for structural breaks and demonstrate that accounting for breaks reduces the inflation persistence estimates.

Marques (2004) stresses that it is more natural to assume a time-varying mean of inflation than to assume a constant mean or to search for breaks in the mean of inflation. In his analysis of US and euro area inflation, Marques considers several treatments for the mean of inflation, including the application of an HP filter and a moving average. In general, his results confirm that more flexibility assumed for the mean of inflation delivers lower estimates of persistence. Similar results for the US and the euro area are provided by Dossche and Everaert (2005), who model the time-varying mean as an AR(2) process. Benati (2006), in the framework of AR(p) representation of inflation series for 21 countries, allows for random-walk time-varying parameters. Finally, Darvas and Varga (2007) use time-varying coefficient autoregressive models to investigate Hungarian inflation persistence.

The structural estimates describing inflation dynamics are based on the New Hybrid Phillips Curve introduced in Galí and Gertler (1999). The authors estimate the NHPC on US quarterly data for the period 1960:1–1997:4 and find that forward-looking behavior predominates in comparison with backward-looking behavior. Galí, Gertler, and López-Salido (2001) extend the framework laid down in Galí and Gertler (1999) for the euro area. They consider the period 1970:1–1998:2, and their estimation results suggest backward-looking price setting behavior is even less important in the euro area than in the US.

Both studies use the generalized methods of moments (GMM) approach to estimate the NHPC. The use of GMM, however, has been much criticized for several reasons. The issue of weak instruments is addressed, for example, in Ma (2002). Zhang et al. (2006) also argue that the presence of serial correlation in errors influences the validity of lagged values of inflation and the real variable as instruments. Zhang et al. (2006) estimate the NHPC for US quarterly data for the period 1960:1–2005:1, and question the robustness of the results in Galí and Gertler (1999) regarding the instrument set employed. In this paper, we employ instrument sets from all the studies mentioned.

Most of the available research on inflation persistence in the NMS is based on micro data. Micro analysis is available for the Czech Republic, Hungary, Poland, and Slovakia in Babetskii, Coricelli, and Horváth (2006), Ratfai (2006), Konieczny and Skrzypacz (2005), and Coricelli and Horváth (2006), respectively. Some of the results signal that high inflation persistence can indeed be a problem for some NMS. Two studies that draw on macroeconomic aggregates are Darvas and Varga (2007) and Lendvai (2005). These studies focus on Hungary. Lendvai (2005) estimates a structural Phillips curve for quarterly data covering the period 1995:1–2004:1.The results suggest that inflation exhibits higher inflation inertia in Hungary than in the euro area.

3. Stylized Facts and Models for Estimating Inflation Persistence

In this section we introduce various approaches to measuring inflation persistence. We start with naïve estimates that assume a constant mean of inflation, then move on to models that relax the constant mean assumption. We also discuss ARFIMA models. Finally, we focus on the estimation of the New Hybrid Phillips Curve (NHPC).

The literature provides several definitions of inflation persistence.[4] We stick to the usual approach that relates inflation persistence to the speed at which inflation converges to its equilibrium value after a shock. Intuitively, inflation persistence is high if the inflation series does not frequently oscillate around its mean.[5] So, simple visual inspection of inflation plots for various countries (see Appendix 3) yields the first idea about the persistence of inflation in the euro area countries and the NMS. In addition, Table 1 reports the number of times that inflation series switched from above to below their means and vice versa.

Table 1: Number of Crosses of Inflation Means

Period	Czech Republic	Hungary	Poland	Slovakia	EU12
1993:2–2006:1	11	25	11	16	19
2001:1–2006:1	6	16	11	11	11
	Belgium	Finland	France	Germany	Greece
1993:2–2006:1	28	18	16	17	19
2001:1–2006:1	16	9	9	13	12
	Ireland	Italy	Netherlands	Portugal	Spain
1993:2–2006:1	27	31	27	29	15
2001:1–2006:1	13	11	11	11	12

Source: Own calculations based on OECD OEO database.
Note: Inflation rates for Hungary available since 1995:1.

Table 1 illustrates an issue that often arises when we employ various approaches to measuring inflation persistence in the NMS. For the whole sample (1993:2–2006:1), the inflation series for the NMS cross their means less frequently than the inflation series for the euro area countries. According to the aforementioned definition, fewer switches indicate higher inflation persistence for the NMS compared to the current euro area members. However, this is not necessarily so, since the NMS went through a transformation period, during which high initial values of inflation led to high inflation means of inflation. Moreover, price levels in the NMS have been converging to those of the euro area members. Both factors – transformation as well as convergence – may weaken the link between persistence and the frequency of mean crosses. We indeed observe that once we restrict the sample to the period 2001:1–2006:1, the number of crosses for the NMS and euro area members is comparable (see Table 1).

Going back to the definition of inflation persistence, the focus is on the concept of the equilibrium value of inflation. Some measures of persistence introduced in the following paragraphs view the

[4] See, for example, Batini (2002).

[5] Marques (2004) shows the inverse relationship between inflation persistence and mean reversion when modeling the inflation process as an autoregressive process of order k.

equilibrium value from a long-run perspective, while others focus rather on the medium run[6]. Table 1 implies that the appropriateness of the various measures of persistence for the NMS arises from their ability to take into account specific attributes of inflation processes in the NMS.

3.1 Statistical Measures – Parametric (Autoregressive Models)

(i) Constant mean (naïve estimate)

The most widely used measure of persistence across the literature, the sum of autoregressive coefficients, is based on the assumption that inflation follows a stationary autoregressive process of order K:

$$\pi_t = \mu + \sum_{i=1}^{K} \alpha_i \pi_{t-i} + \varepsilon_t \qquad (1)$$

The sum of the autoregressive coefficients is then defined as:

$$\rho_K = \sum_{i=1}^{K} \alpha_i \qquad (2)$$

where π_t denotes the observed inflation rate at time t. We proceed as follows. First, we obtain OLS estimates of $\alpha = [\alpha_{1,\ldots,}\alpha_K]$ for specifications with lag lengths $K = 1,..,5$. The preferred number of lags is then chosen according to the AIC and BIC criteria and the sum of autoregressive coefficients ρ_K is computed in line with (2), i.e., all coefficients, including the insignificant ones, are summed. Second, we apply Hansen's (1999) grid bootstrap procedure[7] to the same data to estimate the median unbiased ρ_K and its 90% confidence intervals, again for lag lengths $K = 1,..,5$. Unlike OLS estimation of the AR(K) process, Hansen's (1999) grid bootstrap procedure provides median-unbiased estimates with asymptotically correct confidence intervals.

(ii) Time-varying mean

Angeloni et al. (2006) distinguish three types of inflation persistence. Intrinsic inflation persistence relates to nominal rigidities and to the way wages and prices are set. Extrinsic inflation persistence stems from persistence in the inflation-driving real variables (e.g. the output gap). Finally, expectations-based inflation persistence is driven by differences between public perceptions about the inflation target and the central bank's true (explicit or implicit) inflation target. Dossche and Everaert (2005) set up a model that allows these three sources of inflation persistence to be distinguished. Moreover, their model controls for shifts in the inflation mean caused by monetary policy changes. This approach is relevant for the NMS, since it estimates inflation persistence net of expectations-based persistence and persistence related to the effects of monetary policy.

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[6] We find it useful to distinguish these two time horizons when discussing inflation persistence in the NMS, since long-run and medium-run equilibria may differ in periods of convergence. For a discussion on the importance of time horizons when dealing with the concept of equilibrium, see Driver and Westaway (2005).

[7] Hansen's (1999) grid bootstrap procedure is used in several recent studies on inflation persistence, e.g. Benati (2006), Levin and Piger (2004), and Gadzinski and Orlandi (2004).

We draw on the model introduced in Dossche and Everaert (2005), who estimate univariate and multivariate time series models. The univariate time series model should put the naïve statistical measures from the previous subsection into a broader perspective, since the model enables us to identify the part of inflation persistence that stems from monetary policy actions.

The model Dossche and Everaert (2005) start with has the following form:

$$\pi_{t+1}^{T} = \pi_{t}^{T} + \eta_{1t} \tag{3}$$

$$\pi_{t+1}^{P} = (1-\delta)\pi_{t}^{P} + \delta\pi_{t+1}^{T} + \eta_{2t}, 0 < \delta < 1, \tag{4}$$

$$\pi_{t} = \left(1 - \sum_{i=1}^{4}\varphi_{i}\right)\pi_{t}^{P} + \sum_{i=1}^{4}\varphi_{i}L^{i}\pi_{t} + \beta_{1}z_{t-1} + \varepsilon_{1t}, \sum_{i=1}^{4}\varphi_{i} < 1, \tag{5}$$

where π_t^T is the central bank's inflation target, π_t^P is the inflation target as perceived by the public, z_t stands for the output gap, and disturbances $\eta_{1t,}\eta_{2t,}\varepsilon_{1t}$ are mutually independent zero-mean white noise processes.

The central bank's inflation target is modeled as a random walk process in equation (3). The model assumes this equation even if the central bank does not target inflation explicitly. Some countries have adopted inflation targeting during the period of interest (e.g. the Czech Republic in 1997/1998). However, we do not impose known targets into the model.

Equation (4) captures the relationship between the central bank's inflation target and the target as perceived by the public.[8] The parameter δ measures the expectations-based persistence – a value close to zero indicates that the public forms its inflation expectations in a backward-looking manner. The effect of a shock to inflation is then prolonged via inflation expectations. On the other hand a parameter value close to one shows that a central bank is highly credible in communicating its inflation target.[9]

Equation (5) takes a form close to the traditional Phillips curve. Private inflation expectations are represented by the perceived inflation target. The sum of the autoregressive coefficients captures the intrinsic inflation persistence.

[8] The model equalizes the inflation target as perceived by the public, and public inflation expectations.

[9] There is also another possible interpretation of the formula. If the public forecasts inflation ($\pi_{t+1|t}^{forecast}$) in the same way as the central bank (irrespective of what the announced inflation target is) and the central bank behaves such that the inflation forecast equals the inflation target ($\pi_{t+1|t}^{forecast} = \pi_{t+1}^{T}$), then the parameter δ captures the fraction of forward-looking members of the public.

We make two identifying assumptions. First, we assume in accordance with Dossche and Everaert (2005) that $\beta_1 = 0$.[10] Second, to keep the estimation simple we also adopt the following assumption: $\eta_{2t} = 0$ for all *t*.

If we incorporate these assumptions, the basic version of the model has the following form:

$$\pi_t = \left(1 - \sum_{i=1}^{q} \varphi_i\right)\pi_t^P + \sum_{i=1}^{q} \varphi_i L^i \pi_t + \varepsilon_{1t} \qquad \varepsilon_{1t} \approx N(0, \sigma_\varepsilon^2)$$

$$\pi_{t+1}^P = (2-\delta)\pi_t^P + (\delta - 1)\pi_{t-1}^P + \delta\eta_{1t} \qquad \eta_{1t} \approx N(0, \sigma_\eta^2)$$

Since the model includes unobservable components (π_t^P) we transform the system into the state space form and use state space analysis methods.

$$\begin{bmatrix} \pi_{t+1}^P \\ \pi_t^P \end{bmatrix} = \begin{bmatrix} 2-\delta, \delta - 1 \\ 1,0 \end{bmatrix} \begin{bmatrix} \pi_t^P \\ \pi_{t-1}^P \end{bmatrix} + \begin{bmatrix} \delta \\ 0 \end{bmatrix} \eta_{1t}$$

$$\pi_t = \left[\left(1 - \sum_{i=1}^{4} \varphi_i\right), 0\right] \begin{bmatrix} \pi_t^P \\ \pi_{t-1}^P \end{bmatrix} + \sum_{i=1}^{4} \varphi_i \pi_{t-i} + \varepsilon_{1t}$$

To estimate the unobservable series of perceived inflation π_t^P we use the exact initial Kalman filter (the case of unknown initial conditions) as described, for example, in Koopman and Durbin (2003). The Kalman filtering assumes known coefficients; therefore, we have to estimate them.

We follow Dossche and Everaert (2005) and use a Bayesian approach combined with the method of importance sampling.

(iii) ARFIMA model

Regarding structural breaks in parameters of the inflation process, the literature points out that stationary processes with structural breaks and fractionally integrated processes can exhibit similar time behavior along with different properties regarding persistence. The application of the fractionally integrated approach in the context of inflation persistence is introduced in Gadea and Mayoral (2006). In addition to formal tests of inflation time series, the authors show how fractionally integrated behavior can emerge in heterogeneous-agent sticky-price models.

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[10] This assumption implies that the resulting form of the Phillips curve is equivalent to the assumption that the data-generating process for inflation has the following form:

$$\pi_t = \mu_t + \sum_{i=1}^{4} \alpha_i (\pi_{t-i} - \mu_t) + \varepsilon_t,$$

where the time-varying mean equals the perceived inflation target. This formula is the starting point for parametric measures based on AR(p) representations of the data-generating process (assuming a constant intercept $\mu_t = \mu$).

While a shock has a permanent effect in I(1) models and disappears at an exponential rate in I(0) models, the fractionally integrated approach allows for richer representation by introducing the so-called fractional differencing parameter *d*, which can be any real number $d \neq 0$. The time series y_t follows a so-called ARFIMA(p,d,q) model if

$$\phi(L)(1-L)^d (y_t - \mu) = \theta(L)\varepsilon_t, \tag{6}$$

where the roots of $\phi(L)$ and $\theta(L)$ lie outside the unit circle and ε_t is white noise.

As advocated by Baum et al. (1999) and Gadea and Mayoral (2006), the ARFIMA model could be an appropriate representation of the stochastic behavior of inflation time series. ARFIMA allows a high degree of persistence without assuming a unit root (i.e. I(1)) character of the process). We follow Gadea and Mayoral (2006) and estimate parameter *d* from (6) as well as the impulse response function of the appropriate ARFIMA model.

Furthermore, we employ the test suggested by Mayoral (2004), which tests the hypothesis of a time series following a fractionally differentiated process of order *d* versus a stationary process with breaks. Unlike Gadea and Mayoral (2006), we allow for a break not only in the level but also in the trend, to reflect the convergence process observed in parts of the inflation series of some countries.

The test statistics have the following form:

$$R(d) = T^{1-2d} \frac{\inf_{\omega \in \Omega}(\sum (y_t - \hat{\alpha}_1 - \hat{\delta}_1 DC_t - \hat{\beta}_1 t - \hat{\delta}_2 DT_t)^2)}{\sum (\Delta^d (y_t - \hat{\alpha}_0 - \hat{\beta}_0 t))^2}$$

where *d* is the order of differentiation, T is the number of periods, $\Omega = [0.15, 0.85]$ are trimming thresholds, *y* is the time series considered, $DC_t = 1$ if $t > \omega T$ and 0 otherwise, and $DT_t = (t - T_B)$ if $t > \omega T$ and 0 otherwise. α_0, α_1, β_0, β_1, δ_1 and δ_2 are coefficients from the appropriate regressions. Δ^d is the operator of differencing of order *d*. Critical values are computed according to Mayoral (2004).

The null hypothesis assumes a fractionally integrated process; the alternative hypothesis assumes a stationary process with breaks.

3.2 Structural Measures

Both the theory and practical estimation of the structural Phillips curve have been a subject of heightened debate in recent years, and no consensus concerning the related issues has been achieved so far. We try to stick to the approaches used in the studies mentioned in the literature review to make the international comparison meaningful. However, we stress the possible weaknesses of the approach that are raised in the literature and that could affect the resulting estimates.

The aim of the structural Phillips curve estimation is to find a formula that captures the short-run inflation dynamics, and consequently enables us to infer the degree of inflation inertia based on the estimation of the formula.

The parameters of the model introduced in Galí and Gertler (1999) are functions of three model primitives: the probability that a firm has to keep its price unchanged (θ) (the degree of price rigidity), the fraction of backward-looking firms that set their price according to the price in the previous period adjusted for inflation (ω), and the discount factor (β).

The closed-economy version of the New Hybrid Phillips Curve (NHPC) takes the following form:

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t \pi_{t+1} + \lambda mc_t$$

$$\gamma_b = \frac{\omega}{\phi}$$

$$\gamma_f = \frac{\beta\theta}{\phi}$$

$$\lambda = \frac{(1-\omega)(1-\theta)(1-\beta\theta)}{\phi}$$

$$\text{with } \phi = \theta + \omega[1-\theta(1-\beta)].$$

Here the variable mc_t represents the percentage deviation of the average real marginal cost from its steady-state value.

The ongoing debate on the theoretical and econometric issues regarding short-run inflation dynamics is even more pronounced for the NMS. Together with the issues mentioned above, one has to deal with incomplete time series, short time spans of data, and a convergence process in the NMS. Therefore, estimating the NHPC for post-transition countries involves some additional issues.

As post-transition countries have been experiencing a transition towards a new steady state, we use an HP filter to filter out non-business cycle frequencies and thus abstract from the convergence path. This approach can result in various biases (for a detailed discussion, see Lendvai, 2005). In addition, Baum et al. (2003) point out that the GMM estimator can exhibit poor properties in the case of small samples, and we therefore follow Lendvai (2005) in employing a 2SLS estimator.

4. Results

In this section we provide the results of the inflation persistence measures introduced in the previous section. To make our results comparable to previous studies, we employ a seasonally adjusted annualized quarter-on-quarter rate of change of the GDP deflator to represent inflation in all the estimates and computations. All the remaining data are thoroughly described in Appendix 1. The time span considered covers the period 1993:2–2006:1, if not stated explicitly otherwise. In the case of Hungary, data are available since 1995:2. The country abbreviations are also explained in Appendix 1.

We provide inflation persistence estimates for individual countries (not only for the whole EU12), since a direct comparison of persistence in individual NMS and the euro area as a group could be misleading. As shown in Cecchetti and Debelle (2006) and discussed in Altissimo, Ehrmann, and Smets (2006) and Batini (2002), aggregation of inflation indices leads to higher persistence estimates. This holds for aggregation from sectoral to country level as well as aggregation from country indices to euro area indices.

4.1 Statistical Measures – Parametric (Autoregressive Models)

(i) Constant Mean

We start with the estimation of the sum of the autoregressive coefficients.[11] The results of the OLS estimates of ρ_K are reported in Table 2. The estimated persistence reaches 0.68 for Poland and 0.75–0.76 for the Czech Republic, Hungary, and Slovakia. In contrast, the persistence is estimated at below 0.68 for all the other countries. The four NMS thus have higher estimates of inflation persistence than any other country in the sample. A similar pattern (of the six countries with the highest persistence estimates in the sample, four are NMS) is confirmed by estimating the largest autoregressive roots (not reported here).

In Table 3, we report the estimates of ρ_K obtained using Hansen's (1999) grid bootstrap procedure, including 90% confidence intervals. Figure 1 shows the estimates and confidence intervals for the case of $k = 5$ lags. Although the confidence intervals are wide and the estimates embody considerable uncertainty, one pattern is robust across the number of lags considered: the estimates of persistence in the NMS are high and in most cases higher than the persistence in the euro area countries. In all five specifications with different lag lengths, the four NMS rank among the six countries with the highest persistence estimates in the sample.

Table 2: OLS Estimates of ρ_K (Inflation Based on GDP Deflator)

	Preferred model according to AIC		Preferred model according to BIC	
	Number of AR lags	Sum of AR coefficients	Number of AR lags	Sum of AR coefficients
CZE	5	0.75	4	0.76
HUN	5	0.75	4	0.75
POL	4	0.68	4	0.68
SVK	2	0.75	2	0.75
EU12	3	0.66	3	0.66
BEL	2	0.13	2	0.13
ESP	4	0.59	1	0.26
FIN	1	0.33	1	0.33
FRA	1	0.43	1	0.43
GER	4	0.50	3	0.61
GRC	4	0.67	4	0.67
IRL	2	0.11	2	0.11
ITA	2	0.14	2	0.14
NLD	3	0.62	3	0.62
PRT	5	-0.16	5	-0.16

[11] Note that stationarity tests of the inflation time series are included in the analysis. The estimates of the coefficients for the lag length equal to one (see the last column in Table 3) show that we can reject the null of a unit root for all countries at the 90% significance level.

The estimates of persistence in the NMS based on the constant mean assumption could, however, suffer to some extent from upward bias due to the impact of administrative price changes. Gadzinski and Orlandi (2004) as well as Levin and Piger (2004) show that administrative price changes (e.g. changes in VAT) increase the persistence estimates if they are not accounted for. Due to the transition process, the NMS countries experienced numerous administrative price changes during the 1990s. Besides changes in VAT and excise taxes, gradual price deregulations influenced the prices of energy and housing. Since the frequency of these changes and the relatively short sample do not allow us to control for breaks in the way some other studies do, we adopt a different approach.[12]

While we abandon the constant mean assumption in the next section, in Appendix 2 we present the results of the same methodology as before, this time applied to inflation based on non-food, non-energy CPI inflation. The reason is that non-food, non-energy CPI inflation is supposed to be less influenced by price deregulations[13] and therefore allows for a better comparison of inflation persistence between the NMS and the rest of the sample. Nevertheless, even in the case of core inflation, the estimates of persistence in the NMS are (with the exception of Slovakia) still higher than in most of the ten other countries.[14] Using Hansen's (1999) grid bootstrap estimation on the core inflation data, we observe that inflation persistence in Slovakia is relatively low, whereas the Czech Republic, Hungary, and Poland rank in the half of the sample with higher persistence, regardless of the number of lags (see Appendix 2 for tables and figures reporting results for core inflation).

[12] Fidrmuc and Tichit (2004) discuss the role of structural breaks in transition data. They attempt to detect structural breaks in a growth regression for a data frequency and time period similar to ours. Kočenda (2005) searches for structural breaks in the exchange rates of European transition countries.

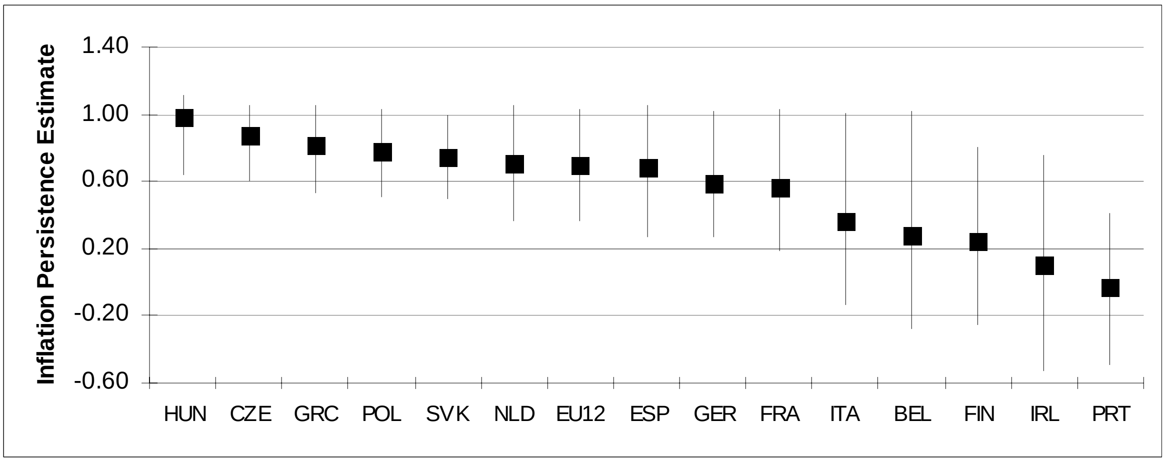
[13] Prices of energy were among the most heavily regulated prices in the NMS over the transition period.

[14] Another reason for including non-food, non-energy CPI inflation is to examine the robustness of our results with respect to the choice of inflation time series.

Table 3: P_K and its 90% Confidence Intervals Estimated Using Hansen's (1999) Grid Bootstrap Procedure (inflation based on GDP deflator)

	Lag length = 5			Lag length = 4			Lag length = 3			Lag length = 2			Lag length = 1		
	lower bound	mean	upper bound	lower bound	mean	upper bound	lower bound	mean	upper bound	lower bound	mean	upper bound	lower bound	mean	upper bound
CZE	0.60	**0.88**	1.05	0.62	**0.87**	1.04	0.49	**0.71**	0.96	0.52	**0.76**	1.01	0.43	**0.63**	0.84
HUN	0.64	**0.98**	1.11	0.60	**0.98**	1.10	0.57	**1.00**	1.08	0.44	**0.76**	1.04	0.11	**0.41**	0.68
POL	0.51	**0.78**	1.03	0.55	**0.83**	1.03	0.52	**0.79**	1.04	0.47	**0.69**	0.99	0.27	**0.50**	0.72
SVK	0.49	**0.74**	1.00	0.52	**0.74**	1.00	0.62	**0.85**	1.03	0.64	**0.84**	1.03	0.52	**0.70**	0.89
EU12	0.36	**0.70**	1.03	0.45	**0.78**	1.05	0.48	**0.80**	1.05	0.21	**0.50**	0.84	0.10	**0.33**	0.58
BEL	-0.28	**0.28**	1.02	-0.16	**0.38**	0.94	-0.33	**0.10**	0.54	-0.15	**0.20**	0.56	-0.39	**-0.15**	0.08
ESP	0.27	**0.69**	1.06	0.35	**0.79**	1.07	0.02	**0.37**	0.79	-0.03	**0.24**	0.54	0.05	**0.31**	0.54
FIN	-0.25	**0.24**	0.81	-0.24	**0.12**	0.56	-0.06	**0.29**	0.70	0.12	**0.41**	0.71	0.13	**0.35**	0.62
FRA	0.19	**0.57**	1.03	0.06	**0.36**	0.68	0.27	**0.56**	0.90	0.35	**0.62**	0.96	0.24	**0.47**	0.69
GER	0.27	**0.59**	1.02	0.28	**0.60**	0.98	0.43	**0.72**	1.03	0.16	**0.41**	0.71	0.13	**0.35**	0.58
GRC	0.53	**0.82**	1.06	0.52	**0.54**	1.07	0.07	**0.41**	0.80	0.06	**0.35**	0.63	0.02	**0.24**	0.46
IRL	-0.53	**0.10**	0.76	-0.35	**0.16**	0.73	-0.25	**0.21**	0.74	-0.19	**0.19**	0.57	-0.53	**-0.31**	-0.09
ITA	-0.13	**0.37**	1.01	0.10	**0.56**	1.05	0.01	**0.46**	1.02	-0.15	**0.20**	0.58	-0.32	**-0.06**	0.20
NLD	0.36	**0.71**	1.05	0.49	**0.93**	1.08	0.42	**0.77**	1.05	0.20	**0.52**	0.88	-0.04	**0.20**	0.44
PRT	-0.49	**-0.03**	0.41	-0.20	**0.20**	0.65	-0.23	**0.14**	0.53	-0.10	**0.22**	0.59	-0.18	**0.04**	0.30

Figure 1: Inflation Based on GDP Deflator, ρ estimate and its 90% Confidence Intervals (lag length = 5, Hansen's (1999) grid bootstrap procedure)



(ii) Time-Varying Mean

In this section, we present the results of the autoregressive model of inflation, allowing for a time-varying mean. The model measures inflation persistence net of the effects of the monetary policy authority.

Tables 4a and 4b report the parameter estimates and 90% confidence intervals obtained by the method of importance sampling.[15] The intrinsic inflation persistence (the sum of the AR coefficients) and expectations-based inflation persistence (δ) are statistically significant.

Table 4a: Estimation Results of the Model with a Time-Varying Mean – NMS

	Czech Republic			Poland			Slovakia		
	lower bound	*parameter estimate*	*upper bound*	*lower bound*	*parameter estimate*	*upper bound*	*lower bound*	*parameter estimate*	*upper bound*
φ_1	0.19	0.31	0.54	-0.01	-0.01	-0.01	0.06	0.21	0.32
φ_2	-0.13	0.01	0.09	0.05	0.05	0.05	0.06	0.18	0.29
φ_3	-0.06	0.05	0.18	0.22	0.22	0.22	-0.13	-0.01	0.14
φ_4	-0.21	-0.12	-0.07	-0.14	-0.14	-0.14	-0.21	-0.10	0.00
$\sum_{i=1}^{4}\varphi_i$	-0.12	0.26	0.49	0.12	0.12	0.12	0.10	0.28	0.49
δ	0.16	0.26	0.33	0.07	0.07	0.07	0.15	0.27	0.39
σ_{ε}^2	2.11	2.37	2.74	2.80	2.80	2.80	1.80	2.04	2.33
σ_{η}^2	0.05	0.13	0.22	0.12	0.12	0.12	0.02	0.08	0.17

[15] During the estimation of coefficients for the filtering algorithm we encountered two main numerical problems. First, for Hungary and Ireland the algorithm for finding the minimum of the constrained nonlinear multivariable function does not converge in a reasonable number of iterations. We therefore do not report estimation results for these two countries. Note that minimization is the first step in the method of importance sampling to obtain the importance density. Second, for Greece and Poland we take only a subsample, since the full sample Hessian matrix obtained during the minimization is too large to be useful for the importance density. Even for the restricted sample, the Hessian matrix for Poland is quite large and thus the lower and upper bounds of the 90% confidence intervals differ little.

Table 4b: Estimation Results of the Model with a Time-Varying Mean – EU12

	Belgium			Finland			France		
	lower bound	*parameter estimate*	*upper bound*	*lower bound*	*parameter estimate*	*upper bound*	*lower bound*	*parameter estimate*	*upper bound*
φ_1	-0.06	0.08	0.23	0.16	0.19	0.25	0.12	0.26	0.40
φ_2	0.05	0.20	0.35	-0.01	0.06	0.13	0.01	0.16	0.30
φ_3	-0.15	0.00	0.14	-0.12	-0.04	0.05	-0.12	0.02	0.16
φ_4	0.04	0.18	0.32	-0.25	-0.15	-0.07	-0.22	-0.07	0.08
$\sum_{i=1}^{4}\varphi_i$	0.11	0.45	0.86	-0.09	0.07	0.21	0.07	0.37	0.67
δ	0.06	0.21	0.37	0.15	0.23	0.39	0.09	0.22	0.37
σ_ε^2	0.87	1.15	1.46	2.10	2.28	2.36	0.40	0.58	0.82
σ_η^2	0.00	0.03	0.09	0.00	0.02	0.09	0.00	0.04	0.10

	Germany			Greece			Italy		
	lower bound	*parameter estimate*	*upper bound*	*lower bound*	*parameter estimate*	*upper bound*	*lower bound*	*parameter estimate*	*upper bound*
φ_1	0.06	0.20	0.35	-0.18	-0.06	0.00	-0.11	0.03	0.14
φ_2	-0.07	0.07	0.22	-0.19	-0.09	0.00	-0.01	0.11	0.24
φ_3	0.08	0.22	0.36	-0.21	-0.12	-0.03	0.00	0.13	0.28
φ_4	-0.14	0.00	0.14	0.30	0.40	0.57	-0.09	0.06	0.16
$\sum_{i=1}^{4}\varphi_i$	0.19	0.50	0.85	-0.09	0.13	0.43	0.13	0.33	0.57
δ	0.09	0.22	0.37	0.12	0.20	0.29	0.08	0.20	0.37
σ_ε^2	0.70	0.94	1.25	1.87	2.19	2.39	1.80	2.05	2.30
σ_η^2	0.00	0.03	0.09	0.00	0.04	0.09	0.00	0.04	0.11

	Netherlands			Portugal			Spain		
	lower bound	*parameter estimate*	*upper bound*	*lower bound*	*parameter estimate*	*upper bound*	*lower bound*	*parameter estimate*	*upper bound*
φ_1	0.01	0.14	0.26	-0.12	-0.01	0.13	0.08	0.22	0.36
φ_2	0.07	0.20	0.34	-0.09	0.04	0.16	-0.10	0.04	0.18
φ_3	0.06	0.19	0.33	-0.14	-0.03	0.10	-0.08	0.07	0.21
φ_4	-0.02	0.11	0.24	0.09	0.19	0.31	0.04	0.18	0.32
$\sum_{i=1}^{4}\varphi_i$	0.36	0.64	0.97	-0.13	0.19	0.51	0.17	0.50	0.90
δ	0.10	0.23	0.39	0.10	0.26	0.40	0.11	0.23	0.37
σ_ε^2	1.44	1.71	1.99	1.62	1.90	2.17	0.88	1.16	1.48
σ_η^2	0.00	0.05	0.12	0.00	0.03	0.10	0.00	0.05	0.12

Note: Data: seasonally adjusted q-o-q change of the GDP deflator.
Time span: 1993:1–2006:1, Greece since 1994:4, and Poland since 1995:3.
The results reported were obtained by importance sampling.
90% confidence interval bounds are reported.

Tables 4a and 4b provide a parameter estimate comparison of the extent of inflation persistence in the selected NMS and euro area countries. Because of possible aggregation bias, we compare inflation persistence at the level of individual countries. The table suggests that for the Czech Republic, Poland, and Slovakia inflation persistence adjusted for the effects of monetary policy is close to the group of euro area countries with lower inflation persistence (Finland, Portugal). For example, the intrinsic and extrinsic inflation persistence in Slovakia is 0.28, while in Belgium the persistence reaches 0.45. On the other hand, the 90% confidence intervals often reject statistical differences in inflation persistence between countries.

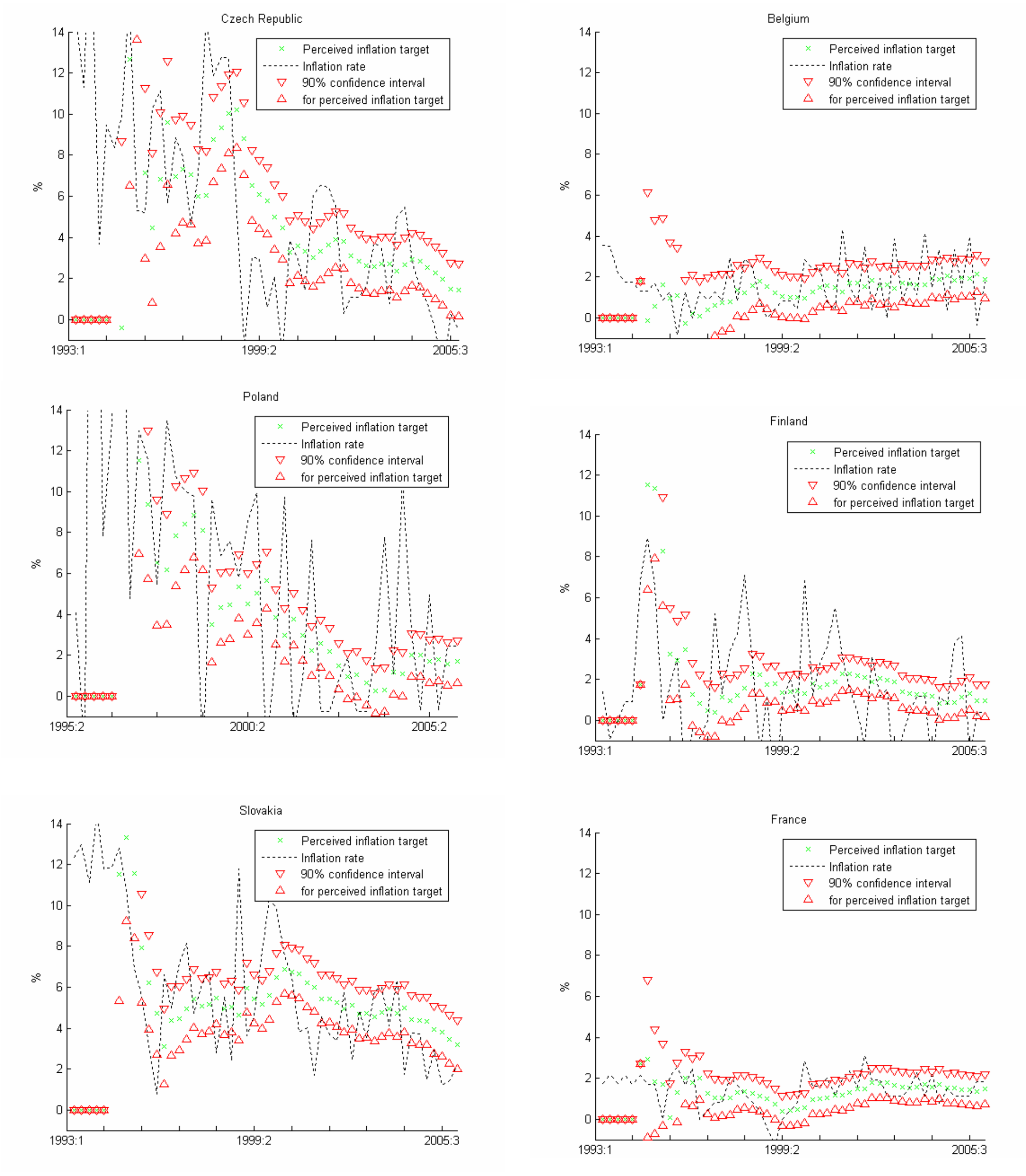
The time-varying mean model enables a discussion of the credibility of monetary authorities and the extent of expectations-based persistence. The values of parameter δ are lower for the selected NMS than for the selected euro area countries, suggesting that the public in the NMS sets its expectations about inflation rates less in accordance with the modeled targets announced by central banks than in the euro area countries (or alternatively, that the fraction of forward-looking members of the public is lower in the selected NMS). The conclusion often holds even in terms of 90% confidence intervals.

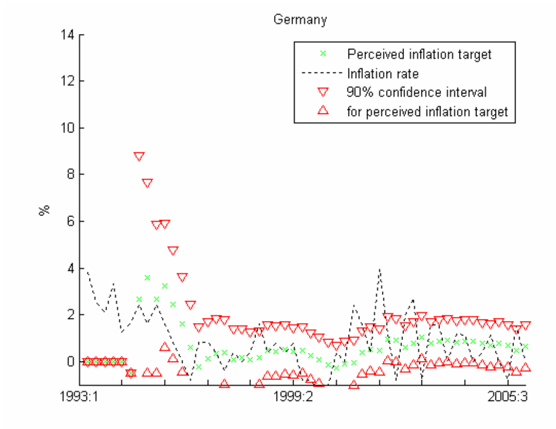
Finally, the Czech Republic, Poland, and Slovakia experience higher variance of shocks to the modeled inflation target and also of shocks in the inflation equation than the euro area countries. This is a consequence of the transition in the 1990s, which included cost-push shocks, significant changes in monetary strategies, etc.

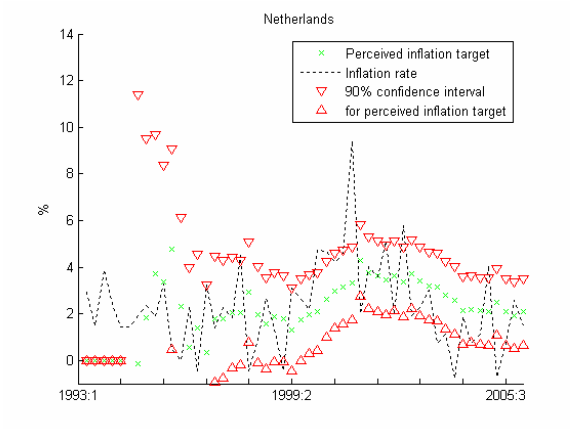
With the estimated parameters, it is possible to use the exact initial Kalman filter method to estimate the unobservable components of the system. One has to bear in mind that we do not know the exact parameter values, and must work with estimates. However, for our purposes our knowledge of the parameter estimates is sufficient.

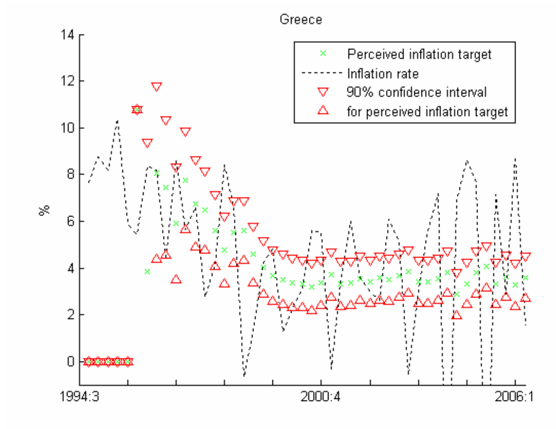
The results of the Kalman filtering are depicted in Figure 2. Note that the inflation target pursued by the central bank is modeled as a random walk and the perceived inflation target that serves as a time-varying mean follows an AR(2) process.

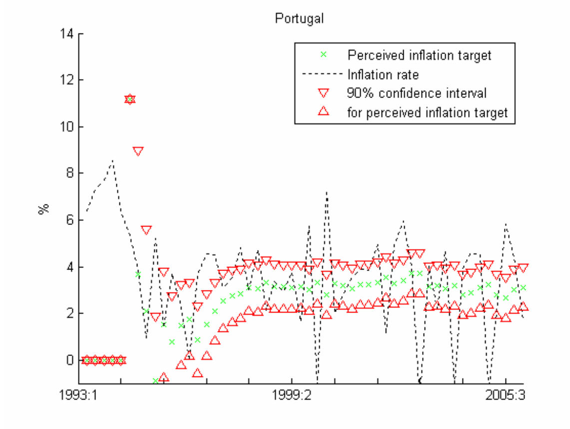
Figure 2: Perceived Targets in the Time-Varying Mean Models

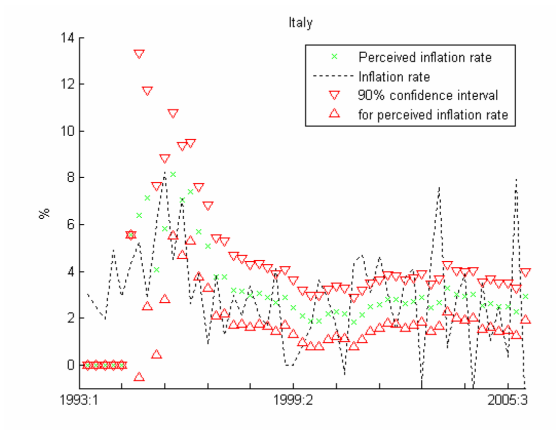


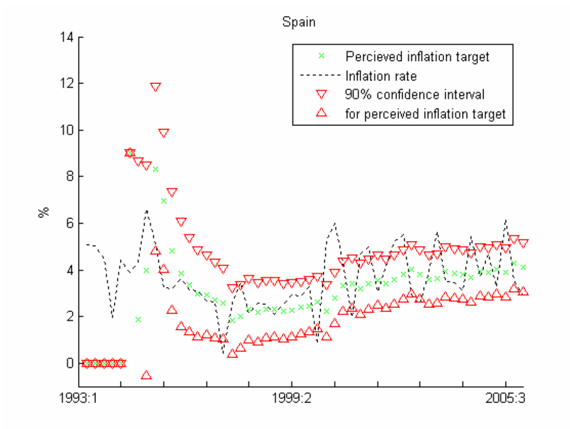

Germany
Perceived inflation target
Inflation rate
90% confidence interval
for perceived inflation target
%
14
12
10
8
6
4
2
0
1993:1
1999:2
2005:3


Netherlands
Perceived inflation target
Inflation rate
90% confidence interval
for perceived inflation target
%
14
12
10
8
6
4
2
0
1993:1
1999:2
2005:3


Greece
Perceived inflation target
Inflation rate
90% confidence interval
for perceived inflation target
%
14
12
10
8
6
4
2
0
1994:3
2000:4
2006:1


Portugal
Perceived inflation target
Inflation rate
90% confidence interval
for perceived inflation target
%
14
12
10
8
6
4
2
0
1993:1
1999:2
2005:3


Italy
Perceived inflation rate
Inflation rate
90% confidence interval
for perceived inflation rate
%
14
12
10
8
6
4
2
0
1993:1
1999:2
2005:3


Spain
Piercieved inflation target
Inflation rate
90% confidence interval
for perceived inflation target
%
14
12
10
8
6
4
2
0
1993:1
1999:2
2005:3

First note that the 90% confidence intervals for the perceived inflation target time series are zero for the few first quarters, and then larger in comparison to the rest of the time span considered. This is a consequence of the exact initial Kalman filter method, which assumes infinite variances for the initial values of the unobserved components (π_0^P) of the system. Thus we do not report the first few confidence intervals, so as to keep the figures in a reasonable range.

The figures suggest why classical measures of inflation persistence could be inappropriate, especially for the NMS. While the time-varying mean (the perceived inflation target) exhibits breaks for the NMS, no such clear breaks can be observed for the euro area countries.

The figures also capture the effect that the adoption of inflation targeting had on the inflation perceived by the public. For example, in the Czech Republic inflation targeting was adopted in 1997/1998. A year later a switch in the formation of the public perception of inflation can be observed. Since then, the time-varying mean of inflation has been close to the target of 3%.

(iii) The ARFIMA model

First we estimate the fractional differencing parameter *d.* We opt for Geweke and Porter-Hudak's technique[16] and report the results in Table 5a. Based on the estimated value of parameter *d*, we estimate the impulse response function of ARFIMA(0,*d*,0)[17]. To compare the persistence of shocks in the time series, we follow Gadea and Mayoral (2006) and report the values of the impulse response function for selected time horizons (*h=4* and *h=12*) after the realization of a shock.

The results show that Hungary, Poland, and Slovakia score high in the persistence suggested by ARFIMA, together with Greece and Spain. The Czech Republic ranks midway in the whole sample of 14 countries.

To assess the relevance of the ARFIMA model in inflation modeling, we test the hypothesis that inflation series follow a fractionally integrated process, against the hypothesis that the series follow a stationary process with breaks. The results of the test outlined in subsection 3.1 are reported in Table 5b. In most cases, the fractionally integrated process hypothesis can be rejected at the 1% level. The only inflation process for which we cannot reject the null of a fractionally integrated process at any reasonable significance level is the inflation series for Slovakia.

[16] Implemented in STATA by Baum and Wiggins (1999).

[17] The impulse response function measures the effects of the realization of a shock in y_t on subsequent values of the time series. See Andrews and Chen (1994) for details. We used the STATA implementation for ARFIMA written by Baum (2000).

Table 5a: Estimation of Fractional Differencing Parameter d and Value of Impulse Response Function for Selected Time Horizons

Inflation based on GDP deflator

Country	*d*	SE(*d*)	IPF(4)	IPF(12)
cze	0.59	0.25	0.38	0.24
hun	0.74	0.21	0.56	0.42
pol	0.93	0.15	0.87	0.81
svk	0.90	0.42	0.81	0.73
bel	0.63	0.33	0.42	0.28
esp	0.84	0.32	0.72	0.60
eu12	0.75	0.21	0.58	0.44
fin	0.23	0.63	0.08	0.04
fra	0.19	0.28	0.07	0.03
ger	0.54	0.29	0.32	0.20
grc	1.06	0.14	1.13	1.20
irl	0.22	0.20	0.08	0.03
ita	0.40	0.33	0.20	0.10
nld	0.75	0.24	0.57	0.43
prt	0.52	0.32	0.30	0.18

Table 5b: Test of Fractional Integration Process of order d versus Stationary Process with Breaks

	d				
Country	0,5	0,6	0,7	0,8	0,9
cze	0,817	**0,353** **	0,151 *	0,064	0,027
hun	0,604 ***	0,258 ***	**0,110** ***	0,046 **	0,020 *
pol	0,507 ***	0,212 ***	0,088 ***	0,036 ***	**0,015** ***
svk	0,784 *	0,342 **	0,147 **	0,062	**0,026**
bel	0,615 ***	**0,252** ***	0,103 ***	0,042 ***	0,017 **
esp	0,658 ***	0,281 ***	0,119 ***	**0,050** *	0,021 *
eu12	0,659 ***	0,280 ***	0,118 ***	**0,049** **	0,020 *
fin	**0,774** *	0,337 **	0,145 **	0,062	0,026
fra	**0,700** ***	0,308 ***	0,133 **	0,057	0,024
ger	**0,675** ***	0,287 ***	0,121 ***	0,050 *	0,021 *
grc	0,614 ***	0,255 ***	0,105 ***	0,043 **	0,018 **
irl	**0,546** ***	0,223 ***	0,090 ***	0,037 ***	0,015 ***
ita	**0,611** ***	0,254 ***	0,105 ***	0,043 **	0,018 **
nld	0,623 ***	0,261 ***	**0,109** ***	0,045 **	0,018 **
prt	**0,592** ***	0,246 ***	0,102 ***	0,042 ***	0,017 **
1% critical values	0,715	0,335	0,132	0,043	0,016
5% critical values	0,768	0,364	0,147	0,050	0,020
10% critical values	0,797	0,381	0,156	0,054	0,022

Note: Computation of the test statistics and critical values are based on Mayoral (2004). ***,**,and * denote the significance at 1%, 5% and 10% levels, respectively. For each country, the cells in bold determines the column closest to the value of d estimated using the Geweke and Porter-Hudak technique and reported in Table 5.

4.2 Structural Measures

The estimation of the New Hybrid Phillips Curve (NHPC) is significantly influenced by the data availability, especially for Slovakia. Some time series are only available for part of the time span considered. Moreover, some time series are available only annually. Therefore, we compromise between data availability and the ability to carry out the analysis, and use yearly instead of quarterly data for some instruments. The data used are described in Appendix 1.

We estimate the closed version of the model, since the instrument set employed performs poorly for the open economy version of the NHPC. As is usual in the related literature, we assume rational expectations. The future actual inflation rate, therefore, stands for the expected inflation rate in the estimation of the NHPC.

Zhang et al. (2006) point out the influence of the instrument set on the estimation results, especially when autocorrelation of residuals is present. We employ the sets of instruments introduced in Galí and Gertler (1999), Galí, Gertler, and López-Salido (2001), Zhang et al. (2006), and Lendvai (2005). We also add some instruments that we think are valid for the estimation in the case of the NMS. Table 6 below reports the estimation results for the Czech Republic, Poland, and Slovakia for various sets of instruments. The estimates for Hungary are available in Lendvai (2005). Staiger and Stock (1997) suggest a rule of thumb for instrument relevance: the F-statistics of the overall relevance of excluded instruments should exceed 10. F-statistics below 10 imply a bias in the estimated coefficients. We therefore do not report estimation results for sets of instruments that are not relevant according to this criterion.

In Table 6, the numbers in the upper panels report the lags of the variables that are included in the various sets of instruments. The panels in the middle of the table provide estimates of the reduced form coefficients. Finally, the lower panels report F-statistics and partial R^2 .

For sets of instruments resulting in F-statistics above 10, we carry out a Hansen J test for overidentifying restrictions. In all cases we cannot reject the null of satisfied overidentifying restrictions at all relevant significance levels. Furthermore, we test for homoskedasticity employing the Pagan-Hall test and for residual autocorrelation using the Breusch-Godfrey test. We detect serially correlated residuals in all cases and we reject homoskedasticity for Poland.[18] Based on the results of the diagnostics test mentioned, we correct for serial correlation and heteroskedasticity using three-lag HAC-robust standard errors.

Overall, the estimation results suggest that the structural NHPC is not an appropriate short-run inflation dynamics model for Poland and Slovakia. The estimated coefficients for these countries are not significant and often have a sign that does not correspond to the underlying theory. On the other hand, for the Czech Republic the estimated reduced form coefficients $\hat{\gamma}_f, \hat{\gamma}_b$ of the model are significant with the expected sign and within the range predicted by the micro theory. However, the slope parameter on the real marginal cost term $\hat{\lambda}$ is not statistically significant.

[18] For a discussion of the possible sources of residual autocorrelation, see Galí, Gertler, and López-Salido (2001).

Table 6: New Hybrid Phillips Curve: Estimation for Various Sets of Instruments – Czech Republic, Poland and Slovakia

Excluded instruments (lags) see Appendix 1	Czech Republic						Poland						Slovakia					
	GG	GGL	ZO	L	IS1	IS2	GG	GGL	ZO	L	IS1	IS2	GG	GGL	ZO	L	IS1	IS2
infl_d	2,3,4	2,3,4,5	x	2	2,3	x	2,3,4	2,3,4,5	x	2	2,3	x	2,3,4	2,3,4,5	x	2	2,3	x
lrulc_d	2,3,4	1,2	x	1,2	2,3	x	2,3,4	1,2	x	1,2	2,3	x	2,3,4	1,2	x	1,2	2,3	x
irspread	1,2,3,4	x	x	x	1,2,3,4	x	1,2,3,4	x	x	x	1,2,3,4	x	1,2,3,4	x	x	x	1,2,3,4	x
ogap	1,2,3,4	x	x	x	1,2	x	x	x	x	x	x	x						
deficit	x	x	x	1,2	1,2	x	x	x	x	1,2	1,2	x	x	x	x	1,2	1,2	x
diff_rer_d	x	x	x	1,2	0,1,2	x	x	x	x	1,2	0,1,2	x	x	x	x	1,2	0,1,2	x
rer_d	x	x	x	0	x	x	x	x	x	0	x	x	x	x	x	0	x	x
u_rate	x	x	1,2,3,4	x	x	1,2	x	x	1,2,3,4	x	x	1,2	x	x	1,2,3,4	x	x	1,2
diff_treasury	x	x	1,2,3,4	x	x	1,2,3,4	x	x	1,2,3,4	x	x	1,2,3,4						
output_d	x	1,2	x	x	x	1,2,3,4	x	1,2	x	x	x	1,2,3,4	x	1,2	x	x	x	1,2,3,4
rg_exp_d	x	x	1,2,3,4	x	x	x	x	x	1,2,3,4	x	x	x						
winfl_d	1,2,3,4	1,2	x	1,2	1,2,3,4	x	x	x	x	x	x	x						
cap_ut	x	x	1,2,3,4	x	x	1,2,3,4	x	x	x	x	x	x						
diff_1day	x	x	1,2,3,4	x	x	1,2,3,4	x	x	1,2,3,4	x	x	1,2,3,4	x	x	1,2,3,4	x	x	1,2,3,4
Results																		
$\hat{\gamma}_f$	0.47*		0.45*		0.42*	0.42*		-0.66**	-0.35			0.02					0.18	0.34
	(0.14)		(0.12)		(0.14)	(0.12)		(0.28)	(0.23)			(0.27)					(0.36)	(0.24)
$\hat{\gamma}_b$	0.35*		0.38*		0.35*	0.38*		-0.31**	-0.26***			-0.19					0.14	-0.02
	(0.08)		(0.09)		(0.07)	(0.09)		(0.15)	(0.13)			(0.15)					(0.18)	(0.15)
$\hat{\lambda}$	-0.09		-0.06		-0.06	-0.04		-0.05	-0.05			-0.05					0.15	0.13
	(0.18)		(0.16)		(0.16)	(0.15)		(0.07)	(0.06)			(0.05)					(0.12)	(0.11)
Instrument relevance																		
F statistics	10.81	1.09	19.51	1.06	72	35.26	3.12	10.46	13.84	2.59	1.84	30.9	8.75	3.64	7.64	1.8	15.41	11.76
Partial R2	0.56	0.19	0.59	0.28	0.57	0.58	0.41	0.34	0.41	0.23	0.08	0.53	0.45	0.14	0.33	0.12	0.49	0.46

* 1% significance level ** 5% ***10%

3-lag HAC-robust standard errors are reported in parentheses.

Estimation results for relevant (F statistics above 10) sets of instruments are reported.

We employ instrument sets that replicate Galí and Gertler (1999) **GG**, Galí, Gertler and López-Salido (2001) **GGL**, Zhang et al. (2006) **ZO**, and Lendvai (2005) **L**. We also add some instruments that we consider as valid for the estimation: **IS1** and **IS2**.

For a definition of these instruments, see Appendix 1. The suffix _d denotes HP filtered time series.

We focus on comparison of the reduced form coefficients γ_b, γ_f, since we are mainly interested in the extent of inflation inertia.[19] A detailed analysis of the structural Phillips curve estimation lies beyond the scope of this current study. The comparison suggests that the predominance of expected future inflation over past inflation seen in the euro area (and the US) is not detected for the Czech Republic and Hungary.[20] If we follow the definition of (intrinsic) inflation persistence from previous sections, we can conclude that the Czech Republic and Hungary exhibit comparable or higher inflation persistence than the euro area countries. Moreover, the lower predominance of the forward-looking term is in accordance with the results of statistical measures based on the autoregressive model with a time-varying mean from the preceding subsection.

5. Summary of Results

Our paper provides results in two areas. First, on the methodological level, we summarize the measures available for estimating inflation persistence, such as various types of autoregressive models, including fractionally integrated, and the New Hybrid Phillips Curve (NHPC). We discuss which measures should be used to assess inflation persistence in the NMS, which have certain specific economic characteristics imposed by the current convergence process as well as echoes of the transformation process. Second, we provide empirical estimates of inflation persistence in the NMS and compare them to those obtained for the current euro area Member States.

Starting with the first area, we consider three statistical measures (the autoregressive model with a constant mean and with a time-varying mean, and the autoregressive fractionally integrated moving average model) and a structural measure (the estimated New Hybrid Phillips Curve). We argue that time-varying mean models should be a preferred option for inflation persistence measurement in the NMS as far as the statistical measures are concerned. According to our results, the constant mean assumption is too restrictive for estimating inflation persistence in the NMS. Constant means cannot fully capture the fact that the medium-run equilibrium gradually moves toward the long-run equilibrium in our data samples covering both the transformation and convergence processes. The constant mean models therefore overestimate the actual persistence by assuming that the medium-run and long-run equilibria are identical. Moreover, changes in expectations and monetary policy regimes are likely to contribute to changes in perceived inflation targets, which are closely related to the means estimated from the data. Given the frequency of changes in targets and even in monetary policy regimes in the NMS, the constant mean assumption is not appropriate. We also find that the time-varying mean models are superior to the ARFIMA models for most of the countries considered.

The empirical findings correspond to the methodological discussion. Estimating the inflation persistence under the constant mean assumption we find that in our sample of 14 countries the NMS (the Czech Republic, Hungary, Poland, and Slovakia) score very high (Table 7). Their values of inflation persistence are among the top five. Only Greece has a comparable persistence level. In this exercise, the Czech Republic has the highest or second highest inflation persistence values. However, when we use the superior statistical measure and assume a time-varying mean, we see a completely different picture. The five countries with the highest inflation persistence are

[19] Note that the reduced form coefficients are a sole function of deep parameters.

[20] See the results for the US, the euro area, and Hungary in Galí and Gertler (1999), Galí, Gertler, and López-Salido (2001), Zhang et al. (2005), and Lendvai (2005). We summarize the results of interest in the next section.

the Netherlands, Spain, Germany, Belgium, and France. The Czech Republic and Slovakia, together with Italy, Portugal, and Greece, form the middle group with mild inflation persistence. Poland and Finland appear to have the lowest inflation persistence in our sample. We therefore conclude that the NMS as a group have comparable inflation persistence to that in the current euro area Member States. This conclusion is also supported by the fact that the 90% confidence intervals often reject statistical differences in inflation persistence between the countries in our sample.

Table 7: Summary of Results – Statistical Measures

	ρ_K (OLS)		ρ_K (Hansen) lag =5		$\Sigma \varphi_i$ (Time-varying mean)	
CZE	0.75 - 0.8	(1)	0.88	(2)	0.26	(8)
HUN	0.75	(2-3)	0.98	(1)	X	
POL	0.68	(4)	0.78	(4)	0.12	(11)
SVK	0.75	(2-3)	0.74	(5)	0.28	(7)
EU12	0.66	(x)	0.70	(x)	X	
BEL	0.13	(12)	0.28	(11)	0.45	(4)
ESP	0.26 - 0.6	(10)	0.69	(7)	0.50	(2-3)
FIN	0.33	(9)	0.24	(12)	0.07	(12)
FRA	0.43	(8)	0.57	(9)	0.37	(5)
GER	0.50 - 0.6	(7)	0.59	(8)	0.50	(2-3)
GRC	0.67	(5)	0.82	(3)	0.13	(10)
IRL	0.11	(13)	0.10	(13)	X	
ITA	0.14	(11)	0.37	(10)	0.33	(6)
NLD	0.62	(6)	0.71	(6)	0.64	(1)
PRT	-0.16	(14)	-0.03	(14)	0.19	(9)

Note: For each approach, we report parameter estimates. Intervals indicate estimates by various methods as presented in the paper. In brackets, the countries are ordered according to the scope of estimated inflation persistence.

To underpin the discussion with measures based on structural parameters, we estimate the New Hybrid Phillips Curve. To the previously published results for Hungary, we add our estimates of the NHPC for the Czech Republic (Table 8). For these two NMS, backward-looking price setting behavior is relatively more important than for the current euro area Member States, where forward-looking behavior dominates. This result might indicate that although inflation persistence in the NMS is comparable to that in the current euro area Member States, it does not have the same roots.

Table 8: Estimates of the New Hybrid Phillips Curve in Various Studies

	Czech Republic	Hungary	euro area					
Coefficient	Summary	L (2005)	Summary	GG (1999) a	GG (1999) b	GGL (2001) a	GGL (2001) b	ZO (2005)
$\hat{\gamma}_b$	0.42-0.47	0.467	0.04-0.59	0.252	0.378	0.043	0.272	0.587
		(0.084)		(0.023)	(0.020)	(0.115)	(0.072)	(0.085)
$\hat{\gamma}_f$	0.35-0.38	0.553	0.43-0.77	0.682	0.591	0.773	0.689	0.429
		(0.084)		(0.020)	(0.016)	(0.064)	(0.047)	(0.089)

Note: See Galí and Gertler (1999) – Table 2, Galí, Gertler, and López-Salido (2001) – Table 2, Zhang et al. (2005) – Table 2, and Lendvai (2005) – Table 3a. The two versions of Galí and Gertler (1999) and Galí, Gertler, and López-Salido (2001) correspond to the two versions of orthogonality conditions. For the euro area the GDP deflator is used; Lendvai (2005) uses core inflation. Standard errors are reported in parentheses.

In comparison to Hungary, the role of the forward-looking term is even less important for the Czech Republic, while the backward-looking terms are similarly important. The estimates for the Czech Republic are obtained by various methods. We conclude that our results for the Czech Republic are relatively robust, since they do not vary as much as in the case of various studies of the euro area NHPC.

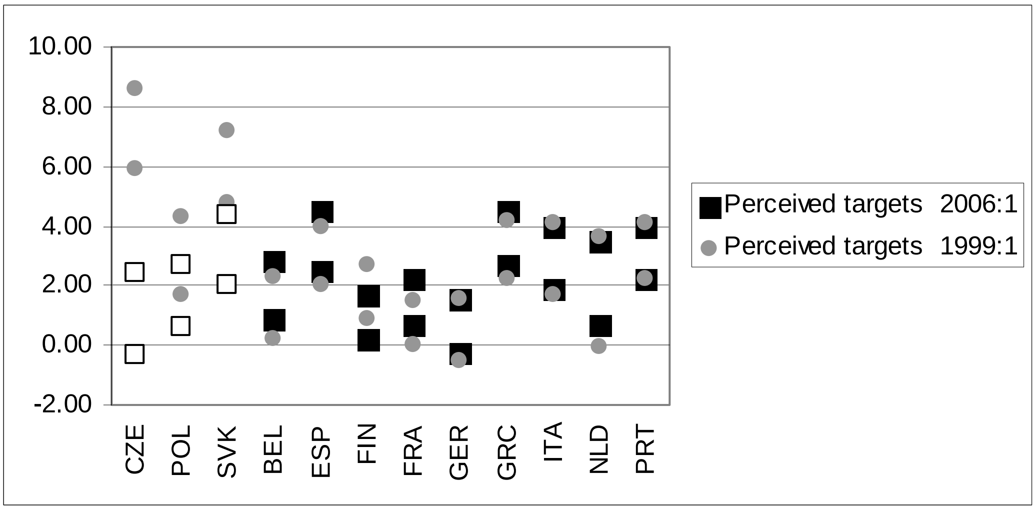
6. Conclusions

Preparation for the euro and euro adoption is easier for economies that have economic characteristics similar to the current euro area Member States. We argue that inflation persistence is an important economic characteristic to look at in this context. If the NMS have different inflation persistence than the euro area, the reaction of national inflation rates to common shocks will magnify the inflation differences already present due to the convergence process. Prevailing inflation differences may subsequently reduce the chances of the NMS to fulfill the Maastricht criterion on inflation and increase the potential risks of euro adoption, such as asset price bubbles resulting from prevailing negative interest rates.

Our first conclusion is that one should be very careful when selecting and interpreting empirical measures of inflation persistence. An inappropriate measure, based on the assumption of a constant mean, can send a very misleading signal suggesting that high inflation persistence poses an enormous problem for the NMS. Moreover, comparing levels of persistence between countries should be done carefully, since the confidence intervals are quite wide and consequently the most frequent outcome of such a comparison is that countries do not have significantly different inflation persistence levels.

Nevertheless, we find the following empirical results relevant to the policy discussion about the euro and the NMS. Out of the three sources of inflation persistence (intrinsic, extrinsic, and expectations-based), the first two seem to be of comparable importance in the NMS and the euro area. This might be partially due to the fact that the way wages and prices are set, as well as the persistence in the inflation-driving real variables, is similar across European countries. In addition, our estimates of the time-varying mean models clearly show that changes in expectations and monetary policy regimes are crucial in analyzing inflation persistence in the NMS. These models provide us with estimates of shifts in perceived inflation targets. These shifts are large for the NMS, supporting an intuitive view that the perception of inflation and monetary policy regimes has changed profoundly in countries preparing for the euro (Figure 3). For example, in 1999 the public-perceived inflation target was 6–8% in the Czech Republic, whereas in 2006 the perceived target was seven times lower. Similar – albeit smaller – shifts can be observed in the cases of Poland and Slovakia. Finally, based on the estimation of the New Hybrid Phillips Curve we find that the NMS in our sample are more backward-looking than the current members of the euro area.

Figure 3: Perceived Inflation Targets from 1999 to 2006



Note: Targets are represented with confidence intervals (vertical axis in %).

The empirical results, which identify a more backward-looking nature of inflation and larger shifts in perceived inflation targets in the NMS than in the euro area, indicate that anchoring inflation expectations should become a very important part of the euro adoption strategy for the NMS. Despite the fact that the perceived inflation targets in the NMS are now similar to those of the current euro area members, the NMS should pay attention to expectations-based persistence. The shifts in perceived inflation targets in the NMS contrast with the remarkably stable perceived inflation targets in the current euro area Member States. Since several examples among the current euro area countries show that upward shifts in perceived targets are also possible, the NMS should not take it for granted that their perceived targets will remain at current levels.

There are several aspects of inflation persistence in the NMS that are worth further research. Our sample group does not cover all the NMS, partially due to data availability problems, and partially due to the new wave of enlargement that came after the project had been started. It would be worth estimating all measures of persistence at least for Bulgaria and Romania. More research is needed on NHPC estimation methods regarding the NMS. It is clear that with the current methodology it is difficult to get reasonable results for some countries. Finally, it will be worth re-estimating all the measures after some time, especially for Slovakia, which plans to adopt the euro soon, in order to see how euro adoption influenced inflation persistence.

References

ANGELONI, I., L. AUCREMANNE, M. EHRMANN, J. GALÍ, A. Y. LEVIN, AND F. SMETS (2006): "New Evidence on Inflation Persistence and Price Stickiness in the Euro Area: Implications for Macro Models and Policy." *Journal of the European Economic Association*, Vol. 4(2–3), 562–574.

ANGELONI, I. AND M. EHRMANN (2004): "Euro Area Inflation Differentials." ECB Working Paper, No. 388.

ALTISSIMO, F., M. EHRMANN, AND F. SMETS (2006): "Inflation Persistence and Price-setting Behaviour in the Euro Area – A Summary of the IPN Evidence." ECB Occasional Paper, No. 46.

BABETSKII, I., F. CORICELLI, AND R. HORVÁTH (2007): "Measuring and Explaining Inflation Persistence: Disaggregate Evidence on the Czech Republic." CNB Working Paper, No. 1.

BAUM, C. F. (2000): "FRACIRF: Stata Module to Compute Impulse Response Function for Fractionally-integrated Time Series." Statistical Software Components S414004, Boston College Department of Economics.

BAUM, C.F. AND V. WIGGINS (1999): "GPHUDAK: Stata Module to Estimate Long Memory in a Timeseries." Statistical Software Components 388101, Boston College Department of Economics, revised 25 June 2006.

BAUM, C. F., J. BARKOULAS, AND M. CAGLAYAN (1999): "Persistence in International Inflation Rates." *Southern Economic Journal*, 65(4), 900–914.

BAUM, C. F., M. E. SCHAFFER, AND S. STILLMAN (2003): "Instrumental Variables and GMM: Estimation and Testing." Working Paper, No. 545, Boston College – Department of Economics.

BATINI, N. (2002): "Euro Area Inflation Persistence." ECB Working Paper, No. 201.

BENATI, L. (2006): "International Evidence on the Persistence of Inflation." mimeo, European Central Bank.

BILKE, L. (2005): "Break in the Mean and Persistence of Inflation: A Sectoral Analysis of French CPI." Banque de France Working Paper, No. 122.

BJORKSTEN, N. (2002): "Real Convergence in the Enlarged Euro Area: A Coming Challenge for Monetary Policy." Bank of Finland Economics Department Working Paper, No. 1.

CA'ZORZI, M. AND R. A. DE SANTIS (2003): "The Admission of Accession Countries to an Enlarged Monetary Union: A Tentative Assessment." ECB Working Paper, No. 216.

CECCHETTI, S. G. AND G. DEBELLE (2006): "Has the Inflation Process Changed?" *Economic Policy*, Vol. 21, No. 46, 311–352.

CORICELLI, F. AND R. HORVÁTH (2006): "Price Setting Behaviour: Micro Evidence on Slovakia." CEPR Discussion Paper, No. 5445.

DARVAS, Z. AND B. VARGA (2007): "Inflation Persistence in the Euro-area, US, and New Members of the EU: Evidence from Time-varying Coefficient Models." Money Macro and Finance Research Group Conference 2006.

DOSSCHE, M. AND G. EVERAERT (2005): “Measuring Inflation Persistence – A Structural Time Series Approach.” ECB Working Paper, No. 495.

DRIVER, R. AND P. WESTAWAY (2005): “Concepts of Equilibrium Exchange Rates.” Bank of England Working Paper, No. 248.

EGERT, B., D. RITZBERGER-GRUNWALD, AND A. M. SILGONER (2004): “Inflation Differentials in Europe: Past Experience and Future Prospects.” *Monetary Policy & the Economy Quarterly Review of Economic Policy*, No. Q1/04, Oesterreichische Nationalbank.

EUROPEAN CENTRAL BANK (2003): “Inflation Differentials in the Euro Area: Potential Causes and Policy Implications.”

EUROPEAN COMMISSION (2002): “Quarterly Report on the Euro Area, No. IV/2002.”

EUROPEAN COMMISSION (2004): “Third Report on Economic and Social Cohesion.”

FIDRMUC, J. AND A. TICHIT (2004): “Mind the Break! Accounting for Changing Patterns of Growth During Transition.” William Davidson Institute Discussion Paper, No. 643.

GADEA, M. D. AND L. MAYORAL (2006): “The Persistence of Inflation in OECD Countries: A Fractionally Integrated Approach.” *International Journal of Central Banking*, Vol. 1, No. 4.

GADZINSKI, G. AND F. ORLANDI (2004): “Inflation Persistence in the European Union, the Euro Area, and the United States.” ECB Working Paper, No. 414.

GALÍ, J., AND M. GERTLER (1999): “Inflation Dynamics: A Structural Econometric Analysis.” *Journal of Monetary Economics,* 44, 195–222.

GALÍ, J., M. GERTLER, AND J. D. LÓPEZ-SALIDO (2001): “European Inflation Dynamics.” NBER Working Paper, No. 8218.

HANSEN, B. E. (1999): “The Grid Bootstrap and the Autoregressive Model.” *Review of Economics and Statistics*, Vol. 81, No. 4, 594–607.

INTERNATIONAL MONETARY FUND (2002): “Monetary and Exchange Rate Policies in the Euro Area – Selected Issues.” IMF Country Report 02/236.

KOČENDA, E. (2005): “Beware of Breaks in Exchange Rates: Evidence from European Transition Countries.” *Economic Systems*, Vol. 29, Issue 3, 307–324.

KONIECZNY, J. AND A. SKRZYPACZ (2005): “Inflation and Price Setting in a Natural Experiment.” *Journal of Monetary Economics,* Vol. 52, No. 3, 621–632.

KOOPMAN, S. J. AND J. DURBIN (2003): “Filtering and Smoothing of State Vector for Diffuse State-space Models.” *Journal of Time Series Analysis*, Vol. 24, No. 1, 85–98.

LENDVAI, J. (2005): “Hungarian Inflation Dynamics.” Occasional Paper, No. 2005/46, Magyar Nemzeti Bank.

LEVIN, A. T. AND J. M. PIGER (2004): “Is Inflation Persistence Intrinsic in Industrial Economies?” ECB Working Paper, No. 334.

MA, A. (2002): “GMM Estimation of the New Phillips Curve.” *Economics Letters*, Vol. 76, No. 3, 411–417.

MARQUES, C. R. (2004): “Inflation Persistence: Facts or Artefacts?” ECB Working Paper, No. 371.

MAYORAL, L. (2004): “Testing for Fractional Integration versus Short Memory with Trends and Structural Breaks.” last version from June 2006 available at http://www.econ.upf.edu/~mayoral/laura_mayoral_research.htm

ORGANIZATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (2002): “Inflation Persistence in the Euro Area.” Economic Outlook 72, Chapter VII.

PERRON, P. (1989): “The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis.” *Econometrica*, Vol. 57, No. 6, 1361–1401, November.

RATFAI, A. (2006): “Linking Individual and Aggregate Price Changes.” *Journal of Money, Credit and Banking*, Vol. 38, No. 8, 2199–2224.

STAIGER, D. AND J. D. STOCK (1997): “Instrumental Variables Regression with Weak Instruments.” *Econometrica*, Vol. 65, No. 3, 557–586.

ZHANG, C., D. R. OSBORN, AND D. H. KIM (2006): “Observed Inflation Forecasts and the New Keynesian Phillips Curve.” University of Manchester Discussion Paper, No. 79.

Appendix 1: Data Description

Inflation based on the GDP deflator: seasonally adjusted annualized q-o-q rate of change of the GDP deflator as published in the OECD OEO Database. Time span: 1993:2–2006:1. The exception is Hungary, for which we used the time span 1995:1–2006:1. Transformation: $inf_{GDP} = 400ln(GDPdefl/GDPdefl_{-1})$.

Inflation based on non-food, non-energy CPI: annualized q-o-q rate of change of the Consumer Price Index as published in the OECD MEI Database. Timespan: 1996:2–2006:2. Transformation: $inf_{coreCPI} = 400ln(coreCPI/coreCPI_{-1})$.

Country name abbreviations: BEL (Belgium), CZE (Czech Republic), FIN (Finland), FRA (France), GER (Germany), GRC (Greece), HUN (Hungary), IRL (Ireland), ITA (Italy), NLD (Netherlands), POL (Poland), PRT (Portugal), SVK (Slovakia), ESP (Spain)

The structural Phillips curve is estimated based on quarterly data covering the period 1993:2–2006:1 for the Czech Republic and Poland, and 1995:2–2006:1 for Slovakia.[21] We take over inflation based on the GDP deflator (*infl*) and the real effective exchange rate (*reer*) from the preceding analysis. Real marginal costs are represented by the log of real unit labor costs deflated by the GDP deflator (*lrulc*). In addition, we employ the following series:

ogap: output gap as a percentage of total GDP
irspread: difference between short-term (1 day) and long-term (3 months) interest rate
deficit: government surplus or deficit in terms of GDP
rer: real exchange rate
diff_rer: q-o-q change of real exchange rate
u_rate: unemployment rate
diff_treasury: first difference of long-term interest rate (10 years)
output: GDP
rg_exp: real government expenditure (deflated by GDP deflator)
winfl: wage inflation (annualized q-o-q change)
cap_ut: capacity utilization
diff_1day: first difference of short-term interest rate.

The output gap is available for the Czech Republic and for the period 1995:1–2006:1 only; we impose zeros for the period 1993:1–1994:4. The government deficit is available annually since 1995:1 (we impose zeros for the period 1993:1–1994:4). GDP is available quarterly since 1996 for the Czech Republic and since 1995 for Poland. Only annual values for the long-term interest rate (10 years) are available for Slovakia, and therefore we do not include *diff_treasury* in the analysis for that country. Quarterly values of the long-term interest rate (10 years) are available since 1999:2 for Poland. Government expenditures are available since 1996 for Poland; we impose values as of 1996 in the period before. For Slovakia, government expenditures are not available. For the Czech Republic, wage inflation is available quarterly since 1998; annual values are available in the preceding period. Time series of wage inflation and capacity utilization are not available for Slovakia and Poland.

[21] The data were downloaded from the ECB Statistical Data Warehouse. The data sources are: OECD Economic Outlook, OECD Main Economic Indicators, ECB Euro Area Accounts and Economic Statistics – Government Statistics and ESA, and the Czech Statistical Office.

Appendix 2: Sum of Autoregressive Coefficients – Core Inflation

Table: OLS estimates of ρ_K (inflation based on non-food, non-energy CPI)

	Preferred model according to AIC		Preferred model according to BIC	
	Lag length	Sum of AR coefficients	Lag length	Sum of AR coefficients
CZE	4	0.75	2	0.65
HUN	4	0.85	4	0.85
POL	4	0.84	4	0.84
SVK	1	0.21	1	0.21
BEL	5	-0.14	5	-0.14
ESP	3	-1.56	1	-0.95
FIN	5	0.65	5	0.65
FRA	4	0.75	4	0.75
GER	4	0.20	4	0.20
GRC	4	0.51	4	0.51
IRL	5	0.49	4	0.57
ITA	4	0.33	2	-0.05
NLD	5	0.67	4	0.85
PRT	4	0.72	4	0.72

Figure 2: Inflation based on non-food, non-energy CPI, ρ estimate and its 90% confidence intervals (lag length = 5, Hansen's (1999) grid bootstrap procedure)

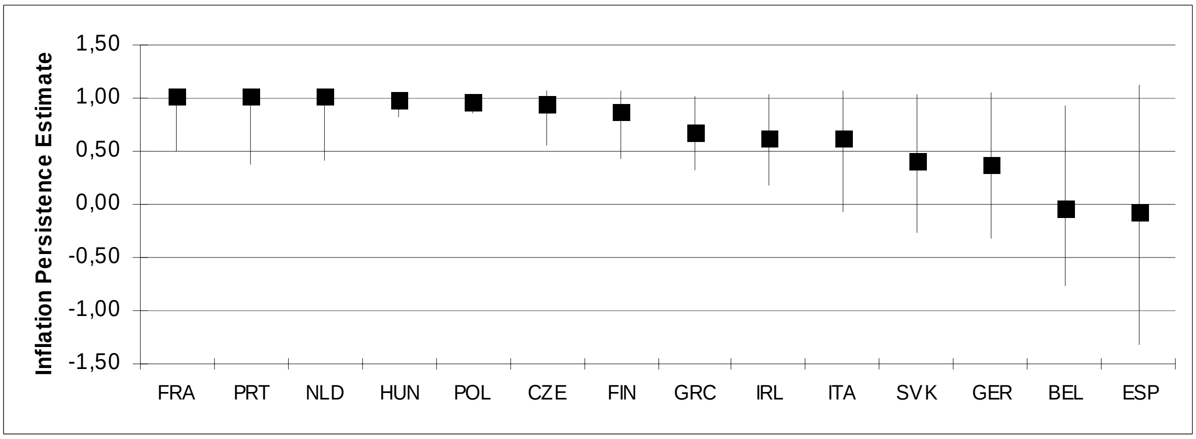
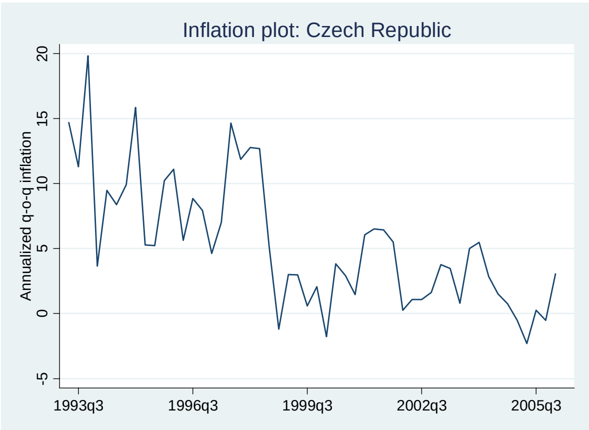
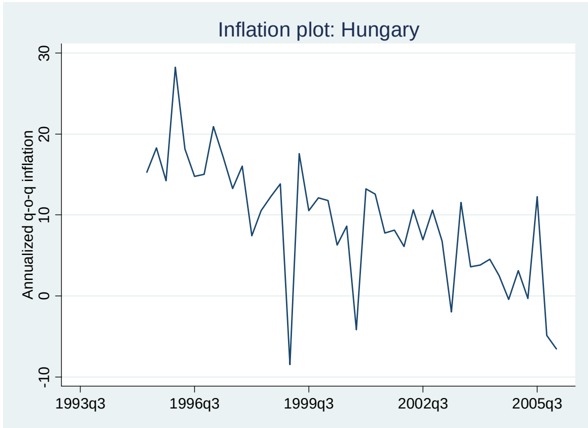


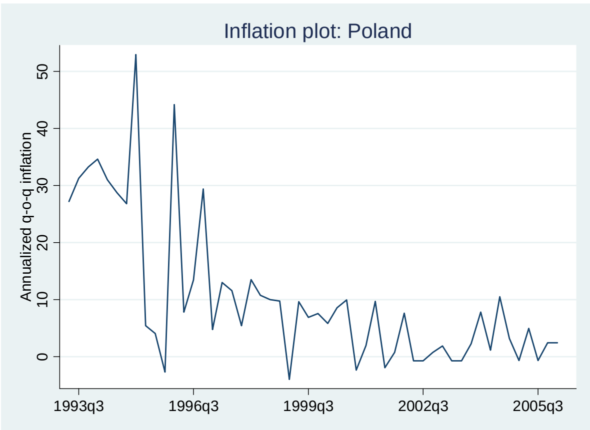
Table: ρ_K and its 90% confidence intervals estimated using Hansen's (1999) grid bootstrap procedure (inflation based on non-food, non-energy CPI)

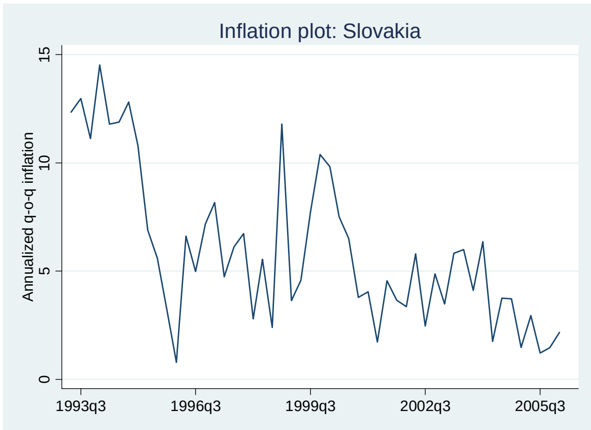
	Lag length = 5			Lag length = 4			Lag length = 3			Lag length = 2			Lag length = 1		
	lower bound	mean	upper bound	lower bound	mean	upper bound	lower bound	mean	upper bound	lower bound	mean	upper bound	lower bound	mean	upper bound
CZE	0.55	**0.95**	1.07	0.60	**1.00**	1.09	0.44	**0.80**	1.04	0.50	**0.81**	1.04	-0.33	**-0.06**	0.17
HUN	0.83	**0.98**	1.04	0.81	**0.95**	1.02	0.73	**0.99**	1.06	0.26	**0.53**	0.83	0.33	**0.55**	0.79
POL	0.85	**0.97**	1.03	0.81	**0.92**	0.99	0.79	**0.99**	1.05	0.76	**0.96**	1.04	0.71	**0.86**	1.02
SVK	-0.26	**0.41**	1.04	0.02	**0.54**	1.05	-0.19	**0.28**	0.79	-0.03	**0.33**	0.75	-0.02	**0.24**	0.53
BEL	-0.77	**-0.03**	0.93	-0.49	**0.28**	1.06	-0.82	**-0.20**	0.46	-0.40	**0.08**	0.59	-0.63	**-0.38**	-0.14
ESP	-1.32	**-0.08**	1.13	-2.11	**-1.03**	0.10	-2.23	**-1.51**	-0.78	-1.31	**-0.76**	-0.18	-1.06	**-0.97**	-0.85
FIN	0.43	**0.87**	1.07	0.39	**0.85**	1.07	0.21	**0.59**	1.03	0.36	**0.76**	1.04	-0.52	**-0.23**	0.04
FRA	0.50	**1.02**	1.09	0.59	**1.03**	1.12	0.12	**0.56**	1.03	0.13	**0.48**	0.95	-0.14	**0.13**	0.41
GER	-0.32	**0.38**	1.06	-0.20	**0.39**	1.04	-0.52	**0.07**	0.65	-0.24	**0.23**	0.71	-0.60	**-0.37**	-0.10
GRC	0.32	**0.67**	1.02	0.32	**0.63**	0.96	0.09	**0.41**	0.80	0.33	**0.72**	1.05	-1.00	**-0.86**	-0.71
IRL	0.17	**0.62**	1.04	0.33	**0.78**	1.06	0.11	**0.51**	1.02	0.23	**0.60**	1.02	-0.16	**0.11**	0.38
ITA	-0.07	**0.62**	1.08	-0.09	**0.56**	1.06	-0.28	**0.17**	0.69	-0.35	**0.00**	0.33	-0.05	**0.19**	0.47
NLD	0.41	**1.01**	1.09	0.71	**1.04**	1.27	-0.14	**0.40**	1.03	0.12	**0.56**	1.03	-0.50	**-0.22**	0.04
PRT	0.37	**1.02**	1.09	0.46	**1.02**	1.14	-0.07	**0.44**	1.03	0.09	**0.55**	1.03	-0.89	**-0.70**	-0.50

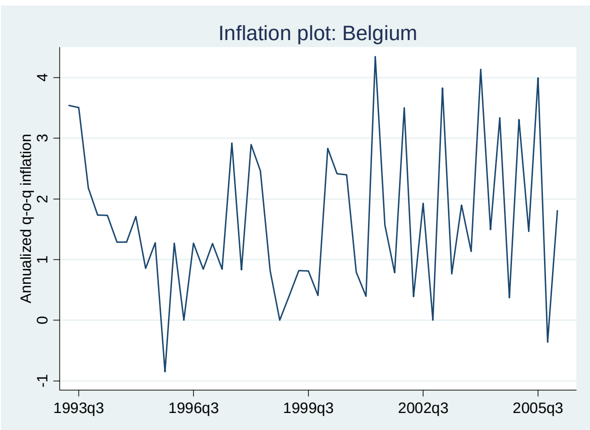
Appendix 3: Inflation Plots for Selected Countries

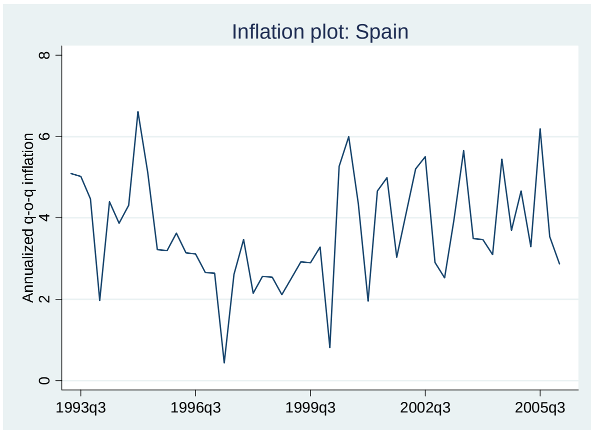


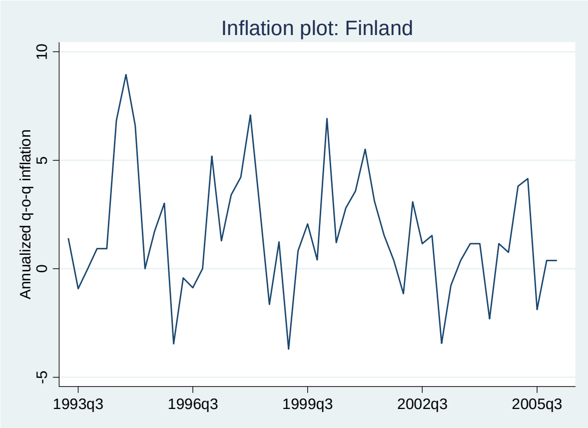


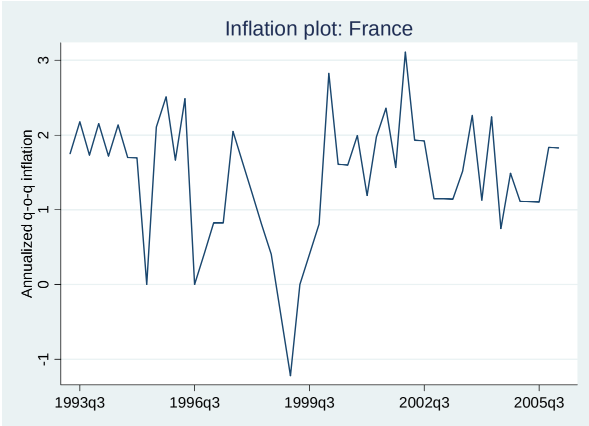


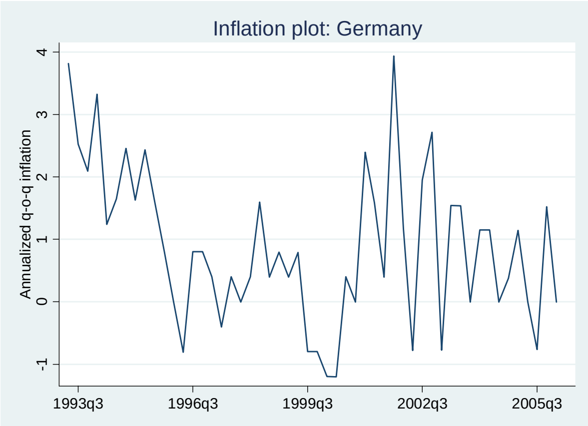


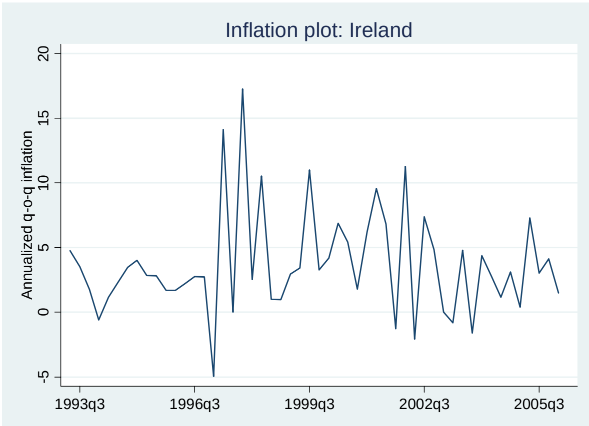


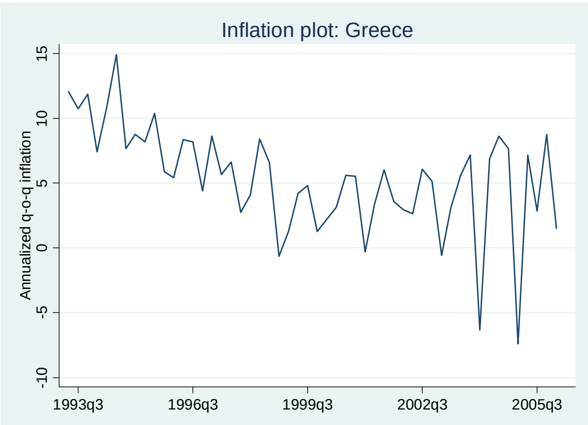


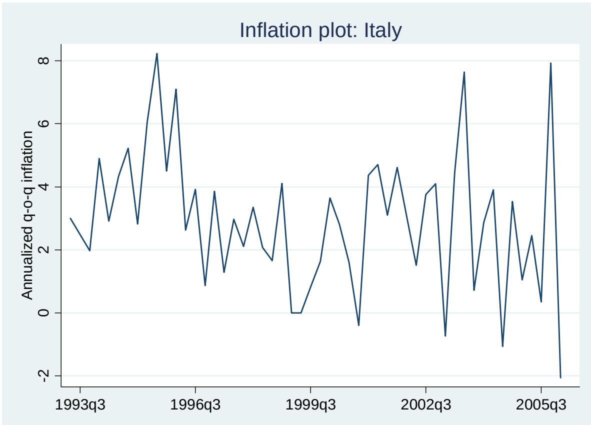

Inflation plot: Finland
Annualized q-o-q inflation
-5
0
5
10
1993q3
1996q3
1999q3
2002q3
2005q3

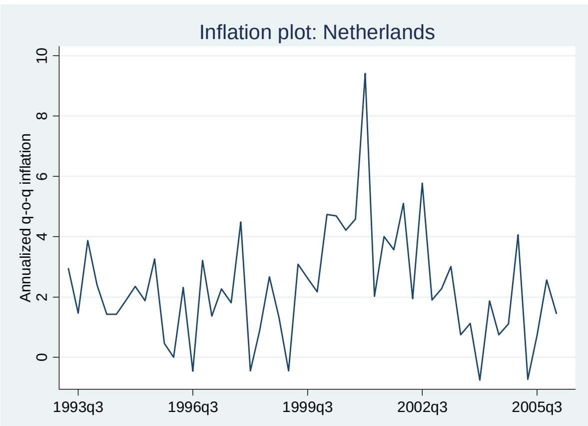

Inflation plot: France
Annualized q-o-q inflation
-1
0
1
2
3
1993q3
1996q3
1999q3
2002q3
2005q3

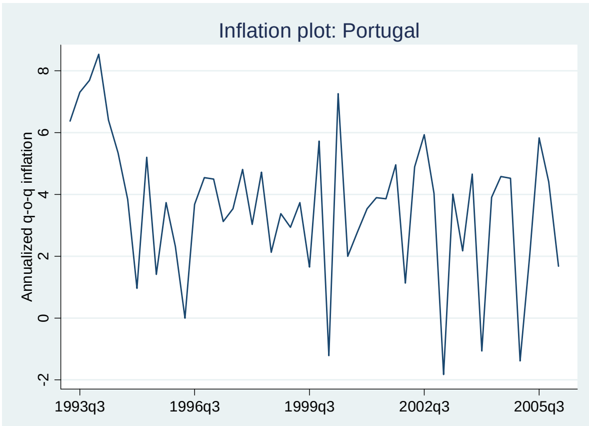

Inflation plot: Germany
Annualized q-o-q inflation
-1
0
1
2
3
4
1993q3
1996q3
1999q3
2002q3
2005q3


Inflation plot: Ireland
Annualized q-o-q inflation
-5
0
5
10
15
20
1993q3
1996q3
1999q3
2002q3
2005q3


Inflation plot: Greece
Annualized q-o-q inflation
-10
-5
0
5
10
15
1993q3
1996q3
1999q3
2002q3
2005q3


Inflation plot: Italy
Annualized q-o-q inflation
-2
0
2
4
6
8
1993q3
1996q3
1999q3
2002q3
2005q3


Inflation plot: Netherlands
Annualized q-o-q inflation
0
2
4
6
8
10
1993q3
1996q3
1999q3
2002q3
2005q3


Inflation plot: Portugal
Annualized q-o-q inflation
-2
0
2
4
6
8
1993q3
1996q3
1999q3
2002q3
2005q3

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