NBP Narodowy Bank Polski

NBP Working Paper No. 239

Linking excessive disinflation and output movements in an emerging, small open economy

A hybrid New Keynesian Phillips Curve perspective

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Economic Institute
Warsaw, 2016

The views expressed herein are those of their author and do not necessarily reflect those of the Narodowy Bank Polski. I would like to thank Aleksandra Hałka, Andrzej Sławiński, Jacek Kotłowski, Tomasz Łyziak, Michał Rubaszek, Michał Hulej, Paweł Baranowski, Grzegorz Szafrański and an anonymous referee for valuable help and comments. I also thank Carlos Montes-Galdón for sharing the codes for time-varying stochastic volatility Phillips curve. Correspondence should be directed to: karol.szafranek@nbp.pl; postal address: ul. Świętokrzyska 11/21, 00-919 Warszawa, Poland.

Published by:
Narodowy Bank Polski
Education & Publishing Department
ul. Świętokrzyska 11/21
00-919 Warszawa, Poland
phone +48 22 185 23 35
www.nbp.pl

ISSN 2084-624X

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Abstract

Excessive disinflation and the flattening of the Phillips curve are recently popular phenomena in many advanced economies. In the environment of low inflation, the fading relationship between the price dynamics and the adjustments in the domestic real activity is vigorously investigated for highly developed economies. Still little evidence has been presented for emerging, small open economies. In this paper I address this issue by investigating the behavior of the Phillips curve for Poland. In particular, I aim at answering the question whether a Phillips curve flattening or a steepening can be observed during the recent abrupt disinflation. The outstanding problem of considerable uncertainty accompanying the model specification is accounted for by estimating a substantial number of regressions and exploring the cross-section properties of the hybrid NKPC *parameters. The results advocate that a statistically significant relationship between inflation and the domestic real activity developments persists. However, in the recently observed disinflation period the Phillips curve tends to flatten as the inflation's sensitivity with respect to changes in economic slack diminishes. That notwithstanding, the impact of external factors rises significantly. Conditional ex-post forecasts suggest that while only a limited number of Phillips curve specifications manage to explain the disinflation process in Poland, employing unemployment gap or real* GDP *as economic slack proxies delivers the most accurate inflation forecasts.*

JEL: C13, C22, C26, E31
Keywords: hybrid NKPC, inflation, Phillips curve flattening, emerging, small open economy

1. Introduction

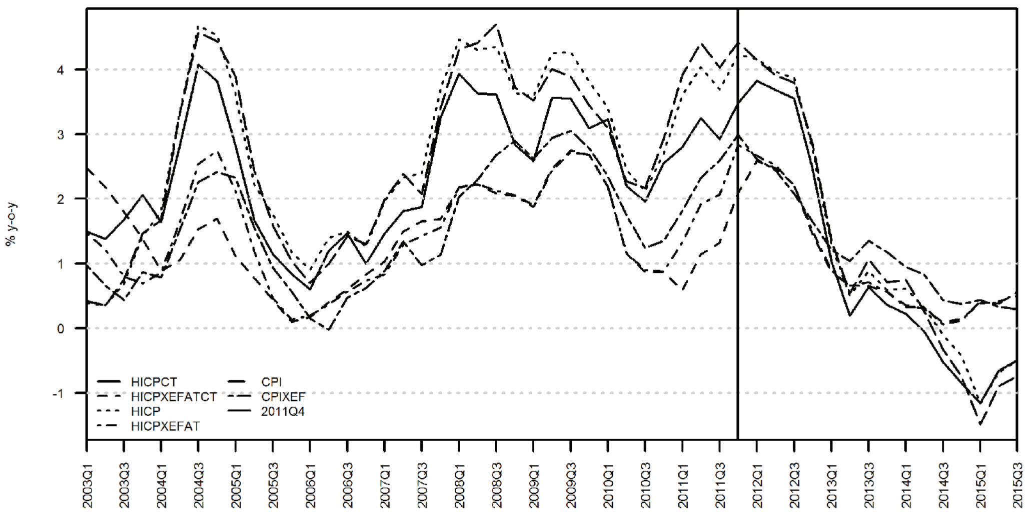
In recent years a steep disinflation process can be observed in many economies raising the question of low inflation determinants for debate (ECB, 2016). In the environment of plummeting commodity prices, protracted period of anemic recovery in highly developed economies as well as struggling emerging markets, several factors can be to blame for the persistently low inflation across countries. The discussion on the determinants of muted inflation, in particular on the relationship between the price dynamics and the adjustments in the domestic real activity, focuses on the highly developed economies (e.g. Blanchard et al., 2015). Still little evidence has been presented for emerging, small open economies, highly dependent on the evolution of external factors. The main contribution of this paper is filling this gap in the literature by investigating the changes in the hybrid New Keynesian Phillips Curve augmented with external factors (henceforth hybrid Nkpc) during the disinflation period for an emerging, small open economy. For this purpose I employ the Polish data.

The principal aim of this paper is to establish the recent changes to the Phillips curve and provide an explanation of the protracted period of the low inflation in a small open economy, such as the Polish one. Following the ongoing debate in the literature concerning the substantial specification uncertainty of the Phillips curve (Mavroeidis et al., 2014), I estimate a battery of equally valid from economic perspective hybrid new-keyenesian Phillips curves for the Polish economy. In order to account for the considerable uncertainty regarding the modeling of the Phillips curve I use two vintage datasets, various measures of inflation, economic slack, external factors and inflation expectations, different Gmm estimation methods as well as three sets of instruments. The Gmm estimates in the two samples are then compared and appropriate tests are conducted to evaluate the statistical significance of the changes of Phillips curve reduced-form parameters between samples. Further, I use the conditional forecasts to evaluate whether the recent disinflation period in Poland can be explained by the adjustments in the domestic real activity. In particular, I compare the root mean square forecasting errors to find a superior combination of the proxy measuring marginal costs and inflation expectations minimizing the forecasting error in the disinflation period. For robustness check I also investigate the behavior of the Phillips curve parameters in a time-varying stochastic volatility approach.

Excessive disinflation is a subject of heated discussion and scrutiny also in emerging, small open economies, such as the Polish one. Starting in 2011Q4, a steep disinflation process can be observed (Figure 1). After reaching 4.4% in 2011Q4, the headline inflation measure has experienced an abrupt fall, which has been followed by an unprecedentedly long period of deflation, during which the annual inflation rate has descended to as much as -1.5% in 2015Q1, a historically low level. Although the protracted period of deflation coincides with the plummeting commodity prices, an anemic economic growth in the developed countries and struggling emerging markets, current Polish inflation rate may seem baffling when looking through the lens of the domestic real activity developments. Surprisingly enough, in the environment of robust domestic economic growth and steadily improving labor market conditions the recent disinflation process is not exclusive to the headline inflation as the core inflation measures decline and currently evolve around their historically lowest levels. This, in turn, may suggest that the responsiveness of inflation to the adjustments in the domestic real activity has recently diminished leading to a flattening of the Phillips curve. Consequently, as this phenomenon unravels, only large changes in output may impact inflation. As a results, the economic cost of reinflation may be substantially larger. The main consequence of the Phillis curve flattening is that the expansionary monetary policy may have an asymmetric influence on the nominal and real economy, stimulating successfully the demand side while leaving the prices unadjusted for a longer period of time.

The identification of the determinants shaping the recent disinflation and the protracted presence of low inflation is crucial to the monetary policy conduct in small open economies. By estimating the strength of the link between the price dynamics and the adjustments in the domestic real activity the monetary authority can assess to what extent inflation is responding to the domestic developments and to what

Figure 1: Annual inflation rate in Poland according to different inflation measures



Note: Abbreviations used: HICPCT – HICP inflation (constant taxes), HICPXEFATCT – HICP inflation excluding energy, food, alcohol and tobacco (constant, taxes), HICP – HICP inflation, HICPXEFAT – HICP inflation excluding energy, food, alcohol and tobacco, CPI – Consumer Price Index, CPIXEF – Consumer Price Index excluding food and energy and food. Source: Eurostat, NBP, own calculations.

extent it is governed by global factors or controlled by high nominal rigidities.

Several conclusions are warranted in the paper. Firstly, based on the Polish data the results advocate that a statistically significant relationship between inflation and the adjustments in the domestic real activity persists in a small open economy. However, during the recent disinflation period the estimates of the Phillips curve's slope coefficient has on average decreased across specifications. This would suggest that the phenomenon of Phillips curve flattening is not exclusive for the highly developed countries but can be present also in emerging, small open economies. Moreover, while the slope flattens, the impact of the external factors has recently strengthened. This claim is robust to different estimation techniques, sets of instruments as well as inflation measures. Secondly, the ex-post forecasts indicate that cyclic factors do not fully explain the gradual lowering of the Polish inflation rate. However, in the environment of robust economic growth and constant improvements in the labor market, the flattening of the Phillips curve may highlight the inadequacy of the pressure exerted on prices by the demand side. Thirdly, the results reveal that in order to model Polish inflation by the Phillips curve, specifications with unemployment gap as a slack measure and survey inflation expectations should be firstly considered as they tend to have superior predictive ability compared to other specifications.

The outline of the paper is as follows. Section 2 attempts to briefly review the comprehensive literature on the Phillips curve. The data and the methodology used in this analysis are presented in section 3. Main results as well as robustness check is presented in section 4 and 5, respectively. Section 6 concludes.

2. Literature review

Literature on the trade-off between inflation and real economic activity is voluminous. Although economists broadly agree that inflation can be curbed at a cost of lower aggregate demand, at least in the short-run, the specification of the Phillips curve has been a subject of vivid debate since the seminal work of Phillips (1958), who introduced the concept for UK's wage inflation and unemployment. Samuelson and Solow (1960) have provided a subsequent extension by gauging the relationship between the U.S. unemployment and price inflation. Since then a myriad of Phillips curve specifications has been studied with the emphasis laid upon the nature of the inflation–aggregate demand relationship and its inference for the monetary policy conduct. This abundance of research, caused by the nontrivial choice regarding the variable proxies, estimation methods or theoretical assumptions imposed on the model, is comprehensively reviewed by, *inter alia*, Gordon (2011), Danišková and Fidrmuc (2012) and Mavroeidis et al. (2014).

Along with the development of the economic theory, the landmark specification of the Phillips curve has been subjected to numerous alterations. Within the new neoclassical synthesis confines (Goodfriend and King, 1997), Gali and Gertler (1999) and (Gali et al., 2001) propose a hybrid new-keynesian Phillips curve to model the U.S. and the European inflation and reconcile the purely backward-looking and forward-looking approaches while accounting for the firm's marginal cost dependent on the nominal rigidities in the economy (Roberts, 1995). Inflation inertia has been introduced into purely forward-looking Phillips curve to improve its statistical properties, following the critique concerning the unsatisfactory fit of expectations-driven models (Fuhrer and Moore, 1995; Fuhrer, 1997; Rudd and Whelan, 2005). Several microeconomic foundations are offered to sanction this, e.g. market rigidities with the information asymmetries Lucas (1976), staggered relative wage contracts (Fuhrer and Moore, 1995), firms updating their prices using a backward-looking rule of thumb (Gali and Gertler, 1999) or indexing prices to past inflation (Christiano et al., 2005).

The choice of optimal proxies for estimating the Phillips curve is problematic. Firstly, a variety of inflation measures can be adopted: Gdp or private consumption deflators, headline, core or supercore inflation (Fröhling and Lommatzsch, 2011). In an emerging, small open economy all these measures may be differently distorted by the external shocks or changes in the institutional factors, such as indirect taxation (Rogers, 2007).

Secondly, firm's marginal costs are unobservable and therefore proxies of this variable are used in empirical research. There is no apparent consensus which measure supremely approximates this latent variable. Gali and Gertler (1999) employ labor share to measure economic slack. However, subsequent studies by Rudd and Whelan (2005, 2006, 2007) reveal its countercyclicality in comparison to the cyclical behavior of the real marginal costs and criticize this measure. Currently, output gaps (e.g. Hałka and Kotłowski, 2014) or unemployment rates or gaps (e.g. Weiner, 1993) are widely used. Other approaches advocate the usefulness of short-run unemployment rates (e.g. Gordon, 2013; Krueger et al., 2014; Ball and Mazumder, 2014; Cao and Shapiro, 2014), as long-run unemployed exert less upward pressure on wages and prices due to their long absence on the labor market and their human capital depreciation (Gordon, 2013; Watson, 2014). A novelty approach is proposed by Stock and Watson (2010), who employ an unemployment recession gap illustrating the deviation between the current and the minimal unemployment rate in 11 preceding quarters. Broadly speaking, using various measures of economic slack may prove beneficial as the uncertainty regarding the proper measurement of the output gap remains high (Jarocinski and Lenza, 2015).

Thirdly, the choice of inflation expectations measure and the assumptions regarding its exogeneity has profound effects on the required estimation method and the parameter's statistical properties (Mavroeidis et al., 2014). Popular proxies for inflation expectations include model-based, survey-based measures or expectations implied from the financial market instruments. Empirical literature points to the superior ability of survey-based inflation expectations in forecasting inflation (e.g. Ang et al., 2007; Łyziak, 2013).

Fourthly, an appropriate baseline specification of the hybrid Nkpc can be augmented with a set of control variables. Gordon (1990) prompts to extend the Phillips curve by the supply-side developments inducing cost-push inflation. Indeed, the importance of globalisation as well as the recent, evident presence of persistent global supply shocks protractedly influencing inflation measures across economies are highlighted in many works (e.g. Borio and Filardo, 2007; Ciccarelli and Mojon, 2010; IMF, 2014; Malikane, 2014; Bianchi and Civelli, 2015; Aastveit et al., 2016). Moreover, Hałka and Szafranek (2016) show that developed economies can transmit inflation to small open economies.

Apart from the choice of adequate proxies, selecting appropriate estimation method as well as necessary instruments poses a dilemma. Within the Nkpc framework, the choice of estimation technique is stricly connected to assumptions regarding inflation expectations. Mavroeidis et al. (2014) summarize commonly employed approaches. These include generalized instrumental variables proposed by McCallum (1976) and propagated under its current name by Hansen and Singleton (1982), inflation expectations derived from a Var framework (Fuhrer and Moore, 1995; Sbordone, 2002), using survey measures or data revisions as external instruments. Commonly, due to the endogeneity problems, Gmm estimation is adopted. However, under strict assumptions about the nature of survey-based inflation expectations hybrid Ols can be employed (Rudebusch, 2002; Adam and Padula, 2011). Furthermore, due to the notorious difficultly of inflation forecasting (Atkeson and Ohanian, 2001; Stock and Watson, 2007; Faust and Wright, 2013), finding exogenous lagged variables correlating sufficiently with future inflation can be a daunting challenge. As a result, potential instruments could likely be subjected to the weak identification problem (Stock et al., 2002) leading to estimates that are biased (Mavroeidis et al., 2014) and sensitive to information set (Rudd and Whelan, 2007).

Finally, the responsiveness of inflation to changes in economic slack may be time-varying. Empirical literature concentrates on the inflation-aggregated output relationship in the U.S, the European and selected highly developed economies and provides ambiguous conclusions. Although numerous prominent studies exemplify the phenomenon of Phillips curve flattening and in extreme cases lack of connection between the inflation and domestic real activity in advanced economies (e.g. Helbling et al., 2006; Mody and Ohnsorge, 2007; Musso et al., 2009; Kuttner and Robinson, 2010; Abbas and Sgro, 2011; Matheson and Stavrev, 2013; Andrle et al., 2013; Broadbent, 2014; IMF, 2014; Coibion and Gorodnichenko, 2015; Blanchard et al., 2015), several studies conclude that recently a steepening both for the U.S. and the euro area is observed (Alvarez and Urtasun, 2013; Stella, 2012; Oinonen and Paloviita, 2014; Riggi and Venditti, 2014). Popularly, globalization as well as high central bank's credibility motivate the decrease in the Phillips curve slope, whereas steepening is explained by structural reforms decreasing nominal rigidities. Although there is some evidence on the flattening of the Phillips curve in emerging markets (Çiçek, 2012), to the best of my knowledge, changes in Phillips curve parameters have not been investigated for emerging, small open economies facing low inflation environment.

From the perspective of an emerging, small open economy's central bank, properly identified parameters of the hybrid Nkpc entail a valuable information for monetary policy action, especially in the low inflation environment. Determining the prices' sensitivity to adjustments in the domestic real activity and external factors as well as comparing the inflation inertia versus the impact of inflation expectations, should allow the central bank to adequately adjust its policy and manage the expectations by communicating the reasons for the short-term deviations of inflation from the central bank's desired target (Blinder, 2000; Blinder et al., 2008). Literature discusses various macroeconomic risks of persistent low inflation in developed economies, e.g. the de-anchoring of the inflation expectations via cost-push shocks coupled with undermined central banks' credibility, ineffectiveness of conventional monetary policy instruments, challenges for financial stability, debt deflation, downward nominal wage rigidities, contractionary effects of cost-push output-expanding shocks at Zlb (Rosengren, 2014; Neri and Notarpietro, 2014; Tenreyro and Thwaites, 2013; Galati and Moessner, 2013). Therefore, pinning down the changes in the hybrid Nkpc in an emerging, small open economy grappling with protracted period of deflation is beneficial, especially if the economic cost of reinflation remains unknown.

With a plethora of possible extensions to the baseline Phillips curve model pursued in the literature, no universal framework has been provided. Therefore, in this paper I estimate a number of a priori economically reasonable hybrid NKPC to investigate the changes in the Phillips curve parameters across specifications for an emerging, small open economy.

3. Data and methodology

This section discusses the estimation procedure of various specifications of the hybrid Nkpc for an emerging, small open economy. For this purpose I employ Polish data. Firstly I present the econometric model specification and discuss adopted proxies of inflation, economic slack, imported inflation and inflation expectations. Next, I move to describing the proposed estimation procedure.

3.3.1. Specification of the econometric model

The baseline setup of the hybrid Nkpc considered in this paper is presented in equation (1):

$$\pi_t = \mu + \rho\pi_{t-1} + \beta x_{t-1} + \gamma\pi_t^e + \lambda\pi_{t-1}^i + \epsilon_t \quad (1)$$

where: π is inflation, μ is a constant term, x is a measure of economic slack, π^e is an inflation expectation measure and π^i is a measure of imported inflation. For inflation indices I use annualized quarterly growth rates. Economic slack enters the estimation as a standardized measure. The lag for the economic slack variable and the influence of the imported inflation has been set to one, which is in line with previous studies of the Phillips Curve on aggregated as well as disaggregated level for the Polish economy (e.g. Przystupa and Wróbel, 2011; Hałka and Kotłowski, 2014).

Specifying the hybrid Nkpc differently by including a variety of different measures of inflation, economic slack, external factors and inflation expectations in a fixed-coefficient approach resembles on the one hand the considerable uncertainty around the choice of optimal proxies and a lack of economic consensus around the proper model specification. On the other hand, it simultaneously allows to hedge against this substantial uncertainty regarding the proper specification by investigating the cross-section of the hybrid Nkpc parameters (ECB, 2016)[1].

In the analysis the following inflation indices have been considered:

1. Hicp inflation (constant taxes),
2. Hicp inflation excluding energy, food, alcohol and tobacco (constant taxes, henceforth core inflation),
3. Hicp inflation,
4. Hicp inflation excluding energy, food, alcohol and tobacco,
5. Consumer Price Index,
6. Consumer Price Index excluding food and energy prices.

My preferred inflation measure is the second one – by construction this measure should be distorted to the smallest extent by external shocks to commodity prices and changes in indirect taxation. External shock proved to be important drivers of broad inflation measures in small open economies (Hałka and Kotłowski, 2016). Therefore, in the paper I will focus the discussion of the outcomes mainly on the estimation results for core measure[2].

As regards economic slack, the following measures have been selected:

1. real Gdp,
2. output gap calculated from a production function of a structural macroeconometric model for the Polish economy (Budnik et al., 2009),
3. output gap published by the EC (interpolated to quarterly series),

[1] The approach presented here is similar to the one found in ECB (2016) and Alvarez and Urtasun (2013). However, in the Ecb report a much smaller set of variables is considered for the Polish economy and the equations are estimated using Ols disregarding the potential endogeneity problems. The conclusions for Poland based on the ECB (2016) report are ambiguous. In this paper I perform a deeper investigation of the link between the nominal and real economy in Poland by studying a larger variable set and employing different estimation techniques.

[2] However, a summary of the changes in the slope steepness, the impact of inflation persistence, external factors as well as inflation expectations is also provided and discussed. Due to the substantial dimensionality of the results additional material is available on request.

4. output gap published by the OECD (interpolated to quarterly series),
5. output gap calculated using a Hodrick-Prescott filter with the standard parameter $\lambda = 1600$,
6. capacity utilization,
7. unemployment rate,
8. underemployment index calculated for the Polish economy by Wyszyński (2016),
9. unemployment gap,
10. unemployment recession gap proposed by Stock and Watson (2010),
11. labor share,
12. long-term unemployment rate.

As far as imported inflation is concerned, the following measures have been used:

1. import price deflator,
2. the commodity price index denominated in Polish zloty,
3. the oil price index denominated in Polish zloty,
4. the real effective exchange rate.

Finally, I adopt inflation expectations indices available for the small open economy of Poland. Detailed information about the construction of inflation expectations for the Polish economy can be found in Łyziak (2013). In this study the following measures have been chosen:

1. an average of headline inflation over four past quarters,
2. the objectified measure of consumer inflation expectations,
3. the subjectified measure of consumer inflation expectations,
4. the alternative subjectified measure of consumer inflation expectations,
5. the inflation expectations of enterprises,
6. the inflation expectations of professional forecasters.

The dataset features observations at quarterly frequency. Time series with seasonal patterns have been seasonally adjusted using automated X-13-Arima-Seats procedures. A summary of all variables used in the paper along with their labels, abbreviation expansions and additional informations are explained in Table A.1.

3.3.2. Estimation procedure

The estimation procedure is conducted in three steps. First, I estimate the reduced-form parameters of the hybrid Nkpc presented in equation (1) on two vintage datasets: 2002Q1-2011Q4 and 2002Q1-2015Q3. The breakpoint set in 2012Q1 is singled out subjectively by the author. I motivate this choice by the changing behavior of the inflation dynamics – as illustrated on Figure 1, starting in 2012Q1, after a period of relative stability and no clear trends, both the headline inflation as well as core inflation measures in Poland have begun to systematically decline.

My preferred method of estimation is the generalized method of moments (Gmm). The reason behind this choice is the necessity to account for the endogeneity problem resulting from the inclusion of the inflation expectation term in the Phillips curve equation. However, as the reliability of Gmm in small samples may be questionable and the estimates of the hybrid Nkpc are sensitive to the choice of the Gmm estimator (Bårdsen et al., 2004), for comparison purposes different versions of the Gmm estimator are implemented, namely the Two-step Gmm of Hansen (1982), the Iterative Gmm, the continuous updating estimator (Cue Gmm) of Hansen et al. (1996) as well as a specific kind of Gmm estimator – a two-stage least squares (Gmm Tsls). Efficient Gmm estimators are obtained by using a heteroscedastic and autocorrelation consistent estimate of the asymptotic variance-covariance matrix with quadratic spectral kernel and a data-driven bandwidth parameter postulated by Andrews (1991). The obtained estimates are contrasted with a standard OLS approach, in which all explanatory variables are treated as exogenous.

For the moments conditions in the GMM approach I propose instruments that are broadly in line with the existing literature (e.g. Budnik et al., 2009; Mavroeidis et al., 2014). However, due to limited sample availability fewer instruments are chosen than, *inter alia* Gali and Gertler (1999) have proposed in their studies. In the baseline specification, I choose the following variables as instruments: a constant, four lags of inflation and two lags of slack measure, one lag of wage inflation (measured as the quarterly change in the compensation per employee), one lag of the measure reflecting imported inflation and one lag of inflation expectations measure.

I also consider two alternative identification schemes. In the first one (henceforth ALTERNATIVE I) I pursue the case where more instruments are employed. Therefore, a constant, four lags of inflation and two of slack measure, two lags of wage inflation, one lag of the measure reflecting external factors and two lags of the inflation expectations are used. However, due to relatively large number of moment conditions compared to the sample size, the GMM CUE as well as the iterative estimator fail to converge more frequently. Moreover, studies show that using too many instruments with respect to the sample size can lead to a severe bias in GMM estimates (Hansen et al., 2008), especially if the instruments are weak. In the second approach (henceforth ALTERNATIVE II) I investigate the case when only few instruments are chosen. I adopt as instruments a constant, two lags of inflation, two lags of slack measure, one lag of the measure of external factors, one lag of wage inflation and one lag of inflation expectations. This time the estimators converge in almost every case, but intuitively the parameters of the intrinsic persistence and slope in the Phillips curve may be underestimated.

The endogeneity of instruments is tested with the J-test of overidentifying restrictions (Hansen, 1982). I also perform a test for dynamic homogeneity property to check, whether in the long-run changes in expectations are resembled in analogous changes in inflation. For that purpose I accomodate a linear restriction test with the null hypothesis $H_0 : \rho + \gamma + \lambda = 1$. Under the null the test statistic follows a F distribution.

In the second step, I evaluate the significance of the hybrid NKPC parameter's change in inflation persistence ρ, Phillips curve slope β, the influence of external factors λ and inflation expectations γ as well as long-term intercept of the Phillips curve θ[3]. In order to assess the changes in the studied coefficients ρ, β, λ, γ and θ I regress the obtained reduced-form parameters of the hybrid NKPC from the first sample–denoted here as (I)–on the respective coefficients from the second sample–denoted here as (II)–using OLS estimator. Equation (2) summarizes this step where variable y represents the variable of interest:

$$y^{(II)} = \kappa_y y^{(I)} + \epsilon_y, \qquad y = \{\rho, \beta, \lambda, \gamma, \theta\} \tag{2}$$

The intercept of these simple regressions is restricted to zero – that way the estimated slope parameter κ informs about the average change in the coefficients of the hybrid NKPC between samples. This parameter is subjected to a one-sided t-test. Under the null hypothesis $H_0 : \kappa = 1$ which reflects that the estimates have not changed between samples. The alternative hypothesis is one-sided depending whether the parameter $\kappa < 1$ or $\kappa > 1$. A caveat should be aired here, as this approach may be subjected to a generated regressors problem (Pagan, 1984). To account for the probable problem of influential observations I impose a specific HAC correction on the variance-covariance matrix (Cribari-Neto, 2004). The proposed correction is claimed to further improve small sample performance of HC estimators. For additional robustness check, to exclude the impact of outliers, the same regression is conducted on a set of estimates from specifications, for which the estimated slope coefficient lies within the 90% interquantile range of the PC slope coefficient in the whole sample for a given inflation measure.

In the third step, in order to answer the question of disinflation determinants I calculate dynamic forecasts of the annual inflation rate throughout the forecast horizon 2012Q1-2015Q3 using the newest information

[3]Here the long-term intercept of the Phillips curve θ is calculated as follows: $\theta_s = \frac{\mu_s}{1-\rho_s} + \frac{\gamma_s}{1-\rho_s}\bar{\pi}^e_s$, where: s denotes the sample considered and $\bar{\pi}_s$ denotes the average level of inflation expectation measure over the sample s.

set and the Phillips curve coefficients estimated on the first vintage (henceforth conditional forecasts). This method is summarized in equation (3):

$$\pi^{f}_{t+h} = \mu^{(I)} + \rho^{(I)}\pi^{f}_{t+h-1} + \beta^{(I)}x^{(II)}_{t+h-1} + \gamma^{(I)}\pi^{e,(II)}_{t+h} + \lambda^{(I)}\pi^{i,(II)}_{t+h-1} \quad (3)$$

where: π^{f}_{t+h} is the inflation forecast in forecast period h, (I) notifies that the estimated parameters via Iterative Gmm with baseline instrument set from the first sample are used, (II) informs that actual values of variables from the second sample in forecast period are employed, h denotes the forecast period. The quality of the forecasts is evaluated by calculating the root mean square forecasting errors (Rmse). Based on this criterion I infer also which measure of economic slack should be used to model inflation in the case of Poland.

4. Results

This section presents the results of the estimation procedure. I concentrate the discussion around the estimation outcomes for the baseline model (with core inflation as dependent variable and the Iterative Gmm estimation method[4]). However, in the appendix I provide the estimation results for all inflation measures and all distinguished estimation methods.

Two main blocks of results are presented in the paper: the significance of changes in the hybrid Nkpc coefficients between samples and the determinants of excessive disinflation from the hybrid Nkpc perspective. I start by discussing the changes in the reduced-form hybrid Nkpc parameters between the samples and in the parameters distributions. As a robustness check I also investigate the relation of parameters between samples after trimming the tails of the slack coefficient in the whole sample by 5% at each side of its distribution and disregarding the corresponding parameters of the hybrid Nkpc in both samples.

In the second part I present the conditional forecasts of the hybrid Nkpc based on fixed-coefficient and time-varying parameters approach. I investigate whether some specifications of the Phillips curve were able to pin down the disinflation period in Poland.

4.4.1. Changes in hybrid NKPC coefficients during low inflation period

I start with presenting the aggregate estimation results for the hybrid Nkpc with core inflation as dependent variable. Table 1 contains the summary statistics for the estimation of 288 hybrid Nkpc on two vintage datasets obtained using different estimation techniques. Estimation results for other inflation measures are presented in tables B.1-B.5 in the appendix.

Several conclusions are warranted. First, the estimation results advocate that a significant relationship linking nominal and real economy developments persists in the emerging, small open economy. Across different Gmm estimation routines, the slope of the Phillips curve β is positive in around 90% of 288 equally reasonable specifications of the hybrid NKPC and significant in more than 50% of them at $\alpha = 0.05$ significance level. However, the median estimate of β falls between samples (on average by 0.07) and so does its fraction significant (on average by 0.11), which could signal the flattening of the Phillips curve and will be discussed later in the paper.

Second, intrinsic inflation persistence coefficient ρ is nearly always positive and statistically significant at $\alpha = 0.05$ significance level implying a robust relation between current and past price dynamics. Between samples the median estimate increases only marginally (on average by 0.03). This would imply a stable inflation persistence throughout time.

Third, the influence of the imported inflation λ is better identified in the whole sample, where the fraction significant at $\alpha = 0.05$ increases on average by 0.23 and approaches around 0.5 in majority of cases. The median coefficient of imported inflation λ also increases which underlines the rising role of the economic environment in shaping the domestic inflation rate in small open economy of Poland.

Fourth, whereas the γ coefficient measuring the impact of inflation expectations is mostly positive, its fraction significant statistic is subjected to large changes between samples and does not exceed 0.5. This would incline that inflation developments on average are driven more by the developments in the real economy and are rather a backward-looking that forward-looking process. However, based on the results of the dynamic homegeneity test, in the long-run the changes in the expectations are reflected in the analogous changes in inflation in around 85% of specifications.

On the aggregate level, there is robust evidence on the validity of overidentifying restrictions of the

[4] The reason for that choice is twofold. Ideally, in large samples the Cue Gmm estimator should be preferred, as the bias properties of this estimator are better with respect to other Gmm procedures. However, this feature comes at a price of fat tails (greater dispersion) in small samples (Hansen et al., 1996), which can lead to lack of convergence or large absolute values of estimates. This features has also been observed whilst estimating the hybrid Nkpc for the Polish economy (tables 1,B.1-B.5). The Two-Step Gmm procedure produces estimates biased more towards Ols estimates (Stock et al., 2002), the Tsls relies on the strong restriction upon the variance-covariance matrix of the instruments, whereas the Ols approach does not account for the endogeneity of the inflation expectations.

Table 1: Summary statistics for the estimation of the hybrid NKPC for core inflation on two vintage datasets with different estimators

	GMM CUE		GMM ITERATIVE		GMM TWO-STEP		GMM TSLS		OLS	
Statistic	I	II	I	II	I	II	I	II	I	II
$\rho: 5^{th}$ percentile	0.090	0.210	0.217	0.293	0.335	0.292	0.367	0.307	0.313	0.278
ρ : Median	0.443	0.489	0.448	0.479	0.456	0.476	0.456	0.458	0.419	0.403
$\rho: 95^{th}$ percentile	0.850	0.853	0.669	0.720	0.657	0.647	0.622	0.608	0.581	0.574
ρ : Fraction positive	0.989	0.977	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
ρ : Fraction significant at $\alpha = 0.05$	0.850	0.931	0.938	0.972	0.997	0.976	1.000	0.997	0.972	0.993
$\beta: 5^{th}$ percentile	-0.039	-0.130	-0.032	-0.077	-0.026	-0.044	-0.014	-0.028	0.002	0.016
β : Median	0.315	0.235	0.283	0.214	0.271	0.201	0.252	0.185	0.217	0.196
$\beta: 95^{th}$ percentile	0.587	0.724	0.493	0.428	0.415	0.396	0.389	0.373	0.367	0.353
β : Fraction positive	0.940	0.862	0.934	0.885	0.924	0.917	0.931	0.934	0.948	0.969
β : Fraction significant at $\alpha = 0.05$	0.738	0.588	0.708	0.563	0.649	0.514	0.448	0.413	0.330	0.458
$\lambda: 5^{th}$ percentile	-0.003	-0.004	-0.003	-0.003	-0.003	-0.004	-0.003	-0.003	-0.003	-0.003
λ : Median	0.000	0.005	0.001	0.006	0.001	0.007	0.003	0.008	0.005	0.008
$\lambda: 95^{th}$ percentile	0.021	0.028	0.020	0.027	0.017	0.027	0.018	0.026	0.020	0.025
λ : Fraction positive	0.539	0.708	0.538	0.715	0.545	0.670	0.514	0.580	0.521	0.524
λ : Fraction significant at $\alpha = 0.05$	0.210	0.412	0.271	0.483	0.219	0.510	0.233	0.451	0.250	0.476
$\gamma: 5^{th}$ percentile	-0.375	-0.139	-0.268	-0.044	-0.229	-0.026	-0.207	-0.022	-0.083	0.048
γ : Median	0.050	0.087	0.083	0.113	0.092	0.140	0.100	0.136	0.224	0.218
$\gamma: 95^{th}$ percentile	0.428	0.570	0.461	0.495	0.439	0.538	0.423	0.506	0.603	0.566
γ : Fraction positive	0.659	0.746	0.708	0.840	0.747	0.896	0.781	0.920	0.906	0.972
γ : Fraction significant at $\alpha = 0.05$	0.180	0.296	0.236	0.396	0.219	0.469	0.066	0.264	0.344	0.677
R^2									0.540	0.581
Convergence ratio	0.927	0.903	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fraction rejections at $\alpha = 0.05$ of Hansen J-test	0.000	0.008	0.010	0.042	0.104	0.247	0.073	0.080		
Fraction rejections at $\alpha = 0.05$ of the F homogeneity test	0.229	0.156	0.212	0.139	0.222	0.149	0.337	0.167	0.417	0.163
Number of Phillips Curves estimated	288	288	288	288	288	288	288	288	288	288

Note: Table presents the summary statistics for the parameters of the hybrid NKPC across specifications with different estimation routines on two vintage datasets. The model is of the form: $\pi_t = \mu + \rho\pi_{t-1} + \beta x_{t-1} + \gamma\pi_t^e + \lambda\pi_{t-1}^i + \epsilon_t$, *where:* π *is inflation,* μ *is a constant term,* x *is a measure of economic slack,* π^e *is an inflation expectation measure and* π^i *is a measure of imported inflation. Baseline set of instruments is used. Dependent variable is proxied by the HICP core inflation (seasonally and indirect-tax adjusted HICP inflation excluding food, energy, tobacco and alcohol). 'I' denotes the sample spanning the period 2002Q1-2011Q4, 'II' denotes the sample spanning the period 2002Q1-2015Q3.*
Source: own calculations.

Phillips curve–the fraction rejections of the Hansen J-test at significance level $\alpha = 0.05$ does not exceed 0.1 (with the exception when the GMM TWO-STEP method is used on the data spanning the period 2002Q1-2011Q4)[5].

A more disaggregate analysis can be conducted based on Figure 2. Each plot illustrates the changes in the Phillips curve reduced-form parameters between samples, where each point on the graph represents a pair of coefficients. The first coordinate resembles a respective reduced-form parameter of the hybrid NKPC in the sample 2002Q1-2011Q4, whereas the second coordinate reflects a reduced-form parameter in the sample 2002Q1-2015Q3. Apart from a 45-degree line drawn to illustrate the no-change border, a fitting procedure through the cloud of points described in section 3 is conducted and regression results are printed in the top-left corner of the graphs (the parameter κ relating the parameters from the second sample to the ones from the first sample). Moreover, as different economic slack, imported inflation and inflation expectations measures are distinguished with different colors, specifications signaling increase and decrease between samples can be easily isolated.

The results illustrate that during the disinflation period in the Polish economy the influence of the domestic real activity on price developments has diminished. The parameter β gauging the slope of the Phillips curve is on average around 39% smaller across specifications in the second sample than in the first sample. Moreover, after adjusting for heteroscedastic errors, the decrease is statistically significant at $\alpha = 0.05$. In specifications relying mostly on real GDP and output gaps as a proxy for marginal costs the slope parameter β crosses the 45-degree line in the second sample indicating a slight steepening of the Phillips

[5] From the technical point of view, in limited number of cases the GMM CUE failed to converge or produced large estimates in absolute values due to the fat tail property of this estimator. This resulted also in broader 90% interquantile ranges for the estimated parameters. Moreover, in some cases the median of the estimates obtained via the GMM TSLS are slightly biased towards the OLS estimates.

curve. However, estimates from hybrid Nkpc specifications with slack measures based on the information from the labor market (with the exception of unemployment gap indicating mostly no change in the steepness of the Nkpc slope) only reluctantly exceed the 45-degree line. This might be explained by the recently observed divergence between the situation on the labor market and in the whole economy. After 2011 economic growth in Poland has considerably slowed down, rebounded after 2013Q2 and has been fairly stable since 2014Q1. On the other hand, unemployment rate revealed much lower variation after 2011 and has been systematically falling since 2013Q2. As this decoupling of labor market conditions from the domestic economic activity proceeds, Phillips curve with slack measure based on information from labor market may reveal stronger flattening effect. Taking into account all specifications, on average the slope estimates β are smaller in full sample and across specifications a flattening can be advocated.

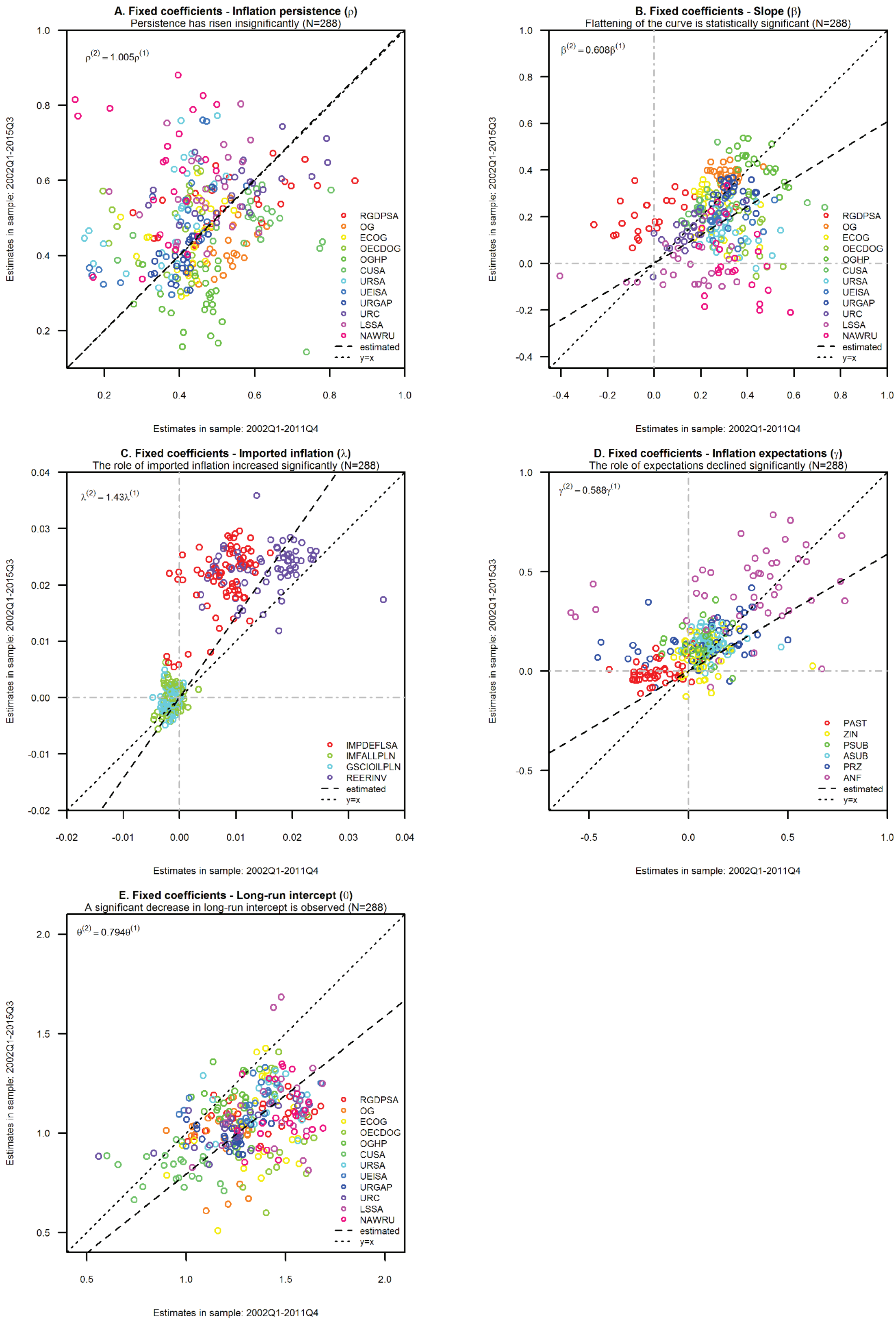
In the disinflation period the inflation persistence has been stable, rising only insignificantly. Moreover, no clear pattern for the behavior of ρ across specifications can be observed here. Further, in majority of specifications the coefficient measuring the influence of the imported inflation has risen considerably (on average by more than 40%), and the change is proved to be statistically significant. This change is observed mostly in specifications with the import price deflator and the real effective exchange rate. This constitutes an important conclusion for the small open economy signaling the growing openness and connectedness to the external environment, which results in higher sensitivity of inflation measure to foreign factors. The role of inflation expectations in driving inflation has recently diminished. Interestingly, almost all coefficients with past inflation as an inflation expectations measure enter the Phillips curve equation with the negative sign. This could imply a mean-reverting property of inflation–an increase in past inflation leads to the decrease in current inflation rate. Finally, due to the decline in average inflation expectations the long-run intercept of the Phillips curve, which can be perceived as a measure of trend inflation, has also decreased and the change is statistically significant.

In order to check whether these results are robust to the influential observations I exclude the impact of outliers by estimating again the simple equations on a set of estimates corresponding to these Nkpc specifications, which slope coefficient β lies within the 90% interquantile range of all slope coefficients in the whole sample. Therefore, a relation of 258 coefficients of hybrid Nkpc between samples is considered. The outcomes indicate that there is very little variation in the estimated κ coefficients with respect to the non-trimmed sample and the conclusions remain the same – a flattening of the Phillips curve is statistically significant as well as the impact of external factors becomes stronger. Detailed results are available on request.

The findings are robust also to different sets of instruments and inflation measures. Table 2 summarizes the changes in the coefficients estimated between analyzed samples for all studied inflation measures and different instrument sets. The hybrid Nkpc coefficients are estimated via Iterative Gmm method. In the table κ coefficients have been reported along with their standard deviations and the outcome of the one-sided t-test.

The results are broadly stable across all inflation measures and point to the decrease in the slope of the hybrid Nkpc. Moreover, quantitatively the parameter κ does not change much across different sets of instruments for all the hybrid Nkpc parameters with two exceptions. One, imported inflation coefficient of the hybrid Nkpc with inflation measures including indirect tax changes fall significantly between samples, whereas for the tax-adjusted measure, the role of imported inflation increases throughout time. Two, the role of inflation expectations rises for the broad inflation measures, when second alternative set of instruments is employed. In other specifications the impact of inflation expectations on actual inflation declines. Overall, reduced-form parameters decline during the disinflation period. This could suggest that a factor not accounted in the specification of the hybrid Nkpc currently governs the inflation dynamics.

Figure 2: Change of the hybrid NKPC parameters between the samples for the core inflation as the dependent variable



Note: Parameters estimated using Iterative GMM. Core inflation stands for the seasonally adjusted HICP inflation excluding energy, food, alcohol and tobacco (constant taxes).
Source: Own calculations.

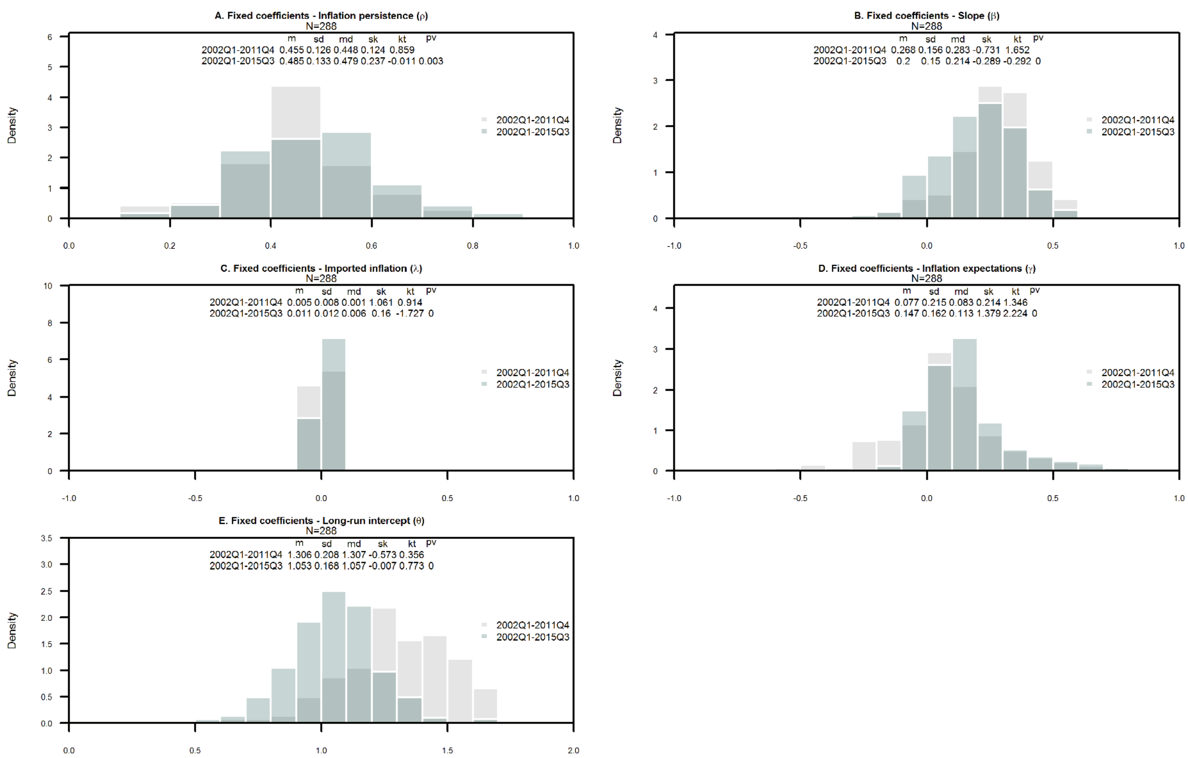
Table 2: Changes of the Phillips curve coefficients between samples with respect to the inflation measure and instruments sets

Set of instruments:	Change in:	HICPCTSA		HICPXEFATCTSA		HICPSA		HICPEFATSA		CPISA		CPIXEFSA	
BASELINE	ρ	0.928 (0.056)	– *	1.005 (0.020)	+	0.970 (0.023)	– *	0.783 (0.018)	– ***	0.771 (0.027)	– ***	0.853 (0.020)	– ***
	β	0.413 (0.044)	– ***	0.608 (0.035)	– ***	0.499 (0.063)	– ***	0.324 (0.064)	– ***	0.376 (0.046)	– ***	0.880 (0.060)	– **
	λ	1.125 (0.022)	+ ***	1.430 (0.103)	+ ***	0.861 (0.024)	– ***	0.715 (0.019)	– ***	0.917 (0.023)	– ***	0.595 (0.022)	– ***
	γ	0.881 (0.035)	– ***	0.588 (0.074)	– ***	0.778 (0.045)	– ***	0.395 (0.015)	– ***	0.717 (0.044)	– ***	0.622 (0.022)	– ***
	θ	0.681 (0.006)	– ***	0.794 (0.008)	– ***	0.656 (0.007)	– ***	0.581 (0.015)	– ***	0.699 (0.007)	– ***	0.763 (0.007)	– ***
ALTERNATIVE I	ρ	0.556 (0.070)	– ***	0.923 (0.020)	– ***	0.894 (0.024)	– ***	0.726 (0.021)	– ***	0.713 (0.038)	– ***	0.769 (0.024)	– ***
	β	0.452 (0.044)	– ***	0.714 (0.037)	– ***	0.502 (0.068)	– ***	0.462 (0.052)	– ***	0.401 (0.044)	– ***	0.760 (0.056)	– ***
	λ	1.077 (0.022)	+ ***	1.318 (0.117)	+ ***	0.739 (0.026)	– ***	0.732 (0.020)	– ***	0.810 (0.026)	– ***	0.501 (0.026)	– ***
	γ	0.815 (0.049)	– ***	0.481 (0.063)	– ***	0.809 (0.047)	– ***	0.435 (0.042)	– ***	0.691 (0.042)	– ***	0.628 (0.024)	– ***
	θ	0.667 (0.008)	– ***	0.696 (0.026)	– ***	0.662 (0.009)	– ***	0.555 (0.039)	– ***	0.708 (0.007)	– ***	0.738 (0.011)	– ***
ALTERNATIVE II	ρ	0.880 (0.024)	– ***	1.023 (0.010)	+ ***	0.904 (0.012)	– ***	0.780 (0.013)	– ***	0.730 (0.014)	– ***	0.924 (0.015)	– ***
	β	0.442 (0.065)	– ***	0.579 (0.046)	– ***	0.339 (0.043)	– ***	0.322 (0.065)	– ***	0.342 (0.044)	– ***	0.663 (0.032)	– ***
	λ	1.237 (0.019)	+ ***	1.511 (0.048)	+ ***	1.130 (0.029)	+ ***	0.921 (0.019)	– ***	1.210 (0.029)	+ ***	0.317 (0.058)	– ***
	γ	1.126 (0.063)	+ **	0.963 (0.032)	–	1.103 (0.055)	+ **	0.629 (0.019)	– ***	1.106 (0.038)	+ ***	0.624 (0.040)	– ***
	θ	0.721 (0.004)	– ***	0.834 (0.005)	– ***	0.713 (0.004)	– ***	0.636 (0.006)	– ***	0.752 (0.004)	– ***	0.807 (0.003)	– ***

*Note: In the table κ estimates from simple regressions are given along with their standard deviations calculated using the Newey-West HAC estimator (in parentheses). '-' denotes a decrease in coefficients between samples, whereas '+' denotes an increase in coefficients between samples. A one-sided test has been conducted to establish the significance of the change. Under the $H_0 : \kappa = 1$. *** denotes significant change at $\alpha = 0.01$, ** denotes significant change at $\alpha = 0.05$ and * denotes significant change at $\alpha = 0.1$ significance level. Results are presented for hybrid NKPC parameters identified using a baseline and two alternative sets of instruments described in Section 3 and obtained using the GMM ITERATIVE estimator.*
Source: own calculations.

Next, I analyze the changes to the cross-sectional distributions of the hybrid NKPC parameters. Figure 3 illustrates overlaying histograms of the reduced-form coefficients between samples for the whole cross-section. Elementary statistics and p-value corresponding to a one-sided t-test for the equality of mean are provided as well.

Figure 3: Distribution of the hybrid NKPC parameters between the samples for the core inflation as the dependent variable



Note: Parameters estimated using Iterative GMM. Core inflation stands for the seasonally adjusted HICP inflation excluding energy, food, alcohol and tobacco (constant taxes).
Source: Own calculations.

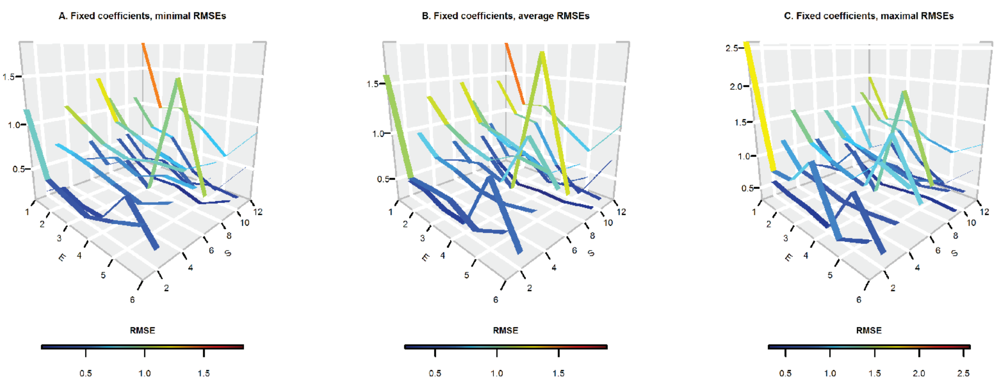
The distribution of the intrinsic inflation persistence ρ in the full sample moves marginally to the right with

respect to the first sample, but the increase in its mean is statistically significant at $\alpha = 0.05$ significance level. On the other hand, the distribution slope coefficient β in the full sample has a stronger negative skew as the fraction of the β parameters approaching zero increases. A one-sided t-test for the equality of means confirms the flattening of the Phillips curve. The mean estimate of the parameter λ gauging the influence of imported inflation and the inflation expectations parameter γ approximately double between samples. Moreover, in the case of parameter γ the distribution becomes more positively skewed, as the fraction of negative parameters fades out to the benefit of the center of the parameter's distribution in the whole sample[6]. Finally, the distribution of the long-term intercept of the Phillips curve shifts to the right in the full sample and the parameter θ becomes more evenly distributed.
The conclusions hold once the parameters set is restricted to contain the specifications with the parameter β within its 90% interquantile range.

4.4.2. Determinants of the disinflation period in Poland - a hybrid NKPC perspective

In this section I discuss the forecasting performance of the hybrid NKPC during the disinflation period in Poland. Based on the results of this exercise I infer about the determinants of the Polish low inflation. I adopt the conditional forecasts methodology described in Section 3. Core inflation is the forecast variable. RMSE statistics are calculated between the forecast inflation rate the actual core inflation throughout the forecast horizon 2012Q1-2015Q3.

Figure 4: Root mean square errors of the NKPC-implied conditional forecasts for core inflation



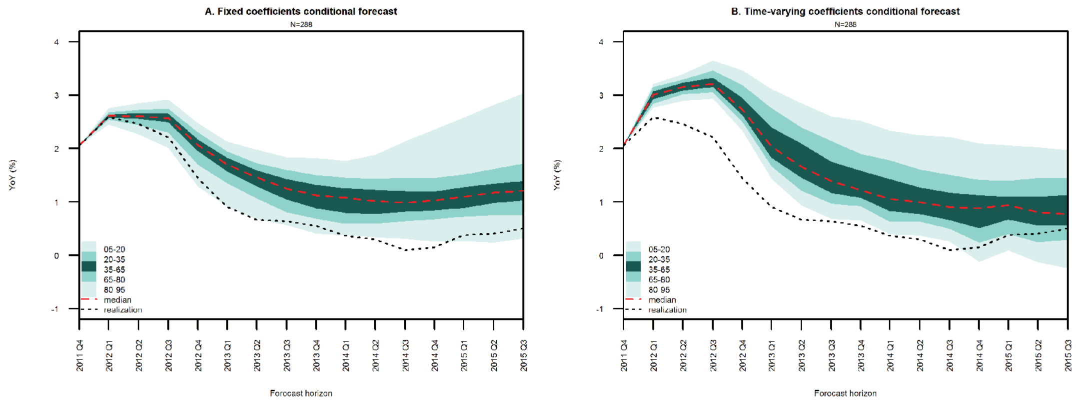
Note: Plots present the RMSEs of the conditional forecasts in a fixed-coefficient approach depending on the slack measure (axis S) and inflation expectations measure (axis E) calculated as a root of the averaged squared error between the forecast and realized values over all horizons. The numbers on both axes represent subsequent measures according to the order of appearance in the text. Minimal, average and maximal errors are reported due to the fact these errors are not averaged across the dimension of external factors. Core inflation stands for the seasonally adjusted HICP inflation excluding energy, food, alcohol and tobacco (constant taxes).
Source: Own calculations.

Figure 4 illustrates the RMSE of various specifications of the hybrid NKPC for core inflation. The best performing model includes unemployment gap, import price deflator and firm's inflation expectations. Regardless the inflation expectations and imported inflation measure the forecasts based on the unemployment gap tend to have lowest error statistics. Using past inflation as an inflation measures generates high errors, while the use of inflation expectations of professional forecasters generally delivers mixed results. In general, the forecasting ability is sensitive to the choice of slack measure. Additional analysis for other inflation measures reveal that while using past inflation delivers substantial errors, the use of survey-based methods lead to the substantial decrease of errors, but no apparent pattern is observed.

[6]This could produce confusion with the previous results, but actually here the test evaluates the change in the mean of the distribution, whereas the κ coefficient reported the average change of the parameters between samples.

Table B.7 provides the minimal error statistics across different inflation measures, economic slack and inflation expectations. Broadly speaking, for four out of six inflation measures the forecast which includes information about the development of the real GDP and the survey-based inflation expectations proves to mimic the inflation dynamic most closely. However, the use of unemployment gap delivers only slightly worse results. Therefore, it can be concluded that the developments in the real economy measured either by the real GDP or the unemployment gap have not exerted enough pressure on prices recently, contributing to the disinflation period in Poland. However, more structural analysis is required here to disentangle influence of inadequate demand and global factors on domestic inflation.

Figure 5: Hybrid NKPC conditional forecast of the annual core inflation in Poland



Note: For a fixed-coefficient approach parameters estimated using Iterative GMM in the first sample and used along with the realized paths of economic slack, external factors and inflation expectations to produce dynamics forecast. For a time-varying approach similar exercise has been conducted but the NKPC parameters in the forecast horizon equal to the estimated ones at 2011Q4 (the methodology behind the time-varying approach is discussed in more detail in the next section while forecast results are presented here for clarity of comparison). Core inflation stands for the seasonally adjusted HICP inflation excluding energy, food, alcohol and tobacco (constant taxes).
Source: Own calculations.

Finally, Figure 5 illustrates the cross-section distribution of all hybrid NKPC forecasts aggregated into fancharts using the percentile method. Median forecasts (red line), subsequent percentiles of the forecast distribution and the realization (dashed black line) are presented for fixed-coefficient and time-varying coefficient approach. The graphs illustrate that the conditional forecasts implied by the 2002Q1-2011Q4 parameters and the 2012Q1-2015Q3 data overshoot inflation and the median forecast lies above the realization of inflation throughout the forecasting horizon. In the fixed-coefficient approach the realized inflation lies within the 5^{th} and the 20^{th} percentile of the forecast distribution, whereas the path implied by the time-varying Phillips curve converges at the end of the forecasting period towards the actual inflation rate. Importantly, the path of forecast inflation does not pick up during the rebound of economic growth in Poland, which could indicate an insufficient pressure exerted by the demand side on prices in the environment of low commodity prices.

5. Robustness check

For robustness check I estimate a time-varying stochastic volatility version of the hybrid Nkpc (Tvp-Nkpc). I base this robustness check on the exercise conducted by the ECB (2016) with minor modifications. Equation (4) specifies the model[7].

$$\pi_t = \mu_t + \rho_t \pi_{t-1} + \beta_t x_{t-1} + \gamma_t \pi_t^e + \lambda_t \pi_{t-1}^i + e^{\frac{h_t}{2}} \epsilon_t \tag{4}$$

The evolution of the time-varying parameters of the model is given by independent Rw processes:

$$\begin{aligned} \mu_t &= \mu_{t-1} + \sigma_\mu \nu_t^\mu \\ \rho_t &= \rho_{t-1} + \sigma_\rho \nu_t^\rho \\ \beta_t &= \beta_{t-1} + \sigma_\beta \nu_t^\beta \\ \gamma_t &= \gamma_{t-1} + \sigma_\gamma \nu_t^\gamma \\ \lambda_t &= \lambda_{t-1} + \sigma_\lambda \nu_t^\lambda \\ h_t &= h_{t-1} + \sigma_h \eta_t \end{aligned} \tag{5}$$

In this approach, the hybrid Nkpc coefficients and the log-volatility vary over time and follow a unit root process with structural breaks and unobserved shocks ν_t^μ, ν_t^ρ, ν_t^β, ν_t^γ, ν_t^λ, η_t.
To estimate the equation I employ Bayesian methods – a of Gibbs sampler similar to the one developed by Primiceri (2005). A priori, the constant parameters of the model – the variances of the transition equation – follow Inverse Gamma distributions given by equation (6).

$$\begin{aligned} \sigma_\nu^2 &\sim IG(5, 0.005) \\ \sigma_\rho^2 &\sim IG(5, 0.005) \\ \sigma_\beta^2 &\sim IG(5, 0.005) \\ \sigma_\gamma^2 &\sim IG(5, 0.005) \\ \sigma_\lambda^2 &\sim IG(5, 0.005) \\ \sigma_h^2 &\sim IG(5, 0.5) \end{aligned} \tag{6}$$

A priori, I assume the variation of the coefficients is to be equally small, while allowing the log-volatility process to capture the most variation. Such parametrization allows the data to establish the necessity of using time-varying structural coefficients. I use diffuse priors for initial conditions of the transition equation to initialize the smoothing algorithm extracting the latent states of the model (Carter and Kohn, 1994).
I estimate the time-varying Phillips curve in the whole sample for the specification yielding the lowest Rmse of the conditional forecast in the fixed-coefficient approach. Along with the median estimates, I report $16, 25, 75$ and 84 credibility bands. While calculating conditional forecasts in the Tvp approach, I set the parameters in the forecasting horizon to the observed ones at the end of the first sample period.
The results imply that the forecast from the hybrid Nkpc based on the unemployment gap, import price deflator and firm's inflation expectations[8] has followed core inflation dynamics over the forecasting period most closely achieving a Rmse of 0.13. Therefore, this specification will be considered now.
Figure 6 illustrates the time-varying coefficients of the Tvp-Nkpc for the Polish economy and Table 3

[7] In the time-varying approach the long-term intercept of the Phillips curve in the two samples is calculated as follows: $\theta_t = \frac{\mu_t}{1-\rho_t} + \frac{\gamma_t}{1-\rho_t}\bar{\pi}^e$, where: t denotes the parameter at time t and $\bar{\pi}$ denotes the average level of inflation expectation measure over the whole sample.

[8] The use of firm's inflation expectations has also been recently encouraged by Łyziak (2016), who shows that firm's inflation expectations is the best-performing forecasting measure in a small New Keynesian model of monetary policy.

contrasts the time-invariant coefficients estimated in the full sample and the average of the median time-varying coefficients during the excessive disinflation period of 2012Q1-2015Q3 for the RMSE-minimizing specification.

In this approach a systematic, but only slight flattening of the Phillips curve can be observed after the outburst of the financial crisis. However, the modest decline in the parameter β_t is accompanied by a significant amount of uncertainty. The average of the median estimate of the β_t throughout 2012Q1-2015Q3 signals a weaker connection between inflation and domestic economic slack than in the case of fixed coefficient approach. The same conclusion holds for the parameter ρ_t. Throughout the estimation period the intrinsic inflation persistence ρ_t has gradually declined. The estimates of the imported inflation are volatile but increase during strong upswings in commodity prices and correlate closely with the annual growth rate of the import price deflator. The average median of the parameter λ_t during 2012Q1-2015Q3 is similar to the fixed coefficient λ estimated on the full sample. The role of inflation expectations γ in shaping the inflation developments after slowly rising, remains in the recent period stable. Interestingly, in the TVP approach the model estimates the impact of the inflation expectations to be more than twice as strong. The long-run intercept of the Phillips curve does not reveal a lot of volatility, however, the uncertainty around the median is vast in the beginning of the sample. Finally, stochastic volatility generally declines throughout the sample, although during the financial crises it remained elevated.

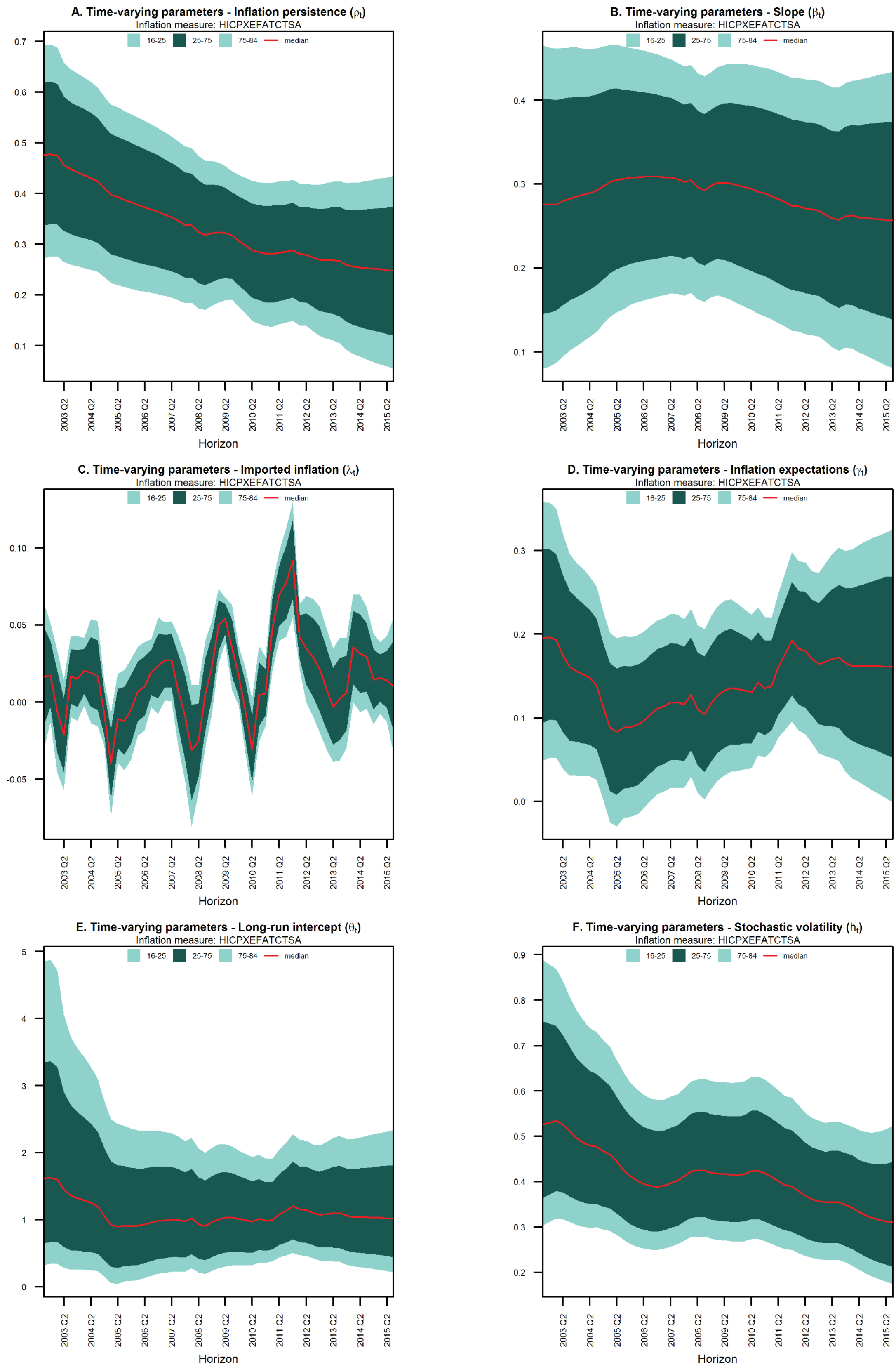
Table 3: Comparison of the fixed-approach and time-varying parameters of the hybrid NKPC minimizing the RMSE over the forecast period

	μ	ρ	β	λ	γ
fixed coefficients	0.422	0.389	0.344	0.018	0.073
time-varying coefficients	0.378	0.262	0.262	0.019	0.167

Note: Table presents the comparison between the hybrid NKPC *coefficients in the time-invariant approach and the average of the median of the time-varying coefficients during 2012Q1-2015Q3. The fixed-coefficient model is of the form:* $\pi_t = \mu + \rho\pi_{t-1} + \beta x_{t-1} + \gamma\pi^e_t + \lambda\pi^i_{t-1} + \epsilon_t$. *Baseline set of instruments and the* GMM ITERATIVE *estimation technique is employed. The time-varying parameters model is of the form:* $\pi_t = \mu_t + \rho_t\pi_{t-1} + \beta_t x_{t-1} + \gamma_t\pi^e_t + \lambda_t\pi^i_{t-1} + \epsilon_t$. *For both models* π *is core inflation,* μ *is a constant term,* x *is unemployment gap,* π^e *is firm's inflation expectation and* π^i *is import price deflator. In the estimation process sample 2002Q1-2015Q3 has been employed.*
Source: own calculations.

By investigating the median estimates on Figure 6 and the average parameters over the forecast period in Table 3, one can state that the conclusions remain broadly in line with the results obtained in a fixed-coefficient analysis–in both approaches a flattening of the Phillips curve is observed. However, the significant uncertainty accompanying the median estimate of slack parameter in a time-varying approach urges to take these results with a pinch of salt. Moreover, whereas in the fixed-coefficient framework the inflation persistence does not change significantly, in the time-varying approach is quite substantially declines in time. The time-varying approach illustrates also the dynamically changing, almost cyclic and closely correlating with the annual growth rate of import price deflator, influence of external factors–an important driver of inflation in small open economies. This implies that domestic inflation in small, open economy is heavily dependent on the imported inflation and its impact varies considerably in time. Additionally, the impact of inflation expectations is expected to be greater, when a TVP analysis is conducted.

Figure 6: Change of the hybrid NKPC parameters estimated using TVP approach for the core inflation as the dependent variable



Note: Core inflation stands for the seasonally adjusted HICP inflation excluding energy, food, alcohol and tobacco (constant taxes).
Source: Own calculations.

6. Conclusion

In the paper I have established the changes to the hybrid Nkpc reduced-form parameters in an emerging, small open economy and provided an explanation for the abrupt disinflation process and a protracted period of low inflation from the Phillips curve perspective. For that purpose I have based my analysis on the Polish data. By estimating a variety of a priori equally plausible Phillips curves on two vintage datasets using different sets of instruments and estimation routines I have conveyed the substantial specification uncertainty surrounding the estimation of the Phillips curve. By analyzing the cross-section of the hybrid Nkpc parameters I have inferred about the changes of parameters during the disinflation period in Poland. I have focused my attention mainly on the ongoing debate concerning the flattening of the Phillips curve across economies, but discussed also changes in the intrinsic persistence of inflation, as well as the role of imported inflation and inflation expectations in shaping inflation developments. In order to isolate the determinants of the low inflation period I have exploited the conditional forecasts approach to determine, whether at least ex-post Phillips curve is a sufficient economic tool to explain the recently observed price dynamics.

Several important conclusion for the monetary policy conduct can be adduced from the paper. Firstly, there is ample evidence pointing to the significance of the Phillips curve flattening during the disinflation period in the Polish economy. Therefore, this process is not exclusive for highly developed countries, but may materialize in small open economies as well. Although a statistically significant relationship between inflation and the developments in the Polish real economy persists, the magnitude of this link has in the recent period of low inflation weakened. In the protracted period of deflation the inflation persistence has not changed, but the impact of imported inflation on core measure has significantly strengthened. Importantly, this conclusion is robust to changes in the estimation methods, sets of instruments and Phillips curve specifications. Secondly, the Phillips curve should still be considered as a valid economic tool linking the relation of price developments to the adjustments in the Polish economy. The ex-post forecasts indicate that although inflation rates implied by the Phillips curve are generally upwardly biased, some specifications (e.g. ones that include unemployment gap, import price deflator and firm's inflation expectations) still manage to follow closely the realized inflation path during the ongoing low inflation period in Poland. Thirdly, for forecasting purposes the use of unemployment gap or the real Gdp should be beneficial to the furthest extent.

The flattening of the Phillips curve may pose a substantial puzzle for monetary policy. In the environment of robust economic growth and constant improvements in the labor market, the flattening of the Phillips curve may highlight the inadequacy of the pressure exerted on prices by the demand side as well as high nominal rigidities. If inflation will continue to adjust only partially and with a high degree of uncertainty to inflationary pressure stemming from high resource utilization in the economy and protracted period of low inflation will persist, several questions arise. Should the monetary policy horizon be prolonged to better account for extensive periods of economy imbalances as postulated by Carney (2013)? Will allowing for prolonged periods of inflation deviation from its target for stabilization purposes (Weber, 2015) influence the central bank's credibility and lead to inflation expectations deanchoring? If inflation responds marginally to robust macroeconomic conditions, could it be the case that only large movements of output will counterbalance high inflation in the future? These questions remain open to debate.

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A. Data

Table A.1: Abbreviations used along with their expansions and additional information.

Variable	Expanded abbreviation and additional informations
Hicpctsa	HICP inflation (seasonally and indirect-taxes adjusted)
Hicpxefatctsa	HICP inflation excluding energy, food, alcohol and tobacco (seasonally and indirect-taxes adjusted)
Hicpsa	HICP inflation (seasonally adjusted)
Hicpefatsa	HICP inflation excluding energy, food, alcohol and tobacco (seasonally adjusted)
Cpisa	CPI inflation (seasonally adjusted)
Cpixefsa	CPI inflation excluding food and energy (seasonally adjusted)
Rgdpsa	Real GDP (seasonally adjusted)
Og	Output gap (Narodowy Bank Polski's estimates)
Ecog	Output gap (European Commision's estimates)
Oecdog	Output gap (OECD's estimates)
Oghp	Output gap (Hodrick-Prescott cycle's estimates)
Cusa	Capacity utilization (seasonally adjusted)
Ursa	Unemployment rate (seasonally adjusted)
Ueisa	Underemployment index (seasonally adjusted)
Urgap	Unemployment gap
Urc	Unemployment recession gap
Lssa	Labor share (seasonally adjusted)
Nawru	Non-accelerating wage rate of unemployment (Narodowy Bank Polski's estimates)
Impdeflsa	Import price deflator (seasonally adjusted)
Imfallpln	IMF all commodities index (denominated in Polish zloty)
Gscioilpln	GSCI Oil price index (denominated in Polish zloty)
Reerinv	Real effective exchange rate (increase means a depreciation, BIS data)
Past	Past inflation (average headline inflation over past four quarters)
Zin	Objectived measure of consumer inflation expectations
Psub	Subjectived measure of consumer inflation expectations
Asub	Alternative subjectived measure of inflation expectations
Prz	Firm's inflation expectations
Anf	Inflation expectations of professional forecasters

Source: own elaboration.

B. Estimation results

Table B.1: Summary statistics for the estimation of the hybrid NKPC for seasonally adjusted HICP inflation (constant taxes)

	Gmm Cue		Gmm Iterative		Gmm Two-Step		Gmm Tsls		Ols	
Statistic	I	II	I	II	I	II	I	II	I	II
ρ : 5^{th} percentile	-0.524	-0.245	-0.260	0.035	-0.129	0.063	-0.019	0.079	-0.092	-0.055
ρ : Median	0.101	0.262	0.126	0.243	0.107	0.221	0.158	0.205	0.082	0.122
ρ : 95^{th} percentile	0.451	0.593	0.467	0.581	0.373	0.542	0.368	0.519	0.299	0.436
ρ : Fraction positive	0.705	0.868	0.778	0.986	0.781	1.000	0.927	1.000	0.847	0.872
ρ : Fraction significant at $\alpha = 0.05$	0.251	0.390	0.243	0.389	0.132	0.358	0.069	0.205	0.024	0.149
β : 5^{th} percentile	-0.394	-0.721	-0.196	-0.595	-0.131	-0.415	-0.115	-0.294	-0.120	-0.167
β : Median	0.672	0.365	0.496	0.215	0.429	0.202	0.399	0.218	0.259	0.192
β : 95^{th} percentile	1.737	1.021	1.048	0.881	0.937	0.843	0.796	0.778	0.549	0.654
β : Fraction positive	0.802	0.732	0.868	0.639	0.913	0.663	0.903	0.733	0.872	0.726
β : Fraction significant at $\alpha = 0.05$	0.573	0.469	0.389	0.375	0.292	0.344	0.233	0.299	0.045	0.170
λ : 5^{th} percentile	-0.004	-0.003	0.001	0.001	0.002	0.001	0.002	0.002	0.001	0.000
λ : Median	0.017	0.017	0.022	0.031	0.019	0.026	0.019	0.023	0.021	0.022
λ : 95^{th} percentile	0.065	0.097	0.074	0.078	0.059	0.065	0.054	0.059	0.043	0.049
λ : Fraction positive	0.877	0.917	0.958	0.965	0.990	0.976	0.993	0.965	0.972	0.958
λ : Fraction significant at $\alpha = 0.05$	0.529	0.526	0.583	0.531	0.559	0.521	0.465	0.531	0.358	0.538
γ : 5^{th} percentile	-0.879	-0.105	-0.737	-0.042	-0.639	-0.021	-0.506	0.026	-0.161	0.157
γ : Median	0.455	0.487	0.407	0.558	0.369	0.569	0.339	0.566	0.647	0.760
γ : 95^{th} percentile	3.139	1.946	2.088	2.030	2.105	2.142	1.858	2.107	1.663	1.870
γ : Fraction positive	0.665	0.912	0.736	0.931	0.795	0.931	0.799	0.972	0.896	1.000
γ : Fraction significant at $\alpha = 0.05$	0.441	0.500	0.413	0.622	0.347	0.681	0.177	0.684	0.569	0.830
R^2									0.332	0.489
Convergence ratio	0.788	0.792	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fraction rejections at $\alpha = 0.05$ of Hansen J-test	0.009	0.066	0.035	0.128	0.285	0.455	0.069	0.358		
Fraction rejections at $\alpha = 0.05$ of the F homogeneity test	0.424	0.469	0.510	0.590	0.517	0.556	0.587	0.635	0.622	0.653
Number of Phillips Curves estimated	288	288	288	288	288	288	288	288	288	288

Note: Table presents the summary statistics for the parameters of the hybrid NKPC across specifications with different estimation routines on two vintage datasets. The model is of the form: $\pi_t = \mu + \rho\pi_{t-1} + \beta x_{t-1} + \gamma\pi^e_t + \lambda\pi^i_{t-1} + \epsilon_t$, where: π is inflation, μ is a constant term, x is a measure of economic slack, π^e is an inflation expectation measure and π^i is a measure of imported inflation. Baseline set of instruments is used. Dependent variable is proxied by the HICP inflation (seasonally and indirect-tax adjusted HICP inflation). 'I' denotes the sample spanning the period 2002Q1-2011Q4, 'II' denotes the sample spanning the period 2002Q1-2015Q3.

Source: own calculations.

Table B.2: Summary statistics for the estimation of the hybrid NKPC for seasonally adjusted HICP inflation

	GMM CUE		GMM ITERATIVE		GMM TWO-STEP		GMM TSLS		OLS	
Statistic	I	II	I	II	I	II	I	II	I	II
ρ : 5^{th} percentile	-0.123	0.062	0.054	0.148	0.189	0.202	0.254	0.244	0.117	0.039
ρ : Median	0.397	0.422	0.400	0.406	0.404	0.397	0.404	0.406	0.319	0.333
ρ : 95^{th} percentile	0.810	0.787	0.659	0.738	0.667	0.740	0.635	0.737	0.605	0.698
ρ : Fraction positive	0.908	0.959	0.969	0.983	0.997	1.000	1.000	1.000	1.000	0.993
ρ : Fraction significant at $\alpha = 0.05$	0.564	0.659	0.618	0.764	0.684	0.795	0.524	0.736	0.385	0.549
β : 5^{th} percentile	-0.389	-0.552	-0.231	-0.369	-0.222	-0.362	-0.148	-0.266	-0.125	-0.186
β : Median	0.439	0.072	0.360	0.154	0.313	0.162	0.315	0.170	0.234	0.141
β : 95^{th} percentile	1.116	0.753	0.890	0.740	0.698	0.693	0.639	0.655	0.481	0.561
β : Fraction positive	0.760	0.574	0.819	0.628	0.837	0.642	0.868	0.656	0.896	0.681
β : Fraction significant at $\alpha = 0.05$	0.488	0.389	0.378	0.372	0.281	0.344	0.142	0.288	0.031	0.174
λ : 5^{th} percentile	-0.003	-0.006	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
λ : Median	0.010	0.023	0.013	0.016	0.014	0.012	0.013	0.011	0.014	0.011
λ : 95^{th} percentile	0.063	0.065	0.056	0.050	0.054	0.046	0.046	0.043	0.040	0.039
λ : Fraction positive	0.860	0.878	0.847	0.806	0.854	0.788	0.858	0.743	0.747	0.767
λ : Fraction significant at $\alpha = 0.05$	0.404	0.519	0.465	0.458	0.476	0.448	0.431	0.316	0.295	0.250
γ : 5^{th} percentile	-0.757	-0.258	-0.649	-0.088	-0.606	-0.088	-0.503	-0.073	-0.273	-0.009
γ : Median	0.442	0.420	0.433	0.459	0.407	0.483	0.357	0.469	0.637	0.766
γ : 95^{th} percentile	2.786	2.326	2.229	2.146	2.260	2.048	1.986	2.018	1.546	1.731
γ : Fraction positive	0.656	0.793	0.740	0.878	0.781	0.889	0.802	0.896	0.854	0.941
γ : Fraction significant at $\alpha = 0.05$	0.500	0.393	0.476	0.455	0.476	0.497	0.299	0.427	0.576	0.684
R^2									0.493	0.618
Convergence ratio	0.868	0.938	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fraction rejections at $\alpha = 0.05$ of Hansen J-test	0.000	0.011	0.021	0.118	0.236	0.361	0.160	0.278		
Fraction rejections at $\alpha = 0.05$ of the F homogeneity test	0.556	0.576	0.632	0.639	0.660	0.646	0.747	0.715	0.806	0.799
Number of Phillips Curves estimated	288	288	288	288	288	288	288	288	288	288

Note: Table presents the summary statistics for the parameters of the hybrid NKPC across specifications with different estimation routines on two vintage datasets. The model is of the form: $\pi_t = \mu + \rho\pi_{t-1} + \beta x_{t-1} + \gamma\pi^e_t + \lambda\pi^i_{t-1} + \epsilon_t$, where: π is inflation, μ is a constant term, x is a measure of economic slack, π^e is an inflation expectation measure and π^i is a measure of imported inflation. Baseline set of instruments is used. Dependent variable is proxied by the HICP inflation (seasonally adjusted). 'I' denotes the sample spanning the period 2002Q1-2011Q4, 'II' denotes the sample spanning the period 2002Q1-2015Q3.
Source: own calculations.

Table B.3: Summary statistics for the estimation of the hybrid NKPC for seasonally adjusted HICP inflation excluding energy, food, alcohol and tobacco prices

	GMM CUE		GMM ITERATIVE		GMM TWO-STEP		GMM TSLS		OLS	
Statistic	I	II	I	II	I	II	I	II	I	II
ρ : 5^{th} percentile	0.152	-0.010	0.243	0.103	0.319	0.258	0.338	0.286	0.313	0.231
ρ : Median	0.611	0.440	0.521	0.400	0.524	0.405	0.512	0.417	0.465	0.368
ρ : 95^{th} percentile	1.340	0.778	0.772	0.706	0.740	0.663	0.695	0.645	0.670	0.614
ρ : Fraction positive	0.984	0.947	1.000	0.986	1.000	1.000	1.000	1.000	1.000	1.000
ρ : Fraction significant at $\alpha = 0.05$	0.852	0.756	0.833	0.747	0.958	0.910	0.882	0.917	0.903	0.858
β : 5^{th} percentile	-0.400	-0.334	-0.353	-0.171	-0.256	-0.132	-0.163	-0.077	-0.095	-0.005
β : Median	0.063	0.195	0.076	0.214	0.066	0.167	0.078	0.146	0.119	0.140
β : 95^{th} percentile	0.626	0.546	0.463	0.555	0.399	0.385	0.384	0.354	0.304	0.358
β : Fraction positive	0.584	0.654	0.601	0.792	0.632	0.823	0.691	0.830	0.826	0.941
β : Fraction significant at $\alpha = 0.05$	0.208	0.425	0.188	0.462	0.160	0.313	0.066	0.201	0.038	0.198
λ : 5^{th} percentile	-0.003	-0.005	-0.003	-0.002	-0.003	-0.004	-0.003	-0.003	-0.004	-0.002
λ : Median	0.013	0.003	0.021	0.014	0.017	0.014	0.014	0.012	0.012	0.009
λ : 95^{th} percentile	0.049	0.046	0.048	0.037	0.043	0.035	0.040	0.032	0.036	0.028
λ : Fraction positive	0.840	0.594	0.740	0.667	0.677	0.681	0.632	0.625	0.642	0.632
λ : Fraction significant at $\alpha = 0.05$	0.488	0.323	0.528	0.455	0.503	0.500	0.497	0.465	0.455	0.344
γ : 5^{th} percentile	-0.766	-0.223	-0.325	-0.095	-0.261	-0.093	-0.284	-0.091	-0.138	-0.007
γ : Median	0.185	0.180	0.428	0.162	0.350	0.173	0.334	0.190	0.425	0.316
γ : 95^{th} percentile	1.972	0.888	1.572	0.733	1.366	0.760	1.258	0.812	0.942	0.789
γ : Fraction positive	0.660	0.801	0.823	0.813	0.830	0.847	0.826	0.844	0.858	0.927
γ : Fraction significant at $\alpha = 0.05$	0.388	0.402	0.649	0.351	0.556	0.396	0.378	0.257	0.549	0.736
R^2									0.546	0.541
Convergence ratio	0.868	0.924	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fraction rejections at $\alpha = 0.05$ of Hansen J-test	0.008	0.004	0.010	0.042	0.229	0.247	0.090	0.184		
Fraction rejections at $\alpha = 0.05$ of the F homogeneity test	0.611	0.188	0.653	0.194	0.656	0.184	0.733	0.194	0.819	0.198
Number of Phillips Curves estimated	288	288	288	288	288	288	288	288	288	288

Note: Table presents the summary statistics for the parameters of the hybrid NKPC across specifications with different estimation routines on two vintage datasets. The model is of the form: $\pi_t = \mu + \rho\pi_{t-1} + \beta x_{t-1} + \gamma\pi^e_t + \lambda\pi^i_{t-1} + \epsilon_t$, where: π is inflation, μ is a constant term, x is a measure of economic slack, π^e is an inflation expectation measure and π^i is a measure of imported inflation. Baseline set of instruments is used. Dependent variable is proxied by the HICP core inflation (seasonally adjusted HICP inflation excluding energy, food, alcohol and tobacco). 'I' denotes the sample spanning the period 2002Q1-2011Q4, 'II' denotes the sample spanning the period 2002Q1-2015Q3.
Source: own calculations.

Table B.4: Summary statistics for the estimation of the hybrid NKPC for seasonally adjusted CPI inflation

	GMM CUE		GMM ITERATIVE		GMM TWO-STEP		GMM TSLS		OLS	
Statistic	I	II	I	II	I	II	I	II	I	II
ρ : 5^{th} percentile	-0.187	0.003	-0.021	0.063	0.019	0.093	0.052	0.097	-0.069	-0.134
ρ : Median	0.228	0.257	0.297	0.278	0.319	0.274	0.311	0.235	0.185	0.142
ρ : 95^{th} percentile	0.676	0.594	0.628	0.603	0.641	0.613	0.586	0.601	0.534	0.559
ρ : Fraction positive	0.802	0.953	0.938	0.979	0.976	0.993	0.997	1.000	0.861	0.813
ρ : Fraction significant at $\alpha = 0.05$	0.360	0.433	0.396	0.538	0.458	0.542	0.271	0.243	0.170	0.163
β : 5^{th} percentile	-0.413	-0.542	-0.308	-0.392	-0.285	-0.360	-0.213	-0.319	-0.156	-0.225
β : Median	0.587	0.153	0.484	0.156	0.449	0.158	0.400	0.176	0.266	0.186
β : 95^{th} percentile	1.461	0.877	1.040	0.780	0.857	0.798	0.731	0.755	0.567	0.626
β : Fraction positive	0.830	0.582	0.868	0.635	0.878	0.660	0.892	0.656	0.875	0.681
β : Fraction significant at $\alpha = 0.05$	0.538	0.411	0.465	0.351	0.403	0.309	0.226	0.260	0.056	0.153
λ : 5^{th} percentile	-0.003	-0.003	-0.002	-0.001	-0.002	-0.003	-0.001	-0.001	-0.002	-0.001
λ : Median	0.015	0.035	0.014	0.022	0.021	0.017	0.019	0.015	0.017	0.015
λ : 95^{th} percentile	0.065	0.075	0.056	0.058	0.054	0.054	0.051	0.050	0.045	0.042
λ : Fraction positive	0.881	0.880	0.903	0.892	0.896	0.854	0.889	0.833	0.830	0.892
λ : Fraction significant at $\alpha = 0.05$	0.490	0.589	0.493	0.486	0.497	0.483	0.476	0.420	0.413	0.243
γ : 5^{th} percentile	-0.773	-0.027	-0.685	0.033	-0.621	0.007	-0.540	0.028	-0.299	0.069
γ : Median	0.429	0.596	0.458	0.629	0.433	0.660	0.454	0.697	0.917	1.028
γ : 95^{th} percentile	3.193	2.530	2.852	2.321	2.841	2.250	2.680	2.477	2.096	2.394
γ : Fraction positive	0.668	0.938	0.767	0.969	0.750	0.958	0.809	0.979	0.854	0.993
γ : Fraction significant at $\alpha = 0.05$	0.439	0.575	0.448	0.597	0.399	0.625	0.389	0.639	0.660	0.823
R^2									0.482	0.558
Convergence ratio	0.878	0.955	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fraction rejections at $\alpha = 0.05$ of Hansen J-test	0.004	0.004	0.031	0.080	0.236	0.236	0.128	0.156		
Fraction rejections at $\alpha = 0.05$ of the F homogeneity test	0.500	0.628	0.618	0.691	0.653	0.681	0.701	0.740	0.795	0.753
Number of Phillips Curves estimated	288	288	288	288	288	288	288	288	288	288

Note: Table presents the summary statistics for the parameters of the hybrid NKPC across specifications with different estimation routines on two vintage datasets. The model is of the form: $\pi_t = \mu + \rho\pi_{t-1} + \beta x_{t-1} + \gamma\pi_t^e + \lambda\pi_{t-1}^i + \epsilon_t$, *where:* π *is inflation,* μ *is a constant term,* x *is a measure of economic slack,* π^e *is an inflation expectation measure and* π^i *is a measure of imported inflation. Baseline set of instruments is used. Dependent variable is proxied by the CPI inflation (seasonally adjusted). 'I' denotes the sample spanning the period 2002Q1-2011Q4, 'II' denotes the sample spanning the period 2002Q1-2015Q3.*

Source: own calculations.

Table B.5: Summary statistics for the estimation of the hybrid NKPC forseasonally adjusted CPI inflation excluding food and energy prices

	GMM CUE		GMM ITERATIVE		GMM TWO-STEP		GMM TSLS		OLS	
Statistic	I	II	I	II	I	II	I	II	I	II
ρ : 5^{th} percentile	-0.093	0.096	-0.047	0.180	0.054	0.183	0.054	0.175	-0.025	0.038
ρ : Median	0.373	0.348	0.308	0.329	0.302	0.341	0.269	0.312	0.267	0.269
ρ : 95^{th} percentile	0.767	0.619	0.675	0.606	0.673	0.633	0.597	0.612	0.562	0.559
ρ : Fraction positive	0.921	0.978	0.934	1.000	0.979	1.000	0.983	1.000	0.885	1.000
ρ : Fraction significant at $\alpha = 0.05$	0.552	0.681	0.510	0.660	0.490	0.733	0.396	0.538	0.382	0.528
β : 5^{th} percentile	-0.132	-0.109	-0.143	-0.046	-0.149	-0.014	-0.137	-0.053	-0.112	-0.028
β : Median	0.265	0.254	0.194	0.242	0.178	0.210	0.193	0.199	0.182	0.175
β : 95^{th} percentile	0.665	0.594	0.480	0.571	0.451	0.398	0.444	0.380	0.406	0.343
β : Fraction positive	0.881	0.893	0.819	0.931	0.830	0.927	0.851	0.920	0.844	0.924
β : Fraction significant at $\alpha = 0.05$	0.412	0.559	0.313	0.556	0.240	0.438	0.194	0.358	0.115	0.243
λ : 5^{th} percentile	-0.002	-0.002	-0.001	-0.002	-0.002	-0.003	-0.001	-0.002	-0.001	0.000
λ : Median	0.007	0.002	0.008	0.005	0.008	0.006	0.008	0.006	0.008	0.007
λ : 95^{th} percentile	0.058	0.046	0.033	0.022	0.032	0.021	0.031	0.020	0.029	0.016
λ : Fraction positive	0.859	0.726	0.903	0.715	0.802	0.642	0.840	0.733	0.813	0.927
λ : Fraction significant at $\alpha = 0.05$	0.466	0.226	0.434	0.222	0.444	0.344	0.392	0.135	0.295	0.090
γ : 5^{th} percentile	-0.193	0.018	-0.242	0.057	-0.248	0.029	-0.222	0.040	-0.068	0.074
γ : Median	0.534	0.277	0.573	0.298	0.618	0.322	0.594	0.341	0.698	0.440
γ : 95^{th} percentile	1.264	1.394	1.856	1.342	1.697	1.326	1.555	1.385	1.359	1.174
γ : Fraction positive	0.895	0.959	0.865	0.993	0.858	0.986	0.865	0.990	0.910	0.997
γ : Fraction significant at $\alpha = 0.05$	0.643	0.696	0.715	0.778	0.726	0.799	0.667	0.743	0.823	0.833
R^2									0.590	0.582
Convergence ratio	0.962	0.938	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fraction rejections at $\alpha = 0.05$ of Hansen J-test	0.000	0.000	0.007	0.028	0.038	0.212	0.007	0.080		
Fraction rejections at $\alpha = 0.05$ of the F homogeneity test	0.705	0.128	0.656	0.080	0.646	0.083	0.632	0.101	0.656	0.160
Number of Phillips Curves estimated	288	288	288	288	288	288	288	288	288	288

Note: Table presents the summary statistics for the parameters of the hybrid NKPC across specifications with different estimation routines on two vintage datasets. The model is of the form: $\pi_t = \mu + \rho\pi_{t-1} + \beta x_{t-1} + \gamma\pi_t^e + \lambda\pi_{t-1}^i + \epsilon_t$, *where:* π *is inflation,* μ *is a constant term,* x *is a measure of economic slack,* π^e *is an inflation expectation measure and* π^i *is a measure of imported inflation. Baseline set of instruments is used. Dependent variable is proxied by the CPI core inflation (seasonally adjusted). 'I' denotes the sample spanning the period 2002Q1-2011Q4, 'II' denotes the sample spanning the period 2002Q1-2015Q3.*

Source: own calculations.

Table B.6: Summary statistics for the hybrid NKPC parameters with different inflation measures

		2002Q1-2011Q4			2002Q1-2015Q3			
		median	mean	std. dev.	median	mean	std. dev.	p-value
HICPCTSA	ρ	0.126	0.126	0.207	0.243	0.266	0.178	0.000
	β	0.496	0.474	0.382	0.215	0.188	0.452	0.000
	λ	0.022	0.031	0.026	0.031	0.036	0.030	0.013
	γ	0.407	0.453	0.803	0.558	0.690	0.626	0.000
	θ	2.559	2.605	0.319	1.742	1.776	0.325	0.000
HICPXEFATCTSA	ρ	0.448	0.455	0.126	0.479	0.485	0.133	0.003
	β	0.283	0.268	0.156	0.214	0.200	0.150	0.000
	λ	0.001	0.005	0.008	0.006	0.011	0.012	0.000
	γ	0.083	0.077	0.215	0.113	0.147	0.162	0.000
	θ	1.307	1.306	0.208	1.057	1.053	0.168	0.000
HICPSA	ρ	0.400	0.393	0.184	0.406	0.423	0.181	0.023
	β	0.360	0.349	0.379	0.154	0.177	0.371	0.000
	λ	0.013	0.022	0.023	0.016	0.020	0.020	0.109
	γ	0.433	0.547	0.891	0.459	0.607	0.703	0.184
	θ	2.976	2.993	0.348	2.032	1.971	0.383	0.000
HICPXEFATSA	ρ	0.521	0.501	0.159	0.400	0.401	0.177	0.000
	β	0.076	0.059	0.249	0.214	0.197	0.219	0.000
	λ	0.021	0.021	0.020	0.014	0.015	0.016	0.000
	γ	0.428	0.455	0.543	0.162	0.197	0.240	0.000
	θ	1.778	1.758	0.480	1.056	1.091	0.222	0.000
CPISA	ρ	0.297	0.301	0.197	0.278	0.291	0.157	0.258
	β	0.484	0.452	0.410	0.156	0.183	0.381	0.000
	λ	0.014	0.026	0.024	0.022	0.024	0.023	0.283
	γ	0.458	0.650	1.047	0.629	0.776	0.693	0.044
	θ	2.784	2.801	0.405	2.000	1.981	0.300	0.000
CPIXEFSA	ρ	0.308	0.320	0.211	0.329	0.346	0.129	0.039
	β	0.194	0.189	0.196	0.242	0.251	0.177	0.000
	λ	0.008	0.013	0.012	0.005	0.008	0.008	0.000
	γ	0.573	0.640	0.557	0.298	0.418	0.392	0.000
	θ	1.625	1.636	0.207	1.266	1.258	0.187	0.000

Note: Table summarizes the mean, standard deviation and median of the hybrid NKPC parameter estimates in both samples across different inflation measures. Baseline set of instruments and the GMM ITERATIVE *estimator is used. P-value corresponds to a one-sided t-test of equal means and indicates at which significance level H_0 is rejected.*
Source: Own calculations.

Table B.7: Minimal RMSE statistics from conditional forecasts across inflation, economic slack and inflation expectations measures

	Rgdpsa	Og	Ecog	Oecdog	Oghp	Cusa	Ursa	Ueisa	Urgap	Urc	Lssa	Nawru
Hicpctsa												
Past	2.665	2.005	2.937	3.183	2.359	2.515	3.763	3.427	2.457	3.108	3.781	4.133
Zin	**0.633**	1.117	1.523	1.531	1.316	1.550	1.428	1.417	1.188	1.352	1.522	1.334
Psub	0.852	0.877	1.424	1.649	1.116	1.517	1.428	1.496	0.930	1.340	1.538	1.393
Asub	**0.405**	0.728	0.982	1.006	0.966	1.127	0.910	0.919	**0.682**	0.915	0.775	1.020
Prz	**0.504**	1.078	0.806	0.982	1.867	1.409	0.948	0.847	**0.531**	0.749	0.941	0.709
Anf	1.106	1.265	1.344	1.505	1.515	1.402	1.271	1.312	0.956	0.946	0.959	1.233
Hicpxefatctsa												
	Rgdpsa	Og	Ecog	Oecdog	Oghp	Cusa	Ursa	Ueisa	Urgap	Urc	Lssa	Nawru
Past	1.164	**0.183**	0.713	1.136	0.443	0.646	1.413	1.150	0.571	0.606	1.105	1.834
Zin	0.486	0.343	0.685	0.983	0.550	0.427	0.926	0.813	0.350	0.340	0.744	0.984
Psub	0.418	0.271	0.632	0.838	0.648	0.574	0.827	0.682	**0.207**	0.398	0.672	1.029
Asub	0.357	0.282	0.561	0.772	0.542	0.355	0.700	0.611	0.223	**0.216**	0.317	0.824
Prz	0.463	0.635	0.497	0.838	0.655	1.531	0.626	0.386	**0.128**	0.296	**0.179**	0.554
Anf	0.586	0.311	0.637	0.853	0.652	0.519	0.796	0.662	0.292	0.270	0.577	0.912
Hicpsa												
	Rgdpsa	Og	Ecog	Oecdog	Oghp	Cusa	Ursa	Ueisa	Urgap	Urc	Lssa	Nawru
Past	1.930	2.184	3.401	3.728	2.411	3.006	4.143	3.610	2.559	2.906	4.644	4.517
Zin	0.718	1.235	1.954	2.971	2.132	1.921	1.668	1.845	1.485	1.988	1.515	1.604
Psub	**0.650**	1.031	1.319	1.391	1.426	1.663	1.267	1.134	1.001	1.296	1.383	1.306
Asub	**0.463**	0.721	1.169	1.072	1.388	1.577	1.047	1.021	1.215	1.214	1.297	1.028
Prz	**0.471**	0.876	0.868	0.929	1.733	1.462	0.802	0.750	**0.520**	0.908	**0.641**	0.912
Anf	0.947	0.971	1.333	1.197	1.446	1.274	1.037	1.130	1.131	1.059	1.061	0.957
Hicpxefatsa												
	Rgdpsa	Og	Ecog	Oecdog	Oghp	Cusa	Ursa	Ueisa	Urgap	Urc	Lssa	Nawru
Past	0.732	0.837	1.056	1.080	1.086	0.984	1.334	1.244	1.098	1.176	1.739	1.186
Zin	0.689	**0.452**	0.841	0.871	0.884	0.807	0.826	0.803	0.821	0.619	1.502	0.788
Psub	**0.436**	0.836	0.737	0.905	0.860	0.766	0.833	0.874	0.779	0.716	1.006	0.787
Asub	0.643	0.524	**0.435**	0.571	0.631	0.600	0.715	0.741	0.657	**0.521**	1.173	0.692
Prz	1.430	0.844	0.821	0.941	0.670	1.089	0.760	1.408	0.791	0.872	1.409	1.016
Anf	**0.412**	0.548	0.699	0.704	0.619	0.538	0.715	0.744	0.610	0.573	0.904	0.666
Cpisa												
	Rgdpsa	Og	Ecog	Oecdog	Oghp	Cusa	Ursa	Ueisa	Urgap	Urc	Lssa	Nawru
Past	0.808	1.963	3.064	3.399	2.244	2.394	3.645	3.061	2.298	2.741	4.219	4.031
Zin	**0.642**	1.280	1.763	2.097	1.348	1.647	2.054	1.974	1.260	2.026	2.343	2.076
Psub	**0.576**	0.740	1.204	1.214	1.183	1.457	1.257	1.138	0.835	1.076	1.257	1.219
Asub	**0.534**	1.024	1.248	1.316	1.008	1.028	1.448	1.316	1.095	0.967	1.429	1.326
Prz	0.828	0.943	0.801	0.818	1.354	0.841	**0.687**	0.913	**0.694**	0.762	0.913	0.867
Anf	0.876	1.188	1.357	1.263	1.427	1.269	1.007	1.182	1.156	1.276	0.964	1.109
Cpixefsa												
	Rgdpsa	Og	Ecog	Oecdog	Oghp	Cusa	Ursa	Ueisa	Urgap	Urc	Lssa	Nawru
Past	0.576	0.393	0.882	1.242	0.624	0.750	1.159	0.916	**0.337**	0.660	1.208	1.302
Zin	0.668	0.578	0.633	0.577	0.552	0.604	0.498	0.621	0.636	0.622	**0.329**	0.534
Psub	0.711	0.927	1.044	0.895	0.661	0.808	0.838	0.954	0.826	0.679	0.905	0.898
Asub	0.671	0.627	0.665	0.604	0.650	0.760	0.673	0.764	0.629	0.682	0.727	0.626
Prz	0.781	0.405	0.692	0.529	0.618	0.358	0.807	1.100	1.431	0.483	0.782	0.570
Anf	0.407	**0.358**	0.429	0.480	0.479	0.441	**0.345**	0.373	0.412	0.426	**0.280**	0.401

Note: Table summarizes the minimal RMSE statistics from conditional forecasts across different inflation, economic slack and inflation expectations measures. Forecasting horizon: 2012Q1-2015Q3. Conditional forecasts calculated for the fixed-coefficient approach by combining the hybrid NKPC parameters estimated using Iterative GMM on sample 2002Q1-2011Q4 and the information set from 2012Q1-2015Q3. Five lowest RMSEs for each inflation measure are reported in bold.
Source: own calculations.

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