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Analysing euro area inflation outlook with the Phillips curve

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Abstract

This paper presents the New Keynesian Phillips Curve (NKPC) -based framework for analysing euro area inflation outlook. Our NKPC specification, that relies on market- and survey-based inflation expectations, explains well euro area inflation dynamics. Its forecasting performance is also comparable to the performance of the ECB's official forecasts in both short- and long-horizons. Overall, the NKPC is a useful tool for monitoring euro area inflation outlook. Thanks to its fast and light updating procedure it provides almost real-time information on inflation outlook.

Keywords: euro area, inflation expectations, inflation forecasting, Phillips curve

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1. Introduction

The relationship between inflation and real variables is of crucial importance for understanding the effects of monetary policy on inflation. Short and medium -term inflation dynamics is a key issue in macroeconomics and monetary policy decision-making. The New Keynesian Phillips curve (NKPC) is nowadays the dominant approach to wage and price modelling in macroeconomics and a key relationship in modern macroeconomic models relating inflation to inflation expectations and marginal costs, which are often proxied with some measure of economic slack.

This paper discusses the identification of the Phillips curve in the euro area and its usefulness in inflation forecasting and analysing inflation outlook. First, we go through the basic Phillips curve set-up and estimate the reduced-form Phillips curve for the euro area testing different specifications of the model. We concentrate particularly on the features of different measures of inflation expectations. We then discuss more broadly on the role of expectations in the inflation dynamics and test potential endogeneity problem by estimating NKPC also with the GMM methods. We conclude that our NKPC specification estimated with the method of ordinary least squares (OLS) explains well euro-area inflation dynamics and provides information on inflation outlook. Finally, we test the real-time forecasting performance of our model and compare it both to the performance of the ECB's official forecasts and to the performance of naïve backward-looking model. We show that the NKPC is a useful tool for monitoring euro area inflation and provides important information on medium-term inflation outlook.

The Phillips curve was first introduced as a simple statistical relationship between wage growth and unemployment by Phillips (1958). Over the years this pure statistical relationship has undergone several revisions. Two key improvements to inflation modelling were behind the development of the New Keynesian Phillips Curve. First, the explicit modelling of expectations and the emphasis on forward-looking behavior in the inflation process stemming from the works of Friedman (1968), Phelps (1967), Sargent (1971) and Lucas (1972, 1976). This had important consequences for monetary policy making as it gave policy authorities new instrument to conduct monetary policy by influencing forward-looking expectations.

The second improvement in inflation modelling was the introduction of implicit price and wage optimization problems within a monopolistic environment, most often of the Dixit and Stiglitz's (1977) type model leading to staggered price and wage setting in the tradition of Fisher (1977), Taylor (1980) and Calvo (1983). New Keynesian Phillips curve based on Calvo-type pricing was versatile but theoretically consistent framework. Galí and Gertler (1999) were among the first to estimate parameter values for NKPC consistent with the microfoundations.[1]

Phillips curve have long been a popular empirical tool. However, the functional form of the Phillips curve and its precise specification remain subject to discussion. There are numerous specifications, for example using different measures of economic slack and inflation, different assumptions on the role and form of expectations, or different econometric estimation techniques. Up to date, there is still no consensus on which proxy of economic activity, inflation expectations or foreign price pressures to consider and the debate continues.[2] Especially recent episodes of missing disinflation followed by missing inflation have raised a debate about whether the Phillips curve relationship is linear or non-linear and has the curve become steeper of flatter.

Despite the controversies in the exact specification of the Phillips curve, it can still serve well as a tool to analyze and forecast inflation. Not only it is important to have a good and reasonable projection of the future inflation but from the monetary policy perspective it is also crucial that these projections have some solid theoretical grounding to evaluate the implications of monetary policy decisions. The New Keynesian Phillips curve can be used as a framework for analyzing inflation outlook and predicting the future inflation path. However, the prediction produced by the Phillips curve is in our specifications conditional on the variables used in the calculations, and therefore the selection of the exact Phillips curve specification has relevance for the analysis. Carefully formulated specification provides a simple and theoretically consistent description of inflation dynamics and inflation projections.

Various Phillips curve (PC) specifications have been used to forecast inflation. Usually different Phillips curve specifications have been compared against some naïve or statistical time series forecasts and there seems to be some consensus that Phillips curve forecasts outperform or at least do not perform consistently worse than these benchmark projections. However, Atkeson and Ohanian (2001) tested several PC forecasting models and found that none of them improved forecast performance over random walk model for US inflation. Extensive literature review (also mostly concentrating US inflation) provided by Stock and Watson (2009) conclude that overall the forecast performance of the Phillips curve strongly depend on the forecast period, the inflation series and the benchmark models. Also Stock and Watson (2010) find that the usefulness of the PC is asymmetric so that it helps forecast US inflation in downturns. Same result was reported in recent paper by Dotsey et. al. (2018).

[1] *An extensive analysis of the microfoundations of the NKPC under the standard assumption of the Calvo price setting scheme can be found e.g. in Galí (2015, Chapter 3) and Walsh (2017 pp. 378-380) among others.*

[2] *For a recent survey of the empirical literature see Mavroeidis et al. (2014)*

Turning to the euro area, Jarociński and Lenza (2018) show that the Phillips curve inflation forecasts can outperform a simple benchmark model, but the exact specification of the PC matters crucially for the forecasting performance. They find that the models including the measure of long-term inflation expectations provide better forecasts of inflation than those with a comparable set of real activity variables and excluding inflation expectations. Bereau et. al. (2018) find a lot of time instability in the forecast performance of the Phillips curve for headline inflation against univariate benchmarks. They conclude that the performance of Phillips curve forecasts is periodic. Ciccarelli and Osbat (2017) confirm that the conditional forecasts of some Phillips curve specifications capture well the latest episode of euro area disinflation. Recently, Banbura and Bobeica (2020) also conclude that there is lots of instability in forecasting ability of the most simple Phillips curve models but overall PC can offer at least minor improvements over univariate models for most of the time. In addition, they don't find any difference in forecasting performance of the Phillips curve between economic downturns or upturns. Instead, they find that PC could not forecast inflation during the run-up to the EMU and the aftermath of the sovereign debt crisis and suggest that including a time-varying inflation trend to the Phillips curve can improve the forecasting accuracy in certain periods.

We contribute to this literature by studying the NKPC's forecasting performance in real life economic monitoring and projection exercises at the Bank of Finland. Particularly, we compare its conditional projections to the naïve backward-looking forecasts and to the ECB's macroeconomic projections. In addition, we discuss and highlight the ability of measured expectations to explain medium-term inflation outlook.

We find that since 2017 the NKPC-based projections have not performed worse than the ECB's forecasts and may have even outperformed both the ECB's and naïve backward-looking forecasts. Kontogeorgos and Lambrias (2019) have recently analyzed forecasting performance of the Eurosystem/ECB projections. They focused on the projections of GDP and inflation at one quarter to two-year horizon over the period 2001Q4 – 2016Q3. Considering inflation, they find that there is no systematic bias in the projections. They also conclude that forecasts feature relatively well against simple forecasting benchmark models and against other institutions forecasts. Granziera et al. (2021) find that the ECB's forecasts are unbiased and efficient on average, but there is a tendency to overpredict (underpredict) inflation at intermediate forecast horizons when inflation is below (above) target. Overall, earlier literature shows that the ECB forecast seem to offer well-performing and unbiased benchmark for the forecast accuracy.

The paper is organized as follows. Chapter 2 discusses the challenges linked to the estimation of the NKPC and reports estimation results for different NKPC specifications. Chapter 3 and 4 extend the analysis on the role of inflation expectations and tests the possible endogeneity problem in the estimation. Chapter 5 studies the real-time performance of the NKPC projections and chapter 6 discusses the role of NKPC error term in interpreting euro area inflation outlook. Finally, chapter 7 concludes the main results of the paper.

2. Estimating New Keynesian Phillips Curve for the euro area

The New Keynesian Phillips Curve (NKPC) can be derived from the microfoundations[3] and thus, it is theory-consistent description of the inflation process. For the purposes of inflation analysis and forecasting, we apply the following reduced-form NKPC:

$$\pi_t = \alpha E_t \pi_{t+1} + \beta \widehat{y_t} + \gamma_1 \Delta p_t^{oil} + \gamma_2 \Delta p_{t-1}^{oil} + \rho_1 \Delta e_t + \rho_2 \Delta e_{t-1} + \epsilon_t. \quad (1)$$

According to the NKPC monthly inflation (π_t) is determined by the expected future inflation $E_t \pi_{t+1}$, domestic costs proxied by output gap $\widehat{y_t}$, and external factors. In the case of euro area, major external factors affecting headline inflation are monthly changes of oil prices (Δp_t^{oil}) and monthly changes of euro-dollar exchange rate (Δe_t). These factors correlate slightly with each others[4] as dollar exchange rate affects somewhat oil prices. This may complicate the identification of corresponding factors' impact on prices and therefore they should be interpreted as external control variables rather than exactly identified contributions to the consumer prices. As external factors may affect prices with some lag we add also one month lagged values to the equation. Oil prices are measured by the Brent crude price in dollars.

The forward-looking component plays a central role in the NKPC as firms take into account future price developments due to frictions in the price-setting. However, earlier literature has argued that purely forward-looking Phillips curve cannot alone catch inflation dynamics and some papers have introduced so-called hybrid version of the Phillips curve, in which inflation is affected also by the lagged term of inflation (Galí and Gertler (1999); Christiano et al. (2005)). For the comparison, we estimate also the hybrid NKPC of the form:

$$\pi_t = \alpha E_t \pi_{t+1} + \sigma \pi_{t-1} + \beta \widehat{y_t} + \gamma_1 \Delta p_t^{oil} + \gamma_2 \Delta p_{t-1}^{oil} + \rho_1 \Delta e_t + \rho_2 \Delta e_{t-1} + \epsilon_t\ . \quad (2)$$

Theoretical foundation for the backward-looking expectations can be traced to the price indexation of contracts (Christiano et al. 2005) or to the idea that part of the firms form their expectations based on some kind of rule-of-thumb that is based on realised inflation (Galí and Gertler (1999)).

Medium-term inflation expectations are affected by the level of expected future gaps but also by the degree of the credibility of central bank's inflation target. Accordingly, Christelis et al. (2020) find that trust in the European Central Bank (ECB) influences individuals' expectations and uncertainty about future inflation. Gürkaynak et al (2010) find the support for the view

[3] See for example Mavroeidis et al. (2014) for the derivation of the NKPC.
[4] Cross-correlation of monthly changes of exchange rate and oil prices is 0,36.

that explicit and credible inflation target helps to anchor inflation expectations. Beechey et al (2011) measure the degree of anchoring of expectations around inflation aim and argue that when expectations are not firmly anchored, long-run inflation expectations will be prone to revision in response to incoming news. Furthermore, Hills et al. (2019) show that even the increased probability of policy rate becoming constrained by the effective lower bound might have a downward impact on inflation expectations. Inflation expectations seem to also adapt gradually to a change in central bank's target possible due to information rigidities (Coibion & Gorodnichenko 2015) or due to the adaptive learning of central bank's inflation target.

Inflation expectations can differ greatly also depending on whose expectations are measured. Meyler & Reiche (2021) report that the consumer's average expectation has tended to be systematically above actual inflation. Surveys based on the professional forecaster's views are found to have predictable forecast errors because of sticky or noisy information (Andrade & Le Bihan 2013). Also, the prices that households face may differ from the measured prices particularly as in Europe housing prices are not included in the consumer price index. Thus, there is a possible measurement bias between true inflation expectations and measured expectations.

As discussed above inflation expectations are not directly and uniquely observed, and therefore (1) or (2) type of NKPC has been estimated with different strategies discussed detailed by Mavroeidis et al. (2014). Generally, there are three possible approaches of handling the expectations. First, it is possible to replace expectations with realised observation and apply GMM methods with appropriate instruments.[5] Second, expectations can be derived from the vector autoregressive models and third, it is possible to measure expectations directly with different time-series. We follow Roberts (1995), Adam and Padula (2011), Coibion and Gorodnichenko (2015) and Berge (2018) in using the third approach of measured expectations. Measuring expectations directly has gained popularity in recent years and is also in line with the daily monitoring practices at the central bank where measured expectations are a standard part of policy related analysis[6].

Theoretically fully consistent expectation measure would be agent's expectations for the next month's inflation. However, there are not direct measure of such expectations and we approximate expectations by using 1 year ahead expectations from the ECB's Survey of Professional Forecasters and expectations 1 year forward 1 year ahead derived from inflation swaps. For example, Coibion and Gorodnichenko (2015) apply SPF expectations whereas Berge (2018) uses also expectations from consumer survey. Alternative measures such as business and consumer surveys are not taken into analysis as these measures provide only

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[5] *This approach does not provide projection path for inflation and is thus not suitable for our purpose of analysing inflation outlook.*

[6] *See for example recent blog of Lane (2021).*

short-term inflation outlook and balance index instead of inflation number. Therefore, from those measures it is not possible to construct forecast of expectations by the law of iterative expectations (see section "Real-time performance of the NKPC projection").

Table 1 presents main estimation results for five different measures of inflation expectations. The table reports estimated parameters for both the expectations (α) and output gap (β) and the coefficient of determination (R2).[7] Estimation results are reported for the full sample (2004 June to 2020 December) and also for shorter subsamples to study possible structural changes in main parameters or in the fit.

Table 1. Estimates for different measures of inflation expectations

	2004M6-2020M12			2004M6-2012M12			2013M1-2020M12		
	expectation	output gap		expectation	output gap		expectation	output gap	
Expectations	α	β	R2	α	β	R2	α	β	R2
Equally weighted swap and SPF	0,93*	0,17*	0,64	0,89*	0,2*	0,63	0,89*	0,13*	0,63
SPF 1 year ahead	0,92*	0,19*	0,63	0,93*	0,19*	0,64	0,79*	0,14*	0,63
Swap 1 year forward 1 year ahead	0,92*	0,15*	0,63	0,85*	0,21*	0,63	1,00*	0,11*	0,64
1 month lagged inflation	0,54*	0,07	0,43	0,42*	0,18*	0,42	0,44*	-0,01	0,44
Hybrid (1 month lag + equally weighted)	0,93*	0,17*	0,64	0,87*	0,19*	0,63	0,95*	0,14*	0,64

* indicates statistical significance at 5 % significance

Three first rows represent the estimation results for equation (1) using different inflation expectation measures whereas estimation results of equation 2 are reported in the fourth and fifth rows. Results are reported for the whole period (June 2004 to December 2020) and two subperiods. The table reports estimated parameters for both the expectations (α) and output gap (β) and the coefficient of determination (R2).

Results highlight several interesting outcomes. First, the NKPC manages overall to explain very well variation in the euro area monthly inflation rate. Forward-looking models explain over 60 % of the variation. If exceptional year 2020 is excluded the coefficient of determination would arise further to over 70 % of the variation. The explanatory power of forward-looking models is good especially taken the fact that part of the variation in the HICP index is due to fully exogenous reasons such as VAT or administrative price changes or due to weather conditions. Second, our results indicate clearly that purely backward-looking Phillips curves perform quite poorly with the coefficient of determination of 0,43. Neither hybrid model, that have both forward- and backward-looking components, does improve overall fit compared to purely forward-looking model. The results contradict with older literature that have found backward-looking components important though forward-looking component more dominant (see for example Galí et al. (2001, 2005)). It is possible that diminishing role of backward-looking element is explained by the declining indexation or by that we measure inflation expectations in a more accurate way that was not available yet in the early 2000s.[8]

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[7] *Parameters for the external variables are reported in table 2 only for the specification of mixed expectations as their multipliers do not depend significantly on the chosen expectation measure.*

[8] *For example, many euro area member states used to have wage indexation based on past inflation but in many countries such indexations are abolished (Eurofound 2010). Also inflation swap data is available just from mid-2004 onwards.*

Third, all forward-looking specifications seem to perform similarly with the relatively good coefficient of determination (0,63 to 0,64). Overall, parameter values of inflation expectations stay relatively close to its microfounded value of close to unity. However, there seems to be a structural change in the parameter for survey-based measures indicating a small drop in the parameter in the latter half of the estimation period. At the same time there is a slight increase in the parameter for swap-based measures. Whereas these changes reflect different behavior of corresponding expectation measures, particularly the value of 0,78 for the SPF expectations is already relatively far from the common assumption and theoretically consistent value of close to 1. Instead the average of two expectation measures seem to lead to stable parameter of around 0,9 over the whole sample. Based on these and on the fact that in economic monitoring it is important to nest most important information together, we choose the mixed expectation specification as our baseline model.

The differences in the parameter estimates of swap- and SPF based expectations since 2012 stem from the different behavior of expectations (see figure 1). Swap-based expectations have been more volatile than SPF expectations. On the one hand, as swap-based expectations are formed based on real financial transactions, they are likely to react more sensitively to new information. On the other hand, as all financial instruments also prices of inflation swaps include risk premia. Recently, there have been studies arguing that risk-premia has fallen[9] which would explain part of the volatility in the swap-based measure. Instead, SPF surveys are based on the panel survey of professional forecasters. As forecasters update infrequently their analysis and surveys are executed only once in a quarter, survey data may not react as fast as market-based data. Also, gathering information has a cost that may lead to slow movement of survey-based measures. Coibion and Gorodnichenko (2012;2015) report actually under-reaction of survey expectations to economic news. Angeletos et al. (2020) find instead that following any shock survey forecasts appear to under-react for the first few quarters but overshoot later on. Angeletos et al. (2020) and Coibion and Gorodnichenko (2012) find that the dynamics of survey forecast errors after shocks are consistent with the predictions of models with information rigidities. Overall, there seems to be evidence that recently swap-based measures overestimate the fall of expectations whereas SPF surveys might underestimate it. Thus, approach of using the 50:50 mixture of these expectations seem to be well-justified measure that balance out the cons related to different measures.

[9] *See for example Cœuré (2019).*

Figure 1. Swap- and SPF based euro area inflation expectations

Market expectations derived from inflation swaps. SPF = ECB survey of professional forecasters.
Sources: ECB, Bloomberg and calulations by the Bank of Finland.
32426@odotusSPF(en)

Market-based expectations are derived from 2 years and 1 year ahead inflation swaps.

Fourth main result of the estimations reported in Table 1 is that the multiplier of the output gap seems to have slightly fallen on the latter (2013M1–2020M12) part of the estimation period. Earlier there has been evidence that the Phillips curve has flattened compared to 80s and 90s (see for example Blanchard (2016), Oinonen et al. (2013; 2014) and IMF (2013)) but both Ciccarelli and Osbat (2017). and Stevens and Wauters (2018) do not find significant change in the slope in more recent periods. Our results provide weak indication that the flattening would have continued, and inflation process would more strongly be driven by expectations. However, expectations and output gap should also be correlated, and thus possible multicollinearity issues might affect estimates. McLeay and Tenreyro (2020) show also that the central bank targeting rule, that minimizes deviations of inflation and output gaps, will impart a negative correlation between inflation and the output gap, blurring the identification of the (positively sloped) Phillips curve. Whereas conclusions about possible further flattening of the Phillips curve are left for future studies, our estimated parameters values of the magnitude 0,1 to 0,2 for the output gap are however well in line with the findings of Ball and Mazumder (2011) for the US data. For the euro area, Eser et al. (2020) report that with the reduced-form estimates of the slope of the Phillips curve, the median estimate across 780 specifications for the coefficient on slack lies in the range of 0,09 to 0,24.

3. The role of expectations in the price-setting

According to the NKPC, inflation expectations form the backbone of the inflation trend. Mavroeidis et al. (2014) show that our approach of using measured inflation expectations may have a potential endogeneity issue. First, measured expectations may correlate with the cost-push shock ϵ_t that would lead to endogeneity of expectations. Second, measured expectations may have a so-called survey error (i.e. difference between true expectations and surveyed value) that may either be due to measurement error or the news shock. If the measurement error is large enough, it may lead to endogeneity problem. In addition, Mavroeidis et al. point out that measured expectations should be predetermined to be exogenous, meaning that information of current period inflation should not be known before expectations are measured. This is not likely to be a problem in our specification as market-based inflation expectations are formed continuously on financial markets whereas Eurostat typically publishes inflation figure just in the end of period. Also, SPF surveys are published in the beginning of the quarter and data is collected before the end of month.

The endogeneity bias can be addressed by estimating NKPC with proper instruments that are exogenous to current period inflation but correlate strongly with expected inflation. Such instruments are, however, difficult to find and therefore instrument estimations lead easily to biases linked to the weak instruments. Weak identification means that instrumental variables are only weakly correlated with the endogenous regressors (Mavroeidis et al. 2014). Mavroeidis et al. reviews literature estimating Phillips curve with instruments. We apply most commonly used instrument sets in our estimations. The common feature for all chosen instruments is that they are based on lagged variables as earlier literature has argued that lagged variables (see for example Galí and Gertler (1999) and Galí, Gertler, and López-Salido (2001)) are plausibly exogenous to current period inflation particularly if cost push shocks ϵ_t are independently and identically distributed. Thus, this approach is considered to control reversed causality. However, as discussed by Mavroeidis et al. and Zhang and Clovis (2010) identification by lagged values is invalid approach if cost push shocks are autocorrelated. Kuester, Gernot and Stölting (2009) report that autocorrelated cost push shocks would lead to overly flat Phillips curve estimates.

Table 2 presents the estimation results from the OLS estimation and for the robustness check from different GMM estimations using different instrumental variables. The first and second GMM specifications treat oil and exchange rate and their first lag as exogenous and use instruments for estimating inflation expectations and output gap parameters. The first specification uses 3 lags of output gap and 4 lags of expectations as instruments whereas second specification follow one specification of Mavroeides et al. and uses the two lags of GDP deflator, change of labour share and output gap as instruments. GMM specifications 3 to 6 treat oil and exchange rate as endogenous. Specification 3 follows directly version of Mavroeidis et al.

in using 3 lags of output gap and 4 lags of realised inflation as instruments whereas specification 5 has same instrument set as specification 1. Specification 4 apply just-identified instrument set of Mavroeidis et al. and uses 1 lag of each variable. Finally, in specification 6 instruments are the first lag of each endogenous variable but second and third lag of external variables.

Results from GMM estimations are reported in Table 2. Overall, results indicate that parameters for inflation expectations (α) and output gap (β) remain practically unchanged between different specifications and compared to OLS estimation. Thus, OLS estimates of 0,93 and 0,17 seem to be robust parameter estimates of α and β, respectively. The only parameters that change in instrumental estimations are parameters for oil and exchange rate (specifications GMM 3 – 6). The parameters for exchange rate get tenfold values when treated endogenous and also oil parameters get in many specifications values of multiple magnitude compared to baseline estimates. High parameter values might be the consequence of weak instruments for external variables that can be tested with the Cragg-Donald F-test.[10] Instrument estimates that treat oil and exchange rates as exogenous get relatively high F-test values indicating low probability of instrument weakness. This is not the case for specification that treat oil and exchange rate as endogenous variables. F-test values get very low values indicating possible significant bias due to weak instruments.[11]

Table 2. Comparison of different NKPC specifications

	Estimations						
Parameters	OLS	GMM 1	GMM 2	GMM 3	GMM 4	GMM 5	GMM 6
α	0,93*	0,97*	0,95*	0,92*	0,87*	0,85*	0,90*
β	0,17*	0,16*	0,12*	0,1	0,22*	0,21	0,12
γ_1	0,012*	0,01*	0,01*	0,005	0,034*	0,024	0,013
γ_2	0,005*	0,004*	0,004*	0,01		0,031	0,017
ρ_1	-0,009*	-0,007*	-0,007	-0,1*	-0,079*	-0,118	-0,154
ρ_2	-0,008*	-0,01*	-0,01*	-0,06		-0,1856	-0,048
Weak instrument test (Cragg-Donald F-test)		535	580	0,13	1,07	0,07	0,05
Variable exogeneity (p value of difference in J-test)		0,19	0,44	0,45	0	0,23	0,14
Hansen J-test		3,8 (0,7)	5,97 (0,30)	0,01 (0,99)	0,32 (0,57)	0,05 (0,97)	0,004 (0,95)
Exogenous variables		oil exchange rate	oil exchange rate				

* denotes statistical significance at 5 % confidence

Estimation results for equation (1) with different estimation methods and instrument sets. List of instruments in the GMM estimations: GMM1: 3 lags of gap and 4 lags of expectations; GMM2: 2 lags of GDP deflator, labour share and output gap; GMM3: 3 lags of output gap and 4 lags of inflation; GMM4: 1 lag of each variable; GMM5: 3 lags of output gap and 4 lags of expectations; GMM6: 1 lag of expectations and output gap, 2nd and 3rd lag of inflation, and exchange rate.

Exogeneity of regressors can be tested by treating variables exogenous and testing whether Hansen J-test statistics differ between restricted and unrestricted models. According to test results reported in Table 2 all but specification GMM 4 fail to reject the hypothesis of regressors

[10] *The Cragg-Donald F-test tests whether regression coefficients from the first stage regression equals to zero.*

[11] *Alternatively, huge sensitivity of parameter estimates could be due to too few instrumental variables but the parameter estimates of oil and exchange rate remain tenfold to OLS estimates also if external variables are only endogenously treated variables. Thus, the weak instrument bias is more likely explanation than bias due to too few instrumental variables.*

being exogenous to cost push shocks. This would indicate that possible endogeneity bias, discussed by Mavroeidis et al., does not largely affect parameter estimates. The finding is in line with Mavroeidis et al. who find for the U.S. data that treating surveys as endogenous or exogenous does not seem to make much difference to the central tendency of the estimates. However, they still conclude that “it is more robust to treat survey data as endogenous and use instruments for them”. Finally, Hansen J-test results show that selected instruments satisfy orthogonality condition, i.e. they are uncorrelated with the model error terms.

Our estimation results confirm that also in the euro area inflation expectations seem to explain well inflation developments and that treating them as exogenous variables does not affect meaningfully parameter estimates. The result is in line with the results of Coibion and Gorodnichenko (2015) that find for U.S. data that whether applying OLS or instrumental variable estimations do not affect parameter estimates. Overall, the parameter estimates for forward-looking term seem to be close to and slightly below unity. This is in line with the common restriction of the unity restriction for the sum of backward- and forward-looking terms in the NKPC and with the parameter estimates reported in Mavroeidis et al (p. 152 – 153).

How to interpret high importance of expectations in the NKPC?

Our Phillips curve estimates suggest a prominent role for expectations in the price-formatting process and also in forecasting inflation. This is also in line with Groen, Paap, and Ravazzolo (2013) that find expectations being important variables in inflation models. Also, Mavroeidis et al. find that the NKPC specifications with survey forecasts as a proxy for inflation expectations seem to be strongly identified. According to the microfoundations, the linkage between expectations and realised inflation would stem from price stickiness and the causality from expectations to inflation. However, as discussed in chapter 2 expectation formation is a complicated process that is influenced among others by the credibility of the central bank’s inflation aim and possible by the adaptive learning process. Thus, our findings on the importance of expectations are not necessarily driven from the causal relationship between expectations and inflation. Alternatively, strong co-movement between inflation and expectations can be explained by the slow-moving trend that would drive both inflation and inflation expectations. For example, if inflation trend followed random walk process: $\bar{\pi}_{t+1} = \bar{\pi}_t + \bar{\epsilon}_{t+1}$, in which $\bar{\epsilon}_{t+1}$ follows i.i.d error process, inflation would consist of inflation trend and deviation from the trend ($\hat{\pi}_t$) and the NKPC could be written as:

$$\bar{\pi}_t + \hat{\pi}_t = \alpha E_t(\bar{\pi}_t + \bar{\epsilon}_{t+1} + \hat{\pi}_{t+1}) + \beta\widehat{y_t} + \gamma_1 \Delta p_t^{oil} + \gamma_2 \Delta p_{t-1}^{oil} + \rho_1 \Delta e_t + \rho_2 \Delta e_{t-1} + \epsilon_t. \quad (3)$$

Now, according to equation (3), measured inflation expectations would consist of current inflation trend ($\bar{\pi}_t$) and expected future inflation gap ($\hat{\pi}_{t+1}$). Our results do not separate the trend component from the expectations and therefore it is possible that the observed strong correlation between expectations and actual inflation is driven by common trend. Whether the observed correlation is due to a change in current trend or due to a truly causal relationship between expectations and current inflation has an impact for policy conclusions and for analyzing counterfactuals. However, for our purposes of monitoring inflation outlook and forecasting inflation, information derived from the inflation expectations is useful information. However, the results should be interpreted with caution and interpretation should be limited to assessing inflation outlook.

4. Real-time performance of the NKPC projection

This section presents and compares the inflation forecasts of the NKPC -based model to the ECB's confidential monthly forecasts and to the published quarterly numbers. The main interest is to analyze whether a simple NKPC -based forecast model can compete with more extensive methods used at the ECB. We examine the performance of these two forecasts from Autumn 2017 onward as the NKPC -based estimates have been used systematically at the Bank of Finland since then and also compare their forecasting ability against a simple AR(1) time series model.

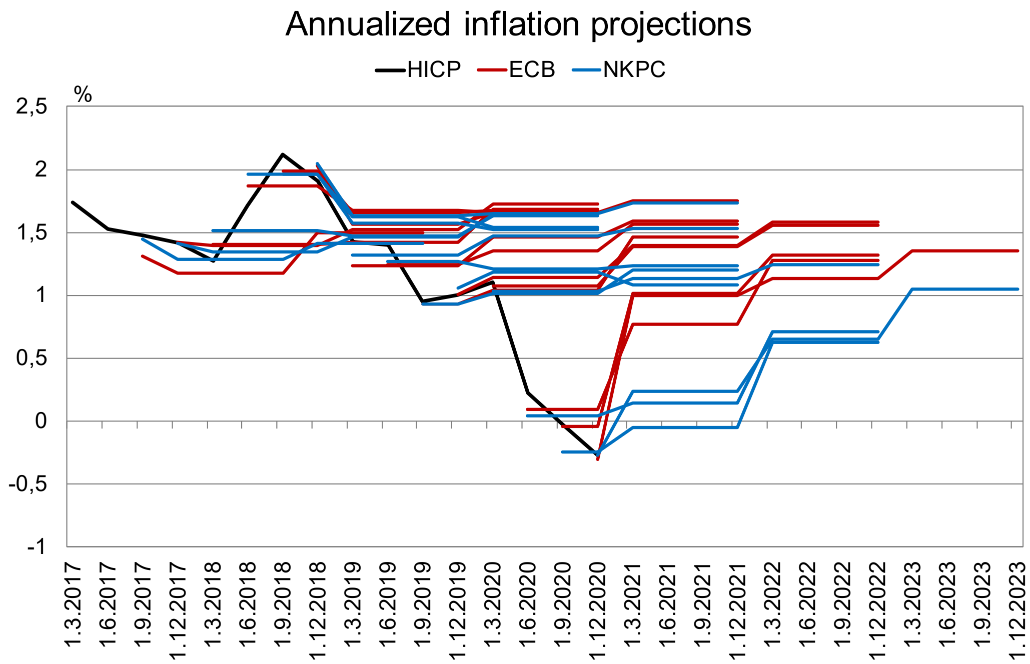
Based on the estimated Phillips curve parameters, it is possible to construct the projection for the euro area inflation conditional on market information and forecast assumptions. The assumption of future oil prices is typically in institutional forecasts based on oil future prices and for exchange rate a constant exchange rate assumption is standard approach. Future inflation expectations can be iterated forward by applying the law of iterated expectations , i.e. $E_t\pi_{t+2} = E_t(E_{t+1}\pi_{t+2})$ and interpolation for both SPF survey expectations and inflation swaps. Finally, forecast assumptions of future output gap is formed based on the confidential forecast of the ECB's output gap. The differences across different output gap estimates from different international institutions is relatively small and the choice of exact forecast on which to rely has not usually had economically significant impact on inflation projection. [12]

Figure 2 presents the NKPC-based and ECB annual inflation forecasts relative to the euro area HICP inflation from September 2017 to December 2020. First impression stemming from the figure is that two different forecasts seem to provide relatively similar paths for future inflation. Over time forecasts tend to move more or less in tandem. Overall, the longer horizon forecasts have hovered around 1,2 % to 1,8 % with the NKPC-based forecasts being systematically slightly lower.

[12] *Alternatively, the framework could measure output gap as a deviation of output or unemployment forecasts from their filtered trends.*

Overall, the chart indicates that both forecasts have performed quite well in forecasting inflation dynamics in the shorter horizon. However, the declining trend of the HICP inflation has turned out to be difficult to forecast. Since the sharp upward inflation spike in the late 2018 both forecasters have constantly overestimated inflation development.

Figure 2. Inflation projections of the Bank of Finland NKPC-model and the ECB



Forecasts are presented as annual average inflation. Actual realized inflation (black line) is on quarterly level.

To provide a more quantitative evaluation, we look at three standard forecast performance statistics reported in table 3. First columns indicate the forecast horizon to be tested. In parenthesis is the number of observations. We run the tests for different forecast horizon from one month ahead to 2,5 years ahead. Because the analysis period is relatively short, starting from 2017, there is relatively few observations to be tested, especially in the longer horizon. For forecast horizon less than a year we compare the NKPC-based forecasts to the ECB's unpublished NIPE (narrow inflation projection exercise) forecasts.[13] For longer horizons the NKPC-based forecasts are compared to the ECB's quarterly inflation forecasts made four times a year. As a benchmark, both forecast errors are also compared to a naïve autoregression based forecast whose long-term forecast equals inflation average over the estimation horizon[14].

[13] *NIPE is the ECB's monthly short-term inflation forecast for one year ahead.*
[14] *Naïve forecast is based on the estimated equation* $\pi_t = c + \sigma\pi_{t-1} + \epsilon_t$.

Table 3. Forecast performance statistics

Bias and accuracy for HICP forecasts									
Forecast horizon	RMSE			Mean Error			Mean Absolute Error		
	NKPC	*ECB*	*AR-model*	*NKPC*	*ECB*	*AR-model*	*NKPC*	*ECB*	*AR-model*
1m* (14 obs.)	0,159	0,160	0,162	-0,080	-0,057	-0,044	0,106	0,122	0,113
3m* (13 obs.)	0,307	0,309	0,318	-0,080	-0,064	-0,113	0,222	0,201	0,238
6m* (12 obs.)	0,518	0,544	0,568	-0,187	-0,187	-0,310	0,379	0,427	0,421
1y** (11 obs.)	0,665	0,687	0,800	-0,283	-0,236	-0,478	0,563	0,582	0,548
1,5y** (9 obs.)	0,807	0,860	0,987	-0,474	-0,512	-0,717	0,662	0,695	0,667
2y** (7 obs.)	1,091	1,162	1,115	-0,775	-0,838	-0,941	0,886	0,958	0,796
2,5y** (5 obs.)	1,283	1,400	1,300	-0,956	-1,055	-1,171	1,148	1,266	1,002

*NIPE
**(B)MPE

The table presents root mean squared error (RMSE), mean error and mean absolute error for forecasts from September 2017 to December 2020 for forecast horizons of 1 month to 2 and half years. Analysed forecasts are the baseline Phillips curve -based forecast, ECB's NIPE (narrow inflation projection exercise, unpublished) and BMPE (broad macroeconomic projections exercise) forecasts and naive auto-regressive forecasts.

First, we simply calculate the mean error (ME), which indicates the average forecast errors and whether the forecasts in the sample are systematically overestimated or underestimated. According to ME values in table 3, ECB has on average had slightly better performing forecasts on a short-term horizon while the opposite is true on a longer horizon. Negative values of the ME test indicate that both NKPC-based forecasts and ECB forecasts have been consistently upwards biased. However, the mean error alone is a poor indicator of forecast accuracy. This is because if forecast errors are large but of different sign, ME indicates small mean error, although the forecasts may in fact differ significantly from actual inflation.

The accuracy can be tested by mean absolute error (MAE), which measures the average error in a set of forecasts indicating the average forecast accuracy. So, MAE values tell us which of the two forecasters have been more accurate on average. The statistics in Table 3 indicate that the NKPC-based forecasts have performed better than forecasts made by ECB almost in every forecast horizon. Despite differences in MAE values are quite small, one can say that on average NKPC-based forecasts have been able to produce more accurate forecasts on euro area HICP inflation than ECB. However, it should be pointed out that when performing the t-test to ME and MAE statistics, we cannot reject the hypothesis that forecasts produced by these two institutions have same mean absolute error.

As a third statistical forecast error measure we use the forecast root mean squared error (RMSE) which is the most common measure of the forecast accuracy. Since the errors are squared before they are averaged, the RMSE is more sensitive to very large forecast errors or outliers. The values of RMSE also indicate that the NKPC-based forecasts have outperformed on all forecast horizons. But again, the advantage in favor of the NKPC-based forecasts is marginal taken into account small differences in RMSE and small number of observations.

Overall, conclusions drawn from the table is that there is not much difference between forecast errors of the NKPC-based forecasts and ECB projections and neither one is noticeably able to constantly outperform the other.

When compared to the naïve forecast[15], both NKPC-based and ECB projections seem to outperform them particularly in the short-horizon up to 1,5 years. Naïve forecasts seem to have also larger systematic bias in the forecast that is reflected in the systematically higher mean error compared to both the NKPC-based and the ECB's projections. Over the longer horizons outperformance of two more advanced projection methods seem to dissipate but this is largely reflecting negative inflation shocks euro area has faced in year 2020 as the naïve model predicts long-term average inflation as a long-term inflation projection. Long-term accuracy of forecasts has also very limited amount of observations that limits drawing conclusions of the superiority of different models.

To sum up, the above findings indicate that despite the forecast performance statistics are slightly in favor of the NKPC forecasts, the overall difference is quite small, and one cannot statistically draw conclusions about the superiority of either forecasts. In addition, there is very few observations to make very profound comparison of the forecast performance. In general, we notice increasing forecast errors with the length of the forecast horizon which is not surprising as particularly oil price movements are difficult to forecast at longer horizons[16].

The forecast errors seem to increase longer the forecast horizon is and in the long-horizons the forecast benefits of the NKPC-based model over the naïve forecast seem quite limited. However, the forecast error can stem from the truly exogenous shocks that are impossible to predict or from the biases linked to the model specification itself. Figure 3 dispenses forecast errors to those stemming from the exogenous deviations of oil prices from their forecast assumptions (pink bars), to the error due to exceptional corona year 2020 (green bars) during which economy faced unpredictable shocks and inflation had several measurement biases and to the other reasons (blue bars). The contributions reveal that most of the forecast error in the longer horizons stem from the exogenous reasons whereas the error due to other reasons remain relatively unchanged over the forecast horizons. This would mean that the NKPC-based model provides consistently reasonable description of inflation outlook over the short- to medium horizons.

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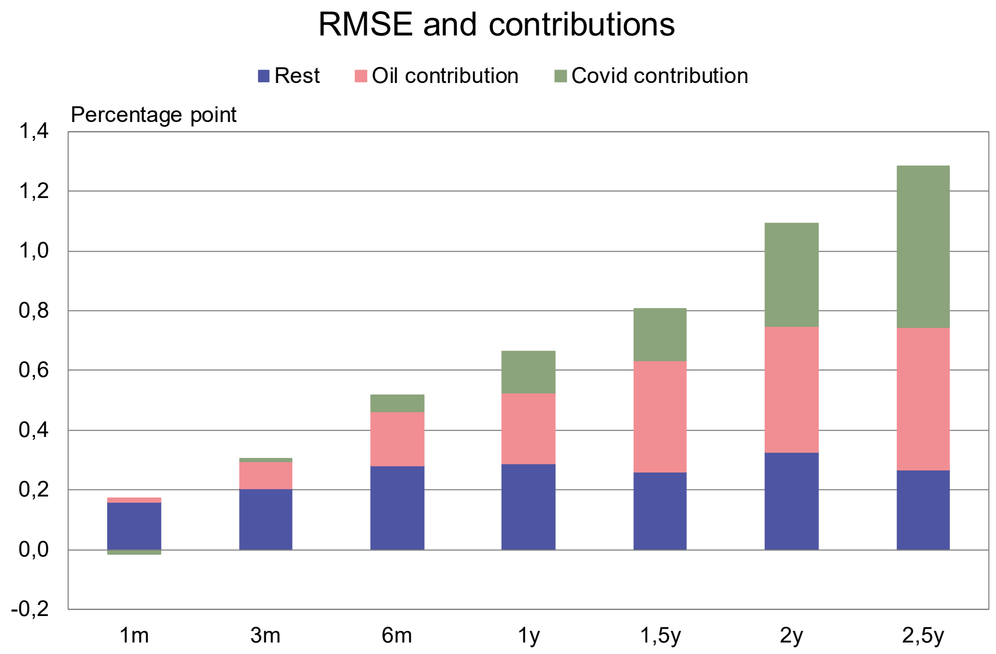
[15] Naïve forecast provide also very limited information about inflation outlook for analyzing purposis as it does not have theoretical foundations.

[16] ECB (2015) and Baumeister and Kilian (2012) provide more detailed discussion on the difficulty of forecasting oil price movements.

Figure 3. The impact of oil price and covid-19 to forecast errors



The bars decompose forecast root mean squared error to the factors stemming from the oil price assumptions (pink bars), from exceptional inflation dynamics due to corona shock (green bars) and from other factors (blue bars).

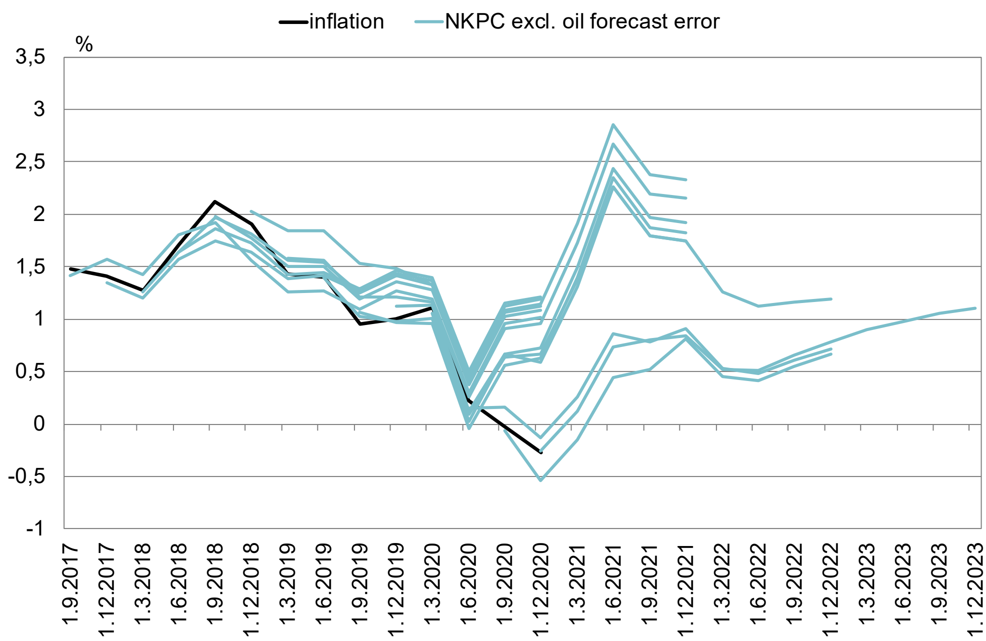
To investigate further the performance of the NKPC-based projection, we investigate what is the effect of the deviations of oil prices from its forecast assumptions on forecast errors and how would the projections paths that control these changes look. The most visible forecast errors can be seen in 2018 and since the onset of the covid-19 crisis in 2020. However, it is noteworthy that most of the forecast error appears to be caused by energy (namely oil) price developments which is famously hard to anticipate particularly at the longer horizons and whose forecasts are based on external assumptions. In 2018 oil price increased from 50-dollar levels in mid-2017 to over 80 dollar driving inflation around 2 %. Correspondingly, during the second quarter of 2020 oil price dropped sharply from 60 to 70 dollar levels to as low as 20 dollar and inflation fell into negative territory. The contribution of the energy price inflation to the HICP inflation was approximately one percent point in both cases.

Figure 4 shows the inflation paths of the NKPC-based projections that correct the oil price assumptions with realised oil price movements. Inflation projections which control errors from the wrong oil price assumptions tracks actual inflation quite well and eliminates most of the forecast error. [17] Taking account and removing the effects of errors stemming from the oil price assumptions, the NKPC -based model is able to predict the declining trend of the HICP inflation starting from late 2018 even at the longer forecast horizon. Thus, the model has managed

[17] *Also Kontogeorgos and Lambrias (2019) find that after correcting for the errors in assumptions improves the accuracy of ECB forecasts and also improves forecast performance against benchmark models.*

quite well to track the factors affecting inflation in the longer term, and most forecast errors stem from the short-time volatility caused by the sudden oil price movements. But, as can be seen in figure 4 the model was still unable to predict the unforeseen Covid-19 and its effects to euro area inflation.

Figure 4. NKPC projections with realized oil price movements

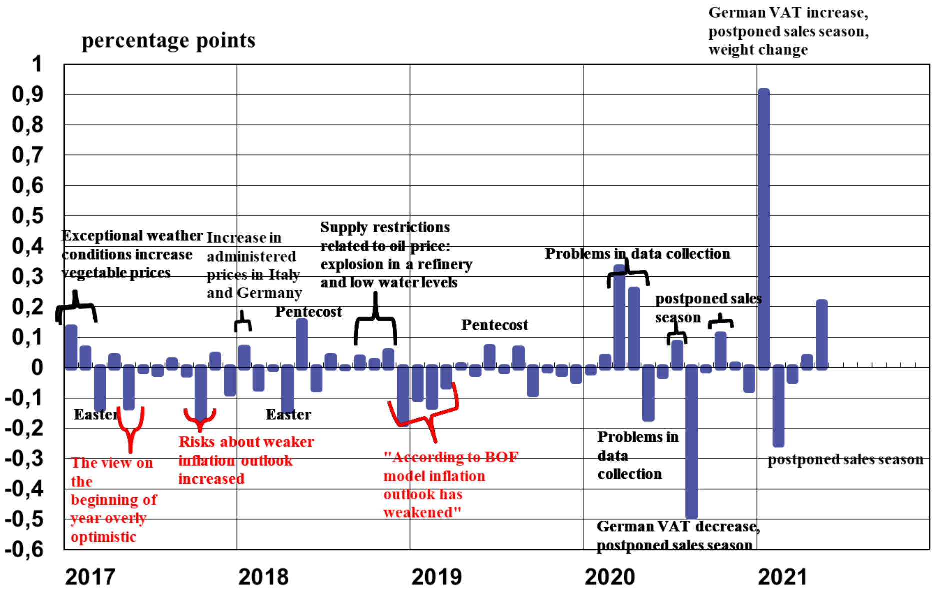


Blue lines represent ex-post corrected forecasts that correct errors due to wrong oil price assumptions. Black line draws the actual realized (quarterly) inflation.

5. What does the NKPC error term tell us about euro area inflation outlook?

In monitoring inflation outlook at the central bank, the special focus is in changes of medium-term inflation outlook. The NKPC projections provide us information about medium-term inflation outlook in two different ways. First, such as discussed in previous chapter, changes in the conditional projection path has straightforward implications on the euro area inflation outlook. Second, also large and/or systematic error terms provide information of exceptional inflation dynamics that could lead to a revision in inflation outlook. In addition, possible change in economic fundamentals might lead to a change in inflation dynamics and estimated parameters. Possible large and systematic error terms might also reflect such dynamics. Thus, large error terms alert about exceptional inflation developments and demands further economic assessment.

Figure 5. Error term of the NKPC-based inflation model



Source: BOF calculations.

The bars show the error terms of baseline regression model in percentage points on month on month inflation rate.

The figure 5 shows the error term since year 2017 when the current form NKPC-based inflation assessment was launched at the Bank of Finland. Graph also provides a short explanation for the exceptional price developments. Sometimes error terms provide “false alarms” in the sense they are not the symptom of a change in longer-term inflation outlook. Examples of “false alarms” are described shortly in figure 5 with black font. These temporary factors have become very common during the corona crisis since March 2020 but before that they were often related to the timing of the Easter or the Pentecost when particularly travel-related items had large swing in the prices. Also, exceptional weather conditions (early 2017 and late 2018) and changes in taxes or administrative prices (early 2018, summer 2020, January 2021) have caused temporary swings in inflation dynamics. The model error term has proven to be a useful tool for recognizing such exceptional events in practical economic monitoring.

In addition, NKPC error term has provided information about changing inflation trend or the risk of a change in the trend, before other variables such as inflation expectations, have alerted of it (red font in figure 5). These periods have existed for example in 2017 and in early 2019. For example, in early 2019 the model error term alerted about weakening trend from December 2018 onwards whereas drop in market-based inflation expectations realized just from 17 March 2019 to 16 June 2019 and SPF surveys pointed out to weaker inflation trend slightly in the report published 11 April 2019 and more clearly in the report released 26 July 2019.

6. Conclusions

We demonstrate that the purely forward-looking New Keynesian Phillips curve describes well euro area inflation dynamics. The results highlight the relevance of inflation expectations in the inflation analysis. The importance of expectations does not seem to be driven by common backward-looking trend of expectations and inflation process itself. However, the observed covariance is not necessary reflecting causality from expectations to inflation but can for example reflect new information of changes in trend inflation. Whereas the detailed analysis of the behavior and role of inflation expectations deserves further studies, our results indicate that inflation expectations are the essential part of analyzing inflation outlook and developments.

The NKPC-based conditional projections perform also equally-well compared to the forecasts of the ECB for both short- and medium-horizons. Significant share of forecast errors seem to be explained by changes in the oil prices and by the very exceptional year 2020. Overall, the NKPC-based forecasts can in normal times provide reasonable inflation projections and are therefore a useful tool for analyzing euro area inflation outlook.

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