Estimating open economy Phillips curves for the euro area with directly measured expectations

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Abstract

This paper examines euro area inflation dynamics by estimating open economy New Keynesian Phillips curves based on the assumption that all imports are intermediate goods. Instead of imposing rational expectations a priori, Consensus Economics survey data and OECD inflation forecasts are used to proxy inflation expectations. The results suggest that, compared with a closed economy New Keynesian Phillips curve, euro area inflation dynamics are better captured by the open economy specification. Moreover, in the open economy context, and even if we allow for persistence in expectations, the hybrid specification of the New Keynesian Phillips curve is needed in order to capture the euro area inflation process properly. We also provide some evidence that in recent years of low and stable inflation, euro area inflation dynamics have become more forward-looking and the link between inflation and domestic demand has weakened (ie the euro area Phillips curve has flattened). On the other hand, in low-inflation euro area countries the inflation process seems to have been more forward-looking already since the early 1980s.

Keywords: New Keynesian Phillips curve, open economy, expectations, euro area

JEL classification numbers: E31, F41, C52

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1 Introduction

Inflation dynamics are a crucial issue in macroeconomics, empirical macroeconomic modelling and monetary policy making. The modelling of inflation has recently been subject to important new developments. Nowadays, inflation is often modelled using the New Keynesian Phillips curve, which is explicitly based on microfoundations where monopolistically competitive firms set prices, which are sticky. The New Keynesian approach is also explicitly forward-looking, usually applied under the rational expectations hypothesis.

So far the empirical evidence on the New Keynesian Phillips curve has been mixed (see for example Galí and Gertler, 1999; Galí et al, 2001; Sbordone, 2002; Neiss and Nelson, 2005; and Rudd and Whelan, 2002). Among other things, it is still challenging to capture the observed persistence in inflation dynamics and how to best model expectations formation. Typically it has been assumed that expectations are rational, but alternative assumptions of expectations formation have also attracted renewed interest recently. For example, the learning approach (Evans and Honkapohja, 2001, 2003; and Milani, 2007) and sticky information models (Mankiw and Reis, 2001, 2002) have been investigated. Alternatively, we can assume that agents have limited information channels (Woodford, 2002; and Adam, 2007) or heterogeneous expectations (Branch, 2004). Also so-called epidemiology approach has been analyzed (Carroll, 2001).

The introduction of open economy aspects into the New Keynesian Phillips curve is another debated issue in recent literature. In the original closed economy version of the New Keynesian model, current inflation is related to the expected future inflation rate and the current domestic output gap, ie the balance between aggregate demand and potential output. If output is above potential, inflation increases and in the case of slack, inflation falls relative to what is expected. However, inflation dynamics become more complicated in the open economy context, as new channels arise due to exchange rate changes and the effects of foreign shocks. In addition to domestic demand and supply, foreign economic conditions affect domestic inflation, as price setting behavior of foreign firms influences exchange rate developments and import prices. In recent years, globalization, ie the growing interdependence of national economies has arguably emphasized the open economy aspects of inflation dynamics. On the other hand, as imported intermediate inputs (for example energy and food) are widely used in domestic production, their price changes, which can be large and very volatile, may affect the domestic inflation process in a way which is impossible to overlook.

Various open economy extensions of the New Keynesian models of inflation have been suggested. These models differ in the way how the relationship between the real exchange rate and inflation is captured. Imported goods can be modelled as intermediate goods (McCallun and Nelson, 1999, 2000; Kara and Nelson, 2003; Allsopp, Kara and Nelson, 2006), or as final consumption goods

(Galí and Monacelli, 2005). Also more complex models have been examined (Batini et al, 2005; Leith and Malley, 2007; Rumler, 2007). The exchange rate pass-through is assumed to be full in the case of final consumption goods, but incomplete, if imported goods are treated as intermediate goods.

In this paper we follow McCallum and Nelson (1999, 2000) and estimate open economy New Keynesian Phillips curves for the euro area, working on the assumption that all imports can be treated as intermediate goods. This choice can be motivated by the fact that in the domestic consumer markets there are strictly speaking almost no directly imported consumer goods. In fact domestic firms, such as retailers, are always involved, when prices of imported goods are set on the domestic consumer markets. For the retailers, the imports can be treated as intermediate inputs.

Since our aim is to capture inflation dynamics with a reasonably simple model, the intermediate goods approach is a natural choice. In this study, both the purely forward-looking Phillips curves and the hybrid Phillips curves (which is distinguished by the presence of the lagged inflation term) are applied to aggregated and pooled euro area data using generalized method of moments (GMM). The cost of imported intermediate inputs is proxied by the real price of commodity imports or the level of the real exchange rate. Instead of assuming any specific form of expectations formation, we follow Adam and Padula (2003) and Paloviita (2006, 2007a, 2007b) and Paloviita and Mayes (2005) and measure expectations directly using Consensus Economics survey data and OECD inflation forecasts. This approach is obviously compatible with many alternative kinds of expectation formation. With directly measured expectations, we are able to relax a possibly too restrictive assumption of rationality and still model inflation dynamics in a forward-looking way, using the New Keynesian Phillips curve with its microfoundations with optimal price setting.

Direct measures for inflation expectations have not been used in the present open economy context before. This may have distorted the conclusions, as the previous studies have had to test a composite hypothesis, the New Keynesian Phillips curve specification and the assumption of rational expectations. The main purpose is to analyze whether, when using directly measured expectations, open economy extensions improve the empirical fit of the New Keynesian Phillips curve. We examine the (present) euro area as a whole since the early 1980s, although the possible heterogeneity of inflation dynamics is also taken into account by robustness tests, performed across different sub-periods and country groups. Special focus in the analysis of the results is on the forward-looking features of inflation dynamics and the slope of the Phillips curve.

The results of this study suggest that, when modelling imports as intermediate goods, the open economy extension improves the empirical relevance of the New Keynesian Phillips curve in a very significant way. Moreover, also in the open economy framework, the hybrid specification with the lagged inflation term is needed in order to model the inflation process accurately. The empirical evidence is qualitatively same in aggregated and panel data sets. According to the sub-sample analysis, in recent years inflation dynamics seem to have become more forward-looking and the link between inflation and domestic demand has become weaker (ie the euro area Phillips curve has 'flattened'). On the other hand, the inflation process seems to have been relatively forward-looking already in the 1980s in those euro area countries that have had more stable inflation all along. Overall, this study confirms, in the open economy context, the results on euro area inflation dynamics obtained in Paloviita (2006) with the closed economy approach.

This paper proceeds as follows. Section 2 derives alternative specifications of the New Keynesian Phillips curve and section 3 reports on the empirical results. Section 4 presents robustness analysis and section 5 concludes.

2 Alternative specifications of the New Keynesian Phillips curve

Nominal price setting is assumed to be staggered in the New Keynesian approach. In this framework, each monopolistically competitive firm maximizes profits subject to stochastic constraints on the frequency of price adjustments (Calvo, 1983) or subject to menu costs related to changing prices (Rotemberg, 1982). When prices are set optimally, agents take into account expected future costs and demand conditions. At the aggregate level we can express the following linearized relationship between current inflation, expected future inflation, and real marginal cost

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \lambda \hat{mc}_t \tag{2.1}$$

where π_t denotes the period t inflation rate and $\hat{mc}_t$ the period t log deviation of firms' real marginal cost from its steady state value. E_t is the expectation operator conditional on information available in period t. If expectations are rational, agents do not make systematic errors, when forming inflation expectations. In this model, inflation is entirely forward-looking and the parameter β refers to the subjective discount factor, which is taken to be 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 given period, the coefficient of real marginal cost, λ, is decreasing in θ. Thus, the longer prices remain fixed on average, the less sensitive inflation is to current real marginal cost. In empirical studies, the output gap and labor income share (real labor cost) are commonly used as alternative proxies for real marginal cost. When output gap is used, one obtains the pricing equation

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \kappa \hat{y}_t \quad (2.2)$$

where $\kappa = \lambda\delta$ and δ is output elasticity of real marginal cost.

In the hybrid Phillips curve, price setting of some firms is based on recent history of aggregate prices. The hybrid specification (Galí and Gertler, 1999) is based on the idea that some price setters use rules of thumb or indexation in price setting. When the proportion of these 'backward-looking' price setters is denoted by ω, the model can be expressed as

$$\pi_t = (1-\omega)E_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \gamma \hat{mc}_t \quad (2.3)$$

where π_{t-1} denotes the lagged inflation rate. As written in equation (2.3), the sum of the estimated coefficients of the inflation terms can be restricted to unity in order to consider their relative weights in the inflation process. In the output gap-based model, the last term (real marginal cost) is replaced by $\phi\hat{y}_t$.

The two Phillips relations have clearly different implications for inflation persistence. The ad hoc interpretation of backward-looking behaviour in the hybrid Phillips curve has been questioned in recent literature. It has been argued that the lagged inflation term in the hybrid model does not necessarily reflect backward-looking behaviour of price setting. Instead, it has been suggested that the persistence captured by the hybrid Phillips curve is actually related to inertia in inflation expectations: the lagged inflation term potentially reflect a departure of expectations from rationality (Woodford, 2007).

In an open economy, firms' total cost is not necessarily captured properly by labor income share or the output gap as such. If imported intermediate inputs are important in production of final goods and services, they need to be taken into account when measuring real marginal cost. This is especially important because the price changes of imported inputs are often different and more volatile than those of domestic intermediate inputs.

Following McCallum and Nelson (1999, 2000), Kara and Nelson (2003) and Allsopp, Kara and Nelson (2006) the closed economy Phillips curves can be extended to open economy context by assuming that all imported goods are in fact intermediate goods for domestic price setters, which implies that the original real marginal cost variable must be modified to take this into account. In this framework, all final consumer goods are assumed to be produced domestically. We assume that the pass-through of exchange rate changes into imported materials is complete but aggregate consumer prices are sticky due to domestic price making. When modelling imports as intermediate goods, exchange rate changes affect inflation only through marginal costs of firms, as there is then no direct channel from exchange rates to domestic inflation. If real exchange rate increases (depreciation), rise in exports increase aggregate demand and potential output fall due to increasing production costs of domestic goods. As a result, positive output gap increases and inflation pressure rises in the economy.

When extending the output gap -based closed economy models to open economy context, we obtain

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \kappa\hat{y}_t + \varphi_1 q_t \text{ and} \tag{3.4}$$

$$\pi_t = (1-\omega)E_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \phi\hat{y}_t + \varphi_2 q_t \tag{3.5}$$

The term q_t refers to the open economy variable, which is proxied by the real price of commodity imports or the real exchange in the level form[2,3]. Since all imports are assumed to be included in the production function, we assume that the open economy variable captures the effect of intermediate goods on potential output (and thus marginal cost). When using directly measured expectations, we need to modify equations (3.4) and (3.5) slightly to get

$$\pi_t = \beta\overline{E}_t\{\pi_{t+1}\} + \kappa\hat{y}_t + \varphi_1 q_t + \varepsilon_t \text{ and} \tag{3.6}$$

$$\pi_t = (1-\omega)\overline{E}_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \phi\hat{y}_t + \varphi_2 q_t + \varepsilon_t \tag{3.7}$$

where $\overline{E}_t\{\pi_{t+1}\}$ refers to period t representative expectations, which are not necessarily rational. Adam and Padula (2003) have shown that we can derive New Keynesian Phillips curve with directly measured expectations.

3 Empirical results

3.1 Data description

OECD National Accounts were used to construct annual inflation rates, the output gaps and real price of commodity imports for twelve euro area countries for the years 1977–2006. Import structures of individual countries are taken into account in commodity import prices. Respectively, real effective exchange rates, based on relative consumer prices, were obtained from the IMF (International Financial

[2] In McCallum and Nelson (1999) the open economy Phillips curve specification is based on the CES production function $Y_t = [a_1(A_tN_t)^{v1}+(1-a_1)(IM_t)^{v1}]^{1/v1}$. In this expression, A_t refers to a labour-augmenting technology shock, N_t is labour input, IM_t is the quantity of imports, and $0<a_1<1$. CES technology leads to real marginal cost, which is a combination of real wages (deflated by a productivity shock) $(W_t/P_t)/A_t$ and the real import price $\log[(W_t/P_t)/A_t]$. After log-linearising and assuming full pass-through, and using unit labour cost to proxy $\log[(W_t/P_t)/A_t]$, we obtain a Phillips curve specification, where q_t enters in a level form with a positive coefficient.

[3] The real exchange rate enters the equation in the difference form, if we assume that all imports are final consumer goods, priced abroad (see Galí and Monacelli, 2005).

Statistics database). In estimations, detrended series were used for the open economy variables. The output gaps are based on Hodrick-Prescott filtering. Inflation was measured by annual percentage changes of consumer prices. Corresponding inflation expectations were obtained from two alternative sources: Consensus Economics monthly survey[4] and the OECD Economic Outlook, which is published twice a year (in June and December). Since we cannot pin down the exact timing of the expectations term with annual data, we collected June estimates for the next calendar year from both sources. In the analyses using the OECD forecasts, which are available since 1981, both approaches, aggregated data and pooled data were used (the latter in the form of a balanced panel). Instead, due to a relatively short sample, 1990–2006, it was deemed reasonable to use the pooled data approach only in our analyses with the Consensus Economics survey information.[5,6]

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[4] Luxembourg is missing in Consensus Economics survey.

[5] ECB GDP weights, based on actual exchange rates, were used in the aggregation. Country weights for 2004 are: Germany 27.9, France 21.3, Italy 17.7, Spain 11.3 Netherlands 6.3, Belgium 3.7, Austria 3.1, Finland 2, Greece 2.3, Portugal 1.8, Ireland 2 and Luxembourg 0.4. For Germany and the euro area, German unification was taken into account using OECD Economic Outlook estimates.

[6] Paloviita (2007a) compares Consensus Economics inflation forecasts with corresponding OECD estimates. She shows that the two proxies of inflation expectations, which seem to follow a similar pattern, are highly correlated (the correlation coefficient is over 0.9). Therefore, comparison of estimation results using alternative proxies for inflation expectations is plausible in the present study.

Figure 3.1 **Actual and expected inflation rates and the output gap for the euro area (aggregated data)**

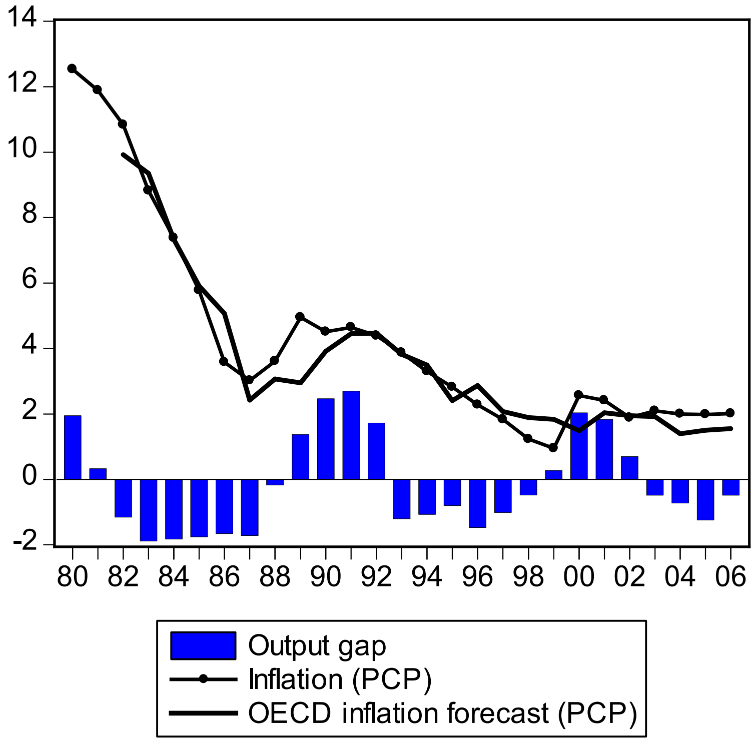

Figure 3.2 **Open economy variables for the euro area (aggregated data)**

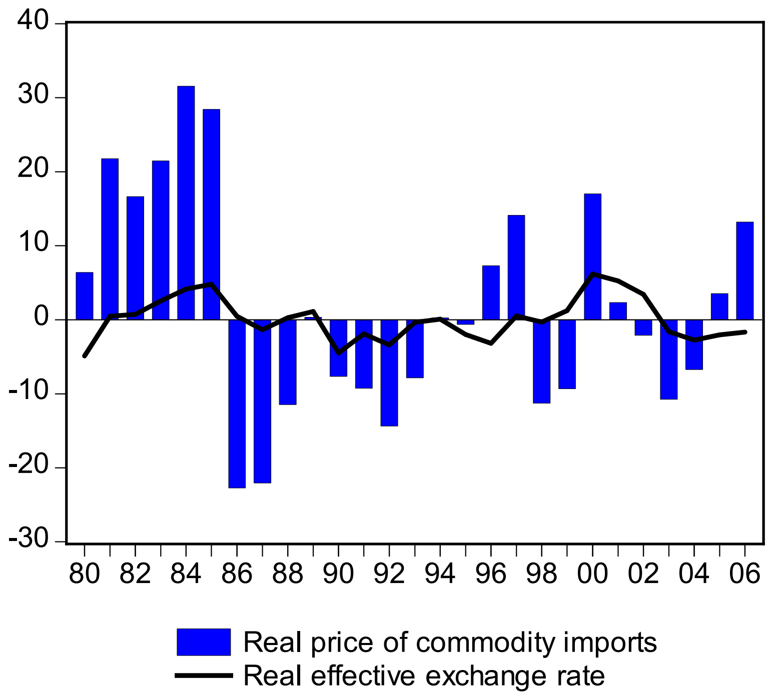

Figure 3.1 shows the inflation history and inflation forecasts for the euro area. The four biggest economies – Germany, France, Italy and Spain – dominate the euro

area, with a combined weight of over 80 per cent. In the beginning of the sample, the euro area inflation was over 10 per cent, but during the 1980s it decreased sharply to 3 per cent in 1987. After a small peak in 1989 inflation gradually moderated again almost throughout the 1990s. In the last years of our sample, euro area inflation was quite low and stable. Figure 3.1 seems to support the view that inflation expectations have been based, at least partly, on forward-looking information, since major changes in the actual inflation rate have been anticipated fairly well by expectations. However, decreasing inflation has typically been overestimated and increasing inflation underestimated, suggesting a degree of inertia in expectations.

The euro area output gap, which peaked in 1991 and 2000, was negative in seven subsequent years in the 1980s and six years in the 1990s. Negative output gaps were also experienced in the four last years in the sample. Real price of commodity imports has been clearly more volatile than the real effective exchange rate (see Figure 3.2).

3.2 Statistical properties of expectational errors

When measuring inflation expectations directly, we are able to examine how actual and expected inflation are related, according to our measures of expectations, and whether inflation expectations are accurate and unbiased estimates of the actual inflation rate. We can also investigate time series properties of expectational errors (differences between expected and actual inflation), which should be white noise under rationality. Possible autocorrelation of expectational errors would indicate informational problems, which are against a strict assumption of rationality. If rational expectations are imposed although the data would reject the hypothesis, we may obtain biased parameter estimates for the New Keynesian model and a wrong assessment of the overall empirical performance of the New Keynesian Phillips curve. In particular, possible persistence of expectations, which may be an important determinant of inflation dynamics, needs to be taken into account in order to avoid wrong policy conclusions.

In the pooled (panel) data set, the correlation coefficient between actual inflation rates and expectations is 0.853, when Consensus Economics survey data is used (shorter sample) and 0.944, when OECD inflation forecasts are used (longer sample). Respectively, when OECD inflation forecasts are investigated in the aggregated data set, we obtain the correlation coefficient 0.956 for the years

1981–2006.[7] Overall, the correlation coefficients are relatively high in the euro area.

Next, we calculate some standard statistics in order to examine inflation expectations in more detail. The mean error (ME) shows the average expectational error and provides evidence of any systematic over- or underprediction of inflation in the sample. The mean absolute error (MAE) statistic measures the average accuracy of expectations. If expectational errors are large but counterbalancing, we get a low mean error but a mean absolute error is higher. Also root mean squared errors (RMSE) are constructed to measure expectational accuracy.[8] Compared to the mean absolute error, the root mean squared error is more sensitive to very large errors in expectations. For the sake of comparison, the three statistical measures are also calculated for naïve inflation forecasts based on the assumption that the expected next year inflation rate is always equal to the current year inflation rate.

Table 3.1 **Inflation forecast performance statistics**

Pooled data	**Consensus forecast**	**Naive forecast**	**Aggregated data**	**OECD forecast**	**Naive forecast**
1990 - 2006			**1981 - 2006**		
ME	0.099	0.203	ME	-0.147	0.395
MAE	0.775	0.788	MAE	0.536	0.707
RMSE	0.973	1.059	RMSE	0.703	0.939

Pooled data	**OECD forecast**	**Naive forecast**
1981 - 2006		
ME	-0.218	0.425
MAE	1.031	1.153
RMSE	1.563	1.634
1981-1993		
ME	-0.347	0.698
MAE	1.377	1.524
RMSE	2.024	2.075
1994-2006		
ME	-0.099	0.173
MAE	0.711	0.809
RMSE	0.957	1.078

ME = Mean error, MAE = Mean Absolute Error, RMSE = Root Mean Squared Error.

The upper part of table 3.1 shows that, according to all statistics, naïve forecasts are outperformed by directly measured expectations, especially in the aggregated data set. The OECD forecast is more accurate than the Consensus forecast in terms of the MAE and RMSE statistics, but less accurate than the Consensus forecast in terms of the mean error.

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[7] Paloviita and Mayes (2005) examine euro area inflation dynamics and use OECD inflation forecasts to proxy expectations. In their study, the corresponding correlation coefficient is 0.955 for the years 1977–2002.

[8] More precisely, $\text{RMSE} = \left((1/T) \sum_{i=1}^{T} \left\{ \left[x_i - x_i^* \right]^2 \right\} \right)^{1/2}$.

The lower part of table 3.1, evaluating the OECD inflation forecast measure in different sub-periods, indicates that the performance of expectations has clearly improved over time. In the second sub-period both the MAE and the RMSE are about half of their levels in the first sub-period. This indicates that most of the bias in expectations in the whole sample is related to the first sub-period. On the other hand, within the sub-periods, the difference between the MAE and the RMSE is smaller in the second one. Sub-period results are probably a result from the fact that lower and more stable inflation rates were achieved in the euro area countries in the second sub-period. Sub-period analysis also confirms the result from the whole sample analysis that measured expectations compare favourably with naïve forecasts.

Under rationality, expectations should be unbiased. To assess this, we estimate, by using ordinary least squares, simple equations of the form $\pi_t = a + b\pi_t^*$ where π_t refers to the actual inflation rate and π_t^* to the corresponding inflation expectations. Using the Wald test we consider the joint hypothesis according to which the constant a is equal to zero and the coefficient b is equal to one. If this joint hypothesis is rejected, we get evidence against unbiasedness in a statistical sense.

As reported in table 3.2, the Wald test provides support to the hypothesis of unbiasedness of euro area inflation expectations for both expectations proxies and both data sets. Even when we examine the whole sample since the beginning of the 1980s, expectations seem to be unbiased. The null hypothesis is never rejected at a reasonable level of significance.[9]

Table 3.2 **Unbiasedness of inflation forecasts**

	Wald test	
Pooled data, Consensus Economics	F = 1.272	(0.283)
Pooled data, OECD forecasts		
– Whole sample	F = 2.606	(0.076)
– 1981–1993	F = 1.941	(0.147)
– 1994–2006	F = 1.621	(0.201)
Aggregated data, OECD forecasts	F = 0.602	(0.556)

Note: Newey-West HAC standard errors, p-values in parentheses.

On the whole, the forecast performance statistics and the Wald test results give support to the rationality of expectations in a static sense and expected inflation

[9] Paloviita (2006) uses OECD inflation forecasts to proxy euro area inflation expectations and provides evidence that in 1977–1990, when inflation was high and volatile in many European countries, inflation expectations were biased. By contrast, the hypothesis of unbiasedness cannot be rejected in the euro area for the period 1991–2003.

seems to provide a reasonable estimate of the actual future inflation. However, on the basis of static analysis we are not able to assess dynamics of expectations. In every period, expectations may be revised on the basis of new information and past expectational errors. Under rationality, the expectational errors should be uncorrelated white noise.

Table 3.3 **Ljung-Box autocorrelation tests**

Pooled data, Consensus Economics forecasts

Expectational errors:		Residual of unbiasedness test:	
Q(1)	18.336*	Q(1)	18.037*
Q(2)	23.132*	Q(2)	22.382*
Q(3)	23.338*	Q(3)	22.47*

Pooled data, OECD forecasts

Expectational errors:		Residual of unbiasedness test:	
Q(1)	26.928*	Q(1)	20.953*
Q(2)	27.07*	Q(2)	21.198*
Q(3)	32.053*	Q(3)	31.006*

Aggregated data, OECD forecasts:

Expectational errors:		Residual of unbiasedness test:	
Q(1)	0,5929	Q(1)	0,5764
Q(2)	0,6577	Q(2)	0,6337
Q(3)	1,6405	Q(3)	1,6017

Note: Q(n) denotes the Ljung-Box autocorrelation test statistics for up to *n* th-order autocorrelation. *indicates significance at 5 per cent level.

Time series properties of both expectational errors and residuals of unbiasedness tests are investigated in table 3.3. With the pooled data Ljung-Box Q-statistics provides evidence that expectational errors are clearly positively autocorrelated, as the test strongly rejects the null hypothesis of no autocorrelation up to order 1–3. Strong autocorrelation seems to be also present when considering residuals of the above reported unbiasedness tests. With the aggregated data, which includes clearly less observations, the null hypothesis is not rejected, however.

Finally, orthogonality tests are used to test the efficiency of expectations. If expectations are efficient, errors of expectations are orthogonal with respect to information available at the time, when expectations are formed. Therefore, under rationality, past information should not explain expectational errors. If only past inflation rates are included in the information set, we test the weak-form efficiency of expectations. If, instead, the information set includes also other macroeconomic variables, we test efficiency in the strong form.

First efficiency test was applied to both data sets by regressing expectational errors on past actual inflation rates (two or three lags). The Wald test was used to test the null hypothesis, according to which all estimated coefficients are jointly equal to zero. With both data sets the null hypothesis is clearly rejected in all cases at the conventional 5% level (see the upper part of Appendix 1). The strong from of efficiency is examined using two alternative specifications. The lagged output gap and the lagged actual inflation rate are the explanatory variables in Model E1, and the lagged values of expected inflation, the level of real exchange rate and the real price of commodity imports in Model E2. The lower part of Appendix 1 shows that according to the Wald test, the strong form of efficiency is decisively rejected by the pooled data at the 5% significance level, but not rejected by the aggregated data (which has less observations). Overall, the results reported in Appendix 1 give clear evidence against the efficiency of inflation expectations (in either weak or strong form of efficiency).

The analysis of this section suggests that in inflation expectations seem to be rational only in the static sense. According to the time series properties of expectational errors, rationality does not get support, however. As expectational errors are not white noise, expectations seem not to be formed on the basis all relevant information available at the time. Overall, the inflation expectations analysis indicates that possible deviations of expectations from rationality need to be taken into account in empirical analysis of Phillips curves, for instance. This provides a strong case for using empirical measures of expectations instead of relying on the rational expectations hypothesis. When using direct proxies of inflation expectations, we can allow possible persistence in expectations to affect the empirical fit of the New Keynesian Phillips curve without making any specific assumption of expectations formation.

3.3 Estimations

First, both closed and open economy specifications of the New Keynesian Phillips curve were estimated using pooled euro area data. Both the purely forward-looking and the hybrid model were examined. Across all estimations, survey-based expectations were used, and thus the estimation period was 1990–2006. In these years, inflation was relatively low and stable in the euro area. Following Galí and Gertler (1999), who examine US inflation dynamics and euro area inflation analysis of Galí et al (2001), our empirical analysis is based on the GMM technique.[10,11] In order to enable comparisons, same instruments were used in all cases and the standard errors of the estimated coefficients were modified in the same way (using the Bartlett kernel). Two alternative specifications of the open economy Phillips curve were considered: the model A with the real price of commodity imports (rci) and the model B with the level of the real exchange rate (rer). In the case of the purely forward-looking model, the imposed value of the coefficient of the expectations term, β was 0.97. Respectively, the sum of the expectations terms was restricted to unity, when estimating the hybrid model.

As reported in upper part of table 3.4, in the purely forward-looking model, all estimated coefficients are statistically significant. Moreover, output gap coefficients are quite reasonable, 0.2–0.3, and the lowest one is obtained for the closed economy model. The estimated coefficient for the real price of commodity imports is 0.02 (model A) and, when using the real exchange rate, a clearly higher coefficient is received: 0.1 (model B). Higher coefficient in model B reflects the smaller variance in absolute terms of the open economy variable in that model. Overidentifying restrictions are not rejected in any case at the conventional 5% level. Overall, the estimation results for the purely forward-looking model with pooled euro area data are quite acceptable in their own terms.

Also in the case of the hybrid model, all estimated coefficients are correctly signed and statistically significant (with one exception), as shown in lower part of table 3.4. Relative weights of the backward-looking inflation term are quite close to 0.5 in two of the cases, but a clearly higher coefficient for the lagged inflation term, 0.7, is obtained for the open economy model using real exchange rate (model B). Only in the case of closed economy model, the forward-looking expectations seem to dominate the inflation process (the estimated ω coefficient is below 0.5 in that case). Compared with the corresponding purely forward-looking models, lower output gap coefficients are always obtained with the hybrid

[10] Traditionally, the New Keynesian Phillips curve analysis is based on the assumption that inflation is stationary. Possible non-stationarity invalidates GMM estimation results, but Engle and Granger (1987) have shown that a linear combination of non-stationary time series may be stationary. The New Keynesian Phillips curve is explicitly based on microfoundations and in the present study we use directly measured expectations and additional open economy variables. Thus, we make a conventional assumption of stationarity and rely on GMM, which is widely used in empirical analysis of inflation dynamics.

[11] According to Ma (2002) and Mavroeidis (2005), when estimating the New Keynesian Phillips curve with GMM, backward-looking and forward-looking terms cannot be distinguished correctly (identification problem). Mavroeidis (2005) points out that identification is determined by the uniqueness of the solution to the system, which contains both the New Keynesian Phillips curve and the equations, which determine the exogenous variables. Ma (2002) shows that the estimated parameters for the forward-looking and backward-looking inflation terms in the hybrid specifications are only weakly identified. He argues that this is due to the fact that the objective function is non-quadratic and contrary that, GMM is based on quadratic objective function. However, in this study we want to avoid a system, in which we need to test a complicated joint hypothesis, which determine at the same time both the New Keynesian Phillips curve and all exogenous variables. Instead, as we are interested in open economy aspects of inflation dynamics, instrumental variable techniques (GMM) is used to treat endogeneity of external variables without any specific assumption of the form of endogenity. It is also worth noting that with directly measured expectations, endogeneity issue is not necessarily a major problem when using GMM.

specification and, interestingly, the lowest output gap coefficient is again obtained for the closed economy model. The estimated coefficients of the open economy variables are close to the ones with the purely forward-looking models. Overidentifying restrictions are never rejected at 5% level.[12]

Table 3.4 **GMM estimates using pooled data**

New Keynesian Phillips curve

Closed economy model $\pi_t = 0.97 * \overline{E}_t\{\pi_{t+1}\} + \kappa\hat{y}_t$

Open economy model A $\pi_t = 0.97 * \overline{E}_t\{\pi_{t+1}\} + \phi\hat{y}_t + \varphi_1 rci_t$

Open economy model B $\pi_t = 0.97 * \overline{E}_t\{\pi_{t+1}\} + \phi\hat{y}_t + \varphi_2 rer_t$

	κ or ϕ	φ_1	φ_2	J-stat.
Closed model	0.230			0.027
	(0.033)*			[0.085]
Open economy model A	0.278	0.023		0.030
	(0.034)*	(0.007)*		[0.063]
Open economy model B	0.248		0.109	0.032
	(0.053)*		(0.046)*	[0.054]

Note: Numbers in parentheses are standard errors, * indicates significance at 5 per cent level. J-statistic corresponds to Hansen test of overidentifying restrictions (p-values below in brackets). Instruments: the lagged output gap, second and third lags of inflation. Additional instrument in open economy models: lagged real oil price change.

Hybrid Phillips curve

Closed economy model $\pi_t = (1-\omega)\overline{E}_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \kappa\hat{y}_t$

Open economy model A $\pi_t = (1-\omega)\overline{E}_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \phi\hat{y}_t + \varphi_1 rci_t$

Open economy model B $\pi_t = (1-\omega)\overline{E}_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \phi\hat{y}_t + \varphi_2 rer_t$

	ω	κ or ϕ	φ_1	φ_2	J-stat.
Closed model	0.437	0.126			0.007
	(0.056)*	(0.021)*			[0.530]
Open economy model A	0.591	0.152	0.031		0.028
	(0.060)*	(0.022)*	(0.007)*		[0.076]
Open economy model B	0.703	0.136		0.168	0.008
	(0.092)*	(0.070)		(0.047)*	[0.492]

Note: Numbers in parentheses are standard errors, * indicates significance at 5 per cent level. J-statistic corresponds to Hansen test of overidentifying restrictions (p-values below in brackets). Instruments: the lagged output gap, second lag of inflation, lagged real oil price change, lagged real oil price level. Additional instruments in open economy model B: second lag of real oil price level, lagged real exchange level.

[12] We also estimated unrestricted hybrid Phillips curves (not reported here). The estimated coefficients were almost unchanged and according to Wald test, the restriction of the inflation terms was never rejected.

Next, we repeated the estimations reported in table 3.4, this time with aggregated data. In this case inflation expectations were proxied by OECD forecasts and therefore, the estimation period was longer, from 1981 to 2006. In this case, the empirical performance of the purely forward-looking model was poor, probably due to sharply decreasing inflation in the 1980s.[13] Instead, the hybrid Phillips curve results are reasonable, as shown in table 3.5. The estimated coefficient for the lagged inflation rate varies between 0.5–0.6, which implies that backward-looking expectations dominate slightly the inflation process. Again, the lowest output gap coefficient (0.1) is obtained for closed economy model and the estimated open economy coefficients are close to the ones obtained with corresponding pooled data. According to J-statistics, in none of the cases overidentifying restrictions are rejected at 5% level.

Table 3.5 **GMM estimates using aggregated data**

Hybrid Phillips curve

Closed economy model $\pi_t = (1-\omega)\overline{E}_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \kappa\hat{y}_t$

Open economy model A $\pi_t = (1-\omega)\overline{E}_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \phi\hat{y}_t + \varphi_1 rci_t$

Open economy model B $\pi_t = (1-\omega)\overline{E}_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \phi\hat{y}_t + \varphi_2 rer_t$

	ω	κ or ϕ	φ_1	φ_2	J-stat.
Closed model	0.536	0.108			0.171
	(0.051)*	(0.049)*			[0.108]
Open economy model A	0.487	0.276	0.019		0.106
	(0.057)*	(0.074)*	(0.006)*		[0.096]
Open economy model B	0.615	0.383		0.120	0.178
	(0.063)*	(0.091)*		(0.055)*	[0.202]

Note: Numbers in parentheses are standard errors, * indicates significance at 5 per cent level. J-statistic corresponds to Hansen test of overidentifying restrictions (p-values below in brackets). Instruments: the lagged output gap, second lag of inflation, lagged real oil price change, lagged real oil price level. Additional instruments in open economy model B: second lag of real oil price level, lagged real exchange level.

All in all, the results in tables 3.4 and 3.5 are quite robust across different data sets. They indicate that the open economy extension to the New Keynesian Phillips curve is warranted and its omission would not be accepted by the data. In all cases open economy variables are statistically significant, and therefore they improve the empirical relevance of the model. Even if we allow for a departure of expectations from rationality in the open economy framework, the purely

[13] For the purely forward-looking models only in the case of model A, a reasonable output coefficient is obtained (not reported here). However, in all cases the estimated parameters for open economy variables are quite reasonable and close to the ones with pooled data. For the closed model overidentifying restrictions are rejected at the 5% level according to the Hansen test.

forward-looking specification is not able capture the persistence in inflation dynamics properly. Thus, the hybrid model with the lagged inflation term seems to be needed in order to capture the inflation process properly. In Paloviita (2006), where directly measured expectations are used in the closed economy context, qualitatively similar results are obtained: the purely forward-looking model is outperformed by the hybrid specification.

Next, we wanted to consider, how critical the choice of the estimation method is in this context (see footnotes 9 and 10). For comparison, hybrid Phillips curve estimations were repeated using ordinary least squares. In this case, only the survey-based expectations were considered and the pooled sample was used. Least squares estimation is based on the assumption that all model variables are measured correctly and are thus not correlated with the error term of the model. Thus, when using least squares, we have to assume that possible measurement errors or simultaneity problems need not to be taken into account in empirical analysis.[14]

According to least squares estimates reported in Appendix 2, forward-looking expectations clearly dominate the euro area inflation process. In the corresponding GMM estimates, the relative weight of backward-looking expectations was clearly higher (see table 3.4). With both estimation methods the estimated output gap coefficients are almost the same. As reported in Appendix 2, the estimated open economy parameters are very close to each other (0.02 and 0.03). Overall, we can conclude that the least squares results support the validity GMM results reported above. The results of the analysis seem not to be due to any problems specific to the GMM method.

Finally, the timing of the expectations term was considered. Instead of using June information, December forecasts were collected from both sources and open economy Phillips curves were estimated with both data sets. As before, OECD measures were used with aggregated, and survey measures with pooled data. Results are reported in Appendix 3. In the case of aggregated data, when December survey information is used, slightly lower coefficients for the lagged inflation term and the output gap are obtained, but the estimated coefficients for the open economy variables are almost unchanged. When estimating the pooled data with December forecasts, we get again evidence of more backward-looking inflation dynamics. Broadly speaking, however, we can conclude that the empirical results seem to be qualitatively robust with respect to the timing of the expectations term.

The empirical relevance of the open economy Phillips curve specification based on imported intermediate goods is supported by several other studies also. For example, Kara and Nelson (2003) have examined UK inflation dynamics

[14] Under rationality assumption, least squares is not an appropriate estimation method of the New Keynesian Phillips curve. However, it can be used with directly measured expectations, if certain assumptions are valid, as described in the text.

since the mid-1960s by estimating several alternative specifications. They argue that if imports are treated as intermediate goods in the New Keynesian model, the best empirical fit is obtained. According to their view, the good performance of the imported intermediate goods specification is due to the fact that import prices are more closely related to exchange rate developments than final consumption goods prices. The same evidence can be found in Allsopp, Kara and Nelson (2006), who also argue that when analyzing the UK inflation process, it is appropriate to model imports as intermediate goods rather than final consumer goods.

Batini et al (2005) examine more complex open economy Phillips curves, where employment adjustment costs are included, variations in the equilibrium price markup are allowed (due to external competitive pressures) and the cost impact of changes in material input prices are accounted for. They provide evidence that inflation in the UK is explained both by changes in labor adjustment costs and by changes in relative prices of imported intermediate goods, including oil prices.

Lendvai (2005) has examined inflation dynamics in Hungary since 1995. According to her findings, the Hungarian inflation dynamics, which can be characterized by a history of relatively high inflation, can be reasonably well captured by the closed economy New Keynesian Phillips curve. However, it can also be described using the open economy specification, where imported goods are treated as intermediate goods. Lendvai (2005) argues that the imported final consumption goods specification is not supported by the data, however.

4 Robustness analysis

Table 4.1 **Sub-period estimates**

Open economy model A $\pi_t = (1-\omega)\overline{E}\{\pi_{t+1}\} + \omega\pi_{t-1} + \phi\hat{y}_t + \varphi_1 rci_t$

Open economy model A	ω	ϕ	φ_1	J-stat.
Whole sample	0.568	0.164	0.024	0.009
	(0.051)*	(0.028)*	(0.007)*	[0.249]
1981–1993	0.584	0.187	0.018	0.014
	(0.057)*	(0.046)*	(0.009)	[0.337]
1994–2006	0.460	0.115	0.030	0.005
	(0.042)*	(0.036)*	(0.007)*	[0.668]
F(3,306)	2.155			
Probability	0.093			

Open economy model B $\pi_t = (1-\omega)\overline{E}_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \phi\hat{y}_t + \varphi_2 rer_t$

Open economy model B	ω	ϕ	φ_2	J-stat.
Whole sample	0.584	0.158	0.140	0.012
	(0.050)*	(0.047)*	(0.044)*	[0.156]
1981–1993	0.595	0.240	0.088	0.023
	(0.053)*	(0.075)*	(0.055)	[0.170]
1994–2006	0.513	-0.052	0.176	0.007
	(0.067)*	(0.096)	(0.057)*	[0.570]
F(3,306)	2.560			
Probability	0.055			

Note: see table 3.4.

The full sample results of the previous section indicate that euro area inflation dynamics are better captured using open economy models. In addition, both in the closed and open economy models, the hybrid specifications are needed to model the dynamics of the inflation process accurately. Thus, inflation persistence cannot be properly captured with purely forward-looking models, even if possible persistence of expectations is taken into account by using direct expectations proxies. Qualitatively, the results seemed not to be sensitive to choice of the data sets or the choice of the open economy variable to be included in the New Keynesian model. Moreover, the estimation results are not much sensitive to the timing of the expectations term (mid-year or close-of-the-year information).

Next, we examine the general validity of the empirical results of the previous section in more detail. More specifically, we use the pooled (panel) data set with OECD inflation forecasts in order to investigate, whether the empirical fit of the Phillips relation in the open economy context is different in different policy regimes. We estimate open economy hybrid Phillips curves for the whole sample and for the periods 1981–1993 and 1994–2006. In the first sub-period, higher inflation rates were experienced and there was clearly more heterogeneity in price developments across euro area countries. The Chow test is used to analyze whether the same model is appropriate for different sub-samples.

Sub-period results are shown in table 4.1. Both models indicate that the euro area inflation process was more forward-looking in the second sub-period than in the first one. According to model A, forward-looking expectations dominated slightly the inflation process in 1994–2006, and in the case of model B, the estimated coefficient for the lagged inflation term was also very close to 0.5. Both open economy models provide evidence that euro area Phillips curve has become flatter in recent years. In the case of model B we even obtain a negative (but insignificant) output gap coefficient.[15] When using real price of commodity imports as a proxy for intermediate goods, the estimated open economy coefficient is almost unchanged across the two sub-periods. By contrast, for the real exchange rate a remarkably higher coefficient is obtained in the second sub-period (model B). The Hansen test led to rejection in none of the cases.

The Chow test results are also reported in table 4.1. Interestingly, they indicate that the same open economy model parameters apply to both sub-periods at conventional 5 per cent level significance. Thus, we get evidence that euro area inflation dynamics is properly captured in the whole sample, although price developments were quite different in the 1980s and after that. At the same time, the quantitative results are consistent with the view, also given in Paloviita (2006) in the closed economy context, that in recent years inflation expectations seem to have become more forward-looking in the euro area. Moreover, compared to the 1980s, the link between inflation and domestic demand has become weaker.

Also many other recent studies indicate that the relationship between inflation and domestic demand has weakened over time. For example, IMF (2006) investigates the Phillips curve in G7 countries and Australia and finds this evidence for many countries. The same can be found also in Pain et al (2006) for several OECD countries. Inflation in 16 industrial countries is analyzed in Borio and Filardo (2007) since the beginning of the 1980s and 11 industrial countries are examined in Ihrig et al (2007) since the late 1970s. Both of these studies, and also Paloviita (2006), confirm the view that in recent years the slope coefficient of the Phillips curve has become smaller.

Due to heterogeneity in inflation history the across euro area countries, we finally examined, whether inflation dynamics are different in high and low inflation countries. The countries in the sample 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 Netherlands). Again pooled data and OECD inflation forecasts were used and

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[15] If lagged real oil price change is removed from the instrument set, a positive coefficient for the output gap is obtained in this case.

hybrid Phillips curves were estimated since 1981. As reported in table 4.2, we obtained reasonable results for both country groups with both models. Results of both models in table 4.2 indicate that forward-looking expectations dominate the inflation process in the whole sample (1981–2006), when low inflation countries are considered. The other coefficients are almost the same for both country groups, when model A with real price of commodity imports is examined. By contrast, with model B based on the real exchange rate we get clearly lower coefficient for the output gap and the open economy coefficients in the case of low inflation countries. In table 4.2 overidentifying restrictions were never rejected. The dominance of forward-looking expectations for low inflation euro area countries is also found in Paloviita (2006) in the closed economy context. According to the Chow test, however, the same model is appropriate for both county groups, so the open economy version of the New Keynesian Phillips curve is generally valid, in a statistical sense, despite the differences in point estimates discussed above.

Table 4.2 **Robustness analysis: GMM estimates for high inflation and low inflation countries**

Open economy model A $\pi_t = (1-\omega)\overline{E}_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \phi\hat{y}_t + \varphi_1 rci_t$

Open economy model A	ω	ϕ	φ_1	J-stat.
High inflation countries	0.576	0.156	0.029	0.013
	(0.055)*	(0.036)*	(0.008)*	[0.315]
Low inflation countries	0.399	0.179	0.018	0.018
	(0.109)*	(0.046)*	(0.010)	[0.312]
F(3,306)	-0.260			
Probability	1			

Open economy model B $\pi_t = (1-\omega)\overline{E}_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \phi\hat{y}_t + \varphi_2 rer_t$

Open economy model B	ω	ϕ	φ_2	J-stat.
High inflation countries	0.588	0.180	0.159	0.021
	(0.053)*	(0.063)*	(0.059)*	[0.144]
Low inflation countries	0.427	0.132	0.101	0.021
	(0.119)*	(0.061)*	(0.056)	[0.258]
F(3,306)	1.017			
Probability	0.386			

Note: see tables 3.4.

Overall, the robustness analysis in this section gives weak evidence that in recent years the euro area inflation process has become more forward-looking and the Phillips curve has flattened. Statistically speaking, with conventional levels of significance, this change is not sharp enough to invalidate the applicability of a single model to describe the data throughout the period. Moreover, in the whole sample, in those countries, were inflation has been quite low and stable all the time, forward-looking expectations seems to have dominated inflation dynamics all along.

5 Concluding remarks

In recent years, New Keynesian Phillips curves have been intensively applied and tested in macroeconomic research and monetary policy analysis. However, how expectations are actually formed, and how to model openness accurately are still unresolved questions. Various assumptions of expectations formation have been analyzed and different open economy extensions of New Keynesian models have been proposed.

In this study we analyze euro area inflation dynamics by estimating open economy New Keynesian Phillips curves based on the assumption that all foreign imported goods are used as inputs in production. All consumer goods are assumed to be produced domestically using labor inputs and imported inputs. Moreover, exchange rates affect inflation only through real marginal costs, as there is no direct channel in the model from exchange rates to domestic inflation. In our estimations, intermediate goods are proxied by the real price of commodity imports or the real exchange rate level. Consensus Economics survey data and OECD forecasts are used to proxy inflation expectations. The focus of this study is to analyze, whether open economy extensions improve the empirical fit of the New Keynesian Phillips curve. Moreover, forward-looking features of the inflation process and the link between inflation and domestic demand are considered.

We find evidence that the empirical relevance of the original closed economy version of the New Keynesian Phillips curve is significantly improved, when the specification is extended to the open economy framework under the assumption that imports can be treated as intermediate goods. Moreover, in the open economy context, the hybrid specification with the backward-looking lagged inflation rate is needed in order to capture inflation dynamics properly. The empirical results are robust with respect to the chosen proxy for inflation expectations (a survey-based measure or the OECD forecast) and to the data set, aggregated or pooled. The evidence is also not sensitive to the timing of the expectations term (June/December forecasts). We get some, albeit weak, evidence that in the recent years of low and stable inflation, euro area inflation dynamics has become more forward-looking and the link between inflation and domestic demand has flattened, since the euro area Phillips curve has flattened. On the other hand, the inflation process seems to have been more forward-looking in those euro area countries, which have experienced lower inflation already since the beginning of the 1980s. However, and despite these patterns in the point estimates of the various parameters, the formal Chow test cannot reject the hypothesis that the same model is actually appropriate for the whole sample, which covers different inflation regimes (high inflation rates in the 1980s and low inflation rates in recent years).

When conducting monetary policy, central banks need to understand dynamics and determinants of inflation. Among other things, forward-looking features of the inflation process and the effects of foreign shocks (for example energy and food price shocks) on domestic inflation must be carefully analyzed. The appropriate response of monetary policy to shocks depends on the degree, to which the effects of shocks on inflation are persistent. It also depends on the way, how inflation is linked to domestic demand conditions and how the exchange rate and inflation are related. If monetary policy is credible and inflation expectations are successfully anchored, the central bank can ensure that actual inflation is closely related to the monetary policy inflation target in the medium term. Overall, better structural models, which capture expectations dynamics and the open economy aspects of the inflation process accurately, are needed in monetary policy analysis. Recently, due to globalization and the highly volatile commodity prices, maintaining a deep understanding of inflation dynamics in the open economy context has become even more challenging for central banks.

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Appendix 1

Efficiency tests

$$\pi_t^* - \pi_t = \gamma_0 + \gamma_i \sum_{i=1}^{j} \pi_{t-i},$$

where j = 2 or 3.

	Wald test	Probability				
Pooled data, Consensus Economics						
Two lags of actual inflation	F=10.227	(0.0000)				
Three lags of actual inflation	F=14.461	(0.0000)				
Pooled data, OECD forecast	**Whole sample**		**1981-1993**	**Probability**	**1994-2006**	**Probability**
Two lags of actual inflation	F=8.626	(0.0000)	F=6.021	(0.0007)	F=7.890	(0.0001)
Three lags of actual inflation	F=7.646	(0.0000)	F=4.862	(0.0010)	F=8.629	(0.0000)
Aggregated data, OECD forecast						
Two lags of actual inflation	F=4.070	(0.0192)				
Three lags of actual inflation	F=3.345	(0.0287)				

$$\pi_t^* - \pi_t = \mu_0 + \mu_m \sum_{m=1}^{n} X_{t-1}^m,$$

where n= 2 or 3.

	Wald test	Probability				
Pooled data, Consensus Economics						
Model E1	F=10.576	(0.0000)				
Model E2	F=6.281	(0.0001)				
Pooled data, OECD forecast	**Whole sample**		**1981-1993**	**Probability**	**1994-2006**	**Probability**
Model E1	F=4.452	(0.0045)	F=3.480	(0.0175)	F=5.170	(0.0020)
Model E2	F=7.486	(0.0000)	F=7.667	(0.0000)	F=5.143	(0.0007)
Aggregated data, OECD forecast						
Model E1	F=1.549	(0.2300)				
Model E2	F=2.081	(0.1214)				

Appendix 2

Hybrid Phillips curve estimates using pooled data and least squares

Open economy model A $\pi_t = (1-\omega)\overline{E}_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \phi\hat{y}_t + \varphi_1 rci_t$

Open economy model B $\pi_t = (1-\omega)\overline{E}_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \phi\hat{y}_t + \varphi_2 rer_t$

	ω	ϕ	φ_1	φ_2	D-W
Open economy model A	0.385 (0.054)*	0.150 (0.022)*	0.022 (0.005)*		1.968
Open economy model B	0.362 (0.058)*	0.136 (0.024)*		0.034 (0.011)*	1.980

Note: Numbers in parentheses are Newey-West HAC standard errors, * indicates significance at 5 per cent level.

Appendix 3

Alternative measures for expectations

Open economy model A $\pi_t = (1-\omega)\overline{E}_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \phi\hat{y}_t + \varphi_1 rci_t$

Open economy model B $\pi_t = (1-\omega)\overline{E}_t\{\pi_{t+1}\} + \omega\pi_{t-1} + \phi\hat{y}_t + \varphi_2 rer_t$

Aggregated data	ω	ϕ	φ_1	φ_2	J-stat.
Open economy model A	0.426	0.147	0.015		0.068
	(0.046)*	(0.098)	(0.006)*		[0.148]
Open economy model B	0.549	0.201		0.091	0.171
	(0.045)*	(0.073)*		(0.022)*	[0.216]

Pooled data	ω	ϕ	φ_1	φ_2	J-stat.
Open economy model A	0.527	0.142	0.020		0.003
	(0.048)*	(0.022)*	(0.008)*		[0.770]
Open economy model B	0.615	0.142		0.104	0.006
	(0.083*)	(0.041)*		(0.047)	[0.554]

Note: See tables 3.4 and 3.5.