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Maritta Paloviita

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EUROJÄRJESTELMÄ
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Abstract

This paper examines empirical performance of three different Phillips curve specifications in the euro area. Instead of imposing rational expectations, direct measures, ie OECD forecasts, are used to proxy economic agents' inflation expectations. Real marginal costs are measured in three different ways. The results suggest that with directly measured expectations the estimated New Classical Phillips curve has satisfactory statistical properties. Moreover, the driving variable enters the estimated, purely forward-looking, New Keynesian Phillips curve with the correct sign, but it is clearly outperformed by the New Classical and Hybrid Phillips curves. We interpret our results as indicating that the European inflation process is not purely forward-looking, so that inflation cannot instantaneously adjust to new information. Consequently, even allowing for possible non-rationality in expectations, a lagged inflation term enters the New Keynesian Phillips curve for European inflation dynamics. The inflation process seems to have become more forward-looking in the recent years of low and stable inflation. Furthermore, in the New Keynesian Phillips curve relationship, the output gap turns out to be at least as good a proxy for real marginal cost as is the labour income share.

Key words: Phillips curve, expectations, euro area

JEL classification: E31, C52

Tiivistelmä

Tässä tutkimuksessa tarkastellaan kolmen erilaisen Phillips-käyrän empiiristä soveltuvuutta euroalueen inflaatiodynamiikan estimointiin. Talouden päätöksentekijöiden inflaatio-odotuksia ei oleteta rationaaliksi, vaan niitä mitataan suoraan käyttämällä OECD:n ennusteita. Reaalisia rajakustannuksia mitataan kolmella eri tavalla. Tulosten mukaan uusklassinen Phillips-käyrä estimoituu suoraan mitattuja inflaatio-odotuksia käytettäessä tilastollisesti järkevästi. Lisäksi puhtaasti eteenpäin katsova uuskeynesiläinen Phillips-käyrä tuottaa järkeviä empiirisiä tuloksia, mutta nämä tulokset ovat selvästi huonompia kuin uusklassisen Phillips-käyrän ja uuskeynesiläisen Phillips-käyrän hybridimuodon tulokset. Tulosten mukaan euroalueen inflaatioprosessi ei ole puhtaasti eteenpäin katsova, minkä vuoksi inflaatio ei voi sopeutua uuteen informaatioon heti. Lisäksi uuskeynesiläisessä Phillips-käyrässä tarvitaan euroalueen inflaatiodynamiikkaa kuvattaessa viivästetty inflaatiotermi odotusten mahdollisesta epärationaalisuudesta huolimatta. Inflaatioprosessi on muuttunut enemmän eteenpäin katsovaksi viime vuosina, kun inflaatio on ollut vaimea ja vakaa. Toisaalta tuotantokuilu on uuskeynesiläisessä Phillips-käyrässä ainakin yhtä hyvä reaalisten rajakustannusten empiirinen vastine kuin työtulojen BKT-osuus.

Avainsanat: Phillips-käyrä, odotukset, euroalue

JEL-luokittelu: E31, C52

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Helsinki, August 2005
Maritta Paloviita

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1 Introduction

Inflation dynamics have continuously been one of the most debated issues in macroeconomics. Among other things, the puzzling combination of low inflation and high real growth in many industrialised countries in the 1990s has underlined the importance of examining price changes. Moreover, establishment of the European Central Bank, with the explicit mission of price stability, has highlighted the importance of understanding the determinants and dynamics of inflation. During the last several decades, price developments have changed a great deal in the euro area and inflation histories have been quite divergent across the twelve EMU countries. This has pointed to the need to understand the inflation process. Recent methodological advances have also increased the level of interest in studying the nature of inflation dynamics, which are crucial for designing optimal monetary policy.

Reducing inflation seems to be costly. Changes in monetary policy affect employment and production in the short run; many countries have over the years experienced disinflation along with output and employment losses. For example, in the 1970s and 1980s, a tightening of US monetary policy was typically followed by a period of substantial decline in production and employment (Romer and Romer 1989). Also, since the 1960s, moderate-inflation OECD countries have experienced a substantial decline in production together with disinflation (Ball 1994).

Many empirical studies find evidence that the inflation process is persistent, ie that inflation is strongly correlated with its own lagged values (see eg Gordon 1997). Inflation persistence has received a lot of attention in recent monetary research. It is still a mystery, whether inflation persistence is structural, which would mean that its sluggishness is due to deep parameters or institutional constraints (such as indexation) in the economy. On the other hand, inflation may be persistent because of more transient factors such as expectations or policy regimes.

The central role of expectations in macroeconomics was already recognised by Keynes (1936). However, until recently, there has been only little interest in modelling expectations formation and typically rational expectations have been imposed in empirical studies. Under rational expectations, agents use all available information and do not make systematic errors in forming their expectations. Rationality of expectations has been questioned. It may be an unrealistic and overly restrictive assumption.

In inflation dynamics, expectations seem to play a central role, since the causes of short-run effects of monetary policy on employment and production appear to be associated with credibility and thus expectations formation. Under a low inflation regime, a central bank's announcement of a low inflation target is credible for the public. Thus, inflation expectations are low and there seems to be a favourable shift in the short-run tradeoff between inflation and unemployment, since wage and price setting behaviour is affected by low inflation expectations. Inflation expectations of the private sector are important for inflation-targeting central banks. Because the effects of monetary policy are delayed, changes in monetary policy regimes also affect inflation expectations and thus inflation dynamics.

Structural models can be used in empirical analysis of inflation dynamics. With these models, we can explore the short-run inflation process and examine how changes in monetary policy regime and other structural changes affect price developments. Since the late 1950s research on inflation dynamics has been largely based on the Phillips curve, the economic modelling of which has changed considerably over the years. Originally Phillips (1958) and Samuelson and Solow (1960) hypothesised a stable negative relationship between unemployment and inflation without paying special attention to the role of expectations. About ten years later, Phelps (1967) and Friedman (1968) developed the expectations-augmented Phillips curve, which ascribed a central role to expectations in the inflation process, via wage bargaining and price setting. In the 1970s, when rational expectations was a major theme of macroeconomic research, Lucas (1976) presented the rational expectations hypothesis, which holds that inflation expectations cannot systematically differ from actual inflation. In later empirical work on the expectations-augmented Phillips curve, which is nowadays often called the New Classical Phillips curve, rational expectations are typically assumed and real economic activity is measured by actual output relative to potential, ie by the output gap. Other measures have also been used such as the capacity utilisation rate and the unemployment gap, which is the difference between the actual rate of unemployment and the non-accelerating inflation rate of unemployment (NAIRU). Alternative specifications of the New Classical Phillips curve may include additional lags of excess demand. In applied work, oil price and other additional variables have often been incorporated into the model in order to capture the supply shocks of the 1990s.

Recent advances in the theoretical modelling of inflation dynamics have led to dynamic equilibrium models of price adjustment, which are based on optimisation of a representative agent, differentiated

goods and monopolistic competition. As regards price setting, these models assume state-contingent or time-contingent rules. Under state-contingent rules, the timing of price changes is endogenous, as it is assumed that changes in economic conditions affect firms' incentives to adjust prices. Firms are constantly monitoring cost conditions and able to adjust their prices in every period if they assess that it is profitable, given the costs of adjustment (see Caplin and Spulber 1987, Caplin and Leahy 1991, Dotsey et al 1999). One can alternatively assume that costs of price changes are due to costs of collecting information and making decisions.

When a firm follows time-contingent rules in its pricing behaviour, it resets prices according to a schedule. Scheduled price changes are often viewed as reasonable for low inflation economies, where in practice price changes are quite rare. The New Keynesian Phillips curve is based on the assumption of time-contingent price setting. It can be derived using Taylor's overlapping contracts model (Taylor 1980), Rotemberg's model of quadratic costs of price adjustment (Rotemberg 1982) or the Calvo (1983) model with random price adjustment. In Taylor's staggered wage model, only a fraction of wages are reset in each period, and contract wages are assumed to be fixed for a certain number of periods. In Rotemberg's model it is costly to adjust prices, which means that firms do not change prices in every period. Typically, in that model, prices change frequently and by small amounts. Costs of changing prices may be small for individual price setters, but they can cause stickiness in the aggregate price level. In the Calvo model, firms care about relative prices, since price setting is staggered. Although individual prices are readjusted frequently, the aggregate price level may change slowly because of staggering. All these models yield the same reduced-form equation, which relates current inflation to currently expected future inflation and the current driving variable.

The New Keynesian Phillips curve is purely forward-looking and based explicitly on microfoundations. It suggests that prices are sticky and inflation depends entirely on current and expected future economic conditions. The New Keynesian Phillips curve relationship is appealing, since it has features of both the 'old' Keynesian models and dynamic equilibrium models. It assumes, in the Keynesian tradition, that competition is imperfect and that there are nominal rigidities in price adjustment. In the New Keynesian theory, excess demand enters through real marginal costs, the empirical measure of which is often the output gap or real unit labour cost (labour income share). In empirical studies the New Keynesian Phillips curve relationship and rational expectations are typically jointly assumed.

Many studies suggest that when rational expectations are imposed, the empirical performance of the New Keynesian Phillips curve is poor and, contrary to the theory, the estimated coefficient of the driving variable is insignificant or incorrectly signed. Moreover, a drawback of the purely forward-looking New Keynesian model is its inability to explain inflation persistence. Some studies find evidence that the observed stickiness in the inflation process cannot be explained by the New Keynesian Phillips curve with a reasonable length of wage contracts (Fuhrer and Moore 1995). In order to better capture the observed inflation dynamics, the New Keynesian Phillips curve has been typically modified in one of two ways: by experimenting with alternative empirical measures for real marginal costs or by incorporating some backward-lookingness in price setting behaviour.

Empirical studies of the New Keynesian Phillips curve have not so far been able to firmly establish which of the two alternatives is the appropriate measure for real marginal costs. Several studies suggest, that under rational expectations, real unit labour cost is a better proxy for real marginal cost than is the output gap. The superiority of real unit labour cost is based on the idea that real marginal costs and output gap are not closely related and that labour market rigidities must be taken into account in modelling short-run inflation dynamics. On the other hand, it has been argued that labour market rigidities are not important in inflation dynamics and that the output gap can be used with the New Keynesian Phillips curve, if it is measured correctly. Thus, the choice of empirical proxy for real marginal cost in the New Keynesian Phillips curve relationship is not unambiguous.

The hybrid specification of the New Keynesian Phillips curve includes elements of both forward-looking and backward-looking price setting, since it has the lagged inflation term as an additional explanatory variable. The Hybrid Phillips curve has been widely used in recent studies of inflation dynamics. The basic idea in the Hybrid model is that only some price setters behave optimally when adjusting prices while the rest use rules of thumb or indexation. Price setting of backward-looking firms is based on recent history of aggregate prices. Empirical studies of the Hybrid Phillips curve have yielded conflicting results. Many studies have found evidence on the predominant role of forward-looking expectations in the inflation process, but the importance of backward-looking expectations has also received support in the data.

Inflation dynamics have also been explained using models that do not explicitly impose rational expectations. Already in the 1970s Lucas (1972) presented the famous islands model, where agents do

not share the same information and have different inflation expectations, since they live on separate islands. After a change in money supply, an agent realises the change in his/her goods price. However, the agent is not able to assess how much the relative price of his/her good has changed and how much the general price level has changed. In the mid-1970s deviation from rational expectations was also discussed by Sargent (1976) and McCallum (1976), who presented the idea of ‘partly rational expectations’.

Deviation from rational expectations can be modelled using limited information channels, sticky information, or bounded rationality and learning. These models are based on the idea that expectations may adjust gradually, as they react slowly to changing economic conditions. Another way of relaxing the assumption of rational expectations is to measure expectations directly.

Using information theory and assuming that economic agents have finite information processing capacity, one can model a sluggish inflation process (Woodford 2002, Adam 2004). In this model, agents do not share the same information and price setting decisions depend on ‘higher order expectations’, which are crucial for the aggregate inflation dynamics. In other words, in addition to their own inflation expectations, price setters care about their expectations of others’ expectations, and their expectations of others’ expectations of others’ expectations, and so on.

In a sticky information model by Mankiw and Reis (2001, 2002), inflation persistence is explained by imperfect information among wage setters. It is assumed that prices are changed in every period, but pricing decisions are not always based on current information. In every period there is a fixed probability that a price setter will update his/her information set. If an information set is not updated, price adjustment is based on old plans and outdated information. Since information disseminates slowly throughout the population, due to costs of acquiring information or costs of re-optimisation, wages respond slowly to news about changing economic conditions and the inflation process is persistent.

Bounded rationality and learning is a new and rapidly growing area of macroeconomics. It is based on the idea that boundedly rational agents are always trying to learn about the true economic conditions (see eg Sargent 1999 and Sims 2003). For example, in Evans and Honkapohja (2001), agents use a least-squares updating rule instead of rational expectations, since they do not know the true structure and probability distribution of the economy. Although agents use information efficiently when forming expectations, they take account the limits and costs of processing information.

Survey estimates of inflation expectations, which do not make any a priori assumptions about inflation expectations, have been used in many empirical studies of inflation dynamics. This approach is appealing, since when applying to data, one need not assume any specific form of non-rationality in expectations. Contrary to the US, for Europe, availability of survey data is quite poor. For empirical analysis, it is not possible to find reasonably long quantitative survey estimates for inflation expectations for the all the euro area economies. However, the European Commission provides monthly survey estimates, which are qualitative, for all the member states. This information, which is available since 1986, has been quantified by statistical methods in some empirical studies. Moreover, the European Central Bank has conducted a quarterly Survey of Professional Forecasters since 1999 (see Garcia 2003). Monthly survey estimates for future inflation rates provided by Consensus Economics are also available for the euro area countries since the late 1980s. The reliability of survey-based expectations has been questioned. Survey data quality depends on sample size, the questions asked, and the motivation of those surveyed. Inflation expectations can alternatively be derived from financial asset prices, but the derivation is necessarily based on certain non-testable assumptions on ex ante real interest rates.

This study examines empirically inflation dynamics in the euro area. Three different Phillips curves are applied to aggregated and pooled euro area data since the late 1970s. The New Classical Phillips curve, the New Keynesian Phillips curve and its hybrid specification are each estimated using least squares and the generalised method of moments (GMM), with special attention being paid to the role of expectations in European inflation dynamics. Instead of imposing rational expectations, an alternative, and in principle less restrictive, approach to measuring expectations is followed in this study. Direct measures of inflation expectations are used as empirical proxies for unobservable economic agents' inflation expectations. More specifically, inflation expectations are measured using OECD inflation forecasts. OECD forecasts have not been used in this context before the project reported here (see also Paloviita 2004 and Paloviita and Mayes 2004a and 2004b). 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). Directly measured expectations need not be rational, although they may be. When studying euro area inflation dynamics, data availability is one reason for using OECD forecasts to proxy inflation expectations. It is not possible to obtain any other

series of forecasts of similar length and coverage from any other source (Gerlach 2004).

It is challenging to question the Phillips curve relationship under the hypothesis of rational expectations. Although monetary policy actions are widely reported in the media, it is possible that the public does not fully process all relevant information in the news. Thus inflation expectations may not be rational. In principle, we may be able to improve the empirical performance of the New Keynesian Phillips curve by allowing a departure from rational expectations that allows for slow adjustment of expectations. In using directly measured expectations, we do not impose the hypothesis of rational expectations, but we do maintain appealing microfoundations for price adjustment behaviour in the New Keynesian theory. Moreover, only by using this approach can we examine empirically whether the timing of expectations matters in the Phillips curve relationship, ie we can compare empirically the New Classical Phillips curve and the New Keynesian Phillips curve. Using directly measured expectations, we may be able to analyse better the effects of monetary policy regime changes on inflation dynamics. The main interest of this study is in euro area inflation dynamics since the late 1970s, although potential heterogeneity of inflation dynamics is also examined across different sub-periods and country groups. In applying the New Keynesian Phillips curve and its hybrid specification to data, we are also able to examine the appropriate empirical measure for real marginal cost.

The results of this study suggest that if OECD inflation forecasts are used as a proxy for inflation expectations, the New Classical Phillips curve is able to capture European inflation dynamics since the late 1970s. Also, the driving variable enters the estimated, purely forward-looking, New Keynesian Phillips curve with the correct sign, but it is definitely outperformed 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 curve relationship. Since both the New Classical and Hybrid Phillips curves outperform empirically the New Keynesian Phillips curve, the results indicate that the basic features of the New Keynesian Phillips curve are rejected by the data. Contrary to the implications of New Keynesian economics, the inflation process seems not to be purely forward-looking, and the inflation rate does not adjust instantaneously to new information. In the New Keynesian Phillips curve, with directly measured expectations, the output gap turns out to be at least as good a proxy for real marginal costs as is the labour income share. The empirical results indicate that the euro area inflation process seems to have become more forward-looking in the

recent years of low and stable inflation. It has also been more forward-looking in the low inflation countries of the euro area prior to the inception of EMU.

The rest of this study is structured as follows. In chapter 2 alternative price setting models are derived in a common framework. The different Phillips curves are derived in chapter 3. Previous empirical results of the New Keynesian Phillips curve relationship and deviation of inflation expectations from rationality are discussed in chapter 4. Chapter 5 offers empirical evidence on euro area inflation dynamics. Chapter 6 concludes.

2 Alternative models for optimal price setting

In this part of the study, we present alternative optimal price setting models using a production function with one variable factor of demand, labour. Optimising models with endogenous supply and nominal rigidities enable analysis of the real effects of monetary policy. Due to nominal rigidities, prices do not adjust in every period, so that in some periods certain factors of production, such as labour, may be under- or over-utilized and aggregate output may differ from its potential level. Nominal rigidities can be due to sticky prices or sticky wages. Since the aim of this study is to examine inflation dynamics in a simple framework, only sticky prices are considered. The optimal price setting models of this chapter are needed to derive microfoundations for different Phillips curve relationships that will be applied to euro area data in chapter 5.

Price setting models are based on the representative agent's optimisation. They assume that goods are differentiated and competition is monopolistic, which means that firms have some monopoly power in setting their prices. If prices are fully flexible, they can be adjusted in every period on the basis of full information about current demand and cost conditions, and equilibrium output is completely independent of monetary policy. In more realistic models, where monetary policy affects real economic activity, there are nominal rigidities in the economy, ie firms are not able to change their product prices in every period. Delayed price adjustment may be due to many reasons: prices effective in a certain period must be announced in an earlier period or suppliers will have to decide the price on the basis of old information.

This chapter follows Woodford (2003) and proceeds as follows. First, we develop the basic framework using very general forms of the maximisation problem, profit function and first order conditions. Necessary and sufficient conditions for the optimal price are presented. Also, nominal and real marginal supply costs are derived from the production function with labour as the only factor of production. Second, we discuss the maximisation problem of the representative agent and the first order conditions in a model with fully flexible prices and two alternative models for price stickiness. In all models we use linear approximations, which are needed for deriving the different Phillips curves in chapter 3. Linear approximations are relevant in a moderate inflation environment. As

will be shown, expectations play a central role in optimal price setting with nominal rigidities.

2.1 Basic model with endogenous supply

The basic model for optimal price setting is based on the representative agent, who obtains utility from consumption and real balances and disutility from labour supply. Supply of goods is assumed to be endogenous, as one factor of production, labour, is variable. In addition, goods are assumed to be differentiated and competition monopolistic, following the New Keynesian literature by Rotemberg (1982), Mankiw (1985) and Svensson (1986). In monopolistic competition, suppliers of goods have some market power, which means that they are able to make price setting decisions.

The problem is to maximise

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[u(C_t, M_t / P_t; \xi_t) - \int_0^1 v(h_t(i); \xi_t) di \right] \right\} \quad (2.1)$$

where

E_0 = expected value in period 0

C_t = index of household consumption of all the supplied goods in period t

P_t = index of prices of all the supplied goods in period t

M_t = nominal money balances in period t

$h_t(i)$ = quantity of labour of type i supplied in period t

ξ_t = a vector of aggregate shocks in period t

$u(\cdot)$ = utility in period t

$v(\cdot)$ = disutility in period t

β^t = discount factor for period t.

It is assumed that labour of type i is the only variable input used in the production of differentiated good i. The representative agent supplies all the types of labour, as indicated by the integral in the above equation.

For optimal price setting, we need to derive the first-order conditions for optimal supply of each type of labour. It is assumed that the consumption index, C_t , is a constant-elasticity-of-substitution aggregator

$$C_t \equiv \left[\int_0^1 c_t(i)^{(\theta-1)/\theta} di \right]^{\theta/(\theta-1)} \quad (2.2)$$

where $\theta > 1$, and the corresponding price index can be expressed by

$$P_t \equiv \left[\int_0^1 p_t(i)^{1-\theta} di \right]^{1/(1-\theta)} \quad (2.3)$$

(see Dixit and Stiglitz 1977). When individual goods prices are given, the price index, P_t , defines the minimum cost of a unit of aggregate consumption, C_t . Nominal money balances, M_t , deflated by P_t gives the purchasing power of the representative agent.

The agent receives wage income and profits, and his/her budget constraint takes the form

$$\int_0^1 w_t(i) h_t(i) di + \int_0^1 \Pi_t(i) di \quad (2.4)$$

where

$w_t(i)$ = nominal wage of labour type i in period t

$\Pi_t(i)$ = nominal profit from sales of good i .

We need to consider three different requirements in order to obtain necessary and sufficient conditions for household optimisation. First, in every period consumption must be allocated optimally across differentiated goods. This means that, as the household maximises (2.2) given the level of total expenditure, the composition of goods must satisfy

$$c_t(i) = C_t \left(\frac{p_t(i)}{P_t} \right)^{-\theta} \quad (2.5)$$

where the consumption of good i is related to its relative price. This implies that total expenditure is equal to $P_t C_t$ and the utility and budget constraints can be expressed using aggregate consumption and aggregate price index, without individual goods and individual prices.

Second, optimal behaviour requires that, with given optimal allocation of consumption expenditure and amount of labour supply, the agent must in every period choose the optimal levels of total consumption and money balances, as well as the amount of financial wealth and its composition from available bonds. In equilibrium,

necessary and sufficient conditions must be satisfied also for these choices of the agent.

The third requirement is the optimal choice of labour supply of each type, given the wages and value of additional income. The first order condition for optimal supply of labour type i in period t is given by

$$\frac{v_h(h_t(i); \xi_t)}{u_c(C_t, m_t; \xi_t)} = \frac{w_t(i)}{P_t} \quad (2.6)$$

As shown in equation (2.6), in period t , with given exogenous disturbances, the ratio of disutility of supplying labour of type i to utility of consumption and money balances is equal to the real wage of labour type i .

Next, the production function is used to derive real marginal cost, which is the basic element in endogenous supply decisions. The production function for good i is given by

$$y_t(i) = A_t f(h_t(i)) \quad (2.7)$$

where labour is the only factor of production, A_t is a positive time-varying exogenous technology factor and f is an increasing, concave function. It can be shown that the variable cost of supplying a quantity $y_t(i)$ of good i can be expressed by $w_t(i)h_t(i) = w_t(i)f^{-1}(y_t(i)/A_t)$. Differentiating the (variable) cost function yields the nominal marginal cost function of supplying good i

$$S_t(i) = \frac{w_t(i)}{A_t} \Psi(y_t(i)/A_t) \quad (2.8)$$

where

$$\Psi(y) \equiv \frac{1}{f'(f^{-1}(y))} \quad (2.9)$$

is an increasing, positive function. Equation (2.8) determines how much nominal supply costs change when the quantity of supplied good i is increased by one unit. It is assumed that all producers of differentiated goods take wages as given. In order to get the real marginal cost function, we insert the labour-supply function (2.6) into the wage equation (2.8), which yields

$$s_t(i) \equiv S_t(i) / P_t = s(y_t(i), Y_t; \tilde{\xi}_t) \quad (2.10)$$

where the real marginal supply cost is related to the supplied quantity of good i . Thus the real marginal cost function is given by

$$s(y, Y; \tilde{\xi}) = \frac{v_h(f^{-1}(y/A); \xi)}{u_c(Y; \xi)A} \Psi(y/A) \quad (2.11)$$

where ξ_t is the vector of all exogenous shocks and C_t has been replaced by Y_t , since aggregate consumption is equal to the aggregate output in every period. For simplicity, real balances have been suppressed from u_c .

We have thus derived the maximisation problem and real marginal cost function in a model with endogenous supply. These can be used to derive optimal price setting models with fully flexible or sticky prices.

2.2 Optimal price setting models

Next, we examine maximisation problems for alternative forms of optimal price setting, the first order conditions of which are needed to obtain microfoundations for different Phillips curve relationships. First, we discuss optimal price setting with fully flexible prices and present a specific example. Then we introduce two alternative forms of price stickiness. For each case, we derive the maximisation problem of the representative agent and the first order conditions for optimal price adjustment. In order to express all the models within a common framework, very general forms of profit functions are used.

Alternative models for optimal price setting can be used in monetary policy analysis. As will be shown, with fully flexible prices, equilibrium output is totally independent of monetary policy decisions. If prices are set one period in advance, monetary policy has only unexpected and temporary effects on real economic activity. With staggered price setting, we are able to model longer-lasting real effects of monetary policy.

2.2.1 Optimal price setting with fully flexible prices

Goods prices are perfectly flexible if all suppliers of goods are able to set their goods prices in every period. Past price changes do not constrain price setting decisions in period t and suppliers always have perfect knowledge of current demand and cost conditions. In period t the demand function for good i is given by

$$y_t(i) = Y_t \left(\frac{p_t(i)}{P_t} \right)^{-\theta} \quad (2.12)$$

which shows that demand is related to the relative price of the good, given aggregate demand, Y_t , and aggregate price index, P_t . With optimal price setting, the equation for the price of good i is given by $p_t(i) = \mu S_t(i)$, where $\mu = \theta/(\theta-1) > 1$ is the desired markup of the supplier of good i . Dividing by the aggregate price level yields the optimal relative price as a function of real marginal cost

$$\frac{p_t(i)}{P_t} = \mu s(y_t(i), Y_t; \tilde{\xi}_t) \quad (2.13)$$

Using equation (2.12), we obtain the relative supply of good i as

$$\left(\frac{y_t(i)}{Y_t} \right)^{-1/\theta} = \mu s(y_t(i), Y_t; \tilde{\xi}_t) \quad (2.14)$$

Real marginal costs increase with the supply of good i , which means that, given aggregate output Y_t , there is a unique solution for the supply of good i . In equilibrium, the same quantity of all goods is supplied, which is equal to Y_t . Thus equilibrium output can be presented by $Y_t = Y^n(\xi_t)$, where the RHS term refers to the natural rate of output (Friedman 1968), ie the solution to the equation

$$s(Y_t^n, Y_t^n; \tilde{\xi}_t) = \mu^{-1} \quad (2.15)$$

Thus the natural output level is determined by the level at which real marginal cost is equal to the reciprocal of desired markup. Real marginal cost also increases with aggregate output, which means we can solve for the unique optimal supply of good i for any vector of exogenous shocks, ξ_t . In spite of endogenous supply and monopolistic

competition, with perfectly flexible prices, we get the neutrality result, where equilibrium output is completely independent of monetary policy, as seen from equation (2.15).

The above neutrality result can also be applied to a broad range of models with different cost and demand structures by using the following very general form of nominal profit function of the supplier of good i in period t

$$\Pi_t(i) = \Pi(p_t(i), p_t^I, P_t; Y_t, \tilde{\xi}_t) \quad (2.16)$$

where

$p_t(i)$ = price of good i in period t

p_t^I = price index for industry I

P_t = aggregate price index.

It is assumed that in a given industry all suppliers adjust goods prices at the same time. Following the previous example, the profit function takes the form

$$\begin{aligned} \Pi(p, p^I, P; Y, \tilde{\xi}) \equiv & py - wh = pY(p/P)^{-\theta} \\ & - \frac{v_h(f^{-1}(Y(p^I/P)^{-\theta}/A); \xi)}{u_c(Y - G; \xi)} Pf^{-1}(Y(p/P)^{-\theta}/A) \end{aligned} \quad (2.17)$$

As seen from equation (2.17), the given wage rate for the supplier of industry I is dependent on total labour demand in industry I . It is assumed that the profit function Π is homogeneous of degree one in its first three arguments (price of good i , price index for industry I and aggregate price index). It is also a single-peaked function of the price of good i , with maximum at a positive price for any values of its other arguments.

The first order condition for the optimal price of good i is given by

$$\Pi_1(p_t(i), p_t^I, P_t; Y_t, \tilde{\xi}_t) = 0 \quad (2.18)$$

which can be solved uniquely, as implied by the previous assumption. With fully flexible prices, the first order condition can be written as

$$\Pi_1(P_t, P_t, P_t; Y_t, \tilde{\xi}_t) = 0 \quad (2.19)$$

As the LHS of equation (2.19) is independent of the aggregate price index, P_t , the equilibrium output is independent of monetary policy. For each good, the level of equilibrium output is given by $y_t(i) = Y_t^n$, where the natural rate of output is defined by the equation

$$\Pi_1(1, 1, 1; Y_t^n, \tilde{\xi}_t) = 0 \quad (2.20)$$

The first order condition (2.18) is needed for derivating the New Classical Phillips curve, since a fraction of goods are assumed to be fully flexible in this aggregate supply relationship.

2.2.2 Optimal non-overlapping price setting with nominal rigidities

A simple form of price stickiness can be modelled by assuming that all goods prices must be predetermined one period in advance. Thus, when the goods price $p_t(i)$ is set in period $t-1$, the supplier knows all the exogenous shocks in period $t-1$ and earlier, but he/she does not know the cost and demand conditions in period t . With price predetermined, we assume that the supplier uses the amount of labour needed to fill all the orders.

With delayed price adjustment, expectations are important, since the firm's maximisation problem can be written as

$$E_{t-1}[Q_{t-1,t} \Pi(p_t(i), p_t^I, P_t; Y_t, \tilde{\xi}_t)] \quad (2.21)$$

where the present value of period t profits is maximised. In equation (2.21), the profit function has the same general form as in the previous section with fully flexible prices. The additional term $Q_{t-1,t}$ denotes the stochastic discount factor. The choice of optimal price is based on the expected values of random variables $Q_{t-1,t}$, Y_t , p_t^I , P_t and the vector of exogenous shocks, $\tilde{\xi}_t$.

The first order condition for optimal price setting takes the form

$$E_{t-1}[Q_{t-1,t} \Pi_1(p_t(i), p_t^I, P_t; Y_t, \tilde{\xi}_t)] = 0 \quad (2.22)$$

In equilibrium, all firms set a common price, as they face the same maximisation problem. This implies the first order condition

$$E_{t-1}[Q_{t-1,t} \Pi_1(P_t, P_t, P_t; Y_t, \tilde{\xi}_t)] = 0 \quad (2.23)$$

This condition is independent of P_t , which implies

$$E_{t-1}[Q_{t-1,t}\Pi_1(1, 1, 1; Y_t, \tilde{\xi}_t)] = 0 \quad (2.24)$$

When using the New Classical Phillips curve to analyse inflation dynamics, we assume that a fixed share of goods prices are set one period in advance and the rest are fully flexible. Thus we need the first order condition (2.22) to derive the New Classical Phillips curve.

When using the general profit function (2.17), equation (2.24) can be written as

$$E_{t-1}\{u_c(Y_t; \xi_t)Y_t[\mu^{-1} - s(Y_t, Y_t; \tilde{\xi}_t)]\} = 0 \quad (2.25)$$

Thus output is equal to the natural rate only on average – not in every period. By contrast, as has been shown in the previous section, when prices are fully flexible, output is always at the natural level. In other words, with fully flexible prices, the equation $s(Y_t^n, Y_t^n; \tilde{\xi}_t) = \mu^{-1}$ holds in every period.

Suppose that the monetary policy target can be expressed in terms of the path of nominal GDP, denoted by $\Gamma_t = P_t Y_t$. Solving for real GDP and inserting it into the first order conditions (2.25) yields

$$E_{t-1}\{u_c(\Gamma_t/P_t; \xi_t)\Gamma_t[\mu^{-1} - s(\Gamma_t/P_t, \Gamma_t/P_t; \tilde{\xi}_t)]\} = 0 \quad (2.26)$$

Thus the price level in period t is determined by the joint distribution of nominal GDP and aggregate shocks in period t , conditional upon information in period $t-1$. In order to present this result in a simpler form, we can use a log-linear version of the equation $E_{t-1}[Q_{t-1,t}\Pi_1(1, 1, 1; Y_t, \tilde{\xi}_t)] = 0$. When the natural rate of output is defined by $\Pi_1(1, 1, 1; Y_t^n, \tilde{\xi}_t) = 0$, we can use the log-linear approximation

$$\Pi_1(P_t, P_t, P_t; Y_t, \tilde{\xi}_t) = \psi_y(\hat{Y}_t - \hat{Y}_t^n) \quad (2.27)$$

where ψ_y is a positive coefficient in the case of a moderate shock.

Thus the aggregate-supply relation $E_{t-1}[Q_{t-1,t}\Pi_1(1, 1, 1; Y_t, \tilde{\xi}_t)] = 0$ simplifies to

$$E_{t-1}[\hat{Y}_t - \hat{Y}_t^n] = 0$$

which means that the first order condition can be written as the expected deviation of real output from its natural value, ie the expected output gap. By solving $\Gamma_t = P_t Y_t$ for real output and inserting it into $E_{t-1}[\hat{Y}_t - \hat{Y}_t^n] = 0$ we obtain

$$\log P_t = E_{t-1} \log \Gamma_t - E_{t-1} \log Y_t^n \quad (2.28)$$

which can be solved for real output

$$\log Y_t = E_{t-1} \log Y_t^n + [\log \Gamma_t - E_{t-1} \log \Gamma_t] \quad (2.29)$$

The first term on the RHS of equation (2.29) refers to the expected natural rate of output, which can be forecast one period in advance and which is independent of monetary policy decisions. The last term is the unexpected part of nominal GDP. Thus, contrary to the model with fully flexible prices, where equilibrium output is completely independent of monetary policy, monetary policy has real effects, when prices are set one period in advance. In this model, monetary policy generates unexpected variation in nominal GDP due to unexpected variation in nominal spending.

2.2.3 Optimal overlapping price setting with nominal rigidities

In this section we assume that the intervals over which goods prices remain fixed overlap, as was first suggested by Phelps (1978) and Taylor (1980). Following Calvo (1983) we examine a discrete staggered price setting model, where in every period a fraction $0 < \alpha < 1$ of goods prices remain unchanged and the rest are adjusted. It is assumed that $1-\alpha$ denotes the probability that a given price will be adjusted in a given period. The probability is independent of the timing of the last price change and of the current price.

Again, all suppliers who are able to adjust prices in period t choose the common price p_t^* because of the common decision problem. In every period, the fraction α of prices remain unchanged, are these are a subset of the previous period's prices. In period t , the Dixit-Stiglitz price index is given by

$$P_t^{1-\theta} \equiv \int_0^1 p_t(i)^{1-\theta} di = (1-\alpha)p_t^{*1-\theta} + \alpha \int_0^1 p_{t-1}(i)^{1-\theta} di \quad (2.30)$$

which implies that

$$P_t = [(1-\alpha)p_t^{*1-\theta} + \alpha P_{t-1}^{1-\theta}]^{1/(1-\theta)} \quad (2.31)$$

The time path of the aggregate price index can be determined by using the initial value and the common new price chosen in every period. The optimal choice, p_t^* , depends on current and expected-future demand conditions of the individual good. The demand function (2.12) implies that other prices have an impact on the demand curve for good i only through the aggregate price index, P_t . If the supplier is able to set the new price in period t , the optimal choice is based on the maximisation of

$$E_t \left\{ \sum_{T=t}^{\infty} \alpha^{T-t} Q_{t,T} \Pi(p_t(i), p_T^I, P_T; Y_T, \tilde{\xi}_T) \right\} \quad (2.32)$$

where the term $\alpha^{T-t} Q_{t,T}$ refers to the probability that the price chosen in period t will still be charged in period T . Again, expectations are important in optimal price setting, since the pricing decision is based on the expected present value of future profits. The first order condition is given by

$$E_t \left\{ \sum_{T=t}^{\infty} \alpha^{T-t} Q_{t,T} \Pi_1(p_t(i), p_T^I, P_T; Y_T, \tilde{\xi}_T) \right\} = 0 \quad (2.33)$$

When all suppliers in a given industry change prices at the same time, the first order condition reduces to

$$E_t \left\{ \sum_{T=t}^{\infty} \alpha^{T-t} Q_{t,T} \Pi_1(p_t^*, p_t^*, P_T; Y_T, \tilde{\xi}_T) \right\} = 0 \quad (2.34)$$

As shown above, the first order condition for optimal staggered price setting with nominal rigidities can be expressed by using the same general form of the profit function as in the two previous sections. This condition is needed for deriving the New Keynesian Phillips curve.

With staggered price setting, the general price level and first order conditions (equations 2.31 and 2.34) can be approximated using the log-linear expressions

$$\log P_t = \alpha \log P_{t-1} + (1 - \alpha) \log p_t^* \quad (2.35)$$

and

$$\sum_{T=t}^{\infty} (\alpha\beta)^{T-t} E_t [\log p_t^* - \log P_T - \zeta(\hat{Y}_T - \hat{Y}_T^n)] = 0 \quad (2.36)$$

In this model the evolution of the aggregate price level is smooth, despite frequent adjustments of individual prices. In the empirical analysis, the output gap is proxied using detrended output. It has been argued, however, that the output gap does not necessarily capture productivity shocks, taste shocks and other real disturbances.

As an alternative measure, it has been suggested that variation in production costs should be included in (2.36) instead of variation in output (Sbordone 1998, 2002 and Galí and Gertler 1999). Theory-based proxies for the output gap have also been used in empirical studies: hours worked (McCallum and Nelson 1999) and the real-interest rate gap (Nelson and Nikolov 2001).

3 Three Phillips curve relationships

In this section we follow Woodford (2003) and derive three different Phillips curve relationships to be applied to euro area data in chapter 5. These models are based on alternative optimal pricing models presented in chapter 2. As will be shown, the New Classical Phillips curve, the New Keynesian Phillips curve and the hybrid modification of the New Keynesian Phillips curve involve very different assumptions about the role of expectations in the inflation process. In the New Classical Phillips curve, previously expected current inflation is an important determinant of inflation dynamics, since only a certain portion of prices are fully flexible and the rest are set one period in advance. By contrast, in the New Keynesian Phillips curve, based on staggered price setting, inflation is determined by currently expected future inflation. In modelling inflation dynamics with the Hybrid Phillips curve, we assume that only some firms are forward-looking and set their prices optimally. The rest of the firms are assumed to be backward-looking and to adjust their prices mechanically by rules of thumb.

Whether price setting is synchronised or staggered is important for the effects of monetary policy. If all firms change prices at the same time, relative prices do not matter in optimal pricing decisions. When price setting is staggered, firms care about relative prices when readjusting their prices. When firms reset their goods prices on a staggered basis, they know that some of the other firms have already adjusted prices in earlier periods and that some will change prices in later periods. Thus, when increasing goods prices, firms try to adjust only slightly, since large price increases change relative prices substantially and a firm will not want to lose customers. Other firms behave in exactly the same way: since some firms have already made moderate price changes, it is reasonable for a firm not to make a big price change. Thus, in staggered price setting, the aggregate price level behaves smoothly in spite of frequent adjustment of individual prices.

Alternative Phillips curve relationships are based on time-dependent optimal price setting. When price adjustment is delayed due to nominal rigidities, firms cannot know the consequences of their pricing decisions for sales and profits. This means that optimal pricing decisions are based on the present value of expected profits. Thus expectations play a crucial role in pricing decisions. Due to differences in the nature of optimal price setting and in the role of expectations, alternative Phillips curves have clearly different policy

implications. The New Classical Phillips curve implies that monetary policy will have only temporary effects on real economic activity. By contrast, longer-lasting real effects of monetary policy can be modelled using the New Keynesian Phillips curve. The Hybrid model is able to explain inflation persistence due to delayed effects of monetary policy on inflation.

3.1 The New Classical Phillips curve

The New Classical Phillips relation was originally presented in the late 1960s by Phelps (1967) and Friedman (1968). It can be derived in the general framework of the previous chapter by combining two optimal price setting models. In the New Classical Phillips curve it is assumed that a fraction $0 < \iota < 1$ of goods prices are fully flexible and the rest are fixed one period in advance. Thus, in order to derive microfoundations for this aggregate supply relation, we need the first order conditions derived in chapter 2, ie equations (2.18) and (2.22) with minor modifications

$$\Pi_1(p_{1t}, p_{1t}, P_t; Y_t, \tilde{\xi}_t) = 0 \quad (3.1)$$

and

$$E_{t-1}[Q_{t-1,t} \Pi_1(p_{2t}, p_{2t}, P_t; Y_t, \tilde{\xi}_t)] = 0 \quad (3.2)$$

Condition (3.1) is for goods prices which can be adjusted in every period. Condition (3.2) is for sticky prices, which must be predetermined on the basis of information available in period $t-1$. A common price is assumed to be chosen for all flexible-price goods and for all sticky-price goods.

When a log-linear approximation of Π_1 near the values $(1, Y, 0)$ is inserted into $\Pi_1(P_t, P_t, P_t; Y_t, \tilde{\xi}_t) = \psi_y (\hat{Y}_t - \hat{Y}_t^n)$, we obtain

$$\Pi_1(p_t, p_t, P_t; Y_t, \tilde{\xi}_t) = \psi_p \log(p_t / P_t) + \psi_y (\hat{Y}_t - \hat{Y}_t^n) \quad (3.3)$$

where $\psi_p < 0$. This can be written as

$$\Pi_1(p_t, p_t, P_t; Y_t, \tilde{\xi}_t) = \psi_p [\log(p_t / P_t) - \zeta (\hat{Y}_t - \hat{Y}_t^n)] \quad (3.4)$$

where $\zeta = -\psi_y/\psi_p > 0$. Log-linear approximations of the first order conditions (3.1) and (3.2) are given by¹

$$\begin{aligned}\log p_{1t} &= \log P_t + \zeta(\hat{Y}_t - \hat{Y}_t^n) \quad \text{and} \\ \log p_{2t} &= E_{t-1}[\log P_t + \zeta(\hat{Y}_t - \hat{Y}_t^n)] = E_{t-1} \log p_{1t}.\end{aligned}\tag{3.5}$$

These approximations are valid if price and output changes are moderate. A log-linear approximation of the general price index, aggregated from two kinds of prices, is given by

$$\log P_t = \iota \log p_{1t} + (1 - \iota) \log p_{2t}\tag{3.6}$$

We can show that

$$\pi_t - E_{t-1}\pi_t = \log P_t - E_{t-1} \log P_t = \frac{\iota}{1 - \iota} (\log p_{1t} - \log P_t)\tag{3.7}$$

Inserting equation (3.5) into equation (3.7) yields the New Classical Phillips curve

$$\pi_t = E_{t-1}\pi_t + \varphi(\hat{Y}_t - \hat{Y}_t^n)\tag{3.8}$$

where $\varphi \equiv \frac{\iota}{1 - \iota} \zeta > 0$. As shown in equation (3.8), the New Classical Phillips curve relates the current inflation rate to the previously expected current inflation rate and to current excess demand. The slope of the New Classical Phillips curve depends on the parameters ι and ζ , ie on the share of fully flexible prices and the slope parameter in the two price equations. The New Classical Phillips curve is the steeper, the larger the parameter ι , ie the larger the portion of firms with fully flexible prices. The New Classical Phillips curve suggests that monetary policy has only temporary and unexpected effects on real activity. These effects are completely non-forecastable, since monetary policy causes unexpected variation in nominal spending and thus in nominal GDP. Some empirical studies indicate that the observed long-lasting real effects of monetary policy cannot be explained by the New Classical Phillips curve unless one assumes that prices are fixed for an unrealistically long time. Next, we derive an

¹ See a more detailed derivation in annex 1.

alternative Phillips curve relationship with longer-lasting real effects of monetary policy, ie the New Keynesian Phillips curve.

3.2 The New Keynesian Phillips curve

The New Keynesian Phillips curve is also based on nominal rigidities, but price setting is staggered rather than synchronised. Optimal price setting behaviour is strongly affected by staggering, and thus firms pay attention to relative prices of goods. If the fixed time intervals between price changes overlap, the model produces more realistic real effects of monetary policy than with synchronised price setting, but it can still be assumed that individual prices are reset optimally quite frequently. The New Keynesian Phillips curve implies that monetary policy effects on real activity are forecastable.

The New Keynesian Phillips curve can be derived following the Calvo model (Calvo 1983), which assumes that in every period a fraction $0 < \alpha < 1$ of the goods prices are unchanged and the remaining prices are readjusted. When goods prices are reset, the price setters take into account that a price may be fixed for many periods. Each price has an equal probability of being revised in any given period and this probability is independent of the timing of the last price change. We assume that a stochastic discount factor for profits is on average $0 < \beta < 1$ and that the profit function has the same general form as in the two previous sections: $\Pi_t(i) = \Pi(p_t(i), p_t^1, P_t; Y_t, \tilde{\xi}_t)$.

The aggregate price index can be expressed by a weighted average of the lagged aggregated price index and the optimal price in period t : $\log P_t = \alpha \log P_{t-1} + (1 - \alpha) \log p_t^*$. The optimal price, p_t^* , takes the form

$$\sum_{T=t}^{\infty} (\alpha\beta)^{T-t} E_t[\log p_t^* - \log P_T - \zeta(\hat{Y}_T - \hat{Y}_T^n)] = 0.$$

When making a pricing decision, it is optimal for a firm to set the price equal to the weighted average of prices it would have expected to set in future periods, in the absence of price rigidities. Solving the optimal solution for p_t^* and modifying, we get the following form, where current optimal price is a function of expected next-period optimal price²

² A more detailed derivation is shown in annex 2.

$$\begin{aligned}\log p_t^* &= (1 - \alpha\beta) \sum_{T=t}^{\infty} (\alpha\beta)^{T-t} E_t \left[\log P_t + \zeta(\hat{Y}_t - \hat{Y}_t^n) \right] \\ &= (1 - \alpha\beta) \left[\log P_t + \zeta(\hat{Y}_t - \hat{Y}_t^n) \right] + \alpha\beta E_t \log p_{t+1}^*\end{aligned}\quad (3.9)$$

Subtracting $\log P_t$ from both sides, we obtain the optimal relative price for period t , $\hat{p}_t^* = \log(p_t^*/P_t)$

$$\begin{aligned}\hat{p}_t^* &= (1 - \alpha\beta) \zeta(\hat{Y}_t - \hat{Y}_t^n) + \alpha\beta E_t \left[\log p_{t+1}^* - \log P_t \right] \\ &= (1 - \alpha\beta) \zeta(\hat{Y}_t - \hat{Y}_t^n) + \alpha\beta E_t \left[\hat{p}_{t+1}^* + \pi_{t+1} \right]\end{aligned}\quad (3.10)$$

Finally, combining the equation (3.10) with the aggregate price index, we obtain the New Keynesian Phillips curve

$$\pi_t = \beta E_t \pi_{t+1} + \kappa(\hat{Y}_t - \hat{Y}_t^n)$$

$$\text{where } \kappa = \frac{(1 - \alpha)(1 - \alpha\beta)}{\alpha} \zeta > 0 \quad (3.11)$$

Thus, in the New Keynesian Phillips curve, the current inflation rate is a function of the currently expected future inflation rate and current excess demand. The parameter κ is positive since, with excess demand, inflation tends to increase. Under excess demand, inflationary pressures are due to the fact that those firms that are readjusting their prices raise them, on average. Iterating equation (3.11) forward, we obtain

$$\pi_t = \kappa \sum_{k=0}^{\infty} \beta^k E_t (\hat{Y}_{t+k} - \hat{Y}_{t+k}^n) \quad (3.12)$$

Since the current inflation rate is equal to the weighted, discounted stream of current and future output gaps, it is entirely forward-looking. Hence there is no persistence in the inflation process. Current pricing decisions are less related to cost and demand conditions in the far future than in the near future. This is due to the fact that, at the micro level, individual price setters are the more likely to make another price adjustment, the farther off the future period in question.

In empirical work, real marginal cost can be proxied by real unit labour cost (labour income share). We assume that when minimising costs the firm sets nominal marginal cost equal to the ratio of nominal

wage to marginal product of labour: $MC_t^n = W_t / MPL_t$. In the simplest model we assume a Cobb-Douglas production function of the form $Y_t = K_t^b N_t^{1-b}$, which implies that nominal marginal cost can be expressed by

$$MC_t^n = W_t / [(1-b)Y_t / N_t] \quad (3.13)$$

which can be modified to yield real marginal cost

$$MC_t = W_t N_t / [(1-b)P_t Y_t] \quad (3.14)$$

Thus, real marginal cost is proportional to labour's share of income or equivalently to real unit labour cost

$$MC_t \propto S_t = W_t N_t / P_t Y_t \quad (3.15)$$

The use of labour income share as an empirical proxy for real marginal cost is not unambiguous, since it is based on aggregate variables, not on the firm-level marginal cost of the theory. Since average and marginal cost are not equal, they can move in opposite directions. For example, during a recession, average cost of production and thus labour income share may increase, if employed labour is underutilised. However, overtime compensation declines in recessions, which reduces both average cost and labour income share.

3.3 The Hybrid Phillips curve

It may not be reasonable to assume that in the Calvo model prices are unchanged between optimising periods. Instead, we can assume that firms can save costs if prices are changed between price adjustment periods according to a mechanical rule. Under this assumption we are able to derive the Hybrid Phillips curve, which implies persistence in the inflation process. The Hybrid model relates current inflation to both currently expected future inflation and the lagged inflation rate. Only some firms are assumed to be forward-looking and to set their prices optimally. The rest are assumed to be backward-looking in their pricing decisions. Thus, in this aggregate supply relationship, the lagged inflation term is needed as an additional explanatory variable.

The same implications of the Hybrid Phillips curve can be derived in two different ways. One can assume that prices remain fixed

between optimising periods and that, when prices can be adjusted, only some of them are reset optimally and the rest are changed according to backward-looking rules of thumb (see eg Galí and Gertler 1999). Alternatively, all prices can be assumed to be adjusted in every period, in indexation models. When every price is reset in every period, price setting is based on optimisation or backward-looking indexation. Different forms of indexation models have been developed by several authors. Yun (1996) has proposed a model in which backward-looking indexation between optimising periods automatically follows the long-run average inflation rate as follows (Yun 1996)

$$\pi_t = (1 - \beta)\bar{\pi} + \kappa(\hat{Y}_t - \hat{Y}_t^n) + \beta E_t \pi_{t+1}. \quad (3.16)$$

We can also assume that backward-looking indexation is based on the most recent inflation rate. In principle, indexation of the current inflation rate is possible, but this assumption is unrealistic, since it is too costly to firms, and it would lead to simultaneity problems.

Next, we assume that in every period a fixed portion, $(1-\alpha)$, of all goods prices are re-optimised and the rest are changed mechanically according to the rule

$$\log p_t(i) = \log p_{t-1}(i) + \gamma \pi_{t-1}, \quad (3.17)$$

where the term $0 \leq \gamma \leq 1$ determines the rate of indexation. In this case, the maximisation problem and first order condition can be expressed as follows: Maximise

$$E_t \left\{ \sum_{T=t}^{\infty} \alpha^{T-t} Q_{t,T} \left[\Pi_T^i(p_t(i)(P_{T-1}/P_{t-1})^\gamma) \right] \right\} \quad (3.18)$$

and

$$E_t \left\{ \sum_{T=t}^{\infty} (\alpha\beta)^{T-t} u_c(Y_T; \xi_T) Y_T P_T^\theta \left(\frac{P_{T-1}}{P_{t-1}} \right)^{\gamma(1-\theta)} \times \left[p_t^* - \mu P_T s(Y_T (p_t^*/P_T)^{-\theta} (P_{T-1}/P_{t-1})^{-\gamma\theta}, Y_T; \tilde{\xi}_T) \right] \right\} \quad (3.19)$$

The aggregate price index can be expressed as

$$P_t = \left[(1 - \alpha) p_t^{*1-\theta} + \alpha \left(P_{t-1} \left(\frac{P_{t-1}}{P_{t-2}} \right)^\gamma \right)^{1-\theta} \right]^{1/(1-\theta)} \quad (3.20)$$

Using log-linear approximations of equations (3.19) and (3.20), we are able to make similar modifications as in the derivation of the New Keynesian Phillips curve, and we get the Hybrid Phillips curve

$$\pi_t - \gamma\pi_{t-1} = \kappa(\hat{Y}_t - \hat{Y}_t^n) + \beta E_t(\pi_{t+1} - \gamma\pi_t), \quad (3.21)$$

where β , κ and \hat{Y}_t^n are defined as in the purely forward-looking New Keynesian model. Solving equation (3.21) forward, we obtain

$$\pi_t = \gamma\pi_{t-1} + \kappa \sum_{j=0}^{\infty} \beta^j E_t [\hat{Y}_{t+j} - \hat{Y}_{t+j}^n] \quad (3.22)$$

According to equation (3.22), the current inflation rate depends not only on the expected path of the output gap but also on the lagged inflation rate, π_{t-1} . Therefore, the hybrid specification of the New Keynesian Phillips curve implies persistence in inflation. The inflation process is the more persistent, the larger the indexation parameter γ .

The indexation parameter γ varies across different studies. For example, in Christiano et al (2001), the indexation parameter is equal to one, which means full indexation. On the other hand, Smets and Wouters (2002) have proposed that a reasonable rate of indexation is 0.64. If the parameter β is equal to one in the indexation model, the model is identical to Galí and Gertler's (1999) hybrid model, where backward-looking behaviour is based on rule-of-thumb behaviour, and to Fuhrer and Moore's (1995) two-sided Phillips curve, where workers are concerned about their relative wages.

4 Previous empirical evidence of the New Keynesian Phillips curve

In recent years inflation dynamics have been intensively examined using the New Keynesian Phillips curve relationship, but the empirical results have not been firmly established. In many studies the empirical fit of the New Keynesian Phillips curve under rational expectations has been poor and, moreover, studies of the Hybrid Phillips curve have yielded conflicting results. Only mixed support has been found for both the real unit labour cost and output gap as a relevant driving variable in the New Keynesian models.

Several studies have questioned the rational expectations hypothesis. Some studies have provided empirical evidence that it may be too restrictive to assume that agents behave rationally in forming their expectations. In the last few years there has been growing interest in studying the inflation process under non-rational expectations. Instead of assuming that agents are rational, alternative models are used for expectations formation or no specific form of non-rationality is assumed and expectations are measured directly.

In this chapter we summarise previous empirical evidence on the New Keynesian curve relationship, with and without the assumption of rational expectations. We also summarise some empirical studies which examine whether inflation expectations are rational.

4.1 The New Keynesian Phillips curve with rationality

Recent years have seen an explosion in research of inflation dynamics and the New Keynesian Phillips curve. Some studies suggest that the purely forward-looking New Keynesian Phillips curve is a good approximation of inflation dynamics. On the other hand, there are also studies that indicate that the Hybrid Phillips curve with the lagged term is needed in order to capture the inflation process properly. The empirical fit of the New Keynesian models seems to depend on the choice of driving variable. Most studies suggest that real unit labour cost is the relevant driving variable, but the output gap has also received support. Besides the empirical successes of the New Keynesian Phillips curve, some completely opposite results have been presented, according to which backward-looking expectations are

dominant in inflation dynamics. There has been disagreement on methodological issues, in connection with instrumental variable methods in the empirical analysis of the forward-looking Phillips curve. In particular, concerns have been raised about small sample bias, choice of instruments and normalisation. In sum, one can say that the empirical validity of the New Keynesian Phillips curve is still unclear. Neither the theoretical model nor its empirical implementation is uncontroversial. The typical assumption of rational expectations may have an important role in the empirical performance of New Keynesian Phillips specifications.

In empirical studies that find support for the New Keynesian Phillips curve, real unit labour costs are typically used to proxy real marginal costs. Real unit labour costs take into account the impact of productivity gains on inflation and adjust sluggishly for output variation. Galí and Gertler (1999) obtain such results for the US and Galí, Gertler and López-Salido (2001) for the euro area. These studies indicate that the New Keynesian Phillips curve provides a reasonably good approximation of inflation dynamics and that most agents are forward-looking when setting their prices. In Galí and Gertler (1999), about sixty to eighty per cent of individual price setters exhibit forward-looking behaviour in adjusting goods prices. Backward-looking price setting is also statistically important, but it is not quantitatively very important. The New Keynesian Phillips curve can be formally rejected against the Hybrid model with some mild backward-lookingness in Galí, Gertler and López-Salido (2001). However, it still describes euro area inflation dynamics quite well. Both Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001) find strong evidence against the output gap -based New Keynesian Phillips curve.

The dominant role of the forward-looking expectations term in explaining US inflation dynamics has also been stressed in studies using a two-step estimation procedure (Sbordone 2002). When real marginal cost is proxied by unit labour cost and backward-looking firms are allowed to index their prices to the lagged inflation rate, the hybrid model results indicate a relatively small weight for the backward-looking term. Sbordone argues that inflation dynamics can be even captured fairly well with a purely forward-looking model. By contrast, McAdam and Willman (2003) find evidence that the New Keynesian Phillips curve fits euro area data poorly. The New Keynesian Phillips curve has also been applied to data on individual European countries. For example, Balakrishnan and López-Salido (2002) show that the New Keynesian and Hybrid Phillips curves both perform poorly with the UK data. Benigno and López-Salido (2001)

find that the marginal cost -based New Keynesian Phillips curve fits the German data.

The dominance of forward-looking expectations is not unambiguous, since several studies suggest that the Hybrid model outperforms the New Keynesian Phillips curve. In Jondeau and Le Bihan (2001), the Hybrid specification fits better with US and euro area data, and the relative weights of forward- and backward- looking components are roughly equal. However, the driving variable is typically insignificant. A model with additional lags and leads seems to improve the empirical performance of the model, although it lacks theoretical foundation. In spite of the dominance of forward-looking expectations, the relative weight of the backward-looking component is still significant in Jondeau and Le Bihan (2001). Benigno and López-Salido (2001) find that for France, Italy and the Netherlands the Hybrid model fits the data better than does the New Keynesian Phillips curve. On the other hand, the results are mixed for Spain.

Sondergaard (2003) studies the inflation process in European countries. He argues that the New Keynesian Phillips curve is rejected in favour of the Hybrid model for France and Italy, but the results are mixed for Spain. European countries being more open than the US economy, Sondergaard (2003) derived real marginal cost measures using a production function that includes (imported) intermediate inputs. However, open-economy considerations do not much improve the empirical performance of the New Keynesian Phillips curve for France, Italy or Spain.

The output gap -based New Keynesian models, with rational expectations, have also received empirical support, but to a lesser degree. It has been shown that for the US, United Kingdom and Australia inflation dynamics can be modelled using the output gap as the driving variable (see Neiss and Nelson 2002). On the other hand, it has been argued that replacing the output gap with real unit labour cost does not improve the empirical fit of the New Keynesian Phillips curve for the US (Rudd and Whelan 2002). Jondeau and Le Bihan (2001) show that the output gap -based Hybrid model is favoured for the euro area, Germany and Italy. By contrast, the Hybrid Phillips curve results for France are poor, with both real marginal cost and the output gap.

The reason for the dominant role of forward-looking expectations in the US inflation process is not clear. According to Fuhrer (1997) forward-looking expectations are essentially unimportant in US data. Rudd and Whelan (2003) find little evidence for the rational forward-looking behaviour implied by the New Keynesian theory. Instead, the New Keynesian model may suffer from reliance on a strict form of

rational expectations. Although agents may not be rational, price setters may behave optimally. Rudd and Whelan (2003) suggest that further research on how agents process information and improve their forecasts would be worthwhile.

The empirical success of the New Keynesian Phillips curve suggested in Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001) has been questioned for methodological reasons. For example, Rudd and Whelan (2001) and (2002) find evidence that the instrumental variable estimation procedure is sensitive to small specification errors. Also, Lindé (2001) argues that there may be specification bias associated with GMM, and full information maximum likelihood (FIML) may be more robust than the GMM. Galí, Gertler and López-Salido (2003) have responded to the criticism and provided evidence that the importance of forward-looking behaviour is robust to a variety of estimation methods.

Mavroeidis (2002) discusses possible identification and misspecification problems in his examination of forward-looking monetary models. He argues that the possible low power of the Hansen test in these models is due to ‘over-instrumenting’ and ‘over-correction’. In other words, using too many instruments and too much autocorrelation correction reduces the power of the Hansen test. Ma (2002) investigates problems with identification and weak instruments, in estimating the New Keynesian Phillips curve with GMM. He argues that GMM is inadequate methodology for estimation of New Keynesian models, since the purely forward-looking New Keynesian Phillips curve suffers from observational equivalence and the hybrid model results are poor due to problems of weak identification. Sondergaard (2003) shows that using GMM with small samples produces results for the New Keynesian Phillips curve that may be highly sensitive to normalisation. He provides evidence that, when using Monte Carlo simulations, the normalisation used in Galí and Gertler (1999) suggests that some firms are backward-looking, although there are no backward-looking firms by construction. Thus, the normalisation tends to overestimate the portion of backward-looking firms. Regarding instrumental variable methods, possible small sample problems like normalisation are also discussed in Fuhrer, Moore and Schuh (1995).

The New Keynesian Phillips curve has been estimated using exact methods (Khalaf and Kichian 2004). Using these methods, which are valid for small samples and immune to the presence of weak instruments, one can assess how well the model is identified. Although the results reject Galí and Gertler (1999) estimates, the New Keynesian Phillips curve is supported by the data. Moreover, in

Khalaf and Kichian (2004) the share of backward-looking firms seems to be the least-well-determined parameter in the Hybrid model.

4.2 Deviation from rationality

There are only a few sources of data on inflation expectations in the euro area. Since January 1986 the European Commission has conducted a monthly consumer survey in the 15 member states, seasonally adjusted results of which are published for the single countries, the European Union and the euro area. The questionnaire includes qualitative questions about recent and future price developments. For empirical analysis, consumers' answers are quantified using statistical methods.

The probability method is used in Berk (2000), Gerberding (2001) and Nielsen (2003) to derive quantitative measures from European Commission survey data. Berk (2000) shows that survey-based inflation expectations in the euro area, European Union and individual European countries are typically unbiased. However, they do not react systematically to changes in the actual inflation rate and short-term interest rate surprises.

In Gerberding (2001), survey-based expectations from both the European Commission and Consensus Economics are used to study inflation dynamics in individual euro area economies. Results from tests of unbiasedness and informational efficiency of inflation expectations suggest that expectations play a central role in short-run inflation dynamics. While survey expectations pass the standard test of unbiasedness, agents do not use all available information efficiently when forming inflation expectations. Moreover, expectations seem to be neither purely forward-looking nor purely adaptive.

Nielsen (2003) examines the rationality of consumers' inflation expectations in the European Union. Cointegration analysis and rationality tests for nonstationary time series indicate that the hypothesis of rational expectations has to be rejected. However, there seems to be a long-run relationship between actual inflation and inflation expectations.

Compared to Europe, more data is available for inflation expectations in the US. Inflation expectations data from several sources is widely examined in Mankiw, Reis and Wolfers (2003), which provides evidence that the assumption that all agents have the same expectation of future inflation is rejected. Consumers and professional forecasters have different inflation expectations and this

disagreement varies considerably over time. This study shows that the sticky-information model by Mankiw and Reis (2002), which assumes that agents readjust their expectations only infrequently, because of costs over collecting and processing information, is able to explain the disagreement over inflation expectations in survey data. Various statistical tests indicate that inflation expectations depart from full rationality. However, a model of adaptive expectations seems to be too simple to describe expectations formation.

The rational expectations hypothesis can be relaxed if it is assumed that agents use only part of the available information in forming their expectations. Near-rational expectations are assumed in Ball (2000), where the inflation forecast is based only on recent inflation history. When agents make univariate forecasts of inflation, they are assumed to use recent inflation history optimally but to ignore other variables. A lot of information has to be collected and processed in order to form expectations rationally. By forming instead near-rational expectations, agents can reduce gathering and processing costs. Ball's sticky price model with near-rational expectations performs well for two historical periods in the US. It is able to explain inflation dynamics in both the post-1960 period of persistent inflation and the non-persistent-inflation period from 1879 to 1914. He finds evidence that neither models with rational expectations and nor models with backward-looking expectations are able to capture inflation dynamics in both of these periods.

Empirical support for the deviation of household inflation expectations from the rational expectations benchmark and sluggish inflation expectations is found in Carroll (2001). This study uses US survey data and compares inflation expectations of the general public with those of professional forecasters. The empirical evidence supports an epidemiological model of inflation expectations, in which 'expert opinion' spreads slowly throughout the economy, like a disease. Thus the general public reacts to professionals' expectations with a lag.

The theory of rationally heterogeneous expectations, which is related to Carroll's epidemiology model and Ball's near-rational expectations model, has been used to analyse inflation dynamics (see Brock and Hommes 1997 and Branch 2002). The basic idea behind the theory is that in forming expectations it may be reasonable for price setters to choose methods other than rational expectations, since it is costly to collect information. In every period agents choose whether to update their previous expectation by weighting the costs and benefits of revision. Branch (2004) studies household inflation expectations in the US using survey data. He finds evidence that the

failure of the rational expectations hypothesis is not because agents follow an ad hoc rule. Instead, in some periods it is not reasonable for them to collect costly information and form rational expectations. Thus expectations seem to be boundedly rational and consistent with optimising behaviour.

Roberts (1997 and 1998) analyses inflation dynamics in the US using the New Keynesian specification and survey estimates of inflation expectations. These studies provide evidence that inflation expectations are not rational, which appears to be connected with the poor empirical fit of the New Keynesian theory. Roberts (1997) argues that, with survey-based expectations, one can distinguish between the structural and expectational sources of lagged inflation. The need for the lagged inflation rate may be due to non-rationality of expectations rather than to the underlying structure of the economy. Roberts (1998) considers the case where survey expectations are a weighted average of forward- and backward-looking expectations. The empirical evidence suggests that forty per cent of price setters use a simple univariate rule for forecasting inflation, and sixty per cent have rational expectations. Robert (2001) argues that backward-looking expectations are important in US inflation dynamics.

Forsells and Kenny (2002) use 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 by eventually adjusting their expectations. They find also evidence of 'growing' rationality over the 1990s compared with the 1980s.

Survey-based measures of inflation expectations are used in Adam and Padula (2003), which examines US inflation dynamics in 1968-2003. The empirical results show that the New Keynesian Phillips curve fits the data, since the estimated parameters are significant and plausible. Reasonable results are obtained with both the output gap and unit labour cost. Although possible non-rationality in survey-based expectations seems to improve the empirical fit of the New Keynesian Phillips curve, the lagged inflation rate, ie the Hybrid model, is needed to capture inflation dynamics properly.

Several studies have stressed the impact of expectations on monetary policy design. It has been shown that, if expectations formation is non-rational, optimal monetary policy is more difficult than it would be with rational expectations (see Orphanides and Williams 2003). If agents update their expectations continuously and use an adaptive learning technology, the optimal monetary policy design can be clearly different than under rational expectations.

Dahl and Hansen (2001) have examined the effect of the change in monetary policy regime on inflation expectations. Although the rationality of inflation expectations is typically rejected, rationality receives support if expectations formation is examined under changing monetary policy regimes. Because of ex post bias, persistent forecast errors cannot be taken as an argument against rational expectations. Instead, the errors indicate that there is nonzero probability of a change in monetary policy regime. When forming inflation expectations, systematic forecast errors are possible if agents have difficulty in identifying the monetary policy regime.

5 Empirical evidence

In this chapter we examine empirically euro area inflation dynamics. The analysis is based on the three Phillips curves which were derived from microfoundations in the previous chapter³. After describing the data and estimating formulas, we report estimation results for aggregated and pooled euro area data. Two methods are used in the estimations: least squares and generalised method of moments (GMM). In all specifications, the driving variable is proxied by two different measures of the output gap. In addition, labour income share is used as a proxy for real marginal cost in the New Keynesian and Hybrid Phillips curves. The empirical success of the different Phillips curve relationships is compared using two tests: a specification test by Davidson and MacKinnon (1993) and the Wald test of coefficient restrictions. Since European price developments have changed a great deal since the late 1970s and inflation history has been quite heterogeneous across the euro area countries, we perform a robustness analysis at the end of this chapter. The purpose is to determine whether the GMM results are sensitive to sample choice or choice of countries. In all of the empirical analysis, we use OECD forecasts to proxy inflation expectations, which means that expectations may but not necessarily deviate from rationality.

5.1 Data description

Annual inflation rates and alternative driving variables for twelve EMU countries were constructed for the years 1977–2003 using the OECD Economic Outlook data set and OECD National Accounts. Inflation was measured by annual changes in the 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 each following calendar year⁴. Labour income share is defined as the ratio of compensation of employees to nominal GDP. The output gap is the difference between log real GDP and Hodrick-Prescott filtered log

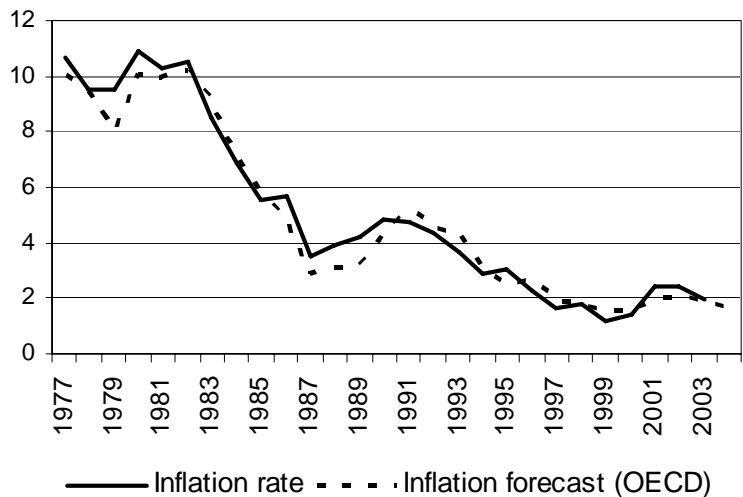
³ Some of the empirical analysis of this chapter is presented in Paloviita (2004).

⁴ The choice between June and December forecasts is somewhat arbitrary and indeed we could also average them. In Paloviita and Mayes (2004a), June forecasts are used to measure inflation expectations.

real GDP with smoothing parameter of 100. Alternatively, we used production function -based OECD output gap estimates^{5,6}. Figure 1 gives 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.

Figure 1.

Actual and expected inflation in the euro area



In the late 1970s the euro area annual inflation rate was about 10 per cent, but it decreased rapidly to about 4 per cent during the 1980s. Since a minor peak of about 4.5 per cent in the beginning of the 1990s, inflation has remained subdued in the euro area. Inflation histories diverged across countries, especially in the 1980s.

Labour income share and the two output gap measures for the euro area are shown in figure 2. Since the late 1970s, labour income share has decreased almost continuously in the euro area. By contrast, there has been more variation in the output gap. In the mid-1980s and mid-

⁵ Availability of data varies somewhat. Forecast information is available for 1977–2004 for ten countries in the euro area. For Luxembourg, forecasts are available since 1982 and for Portugal since 1980. OECD output gap information is available since 1973–1979 for eleven euro area countries and not available for Luxembourg. For eight countries, labour income share is available to 2003 and for Belgium, Ireland, Netherlands and Portugal to 2002.

⁶ ECB GDP weights, based on actual exchange rates, were used in aggregation. Country weights for the year 2002 are: Germany 29.8, France 21.6, Italy 17.8, Spain 9.8, 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, missing forecast data for Portugal 1977–1979 were replaced by data for Spain.

1990s, as well as in the most recent years, the output gap was negative in the euro area. On the other hand, output was above potential in the beginning of all the decades in the sample. Since the late 1970s there has been remarkable heterogeneity in labour income share and output gap developments across the individual EMU countries.

Figure 2.

Labour income share and output gaps in the euro area

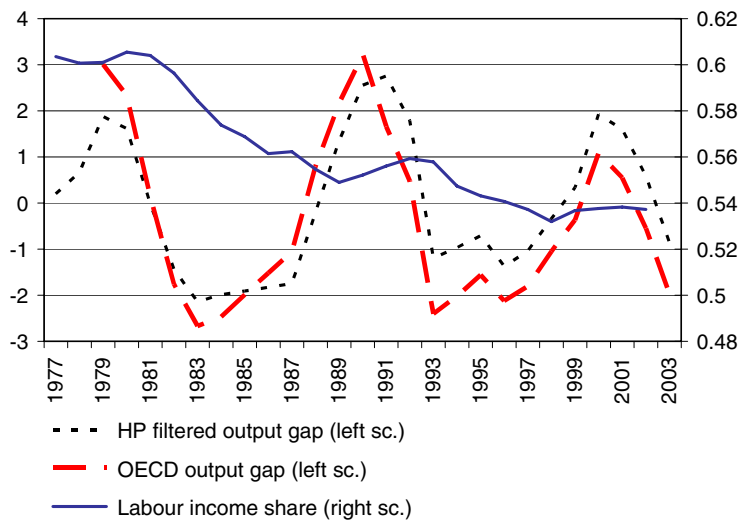


Table 1.

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) $\chi^2=3.702$ (0.157)	F=6.361 (0.002) $\chi^2=12.723$ (0.002)
Euro area, 1977–1990	(a,b) = (0,1)		F=13.759 (0.000) $\chi^2=27.519$ (0.000)
Euro area, 1991–2003	(a,b) = (0,1)		F=0.312 (0.733) $\chi^2=0.623$ (0.732)

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

The unbiasedness of OECD inflation forecasts was tested by estimating the equation $\pi_t = a + b\pi_t^*$, where π_t^* refers to period t inflation forecast, made in period t-1. As shown in table 1, for the 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 pooled data, we found evidence that OECD inflation forecasts are biased. The two

sub-period results for the 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 euro area 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, regressing forecast error on lagged inflation rate and lagged driving variable led in most cases to rejection of the null hypothesis that estimated coefficients are jointly equal to zero. These results provide evidence that deviations from full rationality may be important in empirical analysis of the Phillips curve relationship.

Next, we compare OECD forecasts with other measures for euro area inflation expectations. Annex 3 gives survey-based expectations for the Harmonised Index of Consumer Prices. The probability approach was used to derive quantitative estimates from qualitative survey information provided by the European Commission (see Forsells and Kenny 2002⁷). In the same figure we also show OECD forecasts for two inflation measures: GDP deflator and private consumption deflator. All alternative proxies seem to follow a similar pattern. The correlation of survey-based expectations with the private consumption deflator forecast is 0.748, and with the GDP deflator forecast 0.711. Although inflation measures vary by proxy, alternative measures are relatively highly correlated.

Another measure for euro area inflation expectations, found in Gerlach (2004), is also presented in annex 3. Gerlach studies inflation dynamics with a model that incorporates money explicitly in the analysis, as he assumes that trend money growth determines expected inflation. As reported in Gerlach (2004), trend money growth and the OECD forecast for private consumption deflator both decrease between 1992 and 1997. After that, they remain quite stable for a few years, and start to increase towards the end of the sample. Thus Gerlach's model-dependent measure for inflation expectations is closely related to OECD inflation forecasts. He finds evidence that Consensus Economics estimates for euro area inflation expectations perform noticeably worse than the OECD estimates of this study. All

⁷ The monthly data was kindly provided by Forsells.

in all, we would conclude that in comparing OECD inflation forecasts to the two alternative measures of euro area inflation expectations, we obtain support for the reliability of OECD forecasts as a proxy for inflation expectations.

5.2 Estimating formulas

The standard specifications for the New Classical, New Keynesian and Hybrid Phillips curves under rational expectations were presented in chapter 3. When rational expectations are not imposed and inflation expectations are measured directly, these specifications need to be modified slightly for application to the data. When inflation expectations are measured directly, we obtain the following modified estimating formulas from the standard specifications (3.8), (3.11) and (3.22)

$$\pi_t = \pi_t^* + \phi \hat{y}_t \quad (5.1)$$

$$\pi_t = \beta_t \pi_{t+1}^* + \kappa \hat{y}_t \quad (5.2)$$

$$\pi_t = (1 - \omega) \pi_{t+1}^* + \omega \pi_{t-1} + \phi \hat{y}_t \quad (5.3)$$

where the terms $\pi_t^* = \bar{E}_{t-1}\{\pi_t\}$ and $\pi_{t+1}^* = \bar{E}_t\{\pi_{t+1}\}$ refer to period t-1 and period t representative market expectations, which are not necessarily rational. The term \hat{y}_t denotes to the output gap, $(\hat{Y}_t - \hat{Y}_t^n)$. In the New Keynesian and Hybrid models, the driving variable can alternatively be labour income share. As Adam and Padula (2003) have shown, we can derive the New Keynesian Phillips curve with directly measured expectations. In applying equations (5.1)–(5.3) to the data, one need not assume any specific form of non-rationality in expectations. Thus we can concentrate on relative performance of alternative elements of expectations in inflation dynamics. Since the task here is to compare the different models on their own terms, the theoretical restrictions are imposed in the estimated specifications of the New Keynesian models. Thus, in the New Keynesian Phillips curve, the imposed value of β is 0.97 and, as seen in equation (5.3), the sum of forward- and backward-looking components is restricted to unity for the Hybrid Phillips curve.

In all specifications, inflation varies positively with driving variable, which is measured in two alternative ways: Hodrick Prescott filtered output gap and OECD output gap estimate based on the production function method. In addition, for the New Keynesian and Hybrid Phillips curves, real marginal cost is proxied by labour income share. Labour income share is probably the closest proxy for real marginal cost, but unfortunately not all forms of labour compensation are measured accurately for the euro area. As the final goal is to model output and inflation behaviour together, it is worth investigating whether, in this approach, we can generally use more up-to-date and reliable output information in constructing the output gap in the Phillips curve relationship. Using the output gap enables one to avoid inaccuracy in labour income share and possible problems in linking it to output dynamics. On the other hand, the output gap clearly cannot be measured without error.

5.3 Estimation results

5.3.1 The New Classical Phillips curve

First, the New Classical Phillips curve, equation (5.1), was estimated for the aggregated and pooled euro area data using least squares (LS). As shown in table 2, the estimated coefficient for the output gap always entered with a positive sign, and one statistically significant coefficient was obtained for each data sets. Moreover, the estimated New Classical model was always slightly flatter with the pooled euro area data. All in all, the LS results for the euro area are quite reasonable. However, there seems to be autocorrelation in the residuals, which may indicate an errors-in-variables problem⁸.

⁸ For the New Classical Phillips curve the estimated parameters seem to be stable according to the Chow test. F-statistic for structural break in 1991 was 2.432 with HP filtered output gap and 1.332 with OECD output gap.

Table 2.

**Euro area estimation results
for New Classical Phillips curve
using ordinary least squares**

	Aggregated			Pooled		
	ϕ	D-W	R ²	ϕ	D-W	R ²
HP filtered output gap	0.120 (0.106)	1.022	0.972	0.083* (0.040)	1.570	0.906
OECD output gap	0.151* (0.057)	0.834	0.971	0.054 (0.029)	1.515	0.917

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

Next we re-estimated the same equations using GMM (Hansen 1982). With both data sets, the chosen instruments were two lags of the output gap⁹. They represent variables which are predetermined in period t . The standard errors of the estimated parameters were modified using a Bartlett or quadratic kernel with variable Newey-West bandwidth. In addition, prewhitening was used for the aggregated data. In all cases, the J-statistic was used to test overidentifying restrictions of the model.

⁹ Estimation results for the New Classical Phillips curve were less sensitive to choice of instruments than were those for the New Keynesian and Hybrid Phillips curves.

Table 3.

**Euro area estimation results for
New Classical Phillips curve using GMM**

$$\text{NCPC} \quad \pi_t = \pi_t^* + \phi \hat{y}_t$$

Aggregated	ϕ	J-statistic	Instruments	GMM	Obs
HP filtered output gap	0.112 (0.085)	0.044	$\hat{y}_{t-1}, \hat{y}_{t-2}$	B, V, P	27
OECD output gap	0.090* (0.024)	0.062	$\hat{y}_{t-1}, \hat{y}_{t-2}$	Q, V, -	23

Pooled	ϕ	J-statistic	Instruments	GMM	Obs
HP filtered output gap	0.060 (0.068)	0.015	$\hat{y}_{t-1}, \hat{y}_{t-2}$	B, V, P	316
OECD output gap	0.140* (0.064)	0.015	$\hat{y}_{t-1}, \hat{y}_{t-2}$	B, V, -	285

Notes: Numbers in parentheses are standard errors, * indicates significance at 5 per cent level.

J-statistic corresponds to Hansen test of overidentifying restrictions. GMM options: B = Bartlett kernel, Q = Quadratic kernel, V = variable Newey-West bandwidth, P = prewhitening.

As reported in table 3, quite similar results qualitatively were found for both data sets and both driving variables¹⁰. Compared with table 2 using LS, the results are almost unchanged when the HP filtered output gap is used as the driving variable. Greater change in the estimated parameter was found when using the OECD output gap, with which the driving variable coefficient was always significant. With the pooled data, the overidentifying restrictions were rejected according to the Hansen test. The potential weakness of the instruments for estimating the New Classical Phillips curve by GMM was obviated by the applied test, in which the endogenous regressor of the model was regressed on the variables in the instrument set. The R-squared values for least squares estimations for both the data sets are reported in annex 4. They show that three of four of the R-squared values were above 0.70 and the lowest value was 0.66. Thus the chosen instruments seemed to be relevant for the variables we seek to model.

All in all, euro area inflation dynamics were captured relatively well using the New Classical Phillips curve, where current inflation is related to previously expected current inflation and the current driving variable. Next, we investigate how the empirical fit of the Phillips

¹⁰ The number of observations varies in GMM estimations, since the original series are of different lengths.

curve relationship changes when we change the timing of expectations and alternatively also assume that some price setters are backward-looking. In other words, we consider the empirical performance of the New Keynesian Phillips curve and its hybrid specification.

5.3.2 New Keynesian Phillips curve and Hybrid Phillips curve

Typically, empirical analysis of the New Keynesian Phillips curve relationship is based on the joint hypothesis of New Keynesian Phillips curve and rational expectations, which means that instrumental variable (IV) methods are needed. By contrast, when inflation expectations are measured directly, the New Keynesian Phillips curve can be estimated with ordinary least squares (LS), if one can assume that 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 New Keynesian and Hybrid Phillips curves using LS and GMM should serve as useful input in assessing how important these problems may be in the present context. Empirical results for the two specifications can be compared in order to investigate whether the lagged inflation term is needed after relaxing the rational expectations assumption.

Table 4.

Estimation results for New Keynesian models in the euro area using ordinary least squares

$$\text{NKPC} \quad \pi_t = 0.97 \cdot \pi_{t+1}^* + \lambda \hat{m}c_t \quad \text{or} \quad \pi_t = 0.97 \cdot \pi_{t+1}^* + \kappa \hat{y}_t$$

	Aggregated			Pooled		
	λ or κ	D-W	R ²	λ or κ	D-W	R ²
Labour 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

$$\text{HPC} \quad \pi_t = (1-\omega)\pi_{t+1}^* + \omega\pi_{t-1} + \delta \hat{m}c_t \quad \text{or} \quad \pi_t = (1-\omega)\pi_{t+1}^* + \omega\pi_{t-1} + \phi \hat{y}_t$$

	Aggregated				Pooled			
	ω	δ or ϕ	D-W	R ²	ω	δ or ϕ	D-W	R ²
Labour 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 labour income share, 1977–2003 with HP filtered output gap and 1979–2003 with OECD output gap. Numbers in parentheses are Newey-West HAC standard errors, * indicates significance at 5 per cent level.

First, the New Keynesian Phillips curve (equation 5.2) was estimated by LS with aggregated and pooled euro area data, using three alternative proxies for real marginal cost (see table 4). Overall, the estimation results are relatively poor for the data, since only with labour income share did we get a correctly signed coefficient, and the residuals are strongly autocorrelated in all cases. Qualitatively similar results were obtained for the pooled euro area data. All in all, LS results for the New Keynesian Phillips curve 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 New Keynesian Phillips curve, even with directly measured expectations¹¹.

Next we considered the possibility that the lagged inflation term is needed in the New Keynesian Phillips curve, which would result in the Hybrid specification, ie equation (5.3). 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 4, Hybrid Phillips curve results for aggregated euro area data were 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 was obtained when labour income share (HP filtered output gap) was 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 was reliable, about 0.45 in all cases. Moreover, the lowest and the highest coefficients for the driving variable again appeared with labour income share and HP filtered output gap¹². Looking at the estimation results with LS, the lagged inflation rate seemed to improve the empirical results for the purely forward-looking New Keynesian Phillips curve relationship, but still we obtained many unreliable and imprecise estimates. Overall, estimation results using LS clearly suggested that the forward-looking New Keynesian specification is mis-specified. Also, IV methods seem to be needed because of errors-in-variables and/or simultaneity problems. Measurement errors may occur in both the expectations term and the driving variable.

Next we estimated the New Keynesian and Hybrid Phillips curves by IV method, as shown in table 5. Respectively, also for these specifications, the instruments used were chosen to represent variables which are predetermined at time t . Since the New Keynesian models seem to be more sensitive to choice of instruments than is the New Classical Phillips curve, the instrument sets were allowed to vary across the equations¹³. However, in order to avoid too many

¹¹ For the New Keynesian Phillips curve, when using labour income share, HP filtered output gap or OECD output gap as driving variable, the F-statistics for the Chow test were 0.018, 4.187 and 3.202. Thus the test indicated that the estimated parameter seemed to be stable only with labour income share.

¹² For the Hybrid Phillips curve, the estimated parameters seemed to be stable according to the Chow test. F-statistic was below 1.0 with all driving variables.

¹³ The number of observations varies in GMM estimations, since the original series are of different lengths and the number of lagged variables in the instrument sets varies across the equations.

Table 5.

Estimation results for New Keynesian models in the euro area using GMM

$$\text{NKPC} \quad \pi_t = 0.97 \cdot \pi_{t+1}^* + \lambda \hat{m}c_t \text{ or } \pi_t = 0.97 \cdot \pi_{t+1}^* + \kappa \hat{y}_t$$

Aggregated	λ or κ	J-statistic	Instruments	GMM	Obs
Labour income share	0.003 (0.039)	0.123	$\hat{m}c_{t-1}, \pi_{t-1}$	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}, π_{t-1}	Q, V, -	24

Pooled	λ or κ	J-statistic	Instruments	GMM	Obs
Labour income share	0.073 (0.048)	0.037	$\hat{m}c_{t-1}, \hat{m}c_{t-2}$	B, V, P	312
HP filtered output gap	0.126 (0.093)	0.036	\hat{y}_{t-1}, π_{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

$$\text{HPC} \quad \pi_t = (1-\omega)\pi_{t+1}^* + \omega\pi_{t-1} + \delta \hat{m}c_t \text{ or } \pi_t = (1-\omega)\pi_{t+1}^* + \omega\pi_{t-1} + \phi \hat{y}_t$$

Aggregated	ω	δ or ϕ	J-stat.	Instruments	GMM	Obs
Labour income share	0.552* (0.053)	0.047* (0.005)	0.093	$\hat{m}c_{t-1}, \hat{m}c_{t-2}, \pi_{t-2}$	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	δ or ϕ	J-stat.	Instruments	GMM	Obs
Labour income share	0.632* (0.057)	0.001 (0.015)	0.006	$\hat{m}c_{t-1}, \pi_{t-2}, \pi_{t-3}$	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: See table 3.

instruments, ie possible small sample problems due to ‘overinstrumenting’, two instruments were always used for the New Keynesian Phillips curve and three instruments were always used for the Hybrid specification. Again, in all cases, the standard errors of estimated parameters were modified using a Bartlett or quadratic kernel with variable Newey-West bandwidth. Moreover, prewhitening was used in four of six cases for the New Keynesian model and in one of six cases for the Hybrid model. For both models, the Hansen test was used to test the overidentifying restrictions.

As can be seen from table 5, for the New Keynesian Phillips curve with aggregated euro area data, the driving variable always entered 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 New Keynesian Phillips curve fits the data with the correctly signed driving variable. Instrumenting seemed to improve the estimation results, especially when the output gaps were used to determine inflation. The lowest estimate was obtained for labour income share. By contrast, the estimated coefficient for OECD output gap was the highest. All in all, although overidentifying restrictions are not rejected in any of the cases, the estimated parameters are not significant and the model may not be correctly specified. We may be able to improve the empirical performance of the New Keynesian Phillips curve by adding the lagged inflation term, ie by using the Hybrid model.

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 were qualitatively quite similar, as table 5 shows. When the pooled data were used, the driving variable was always correctly signed and, when labour income share or HP filtered output gap were used, we got more precise estimates than with the aggregated data. However, a caveat is appropriate due to the fact that the overidentifying restrictions were rejected with the pooled data. All in all, the New Keynesian Phillips curve results for pooled euro area data suggested also that the Hybrid Phillips curve may fit the data better.

The Hybrid Phillips curve results are also reported in table 5. For the aggregated euro area data, the results suggested that expectations are more backward-looking, since the relative weight of backward-looking expectations was 0.55 with labour income share and slightly higher, 0.63, with both output gaps. The three estimated coefficients for the driving variable were reasonably signed and significant, and the lowest values were obtained for labour income share. In addition, overidentifying restrictions were not rejected. Also the Hybrid Phillips

curve results for the pooled data indicated that backward-looking expectations dominate the inflation process, with a weight of about 0.6. The estimated coefficients for the driving variable were quite plausible and again the lowest value was obtained with labour income share. Overidentifying restrictions were not rejected.

We tested the validity of instruments used in GMM estimations for the New Keynesian and Hybrid Phillips curves. The results are reported in annex 4. For the aggregated data, looking at both models, only one R-squared value was below 0.70 and eight of twelve were above 0.80. Accordingly, for the pooled data we obtained in most cases lower values, but nine of twelve of the R-squared values were above 0.70. We can conclude that the instrument sets for the New Keynesian and Hybrid specifications seem to be valid.

Overall, the 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 New Keynesian Phillips curves 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 the pooled euro area data, overidentifying restrictions were rejected, which indicates possible problems with the purely forward-looking New Keynesian Phillips curve.

In spite of the correctly signed driving variable, the empirical fit of the New Keynesian Phillips curve was not very good, since in many cases the coefficient of the driving variable was estimated 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 properly capture all of the persistence in the inflation process. Even if expectations are measured directly, the Hybrid Phillips curve with lagged inflation rate is needed. This conclusion can be drawn for the aggregated and pooled euro area data alike. Estimation results using both the data sets suggested that the backward-looking factor dominates the inflation process, with a relative weight of about 0.6. The Phillips curve relationship must be estimated using GMM due to measurement and/or simultaneity problems. These results are qualitatively robust to choice of driving variable. However, higher coefficients for the driving variable were obtained with the output gaps. Moreover, we obtained almost the same estimates for relative weight of backward-

looking expectations when output gaps were used as determinant of inflation in both data sets.

5.3.3 Comparison of alternative Phillips curves

The empirical results of the previous section indicated that when measuring inflation expectations directly, euro area inflation dynamics can be captured by the New Classical Phillips curve. Moreover, the New Keynesian Phillips curve fits the data with correctly signed driving variable. The Hybrid Phillips curve results suggested, however, that the lagged term is needed in the New Keynesian Phillips curve relationship in order to properly describe the inflation process.

On the basis of the results reported above, clear statistical preference cannot yet to be claimed for any of the three alternative Phillips curve relationships. In order to facilitate the comparison of models, we applied two statistical tests to the data. First, the empirical performances of the New Classical and New Keynesian Phillips curves were compared using a specification test proposed by Davidson and MacKinnon (1993). Then we used the Wald test, which is based on parameter restrictions. Compared with the specification test, the Wald test is weaker. It compares the three Phillips curves against a very general model, which incorporates all variables of the alternative models.

Applying the specification test to the data, we were able to analyse, whether current or lagged expectations dominate the inflation process

$$\pi_t = \theta_1(\pi_t^*) + \theta_2(0.97 \cdot \pi_{t+1}^*) + \phi \hat{y}_t \quad (5.4)$$

Equation (5.4) includes both expectations variables and then encompasses both models under consideration as special cases. If the sum of the estimated coefficients θ_1 and θ_2 is restricted to one, we can analyse the relative weights of alternative components in the inflation process, as the test typically puts strong weight on either of the variables compared. Since comparison of the New Classical and New Keynesian specifications was done by using the same driving variable, we were able to focus clearly on the timing of the expectations term in the Phillips curve relationship.

The results for the restricted specification test using the two different output gap measures and the two data sets are reported in table 6. They showed that in explaining inflation dynamics, lagged inflation expectations for the current year have clearly bigger relative

weights than current expectations for the next year. This result was robust to choice of data set and driving variable. Thus, the New Classical Phillips curve was favoured in all of the cases.

Table 6. Comparison of New Classical and New Keynesian Phillips curves under GMM

$$\pi_t = \theta(\pi_t^*) + (1-\theta)(0.97 \cdot \pi_{t+1}^*) + \phi_t \hat{y}_t$$

Driving variable						
	HP filtered output gap			OECD output gap		
	S.E. of the NCP	S.E. of the NKPC		S.E. of the NCP	S.E. of the NKPC	
Aggregated euro area data	0.547	1.146		0.472	1.209	
	Encompassing test ¹⁾			Encompassing test ²⁾		
	θ	ϕ	J-statistic	θ	ϕ	J-statistic
Aggregated euro area data	1.365* (0.186)	0.301* (0.098)	0.046	1.125* (0.147)	0.185 (0.083)	0.070

Driving variable						
	HP filtered output gap			OECD output gap		
	S.E. of the NCP	S.E. of the NKPC		S.E. of the NCP	S.E. of the NKPC	
Pooled euro area data	1.716	2.036		1.617	1.990	
	Encompassing test ³⁾			Encompassing test ⁴⁾		
	θ	ϕ	J-statistic	θ	ϕ	J-statistic
Pooled euro area data	1.317* (0.202)	0.141 (0.083)	0.006	1.224* (0.225)	0.167 (0.091)	0.013

Notes: Sample period 1977–2003 with HP filtered output gap and 1981–2003 with OECD output gap. Numbers in parentheses are standard errors, * indicates significance at 5 per cent level. Instruments with aggregated data: lagged inflation rate, π_{t-1} , and two lags of output gap, \hat{y}_{t-1} and \hat{y}_{t-2} . Instruments with pooled data: two lags of output gap, \hat{y}_{t-1} and \hat{y}_{t-2} . GMM options: ¹⁾ Q, V, P; ²⁾ Q, V, -; ³⁾ B, V, P; ⁴⁾ Q, V, P.

The empirical success of the three alternative Phillips curves was next compared against the following very general model, which incorporates all the specifications as special cases

$$\pi_t = a\pi_t^* + b\pi_{t+1}^* + c\pi_{t-1} + d\hat{y}_t \tag{5.5}$$

Previously expected current inflation, currently expected future inflation, lagged inflation rate, and current output gap are the explanatory variables in the general model. If the parameters b and c are equal to zero, the model reduces to the New Classical Phillips curve. Alternatively, if the coefficients a and c are equal to zero, we

obtain the New Keynesian Phillips curve. Moreover, the general model reduces to the Hybrid model if the parameter a is equal to zero. Using the Wald test of coefficient restrictions, we can determine whether restricted specifications are accepted by the data.

The Wald test results using HP filtered output gap and OECD output gap are reported in table A5.1 and table A5.2 (see annex 5). When the parameter restrictions of the New Keynesian Phillips curve were tested against the general model, using the two output gaps and two alternative data sets, the Wald test clearly rejects parameter restrictions implied by the New Keynesian Phillips curve specification. When the same test is used to evaluate the Hybrid model against the general model, the results of the both data sets and both alternative driving variables indicate that the Hybrid model is accepted. Comparing the New Classical Phillips curve to the general model, the test results are slightly mixed. With pooled data and HP filtered output gap, the New Classical specification is accepted at the conventional 5 per cent level. In other cases (with aggregated data and HP filtered output gap and both data sets, using the OECD output gap) the New Classical Phillips curve is accepted at the 1 per cent significance level.

To conclude, the results suggest that both the New Classical and Hybrid Phillips curves provide a better description of the euro area inflation process than does the New Keynesian Phillips curve. Changing the timing of the expectations term in the New Keynesian Phillips curve, ie replacing currently expected future inflation by previously expected current inflation, we obtain the New Classical Phillips curve, which gives a better approximation of the inflation process than does the New Keynesian specification. In this case, we do not assume any backward-looking price setting, but the timing of expectations term is different than in the New Keynesian specification. On the other hand, when the backward-looking expectations term is added to the purely forward-looking New Keynesian Phillips curve, ie using the Hybrid model, the empirical fit of the New Keynesian Phillips curve relationship is much improved. Overall, since both New Classical and Hybrid Phillips curves outperform the New Keynesian Phillips curve, we have found evidence against basic features of the New Keynesian model, ie that the inflation process is purely forward-looking and that the inflation rate can adjust instantaneously to new information. The backward-looking or sluggish features are different in the New Classical and Hybrid models, but the results indicate that they are important in European data.

5.4 Robustness of GMM results

The above results for the full sample period, 1977–2003, indicate that using OECD inflation forecasts to proxy inflation expectations, one can explain euro area inflation dynamics using the New Classical Phillips curve. Moreover, we get a correctly signed driving variable for the New Keynesian Phillips curve, and the Hybrid model also fits the data. Statistical tests indicate that both New Classical and Hybrid specifications outperform the purely forward-looking New Keynesian Phillips curve. Qualitatively, the results seemed not to be very sensitive to choice of driving variable. Next, the empirical results of the previous section are analysed in more detail with the pooled data. Although the New Classical and Hybrid models are relevant approximations for euro area inflation dynamics, it is worth investigating how the relative role of forward-looking expectations changes when two sub-periods and different country groups are used. Robustness analysis is reported in annex 6.

Since 1977 price developments have changed a great deal in the euro area. During the 1980s euro area inflation decreased from two-digit rates to approximately 3 per cent. Since then euro area inflation has remained subdued and quite stable, in spite of a minor peak in the early 1990s. First, the New Classical Phillips curve was estimated for two sub-periods, 1977–1990 and 1991–2003. As seen from table A6.1, for both periods, the estimated coefficients were almost the same with both driving variables, but a correctly signed coefficient were obtained only for the first sub-sample. The Hansen test was never rejected.

Estimating the Hybrid Phillips curve for two sub-periods resulted in quite reasonable results for five of six cases (see table A6.2). The Hansen test was rejected only when OECD output gap was used for the first sub-period. Moreover, only with labour income share was the driving variable coefficient incorrectly signed for the first sub-period and extremely low for 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 Phillips curve relationship. 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 cost in the Hybrid Phillips curve also on the

basis of sub-sample results. Particularly for the more volatile inflation regime, we got very similar coefficients with both output gap measures in estimating the New Classical Phillips curve. For the stable inflation regime, parameter estimates of the Hybrid model were very similar with both alternative output gaps.

Inflation history clearly varies across the EMU countries, especially for 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 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 Netherlands). As reported in table A6.3, the results for the New Classical Phillips curve were plausible, since all estimated parameters were positive. In addition, the overidentifying restrictions were rejected only for high inflation countries, with both output gap measures. For the Hybrid Phillips curve we got reasonable results for both country groups, with all of the driving variables (see table A6.4). 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 the backward-looking factor was over 0.5 for high inflation countries. Accordingly, forward-looking expectations clearly dominated the inflation process for low inflation countries. 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, Netherlands and Spain, the output gap has been less volatile. The New Classical Phillips curve results in table A6.5 show that, for the countries with more divergent output gap histories, the estimated coefficient was very low or negative. For countries with less volatile output gaps, we obtained more reasonable coefficients. The Hansen test was never rejected for the New Classical Phillips curve.

For the Hybrid specification, all results indicated that backward-looking expectations dominate, with a relative weight of 0.55–0.73 (reported in table A6.6). The relative weight of backward-looking expectations was always slightly higher for countries with less

divergent output gap histories. Moreover, for these countries, the driving variable coefficient was always higher. For more divergent output gap countries, we obtained an incorrectly signed driving variable when labour income share was used. According to the J-statistic, the Hansen test was rejected 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 suggests that since the late 1970s the inflation process in the euro area has become more forward-looking. It has also been more forward-looking in the low inflation countries of the euro area prior to the inception of EMU. Heterogeneity of inflation and output gap histories across twelve EMU economies affect the empirical fit for the euro area Phillips curve relationship.

6 Conclusions

New Keynesian economics, which was born in the 1980s, has been derived from microfoundations and it emphasises market imperfections. This theory was developed in response to traditional Keynesian theory and the New Classical economics, which stressed the rational expectations hypothesis. According to New Keynesian economics, wages and prices are sticky, which means that small changes in individual wages and prices can lead to large effects on the aggregate price level. New Keynesian theory with staggered price setting suggests that monetary policy affects real economic activity.

Modelling of expectations is crucial in economics, since expectations play a central role in economic behaviour. Under rational expectations people use all available information and do not make systematic or forecastable errors in predicting future events. In empirical studies, rational expectations have typically been assumed. However, the rational expectations hypothesis has been criticised, since it may be an excessively restrictive and unrealistic assumption for economic behaviour.

The New Keynesian Phillips curve relates current inflation to currently expected future inflation and current excess demand. This aggregate supply relationship is purely forward-looking and has strong implications for optimal monetary policy design. The efficiency of monetary policy depends on agents' expectations as to goals and future course of central bank policy. Therefore, transparency is central to monetary policy design, and the empirical relevance of the New Keynesian Phillips curve is a crucial issue. If inflation is purely a forward-looking phenomenon, as the New Keynesian Phillips curve suggests, a fully credible disinflation is possible without output losses. But if the inflation process can be described using the New Classical Phillips curve, monetary policy has only unforecastable, temporary effects on real economic activity. The Hybrid Phillips curve with the lagged inflation term implies a positive sacrifice ratio. Losses in output increase with the portion of backward-looking firms. Modelling the inflation process with the Hybrid Phillips curve enables one to assess the degree of price stickiness (ie average frequency of price adjustment) and also the degree of 'backwardness' (fraction of backward-looking price setters).

The empirical performance of the New Keynesian Phillips curve under rational expectations has had conflicting assessments, since the driving variable is often incorrectly signed and inflation persistence is not captured. Typically, the empirical fit of the New Keynesian

Phillips curve has been improved by assuming backward-looking behaviour for some firms or sluggish adjustment of real marginal cost to output variation. In this paper a different approach has been used: we examined the Phillips curve relationship without imposing rational expectations. In principle, when rational expectations are not imposed, one can explain inflation persistence with the purely forward-looking New Keynesian Phillips curve relationship and without the lagged inflation rate. Moreover, the choice of appropriate empirical measure for real marginal cost may be different with directly measured expectations.

In studying European inflation dynamics, three different Phillips curves were applied to the aggregated and pooled euro area data. Inflation expectations were proxied by OECD inflation forecasts, and three different proxies for the driving variable were used. Alternative specifications were compared by using the specification test by Davidson and MacKinnon and the Wald test of coefficient restrictions. Moreover, robustness of the results was analysed by investigating inflation dynamics across different sub-periods and country groups. When the analysis of inflation dynamics is based on directly measured expectations, we need not use a priori assumptions of expectations formation. OECD forecasts are assumed to be a representative measure of price setters' inflation expectations in the euro area.

The results obtained suggest that using OECD forecasts to proxy inflation expectations one can capture European inflation dynamics with the New Classical Phillips curve. Moreover, we get a correctly signed driving variable for the New Keynesian Phillips curve. However, the New Classical Phillips curve and the Hybrid Phillips curve clearly outperform the New Keynesian Phillips curve. Thus the basic features of the New Keynesian Phillips curve are rejected by the data. The inflation process seems not to be purely forward-looking, as the New Keynesian theory would suggest. Moreover, we found evidence that the inflation rate cannot adjust instantaneously to new information. Hence the backward-looking and sluggish features implied by the New Classical and Hybrid Phillips curves seem to be important in euro area inflation dynamics.

Using directly measured expectations in the New Keynesian Phillips curve relationship, the output gap turns out to be at least as good a proxy for real marginal cost as is the labour income share. The inflation process seems to have become more forward-looking in the recent years of low and stable inflation. It has also been more forward-looking in the low inflation countries of the euro area prior to the inception of EMU. Divergent output gap developments across the twelve EMU countries affect the empirical performance of the euro

area Phillips curve. Overall, the results obtained were qualitatively similar for the aggregated and pooled euro area data.

The empirical evidence of this study is similar to that obtained for the US with survey-based inflation expectations (Adam and Padula 2003). In modelling US inflation dynamics, the lagged inflation term is also needed in the New Keynesian Phillips curve in order to properly describe the inflation process. Moreover, the results for the US inflation process are robust to choice of driving variable. When US inflation expectations are proxied by survey expectations, both detrended output and unit labour costs are relevant proxies for real marginal cost in the New Keynesian Phillips curve relationship.

The empirical results of this study confirm the results in Paloviita and Mayes (2004a), where OECD June forecasts are used to measure European inflation expectations and inflation dynamics are examined using the New Classical and New Keynesian Phillips curves. Using June forecasts, we find the same evidence of the central role of expectations in the inflation process. Moreover, the New Classical model outperforms the New Keynesian model.

In this study, both real time and revised data were used for the Phillips curve relationship. Real time information was used for the expectations term and revised data was used for all the other variables. Instead of making the rational expectations assumption, OECD forecasts were used to measure the thinking at the time when individual pricing decisions were made. Also, in reality, economic decisions are always made in real time without benefit of hindsight. This study shows that the use of real time information for the expectations term of the Phillips relation is central for analysing inflation dynamics. The same result is also presented in Paloviita and Mayes (2004b), which shows that real time information clearly matters for the Phillips curve relationship, and it matters most for the expectations term. Paloviita and Mayes (2004b) argue that using revised data in the Phillips curve may not be the best way to test the role of expectations in inflation dynamics, since revised data may underestimate forward-lookingness of inflation expectations. This is plausible, since revised variables typically include information which is corrected afterwards on the basis of hindsight.

This study shows that if a possible departure from rational expectations is allowed, directly measured expectations in principle provide a channel through which inflation persistence can still be modelled by the New Keynesian Phillips curve with microfoundations for optimal price setting. However, although this channel seems to be important, it is not powerful enough to properly explain all of the

persistence in the euro area inflation process. This is reasonable, since inflation expectations are not far from rationality.

Alternative Phillips curve relationships with different roles for expectations have clearly different implications for inflation persistence and optimal monetary policy design. If direct measures of inflation expectations perform better than the rational expectations assumption in explaining inflation dynamics, the results indicate 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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Annex 1

Derivation of New Classical Phillips curve

The New Classical Phillips curve is based on the assumption that a fraction $0 < \iota < 1$ of goods prices are fully flexible and the rest are fixed one period in advance. A log-linear approximation for the first order condition of fully flexible prices can be written as

$$\log p_{1t} = \log P_t + \zeta(\hat{Y}_t - \hat{Y}_t^n). \quad (\text{A1.1})$$

A log-linear approximation for the first order condition of prices which are set one period in advance takes the form

$$\begin{aligned} \log p_{2t} &= E_{t-1} \left[\log P_t + \zeta(\hat{Y}_t - \hat{Y}_t^n) \right] \\ &= E_{t-1} \left[\log p_{1t} - \zeta(\hat{Y}_t - \hat{Y}_t^n) + \zeta(\hat{Y}_t - \hat{Y}_t^n) \right] \\ &= E_{t-1} \log p_{1t}. \end{aligned} \quad (\text{A1.2})$$

The same optimal price is chosen by all firms, with fully flexible prices. Firms which set their goods prices one period in advance make the same optimal pricing decision. The aggregate price level is a convex combination of the two prices

$$\log P_t = \iota \log p_{1t} + (1 - \iota) \log p_{2t} \quad (\text{A1.3})$$

where ι and $(1-\iota)$ are the portion of firms with fully flexible prices and the portion which adjust their prices one period in advance.

Subtracting $\log P_{t-1}$ and $E_{t-1} \log P_t$ from both sides of equation (A1.3), we obtain

$$\pi_t - E_{t-1} \log P_t = \iota \log p_{1t} + (1 - \iota) \log p_{2t} - \log P_{t-1} - E_{t-1} \log P_t \quad (\text{A1.4})$$

which can be modified as

$$\pi_t - E_{t-1} \pi_t = \iota \log p_{1t} + (1 - \iota) \log p_{2t} - E_{t-1} \log P_t \quad (\text{A1.5})$$

Inserting $E_{t-1} \log P_t = \iota E_{t-1} \log p_{1t} + (1-\iota) E_{t-1} \log p_{2t}$ into equation (A1.5), yields the expression

$$\pi_t - E_{t-1}\pi_t = \iota \log p_{1t} - \iota E_{t-1} \log p_{1t} \quad (\text{A1.6})$$

Combining equations (A1.2) and (A1.3), yields

$$E_{t-1} \log p_{1t} = \frac{1}{(1-\iota)} \log P_t - \frac{\iota}{(1-\iota)} \log p_{1t} \quad (\text{A1.7})$$

which simplifies equation (A1.6) to

$$\pi_t - E_{t-1}\pi_t = \frac{\iota}{(1-\iota)} (\log p_{1t} - \log P_t) \quad (\text{A1.8})$$

Finally, using equations (A1.1) and (A1.2) in equation (A1.8), we obtain the New Classical Phillips curve

$$\pi_t = E_{t-1}\pi_t + \zeta (\hat{Y}_t - \hat{Y}_t^n) \quad (\text{A1.9})$$

where $\zeta = \frac{\iota}{(1-\iota)} \gamma$.

Annex 2

Derivation of New Keynesian Phillips curve

The Calvo model is based on the idea that in every period a fraction $0 < \alpha < 1$ of goods prices are unchanged and the remaining prices are readjusted. Accordingly, the aggregate price index can be expressed as

$$\log P_t = \alpha \log P_{t-1} + (1 - \alpha) \log p_t^* \quad (\text{A2.1})$$

where the optimal price, $\log p_t^*$, takes the form

$$\sum_{T=t}^{\infty} (\alpha\beta)^{T-t} E_t [\log p_t^* - \log P_T - \zeta(\hat{Y}_T - \hat{Y}_T^n)] = 0 \quad (\text{A2.2})$$

Subtracting $\alpha \log P_t$ from both sides of equation (A2.1), enables expression of the optimal relative price in period t , $\hat{p}_t^* = \log(p_t^*/P_t)$, as a function of the inflation rate in period t

$$\begin{aligned} (1 - \alpha) \log P_t &= -\alpha(\log P_t - \log P_{t-1}) + (1 - \alpha) \log p_t^* \\ \Leftrightarrow \alpha \log(P_t / P_{t-1}) &= (1 - \alpha) \log(p_t^* / P_t) \\ \Leftrightarrow \alpha \pi_t &= (1 - \alpha) \hat{p}_t^* \\ \Leftrightarrow \hat{p}_t^* &= \frac{\alpha}{1 - \alpha} \pi_t. \end{aligned} \quad (\text{A2.3})$$

Solving equation (A2.2) for $\log p_t^*$, we obtain

$$\begin{aligned} \sum_{T=t}^{\infty} (\alpha\beta)^{T-t} E_t \log p_t^* &= \sum_{T=t}^{\infty} (\alpha\beta)^{T-t} E_t [\log P_T - \zeta(\hat{Y}_T - \hat{Y}_T^n)] \\ \Leftrightarrow \log p_t^* &= (1 - \alpha\beta) \sum_{T=t}^{\infty} (\alpha\beta)^{T-t} E_t [\log P_T - \zeta(\hat{Y}_T - \hat{Y}_T^n)] \end{aligned} \quad (\text{A2.4})$$

Alternatively, the optimal price in any period can be expressed using the expected optimal price in the next period

$$\begin{aligned}
\log p_t^* &= (1 - \alpha\beta)E_t[\log P_t + \zeta(\hat{Y}_t - \hat{Y}_t^n)] \\
&\quad + (1 - \alpha\beta) \sum_{T=t+1}^{\infty} (\alpha\beta)^{T-(t+1)} E_t[\log P_T - \zeta(\hat{Y}_T - \hat{Y}_T^n)] \quad (\text{A2.5}) \\
&= (1 - \alpha\beta)[\log P_t + \zeta(\hat{Y}_t - \hat{Y}_t^n)] + \alpha\beta E_t \log p_{t+1}^*.
\end{aligned}$$

Subtracting $\log P_t$ from both sides yields the optimal relative price, \hat{p}_t^* in period t

$$\begin{aligned}
\log p_t^* - \log P_t &= (1 - \alpha\beta)[\log P_t + \zeta(\hat{Y}_t - \hat{Y}_t^n)] + \alpha\beta E_t \log p_{t+1}^* - P_t \quad (\text{A2.6}) \\
\Leftrightarrow \hat{p}_t^* &= (1 - \alpha\beta)\zeta(\hat{Y}_t - \hat{Y}_t^n) + \alpha\beta[E_t \log p_{t+1}^* - \log P_t]
\end{aligned}$$

Next, adding and subtracting $\alpha\beta \log P_{t+1}$ from the RHS of equation (A2.6) yields

$$\begin{aligned}
\hat{p}_t^* &= (1 - \alpha\beta)\zeta(\hat{Y}_t - \hat{Y}_t^n) + \alpha\beta E_t[\log p_{t+1}^* - \log P_{t+1} + \log P_{t+1} - \log P_t] \quad (\text{A2.7}) \\
&= (1 - \alpha\beta)\zeta(\hat{Y}_t - \hat{Y}_t^n) + \alpha\beta E_t[\hat{p}_{t+1}^* + \pi_{t+1}]
\end{aligned}$$

Expressing \hat{p}_t^* and \hat{p}_{t+1}^* in terms of inflation (see equation A2.2) and inserting them into equation (A2.7) \hat{p}_t^* , we get the New Keynesian Phillips curve

$$\begin{aligned}
\frac{\alpha}{1 - \alpha} \pi_t &= (1 - \alpha\beta)\zeta(\hat{Y}_t - \hat{Y}_t^n) + \alpha\beta E_t\left[\frac{\alpha}{1 - \alpha} \pi_{t+1} + \pi_{t+1}\right] \\
\Leftrightarrow \pi_t &= \frac{(1 - \alpha)(1 - \alpha\beta)}{\alpha} \zeta(\hat{Y}_t - \hat{Y}_t^n) + \alpha\beta E_t \pi_{t+1} + (\beta - \alpha\beta) E_t \pi_{t+1} \quad (\text{A2.8}) \\
\Leftrightarrow \pi_t &= \beta E_t \pi_{t+1} + \kappa(\hat{Y}_t - \hat{Y}_t^n),
\end{aligned}$$

where $\kappa = \frac{(1 - \alpha)(1 - \alpha\beta)}{\alpha} > 0$.

Annex 3

Alternative proxies for inflation expectations in the euro area

Figure A3.1 **OECD inflation forecasts and survey based expectations (European Commission's Consumer Survey)**

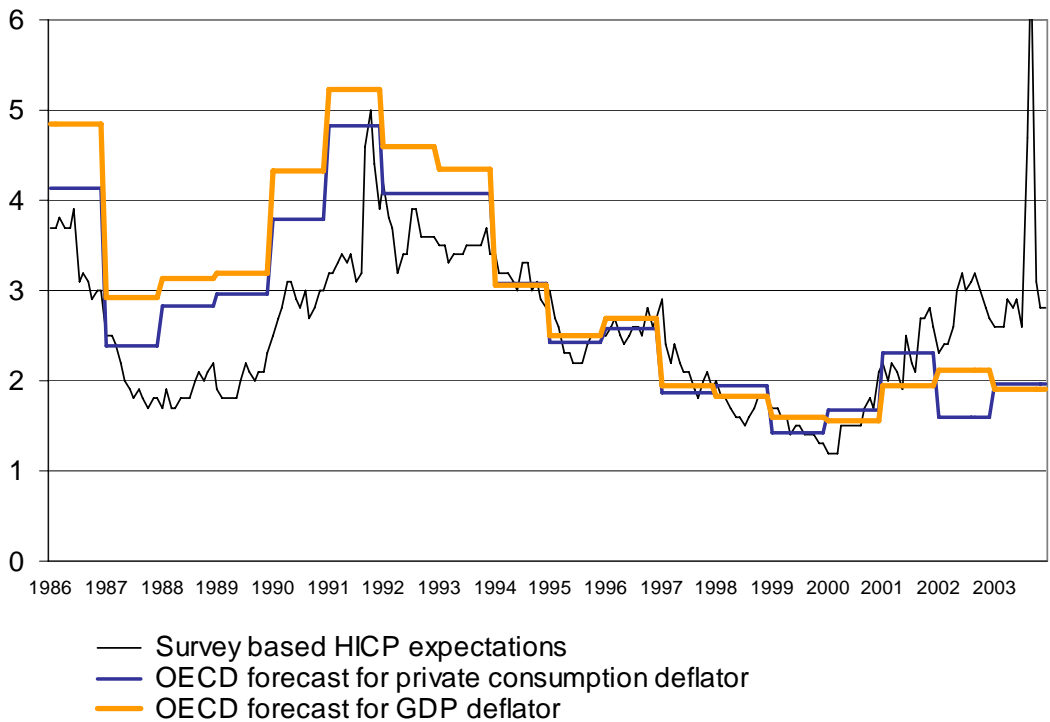
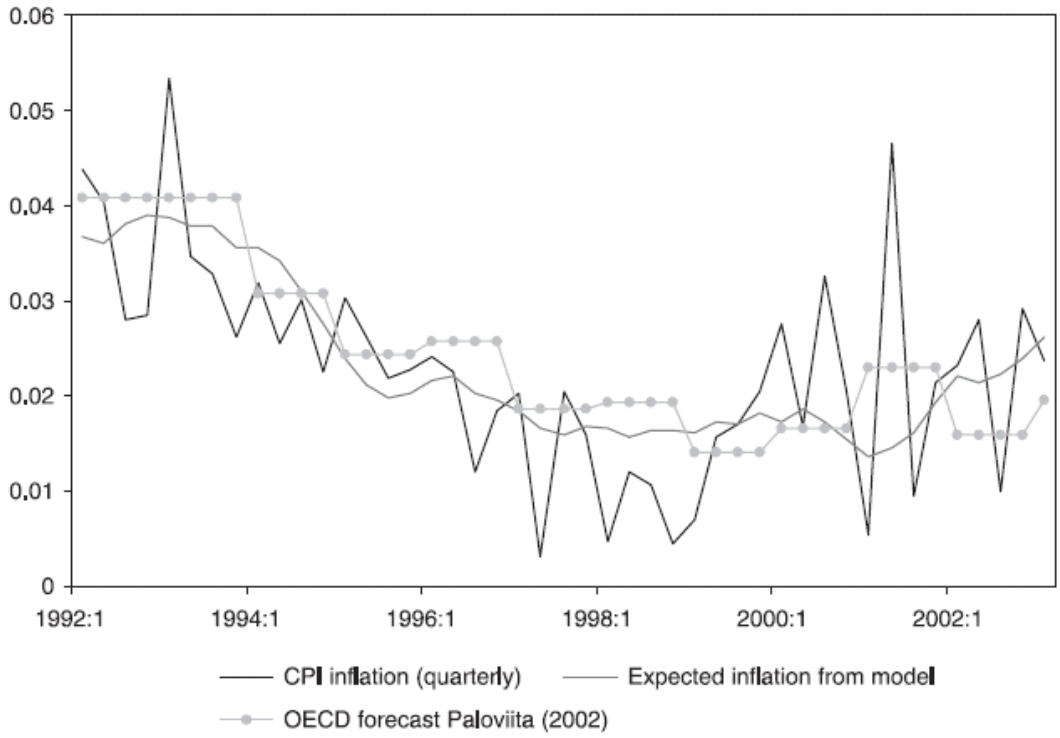


Figure A3.2

Actual inflation and expected inflation in the euro area (Source: Gerlach (2004))



Annex 4

Validity test for GMM instruments

NCPC $\pi_t = \pi_t + \varphi \hat{y}_t$

Driving variable	Endogenous regressor: \hat{y}_t
HP filtered output gap	0.744
OECD output gap	0.716

NKPC $\pi_t = 0.97 \cdot \pi_{t+1}^* + \lambda \hat{m}c_t$ or $\pi_t = 0.97 \cdot \pi_{t+1}^* + \kappa \hat{y}_t$

Driving variable	Endogenous regressor: $\hat{m}c_t$ or \hat{y}_t
Labour income share	0.963
HP filtered output gap	0.744
OECD output gap	0.620

HPC $\pi_t = (1-\omega)\pi_{t+1}^* + \omega\pi_{t-1} + \delta \hat{m}c_t$ or $\pi_t = (1-\omega)\pi_{t+1}^* + \omega\pi_{t-1} + \phi \hat{y}_t$

Driving variable	Endogenous regressor: π_{t+1}^*	Endogenous regressor: π_{t-1}	Endogenous regressor: $\hat{m}c_t$ or \hat{y}_t
Labour income share	0.824	0.948	0.970
HP filtered output gap	0.928	0.964	0.746
OECD output gap	0.894	0.953	0.744

Table A4.2

R-squared values for least squares regressions, pooled data

NCPK $\pi_t = \pi_t + \phi \hat{y}_t$			
Driving variable	Endogenous regressor: \hat{y}_t		
HP filtered output gap	0.657		
OECD output gap	0.740		
NKPC $\pi_t = 0.97 \cdot \pi_{t+1}^* + \lambda \hat{m}c_t$ or $\pi_t = 0.97 \cdot \pi_{t+1}^* + \kappa \hat{y}_t$			
Driving variable	$\hat{m}c_t$ or \hat{y}_t		
Labour income share	0.841		
HP filtered output gap	0.551		
OECD output gap	0.740		
HPC $\pi_t = (1-\omega)\pi_{t+1}^* + \omega\pi_{t-1} + \delta \hat{m}c_t$ or $\pi_t = (1-\omega)\pi_{t+1}^* + \omega\pi_{t-1} + \phi \hat{y}_t$			
Driving variable	Endogenous regressor: π_{t+1}^*	Endogenous regressor: π_{t-1}	Endogenous regressor: $\hat{m}c_t$ or \hat{y}_t
Labour income share	0.714	0.879	0.826
HP filtered output gap	0.752	0.885	0.551
OECD output gap	0.775	0.894	0.654

Annex 5

Wald test of coefficient restrictions

Table A5.1 **Wald test results for euro area with HP filtered output gap**

$$\pi_t = a\pi_t^* + b\pi_{t+1}^* + c\pi_{t-1} + d\hat{y}_t$$

	Joint hypothesis	Aggregated		Pooled	
NKPC vs general model	(a,b,c) = (0,0.97,0)	F=13.553	(0.000)	F=18.152	(0.000)
		$\chi^2=40.658$	(0.000)	$\chi^2=54.457$	(0.000)
HPC vs general model	(a,b+c) = (0,1)	F=0.221	(0.803)	F=0.300	(0.741)
		$\chi^2=0.442$	(0.802)	$\chi^2=5.99$	(0.741)
NCPC vs general model	(a,b,c) = (1,0,0)	F=3.160	(0.044)	F=2.105	(0.100)
		$\chi^2=9.481$	(0.024)	$\chi^2=6.314$	(0.097)

Notes: Instruments: $\hat{y}_{t-1}, \hat{y}_{t-2}, \pi_{t-2}, \pi_{t-3}$. GMM options with aggregated data: B, V, -. GMM options with pooled data: B, V, P.

Table A5.2 **Wald test results for euro area with OECD output gap**

$$\pi_t = a\pi_t^* + b\pi_{t+1}^* + c\pi_{t-1} + d\hat{y}_t$$

	Joint Hypothesis	Aggregated		Pooled	
NKPC vs general model	(a,b,c) = (0,0.97,0)	F=13.521	(0.000)	F=24.669	(0.000)
		$\chi^2=40.563$	(0.000)	$\chi^2=74.008$	(0.000)
HPC vs general model	(a,b+c) = (0,1)	F=0.288	(0.753)	F=0.696	(0.499)
		$\chi^2=0.577$	(0.750)	$\chi^2=1.392$	(0.499)
NCPC vs general model	(a,b,c) = (1,0,0)	F=3.605	(0.033)	F=3.670	(0.013)
		$\chi^2=10.816$	(0.013)	$\chi^2=11.010$	(0.012)

Note: Instruments: $\hat{y}_{t-1}, \hat{y}_{t-2}, \pi_{t-2}, \pi_{t-3}$. GMM options with aggregated data: B, V, -. GMM options with pooled data: B, V, P.

Annex 6

Robustness analysis of GMM results for New Classical and Hybrid Phillips curve

Table A6.1 GMM results for New Classical Phillips curve for two sub-samples

NCPC $\pi_t = \pi_t^* + \phi \hat{y}_t$

Pooled, 1977–1990	ϕ	J-stat.	Instruments	GMM	Obs
HP filtered output gap	0.248* (0.108)	0.024	$\hat{y}_{t-1}, \hat{y}_{t-2}$	Q, V, P	160
OECD output gap	0.239 (0.128)	0.018	$\hat{y}_{t-1}, \hat{y}_{t-2}$	Q, V, P	142
Pooled, 1991–2003	ϕ	J-stat.	Instruments	GMM	Obs
HP filtered output gap	-0.043 (0.044)	0.014	$\hat{y}_{t-1}, \hat{y}_{t-2}$	Q, V, P	156
OECD output gap	-0.025 (0.038)	0.009	$\hat{y}_{t-1}, \hat{y}_{t-2}$	Q, V, -	143

Table A6.2 GMM results for Hybrid Phillips curve for two sub-samples

HPC $\pi_t = (1-\omega)\pi_{t+1}^* + \omega\pi_{t-1} + \delta \hat{m}c_t$ or $\pi_t = (1-\omega)\pi_{t+1}^* + \omega\pi_{t-1} + \phi \hat{y}_t$

Pooled, 1977–1990	ω	δ or ϕ	J-stat.	Instruments	GMM	Obs
Labour income share	0.706* (0.059)	-0.033 (0.030)	0.015	$\hat{m}c_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q, V, P	160
HP filtered output gap	0.723* (0.091)	0.290* (0.094)	0.017	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	B, V, -	160
OECD output gap	0.571* (0.099)	0.174* (0.069)	0.037	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q, V, -	145
Pooled, 1991–2003	ω	δ or ϕ	J-stat.	Instruments	GMM	Obs
Labour income share	0.488* (0.037)	0.001 (0.014)	0.023	$\hat{m}c_{t-1}, \pi_{t-2}, \pi_{t-3}$	B, V, P	152
HP filtered output gap	0.479* (0.041)	0.018 (0.038)	0.014	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	B, V, -	156
OECD output gap	0.482* (0.043)	0.017 (0.037)	0.010	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q, V, -	143

Table A6.3

GMM results for New Classical Phillips curve for high and low inflation countries

$$\text{NCPC} \quad \pi_t = \pi_t^* + \phi \hat{y}_t$$

Pooled, high inflation countries	ϕ	J-stat.	Instruments	GMM	Obs
HP filtered output gap	0.135 (0.079)	0.042	$\hat{y}_{t-1}, \hat{y}_{t-2}$	Q, V, P	186
OECD output gap	0.166 (0.091)	0.036	$\hat{y}_{t-1}, \hat{y}_{t-2}$	Q, V, P	177

Pooled, low inflation countries	ϕ	J-stat.	Instruments	GMM	Obs
HP filtered output gap	0.079 (0.054)	0.019	$\hat{y}_{t-1}, \hat{y}_{t-2}$	Q, V, P	130
OECD output gap	0.188* (0.048)	0.035	$\hat{y}_{t-1}, \hat{y}_{t-2}$	Q, V, -	108

Table A6.4

GMM results for Hybrid Phillips curve for high and low inflation countries

$$\text{HPC} \quad \pi_t = (1-\omega)\pi_{t+1}^* + \omega\pi_{t-1} + \delta \hat{m}c_t \text{ or } \pi_t = (1-\omega)\pi_{t+1}^* + \omega\pi_{t-1} + \phi \hat{y}_t$$

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

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

Table A6.5

GMM results for New Classical Phillips curve for countries with more and less divergent output gaps

$$\text{NCPC} \quad \pi_t = \pi_t^* + \phi \hat{y}_t$$

Pooled, more divergent output gap countries						
	ϕ	J-stat.	Instruments	GMM	Obs	
HP filtered output gap	0.028 (0.056)	0.012	$\hat{y}_{t-1}, \hat{y}_{t-2}$	Q, V, P	100	
OECD output gap	-0.075 (0.067)	0.028	$\hat{y}_{t-1}, \hat{y}_{t-2}$	Q, V, -	73	
Pooled, less divergent output gap countries						
	ϕ	J-stat.	Instruments	GMM	Obs	
HP filtered output gap	0.205* (0.102)	0.017	$\hat{y}_{t-1}, \hat{y}_{t-2}$	B, V, P	216	
OECD output gap	0.138 (0.082)	0.015	$\hat{y}_{t-1}, \hat{y}_{t-2}$	B, V, P	212	

Note: See table 3.

Table A6.6

GMM results for Hybrid Phillips curve for countries with more and less divergent output gaps

$$\text{HPC} \quad \pi_t = (1-\omega)\pi_{t+1}^* + \omega\pi_{t-1} + \delta \hat{m}c_t \text{ or } \pi_t = (1-\omega)\pi_{t+1}^* + \omega\pi_{t-1} + \phi \hat{y}_t$$

Pooled, more divergent output gap countries						
	ω	δ or ϕ	J-stat.	Instruments	GMM	Obs
Labour income share	0.590* (0.098)	-0.006 (0.024)	0.003	$\hat{m}c_{t-1}, \pi_{t-2}, \pi_{t-3}$	B, V, P	98
HP filtered output gap	0.545* (0.114)	0.081* (0.036)	0.011	$\hat{y}_{t-1}, \hat{y}_{t-2}, \pi_{t-2}$	B, V, -	100
OECD output gap	0.716* (0.119)	0.059 (0.047)	0.028	$\hat{y}_{t-1}, \hat{y}_{t-2}, \pi_{t-2}$	Q, V, -	73
Pooled, less divergent output gap countries						
	ω	δ or ϕ	J-stat.	Instruments	GMM	Obs
Labour income share	0.640* (0.067)	0.006 (0.016)	0.013	$\hat{m}c_{t-1}, \pi_{t-2}, \pi_{t-3}$	Q, V, P	214
HP filtered output gap	0.644* (0.074)	0.169* (0.067)	0.023	$\hat{y}_{t-1}, \pi_{t-2}, \pi_{t-3}$	B, V, -	216
OECD output gap	0.733* (0.053)	0.220* (0.045)	0.011	$\hat{y}_{t-1}, \hat{y}_{t-2}, \pi_{t-2}$	B, V, -	212

Note: See table 3.

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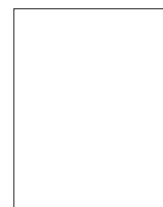
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