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Inflation dynamics in the euro area and the role of expectations: further results

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Inflation dynamics in the euro area and the role of expectations: further results

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Abstract

This paper examines the empirical performance of the New Keynesian Phillips curve and its hybrid specification in the euro area. Instead of imposing rational expectations, direct measures, ie OECD forecasts, are used as empirical proxies for economic agents' inflation expectations. Real marginal costs are proxied by three different measures. The results suggest that OECD inflation forecasts perform relatively well as a proxy for inflation expectations in the euro area, since under this approach the European inflation process can be modeled using the forward-looking New Keynesian Phillips curve. However, inflation can be modeled even more accurately by the hybrid Phillips curve. Thus, even allowing for possible non-rationality in expectations, the additional lagged inflation term is needed in the New Keynesian Phillips relation. In this approach, the output gap turns out to be at least as good a proxy for real marginal costs as the labor income share. Moreover, the inflation process seems to have become more forward-looking in the recent years of low and stable inflation.

Key words: Phillips curve, expectations, euro area

JEL classification numbers: E31, C52

Euroalueen inflaatiodynamiikka ja odotusten merkitys: lisätuloksia

Suomen Pankin keskustelualoitteita 21/2004

Maritta Paloviita
Tutkimusosasto

Tiivistelmä

Tässä tutkimuksessa tarkastellaan uuskeynesiläisen Phillips-käyrän ja sen hybridimuodon empiiristä soveltuvuutta euroalueelle. Taloudellisten päätöksentekijöiden inflaatio-odotuksia ei oleteta rationaaliksi, vaan niitä mitataan suoraan käyttämällä OECD:n ennusteita. Reaalisten rajakustannusten empiirisenä vastineena käytetään kolmea eri käsitettä. Tulosten mukaan OECD:n ennusteita voidaan käyttää euroalueen inflaatio-odotusten mittaamisessa, sillä niiden avulla eurooppalainen inflaatiodynamiikka voidaan mallintaa uuskeynesiläistä Phillips-käyrää käyttäen. Vielä tarkemmin inflaatioprosessi voidaan kuitenkin mallintaa käyttämällä uuskeynesiläisen Phillips-käyrän hybridimuotoa. Siten viivästetty inflaatiotermi tarvitaan uuskeynesiläisessä Phillips-käyrässä odotusten mahdollisesta epärationaalisuudesta huolimatta. Tutkimustulokset osoittavat, että tuotantokuilu on ainakin yhtä hyvä reaalisten rajakustannusten empiirinen vastine kuin työtulojen BKT-osuus. Toisaalta inflaatioprosessi on muuttunut enemmän eteenpäin katsovaksi viime vuosina, jolloin euroalueen inflaatio on ollut vaimea ja vakaa.

Avainsanat: Phillipsin käyrä, odotukset, euroalue

JEL-luokittelu: E31, C52

Contents

1 Introduction

Inflation dynamics and the role of expectations have been hotly debated over the years, for many reasons. The puzzling combination of low inflation and high real growth in many industrialized countries in the 1990s has reignited interest. Moreover, the policy problem in Europe has changed, as the European Central Bank, in conducting a single monetary policy, must cope with different price developments in the twelve member states. Recent theoretical advances have produced alternative views of the inflation process and crucially different implications for optimal monetary policy.

One critical issue in theories of inflation is whether inflation can be modeled using the forward-looking New Keynesian Phillips curve (henceforth the NKPC; see Taylor 1980, Calvo 1983 and Galí and Gertler 1999). When imposing rational expectations, the empirical performance of the New Keynesian Phillips curve is often poor and, contrary to the basic version of the theory, the estimated coefficient of the driving variable is incorrectly signed. Many papers find evidence that when modeling short run inflation dynamics, we need the hybrid specification of the New Keynesian Phillips curve (henceforth the HPC) with the lagged inflation term as an additional explanatory variable (see Galí and Gertler 1999, Galí, Gertler and Lopéz-Salido 2001, Roberts 2001, Fuhrer 1997). Another critical issue in these models has been the choice of an appropriate empirical measure for real marginal costs. Typically, empirical studies using the rational expectations hypothesis favor the labor income share, but the output gap has also received support. The NKPC and HPC provide clearly different implications for monetary policy design and inflation persistence[1].

This paper assesses empirically two alternative Phillips relations, the NKPC and HPC, for the euro area[2]. The main focus is on the comparison of the two specifications, using three alternative proxies for real marginal costs: the labor income share, a Hodrick-Prescott filtered output gap and the OECD’s output gap estimate based on the production function method. Instead of imposing rational expectations, an alternative, and in principle less restrictive, approach is used to operationalize expectations. Direct measures are used as empirical proxies for economic agents’ inflation expectations. More specifically, inflation expectations are measured using OECD's inflation forecasts, which have not been previously used in this context. In wage and price formation, OECD forecasts are assumed to represent prevailing inflation expectations (for accuracy analysis, see Artis 1996, Ash et al 1998, Pons 2000 and Öller and Barot 2000). When rational expectations

[1] See Walsh (1998) and Woodford (2003) for further discussion.

[2] Preliminary results on euro area inflation dynamics using directly measured expectations were presented in Paloviita (2002).

are not explicitly imposed, expectations may adjust gradually. Roberts (1997, 1998) and Adam and Padula (2003) have done similar studies for the US economy using survey-based expectations. Also Ball (2000) has suggested models which relax the rational expectations hypothesis.

The NKPC and HPC are fitted to aggregated and pooled euro area data with single equation estimations using the generalized method of moments (GMM). Statistical tests are used to assess the relevance of OECD inflation forecasts as an empirical counterpart of inflation expectations. The main interest is in the euro area as a whole since the late 1970s, although potential heterogeneity of inflation dynamics is also examined across different sub-periods and country groups.

As this paper shows, in analyzing the role of expectations in the New Keynesian Phillips relation, direct measures of expectations are likely to offer some advantages over the more standard approach of rational expectations. We find evidence that OECD forecasts have been accounting for inflation expectations in the euro area, since the NKPC is consistent with the data. However, in spite of possible deviations from full rationality in expectations, the lagged inflation rate seems to be needed in explaining European inflation more accurately. Contrary to many other empirical studies with rational expectations, the output gap appears to be an adequate empirical measure of cyclical inflationary pressure in the Phillips relation.

This paper proceeds as follows. Section 2 derives the NKPC and HPC and places them in the context of existing empirical studies. Section 3 reports on the empirical analysis and section 4 on the robustness of the estimation results. Section 5 concludes.

2 Two Phillips curve specifications and previous empirical evidence

2.1 The New Keynesian Phillips curve and Hybrid Phillips curve

In the New Keynesian approach, nominal price setting is staggered, as each monopolistically competitive firm maximizes profits subject to constraints on the frequency of price adjustments (Calvo 1983) or subject to costs related to changing prices (Rotemberg 1982). In these models expected future costs and demand conditions are taken into account in optimal price-setting. Aggregation yields the following linearized relationship between current inflation, expected future inflation, and real marginal costs:

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \lambda mc_t, \tag{2.1}$$

where π_t denotes the inflation rate in period t and mc_t is the period t log deviation of the firms' real marginal costs from the steady state value. E_t is the expectation operator conditional on information available in period t. If expectations are rational, inflation expectations do not systematically differ from actual inflation. In this model, inflation is entirely forward-looking and the parameter β is the subjective discount factor, which is less than but very close to unity. In the Calvo model, where each firm has a fixed probability $(1–\theta)$ of changing its price in any period, the coefficient of real marginal costs, λ, is decreasing in θ. Thus, the longer prices are fixed on average, the less sensitive inflation is to current real marginal costs.

In empirical studies, the output gap and the labor income share (real labor costs) are commonly used as proxies for real marginal costs. When the output gap is used, we get the pricing equation

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \kappa\hat{y}_t, \tag{2.2}$$

where $\kappa = \lambda\delta$ and δ measures output elasticity of real marginal costs.

The hybrid specification of the New Keynesian Phillips curve is based on the idea that some price setters use rules of thumb in price setting. The proportion of backward-looking price setters is given by ω and the model can be expressed as

$$\pi_t = (1-\omega)E_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \gamma mc_t, \tag{2.3}$$

where the term $\pi_{t–1}$ denotes the lagged inflation rate. In the output gap-based HPC, the last term is replaced by the term $\phi\hat{y}_t$. In the HPC, price setting of backward-looking firms is based on recent history of aggregate prices. The two Phillips relations clearly have different implications for inflation persistence. If inflation expectations are measured directly, instead of imposing rational expectations, one obtains the following modified estimating formulas from the standard specifications (2.1) and (2.3)

$$\pi_t = \beta_t\pi^*_{t+1} + \lambda\hat{m}c_t, \tag{2.4}$$

$$\pi_t = (1-\omega)\pi^*_{t+1} + \omega\pi_{t-1} + \gamma\hat{m}c_t, \tag{2.5}$$

where the term $\pi^*_{t+1} = \overline{E}_t\{\pi_{t+1}\}$ refers to period t representative expectations, which are not necessarily rational. The driving variable can alternatively be the output gap. As Adam and Padula (2003) have shown, one can derive the NKPC with direct measures of expectations. In applying equations (2.4) and (2.5) to the data, one need not assume any specific form of non-rationality in expectations. Thus we can concentrate on relative performances of alternative elements of expectations in inflation dynamics. Since the task here is to compare the two models on their own terms, the restrictions are imposed in the estimated specifications of the equations. Thus, in the NKPC the imposed value of ß is 0.97 and, as seen in equation (2.5), the sum of forward- and backward-looking components is restricted to unity in the HPC.

In both specifications, inflation varies positively with the driving variable, which is measured in three alternative ways: the labor income share, the Hodrick-Prescott filtered output gap, and the OECD's output gap estimate based on the production function method. The labor income share is probably the closest proxy for real marginal costs, but unfortunately not all forms of labor compensation are measured accurately for the euro area. As the final goal is to model output and inflation behavior together, it is worth investigating whether, in this approach, one can generally use more up-to-date and reliable output information in constructing the output gap in the Phillips relation. When the output gap is used, one can avoid measurement problems in the labor income share and possible problems in linking it to output dynamics. On the other hand, the output gap clearly cannot be measured without errors either.

2.2 Previous empirical evidence

The empirical validity of the NKPC has not hitherto been firmly established. Often the empirical fit of the NKPC under rational expectations has been better when real unit labor cost, instead of the output gap, has been used as the driving variable. For example, Galí and Gertler (1999) and Sbordone (2002) find evidence that the NKPC gives a reasonable approximation of US inflation dynamics when real marginal costs are used. Galí, Gertler and Lopéz-Salido (2001) get the same result for euro area inflation dynamics. The superiority of real marginal cost is based on the idea that real marginal costs and the output gap are not closely related and that labor market rigidities must be taken into account in modeling short run inflation dynamics. However, the outperformance of real unit labor cost in the New Keynesian Phillips relation is not unambiguous. For example, Neiss and Nelson (2002) find evidence that in the US, United Kingdom and Australia the output gap-based NKPC fits the data. They argue that labor market rigidities are not important in inflation dynamics and that the output gap can be used in the NKPC, if it is measured correctly. Also Rudd and Whelan (2002) argue that changing the output gap to real labor cost does not improve the empirical fit of the New Keynesian model.

Empirical studies on the HPC have also yielded conflicting results. In Galí and Gertler (1999) forward-looking expectations have a dominant role in US inflation dynamics and Galí, Gertler and Lopéz-Salido (2001) get the same results for the euro area. On the other hand, according to Fuhrer (1997), forward-looking expectations are essentially unimportant in US inflation. Moreover, Roberts (2001) argues that backward-looking expectations are important for the US.

The rational expectations hypothesis has been relaxed in some empirical studies of the NKPC. For example, Roberts (1997, 1998) analyzes inflation dynamics in the US with the New Keynesian specification using survey estimates of inflation expectations. He finds evidence that inflation expectations are not rational, which appears to be in connection with the poor empirical fit of the New Keynesian theory. Adam and Padula (2003), using survey-based measures of inflation expectations, obtain significant and plausible estimates of the New Keynesian Phillips curve for the US with the output gap and unit labor costs. Near-rational expectations are assumed in Ball (2002), where agents use past information of inflation optimally, but ignore other variables. Forsells and Kenny (2002) have used the probability approach by deriving quantitative estimates of euro area inflation expectations from the European Commission's Consumer Survey. Their results suggest that although survey expectations are not always completely unbiased, consumers seem to avoid systematic expectational errors eventually by adjusting their expectations. They find also evidence of 'growing' rationality over the 1990s compared with the 1980s.

3 Empirical results

3.1 Data description

Annual inflation rates and alternative driving variables for twelve EMU countries was constructed for the years 1977–2003 using the OECD Economic Outlook data set and OECD National Accounts. Inflation was measured by annual changes in GDP deflator, and corresponding OECD inflation forecasts for each country were obtained from OECD Economic Outlook publications. OECD makes forecasts twice a year. We used the December estimates for the next calendar year. The labor income share is defined as the ratio of compensation of employees to nominal GDP. The output gap is constructed as the difference between the log real GDP and the Hodrick-Prescott filtered log real GDP with smoothing parameter of 100. Alternatively, we used production function-based OECD's output gap estimates[3,4]. Figure 1 shows inflation history and inflation forecasts for the euro area. The four biggest economies – Germany, France, Italy and Spain – dominate the euro area, with a combined weight of over 80 percent.

Figure 1. **Actual and expected inflation in the euro area**

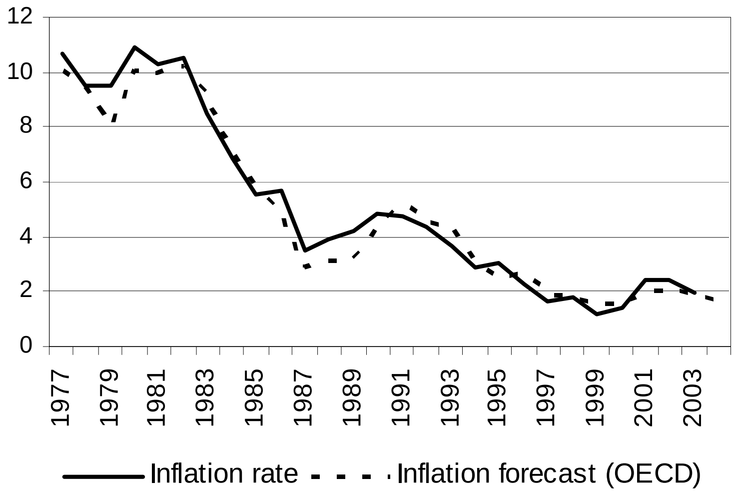

Table 1. **Unbiasedness of OECD inflation forecasts**
$\pi_t = a + b\pi_t^*$

	Joint hypothesis	Aggregated		Pooled	
Euro area, 1977–2003	(a,b) = (0,1)	F=1.851	(0.178)	F=6.361	(0.002)
		χ^2=3.702	(0.157)	χ^2=12.723	(0.002)
Euro area, 1977–1990	(a,b) = (0,1)			F=13.759	(0.000)
				χ^2=27.519	(0.000)
Euro area, 1991–2003	(a,b) = (0,1)			F=0.312	(0.733)
				χ^2=0.623	(0.732)

Notes: Newey-West HAC Standard errors, p-values in parenthesis.

[3] Availability of data varies slightly. Forecast information is available in 1977–2004 for ten countries in the euro area. For Luxembourg, forecasts are available since 1982 and for Portugal since 1980. OECD's output gap information is available since 1973–1979 for eleven euro area countries and not available for Luxembourg. For eight countries labor income share is available until 2003 and for Belgium, Ireland, the Netherlands and Portugal until 2002.

[4] ECB GDP weights, based on actual exchange rates, were used in aggregation. Country weights from the year 2002 are: Germany 29.8, France 21.6, Italy 17.8, Spain 9.8, the Netherlands 6.3, Belgium 3.7, Austria 3.1, Finland 2, Greece 2, Portugal 1.8, Ireland 1.8 and Luxembourg 0. For Germany and the euro area, German unification was taken into account using OECD *Economic Outlook* estimates. For aggregation, the missing forecast data for Portugal 1977–1979 were replaced by data for Spain.

The unbiasedness of OECD inflation forecasts was tested by estimating the equation $\pi_t = a + b\pi_t^*$, where π_t^* refers to the period t inflation forecast, made in period t–1. As shown in Table 1, for aggregated euro area data, the result does not reject the joint hypothesis that the constant a is equal to zero and the coefficient of the expectations, b, is equal to one. However, using the pooled data, we found evidence that OECD inflation forecasts are biased. The two sub-period results for pooled data are also reported in Table 1. They indicate that in 1977–1990, when many countries experienced high and volatile inflation, inflation forecasts were biased. By contrast, for 1991–2003, when inflation was clearly lower and more stable in all euro area countries, the hypothesis of unbiasedness cannot be rejected.

Further analysis of OECD inflation forecasts using aggregated or pooled data (not reported here) shows that forecast errors are positively correlated. Moreover, forecast errors seem not to be orthogonal to lagged information, as assumed under rational expectations. With both data sets, when regressing the forecast error on the lagged inflation rate and lagged driving variable, we in most cases reject the null hypothesis that the estimated coefficients are jointly equal to zero. These results provide evidence that deviations from full rationality may be important in empirical analysis of the NKPC.

3.2 Estimation results

Typically, empirical analysis of the NKPC is based on the joint hypothesis of the NKPC and rational expectations, which means that instrumental variable (IV) methods are needed. By contrast, when inflation expectations are measured directly, the NKPC can be estimated with ordinary least squares (LS), if one can assume the expectations term and contemporaneous driving variable are measured correctly and are not correlated with each other or with the error term. Consequently, estimating the NKPC and HPC using LS and GMM should serve as useful input in assessing how important these problems can possibly be in the present context. Empirical results for the NKPC and HPC are compared in order to investigate, whether the lagged inflation term is needed after relaxing the rational expectations assumption.

Table 2. **Estimation results for the euro area using ordinary least squares**

NKPC $\pi_t = 0.97 \cdot \pi^*_{t+1} + \lambda \hat{mc}_t$ **or** $\pi_t = 0.97 \cdot \pi^*_{t+1} + \kappa \hat{y}_t$

	Aggregated			Pooled		
	λ or κ	D-W	R^2	λ or κ	D-W	R^2
Labor income share	0.055 (0.048)	0.880	0.907	0.002 (0.026)	1.171	0.877
HP filtered output gap	-0.198 (0.175)	0.842	0.913	-0.116* (0.050)	1.185	0.879
OECD output gap	-0.236* (0.093)	1.020	0.926	-0.172* (0.037)	1.220	0.885

HPC $\pi_t = (1-\omega)\pi^*_{t+1} + \omega\pi_{t-1} + \gamma \hat{mc}_t$ **or** $\pi_t = (1-\omega)\pi^*_{t+1} + \omega\pi_{t-1} + \phi \hat{y}_t$

	Aggregated				Pooled			
	ω	γ or ϕ	D-W	R^2	ω	γ or ϕ	D-W	R^2
Labor income share	0.491* (0.125)	0.020 (0.011)	2.852	0.974	0.441* (0.030)	-0.008 (0.017)	2.379	0.935
HP filtered output gap	0.544* (0.062)	0.077 (0.054)	2.913	0.975	0.443* (0.035)	0.016 (0.030)	2.377	0.934
OECD output gap	0.533* (0.133)	0.061 (0.083)	2.973	0.970	0.453* (0.048)	-0.005 (0.028)	2.510	0.936

Notes: Sample period 1977–2002 with the labor income share, 1977–2003 with the HP filtered output gap and 1979–2003 with the OECD output gap. Numbers in parentheses are Newey-West HAC standard errors, * indicates significance at 5 percent level.

First, the NKPC (equation 2.4) was estimated by LS with aggregated and pooled euro area data, using three alternative proxies for real marginal cost (see Table 2). Overall, the estimation results are relatively poor for aggregated data, since only with the labor income share did we get a correctly signed coefficient, and the residuals are strongly autocorrelated in all cases. Qualitatively similar results were obtained for pooled euro area data. All in all, LS results for the NKPC seem to indicate that the model is mis-specified and/or some variables are measured with errors. There may also be a simultaneity problem between inflation and the driving variable. Thus LS is not necessarily an appropriate estimation method for the NKPC even with directly measured expectations.

Next we considered the possibility that the lagged inflation term is needed in the NKPC resulting in the HPC. Possible measurement errors or simultaneity problems were not taken into account, which means that LS was assumed to be sufficient. As shown in lower part of Table 2, the HPC results for aggregated euro area data are quite reasonable for all of the driving variables: relative weights of backward-looking expectations are close to 0.5 and the lowest (highest) coefficient for the driving variable is obtained when the labor income share (the HP filtered output gap) is used. With pooled euro area data, we got two incorrectly signed driving variables, but in this case the coefficient of the relative weight of backward-looking expectations term is reliable, about 0.45 in all cases. Moreover, again the lowest and the highest coefficients for the driving variable appear with the labor income share and the HP filtered output gap. Looking at the estimation results with LS, the lagged inflation rate seems to improve the empirical results for the purely forward-looking Phillips relation, but still we obtained many unreliable and imprecise estimates. Overall, estimation results using LS clearly suggest that the forward-looking NKPC is mis-specified. Also, IV methods seem to be needed because of the errors-in-variables and/or simultaneity problem. Measurement errors may occur in both the expectations term and the driving variable.

Next we estimated the NKPC and HPC by IV method, as shown in Table 3. In all cases, the instruments used were chosen to represent variables which are predetermined at time t. In all cases the standard errors of estimated parameters were modified using a Bartlett or quadratic kernel with variable Newey-West bandwidth. In addition, prewhitening was used in four out of six cases.

As can be seen from Table 3, for the NKPC with aggregated euro area data using GMM, the driving variable always enters with a positive sign. Although inflation history is quite heterogeneous across EMU countries and the euro area has experienced regime shifts since the late 1970s, the forward-looking NKPC fits the data surprisingly well. Instrumenting seems to improve the estimation results, especially when the output gaps are used to determine inflation. The lowest and least precise estimate is obtained for the labor income share. By contrast, the estimated coefficient for OECD's output gap is the highest. All in all, although overidentifying restrictions are not rejected in any case, the estimated parameters are not very significant and the model may not be correctly specified. We may be able to improve the empirical performance of the NKPC by adding the lagged inflation term, ie by using the HPC.

GMM results using the aggregated data may suffer from small sample bias and aggregation may have an effect on the estimated coefficients. However, GMM results for pooled and aggregated data are qualitatively quite similar, as Table 3 shows. When pooled data are used, the driving variable is always correctly signed and, if we use the labor income share or the HP filtered output gap, we get more precise estimates than with aggregated data. However, a caveat is appropriate due to the fact that the overidentifying restrictions are rejected with pooled data. All in all, the NKPC results for pooled euro area data also suggest that the HPC may fit the data better.

Table 3. **Estimation results for the euro area using GMM**

NKPC $\pi_t = 0.97 \cdot \pi^*_{t+1} + \lambda \hat{mc}_t$ **or** $\pi_t = 0.97 \cdot \pi^*_{t+1} + \kappa \hat{y}_t$

Aggregated	λ or κ	J-statistic	Instruments	GMM	Obs
Labor income share	0.003 (0.039)	0.123	$\hat{mc}_{t-1}, \pi_{t-1}$	B, V, P	26
HP filtered output gap	0.207 (0.183)	0.072	$\hat{y}_{t-1}, \hat{y}_{t-2}$	Q, V, P	27
OECD output gap	0.228 (0.188)	0.126	$\hat{y}_{t-1}, \pi_{t-1}$	Q, V, –	24

Pooled	λ or κ	J-statistic	Instruments	GMM	Obs
Labor income share	0.073 (0.048)	0.037	$\hat{mc}_{t-1}, \hat{mc}_{t-2}$	B, V, P	312
HP filtered output gap	0.126 (0.093)	0.036	$\hat{y}_{t-1}, \pi_{t-1}$	B, V, P	316
OECD output gap	0.036 (0.074)	0.043	$\hat{y}_{t-1}, \hat{y}_{t-2}$	B, V, –	285

HPC $\pi_t = (1-\omega)\pi^*_{t+1} + \omega\pi_{t-1} + \gamma \hat{mc}_t$ **or** $\pi_t = (1-\omega)\pi^*_{t+1} + \omega\pi_{t-1} + \phi \hat{y}_t$

Aggregated	ω	γ or ϕ	J-stat.	Instruments	GMM	Obs
Labor income share	0.552* (0.053)	0.047* (0.005)	0.093	$\hat{mc}_{t-1}, \hat{mc}_{t-2}, \pi_{t-2}$	Q, V, –	26
HP filtered output gap	0.627* (0.072)	0.206* (0.071)	0.056	$\hat{y}_{t-1}, \hat{y}_{t-2}, \pi_{t-2}$	B, V, –	27
OECD output gap	0.631* (0.103)	0.125* (0.060)	0.002	$\hat{y}_{t-1}, \hat{y}_{t-2}, \pi_{t-2}$	B, V, –	23

Pooled	ω	γ or ϕ	J-stat.	Instruments	GMM	Obs
Labor income share	0.632* (0.057)	0.001 (0.015)	0.006	$\hat{mc}_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q, V, –	312
HP filtered output gap	0.619* (0.058)	0.078* (0.039)	0.010	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	B, V, P	316
OECD output gap	0.643* (0.068)	0.088 (0.047)	0.006	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	B, V, –	288

Notes: Numbers in parentheses are standard errors, * indicates significance at 5 percent level. J-statistic corresponds to the Hansen test of overidentifying restrictions. GMM options: B = Bartlett kernel, Q = Quadratic kernel, V = variable Newey-West bandwidth, P = prewhitening.

When GMM was used for the HPC, the lagged variables were again used as instruments and the standard errors of the estimated parameters were modified using a Bartlett or quadratic kernel with variable Newey-West bandwidth (see Table 3). Moreover, prewhitening was used in one out of six cases. The HPC results for aggregated data suggest that expectations are more backward-looking, since the relative weight of backward-looking expectations is 0.55 with the labor income share and slightly higher, 0.63, with both output gaps. The three estimated coefficients for the driving variable are reasonably signed and significant and the lowest values can be seen for the labor income share. In addition, overidentifying restrictions are not rejected. Also the HPC results for pooled data indicate that backward-looking expectations dominate the inflation process with a weight of about 0.6. The estimated coefficients for the driving variable are quite plausible and again the lowest value was obtained with the labor income share. Overidentifying restrictions are not rejected.

Overall, the single equation estimation results with LS and GMM indicate that when inflation expectations are measured directly and OECD inflation forecasts are used as a proxy for inflation expectations, European inflation dynamics can be captured by the NKPC with a correctly signed driving variable. In this approach IV methods are needed because of simultaneity and/or measurement errors in the expectations term and/or driving variable. With pooled euro area data overidentifying restrictions are rejected, which indicates possible problems with the purely forward-looking NKPC.

In spite of the correctly signed driving variable, the empirical fit of the NKPC is not very good, since in many cases the coefficient of the driving variable is estimated very imprecisely. The significance of the coefficient can be improved by adding the lagged inflation rate to the model. This has typically been done also in empirical analyses under rational expectations. Thus, although there might be persistence in inflation expectations, simply allowing for non-rationality in expectations is not enough to capture all of the persistence in inflation process properly. Even if expectations are measured directly, the HPC with lagged inflation rate is needed. This conclusion can be drawn for aggregated and pooled euro area data alike. Estimation results using both data sets suggest that the backward-looking factor dominates the inflation process with a relative weight of about 0.6. The Phillips relation must be estimated with GMM due to measurement and/or simultaneity problems. These results are qualitatively robust to the choice of driving variable. However, higher coefficients for the driving variable were obtained with the output gaps. Moreover, we got almost the same estimates for relative weight of backward-looking expectations when the output gaps were used as the determinant of inflation in both data sets.

4 Robustness of GMM results

The above results for the full sample period 1977–2003 indicate that OECD inflation forecasts can be used as a proxy for inflation expectations. In addition, the HPC outperforms the NKPC for the euro area. Qualitatively the results seemed not to be very sensitive to the choice of driving variable. In this section the empirical results of the previous section are analysed in more detail. By estimating the HPC in two sub-periods we can determine whether the empirical fit of this Phillips relation is different in different policy regimes.

Since 1977 price developments have changed a great deal in the euro area. During the 1980s euro area inflation decreased from two-digit numbers to approximately 3 per cent. After that, euro area inflation has remained subdued and quite stable, in spite of a small peak in the early 1990s. When estimating the HPC for two sub-periods, 1977–1990 and 1991–2003, we got quite reasonable results for five out of six cases (see Table A1.1 in Appendix 1). The Hansen test was rejected only when the OECD's output gap was used in the first sub-period. Moreover, only with the labor income share is the driving variable coefficient incorrectly signed in the first sub-period and extremely low in the second sub-period. In all cases backward-looking expectations dominate the inflation process for 1977–1990. The contrary is true for 1991–2003. It is worth noting that we obtained low driving variable coefficients for the second sub-sample. As a whole, the sub-sample results provide more support for the use of OECD forecasts in the HPC. Moreover, expectations seem to be more forward-looking for the more recent regime of stable inflation. The output gap seems to be an adequate measure of real marginal costs also on the basis of sub-sample results. Particularly, for the stable inflation regime, we get very similar parameter estimates with both output gap measures.

Inflation history clearly varies across the EMU countries, especially in the 1980s. Individual countries have also experienced divergent developments in real growth and potential output. Thus it is worth studying whether inflation dynamics are different in high and low inflation countries and whether differences in output gap history can explain differences in inflation dynamics.

First, the EMU countries were divided into two groups: high inflation countries (Finland, France, Greece, Ireland, Italy, Portugal and Spain) and low inflation countries (Austria, Belgium, Germany, Luxembourg and the Netherlands). As reported in Table A1.1, we got reasonable HPC results for both country groups with all driving variables. The overidentifying restrictions were never rejected and the results were qualitatively robust to choice of driving variable, since in all cases the relative weight of backward-looking factor is over 0.5 for high inflation countries. Accordingly, forward-looking expectations clearly dominate the inflation process when low inflation countries are considered. In addition, for low inflation countries we got slightly higher and more precise coefficients for the driving variable when the output gaps were used.

As an alternative, the twelve euro area economies were divided into two groups according to the output gap record. Finland, Ireland, Luxembourg and Portugal belong to the country group with more a divergent output gap history. While in Austria, Belgium, France, Germany, Greece, Italy, the Netherlands and Spain the output gap has been less volatile. For the HPC, all results indicate that backward-looking expectations dominate, with a relative weight of 0.55–0.73 (see Table A1.1). The relative weight of backward-looking expectations is always slightly higher for countries with less divergent output gap history. Moreover, for these countries the driving variable coefficient was always higher and more significant. For more divergent output gap countries we obtained an incorrectly signed driving variable, when the labor income share was used. According to the J-statistics the Hansen test was rejected slightly only when the HP filtered output gap was used as the determinant of inflation for less divergent output gap countries.

All in all robustness analysis of the HPC suggests that since the late 1970s the inflation process in the euro area has become more forward-looking. Moreover, heterogeneity of inflation and output gap history across twelve EMU economies affect the empirical fit of the euro area HPC.

5 Conclusions

In recent studies the empirical validity of the purely forward-looking NKPC under rational expectations has received conflicting assessments, since the driving variable is often incorrectly signed and inflation persistence is not captured. Typically, the empirical fit of the NKPC has been improved by assuming backward-looking behavior of some firms or sluggish adjustment of real marginal costs for output variation. In this paper a different approach was used: the rational expectations hypothesis was relaxed for the NKPC. In principle, when rational expectations are not imposed, we may be able to explain inflation persistence with the purely forward-looking NKPC without the lagged inflation rate. Moreover, the choice of appropriate empirical measure for real marginal costs may be different in this approach than under rational expectations hypothesis.

In studying European inflation dynamics, the forward-looking NKPC and the HPC including the lagged inflation rate were applied to aggregated and pooled euro area data. Instead of assuming rational expectations, inflation expectations were proxied by OECD inflation forecasts and three different proxies for real marginal costs were used. Robustness of the results was analyzed by investigating inflation dynamics across different sub-periods and country groups.

The results obtained suggest that OECD forecasts perform relatively well as a proxy for inflation expectations in the euro area Phillips relation. In single equation estimations using the restrictions for expectations variables, we got a correctly signed driving variable in the NKPC, contrary to many previous studies under the rational expectations assumption. However, the HPC outperforms the NKPC. Thus we find evidence that lagged inflation term seems to be needed in order to explain the persistence of European inflation accurately. In this approach, the output gap turns out to be at least as good a proxy for real marginal costs as the labor income share. Moreover, the inflation process seems to have become more forward-looking in the recent years of low and stable inflation. Divergent output gap developments across the twelve EMU countries affect the empirical performance of the euro area Phillips relation. Qualitatively similar results are obtained for aggregated and pooled euro area data.

The two alternative Phillips relations have clearly different implications for inflation persistence and optimal monetary policy design. The evidence in favor of the HPC implies that even permanent changes in the inflation rate will always have some short run real effects, unlike the New Keynesian specification (see King 2000). Moreover, if direct measures of inflation expectations perform better than the rational expectations assumption in explaining inflation developments, the results suggest that expectations have important autonomous effects on the monetary policy environment, which should be taken into account in conducting monetary policy.

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Appendix 1

Table A1.1 **Robustness of GMM results**

HPC $\pi_t = (1-\omega)\pi^*_{t+1} + \omega\pi_{t-1} + \gamma\hat{mc}_t$ **or** $\pi_t = (1-\omega)\pi^*_{t+1} + \omega\pi_{t-1} + \phi\hat{y}_t$

Pooled, 1977–1990	ω	γ or ϕ	J-stat.	Instruments	GMM	Obs
Labor income share	0.706*	-0.033	0.015	$\hat{mc}_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q, V, P	160
	(0.059)	(0.030)				
HP filtered output gap	0.723*	0.290*	0.017	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	B, V, –	160
	(0.091)	(0.094)				
OECD output gap	0.571*	0.174*	0.037	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q, V, –	145
	(0.099)	(0.069)				

Pooled, 1991–2003	ω	γ or ϕ	J-stat.	Instruments	GMM	Obs
Labor income share	0.488*	0.001	0.023	$\hat{mc}_{t-1}, \pi_{t-2}, \pi_{t-3}$	B, V, P	152
	(0.037)	(0.014)				
HP filtered output gap	0.479*	0.018	0.014	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	B, V, -	156
	(0.041)	(0.038)				
OECD output gap	0.482*	0.017	0.010	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q, V, –	143
	(0.043)	(0.037)				

HPC $\pi_t = (1-\omega)\pi^*_{t+1} + \omega\pi_{t-1} + \gamma\hat{mc}_t$ **or** $\pi_t = (1-\omega)\pi^*_{t+1} + \omega\pi_{t-1} + \phi\hat{y}_t$

Pooled, high inflation countries	ω	γ or ϕ	J-stat.	Instruments	GMM	Obs
Labor income share	0.628*	0.129	0.007	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q, V, P	184
	(0.083)	(0.112)				
HP filtered output gap	0.657*	0.074	0.006	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q, V, P	186
	(0.052)	(0.047)				
OECD output gap	0.658*	0.062	0.004	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q, V, P	180
	(0.055)	(0.045)				

Pooled, low inflation countries	ω	γ or ϕ	J-stat.	Instruments	GMM	Obs
Labor income share	0.029	0.017	0.004	$\hat{mc}_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q, V, P	128
	(0.168)	(0.034)				
HP filtered output gap	0.154	0.103	0.002	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q V, -	130
	(0.156)	(0.059)				
OECD output gap	0.332*	0.112*	0.008	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q, V, P	108
	(0.119)	(0.048)				

HPC $\pi_t = (1-\omega)\pi^*_{t+1} + \omega\pi_{t-1} + \gamma\hat{mc}_t$ **or** $\pi_t = (1-\omega)\pi^*_{t+1} + \omega\pi_{t-1} + \phi\hat{y}_t$

Pooled, more divergent output gap countries	ω	γ or ϕ	J-stat.	Instruments	GMM	Obs
Labor income share	0.590*	-0.006	0.003	$\hat{mc}_{t-1}, \pi_{t-2}, \pi_{t-3}$	B, V, P	98
	(0.098)	(0.024)				
HP filtered output gap	0.545*	0.081*	0.011	$\hat{y}_{t-1}, \hat{y}_{t-2}, \pi_{t-2}$	B, V, –	100
	(0.114)	(0.036)				
OECD output gap	0.716*	0.059	0.028	$\hat{y}_{t-1}, \hat{y}_{t-2}, \pi_{t-2}$	Q, V, –	73
	(0.119)	(0.047)				

Pooled, less divergent output gap countries	ω	γ or ϕ	J-stat.	Instruments	GMM	Obs
Labor income share	0.640*	0.006	0.013	$\hat{mc}_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q, V, P	214
	(0.067)	(0.016)				
HP filtered output gap	0.644*	0.169*	0.023	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	B, V, -	216
	(0.074)	(0.067)				
OECD output gap	0.733*	0.220*	0.011	$\hat{y}_{t-1}, \hat{y}_{t-2}, \pi_{t-2}$	B, V, –	212
	(0.053)	(0.045)				

Notes: See Table 3.

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