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Inflation dynamics and the New Keynesian Phillips curve in EU-4

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Abstract

The paper seeks to shed light on inflation dynamics of four new EU member states: the Czech Republic, Hungary, Poland and Slovakia. To this end, the New Keynesian Phillips curve augmented for open economies is estimated and additional statistical tests applied. We find the following. (1) The claim of New Keynesians that the real marginal cost is the main inflation-forcing variable is fragile. (2) Inflation seems to be driven by external factors. (3) Although inflation holds a forward-looking component, the backward-looking component is substantial. An intuitive explanation for higher inflation persistence may be rather adaptive than rational price setting of local firms.

Keywords: Inflation dynamics, New Keynesian Phillips curve, CEEC, GMM estimation

JEL Classification: C32, E31

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1. Introduction

Understanding the nature of short-term inflation dynamics is very important for the implementation of monetary policy. The traditional (wage) Phillips curve (PC) suggested that there is a trade-off between (wage) inflation and economic activity and inflation was deemed to be very persistent. While the traditional PC was buried already in the 1970's, the persistence became a generally accepted feature of the inflation process. During the 1990's the New Keynesian Phillips curve (NKPC) appeared that, unlike the empirical PC, posses elaborated microeconomic foundations. The NKPC links the current price inflation to expectations of the future inflation of economic agents. This NKPC arises in a framework of monopolistic competition and price rigidities. The proponents of the NKPC criticize the backward-looking nature of the traditional PC as being non-stable across policy regimes (Lucas critique), inconsistent with rational expectations and over-predicting inflation of developed countries in the last decades. At the same time, the traditional cyclical measures of real economic activity (the output gap, the unemployment rate) were disregarded as relevant determinants of inflation in favor of the aggregated marginal cost. Therefore, the current discussion on inflation dynamics boils down into two questions: (i) is inflation a backward-looking or forward-looking process and (ii) what is the main inflation-forcing variable in the short-term. The nature of inflation dynamics has important consequences for monetary policy. In particular, if inflation is predominantly forward-looking phenomenon and its dependence on the past (intrinsic persistence) is limited, a credible monetary policy can achieve disinflation at no cost (in terms of real output loss).

The empirical evidence on the NKPC is vast especially for major economies, but its results are ambiguous. The capacity of the NKPC to explain the inflation dynamics for small open economies is subject to controversy as well, and the (limited) availability and quality of data is the reason why studies for emerging countries are very scant. The new EU member states (NMS) have numerous specific features not only in comparison to developed economies but also with respect to other emerging countries. Therefore, it is of interest to analyze the inflation dynamics of these countries and evaluate whether the NKPC (currently the most influential model of inflation dynamics) can shed some light on this issue. To this end, we test the NKPC augmented by (possible) external inflation sources for the four NMS (the Czech Republic, Hungary, Poland and Slovakia). We use both country-level and panel

estimation and address some concerns related to the GMM estimation of a forward-looking model (identification, weak instruments) as well as to the data used (cointegration).

The inflation process in the NMS is distinguished by some peculiarities that have substantially hampered the empirical analysis of the NKPC so far. (i) The transformation process in general and the price liberalization in particular were decisive determinants of the price inflation during most of the 1990s. Therefore, the period where one could reasonably link the inflation developments to price setting behavior of firms (consistently with the NKPC), is relatively recent and short. (ii) It is not obvious what effect the transitional experience and systematically higher inflation rates had on this price setting behavior. One possibility is that higher inflation rates induced more frequent price reviews. However, it is also possible that local firms have not yet learned to use all the available information or face higher cost of gathering it (Mankiw and Reis, 2002). (iii) Countries subject to our analysis, with the exception of Slovakia, consistently applied a regime of inflation targeting that anchored the inflation rates but it is also believed to drive down inflation persistence (Benati, 2008). (iv) All four NMS are small and very open economies.[1] Therefore, their domestic prices and inflation rates can be affected by external sources that were practically ignored in original empirical studies on the NKPC but have been recognized recently (Batini et al., 2005, Rumler, 2007, Mihailov et al., 2009).

The principal results of our analysis are the following. (i) While the forward-looking NKPC is at odds with data of the four countries, the hybrid specification has a very reasonable fit. (ii) Even though price inflation in the NMS holds a significant forward-looking component, it is also rather persistent. (iii) The evidence in favor of the marginal cost as the main inflation-forcing variable is fragile and inflation dynamics seems to be driven by external factors. (iv) The results of country-level analysis are confirmed overall by the panel framework.

The paper is structured as follows. The next section reviews both theoretic and empiric issues related to the NKPC. In section 3, we present our estimation framework, and section 4 discusses our dataset and resumes the results of basic time series testing. Section 5 presents the estimation results of different version of NKPC both in single-equation and panel settings. The last section concludes and points to possible extensions.

[1] The shares of imports on GDP are following: the Czech Republic – 72.7%, Hungary – 77.3%, Poland – 41.7% and Slovakia – 88.2% (Source: European Commission).

2. The theory and empirics of the NKPC

The New Keynesian policy model became the workhorse of the monetary policy analysis and the NKPC is currently the most influential structural model of the inflation dynamics. The NKPC is based on models of staggered price (or wage) setting by forward-looking monopolistic firms (Taylor, 1980, Calvo, 1983). Such firms set prices as a mark-up over their marginal costs subject to constrains that may temporally impede doing so. In particular, Calvo's (1983) model assumes that a firm faces in each period a given probability θ that it may not be able to reset the price. The aggregation across firms gives rise to dynamic inflation equation where current inflation rate depends on its expected value and the real marginal cost:

$$\pi_t = \beta E[\pi_t] + \lambda mc_t \tag{1}$$

where $\lambda \equiv (1-\theta)(1-\beta\theta)/\theta$, θ represents the frequency of price adjustments and coefficient of expected inflation β is a subjective discount factor. Therefore, any increase in price rigidity θ makes inflation less sensitive to the real marginal cost mc_t. However, this forward-looking model did not allow explaining inflation persistence present in data of most developed countries (inflation tends to be more persistent than marginal cost). Therefore, a substantial effort was made to give inflation persistence some structural basis.[2] Although there are different ways to hardwire the intrinsic inflation persistence, most empirical studies stem from a model that allows that some firms are backward-looking (Galí and Gertler, 1999, GG hereafter and Galí, Gertler and López-Salido, 2001, GGL hereafter).[3] While forward-looking firms set prices optimally, i.e. with respect to the discounted value of the future marginal cost, the backward-looking firms follow simple rule of thumb:

$$p_t^b = p_{t-1}^* + \pi_{t-1} \tag{2}$$

This means that they set prices each period p_t^b with respect to prices in the previous period p_{t-1}^* and correct them for observed inflation. The price index can be written as $p_t^* = \omega p_t^b + (1-\omega)\, p_t^f$. Therefore, if the share of the forward-looking firms $(1-\omega)$ is large,

[2] Several recent studies such as Benati (2008) argue that inflation persistence found in the data is not structural as it significantly varies across monetary policy regimes. Cogley and Sbordone (2008) claim that inflation persistence arises due to variation in the long-run trend of inflation. Zhang et al. (2008) documents that forward-looking behavior is substantially weaker when the inflation rate is high.

[3] Futher and Moore (1995) propose contracting model where relative wages of successive cohorts of workers are linked. Christiano et al. (2005) introduce a price indexation to past inflation. All alternative models lead to a similar hybrid NKPC.

they dominate the price index p_t^* and the price set by backward-looking firms is close to the forward-looking price. The inflation equation with both kinds of firms is the hybrid NKPC:

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E\left[\pi_{t+1}\right] + \lambda mc_t \tag{3}$$

The coefficients depend again on the parameters from the underlying structural model; $\lambda \equiv (1-\omega)(1-\theta)(1-\beta\theta)/\left\{\theta + \omega\left[1-\theta(1-\omega)\right]\right\}$, $\gamma_f = \beta\theta/\left\{\theta + \omega\left[1-\theta(1-\omega)\right]\right\}$ and $\gamma_b = \omega/\left\{\theta + \omega\left[1-\theta(1-\omega)\right]\right\}$. While older studies on the hybrid NKPC such as Fuhrer and Moore (1995) kept using the output gap as the main driving variable, GG suggested to use the real marginal cost, in particular the labor income share.[4] GG and GGL confirm for the US and the Euro area that marginal cost is significant and the forward-looking behavior predominant. They relate inflation persistence to the marginal cost inertia. In particular, the real unit labor cost is inertial because of the wage rigidity.

There are numerous econometric issue related to the estimation of the NKPC. (i) First issue concerns the measure of expected inflation. Most empirical studies in line with GG (and consistently with rational expectations) proxy the expected values of inflation by realized future inflation data and address the endogeneity by means of the GMM estimator. A few recent studies (Henzel and Wollmershäuser, 2008, Zhang et al., 2008, 2009) do not impose rational expectations and use directly the inflation survey data. This focus that allows testing whether the expectations are really formed rationally questions the dominance of the forward-looking term. (ii) The suitability of the GMM framework is subject of major criticism. Bårdsen et al. (2004, 2005) demonstrate that the significance of the marginal cost depends on specific choices in the GMM estimation and is not robust. The sensitivity to instruments can be an indication that some of them should be directly used as regressors (Rudd and Whelan, 2005, 2007). Mavroeidis (2004, 2005) criticizes the GMM approach on grounds of weak identification that can also induce a bias in favor of the forward-looking specification. Lindé (2005) advocates system estimation by Full Information Maximum Likelihood (FIML) as it provides more efficient parameter than limited information methods such as GMM. Rudd and Whelan (2005) claim that GG´s results are inconsistent as the reduced-form estimates are substantially different from the reduced-form parameters derived from the structural estimates, which is rebutted by Galí et al. (2005). (iii) Other issues are related to the suitability

[4] The advantage of the real marginal cost over cyclical measures of the real economic activity is that it includes impact of both productivity and wages on inflation. Moreover, statistical filters derive the potential output as a smooth trend whereas it may be in reality rather humpy as it is affected by shocks (e.g. technology shocks).

of the empirical model so as to reveal the parameters of interest. Del Negro and Schorfheide (2008) insist that the degree of backward-lookiness cannot be identified in the estimated NKPC if the mark-up shocks (the random disturbance to the NKPC) are serially correlated. Mavroeidis (2005) relates the identification issue to possible endogeneity of the marginal cost. If the forcing variable is endogenous, a relation describing its dynamics must be specified. Fuhrer (2006) claims that even when the estimated coefficient of the marginal cost is significant, it is typically too small to explain the persistence present in inflation data. He argues that it is the intrinsic persistence (from the disturbances of the estimated NKPC) what explains most of the persistence of inflation. (iv) A few recent studies consider the effects of changes in economic system and monetary policy on inflation dynamics. Hondroyiannis et al. (2007, 2008) shows (with the US and the EU data) that once the NKPC parameters are allowed to vary, the lagged inflation term turns insignificant and inflation is a purely forward-looking phenomenon. Similar findings are reported by Cogley and Sbordone (2008) claiming that inflation persistence was detected in the data because of omission of the drift in inflation trend. Zhang et al. (2008, 2009) and Benati (2008) support the claim that parameters of the NKPC can vary across policy regimes and inflation persistence is in fact not structural.

Most empirical studies on the NKPC aim at the US or other major economies. However, since the NKPC was proposed as a general theory of inflation dynamics, it is of interest to test if it is supported by the data of other countries. This poses additional problem given that many economies are small and open. Therefore, firms can choose between domestic and foreign intermediate inputs, which effects the marginal cost. Besides, there are additional channels having a direct impact on inflation, which need not even be related to price setting and expectations formations. The import prices of intermediate and final products or the exchange rate volatility and its pass-through to domestic prices are some of the factors having an unquestionable effect on domestic inflation. Galí and Monacelli (2005) derive version of the NKPC for CPI inflation of small open economies, which includes the terms of trade as an additional forcing variable (besides the marginal cost).[5] Mihailov et al. (2009) find some evidence that the terms of trade really effect inflation of small open economies. Batini et al. (2005) propose an open economy NKPC where the marginal cost is affected by import prices and external competition. They present affirmative empirical evidence with the UK data for their model. Rumler (2007) extends the marginal cost by costs of intermediate inputs (both

[5] Their model assumes a complete exchange-rate pass through (ERPT) and producer's currency pricing whereas most empirical studies find that the ERPT is incomplete (e.g. Gagnon and Ihrig, 2004), which is consistent with consumer currency pricing.

domestic and imported). He finds that such model has better fit for EU countries. He claims that the presence of imported inputs (with more volatile prices than the domestic ones) presses upon the domestic firms to adjust their prices more frequently. Other empirical studies question the validity of the NKPC for open economies, e.g. Balakrishnan and Lopez-Salido (2002) for the UK, Sondergart (2003) for Germany, France and Spain, Dufour et al. (2006) for Canada or Genberg and Pauwels (2005) for Hong-Kong.

The research aimed at inflation dynamics in the NMS is very scant. Some papers study inflation persistence using disaggregated or micro data (e.g. Babetski et al., 2007, Konieczny and Skrzypac, 2005). Stavrev (2009) uses generalized dynamic facto model to decompose inflation in the 10 NMS into common and country-specific components. Vašíček (2009) estimates a simplified open economy PC for the 12 NMS finding difference in conditional inflation variance according to monetary and exchange rate regimes.

Studies that directly test the NKPC for the NMS find mostly negative results (e.g. Masso and Staehr, 2005, Debusinskas and Kulikov, 2007 for the Baltic countries). Arlt et al. (2005) rejects the validity of the NKPC for the Czech Republic using cointegration methods. Ledvai (2005) claims that the hybrid NKPC (augmented by imported goods) gives a reasonable account of the Hungarian inflation dynamics. However, convincing evidence of the significance of the marginal cost is not provided. Franta et al. (2007) analyze the importance of inflation persistence in the NMS by means of parametric statistical measures (AR model with constant and time varying mean, ARFIMA) and structural measures (the hybrid NKPC). They find that the NKPC does not adjust to data of any country (CZE, POL, SVK) and that the inflation in the NMS is more persistent than in the countries of the Euro area. Hondroyiannis et al. (2008) use panel data of the seven NMS claiming that once the NKPC is estimated by means of time-varying model, inflation turns to be a purely forward-looking phenomenon. However, his study builds upon problematic assumption of coefficient homogeneity across dissimilar countries whereas the sample poolability is not tested.

Previous studies for the NMS use data starting in mid-nineties, when the price liberalization that was still under way, which had arguably more substantial effects on inflation dynamics than optimizing behavior of monopolistic firms. Moreover, the NKPC is an equilibrium relation departing from model log-linearized at zero inflation steady state. Not only that the steady state inflation were positive but important changes in policy framework lead to varying steady state inflations. These issues became subject to research interest (with application to the US data) only very recently. Cogley and Sbordone (2005) derive the NKPC

with positive steady state inflation. Zhang et al. (2008) documents that the NKPC is not structurally stable across regimes with substantially different inflation levels. Benati (2008) and Cogley and Sbordone (2008) claim that estimation of the NKPC across different policy regimes and across periods with varying inflation trend leads to overestimation of the backward-looking component. Consequently, we strongly believe that it is reasonable to center the analysis only on the post-transitional period with settled monetary policy regimes and inflation rate at one digit level.[6]

3. Econometric approach

We use the hybrid version of the NKPC as developed in GG and GGL as a benchmark. However, we extend the empirical framework to reveal some additional evidence on the nature of inflation dynamics in the NMS. To this end, we employ alternative model specifications, variables, its measures and auxiliary diagnostic tests. We aim at single-equation estimation of different versions of the NKPC in closed form for each analyzed country. There are several reasons why the estimation of the underling structural parameters is not very reasonable in our case. (i) The structural model requires estimation of several additional parameters, which is unfeasible with available data sample. (ii) The estimates of structural parameters are sensitive to normalization of the orthogonality conditions (GG, GGL). (iii) Some of the parameters cannot be directly estimated and must be calibrated by plausible values coming from other studies, which are not available for the NMS. (iv) GGL (2005) show that estimation of overall slope parameters in the reduced form is equivalent to their calculation from the estimated structural parameters. (v) Since our empirical specification is augmented by additional (potentially) inflation-driving variables, the structural relations do not hold anymore and there no is simple procedure mapping the overall slope coefficients with structural parameters of the benchmark NKPC.

We use the marginal cost-based NKPC developed by GG, GGL as a benchmark:

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E\left[\pi_{t+1}\right] + \lambda mc_t + \varepsilon_t \tag{4}$$

[6] Although the inflation target that can be considered a proxy of steady state inflation was steadily decreasing even during the last decade, it was well announced to the public and it is reasonable to assume that the inflation expectations adjusted accordingly. Similarly, even though inflation rates have decreasing trend over the sample, for sake of comparability with previous studies and consistency with the original model we use raw data rather than implementing ad-hoc measures such as inflation detrending. The data span clearly does not allow using of time-varying model. However, given that the NKPC is a structural model, its parameters should be structurally stable at least with the same policy regime (see footnote 9.).

both with the backward- and forward-looking term and ε_t represent the residual. Note that the residual ε_t can be autocorrelated for different reasons: (i) inflation shocks (e.g. cost-push shocks) are autocorrelated, (ii) the prediction error η_{t+1} and the random disturbance ζ_t that form the error term $\varepsilon_t = \zeta_t - \gamma_t \eta_{t+1}$ are correlated and ε_t is autocorrelated (up to first order) by construction (Mavroeidis, 2005), (iii) there are omitted variables (e.g. various external variables for small open economies). The marginal cost enters the empirical model in deviation from its steady state. We use the sample mean and the HP trend for its approximation. However, given uncertainty about the true value of steady state and the noise that can be introduced by demeaning or detrending, we use also the original series of the marginal cost.[7]

A known shortcoming of the GMM estimator is its sensitivity to instruments. In case of the NKPC, Rudd and Whelan (2005, 2007) show that if the instrument set includes inflation-driving variables that are not included as regressors, the estimate of the forward-looking term is upwardly biased. Therefore, we test for alternative domestic forcing variable that GG suggested only as instruments:

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E\left[\pi_{t+1}\right] + \lambda_{in} in_t + \varepsilon_t \tag{5}$$

where in_t stands for the output gap and the nominal wage inflation. Note that the instruments are in all empirical studies selected in rather ad-hoc way given that the theory is not clear about them.

We have suggested that inflation dynamics of small open economies can be affected by external variables unrelated to price setting of domestic firms.[8] Therefore, instead of modifying the domestic variables (e.g. adjusting marginal cost for imported inputs), we test the effect of variables that can directly affect the inflation dynamics of small open economies:

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E\left[\pi_{t+1}\right] + \lambda mc_t + \lambda_{in} in_t + \lambda_{ex} ex_t + \varepsilon_t \tag{6}$$

[7] Consistently with GG, we proxy the real marginal cost by the unit labor cost. It is rather puzzling how to estimate the steady state level since we have rather short data spam (10 years vs. 30 years in GG). Therefore, neither deviation from the sample mean nor from the HP trend has to provide a reasonable approximation. Given this uncertaintly, we use also the original series in the marginal cost (the log of unit labor cost).

[8] This claim seems especially plausible for CPI inflation. Although the producer price inflation or value added inflation (proxied typically by the GDP deflator) is the appropriate measure of inflation per GG model, economic agents and monetary authorities unquestionably perceive rather CPI inflation. CPI inflation is especially relevant in small open economies, which import substantial part of its consumption basket.

where ex_t stands for the oil prices, the import prices, the foreign inflation rate and the exchange rate.[9] The previous relationship links together the inflation equation used in VAR studies on exchange-rate pass-through (e.g. Gagnon and Ihrig, 2004) with empirical studies on the NKPC. The former literature includes routinely foreign variables (as determinants of domestic inflation rate) but ignores entirely the role of inflation expectation. On the other hand, the latter studies usually do not contemplate the possibility that external variable have feedback in domestic inflation that is entirely unrelated to domestic price setting. Given the limited sample size and the fact that the external variables can be correlated, we include them one by one. All estimations are performed by means of Generalized Method of Moments (GMM).[10] In closed economy specification we use similar instruments as GGL (2005): two lags of the inflation rate, the marginal cost, the output gap, the nominal wage inflation and the (log) the unemployment rate.[11] The external variables are treated as endogenous and two lags of each one are added as instruments. The use of the GMM estimator controls for potential reversed causality from inflation rate to explicative variables (e.g. the exchange rate).

A traditional check of the model validity in the context of GMM is Sargan-Hansen J-test of over-identifying restrictions. We report its p-values together with the adjusted R^2 and p-value of Ljung-Box Q-test for the first-order residual autocorrelation. However, the J-test test might not provide reliable results in model with rational expectations (Mavroeidis, 2004). The first problem is the ability of the test to detect misspecification when the number of instruments is very large. As we have pointed out, we use only two lags of the instrumental variables as to maintain the test power. Second issue is related to the identification. In particular, if the structural model has forward-looking solution, a model for the forcing variable must be specified (Mavroeidis, 2005). Such model can be used for testing the under-

[9] This seems to be empirically more reasonable than including the change in the terms of trade (Mihailov et al., 2009): (i) the terms of trade only reflect the changes in underlying factors such as the exchange rate or foreign prices, (ii) without introducing the factors explicitly, one cannot evaluate their differential effect, (iii) while the proposed relation links the inflation to expected change in the terms of trade relative to observed change in the terms of trade (de-facto second difference of the terms of trade), it does not contemplate possibility that inflation in economies such as the NMS (with very high degree of openness) has feedback from foreign sector entirely unrelated to agents' expectations (moreover, it does not seem plausible that agents form expectations about the change of the terms of trade), (iv) the terms of trade are endogenously effected by domestic inflation level.

[10] We use Newey-West (1994) heteroscedasticity and autocorrelation (HAC) consistent covariance matrix estimator. The correlation in moment conditions is soaked up by means of previous VAR(1) estimation for IV (pre-whitening). The Bartlett kernel is used to weight the covariances with Newey-West fixed bandwidth. For the sake of comparability with previous studies, all the results were obtained by means of common N-step (iterative) GMM estimator. However, the main findings hold also with continuously updated GMM estimator (CUE) that is superior in small samples.

[11] Additional lags of instrumental variables used in GG can both bias the results in small sample and weaken the Sargar-Hansen overidentification test.

identification in the structural model (the NKPC). Accordingly, we estimate an auxiliary regression that links each of the domestic forcing variables (the marginal cost, the output gap and the wage inflation) to their lagged values and to lagged value of inflation:

$$in_t = \sum_{i=1}^{p} \rho_i in_{t-i} + \sum_{j=1}^{q} \varphi_j \pi_{t-j} \tag{7}$$

where $p = q = 4$ and the under-identification can not be rejected when $\rho_i = \varphi_j = 0$ for all $i>1$ and all $j>2$.[12]

Another problem inherent to country-level analysis is the limited size of the sample. Therefore, besides single-equation estimation, we employ panel analysis. The use of panel techniques has become popular in macroeconomics, although it is not free of critics. Given the importance of idiosyncrasies of each country, one has to be very cautious when assuming that a country represents a single cross-sectional unit. Although the idiosyncrasies can be accounted for by country fixed effects, an incorrect assumption on the coefficients homogeneity can induce a bias. The reduces-form coefficient can be different if the underling structural equations differ country by country. For example, the pricing behavior of firms can vary across countries, in particular the degree of "the backward-lookiness" and the frequency of the price setting are related to institutional features of national labor markets.[13] On the other hand, the single-equation estimates may be subject to small sample bias and the panel analysis can be a viable alternative. We specify the panel NKPC as:

$$\pi_{i,t} = \gamma_b \pi_{i,t-1} + \gamma_f E\left[\pi_{i,t+1}\right] + \lambda mc_{i,t} + \lambda_{in} in_{i,t} + \lambda_{ex} ex_{i,t} + \varepsilon_{i,t} \tag{8}$$

where the sub-index i stands for each cross section. We use the GMM estimator with cross-section SUR corrections of standard errors and covariances. The instruments are again two lags of all variables in the regression. As for the robustness check, we employ different versions of panel estimators for dynamic panels (Arellano and Bond, Arellano and Bover, 1995).[14]

[12] See Theorem 3.1 in Mavroeidis (2005).

[13] Imbs et al. (2007) provide evidence that when the heterogeneity is not taken into account, in particular the heterogeneity of pricing in different sectors, the (aggregate) NKPC estimates are biased in favor of the backward-looking term.

[14] Note that the first version of GMM panel estimator does not control for country specific characteristics (cross-section fixed effects are not used) but the results are better comparable to country-level estimations given that: (i) the empirical NKPC (used in country-level analysis) is specified without a constant term, (ii) panels with lagged dependent variable and fixed effects require specific estimators that transform the estimated equation (by first differences or orthogonal deviations), while the country-level analysis relies on estimation in levels.

4. Data and time series analysis

4.1 Data description

Our dataset consists of quarterly data ranging from 1998/1.Q until 2007/3.Q but some series are slightly shorter. We note that this period is posterior to major transitional reforms when the monetary policy acted in a very discretional way and diverse administrative measures such as price liberalizations effected the inflation rates. The principal source of the data is OECD (Main Economic Indicators) and Eurostat. Some series were obtained from additional sources. The details on the data are provided in Appendix.

4.2 Unit root testing

Many empirical studies on the NKPC either do not address the properties of the time series used or simply assume their stationarity. However, nonstationarity can be pronounced in macroeconomic series of emerging economies, we remit all the variables to throughout unity root analysis. Both single-equation and panel unit root tests point to stationarity of all variables except the inflation rate, the wage inflation and the (log of) marginal cost. The result for these variables depends on the test used and on the assumption about the deterministic components.[15] Of particular interest is to compare the degree of persistence of the inflation and the marginal cost. We find that the marginal cost is more persistent than inflation (just the opposite finding than for developed countries). Consequently, we test the cointegration between these two variables because its long-term comovement is the main precondition for the reasonability of the NKPC.[16] We apply common Augmented Engle-Granger (AEG) test (Engle and Granger, 1987) consisting in estimation of an auxiliary regression with the I(1) variables (by OLS) and testing the stationarity of the error term by means of ADF test (with specific critical values). If the residuals are stationary, it means that either both variables are I(0) or that they are both I(1) and cointegrated. The ADF statistic is reported in Table 1 below

[15] Many macroeconomic series from transitional countries can be subject to structural breaks. Consequently, traditional unit root test can have low power and unit root test allowing for structural breaks should be used instead. Unfortunately, the power of these tests (e.g. Lanne et al., 2002) can be also distorted in small samples. Given limited sample size, it does not seem reasonable to apply test with structural break. In any case, our time series cover de-facto post-transitional period when no major event occurred that could drive any structural break in the data. Babetskii et al. (2007) find for the Czech Republic that structural breaks in time series of sectoral inflation rates occurred mostly around 1998-99. Franta et al. (2007) document that inflation persistence in the NMS changes as a consequence of changes in monetary policy. The implementation of inflation targeting in the Czech Republic (1997), Poland (1998) and Hungary (2001) is the principal event.

[16] GGL show for several OECD countries that GDP inflation and the (log) unit labor cost closely co-moves in the long-term (See GGL, Fig.3).

(the 5% critical value is -3.34). The test rejects the cointegration of the yearly inflation rate and the (log) marginal cost for the Czech Republic and Poland.

Table 1: Results of AEG cointegration test between HCPI inflation rate and marginal cost

	CZE	HUN	POL	SVK
π (yearly)	-2.90	-4.06	-2.79	-3.38
π (quarterly)	-5.84	-4.52	-4.04	-6.02

4.3 Identification in forward-looking model

We have resumed that the traditional tests of identification in the GMM estimation framework turn unreliable in the context of forward-looking model with rational expectations. Therefore, to test ex-ante the reliability of the GMM estimates we use simple test proposed in Mavroeidis (2004). Table 2 provides the results of the F-test for the joint coefficient restriction that $\rho_i = \varphi_j = 0$ for all $i>1$ and all $j>2$ in equation (7). The rejection of this restriction is a necessary condition for the identification. We report the test using year-on-year HCPI inflation rates and quarter-on-quarter inflation rates from both HCPI and GDP deflator against the main domestic forcing variables (the marginal cost, the output gap, the wage inflation).[17]

The results confirm that under the model for the forcing variable (7) the second measure of the real marginal cost (the ratio of nominal total compensation to employees to the nominal GDP) meets the necessary condition for identification in all countries, no matter what measure of inflation is used. The reported results are for the untransformed series of the (log) marginal cost. The results using its deviation from the sample mean and the HP trend are very similar. As for the output gap series, the gap derived by the HP filter is preferable to OECD gap in all countries but Slovakia (the OECD gap for Slovakia is only available from 2001). Finally, both measures of wage inflation have problems to meet the necessary condition for identification.

[17] All our empirical results are driven upon the (year-on-year) HCPI inflation. We test also the quarter-on-quarter inflation rates from HCPI inflation and GDP deflator so as to see that our measure of inflation does not affect the test results.

Table 2: F-test of the necessary condition for identification in the forward-looking model (p–values)

	CZE			HUN			POL			SVK			Panel		
	t/t-1	t/t-1*	t/t-4	t/t-1	t/t-1*	t/t-4	t/t-1	t/t-1*	t/t-4	t/t-1	t/t-1*	t/t-4	t/t-1	t/t-1*	t/t-4
RULC1	0.00	0.03	0.01	0.01	0.02	0.01	0.00	0.00	**0.20**	**0.50**	0.17	**0.45**	0.00	0.00	0.00
RULC2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WAGE1	**0.20**	**0.67**	0.04	**0.07**	0.00	**0.44**	**0.10**	0.03	**0.11**	0.00	0.00	0.12	0.00	0.00	0.00
WAGE2	**0.08**	0.00	0.00	0.00	0.00	**0.19**	**0.19**	0.00	**0.19**	0.00	0.00	0.00	0.00	0.00	0.00
GAP1	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.20	**0.07**	**0.11**	**0.19**	0.00	0.00	0.00	0.00
GAP2	0.00	0.00	0.00	**0.23**	0.03	**0.30**	**0.05**	**0.79**	**0.12**	0.00	0.00	0.00	0.00	0.00	0.00

Note: t/t-1 – quarterly inflation rate (HCPI), t/t-1* – quarterly inflation rate (GDP deflator), t/t-4 – yearly inflation rate (HCPI), RULC1 – the (log) unit labor cost index deflated by HCPI (OECD), RULC2 - the ratio of the nominal total compensation to employees and the nominal GDP (Eurostat), WAGE1 - the ratio of (nominal) total labor cost and the real output (OECD), WAGE2 - the labor cost index (the total labor costs, main components wages and salaries and non-wage costs (Eurostat), GAP1 – GDP gap by HP filter (OECD), GAP2 – GDP gap by production function (OECD)

4.4 Cross correlations

Another important issue is the temporal effect of the variables. While traditional PC assumes that the output gap (or other cyclical measure) leads inflation, the opposite pattern is consistent with the NKPC (see eq. 8 in GG).

The dynamic cross correlations of the (log) real unit labor cost and the output gap with the HCPI inflation rates are reported in Table 3.[18] The negative correlation for lagged values of inflation and positive for leading values implies that the variable leads inflation. This pattern, found for the output gap for the Czech Republic and less significantly for Slovakia, is consistent with the traditional PC but not the NKPC. On the other hand, the output gap has very strong contemporaneous correlation with inflation in Poland, consistently with the NKPC. Finally, for Hungary the correlations of the output gap with both lags and leads of inflation are negative. As for the real unit labor cost, it is very strongly contemporaneously correlated with inflation in Poland, consistently with the findings of GG with the US data. For all the other countries, both lags and leads of inflation are negatively correlated with inflation. To save the space, we again do not report the results using the deviation of the marginal cost from its mean or trend. The marginal cost deviation from its mean turns highly contemporaneously correlated with inflation for Hungary and Slovakia and the marginal cost deviation from the HP mean is negatively correlated with inflation for all countries.

[18] We test only the second measure of the real marginal cost (RULC2) and the HP output gap (GAP1) because they performed better in the identification test and are used for the empirical estimation of the NKPC. The results for quarterly inflation rates are rather similar.

Table 3: Dynamic cross-correlations of the (log) real unit labor cost (RULC2) and the output gap (GAP1) with lags and leads of yearly HCPI inflation

	CZE				HUN				POL				SVK				Panel			
	RULC2		GAP1		RULC2		GAP1		RULC2		GAP1		RULC2		GAP1		RULC2		GAP1	
	lag	lead	lag	lead	lag	lead	lag	lead	lag	lead	lag	lead	lag	lead	lag	lead	lag	lead	lag	lead
0	-0.45	-0.45	0.05	0.05	-0.56	-0.56	-0.19	-0.19	0.70	0.70	0.62	0.62	-0.15	-0.15	-0.30	-0.30	-0.02	-0.02	0.08	0.08
1	-0.54	-0.37	-0.06	0.15	-0.58	-0.54	-0.27	-0.15	0.73	0.59	0.47	0.68	0.00	-0.25	-0.33	-0.17	0.02	-0.03	0.04	0.15
2	-0.56	-0.29	-0.16	0.20	-0.62	-0.52	-0.32	-0.14	0.76	0.51	0.31	0.65	-0.01	-0.33	-0.38	-0.02	0.02	-0.03	-0.01	0.20
3	-0.51	-0.22	-0.21	0.19	-0.68	-0.46	-0.28	-0.13	0.77	0.44	0.18	0.56	-0.01	-0.33	-0.37	0.12	0.00	-0.00	-0.04	0.23
4	-0.42	-0.19	-0.21	0.13	-0.75	-0.39	-0.18	-0.11	0.74	0.38	0.18	0.45	0.03	-0.41	-0.38	0.32	-0.02	0.06	-0.06	0.26
5	-0.33	-0.16	-0.17	0.05	-0.74	-0.31	-0.05	-0.10	0.69	0.34	0.18	0.35	0.06	-0.45	-0.38	0.49	-0.04	0.06	-0.08	0.27

Note: see Note of Table 2

These preliminary findings indicate caution in using the marginal cost. The only country where alternative measures of the marginal cost are contemporaneously correlated with inflation is Poland. On the other hand, the output gap pattern in the Czech Republic points to the traditional PC.

5. Empirical results

5.1 Individual country analysis

By virtue of comparability, we use the same specifications and instruments for all four countries. Some country-specific choices, especially with respect to the measures of the variables, are noted below.

5.1.1 Czech Republic

The estimates of the marginal-cost based hybrid NKPC provide rather mixed evidence. The mean-deviation and trend-deviation of the marginal cost are each statistically significant but hold a “wrong” negative sign. On the contrary, the untransformed marginal cost (the log of the real unit labor cost) is significant and positive (though we cannot interpret its coefficient size given that this variable is not consistent with the underlying theory). However, we note that this correlation can be spurious as the cointegration test and dynamic cross-correlations indicated. The fit of the model substantially decreases if we in the spirit of the pure forward-looking NKPC exclude the inflation lag (4. line of Table 4). The Ljung-Box test shows that serial correlation is present in several specifications, though as we noted before, it does not automatically disqualify the result. When we alternatively use the output gap, its coefficient is significant and positive and the serial correlation disappears. Additional lags of

inflation in the spirit of the traditional PC do not seem to provide any information and the overall fit remains the same.[19] More interestingly, the additional inflation lags do not affect the size and the significance of the forward-looking term. The coefficient of wage inflation is also significant. The fit of the model is similar for all domestic forcing variables.

The middle panel shows the results of using actual inflation expectation by the financial market instead of implicitly assuming rational expectations (and using realized value of inflation together with the GMM estimator). In this case, endogeneity should not arise and the OLS shall provide consistent estimates. The main feature of the hybrid model is that the sum of the inflation coefficients is significantly above unity and the fit of the model is substantially lower. The GMM estimates used for a robustness have different magnitude but retain their significance. This means that the endogeneity is still an issue even when inflation expectations are used (e.g. due to prevision error). The Figure A.2 demonstrates what lies behind the previous result; the realized inflation in fact significantly deviates from the expectations by financial market's participants. Certainly, this issue should be studied more carefully.

The lower panel reports the results of the hybrid NKPC when we retain the (log) marginal cost and the output gap (two variables that performed best in the close economy model) and stepwise add the external variables. As the former two variables are not significantly correlated in any country, the multicollinearity does not arise. Here we find something very interesting. The coefficients of all external variables are significant and have the expected sign.[20] The oil prices have positive (but limited) effect on yearly inflation and the same applies to import prices. The effect of the inflation in the Euro area seems to be especially relevant. Finally, the currency depreciation (decrease of NEER) leads to an increase of CPI inflation (the size of the coefficient point to very incomplete exchange rate pass-through). The residual autocorrelation does not appear in three of four specifications, which can be an indication that these variables were previously incorrectly omitted. While the output gap is significant and correctly signed in three cases, the real marginal cost is only in one. The effect of forward-looking term is generally reduced.

[19] The reported estimate of the backward-looking term is the sum of the estimates of four lagged values of inflation. The reported standard error is a simple mean of the four estimated standard errors.
[20] Note that the external variables are included in rather ad-hoc way, therefore we cannot simply interpret the size of their coefficients.

Table 4: GMM estimates of different versions of closed economy hybrid PC (upper panel) and the specification augmented by external variables (lower panel) for the yearly HCPI inflation rate – the Czech Republic

Forcing variable	γ_b (π_{t-1})	γ_f (π_{t+1})	λ ($rulc_t$)	λ_{in} (y_{t-1}, w_t*)	λ_{ex} (x_{t-1}, x_t*)	R^2	LB	J-stat
RULC (dev. mean)	**0.43**	**0.55**	**-0.07**			0.90	0.09	0.35
	(0.02)	(0.03)	(0.02)					
RULC (dev. HP trend)	**0.43**	**0.54**	**-0.08**			0.90	0.08	0.26
	(0.02)	(0.03)	(0.02)					
RULC	**0.42**	**0.61**	**0.21**			0.90	0.07	0.33
	(0.02)	(0.03)	(0.07)					
RULC		**0.98**	0.14			0.58	0.00	0.78
		(0.10)	(0.36)					
GAP	**0.56**	**0.37**		**0.23**		0.89	0.19	0.43
	(0.05)	(0.03)		(0.04)				
GAP (4 lags of infl.)	**0.59**	**0.46**		**-0.17**		0.79	0.21	0.20
	(0.08)	(0.03)		(0.03)				
WAGE	**0.43**	**0.47**		**0.05***		0.88	0.66	0.33
	(0.02)	(0.04)		(0.01)				
RULC + infl.exp.(OLS)		**1.25**	**2.37**			0.42	0.00	
		(0.26)	(1.07)					
RULC + infl.exp. (GMM)		**1.90**	**4.75**			0.44	0.00	0.94
		(0.28)	(1.20)					
RULC + infl.exp.(OLS)	**0.70**	**0.57**	1.42			0.73	0.07	
	(0.11)	(0.21)	(0.74)					
RULC + infl.exp. (GMM)	**0.53**	**0.99**	**2.70**			0.76	0.05	0.68
	(0.08)	(0.18)	(0.71)					
RULC + GAP	**0.52**	**0.41**	-0.19	**0.39**		0.90	0.06	0.31
	(0.02)	(0.06)	(0.14)	(0.10)				
RULC + GAP + OIL	**0.69**	0.21	0.23	**0.52**	**0.01***	0.85	0.62	0.68
	(0.08)	(0.14)	(0.16)	(0.20)	(0.00)			
RULC + GAP + IMP2	**0.75**	0.10	-0.80	**0.59**	**0.18***	0.72	0.04	0.72
	(0.12)	(0.22)	(0.53)	(0.28)	(0.07)			
RULC + GAP + π_{EMU}	**0.55**	**0.36**	**1.66**	**-0.14**	**0.80***	0.89	0.58	0.57
	(0.04)	(0.06)	(0.39)	(0.06)	(0.16)			
RULC + GAP + NEER	**0.51**	**0.24**	**-1.36**	**0.35**	**-0.12**	0.88	0.99	0.49
	(0.04)	(0.12)	(0.42)	(0.12)	(0.03)			

Note: Standard errors in parenthesis. Coefficients statistically significant at 5% in bold. Yearly change of HCPI is always the dependent variable. In the first column, there are the forcing variables in each specification. Domestic forcing variables: RULC – log of the ratio of the nominal total compensation to employees and the nominal GDP (Eurostat), GAP (y_{t-1}) - GDP gap by HP filter (OECD), WAGE (w_t) – yearly change of the labor cost index (Eurostat). Foreign forcing variables (x_t): OIL – yearly change of crude oil price, IMP – yearly change of import price index, π_{EMU} – yearly change of HCPI in the Euro area, NEER – yearly change of nominal effective exchange rate. LB is p-value of Ljung-Box test for 1. order serial correlation. J-stat is p-value of Sargan-Hansen overidentification test.

These results indicate that the marginal cost based NKPC might not be suitable to describe the Czech inflation dynamics and that the output gap could be a better proxy of domestic inflation pressures. The Czech inflation seems to be also determined by external factors and it is quite persistent. The results using quarterly inflation rates (not reported here but available upon request) are very similar with the exception that no domestic forcing variables turns significant.

5.1.2 Hungary

The marginal cost measures are not significant for Hungary. The coefficient of the output gap is significant and negative. The additional inflation lags not significant and do not affect the size and significance of the forward-looking term. The wage inflation does have significant impact either.

Table 5: GMM estimates of different versions of closed economy hybrid PC (upper panel) and the specification augmented by external variables (lower panel) for the yearly HCPI inflation rate – Hungary

Forcing variable	γ_b (π_{t-1})	γ_f (π_{t+1})	λ ($rulc_t$)	λ_{in} (y_{t-1}, w_t*)	λ_{ex} (x_{t-1}, x_t*)	R^2	LB	J-stat
RULC (dev. mean)	**0.60**	**0.40**	0.02			0.98	0.76	0.39
	(0.06)	(0.08)	(0.03)					
RULC (dev. HP trend)	**0.63**	**0.37**	-0.09			0.98	0.54	0.46
	(0.06)	(0.06)	(0.07)					
RULC	**0.59**	**0.43**	0.28			0.98	0.93	0.44
	(0.04)	(0.06)	(0.14)					
RULC		**0.99**	-0.20			0.92	0.00	0.81
		(0.06)	(0.70)					
GAP	**0.53**	**0.47**		**-0.50**		0.98	0.47	0.58
	(0.04)	(0.04)		(0.17)				
GAP (4 lags of infl.)	**0.59**	**0.41**		**-0.17**		0.97	0.01	0.64
	(0.08)	(0.02)		(0.08)				
WAGE	**0.62**	**0.42**		-0.03*		0.98	0.85	0.42
	(0.04)	(0.04)		(0.02)				
RULC + GAP	**0.46**	**0.58**	0.26	0.22		0.98	0.65	0.41
	(0.04)	(0.05)	(0.14)	(0.13)				
RULC + GAP + OIL	**0.54**	**0.50**	**0.58**	-0.37	**0.01***	0.95	0.40	0.59
	(0.04)	(0.05)	(0.18)	(0.18)	(0.00)			
RULC + GAP + IMP2	**0.39**	**0.83**	**1.62**	**0.70**	**-0.09***	0.98	0.42	0.65
	(0.04)	(0.06)	(0.22)	(0.19)	(0.01)			
RULC + GAP + π_{EMU}	**0.55**	**0.49**	**1.74**	-0.27	**0.44***	0.98	0.93	0.63
	(0.06)	(0.08)	(0.53)	(0.15)	(0.14)			
RULC + GAP + NEER	**0.46**	**0.54**	-0.06	0.06	-0.03	0.98	0.99	0.59
	(0.04)	(0.07)	(0.41)	(0.24)	(0.03)			

Note: see Table 4

The lower panel of the Table 5 reports estimates of the NKPC with the external variables. The oil prices as well as inflation in the Euro area have positive and significant impact on the Hungarian inflation. The coefficient of import prices is contra-intuitively found significant and negative. This can be related to some specification problem because the sum of the backward and forward inflation coefficients is significantly above unity. The exchange rate does not have significant impact. Although the (log) real unit labor cost is statistically significant in three open economy specifications, we shall recall that the cross correlations with inflation rates were in fact negative. Unlike in the former country, the relative size of backward- vs. forward-looking term is not affected when the external variables augment the model. We can again conclude that the inflation in Hungary has a significant forward-looking

component but it is also quite persistent and driven rather by external than domestic factors. The results using quarterly inflation rates confirms as in the Czech case the predominance of foreign inflation factors while neither the marginal cost nor the output gap is significant.

5.1.3 Poland

Poland is the only country in the sample where both the real unit labor cost (untransformed series in logs and the deviation from the mean) and the output gap are strongly correlated with both lags and leads of inflation. However, the AEG test pointed to the possibility that the correlation between the inflation rate and the (log) marginal cost may be spurious.

The estimation results for Poland are reported in Table 6. The estimates of the hybrid model resemble the findings for large closed economies such as the US. That is, the marginal cost is significant (both in the logs and in perceptual deviation from the sample mean), the forward-looking term is dominant and the serial correlation can be rejected at 5% significance level. The coefficient of the output gap is significant. The additional inflation lags again do not seem to carry any additional information nor the wage inflation. Although the fit of the model is very decent, the Ljung-Box test points to residual autocorrelation in all but one specification.

The middle panel shows the estimates with survey data on inflation expectations of the financial markets. The inflation expectations in Poland move very closely with the actual inflation rates pointing either to very good previsions realized by the financial markets or, more likely, to problematic construction of this variable. This feature is evident if we compare the series with the expectations in the Czech Republic that more logically show pattern of prevision error.[21] Strong correlation of inflation expectation with the actual inflation seems to drive the estimates provided in the middle panel. The coefficient of the forward-looking term is always significant but the coefficient of the marginal cost has “wrong” negative sign. The endogeneity seems to be again relevant issue since the OLS and GMM point estimates are slightly different.

[21] The time series for both countries are plotted together with the actual HCPI inflation in Figure A.2 in the Appendix. Note that the series of inflation expectations are moved forward and in each quarter we have the actual inflation realization together with the expected value (one year ago).

Table 6: GMM estimates of different versions of closed economy hybrid PC (upper panel) and the specification augmented by external variables (lower panel) for the yearly HCPI inflation rate – Poland

Forcing variable	γ_b (π_{t-1})	γ_f (π_{t+1})	λ ($rulc_t$)	λ_{in} (y_{t-1}, w_t*)	λ_{ex} (x_{t-1}, x_t*)	R^2	LB	J-stat
RULC (dev. mean)	**0.42**	**0.62**	**0.01**			0.98	0.17	0.70
	(0.03)	(0.03)	(0.01)					
RULC (dev. HP trend)	**0.46**	**0.55**	**-0.07**			0.97	0.02	0.40
	(0.02)	(0.02)	(0.02)					
RULC	**0.45**	**0.60**	**0.16**			0.98	0.08	0.70
	(0.02)	(0.02)	(0.05)					
RULC		**1.14**	0.11			0.91	0.00	0.77
		(0.04)	(0.22)					
GAP	**0.55**	**0.46**		**0.07**		0.98	0.03	0.68
	(0.03)	(0.03)		(0.02)				
GAP (4 lags of infl.)	**0.56**	**0.44**		**0.07**		0.97	0.00	0.54
	(0.05)	(0.02)		(0.02)				
WAGE	**0.47**	**0.61**		-0.02*		0.98	0.05	0.50
	(0.02)	(0.02)		(0.01)				
RULC + infl.exp.(OLS)		**0.89**	**-0.30**			0.97	0.74	
		(0.02)	(0.15)					
RULC + infl.exp. (GMM)		**0.92**	**-0.16**			0.97	0.66	0.80
		(0.01)	(0.07)					
RULC + infl.exp.(OLS)	-0.26	**1.13**	**-0.37**			0.98	0.82	
	(0.13)	(0.12)	(0.15)					
RULC + infl.exp. (GMM)	**-0.44**	**1.31**	**-0.47**			0.97	0.84	0.82
	(0.08)	(0.07)	(0.10)					
RULC + GAP	**0.50**	**0.54**	**0.15**	0.00		0.98	0.04	0.57
	(0.02)	(0.04)	(0.05)	(0.02)				
RULC + GAP + OIL	**0.44**	**0.68**	**0.42**	-0.05	0.00*	0.96	0.74	0.80
	(0.07)	(0.11)	(0.15)	(0.07)	(0.00)			
RULC + GAP + IMP2	**0.59**	**0.40**	0.05	**0.12**	**0.02***	0.98	0.05	0.65
	(0.03)	(0.04)	(0.06)	(0.03)	(0.00)			
RULC + GAP + π_{EMU}	**0.54**	**0.50**	**2.47**	0.13	**1.14***	0.98	0.65	0.83
	(0.06)	(0.07)	(0.40)	(0.07)	(0.17)			
RULC + GAP + NEER	**0.63**	**0.38**	-0.04	**0.15**	**-0.02**	0.98	0.18	0.69
	(0.04)	(0.05)	(0.12)	(0.06)	(0.00)			

Note: see Table 4

In the lower panel, we evaluate the effect of external variables on Polish inflation dynamics. While the oil prices do not have a significant impact, the coefficients of all the other external variables are significant and correctly signed. The effect of the foreign inflation is again the most substantial. The unreported results based on quarter-on-quarter inflation rate are similar to previous two countries. Neither marginal cost nor the output gap has statistically significant effect and all the foreign variables are significant with the expected sign.

The results on the close economy NKPC show that both the marginal cost and the output gap have positive impact on the Polish inflation rate The external variables seems to have significant impact either, even though Poland is rather middle-sized economy.

5.1.4 Slovakia

The series of HCPI inflation rate (both year-on-year and quarter-on-quarter) for Slovakia have different features as compared to the previous three countries. HCPI inflation is less similar to inflation from GDP deflator and it is more volatile and spiky (see Figure A.1). Possible explanations can be that the Slovak consumer prices are more affected by the changes in imported consumer goods as Slovakia has the highest share of import on the GDP.

The estimation results of the NKPC are reported in the Table 7. The three different transformation of the marginal cost series provide very different results. The deviation from the mean is insignificant, the deviation from the HP trend is significant and negative and the (log) marginal cost is significant and positive. The fit of the pure forward-looking model is again substantially lower. The output gap enters significantly with a negative sign similarly as in Hungary. Neither the additional inflation lags not the wage inflation seem to play any role.

Table 7: GMM estimates of different versions of closed economy hybrid PC (upper panel) and the specification augmented by external variables (lower panel) for the yearly HCPI inflation rate – Slovakia

Forcing variable	γ_b (π_{t-1})	γ_f (π_{t+1})	λ ($rulc_t$)	λ_{in} (y_{t-1}, w_t^*)	λ_{ex} (x_{t-1}, x_t^*)	R^2	**LB**	**J-stat**
RULC (dev. mean)	**0.55**	**0.46**	-0.01			0.85	0.01	0.53
	(0.03)	(0.03)	(0.01)					
RULC (dev. HP trend)	**0.48**	**0.52**	**-0.15**			0.85	0.00	0.73
	(0.02)	(0.03)	(0.06)					
RULC	**0.55**	**0.51**	**0.31**			0.85	0.00	0.61
	(0.02)	(0.03)	(0.15)					
RULC		**1.26**	0.72			0.45	0.15	0.90
		(0.08)	(0.55)					
GAP	**0.55**	**0.46**		**-0.09**		0.86	0.00	0.69
	(0.03)	(0.03)		(0.03)				
GAP (4 lags of infl.)	**0.40**	**0.63**		**-0.15**		0.84	0.00	0.65
	(0.70)	(0.04)		(0.02)				
WAGE	**0.49**	**0.59**		**-0.05***		0.85	0.00	0.81
	(0.02)	(0.04)		(0.01)				
RULC + GAP	**0.54**	**0.45**	-0.09	**-0.11**		0.84	0.01	0.57
	(0.03)	(0.03)	(0.17)	(0.04)				
RULC + GAP + OIL	**0.54**	**0.52**	0.35	-0.07	**0.01***	0.84	0.00	0.69
	(0.03)	(0.03)	(0.17)	(0.04)	(0.00)			
RULC + GAP + IMP2	**0.41**	**0.57**	0.02	-0.08	**0.06***	0.88	0.02	0.58
	(0.07)	(0.06)	(0.14)	(0.05)	(0.02)			
RULC + GAP + π_{EMU}	**0.59**	**0.43**	0.76	-0.05	**0.34***	0.84	0.02	0.65
	(0.03)	(0.03)	(0.45)	(0.05)	(0.13)			
RULC + GAP + NEER	**0.35**	**0.74**	0.17	-0.20	0.07	0.77	0.08	0.48
	(0.05)	(0.06)	(0.24)	(0.11)	(0.07)			

Note: see Table 4

In lower part of the table, we can see that three of four variables that underpin the external factors are significant. The results using quarter-on-quarter HCPI series (not reported here)

feature very low fit of the model, which can be related to the fact that the quarterly inflation series may be a subject to seasonality noise even though the original HCPI series were seasonally adjusted.

The previous country specific estimation allows us to draw some general conclusions. Our analysis provide some evidence in favor of the NKPC. Inflation rates in all countries hold significant forward-looking components and therefore it seems plausible to claim the current inflation is (at least partially) determined by its future expected value. However, the backward-looking term (the first inflation lag) is also significant and often has higher magnitude than the forward-looking term. Nevertheless, there can be some positive bias in favor of the backward-looking term because (i) the quarterly inflation data are constructed from monthly data, which include some degree of autocorrelation and (ii) our empirical model does not take into account slightly decreasing inflation trend (see Cogley and Sbordone, 2008, Kim and Kim, 2008).

The estimates accompanying the forcing variable are more ambiguous. The marginal cost is significant only when we use its absolute value (in logs) rather than its deviation from the steady state. Yet, as we pointed out, neither the mean nor the HP trend have to be a good proxy of the steady state. In any case, the unit labor cost is a good proxy of the aggregate marginal cost only under several restrictive assumptions that in reality might not hold (e.g. that the production technology is consistent with the simple Cobb-Douglas production function).

The potential superiority of the output gap over the marginal cost found in the Czech Republic and Poland has several interpretations. One option is that it is the actual forcing variable and inflation is driven by the cyclical evolution of the output, which is consistent with the traditional PC. Yet, once we in the spirit of the traditional PC include additional lags of inflation, they turn insignificant and their sum is never close to the unity. As the forward-looking term is significant as well, other interpretation of the result can be that the output gap is a better proxy of the unobservable marginal cost. The unit labor cost may not be sufficiently representative as a measure of firms' costs as large share of their inputs is imported. The relevance of the output gap is also reported by Genberg and Pauwels (2005), Jondeaua and Le Bihanb (2005), Henzel and Wollmershäuser (2008) or Zhang et al. (2009).

Our original claim that inflation dynamics of small open economies can be driven by external impulses is confirmed by the NKPC augmented by external variables. In particular, the inflation in the Euro area and the exchange rate are significant.[22]

Our results are in overall consistent with previous analysis for the NMS. As Lendvai (2005) and Franta et al. (2007) we find that inflation is persistent in the NMS and that the role of the marginal cost is unclear. Unlike Franta et al. (2007) we find that inflation holds a significant forward-looking component. This can be related to the fact that we aim only at the post-transitional period (it is more plausible to assume the forward-looking behavior). Besides, we detect that other forcing variables can play a role in explaining inflation variability.

5.2 Panel analysis

In this section, we present the results of the panel estimation. The consistency of the panel estimates rests on the assumption that the slope coefficients are the same for all cross-sections. Strictly speaking, this can never be the case in macro panels since important idiosyncrasies exist between the countries. Therefore, imposing homogeneity of the slope coefficients can bias the estimates. On the other hand, the panel estimation is based on larger sample and is an alternative to country-level analysis arguably subject to small sample bias.

The results are reported in Table 8. Unlike in case of country-level analysis, the panel estimates demonstrate insignificance of all domestic forcing variables (even the log of the marginal cost, compare 4th line in Tables 4-8). The same holds for three of four external variables. The only external variable that is statistically significant is the inflation rate in the Euro area. Interestingly, the (log) marginal cost turns significant in this specifications. The forward-looking term dominates slightly the backward-looking in most specifications and the sum of both terms is very close to unity. The results of estimation with quarter-on-quarter inflation rates are alike. The alternative estimators for dynamic panels with fixed effects (Arellano and Bond, 1991, Arellano and Bover, 1995) provide very similar results. We can conclude that panel analysis confirms that inflation in the NMS is driven rather by external than internal impulses and that substantial part of current inflation is related to future inflation expectations.

[22] The ERPT is confirmed by negative and significant coefficient of nominal effective exchange rate but it is incomplete. This is in line with the existing evidence showing that the pass-through fades away along the distribution chain (McCarthy, 2007).

Table 8: GMM panel estimates of different versions of closed economy hybrid PC (upper panel) and the specification augmented by external variables (lower panel) for the yearly HCPI inflation rate

Forcing variable	γ_b (π_{t-1})	γ_f (π_{t+1})	λ ($rulc_t$)	λ_{in} (y_{t-1}, w_t^*)	λ_{ex} (x_{t-1}, x_t^*)	R^2	LB	J-stat	Panel coint.
RULC (dev. mean)	**0.45**	**0.56**	0.00			0.97	2.54	0.10	0.10
	(0.04)	(0.05)	(0.00)						0.20
RULC (dev. HP trend)	**0.45**	**0.56**	0.00			0.97	2.55	0.10	0.25
	(0.05)	(0.06)	(0.03)						0.00
RULC	**0.43**	**0.60**	0.00			0.97	2.52	0.29	0.92
	(0.05)	(0.06)	(0.00)						0.41
RULC		**1.11**	0.00			0.85	1.27	0.01	0.84
		(0.04)	(0.00)						0.34
GAP	**0.45**	**0.55**		0.05		0.97	2.87	0.12	0.04
	(0.05)	(0.05)		(0.06)					0.00
GAP (4 lags of infl.)	0.32	**0.71**		-0.03		0.95	2.48	0.02	0.00
	(0.18)	(0.10)		(0.06)					0.00
WAGE	**0.43**	**0.60**		0.00*		0.96	2.53	0.14	0.01
	(0.05)	(0.07)		(0.00)					0.00
RULC + GAP	**0.43**	**0.60**	0.00	0.00		0.97	2.53	0.16	0.01
	(0.05)	(0.07)	(0.00)	(0.01)					0.00
RULC + GAP + OIL	**0.44**	**0.59**	0.00	0.01	0.00*	0.97	2.53	0.16	0.01
	(0.05)	(0.07)	(0.00)	(0.07)	(0.00)				0.00
RULC + GAP + IMP2	**0.44**	**0.61**	0.00	0.02	0.00*	0.97	2.47	0.14	0.07
	(0.05)	(0.06)	(0.00)	(0.07)	(0.01)				0.00
RULC + GAP + π_{EMU}	**0.45**	**0.58**	**0.01**	0.02	**0.25***	0.97	2.53	0.04	0.04
	(0.04)	(0.05)	(0.00)	(0.07)	(0.11)				0.00
RULC + GAP + NEER	**0.46**	**0.58**	0.00	0.03	-0.01	0.94	2.89	0.23	0.03
	(0.06)	(0.09)	(0.00)	(0.07)	(0.01)				0.00

Note: see Table 4. The value reported for Panel cointegration test are p-values of Pedroni test (above) and Kao test (below). The value for Pedroni test is an average p-value of 7 panel cointegrations tests proposed in Pedroni (1999) assuming either individual intercepts and trends or no deterministic components in each cross section (average of 14 p-values). Kao test includes by construction a deterministic intercept.

The last column of Table 8 reports the results of panel cointegration test of Pedroni (1999) and Kao (1999) as an additional check of the results´ reliability. The results of both tests usually coincide. The tests are generalization of the Engle-Granger (1987) test for panel framework and test whether the residuals have unit root. The main finding is that the cointegration of variables in the marginal-cost based NKPC is rejected (when no external variable is included), which cast doubt on the validity of this model.[23]

6. Conclusions

In this paper, we have given some account of the inflation dynamics of the four NMS (Czech Republic, Hungary, Poland and Slovakia) by means of econometric estimation of the

[23] The results are not altered whether the stationary variables (the output gap, the exchange rate differential) are included in the test or not. The presence of the marginal cost (ambiguously result for its stationarity) in the test for open economy specification does not affect the results either.

NKPC. The NMS are very specific among open emerging economies, given their previous transitional experience, their high degree of economic openness and their convergence process to the EU. This is why it is very interesting to learn about the nature of inflation dynamics of these economies. The existing empirical evidence on inflation dynamics of the NMS is scant. To our knowledge, this contribution represents the most comprehensive analysis on the NKPC for the NMS. We accompany the empirical framework of GG and GGL by additional tests (cointegration, GMM identification), use alternative definitions of inflation, and employ both rational-expectations-based GMM framework as well as survey data (when available). We test the effect of several alternative forcing variables. Given the recent contributions pointing to the instability of inflation dynamics across policy regimes (Benati, 2008, Cogley and Sbordone, 2008), we focus on post-transitional period (1998-2007), which was free of major changes in monetary policy regimes, and where the inflation series were not subject to structural break.

Our results confirm some claims of the NKPC but contradict others. In particular, we have found strong evidence that inflation is determined by future inflation expectations. However, the NMS exhibit higher degree of inflation persistence than that found for developed economies. This finding is consistent with previous studies based on disaggregated data.[24] An intuitive explanation can be that many firms in the NMS still employ simple backward-looking price setting, which is consistent with adaptive rather than rational expectations. This can be caused by a lack of credible monetary policy or missing nominal anchor in some NMS. When the monetary policy is unable to anchor the agents' inflation expectations, they logically prefer to use the past information. Orphanides and Williams (2004) suggested that expectations formation can be conditioned by the learning process about monetary policy. This sheds some doubt on the suitability of the NK framework, where backward-looking price setting is clearly suboptimal and the welfare loss increases with the rising share of the backward-looking firm.[25]

The main puzzle seems to be the identification of the inflation-forcing variable. We have not found convincing evidence that the average real marginal cost (proxied by the real unit labor cost) plays such a role. The performance of the output gap is better only marginally. We

[24] Disaggregated evidence for the Czech Republic is provided by Babetskii et al. (2007) and for Poland in Konieczny and Skrzypac (2005).

[25] Sheedy (2007) shows that the intrinsic inflation persistence appears in environment where newer prices are stickier than older ones. In this model, inflation persistence can arise even if the price setting is purely forward-looking. Cogley and Sbordone (2008) and Kim and Kim (2008) find for the US that once the structural breaks

obtain some indications that the short-term inflation impulses in the NMS can be external.[26] This is not surprising in face of the economic openness of these countries. Nevertheless, most of the current inflation variance seems to be intrinsic, i.e. it is linked either to the past inflation or to its future expectations. The statistical insignificance of the forcing variable such as the marginal cost or the output gap is problematic for the NKPC but does not automatically disqualify it given that most variables are only noisy proxies of the model variables. Due to the fragile statistical significance of some estimates, we limit our attention to the reduced form estimates rather than the structural parameters of the NKPC (e.g. Calvo's price staggering parameter θ).[27]

Our findings have several potential implications for the monetary policy. First, the fact that inflation process in the NMS has a significant backward-looking component calls for rather inertial monetary policy. Vašíček (2009) shows that the interest rate changes in the NMS have been substantially smoothed over time. If inflation is persistent, its decrease is believed to go along with an output loss. However, our results often cast doubt on the existence of trade-off between inflation and output. Second, the structural model behind the NKPC suggests that the effect of monetary policy on inflation goes via the marginal cost. However, if the marginal cost (the output gap) does affect inflation, the monetary policy can influence inflation only via its credibility and its effect on inflation expectations. This claim seems plausible for the inflation targeters. Finally, if inflation dynamics of the current EMU members is consistent with the NKPC, it is of a rather different nature than inflation dynamics of the NMS (at least the four countries that were analyzed here). While the former is marginal cost driven and forward-looking, the latter has an important backward-looking component and is forced by external factors. Nevertheless, given that prices in the NMS seem to adjust to prices in the Euro area and that the central banks of the NMS have gained credibility over the last decade, it is likely that inflation dynamics of the NMS will converge to the current EMU members as well. Therefore, an interesting agenda for the future research can be to evaluate inflation dynamics of the NMS in time-varying framework. This could allow testing whether the forward-looking component truly strengthens (and inflation persistence decreases) as a result of a more credible monetary policy or whether the external inflation factors gradually displace the domestic ones (as the globalization hypothesis suggests).

(e.g. changes in the steady-state inflation rate) is accounted for, the backward-looking inflation component dissipate.

[26] This is consistent with finding of Stavrev (2009).

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[27] Chari et al. (2009) claim that a structural model of inflation dynamics must be consistent with micro evidence on the price setting while the NKPC is not.

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Appendix: The data

The inflation rate is measured by the harmonized consumer price index (HCPI, 2005=100, Eurostat, quarterly data were obtained as averages of the corresponding seasonally adjusted monthly data). The quarterly inflation rate derived from the implicit GDP deflator (Eurostat, 2000=100), which is usually employed in empirical studies, presents some unusual developments (see Figure A.1).[28] However, both monetary policy and inflation expectations of private subject are usually defined in terms of consumption based indices. Moreover, CPI inflation is even more relevant in small open economies that are highly exposed to imports (Galí and Monacelli, 2005 derive open-economy NKPC in terms of CPI inflation). We use yearly (year-on-year) and quarterly (quarter-on-quarter) inflation rates. The analysis with the latter is not presented here but it is commented on and is available upon request.[29] For the Czech Republic and Poland, we use additionally for the inflation expectations survey data on the CPI inflation expectation of the financial market participants (4 quarters ahead, quarterly frequency calculated as simple mean of monthly data), data come from Czech and Polish National Banks. *The foreign inflation rate* is measured by the inflation rate in the Euro area. The same source and procedures are used as in case of the domestic inflation rates.

The wage inflation is approximated by two measures. (i) The unit labor cost index (OECD, 2000=100, total economy) that is calculated as the ratio of (nominal) total labor cost and the real output (both in national currency). (ii) The labor cost index reported by Eurostat (2000=100) which includes the total labor costs, main components of wages and salaries (e.g. bonuses) and non-wage costs (e.g. social contributions). The wage inflation is calculated as either yearly or quarterly change of each index.

The real marginal cost is proxied by the real unit labor cost. We use two measures of the real unit labor cost: (i) the (log) unit labor cost index (OECD 2000=100, total economy) deflated by price index (HCPI) and (ii) the (log) ratio of the nominal total compensation to employees and the nominal GDP (Eurostat, both series in euros and disaggregated from the annual

[28] See quarterly change of GDP deflator of Hungary in 2002 and Poland in 1999. The series of yearly inflation rates from GDP deflator and HCPI are strongly correlated.

[29] Assenmacher-Wesche and Gerlach (2008) argue that inflation-forcing variables can vary according to inflation frequency. In particular, inflation at high frequency (quarterly) is linked to the output gap while the low-frequency fluctuations (horizon of several years) are driven by monetary factors. In our case, quarterly inflation rate may be influenced by price shocks while the yearly inflation rates affected by the real economic activity (the marginal cost, the output gap).

frequency by Ecotrim software by Eurostat). The deviation from the steady state is defined as a deviation from the sample mean and as a deviation from HP trend.
The output gap is measured as follows: (i) as the difference between the logarithm of the current value of the seasonally adjusted GDP (in millions of euros in 1995 prices, Eurostat) and the trend value obtained by Hodrick-Prescott filter (the smoothing parameter set to 1600) and (ii) as direct measure calculated by the OECD by means of production function approach.

The unemployment rate is standardized unemployment rate (Eurostat, calculated from monthly frequency, seasonally adjusted).

The import prices are proxied by two measures: (i) the ratio of import value and import volume indices (Eurostat, 2000=100, disaggregated from the annual frequency by Ecotrim) and (ii) the ratio of imports in current prices to imports in constant prices (OECD, in national currency, quarterly data calculated as average of seasonally adjusted monthly series). The yearly or quarterly change of each index are used for estimation.

The oil price is measured by average quarterly world price of barrel of crude in USD (quarterly prices are calculated as average from weekly values), data comes from US Energy Information Administration. The yearly or quarterly change is used for estimation.

The exchange rate is the nominal effective exchange rate index (Eurostat, against 12 main trading partners, 1999 is the base year). The yearly or quarterly change of the index is used for estimation.

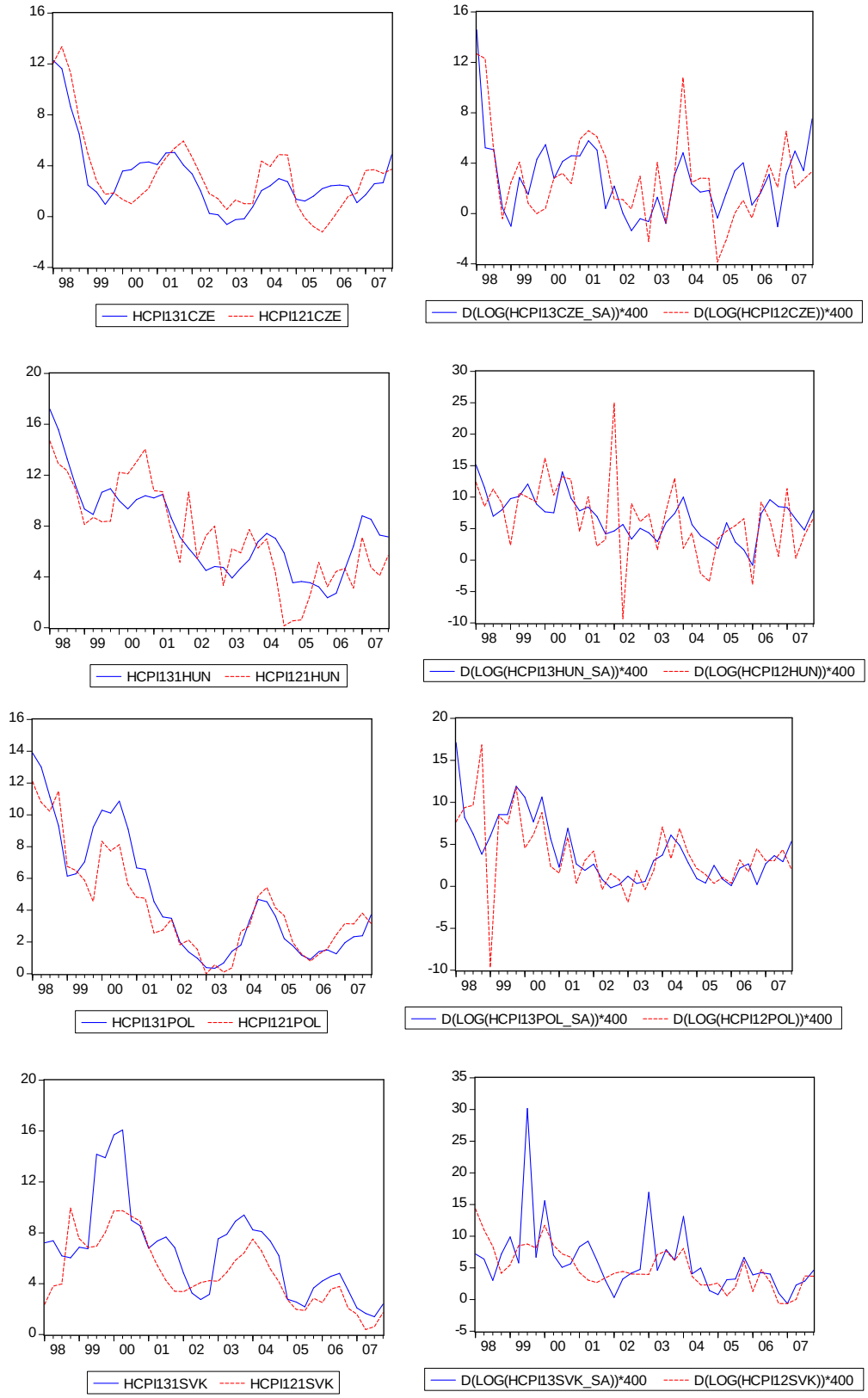

Figure A.1: Yearly inflation rates (left) and annualized quarterly inflation rates (right) derived from HCPI (solid line) and GDP deflator (dotted line)

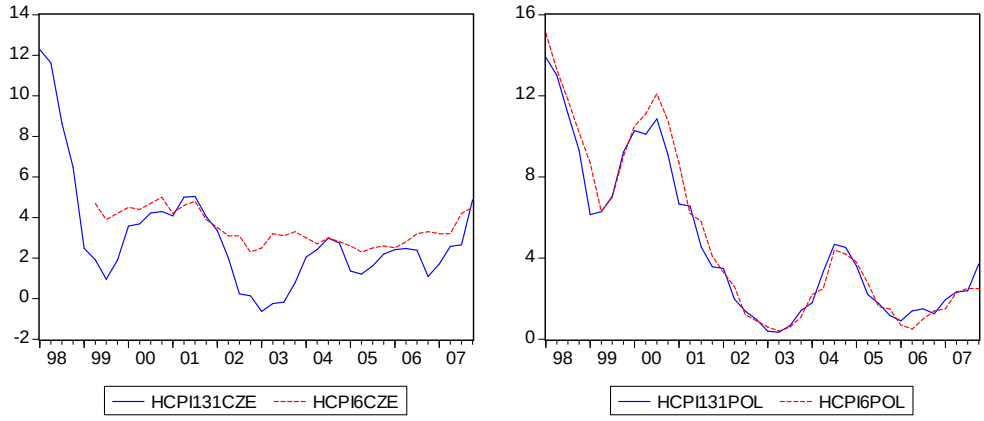

Figure A.2: Yearly rates HCPI inflation (solid line) and inflation expectations 12 months ahead by financial markets (dotted line) – the Czech Republic (left) and Poland (right)

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