The Two Pillars of the ECB

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Abstract

This paper interprets the ECB's two-pillar strategy by proposing a model for inflation that decomposes it into short- and long-run components. The latter of these depends on an exponentially weighted moving average of past monetary growth and the former on the output gap. Estimates for the 1971-2003 period suggest that money can be combined with other indicators to form the "broadly based assessment of the outlook for future price developments" that constitutes the ECB's second pillar. However, the analysis does not suggest that money should be treated differently from other indicators and consequently does not require a two-pillar strategy.

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"Pillar.

1. A detached vertical structure of ... solid material, ... used either as a vertical support of some superstructure, as a stable point of attachment of something heavy and oscillatory, or standing alone as a conspicuous monument or ornament; ..."

The Compact Edition of the Oxford English Dictionary, Vol. II, 1984, p. 2175.

1. Introduction

As the above quotation illustrates, the term "pillar" has several meanings.[1] It is perhaps therefore not surprising that after more than five years of operation, the ECB's monetary policy strategy is still highly controversial. Initially announced in October 1998, the hallmark of the strategy is the use of "two pillars" in formulating and setting monetary policy.[2] The first pillar, which is defined as a:

> *"prominent role for money, as signalled by the announcement of a reference value for the growth of a broad monetary aggregate",*

has remained the object of a lively debate and has been subject to intense criticism.[3] For instance, Begg et al. (2002, p. xiv), writing in the CEPR series on Monitoring the European Central Bank, state that:

> *"the first pillar of the monetary strategy is now flawed beyond repair – both as a matter of theory and empirically".*

By contrast, the second pillar, defined by the ECB as a:

> *"broadly based assessment of the outlook for future price developments and the risks to price stability in the euro area as a whole",*

has been accepted by the public and the economics profession as a natural part of any active monetary policy strategy. In fact, all central banks that gear monetary policy to achieving and maintaining price stability presumably rely on such an assessment in setting interest rates.

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[1] In fact, the OED gives another eleven definitions of "pillar."

[2] The ECB's policy framework is reviewed in "The stability-oriented monetary policy strategy of the Eurosystem", ECB Monthly Bulletin, January 1999, pp. 39-50. For a non-technical review, see ECB (2004).

[3] Summarising the critique of the two-pillar framework goes beyond the scope of this study. In Box A, I instead summarise the analysis in the last report in the CEPR series on *Monitoring the ECB* (Galí et al. 2004) which provides a critical review of a number of arguments in support of the first pillar.

To understand the ECB's views of the role of money in its strategy, it is useful to consider in some detail some of its public statements. In an article explaining its policy framework published in its second Monthly Bulletin, the ECB stated that (p. 29, underlining added):

> *"(a)s there is wide agreement that the development of the price level in the <u>medium to long term</u> is a monetary phenomenon, developments in the amount of money held by the public may reveal useful information about future price movements and thereby offer an important compass for the conduct of monetary policy".*[4]

On the important issue why money may be informative for future inflation, the ECB merely noted that (p. 29):

> *"increases in prices are normally closely linked to rates of money growth in excess of the real growth capacity of the economy over the medium term".*

Importantly, it went on to argue that:

> *"(w)hile broad monetary aggregates normally contain information for price developments in the medium to long term, this link may be distorted by a variety of special factors in the short term"*

and that (p. 30):

> *"(i)t is therefore important to distinguish, as far as this is possible, between changes in monetary aggregates which are caused by special factors, and those changes which signal risks to price stability. The leading indicator properties of money with regard to prices may also be undermined in the short term by shocks directly affecting the price level ...."*

The ECB's initial justification for including a monetary pillar was thus largely based on the observation that money growth and inflation tend to be positively related over time, although this relationship is not necessarily very tight in short time spans of data.

Of course and as noted by Galí (2003), these propositions should not be controversial on their own. For instance, the claim that money growth and inflation are strongly linked is a key lesson in intermediate undergraduate macroeconomic texts and has

[4] See "Euro area monetary aggregates and their role in the Eurosystem's monetary policy strategy," ECB Monthly Bulletin, February 1999, pp. 29-46.

been verified by a number of cross-sectional studies.[5] Furthermore, the fact that the link between money growth and inflation could be blurred in the short run is well established in monetary economics. Lucas (1980) notes that this may be the case and demonstrates that the relationship stands out more clearly if empirical measures of the medium- to long-term components of money growth and inflation are used.[6] More recently, Jaeger (2003) uses spectral methods to demonstrate that the correlation (or, more formally, the coherence) between money growth and inflation in the euro area is above 0.9 for cycles over eight years of periodicity, but only about 0.4 for cycles with shorter duration.

So if the ECB's motivation for the two-pillar framework relies on such standard propositions in monetary economics, why, then, has the monetary pillar become so exceedingly controversial? Two considerations appear to explain this.

First, observers have failed to detect any relationship between the growth rate of M3 and interest rate decisions taken by the Governing Council of the Eurosystem. With the exception of Gerdesmeier and Roffia (2003), econometric estimates of reaction functions for the euro area typically fail to find that money growth plays a role in the ECB's interest rate decisions. Furthermore, in commenting on the reasons for its policy decisions, the Governing Council has repeatedly stated that episodes of rapid money growth were due to special factors and/or shifts in the demand for money arising from changes in portfolio preferences or in the opportunity cost of holding money. For this reason, it interpreted the observed money growth as not signalling *"risks to price stability"* and therefore chose to disregard them. Galí *et al.* (2004) review the statements about economic conditions in the Editorials in the ECB's Monthly Bulletin and conclude that the Governing Council typically interpreted money growth as not signalling risks to price stability even when it exceeded the 4.5 percent reference value.[7] Strikingly, despite the fact that money growth was above the reference value during the entire period between July 2001 and September 2003, the

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[5] See Gerlach (1995), who uses data from Barro (1990), Dwyer and Hafer (1988), Duck (1993) and Vogel (1974). De Grauwe and Polan (2001) is a more recent and widely cited study.

[6] See also King (2002).

[7] See also Gerlach (2004).

Governing Council never took the view that rapid money growth warranted a tightening of monetary policy.

However, in fairness to the ECB, it should be noted that in presenting the framework it emphasised that it should not be expected to move interest rates automatically in response to changes in money growth. In particular, it argued that:

> *"the concept of a reference value does not entail a commitment on the part of the Eurosystem to correct deviations of monetary growth from the reference value of the short term. Interest rates will not be changed "mechanistically" in response to such deviations in an attempt to return monetary growth to the reference value."* [8]

Thus, this critique must be seen as somewhat peculiar by the ECB.

A second and arguably much more important reason for the controversy surrounding the framework is that the ECB has not spelled out in detail the exact role of money in the inflation process and in the setting of interest rates. Indeed, the ECB has never provided a formal explanation for why it believes that money growth and prices are linked over time and, in particular, why it interprets this relationship as reflecting causation, rather than merely correlation. Furthermore, in discussing the role of money in its strategy and conduct of policy the ECB has tended to use terminology that is imprecise and difficult to define. For instance, it has emphasised the "medium-term" orientation of the framework and has repeatedly used the notion of a "monetary overhang" but has never given these concepts unambiguous definitions. Furthermore, it has argued that money growth has been disturbed by "special factors" without necessarily being too clear about whether they were of a once-off nature or could be expected to return.[9] Many observers have arguably interpreted this, rightly or wrongly, as the ECB having given the monetary pillar an extra degree of freedom by its choice of terminology.

For the ECB to overcome the scepticism that surrounds the monetary pillar, it needs to provide a clearer and more transparent explanation of the role of money in the inflation process than it has to date. This necessarily requires a formal, estimable

[8] See ECB Monthly Bulletin, January 1999, p. 49.

[9] Its description of its strategy as "stability oriented" (which could be interpreted as suggesting that other policy strategies are not) may also have been seen by some as an attempt to seize the rhetorical high ground.

model of the inflation process and the role of money in it. The existence of such a model would naturally shift the debate from the general level that characterises the exchange between the ECB and its critics today, to the concrete level at which economics is typically debated in the literature. Instead of arguing about whether the framework is "sensible", the debate would move to technical questions such as whether the model could be derived from first principles, how it should be estimated, whether the resulting estimates are stable over time, whether the empirical results provide support for the two-pillar model, and so on. It is precisely for this reason that central banks, in particular those with inflation targets, tend to make public the models they use to forecast inflation. Formalisation is helpful in that it makes it possible to pin down the exact nature of the disagreement(s) and the areas of agreement. Much of the progress that has been made in macroeconomic thinking in recent decades has resulted precisely because of the use of formal models and the debate they have generated.

In light of this, one would have expected the ECB to put forth a formal model of its framework. However, rather than doing so it has stated that:

> *"it has proven extremely difficult to integrate an active role for money in conventional real economy models ... despite the general consensus that inflation is ultimately a monetary phenomenon."*[10]

In discussing the two pillars, it has gone on to state that:

> *"it is not practically feasible to combine these two forms of analysis in a transparent manner in a single analytical approach."*[11]

While seemingly innocuous, these statements are thought provoking. Why, one may argue, did the ECB adopt a monetary policy framework that it has found difficult to rationalise using standard macroeconomic analysis? Isn't the fact that it is difficult to formalise the two pillars in a clear and transparent fashion a good reason to worry about, or even doubt, the usefulness of such a policy framework?

Given the need for a model of the ECB's two-pillar framework, seeking to formalise it should be high on the research agenda. This paper provides a first attempt to do so

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[10] See "The two pillars of the ECB's monetary policy strategy," ECB Monthly Bulletin, November 2000, pp. 37-48, in particular p. 45.

[11] Ibid. p. 46.

by proposing a simple ad hoc model of inflation in the euro area that incorporates money explicitly in the analysis. The model views inflation as depending on its expected future and past levels and the output gap. Money is introduced in the analysis by assuming that a moving average of money growth determines inflation expectations.

The paper is organised as follows. Section 2 contains a brief characterisation of the joint behaviour of inflation and money growth in the euro area. I show, as many others have, that these variables are closely correlated. In Section 3 I go on to present some evidence to the effect that (a measure of) money growth contained information for future inflation in the 1970-2003 period, even accounting for the information in past inflation and output gaps. Estimates for subperiods show that while money was informative for future inflation in the 1970-1986 period, the information content declined after 1987. Section 4 argues that the two-pillar framework must ultimately rely on a two-pillar view of inflation and goes on to propose a formal model of inflation that integrates money with a standard, although forward-looking, Phillips curve. Section 5 proceeds to estimate the model using data for the 1971-2003 period. Without going through the results in detail here, I argue that the model fits the data well. In Section 6 I provide estimates for two sub-samples. The first of these spans the high inflation period 1971-1991, and the second the low inflation period 1992-2003. Perhaps surprisingly, I find that the model fits well also in the latter sample period.

In Section 7 I conclude by turning to the central question whether the model and the broader literature on money growth and inflation provide support for a monetary pillar. I first argue that the evidence shows that money growth is about as useful for predicting future inflation in the euro area as the output gap. Consequently, I believe that it makes good sense for the ECB to monitor and seek to interpret monetary developments in much the same way as it assesses other indicators of price pressures, including the output gap. Next I turn to the question of the monetary pillar. I believe that while money is a useful indicator for future inflation pressures, all such indicators should be assessed in an integrated manner. To my mind, the main contribution of the paper is that it shows how monetary variables can be integrated with the "economic analysis" to provide a single, composite analysis of inflation pressures. Thus, I do not believe that the analysis lends support to the notion that a monetary pillar is necessary.

Five boxes complement the analysis in the main part of the paper. Box A summarises the analysis in the last report in the CEPR series on *Monitoring the ECB* (Galí et al. 2004) which provides a critical review of a number of arguments in support of the first pillar. Box B surveys research undertaken by the ECB on the information content of money growth for inflation. Box C provides some new results on the usefulness of money in forecasting future inflation in the euro area. Box D reviews how the role of money growth in the ECB's policy strategy was changed as a consequence of the review of the framework that was published in 2003. In Box E I derive the inflation equation I estimate.

2. Money growth and inflation: Empirical regularities

To motivate the subsequent analysis, it is useful to start by looking at the behaviour of inflation and money in the euro area. Graph 1 shows the evolution of CPI inflation and money growth since 1971. Following the practice of the ECB and most other central banks, both growth rates are computed over 4 quarters. The graph tells a familiar story: money growth and inflation were both high in the 1970, declined and reached a low around 1986, and then accelerated until 1991. Subsequently both decelerated before increasing somewhat towards the end of the sample.

The ECB views these correlations as reflecting the impact of money growth on future inflation. In the Monthly Bulletin of February 1999 (p. 39), it provides a graph of a eight-quarter moving average of four-quarter inflation and money growth, with money growth led six quarters, presumably because this captures the lag between movements in money and prices. Graph 2 provides an updated version of this plot, with the data starting already in 1972Q4 and ending in 2003Q1. To facilitate the comparison, the sample period used in the graph in the Monthly Bulletin is also indicated.

--- Graphs 1 – 2 ---

The graph shows a close relationship between the two series. However, that relationship was somewhat less close in the 1972-1983 and the 1999-2003 periods that were not included in the graph in the Monthly Bulletin.[12]

Of course, the quantity theory suggests that the relationship between money and inflation depends on output growth and on velocity. While the ECB has taken the view that velocity is declining at a broadly stable rate over time (see Brand, Gerdesmeier and Roffia 2002), income growth does fluctuate. Graph 3 therefore contains a plot of inflation together with the growth rate of M3 minus the growth rate of real GDP (in what follows, I refer to this as money growth adjusted for income growth or "adjusted money growth").[13] This graph shows that the relationship between inflation and adjusted money growth is perhaps even closer than the relationship between inflation and money growth. However, Graph 4, which is constructed in the same way as Graph 2, does not show any lag between adjusted money growth and inflation. This casts some doubt on the empirical regularity emphasised by the ECB in motivating the monetary pillar.

--- Graph 3 – 4 ---

Further evidence on the relationship between money growth and prices in euro area is provided by Gerlach (2003) who, following the spirit of the analysis by Cogley (2002), studies the behaviour of exponentially weighted moving averages of inflation and adjusted M3 growth. To see how these measures are constructed, let x_t denote the annualised quarterly growth rate of some series (below I use quarterly inflation, money growth and adjusted money growth for x_t). The smoothed measure, x^*_t, is then given by:[14]

(1) $$x^*_t = \lambda x_t + (1-\lambda) x^*_{t-1}.$$

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[12] No foul play is suggested: the data for the 1970s were almost surely constructed by the ECB considerably later.

[13] Alternatively, it could be thought of as the growth of money per unit output.

[14] Sargent (1979, ch. 11) studies a consumption function in which permanent income is determined according to this filter. He states that Muth (1960) shows that this filter is compatible with the assumptions about expectations formation made by Friedman (1956).

To simplify the discussion I refer below to x_t^* as "trend money growth", "adjusted trend money growth" or "trend inflation," depending on what series is smoothed. The "smoothing parameter", λ, plays a critical role in what follows in that $\ln(2)/\lambda$ captures the time it takes for a permanent one-unit change in x_t to lead to a 0.5 unit change in x_t^* (Cogley 2002, p. 103). For the moment I follow Gerlach (2003) and assume a "half-life" of 9.2 quarters ($\lambda = 0.075$); below I estimate the half-life directly.

Because of velocity shocks, there is no reason to expect a one-to-one relationship between trend inflation and money growth. To see more clearly the correlations between the variables, I therefore transform the data so that they have zero mean and unit variance. Graph 5 plots filtered inflation and M3 growth and Graph 6 plots filtered inflation and adjusted M3 growth. The graphs show a close relationship between trend inflation and money growth, in particular adjusted money growth.[15]

--- Graph 5 – 6 ---

Overall, these graphs demonstrate that there is a tight link between money and inflation in the euro area. While informal time series plots such as those above are one reason why the ECB believes that the two-pillar framework is appropriate, it is important to recognise, as emphasised by Galí (2003), that the relationship between money growth and inflation arises from the existence of a money demand relationship irrespectively of the monetary policy strategy followed by the central bank. In order to conclude that a two-pillar framework is warranted one must establish that its use generates smaller fluctuations in inflation and output than alternative policy strategies.

3. Money and prices: Reduced-form evidence

Next I characterise the relationship between money growth and inflation somewhat more formally. While the graphs reviewed above suggest that different measures of money growth are correlated with future inflation and therefore may contain information useful in judging "*risks to price stability*", they do by no means provide any firm evidence to that effect. For money to be a useful information variable, it

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[15] Lucas (1980) discusses how filtering can be used to clarify the relationship between inflation and money growth.

must be that it contains information that is not already embedded in past inflation rates or other traditional indicator variables, in particular measures of the output gap. While a large body of research (which is surveyed in Box B) conducted by the ECB has demonstrated that money growth does indeed contain such information, below I explore whether the measure of trend money growth discussed above and studied by Gerlach (2003) is helpful of predicting future changes inflation (in the sample studied).

My approach is similar to that of Cogley (2002), who uses (what I call) trend inflation as a measure of core inflation and asks whether the discrepancy between headline and trend inflation is useful for predicting future changes in headline inflation. More formally, Cogley explores whether the change in headline inflation over the coming j quarters, $\pi_{t+j} - \pi_t$, is predictable on the basis of the current spread between trend and headline inflation, $\pi_t^* - \pi_t$. He also generalises this approach by asking how these results change if other variables are included in the analysis. I follow Cogley by incorporating trend money growth and the output gap, g_t, in the analysis by estimating the reduced-form equation:[16]

(2) $$\pi_{t+j} - \pi_t = \phi_0 + \phi_\pi(\pi_t^* - \pi_t) + \phi_g g_t + \phi_m(\mu_t^* - \pi_t^*) + \xi_t$$

and study whether the spread between current trend money growth and trend inflation ($\mu_t^* - \pi_t^*$) is statistically significant and how it contributes to the explanatory power of the regression.

Before turning to the results three comments are in order. First, I focus on the wedge between trend money growth and trend inflation since it plays an important role in the analysis below and since its information content has not previously been studied. Of course, other measures of money, in particular "headline" money growth, could also be used. Second, this is a reduced-form relationship. Woodford (1994) demonstrates that the usefulness of an information variable (in my case money growth) for forecasting a target variable (in my case inflation) depends on the policy regime in

[16] The output gaps used in this paper are constructed using the HP-filter. It would be interesting, but beyond the scope of the current study, to compare to what extent the estimates depend on the choice of

force. Woodford's argument implies that the correlation between money growth and inflation can be zero even if money is a structural determinant of inflation. Thus, a finding that money growth does not contain information about future inflation does not necessarily imply that money growth is irrelevant, from a structural perspective, for price formation. Moreover, the information content of money may shift over time in response to shifts in the policy regime. Third, econometric work on the usefulness of information variables is inherently subject to the critique that the results are only valid in the estimation period. Moreover, since I am interested in whether a proposed information variable is operational at monetary-policy relevant time horizons, say one to three years ahead, one needs at least a sample several times longer than that to assess the information content. This makes it difficult to formally explore the hypothesis that money has lost its significance since the establishment of the ECB.

Box C contains a detailed discussion of how I estimate equation (2) and the main results. For my purposes, the most important findings are:

- Trend money growth (relative to trend inflation) does generally contain information about future changes in headline inflation. The exact information content depends on the choice of time horizon (2, 4, 8 and 12 quarters) and sample periods studied (1970-2003, 1970-1986 and 1987-2003). In particular, while money growth helps predict future inflation for all time horizons in the pre-1987 and the full sample, it appears only significant at the 2 and 4 quarter horizons in the post-1986 sample.

- The information in money growth is not already embodied in the output gap and the wedge between headline and trend inflation.

- The information in the output gap appears to have gained importance over time, and is about as significant as money growth in the post-1986 sample, but much less significant in the pre-1987 sample.

These findings are important in that they provide a formal indication of the information monetary data contain for future inflation. Furthermore and more

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measure for the output gap. Gerlach and Smets (1999) estimate the output gap in the euro area using Kalman filtering and argue that the estimates are superior to the type of measure used here.

significantly, they help explain why the ECB adopted a monetary pillar. I believe that this is largely due to three factors.

First, economic theory was seen by the ECB as establishing beyond doubt that high and protracted inflation is due to excessive money growth. Second, the broad empirical evidence for the euro area and other economies was interpreted as indicating that movements in money growth have historically been correlated with subsequent changes in inflation. Insufficient attention was arguably paid to the fact that the episode of high and volatile money growth and inflation in the 1970s and the first half of the 1980s may largely account for the correlation between money growth and inflation, and, furthermore, to the likelihood that it depends on policy. Third, the ECB wanted to adopt a framework similar to that of the Bundesbank, which was widely seen as the most successful central bank in the countries joining EMU, in the hope of being able to appeal to its track record.

4. A Two-Pillar Phillips Curve

In this section I present my interpretation of the ECB's monetary policy strategy. I start from the hypothesis that the strategy must be based on, at least implicitly, a two-pillar view of inflation. The task I face therefore is to construct an inflation equation in which money plays an integral and non-trivial role.

As a first step, it is useful to clarify the main considerations that in my view underpin the ECB's view of the inflation process. This is difficult because the importance the ECB has attached to money has evolved over time. In particular, the review of the monetary policy framework which the ECB announced in 2002 and which was completed in 2003 led to a reassessment of the role and importance of money (this is discussed in greater detail in Box D). Despite this, I believe that the ECB's view is based on the following three propositions:

1. Monetary policy impacts on inflation with a lag. It is therefore important to give monetary policy a "medium-term orientation" and to forecast inflation at the time horizon relevant for monetary policy.

2. Inflation depends on many factors. In the short run, it is largely influenced by cost variables (in particular energy prices and wages), import and food prices, taxes and changes in administratively set prices. In the long run, however, it is

determined solely by monetary factors. In the time horizon relevant for monetary policy, both sets of factors play a role and the central bank therefore faces a non-trivial forecasting problem.

3. To understand inflation at the medium-term time horizon, it is helpful to decompose inflation into two components or pillars. The first pillar is intended to capture the monetary factors that contain information about the long-run evolution of the price level. The second pillar is intended to reflect the factors that generate short-run movements in inflation.

Overall, this analysis suggests that the important conceptual difference between the pillars concerns the time horizon that they apply to. This interpretation seems compatible with the ECB's own statements. In particular, in discussing the outcome of its widely noted review of the framework, it writes:

> *"The two pillars are: economic analysis to identify short- to medium-term risks to price stability; and monetary analysis to assess medium to long-term trends in inflation, given the close relationship between money and prices over extended horizons."*[17]

It goes on to state that:

> *"The inflation process can be broadly decomposed into two components, one associated with the interplay between demand and supply factors at a high frequency, and the other connected to more drawn-out and persistent trend … . The latter component is empirically closely associated with the medium-term trend growth of money."*[18]

In an overview article directed to the scholarly community the ECB (2003, p. 18) writes about the two pillars that (underlining in the original):

> *"One aspect of this approach relates to <u>the different time perspectives</u> relevant to the analysis under the two pillars. This builds on the well-documented findings that long-term price movements are driven by trend money growth, while higher frequency inflation developments appear to reflect the interplay between supply and demand conditions at shorter horizons. Against this background, the broadly based economic analysis gives higher-frequency indications for policy decisions based on the assessment of non-monetary shocks to price developments and the likely*

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[17] See "The outcome of the ECB's evaluation of its monetary policy strategy," ECB Monthly Bulletin June 2003, pp. 79-92, in particular p. 79.

[18] Ibid, p. 87. See also Box 2 on p. 90.

evolution of prices over short to medium-term horizons. Monetary analysis and indices of monetary imbalances, on the other hand, provide information against which these indications can be evaluated and the stance of policy can be cross-checked from a longer-term perspective.” [19]

Thus, there can be little doubt that the main difference between the two pillars pertains to the time horizon they are supposed to be relevant for. Next I propose a model of inflation that combines monetary and non-monetary factors in this spirit.

4.1 A simple theoretical model

It is useful to start by defining the variables that are used in the analysis below. Let π_t denote the annualised rate of inflation between time periods t-1 and t, μ_t and $\tilde{\mu}_t$ the similarly measured rates of growth of M3 and adjusted M3, g_t the output gap, ε_t a regression error and let the superscript “ ^{e} ” denote an expected value.[20] Furthermore, let μ_t^*, $\tilde{\mu}_t^*$ and π_t^* denote trend money growth, adjusted trend money growth and trend inflation.

Consider next a standard Phillips-curve inflation equation of the form:

$$\pi_t = \alpha_f \pi_{t+1}^e + \alpha_b \pi_{t-1} + \alpha_g g_{t-1} + \varepsilon_t \, . \tag{3}$$

Equation (3) states that current inflation is determined by expected future inflation, past inflation and the once-lagged output gap. Since the output gap is unobserved, estimates thereof need to be constructed. Below I use the same measure of the gap as in Section 3. Note also that, empirically, there is typically a time lag between movements in the output gap and movements in inflation. Here I assume that that lag is one period.

An important aspect of this equation concerns the relative weight of past and expected future inflation in the determination of inflation. While theory suggests that expectations should play a dominant role (in the sense that $\alpha_f \approx 1$), a number of studies from a range of economies indicate that past inflation may be more important.

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[19] Interestingly, on the same page the ECB writes “*The medium to long-term focus of the monetary analysis implies that there is no direct link between short-term monetary developments and monetary policy decisions*.”

[20] For clarity, inflation is thus measured as $4\times\log(p_t/p_{t-1})$.

It is therefore of interest to test the hypotheses that the weights on the forward and backward-looking elements sum to unity ($\alpha_f + \alpha_b = 1$), that inflation is fully backward looking ($\alpha_f = 0$ and $\alpha_b = 1$) and that it is fully forward looking ($\alpha_f = 1$ and $\alpha_b = 0$).

To estimate the Phillips curve in equation (3), the treatment of expected future inflation needs to be determined. If money growth ultimately leads to more inflation, then it would also influence inflation expectations. In fact, the ECB (2001, p. 42) has noted that one way in which money growth impacts on inflation is through induced movements in expected inflation:[21]

> *"High money growth may also directly influence inflationary expectations and therefore also price developments. Similarly, low monetary growth may lead to deflationary expectations and price developments."*

I therefore assume that trend money growth, as captured by μ_t^*, determines inflation expectations (disregarding a constant):

$$\pi_{t+1}^e = \mu_{t-1}^*, \tag{4}$$

where μ_t^* evolves over time according to equation (1). This specification warrants several comments. First, it gives rise to a direct channel from money to prices. Nelson (2003) argues that monetarist models hold that changes in money growth impact on prices *indirectly* through the level of aggregate demand and the output gap, and therefore do not require such a direct effect. By contrast, Galí (2003) appears to view such a direct mechanism an important precondition for the use of the first pillar.

Second, while the notion that money growth affects inflation expectations may capture the spirit of the ECB's views of the role of money in the inflation process, as suggested by the quote above, this assumption is arbitrary and may be difficult to motivate. However, it is important to note that the standard approach to modelling inflation expectations, that is to replace expected inflation by actual inflation and estimate the equation using statistical techniques appropriate for the resulting errors-in-variables problem as originally suggested by McCallum (1976), is also subject to

[21] Interestingly, this passage has been deleted in the second edition of this volume (ECB 2004).

important problems.[22] It is from this perspective interesting that several recent studies have modelled inflation using survey measures of expected inflation.[23] It is therefore of interest to consider competing measures of expected inflation in the euro area.

Third, while I interpret the ECB as believing that inflation expectations depend on current and past nominal money growth (as captured by trend money growth, μ_t^*), below I explore two other specifications. Since the quantity theory suggests that inflation is determined by the difference between money and real income growth, I also estimate the model using adjusted trend money growth ($\tilde{\mu}_t^*$). Finally, since recent inflation is just as likely, if not more, to be informative about future inflation, I also explore how well the model fits when trend inflation (π_t^*) is used to model inflation expectations. I show below that, perhaps surprisingly, this does not work as well.

Fourth, since trend inflation, π_t^*, depends on current inflation by construction, I lag it once to use it as a regressor in the inflation equation.[24] To ensure comparability with the other specifications, I therefore model expected inflation as depending on x_{t-1}^* rather than x_t^*. This assumption does not appear to have any material impact on the econometric results presented below.

4.2 The Two-Pillar Phillips curve

Using equations (1), (3) and (4) and assuming for the moment that trend money growth determines inflation expectations, Box E shows how I obtain the following inflation equation, which I refer to as the "Two-Pillar Phillips Curve" (TPPC). It integrates monetary factors into a standard Phillips curve equation and constitutes my

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[22] In applied work, this approach is implemented by assuming that the expectation errors are uncorrelated with the regressors, which are used as instruments. If the regressors involve variables that are not instantaneously observed (such as the output gap or recent inflation rates), this assumption leads to inconsistent estimates. While in principle this problem can be overcome, in practice the information lags are unknown. Furthermore, this approach is silent on what factors determine inflation expectations. This modelling approach is thus also subject to arbitrary assumptions.

[23] Adam and Padula (2003) study the determination of inflation in the euro area and Roberts (1997 and 1998) investigate US data. Paloviita (2003) estimates forward-looking inflation equations on euro-area data, proxying expected inflation by OECD forecasts.

[24] The reason for doing so is that otherwise I would regress inflation on, among other things, a variable that by construction is correlated with inflation. Lagging trend inflation once solves this problem.

proposed interpretation of the ECB's view of the inflation process. The TPPC can be written:

$$\pi_t = \beta_1\mu_{t-1} + \beta_2 g_{t-1} + \beta_3\pi_{t-1} + \beta_4 g_{t-2} + \beta_5\pi_{t-2} + e_t, \quad (5)$$

where $\beta_1 = \alpha_f\lambda$, $\beta_2 = \alpha_g$, $\beta_3 = (1-\lambda+\alpha_b)$, $\beta_4 = -(1-\lambda)\alpha_g$, $\beta_5 = -(1-\lambda)\alpha_b$ and $e_t = \varepsilon_t - (1-\lambda)\varepsilon_{t-1}$. While this equation is more complicated than traditional Phillips curves, it has a straightforward interpretation.

First, nominal money growth, my proposed short cut for the first pillar, enters because it influences trend money growth which in turn impacts on inflation expectations. The impact of money growth depends on the "smoothing parameter", λ, which captures how rapidly expectations change when money growth changes, and the extent to which inflation is forward looking, α_f. Note that only in the case in which $\alpha_f = \lambda =$ 1 is there a one-to-one relationship between (past) money growth and inflation.

Second, inflation depends on the output gap as in a standard Phillips curve. Here the output gap should be thought of as a short-cut for the many factors that enter in the second pillar or, alternatively, in the "economic" analysis of inflation. Needless to say, it would be desirable to incorporate other elements capturing cost-push factors such as import and energy prices, changes in value added taxes and so on. However, this is difficult to do given the lack of long time series for the relevant data. Thus, these factors are all absorbed in the error term.

Third, once-lagged inflation enters the equation for two reasons. Past inflation matters in the standard Phillips curve given by equation (3). The importance of this factor is depends on α_b. Furthermore, past inflation captures the importance of μ^*_{t-1}, which plays a role in determining μ^*_t as evidenced by the term (1-λ).

Fourth, the output gap and inflation at time t-2 enter in the inflation equation, provided that the expected rate of inflation depends also on past, rather than only current, money growth (that is, $\lambda < 1$). Thus, these variables appear solely because of the assumed expectations-formation process, rather than because they impact on inflation directly through the Phillips-curve relationship. To see this most clearly, note that both parameters are negative. Note also that the twice-lagged output gap and inflation do not enter the equation if $\lambda = 1$, in which case expected future inflation is given by μ_{t-1}.

Fifth, the error term follows a moving-average structure, with an MA(1) coefficient that depends on λ. Of course, this results from the assumption that the ε_t-errors are serially uncorrelated, which need not be the case. This issue is discussed further below.

4.3 Summary

Before turning to the empirical results, it is useful to review briefly the progress so far. I assume a Phillips curve in which current inflation depends on expected future and past inflation and on the output gap, which I interpret as capturing the "second pillar." The first pillar is captured by the assumption that expected future inflation depends on trend money growth, which I model as a simple exponential average of past (adjusted) money growth with an unknown smoothing parameter. As a result of this specification, I find that the twice-lagged output gap and inflation should enter the TTPC with, critically, negative signs.

5. Fitting the data

Next I estimate the TPPC. It is important to note that this equation is "structural" in the sense that the five β_i-parameters in equation (5) depend on the underlying coefficients $(\alpha_f, \alpha_g, \alpha_b, \lambda)$. To fit the model thus entails estimating these latter parameters rather than the β_i's.

5.1 Unrestricted estimates

I first estimate the reduced-form equation (5) (allowing for an intercept). This will provide an informal assessment of the adequacy of the model. The estimation period spans 1971Q1-2003Q1.

--- Table 1 ---

In the first column of Table 1 I show the results when expectations are assumed to be driven by money growth and in the second column the results when expectations depend on adjusted money growth.[25] Since the results are quite similar, in the interest of brevity I do not comment on the differences in detail.

Several aspects of the results are noteworthy. First, the parameter on the twice-lagged inflation rate is small and insignificant. This suggests that inflation may not be very backward-looking, that is, α_b may be close to zero. Second, to the extent that this implies that inflation is essentially forward-looking (in the sense that α_f is close to unity), then the parameter on actual or adjusted money growth would provide an estimate of λ. That estimate is between 0.09 and 0.12, that is, somewhat higher than assumed by Gerlach (2003). Third, both the once- and twice-lagged output gaps are significant and have opposite signs, as the model suggests. A further estimate of the smoothing coefficient is provided by the ratio $\beta_4 / \beta_2 + 1$, which implies that λ is 0.20 in the case of adjusted money growth and 0.34 in the case of money growth. Fourth, the moving-average parameter, which theory suggests is given by –(1-λ), is just below 0.5, implying that the smoothing parameter is just above 0.5.

One reason for the high estimates of the smoothing parameter is that the assumption that ε_t is serially uncorrelated may be wrong. Indeed, as suggested by inspection of Graph 7, quarterly changes of inflation display large negative first-order autocorrelation (the correlation coefficient is –0.33). This may be related to the way in which the price data is constructed or deseasonalised. I will therefore not impose the theoretical restriction that the moving average coefficient equals –(1-λ), but rather estimate it as a free parameter, ρ.

--- Graph 7 ---

5.2 Restricted Estimates

Next I estimate the inflation equation:[26]

(4) $$\pi_t = \beta_0 + \beta_1 \mu_{t-1} + \beta_2 g_{t-1} + \beta_3 \pi_{t-1} + \beta_4 g_{t-2} + \beta_5 \pi_{t-2} + e_t$$

[25] It is not possible to interpret the estimated parameters when inflation expectations are determined by trend inflation and I therefore focus on these two cases.

[26] The estimates are restricted in the sense that I estimate the α's and λ rather the β's.

where I have included an intercept, $\beta_1 = \alpha_f \lambda$, $\beta_2 = \alpha_g$, $\beta_3 = (1 - \lambda + \alpha_b)$, $\beta_4 = -(1-\lambda)\alpha_g$, $\beta_5 = -(1-\lambda)\alpha_b$ and where, for the reasons discussed, I assume that $e_t = \varepsilon_t - \rho\varepsilon_{t-1}$.[27]

--- Table 2 ---

Table 2 provides estimates for the sample period 1971Q1-2003Q1. For the time being, I do not impose any additional restrictions on the degree to which expectations are forward or backward looking. The estimates in the first column, where I assume that money growth drives expected inflation, are quite encouraging. The smoothing parameter is highly significant and estimated to be 0.089, which is close to the 0.075 value assumed by Gerlach (2003) and which implies a half-life of 7.8 quarters. The estimation suggests that inflation is fully forward-looking (since α_f is close to unity and is statistically significant). In turn, this implies that the weight on past inflation should be small as indeed it is (α_b= 0.03 and highly insignificant). The parameter on the output gap, α_g, is 0.55 and significant. Finally, the moving-average parameter, ρ, is 0.45 and statistically significantly different from the value I would expect if the model was correct ($1-\hat{\lambda}$). There is in this sense some as evidence against the model.

In column 2 I consider the case in which expected future inflation is determined by adjusted money growth. The results are broadly similar to those just reviewed, with three differences. First, the point estimate of the smoothing parameter is larger, 0.13, implying a faster impact of money growth on expected inflation (half-life of 5.5 quarters). Second, the estimated impact of the output gap is 1.11 rather than 0.55. The reason for this is that adjusted trend money growth (which contains a moving average of past quarterly changes in income) and the output gap are negatively correlated. Third, the log likelihood is higher than before, implying that the model fits the data better when adjusted money growth is used as an explanatory variable for expected inflation.

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[27] To do so, I write equation (4) in state-space form and use the Kalman filter to evaluate the likelihood function.

As noted above, the most natural counter-argument to the notion that money is important in judging future price pressures is that any information that is contained in observations on recent money growth rates must surely already be embedded in recent inflation rates. If so, rather than focus on recent and past money growth rates in assessing the "*risk to price stability*", it would make much better sense to concentrate on recent inflation rates. To assess this argument, I also consider the case in which expected future inflation is modelled as depending on trend inflation. The results, in column 3 of Table 2, are surprising. While most parameter estimates are similar to those obtained when inflation expectations are modelled as being tied to the growth rates of money or adjusted money, the fit of the model is clearly worse as evidenced by the sharp decline in the value of the likelihood function. The second major difference is the smoothing parameter is much larger, 0.22, implying a half-life of 3.2 quarters.

5.4 Summary

In this section I have confronted the model for inflation arising from my proposed interpretation of the ECB's monetary pillar with the data over the period 1971Q1-2003Q1. While preliminary, these results are moderately encouraging in that the parameters are significant and take plausible values. The estimates of α_b, which captures the extent to which inflation is backward looking, are particularly interesting. In contrast to what one would expect from the literature, this parameter is numerically close to zero and statistically insignificant.

Next I therefore refine the empirical work in two dimensions. First, I estimate the model for two sub-periods. I do so because it may be that while money growth played an important role in the high-inflation period in the 1970s and early 1980s, it lost its significance in the low-inflation environment of the 1990s. Gerlach (2003) presents evidence that suggests that the relationship between money growth and inflation in the euro area differed before and after 1992. The first subsample is the "high" inflation period between 1971Q1 and 1991Q4, during which inflation averaged 7.1% per annum. The second is the low inflation period 1992Q1-2003Q1, in which annual inflation averaged 2.3%.

The second refinement is that I investigate more closely some of the theoretical restrictions of the model. For instance, can I reject the hypothesis that $\alpha_f + \alpha_b = 1$? Can I reject that inflation is entirely forward looking, that is, $\alpha_f = 1$ and $\alpha_b = 0$?

6. Subsample estimates

6.1 Inflation in the euro area before 1992

In Table 3 I re-estimate the model on data ending in 1991Q4, assuming that nominal money growth determines inflation expectations. Column 1 shows the results when I do not impose the restriction on the moving-average parameter that $\rho = 1 - \lambda$. Interestingly, in this case I can not reject this restriction and I therefore impose it. The results in column 2 indicate that the sum of the forward- and backward-looking components is marginally above unity, but not significantly so. I therefore introduce this restriction as well (column 3). However, in this case λ is not significantly different from zero. While the degree to which inflation is forward-looking is only about 0.27, I impose the restriction that inflation is fully forward-looking, which leads to a sharp fall in the likelihood function. Overall, I therefore conclude that the theoretical model fits the data quite well in the first sub-sample when inflation expectations are modelled as depending on money growth and if inflation is assumed to be part forward, part backward looking.

--- Table 3 ---

Next I turn to the case in which inflation expectations are modelled as determined by adjusted money growth. Interestingly, the results in Table 4 indicate that the model in this case fits the data better as evidenced by the uniform increase in the value of the likelihood function. The value of the smoothing parameter is also consistently higher than in Table 3 (around 0.2 rather than 0.1), indicating a shorter half-life, and is more significant. As in case of Table 3, the point estimates in column 1 suggest that I can impose the restriction that $\rho = 1 - \lambda$, which I do in column 2. In column 3 I also impose the restriction that the sum of the weights on expected future inflation and past inflation is unity. This results in an estimate of the degree to which inflation is forward-looking of 0.36, which is somewhat higher than in Table 3. Finally, I restrict inflation to be fully forward looking, which again leads to a large fall in the value of the likelihood function.

--- Table 4 ---

In Table 5 I consider the case in which inflation expectations are assumed to depend on trend inflation. The results are generally similar to those in Table 3, except that the fit of the equation is worse than before, as evidenced by the value of likelihood function. In particular, the results in column 1 suggest that the smoothing parameter is insignificant and I therefore impose the restriction that $\rho = 1 - \lambda$. The value of the likelihood function is essentially unaffected (column 2). Since the sum of the weights on expected and realised inflation is close to unity, I impose the restriction that $\alpha_b + \alpha_f = 1$. While the value of the likelihood function in this case rises somewhat, the parameter estimates are largely unchanged, except for the smoothing parameter, which falls in size but becomes significant. Interestingly, the degree to which inflation is forward looking is in this case estimated to about 0.43, which is significantly different from unity. Not surprisingly, imposing the restriction that $\alpha_f = 1$ and $\alpha_b = 0$ (column 4) leads to a deterioration of the fit.

--- Table 5 ---

In sum, the results for the first sample period indicate that the model fits relatively well although inflation expectations appear largely backward looking.[28] Furthermore, the model typically fits worse when expected inflation is assumed to depend on trend inflation rather than either of the measures of trend money growth.

6.2 Inflation in the euro area after 1991

Next I turn to the results for the post-1991 period. The results for this sample period are inherently more interesting than the results for the 1971-1991 period for the simple reason that even the ECB's most vocal critics would probably be willing to accept that money was useful for forecasting and assessing inflation in the high

[28] One reason for this may be that since money demand depends inversely on the inflation rate, the decline in inflation in the first subsample raised the demand for money and led to a situation in which money growth (and therefore my proposed measure of expected inflation) exceeded headline inflation. Of course, this highlights one difficulty in extracting information from money growth.

inflation era. The point of contention is rather whether money is useful in the current low-inflation environment.[29]

In Table 6 I therefore redo the analysis of Table 3, using data for the period 1992Q1 - 2003Q1. Since the results are similar to those above, I review them quite quickly. Note first that $\rho \approx 1-\lambda$, which implies that the degree of autocorrelation in the residuals is compatible with the model, and that $\alpha_f + \alpha_b \approx 1$. Imposing these restrictions yields the model in column 3, for which I do not reject that $\alpha_b = 0$ and $\alpha_f = 1$. I therefore also impose these restrictions and obtain the model in column 4 in which all parameters are highly significant. The smoothing parameter is estimated to be 0.086, implying a half-life of 8.1 quarters.

--- Table 6 ---

Note that while the model in column 1 involves 7 parameters, the model in column 4 involves only 4. I can thus test whether the restrictions imposed by the simple theoretical model are rejected, but find that they are not.[30] This implies that the notions that inflation is fully forward looking and that the expectations-formation mechanism is the only source of the serial correlation in the errors are compatible with the data. Furthermore, I can also use the models estimated for the sub-periods to test for parameter constancy before and after 1991/92. In this case, however, I reject the hypothesis.[31] The main reason for this appears to be that inflation is more forward looking in the second subsample.

Before turning to the issue what these results imply, if anything, for the two-pillar framework, I redo the analysis for the case in which expected inflation is modelled as depending on adjusted trend money growth (Table 7) and trend inflation (Table 8).

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[29] See the discussion in Begg et al. (2002), in particular Box 2, p. 21.

[30] The p-value from a likelihood ratio test is 0.482.

[31] Focussing on the model in column 1, note that the value of the likelihood function when estimated over the full sample is (from Table 2) is 403.631. The likelihoods for the sub-samples are 261.118 (from Table 4) and 155.503 (Table 6), or 416.621 in total. Thus, the likelihood increases by 12.990 when I estimate the model twice, that is, when I estimate 14 rather then 7 parameters. A chi-squared test with 7 degrees of freedom yields a p-value of zero, implying that I reject the hypothesis that the parameters are the same in the two samples.

Since these estimates are very similar, in the interest of brevity I merely highlight the most interesting points.

--- Tables 7 and 8 ---

First, judging by the values of the likelihood functions, it appears that model fits best when nominal money growth is used, marginally less well when adjusted money growth is used, and much worse when trend inflation is used to model expected inflation.

Second, the estimate of α_g is much larger in the case when adjusted rather than actual money growth is used. Again, this result arises because of the correlation between the output gap and $\tilde{\mu}_t$.

Third, the restrictions imposed by the model in column 4 on that in column 1 are not rejected for the case of adjusted money growth, but are rejected in the case in which trend inflation is used to capture inflation expectations.[32]

6.3 Stability 1991-2003

The results so far show that the parameters are typically significant and of plausible magnitude. However, the hypothesis that the parameters are the same in the pre- and post-1991 sample is rejected, most likely because the extent to which inflation is forward-looking has increased over time. Since a number of authors have argued that the information content of money is likely to be lower at lower average rates of inflation, it is of particular interest to investigate more closely the stability of the inflation equation in the 1991-2003 period.[33] I do so by presenting recursive estimates of the model. In the interest of brevity, I focus on the model in which expected inflation is driven by trend money growth since that appears to fit the data best. Furthermore, since the model is estimated by maximising the likelihood function, convergence problems may arise if I estimate versions of the model containing insignificant parameters. I therefore consider the relatively restricted version of the

[32] The p-values are 0.305 and 0.048, respectively.

[33] Gerlach (1995) demonstrates that the relationship between inflation and money growth is weaker for economies with low money growth and low inflation. De Grauwe and Polan (2001) show this more forcefully. See also De Grauwe (2002) and Begg et al. (2002).

model in column (4) in which $\alpha_f = 1$, $\alpha_b = 0$ and $\rho = 1 - \lambda$. That gives me four parameters to estimate: the degree of smoothing (λ), the impact of the output gap on inflation (α_g), a constant and the variance of the errors. For space reasons, I only plot the recursive estimates of the first two parameters that are the most interesting. These are obtained by initialising the model on data for the period 1987Q1-1991Q1 and then expanding the sample period by adding one observation at a time.

--- Graph 8 and 9 ---

Graph 8 shows the results for the smoothing parameter together with 95% confidence bands. While the confidence band becomes narrower as observations are added, the point estimate remains relatively constant. Overall, the graph suggests that the smoothing parameter is stable in the 1991-2003 period. While the results for the coefficient of the output gap in Graph 9 also support the notion that the parameter is stable, the point estimate is rising modestly as the sample size is expanded. More interestingly, the parameter is only significant for samples ending in 2001 or later. I interpret these results as suggesting that it is difficult to find a strong link between inflation and the output gap in short samples.

6.4 Interpretation

The estimates for the period 1991-2003 give rise to a simple Phillips curve. To see this, note that the model performs best when inflation expectations are modelled as depending on trend money growth and that I do not reject the hypothesis that inflation is fully forward-looking. Using equations (3) and (4), this implies that the Phillips curve can be written as (omitting a constant):

(3')
$$\pi_t = \mu^*_{t-1} + \alpha_g g_{t-1} + e_t .$$

This TPPC says that inflation at any point in time depends on the two pillars. First, inflation depends on trend money growth, the first pillar, with a unit coefficient. Changes in trend money growth, which evolves gradually over time, thus explain gradual changes in the level of inflation over time. However, and as discussed by Nelson (2003), in empirical work on inflation dynamics the determination of steady state inflation is typically downplayed. Thus, in empirical research on "old-Keynesian" or New-Keynesian Phillips curves, authors assume that the steady-state rate of inflation is constant and capture this through an intercept (see Galí and Gertler 1999) or by first removing a time trend from inflation (see Coenen and Wieland 2003).[34] Gerlach and Svensson (2003) instead capture trend shifts in inflation in the euro area by assuming that they arise from movements in central banks' inflation objectives. The analysis in this paper suggests that while money may not be useful for explaining movements of inflation *around the steady state*, it is helpful for understanding *changes over time in the steady state*.

Second, inflation also depends on the output gap, which should be understood as a catch-all for the economic analysis of the second pillar. As noted above, it would be desirable to incorporate proxies for other shocks that impact on prices. As the model currently stands, these influences are subsumed in the errors.

6.5 Expected inflation

Before concluding this section, I return to the critical assumption of the model proposed above that trend money growth determines expected inflation. This assumption is non-standard and is therefore likely to be controversial. It is therefore desirable to explore how plausible it is. While this is difficult to do in the absence of good data on inflation expectations, next I compute the expected rate of inflation implied in the estimates of equation (3') in the 1992-2003 period and compare that with two data sets on expected inflation in the euro area. The first of these is that used by Paloviita (2003), which is derived from OECD forecasts, published in December for the following, for the economies constituting the euro area. Unfortunately, this measure pertains to the private consumption deflator rather than to the CPI. Moreover, the data are annual rather than quarterly. The second measure stems from forecasts by Consensus Economics for inflation one to ten years ahead in some of the economies constituting the euro area. These forecasts are published in April and October. One problem with this measure is that it is based solely on data for Germany, Italy and France before 1995, when data for the Netherlands and Spain are added. This measure is consequently not necessarily representative of the overall euro area.

[34] One reason for this approach is that, for statistical reasons, it is desirable to focus on time series that fluctuate around a fixed mean (that is, are stationary) rather than time series that appear to trend over time.

Graph 10 shows the quarterly rate of inflation together with the expected rate of inflation from my model and from Paloviita (2003). Note that trend money growth and expected inflation both decelerate between 1992 and 1997, remain roughly constant for a few years, and start to accelerate towards the end of the sample, and that Paloviita's measure of expected inflation evolves in much the same way over time as the model-dependent measure. In Graph 11 I replace Paloviita's measure with that arising from forecasts from Consensus Economics. While that variable evolves over time in the same way as actual and (the model-dependent measure of) expected inflation, it is systematically below these in the first part of the sample. This is probably due to the fact that Consensus Economics does not forecast inflation in all economies in the euro area so that the resulting measure of expected inflation is not fully representative.

Overall I interpret these graphs as suggesting that the estimate of expected inflation implied by the model is plausible.

6.6 Summary of the empirical results

The empirical analysis presented above shows that it is in fact possible, contrary to the ECB's claim, to integrate money in an explicit model of inflation, which furthermore seems to account quite well for inflation in the euro area. In particular, the restricted models provide a good description of inflation. In sum, I believe that the TPPC provides a plausible interpretation of the ECB's two-pillar framework and that it fits the data no worse than many other ad hoc models of inflation.

An interesting aspect of the results is that the empirical models fit the data better if expected inflation is assumed to depend on actual or adjusted money growth rather than past inflation. This suggests that money does in fact contain information about future inflation in the euro area beyond that contained in the output gap and past inflation.

Turning to the sub-sample estimates, it appears that the model fits better when estimated on data for the low inflation period after 1991 than on data from the 1970s and 80s. This finding calls into question the claim in the literature that the linkages between money and inflation are statistically less clear at low inflation rates.

7. Conclusions

What, then, do I conclude from the analysis above regarding the desirability of the monetary pillar? To answer this question, it seems useful to proceed by first asking whether money should be an indicator and, if so, whether it should have its own pillar.

7.1 Money as an indicator

Does money growth contain information about the future rate of inflation in the euro area? Economists at the ECB and elsewhere have presented evidence that consistently suggests that there is a stable relationship between money growth and inflation in the euro area and that money growth does contain information useful in forecasting future inflation (see Box B). Moreover, Gerlach and Svensson (2003) estimate an inflation equation for the euro area that incorporates money explicitly into the analysis and find that money plays about as important a role for future inflation as the output gap. My interpretation of the broad statistical evidence is that it is difficult to deny that money growth appears to contain information about future inflation in the euro area.[35]

Of course, that conclusion could be challenged by noting that while this has been true in the past, there is no reason to assume that it will remain true also in the future. The information content of money depends on the relative importance of the different shocks that are hitting the economy. These may vary over time. For instance, money may be more informative about future prices during episodes in which it is growing quickly and subject to large supply disturbances, leading to high and volatile inflation, than in episodes characterised by low and stable inflation such as that the euro area is experiencing currently.[36] Begg et al. (2002), relying on work by De Grauwe and Grimaldi (2001) and De Grauwe and Polan (2001), argue that the correlation between money growth and inflation is low when average inflation rates are low. However, Issing et al. (2001, p. 13) present evidence that the correlation between money growth and inflation appears high also in low inflation environments, defined as periods with an average inflation rate of below 20%.

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[35] I thus do not share the sentiment in Galí (2003, p. 58) that *"… the existing evidence even seems to question the 'information content' of monetary aggregates."*

[36] Sargent (1982) contains a by now classic analysis how changes in the process driving money growth impact on inflation.

While undoubtedly valid, the critique that money growth may be an unreliable indicator of future inflation because it depends on the relative importance of the shocks impinging on the economy applies with equal force to other commonly used indicator variables.[37] For instance, the information content of the output gap (which suffers from the additional complication that it is unobservable and needs to be estimated) is likely to depend on the relative importance of shocks to aggregate demand and supply.[38] Similarly, the information content of the slope of the term structure of interest rates may depend on the nature of the monetary policy regime, as demonstrated by Estrella (2003).

Another potential argument against the use of money as an information variable is that while it is correlated with future information, it contains little information beyond that embedded in recently observed inflation rates. However, it is a striking finding that information variables typically do not improve much on univariate forecasts of future goal variables (eg. Stock and Watson 2003). Thus, money may not be much worse (or better) than other commonly used information variables.[39]

On balance, I believe that money growth is one of many useful indicator variables in the euro area.

7.2 A pillar for money?

Do these findings imply that money should be given a separate pillar in the ECB's monetary policy strategy? The empirical work presented above suggests that M3 growth contains information about future inflation in the euro area that is not already embedded in the current rate of inflation or in the output gap. Overall the paper is best seen as demonstrating how that information can be combined with non-monetary indicators to form the *"broadly based assessment of the outlook for future price developments and the risks to price stability in the euro area as a whole*" that

[37] Stock and Watson (2003) discuss reasons why the information content of indicator variables may shift over time.

[38] Here I am referring to the output gap in the sense of the difference between actual and "detrended" output.

[39] Of course, theory suggests that information variables ought not to be too informative about future inflation since, if they were, the central banks should react to them in setting policy and thus reduce their information content. See Woodford (1994) for a discussion of the issue.

constitutes the ECB's second pillar. To my mind, there is nothing in the analysis suggesting that money should be treated differently from any other indicator of inflation pressures. In particular, the model does neither imply that it is the best predictor, nor that is it "always and everywhere" a good predictor, of future inflation. I therefore do not interpret the empirical work in this paper as implying that a separate pillar for money growth is required, but merely as providing further evidence that it is desirable for the ECB to extract any information about future inflation embedded in the monetary aggregates when setting interest rates.

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Box A. Monitoring the ECB 5

Reviewing in detail the large literature criticising the two-pillar strategy would go far beyond the scope of the present paper. This box instead summarises the analysis of a number of claims in favour of a monetary pillar in the most recent of the annual reports by the CEPR on "Monitoring the ECB", entitled: *"The Monetary Policy Strategy of the ECB Reconsidered"* (Galí et al. 2004).[40]

1. One argument in support of the first pillar is that money may be a proxy for variables that are observed with a lag or not at all. For instance, output gaps, which play an important role in most central banks' analysis of inflation, are unobserved and measures thereof must be constructed using data that are published with a lag and may undergo repeated revisions. Since money growth data are rapidly available and money may be correlated with income, it could potentially be used to improve assessments of the current output gap. However, the report argues that other, non-monetary variables are likely to be more informative than money for this purpose. Furthermore, even if money did contain useful information, there is no reason to give it a separate pillar. Rather, the information in money should be used together with other indicators in forming a broader view of economic conditions.

2. A further alleged reason for why it may be helpful to monitor money growth is that money may play an important role in the transmission mechanism of monetary policy. The report analyses this argument but concludes that while it may well be correct, it would suggest looking at more direct measures of the financial conditions of firms and households than the growth rate of the broad money stock. Moreover, also in this case would it be natural to undertake this work as a part of the economic analysis underlying the second pillar.

3. Another claim for why money growth needs to be monitored is that high inflation is always associated with rapid money growth, which in turn suggests that monetary control is essential for ensuring long-run price stability. While the report does not dispute that growth rates of money and prices are frequently

closely related (in the sense that money and prices may be cointegrated), it argues that this is not sufficient to justify a monetary pillar. A finding of cointegration does not imply that prices adjust to money; money being high relative to prices could just as well lead to lower money growth in the future.[41] Moreover, to the extent that prices adjust, they need not do so rapidly. Overall, cointegration between money and prices does not impose much, if any, restriction on the short-run behaviour of inflation. Optimising inflation control therefore requires policy makers to focus on other, short-run factors that are presumably captured in the economic analysis of the second pillar.

4. It is sometimes asserted that while the economic analysis of the second pillar may serve to ensure price stability in the short term, this is not sufficient to safeguard price stability in the long run. Here the report takes the view that maintaining price stability month-by-month presumably must imply maintaining it over the long run as well. Moreover, while the report is open to the notion that there could indeed by potential medium-term risks to price stability, it argues that the ECB's strategy does not at all spell out what policy reactions these should elicit as long as that threat remains merely potential. The usefulness of indicators of medium to long-term risks to price stability is therefore unclear.

5. It has been argued that conducting monetary policy with an eye on money growth may be useful for avoiding the trap of discretionary policy-making with a resultant increase in inflation. While avoiding an inflation bias due to discretionary policy is desirable, the report concludes that this problem is better solved by the ECB committing itself to following an appropriately designed policy rule rather than adopting a two-pillar strategy.

6. Yet another argument in favour of monitoring money is that the two-pillar strategy leads to more robust decision-making by cross-checking the implications for interest rates of alternative models of inflation. While the report recognises the

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[40] Needless to say, my interpretation of these arguments may or may not coincide with those of my coauthors.

[41] In a multivariate setting in which money and prices are cointegrated with, say, income and interest rates, the adjustment to equilibrium may be carried out by movements in these variables rather than money or prices.

need for such cross-checking, this could presumably be done in the context of the economic analysis in the second pillar, which should take into account all information regarding inflation pressures including information about the nature of the inflation process. The report also notes that the ECB has never spelled out in detail what the role of money is in the alternative models of the inflation process it has in mind, and that the ECB appears to view monetary analysis as providing an escape clause for policy. Thus, the ECB seems to argue that although that analysis does not lead to formal inflation forecasts, it helps guard against inflation gradually rising above the objective. The report is recognisant of the need to guard against this and notes that limiting money growth may be one way in which persistently high inflation can be avoided. However, it goes on to argue that a more natural and better way to achieve this is simply to monitor actual inflation developments.

7. The final argument considered by the report is the claim that monitoring monetary aggregates is essential to preventing instability due to self-fulfilling expectations. The report analyses this argument, but concludes that many of these problems can be overcome with interest rate rules.[42] The potential exception is the case of self-fulfilling deflationary traps in case of which the report argues that a commitment by the central bank to maintain money balances at a level above that required to keep the interest rate at zero may be desirable.[43] However, this action is only necessary in some circumstances and does not generally involve a cross-checking of the two-pillar form.

My own interpretation of the report is that it takes the view that the ECB would be ill advised to disregard monetary factors, but that taking proper account of these does neither necessarily entail monitoring the growth rate of M3, nor does it require a separate monetary pillar.

[42] See the discussion in Woodford (2003).

[43] This issue is discussed by Eggertsen and Woodford (2003).

Box B. Money and inflation in the euro area[44]

Much of the research on the relationship between money and prices in the euro area has focused on modelling the demand for money and has been contributed by the staff of the ECB.[45] Coenen and Vega (2001) study quarterly data on real M3, real income, short and long interest rates and inflation for the period 1980-1998. After testing for weak exogeneity, they estimate a single equation error-correction model, which appears stable and well-behaved, for the demand for the real money stock. Brand and Cassola (2000) study the same variables over a slightly longer sample, and estimate a system comprising three long-run relationships. They also find a well-defined money demand relationship and detect no evidence of instability.

Calza et al. (2001) also investigate the demand for money in the euro area. In contrast to the earlier literature, the authors focus on measuring the opportunity cost of holding M3 and argue that it is best captured by the spread between short-term interest rates and the own return on M3. They also estimate a system consisting of a demand equation for the real money stock and an equation for the opportunity cost. This system appears to have good statistical properties and to be stable. Fagan et al. (2001) estimate a money demand function as one equation of their econometric model of the euro area in which, as noted by Begg et al. (2002), money plays a purely passive role. Brand et al. (2002) study the income velocity of money in the euro area, which is of importance in the determination of the ECB's reference value for M3 growth. They find a well-defined empirical relationship between money, income, prices and the opportunity cost of holding money. However, there is some limited evidence that the income elasticity of money demand has risen from 1992Q1 onwards.

The models studied above all focus on the demand for the real money stock, and find that it moves over time to offset monetary disequilibria as captured by an error-correction term. One unfortunate implication of the use of the real money stock in the analysis is that the results are silent on whether it is the nominal money stock or the

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[44] ECB's work in this area is summarised in Masuch et al. (2003).

[45] The EMI, the predecessor of the ECB, also conducted research on this issue, e.g., Fagan and Henry (1998).

price level (or both) that adjust to offset disequilibria. Thus, these models do not permit conclusions to be drawn regarding the role of money in the inflation process.

The relationship between money and prices has been addressed directly by Trecroci and Vega (2000). They argue that while money does not appear to Granger cause inflation, that conclusion depends on the information set used in the forecasting exercise. Moreover, they find that the p-star model, or, equivalently, the real money gap model of Gerlach and Svensson (2003), indicates that money is informative about future inflation. Although the authors argue that the model can be refined, they show that it provides better longer-term forecasts of inflation than the non-monetary inflation equation in the econometric model of Fagan et al. (2001).[46] Nicoletti-Altamari (2001) performs a simulated out-of-sample forecasting exercise to study the information content of money for prices in the euro area. The results suggest that monetary and credit aggregates provide useful information about price developments, particularly at medium-term horizons.

Batini (2002), in an ECB working paper, also studies the relationship between money and prices in the euro area in a model-free manner. She finds that money growth, which she interprets as a measure of overall monetary conditions, impact on inflation with a time lag of over a year.

While the findings discussed above are all compatible with the notion that money contains information that is useful in predicting inflation, it should be remembered that the results stem from non-structural models. They are therefore arguably best seen as establishing the empirical regularities that are to be explained.

I interpret the research conducted by the ECB as indicating that money has predictive content for inflation in the euro area. However, the output gap is also relevant for forecasting inflation.

[46] Trecroci and Vega (2000) use an earlier version of the Gerlach and Svensson (2003) model.

Box C. Reduced form evidence

In this Box I present some reduced-form evidence on the information contained in money growth for future inflation in the euro area. To this end, I estimate prediction equations of the form (suppressing the constant):

(3) $$\pi_{t+j} - \pi_t = \phi_\pi(\pi_t^* - \pi_t) + \phi_g g_t + \phi_m(\mu_t^* - \pi_t^*) + \xi_t$$

and study whether the spread between trend and headline inflation, $\pi_t^* - \pi_t$, is correlated with the change in headline inflation over the coming j quarters, $\pi_{t+j} - \pi_t$. In the empirical work below I explore forecasting horizons of two, four, eight and twelve quarters (j = 2, 4, 8 and 12).

To understand the results, it is helpful to consider the interpretation of the parameters. The coefficient ϕ_π captures the extent to which the wedge between trend and headline inflation predicts future changes in headline inflation. Generally one would expect ϕ_π to be positive and significant. Moreover, since it may take some time for this wedge to be undone, ϕ_π is likely to rise with the length of the forecast horizon, j, and approach unity for longer horizons. The coefficient ϕ_g provides information about the extent to which the output gap impacts on future inflation. Given the importance many central banks attach to the output gap, one would expect ϕ_g to be positive and significant. Since movements in the output gap are transitory although persistent, it is possible that the importance of the output gap declines with the forecast horizon. Finally, the coefficient ϕ_m captures the information content of money growth. The hypothesis is that headline inflation will rise if trend money growth is exceeding trend inflation. A finding of a positive and significant ϕ_m would indicate that money is informative for future changes in inflation even in the presence of the output gap and the discrepancy between trend and headline inflation.

To estimate this model I use data for three sample periods. I first consider the full sample period of 1970Q2-2003Q1. Since the proposition that the high inflation observed in the 1970s was related to the rapid money growth is probably not too controversial, I also estimate the equation for first subperiod ending in 1986Q4 and a second subperiod starting in 1987Q1. Since theory suggests that there should be serial correlation in the residuals of order j-1, I allow for this in estimation.

Table C.1 provides the results. To understand the table, consider the results for the full sample when a forecast horizon of two quarters (j = 2) is used. The estimate of ϕ_π indicates that if trend inflation is one percentage point above headline inflation, the latter is predicted to rise by 0.17 percentage points in the coming two quarters. The p-value for a test of the hypothesis that the parameter is zero is 9.5% and the adjusted R-squared is 4.6%.

Next I add the output gap to the regression. I find that ϕ_g is positive and highly significant (p = 1.7%) and the adjusted R-squared rises to 12.5%. Furthermore, ϕ_π rises to 0.29 and becomes highly significant (p = 0.1%). This implies that the output gap contains information about future changes in inflation in addition to that embedded in the wedge between trend and headline inflation.

I proceed by also including trend money growth relative to trend inflation in the regression. I find that ϕ_m is highly significant (p = 0.0%) and that the adjusted R-squared rises further to 28.9%. However, the estimate of ϕ_g declines and its significance falls (p = 5.1%).

Overall, the results for the full sample period show that money growth contains information for future changes in inflation, irrespectively of the time horizon considered and whether or not the output gap is included. The output gap is also significant, at least at the 10% level, for j = 2, 4 and 12 when money is excluded from the model. However, when money is included, it is only significant for j = 2 (and then with a p-value of 5.1%). The wedge between trend and headline inflation is generally significant, with the point estimate of ϕ_π approaching unity for longer forecast horizons and in fact exceeding unity, but not significantly so, for j = 12. Furthermore, the adjusted R-squareds are consistently considerable higher when money growth in included in the model. Overall, these results suggest that money does contain information useful for predicting future changes in inflation.

Next I turn to the results for the two subsamples. Several findings are readily apparent. First, after 1986 money growth is generally less, and the output gap more, significant, particularly so for longer forecast horizons (j = 8 and 12). Interestingly, models estimated for the second subsample which include the output gap among the regressors have typically much higher adjusted R-squareds than the others. This is supportive of the notion that the information content of money has declined over time and that, if anything, the output gap may have become more useful for predicting changes in inflation. However, money growth appears to remain informative about future inflation in the post 1987 period for j = 2 and 4.

Table C.1

Estimates of $\pi_{t+j} - \pi_t = \phi_\pi(\pi_t^* - \pi_t) + \phi_g g_t + \phi_m(\mu_t^* - \pi_t^*) + \xi_t$

	Sample period: 1970Q2 - 2003Q1				Sample period: 1970Q2 – 1986Q4				Sample period: 1987Q1 - 2003Q1			
Forecast horizon (quarters) / Coefficient	ϕ_π	ϕ_g	ϕ_m	adj. R^2	ϕ_π	ϕ_g	ϕ_m	adj. R^2	ϕ_π	ϕ_g	ϕ_m	adj. R^2
2	0.173			0.046	0.105			0.009	0.552			0.252
	[0.095]				[0.344]				[0.000]			
2	0.291	0.465		0.125	0.244	0.578		0.113	0.716	0.429		0.327
	[0.001]	[0.017]			[0.029]	[0.058]			[0.000]	[0.003]		
2	0.415	0.315	0.664	0.289	0.380	0.407	0.678	0.327	0.776	0.350	0.478	0.351
	[0.000]	[0.051]	[0.000]		[0.000]	[0.078]	[0.000]		[0.000]	[0.008]	[0.002]	
2	0.352		0.734	0.257	0.302		0.750	0.281	0.674		0.646	0.308
	[0.000]		[0.000]		[0.002]		[0.000]		[0.000]		[0.004]	
4	0.276			0.071	0.224			0.039	0.570			0.251
	[0.061]				[0.192]				[0.000]			
4	0.401	0.488		0.119	0.347	0.514		0.070	0.788	0.571		0.385
	[0.004]	[0.081]			[0.048]	[0.241]			[0.000]	[0.000]		
4	0.628	0.212	1.224	0.444	0.620	0.172	1.354	0.497	0.840	0.503	0.414	0.398
	[0.000]	[0.345]	[0.000]		[0.000]	[0.543]	[0.000]		[0.000]	[0.000]	[0.040]	
4	0.586		1.272	0.439	0.587		1.385	0.500	0.693		0.656	0.304
	[0.000]		[0.000]		[0.000]		[0.000]		[0.000]		[0.006]	
8	0.442			0.112	0.368			0.068	0.865			0.405
	[0.004]				[0.037]				[0.000]			
8	0.511	0.270		0.114	0.432	0.266		0.061	1.032	0.429		0.450
	[0.002]	[0.214]			[0.026]	[0.372]			[0.000]	[0.010]		
8	0.869	-0.176	1.940	0.599	0.874	-0.289	2.195	0.706	1.069	0.374	0.309	0.449
	[0.000]	[0.505]	[0.000]		[0.000]	[0.374]	[0.000]		[0.000]	[0.031]	[0.412]	
8	0.905		1.900	0.598	0.930		2.144	0.703	0.959		0.498	0.421
	[0.000]		[0.000]		[0.000]		[0.000]		[0.000]		[0.198]	
12	0.624			0.161	0.602			0.139	0.836			0.308
	[0.001]				[0.004]				[0.000]			
12	0.743	0.467		0.174	0.765	0.681		0.157	0.915	0.184		0.304
	[0.000]	[0.093]			[0.000]	[0.064]			[0.000]	[0.409]		
12	1.158	-0.098	2.217	0.629	1.283	0.030	2.570	0.768	0.880	0.229	-0.200	0.294
	[0.000]	[0.739]	[0.000]		[0.000]	[0.914]	[0.000]		[0.000]	[0.366]	[0.751]	
12	1.177		2.193	0.632	1.277		2.575	0.771	0.820		-0.056	0.295
	[0.000]		[0.000]		[0.000]		[0.000]		[0.000]		[0.917]	

Note: p-values in brackets. All equations are estimated with GMM. The standard errors are computed allowing for serially correlated errors and heteroscedasticity.

Box D. The ECB's 2003 review of the monetary policy strategy

In October 1998, the Governing Council of the ECB announced the main features of its monetary policy strategy, the core of which is a quantitative definition of price stability and a two-pillar framework for assessing the risks to price stability. After more than three years of experience, the ECB stated in 2002 that it would review the framework. The outcome of this evaluation was made public in May 2003. While it considered both the quantitative definition of price stability and the two-pillar framework, in the interest of brevity I focus here on the implications for the monetary pillar. Galí et al. (2004) contains a detailed analysis of the overall outcome of the review.

While it does not say so explicitly, my interpretation of the outcome of the review is that the Governing Council decided to maintain, but to downplay, the monetary pillar. Three notable changes were made.

First, the Governing Council appeared to change, or at least clarify, the motivation for the monetary pillar. When the two-pillar strategy was first introduced, the ECB argued that, given the high degree of uncertainty under which policy is conducted, the two-pillar strategy (ECB 2000, p. 45):

> *"…reduces the risk of policy errors caused by the overreliance on a single indicator or model. Since it adopts a diversified approach to the interpretation of economic conditions, the ECB's strategy may be regarded as facilitating the adoption of a robust monetary strategy."*

It went on to argue that a specific concern was the fact that the inflation process was so poorly understood. On the same page, it stated that:

> *"A reflection of the uncertainties about, and the imperfect understanding of, the economy is the large range of models of the inflation process …. Many of these models capture important elements of reality, but none of them appear to be able to describe reality in its entirety. Therefore, any single model is necessarily incomplete.*
>
> *As the set of plausible models is very broad, any policy analysis needs to be organised within a simplifying framework. The ECB has chosen to organise its analysis under two pillars."*

Thus, when it was initially announced, the ECB motivated the two-pillar strategy by appealing to the risks of that could arise from putting too much faith in any single hypothesis of the price mechanism.

After the conclusion of the review, the ECB continued to emphasise that the two-pillar framework was intended to avoid an excessive reliance on a single conceptual model of inflation (ECB, 2003, p.17):

> *"Monetary policy faces uncertainties about the functioning of the economy. The ECB's monetary policy strategy was designed with the aim of ensuring that no information is lost and that appropriate attention is paid to different analytical perspectives ... . The two-pillar approach is a means to convey the notion of diversification of analysis to the public and ensure robust decision-making on the basis of different analytical perspectives."*

However, following the review, the ECB's motivation focussed on the need to combine information with different time dimensions (ECB 2003, p. 18):[47]

> *"Overall, the two-pillar approach provides a framework for cross-checking indications stemming from the shorter-term economic analysis with those from the monetary analysis, which provides information about the medium to long-term determinants of inflation."*

Moreover, in the summary article in the June 2003 Monthly Bulleting, it writes that (ECB 2003, p. 87):

> *"The Governing Council ... indicated that monetary analysis mainly serves as a means of cross-checking, from a medium to long-term perspective, the short- to medium-term indications coming from economic analysis."*

Overall, it seems that the motivation for the two-pillar approach changed as a consequence of review.

Second, the Governing Council decided to adopt a new structure for the President's Introductory Statement to the ECB's monthly press conference by reversing the order in which the information coming from the two pillars is presented. Thus, it was decided that the statement henceforth would start with the broadly based economic analysis under the second pillar before turning to the monetary analysis of the first pillar. One plausible explanation for this decision is that the economic analysis provides more information about the Governing Council's view of near-term inflation pressures, and therefore about the likelihood of interest rate changes, than the

[47] See also the quote on page 13 in the main text.

monetary analysis. I therefore believe this signals a reduction of the importance attached to the monetary pillar.

The third change concerns the reference value for money growth. While the Governing Council in the past had reviewed this on an annual basis, it decided to discontinue this practice. This decision reflected the fact that since the monetary analysis pertained to the medium to long term, there would presumably be little reason to consider updating the reference value on an annual basis.

Box E. The Two-Pillar Phillips Curve

To obtain the TPPC, I start from the inflation equation and the definition of expected inflation:

(E1) $$\pi_t = \alpha_f \pi^e_{t+1} + \alpha_b \pi_{t-1} + \alpha_g g_{t-1} + \varepsilon_t ,$$

(E2) $$\pi^e_{t+1} = \mu^*_{t-1} .$$

Trend money growth is given by:

(E3) $$\mu^*_{t-1} = \lambda\mu_{t-1} + (1-\lambda)\mu^*_{t-2} .$$

I can write the inflation equation in the compact form:

(E4) $$z_t = \alpha_f \mu^*_{t-1} + \varepsilon_t$$

where $z_t \equiv \pi_t - \alpha_b \pi_{t-1} - \alpha_g g_{t-1}$. Note that (E4) implies that $\mu^*_{t-2} = (z_{t-1} - \varepsilon_{t-1})/\alpha_f$. Substituting (E3) into (E4) I obtain:

(E5) $$z_t = \alpha_f \lambda\mu_{t-1} + \alpha_f (1-\lambda)\mu^*_{t-2} + \varepsilon_t$$

or

(E6) $$z_t = \alpha_f \lambda\mu_{t-1} + (1-\lambda)z_{t-1} + \varepsilon_t - (1-\lambda)\varepsilon_{t-1}$$

Using the definition of z_t, the final inflation equation can be written as:

(E7) $$\pi_t = \beta_1\mu_{t-1} + \beta_2 g_{t-1} + \beta_3\pi_{t-1} + \beta_4 g_{t-2} + \beta_5\pi_{t-2} + e_t ,$$

where $\beta_1 = \alpha_f\lambda$, $\beta_2 = \alpha_g$, $\beta_3 = (1-\lambda+\alpha_b)$, $\beta_4 = -(1-\lambda)\alpha_g$, $\beta_5 = -(1-\lambda)\alpha_b$ and $e_t = \varepsilon_t - \beta_6\varepsilon_{t-1}$ and $\rho = (1-\lambda)$.

This equation is "structural" in the sense that finding significant estimates of the β_i's is not sufficient to conclude that the model is valid. In fact, a finding that money and the lagged output gap matter ($\beta_1, \beta_2 > 0$), that the parameter on lagged inflation is significant and has a plausible value ($0 < \beta_3 \leq 1$) and that the coefficients on the twice-lagged output gap and inflation are insignificant does not, on its own, provide support for the model. Rather, the underlying parameters – the degrees to which inflation is forward- (α_f) and backward-looking (α_b), the impact of the output gap on inflation (α_g) and the extent to which past money growth determines inflation expectations (λ) – need to be significant and of plausible magnitude. In particular, I would expect that $0 \leq \alpha_f, \alpha_b \leq 1$, $\alpha_f + \alpha_b \approx 1$, $\alpha_g > 0$ and that λ is significant and "reasonably" close to the 0.075 value used by Gerlach (2003). Moreover, the errors should obey a first-order MA structure.

Furthermore, the fact that there are six parameters in the empirical model (five β_i parameters and ρ), but only four parameters ($\alpha_f, \alpha_g, \alpha_b, \lambda$) in the theoretical model implies that are testable restrictions. Indeed, there are only four parameters if the restriction that $\alpha_f + \alpha_b = 1$ is imposed, and three if I also assume that $\alpha_f = 1$. In sum, the theoretical model, while simple, does impose nontrivial conditions that the data must satisfy.

Table 1:

Sample period 1971Q1-2003Q1

Estimates of $\pi_t = \beta_0 + \beta_1 x_{t-1} + \beta_2 g_{t-1} + \beta_3 \pi_{t-1} + \beta_4 g_{t-2} + \beta_5 \pi_{t-2} + e_t$

where $e_t = \varepsilon_t - \rho\varepsilon_{t-1}$

x_t	Money growth, μ_t	Adjusted money growth, $\tilde{\mu}_t$
β_0	-0.003** (0.002)	-0.002 (0.001)
β_1	0.092*** (0.032)	0.117*** (0.040)
β_2	0.573*** (0.141)	1.061*** (0.217)
β_3	0.909*** (0.177)	0.886*** (0.175)
β_4	-0.380*** (0.141)	-0.852*** (0.187)
β_5	0.005 (0.155)	0.009 (0.151)
ρ	-0.499*** (0.160)	-0.470*** (0.160)
σ^2	0.011	0.011
Log likelihood	407.323	407.055
Adj. R-sq.	0.906	0.906

Note : * / ** / *** denotes significance at the 10 / 5 / 1 percent level.

Standard errors in parentheses.

Table 2:

Sample period 1971Q1-2003Q1

Estimates of $\pi_t = \beta + \beta_1 x_{t-1} + \beta_2 g_{t-1} + \beta_3 \pi_{t-1} + \beta_4 g_{t-2} + \beta_5 \pi_{t-2} + e_t$

where $\beta = \alpha$, $\beta_1 = \alpha_f \lambda$, $\beta_2 = \alpha_g$, $\beta_3 = 1 - \lambda + \alpha_b$, $\beta_4 = -(1-\lambda)\alpha_g$, $\beta_5 = -(1-\lambda)\alpha_b$,

and $e_t = \varepsilon_t - \rho\varepsilon_{t-1}$

x_t	Money growth, μ_t	Adjusted money growth, $\tilde{\mu}_t$	Inflation, π_t
α	-0.003* (0.002)	-0.002 (0.001)	0.001 (0.001)
λ	0.089** (0.035)	0.129*** (0.032)	0.224** (0.106)
α_f	1.041*** (0.243)	1.080*** (0.225)	0.922*** (0.228)
α_b	0.029 (0.172)	0.020 (0.182)	0.005 (0.233)
α_g	0.553*** (0.141)	1.141*** (0.259)	0.628*** (0.146)
ρ	0.447** (0.191)	0.436** (0.194)	0.468*** (0.197)
σ^2	$1.12*10^{-4}$	$1.09*10^{-4}$	$1.19*10^{-4}$
Log likelihood	403.631	405.521	399.641

Note : * / ** / *** denotes significance at the 10 / 5 / 1 percent level.

Standard errors in parentheses.

Table 3:

Sample period 1971Q1-1991Q4

Estimates of $\pi_t = \beta + \beta_1 x_{t-1} + \beta_2 g_{t-1} + \beta_3 \pi_{t-1} + \beta_4 g_{t-2} + \beta_5 \pi_{t-2} + e_t$

where $\beta = \alpha$, $\beta_1 = \alpha_f \lambda$, $\beta_2 = \alpha_g$, $\beta_3 = 1 - \lambda + \alpha_b$, $\beta_4 = -(1-\lambda)\alpha_g$, $\beta_5 = -(1-\lambda)\alpha_b$,

and $e_t = \varepsilon_t - (1-\lambda)\varepsilon_{t-1}$

x_t	Money growth, μ_t			
α	-0.003*** (0.000)	-0.002*** (0.001)	-0.001* (0.001)	-0.004** (0.001)
λ	0.090** (0.036)	0.079** (0.037)	0.152 (0.101)	0.111*** (0.024)
α_f	0.492*** (0.139)	0.516*** (0.190)	0.268*** (0.085)	1
α_b	0.681*** (0.066)	0.665*** (0.088)	$(1-\alpha_f)$	0
α_g	0.280** (0.117)	0.356*** (0.136)	0.306** (0.122)	0.673*** (0.178)
ρ	0.968*** (0.043)	$(1-\lambda)$	$(1-\lambda)$	$(1-\lambda)$
σ^2	$1.13*10^{-4}$	$1.16*10^{-4}$	$1.21*10^{-4}$	$3.02*10^{-4}$
Log likelihood	261.118	260.656	259.135	220.385

Note : * / ** / *** denotes significance at the 10 / 5 / 1 percent level.

Standard errors in parentheses.

Table 4:

Sample period 1971Q1-1991Q4

Estimates of $\pi_t = \beta + \beta_1 x_{t-1} + \beta_2 g_{t-1} + \beta_3 \pi_{t-1} + \beta_4 g_{t-2} + \beta_5 \pi_{t-2} + e_t$

where $\beta = \alpha$, $\beta_1 = \alpha_f \lambda$, $\beta_2 = \alpha_g$, $\beta_3 = 1 - \lambda + \alpha_b$, $\beta_4 = -(1-\lambda)\alpha_g$, $\beta_5 = -(1-\lambda)\alpha_b$,

and $e_t = \varepsilon_t - (1-\lambda)\varepsilon_{t-1}$

x_t	Adjusted money growth, $\tilde{\mu}_t$			
α	-0.002** (0.001)	-0.002*** (0.001)	-0.001 (0.000)	-0.001** (0.001)
λ	0.196*** (0.053)	0.188*** (0.053)	0.243*** (0.089)	0.236*** (0.047)
α_f	0.518*** (0.145)	0.546*** (0.135)	0.361*** (0.084)	1
α_b	0.612*** (0.096)	0.582*** (0.087)	$(1-\alpha_f)$	0
α_g	0.672*** (0.191)	0.714*** (0.171)	0.609*** (0.147)	1.345*** (0.146)
ρ	0.841*** (0.106)	$(1-\lambda)$	$(1-\lambda)$	$(1-\lambda)$
σ^2	$1.10*10^{-4}$	$1.12*10^{-4}$	$1.16*10^{-4}$	$2.14*10^{-4}$
Log likelihood	262.609	262.456	260.778	235.306

Note : * / ** / *** denotes significance at the 10 / 5 / 1 percent level.

Standard errors in parentheses.

Table 5:

Sample period 1971Q1-1991Q4

Estimates of $\pi_t = \beta + \beta_1 x_{t-1} + \beta_2 g_{t-1} + \beta_3 \pi_{t-1} + \beta_4 g_{t-2} + \beta_5 \pi_{t-2} + e_t$

where $\beta = \alpha$, $\beta_1 = \alpha_f \lambda$, $\beta_2 = \alpha_g$, $\beta_3 = 1 - \lambda + \alpha_b$, $\beta_4 = -(1-\lambda)\alpha_g$, $\beta_5 = -(1-\lambda)\alpha_b$,

and $e_t = \varepsilon_t - (1-\lambda)\varepsilon_{t-1}$

x_t	Inflation, π_t			
α	0.001 (0.003)	0.001 (0.002)	0.000 (0.000)	0.000 (0.001)
λ	0.240 (0.203)	0.327 (0.254)	0.232* (0.128)	0.647*** (0.125)
α_f	0.2647 (0.426)	0.440* (0.260)	0.429** (0.197)	1
α_b	0.148 (0.480)	0.505* (0.266)	$(1-\alpha_f)$	0
α_g	0.581*** (0.207)	0.454** (0.178)	0.496*** (0.159)	0.346** (0.140)
ρ	0.535 (0.418)	$(1-\lambda)$	$(1-\lambda)$	$(1-\lambda)$
σ^2	$1.27 * 10^{-4}$	$1.29 * 10^{-4}$	$1.30 * 10^{-4}$	$1.37 * 10^{-4}$
Log likelihood	257.324	256.499	256.000	254.249

Note : * / ** / *** denotes significance at the 10 / 5 / 1 percent level.

Standard errors in parentheses.

Table 6:

Sample period 1992Q1-2003Q1

Estimates of $\pi_t = \beta + \beta_1 x_{t-1} + \beta_2 g_{t-1} + \beta_3 \pi_{t-1} + \beta_4 g_{t-2} + \beta_5 \pi_{t-2} + e_t$

where $\beta = \alpha$, $\beta_1 = \alpha_f \lambda$, $\beta_2 = \alpha_g$, $\beta_3 = 1 - \lambda + \alpha_b$, $\beta_4 = -(1-\lambda)\alpha_g$, $\beta_5 = -(1-\lambda)\alpha_b$,

and $e_t = \varepsilon_t - (1-\lambda)\varepsilon_{t-1}$

x_t	Money growth, μ_t			
α	-0.003*** (0.000)	-0.003** (0.002)	-0.003*** (0.001)	-0.003*** (0.001)
λ	0.088*** (0.026)	0.081** (0.040)	0.083*** (0.017)	0.086*** (0.023)
α_f	1.053*** (0.171)	1.227* (0.667)	1.173*** (0.102)	1
α_b	-0.132 (0.139)	-0.162 (0.129)	$(1-\alpha_f)$	0
α_g	0.491*** (0.137)	0.542*** (0.159)	0.540*** (0.122)	0.488*** (0.129)
ρ	0.979*** (0.252)	$(1-\lambda)$	$(1-\lambda)$	$(1-\lambda)$
σ^2	$5.52 * 10^{-5}$	$5.71 * 10^{-5}$	$5.43 * 10^{-5}$	$6.05 * 10^{-5}$
Log likelihood	155.503	155.075	155.015	154.271

Note : * / ** / *** denotes significance at the 10 / 5 / 1 percent level.

Standard errors in parentheses.

Table 7:

Sample period 1992Q1-2003Q1

Estimates of $\pi_t = \beta + \beta_1 x_{t-1} + \beta_2 g_{t-1} + \beta_3 \pi_{t-1} + \beta_4 g_{t-2} + \beta_5 \pi_{t-2} + e_t$

where $\beta = \alpha$, $\beta_1 = \alpha_f \lambda$, $\beta_2 = \alpha_g$, $\beta_3 = 1 - \lambda + \alpha_b$, $\beta_4 = -(1-\lambda)\alpha_g$, $\beta_5 = -(1-\lambda)\alpha_b$,

and $e_t = \varepsilon_t - (1-\lambda)\varepsilon_{t-1}$

x_t	Adjusted money growth, $\tilde{\mu}_t$			
α	0.000 (0.001)	0.000 (0.001)	-0.001*** (0.000)	-0.001*** (0.000)
λ	0.120*** (0.036)	0.116*** (0.044)	0.094*** (0.020)	0.094*** (0.019)
α_f	0.733** (0.298)	0.701** (0.294)	1.094*** (0.103)	1
α_b	-0.118 (0.151)	-0.153 (0.136)	$(1-\alpha_f)$	0
α_g	0.876*** (0.224)	0.825*** (0.204)	1.084*** (0.163)	1.008*** (0.158)
ρ	1.002 (5.241)	$(1-\lambda)$	$(1-\lambda)$	$(1-\lambda)$
σ^2	$5.52*10^{-5}$	$5.95*10^{-5}$	$6.14*10^{-5}$	$6.21*10^{-5}$
Log likelihood	155.037	154.314	153.484	153.225

Note : * / ** / *** denotes significance at the 10 / 5 / 1 percent level.

Standard errors in parentheses.

Table 8:

Sample period 1992Q1-2003Q1

Estimates of $\pi_t = \beta + \beta_1 x_{t-1} + \beta_2 g_{t-1} + \beta_3 \pi_{t-1} + \beta_4 g_{t-2} + \beta_5 \pi_{t-2} + e_t$

where $\beta = \alpha$, $\beta_1 = \alpha_f \lambda$, $\beta_2 = \alpha_g$, $\beta_3 = 1 - \lambda + \alpha_b$, $\beta_4 = -(1-\lambda)\alpha_g$, $\beta_5 = -(1-\lambda)\alpha_b$,

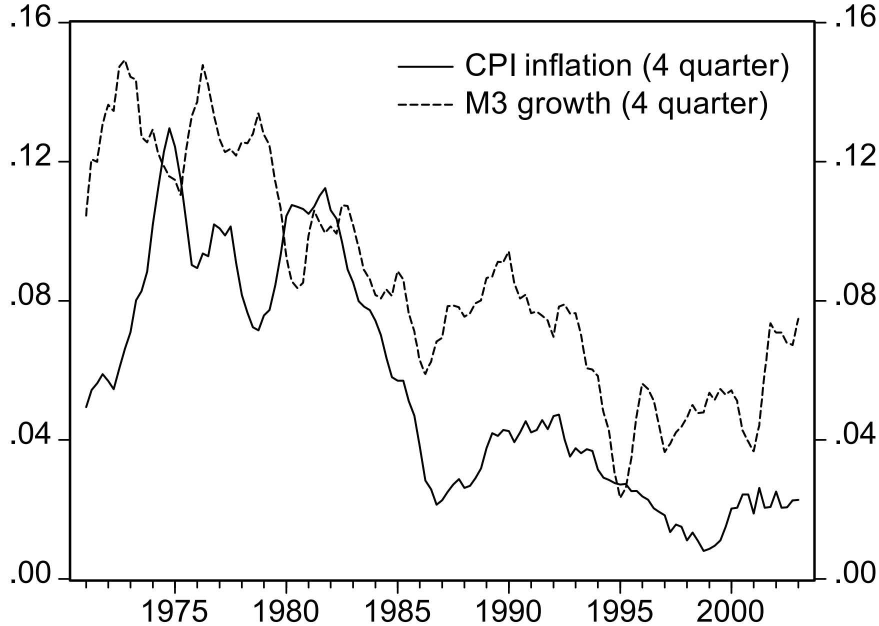
and $e_t = \varepsilon_t - (1-\lambda)\varepsilon_{t-1}$

x_t	Inflation, π_t			
α	0.003 (0.002)	0.003* (0.002)	0.000 (0.000)	0.000 (0.000)
λ	0.347 (0.721)	0.338* (0.186)	0.265* (0.149)	0.192* (0.101)
α_f	1.019 (1.185)	1.002** (0.484)	1.281*** (0.243)	1
α_b	-0.432 (0.566)	-0.426 (0.354)	$(1-\alpha_f)$	0
α_g	0.178 (0.213)	0.179 (0.197)	0.331* (0.195)	0.386** (0.172)
ρ	0.664*** (0.187)	$(1-\lambda)$	$(1-\lambda)$	$(1-\lambda)$
σ^2	$6.63*10^{-5}$	$6.64*10^{-5}$	$7.63*10^{-5}$	$7.82*10^{-5}$
Log likelihood	152.324	152.324	149.087	148.370

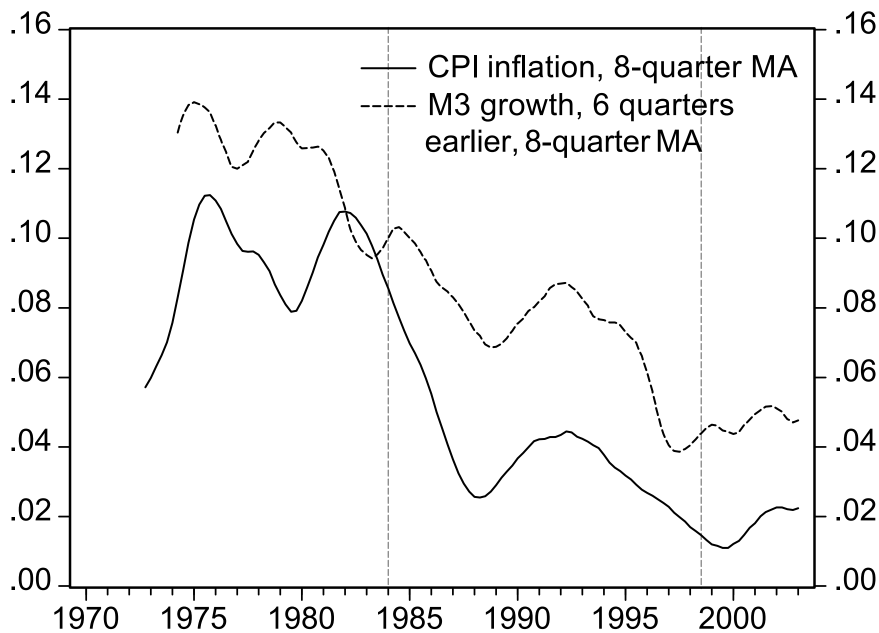
Note : * / ** / *** denotes significance at the 10 / 5 / 1 percent level.

Standard errors in parentheses.

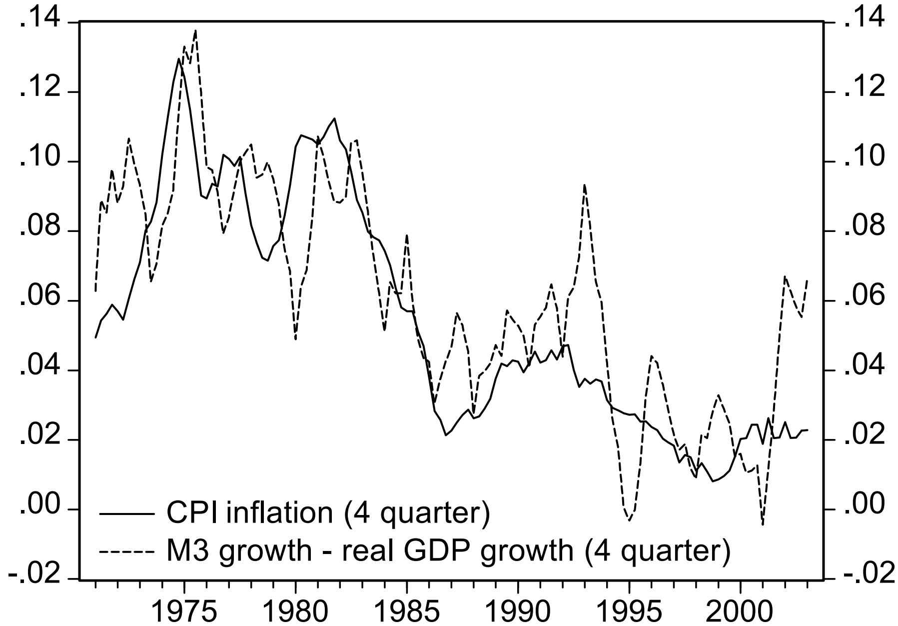
Graph 1



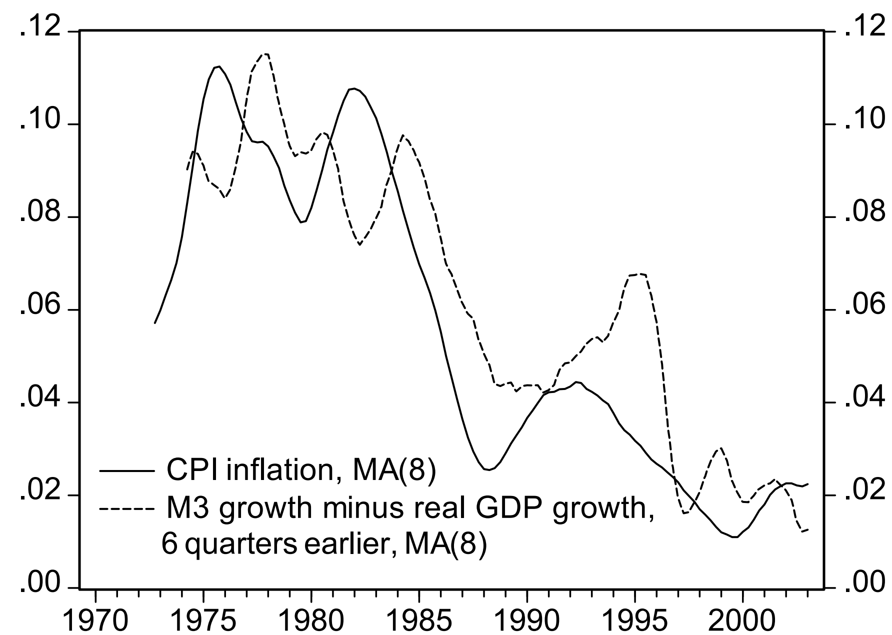
Graph 2



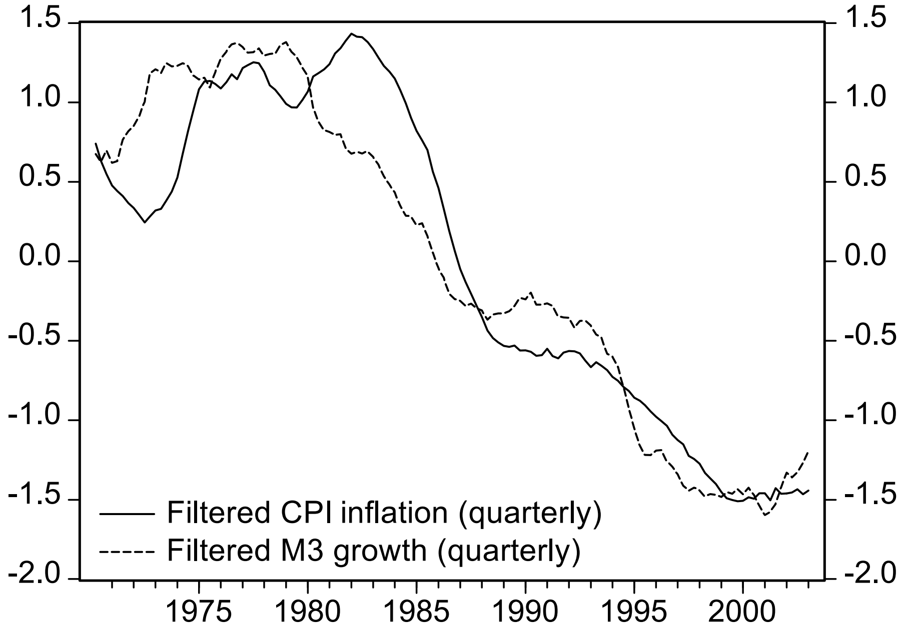
Graph 3



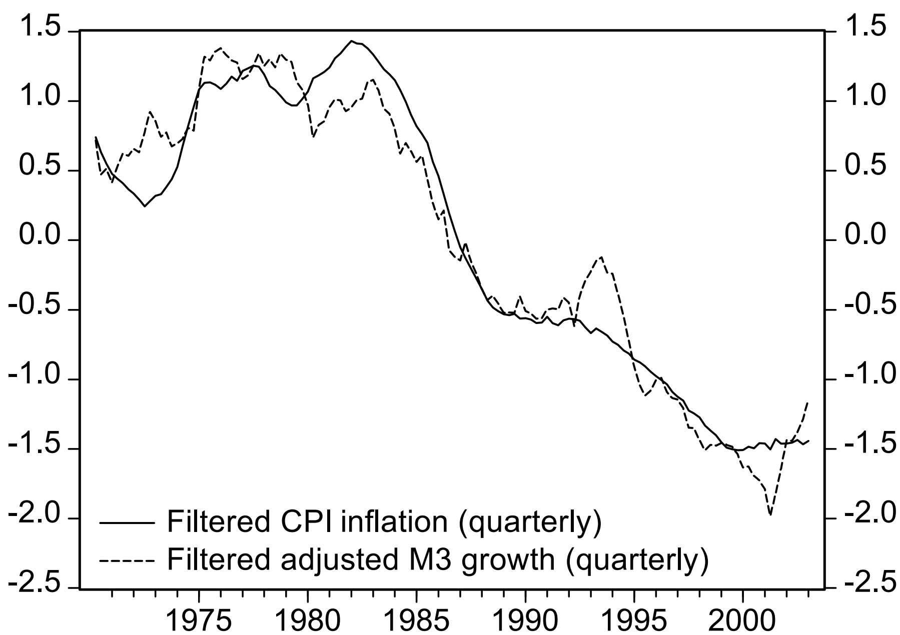
Graph 4



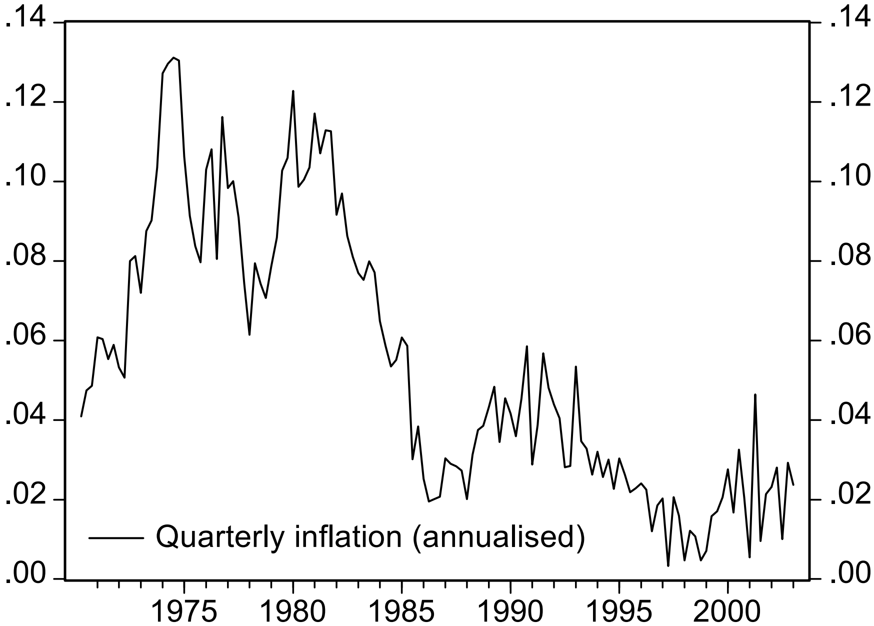
Graph 5



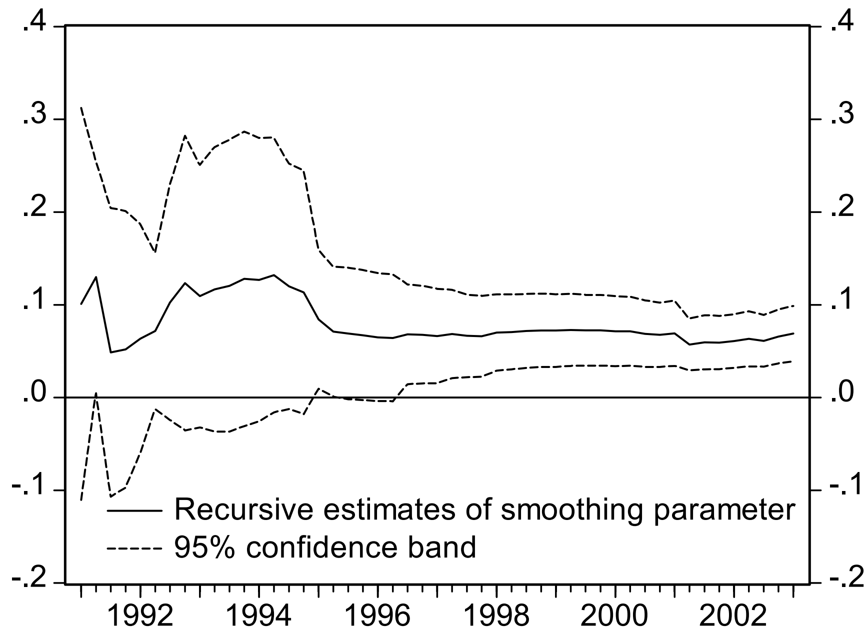
Graph 6



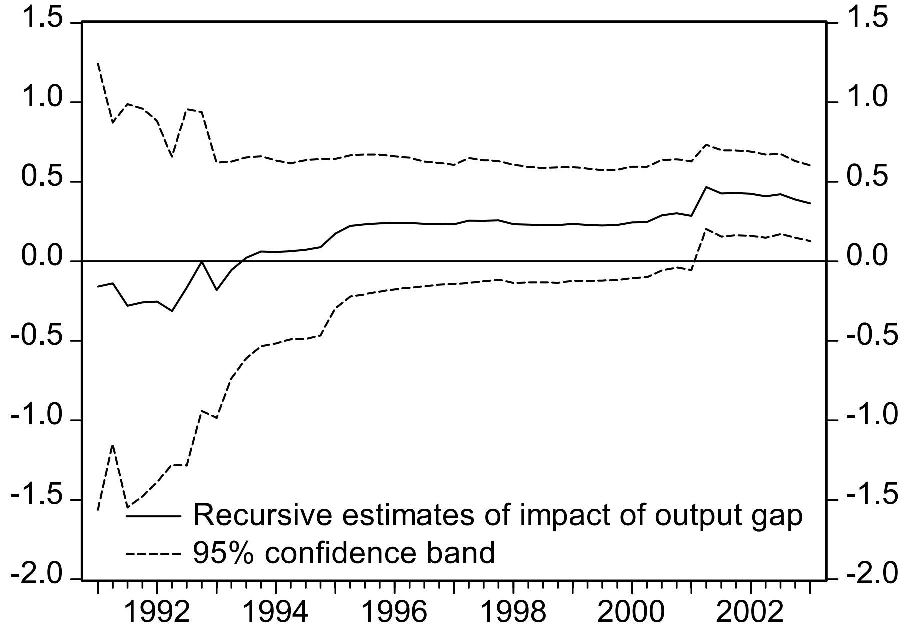
Graph 7



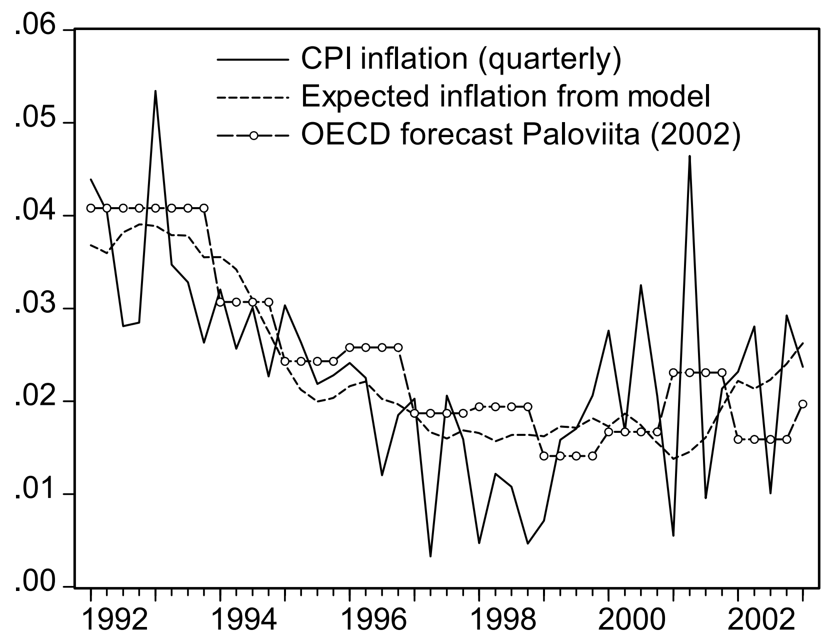
Graph 8



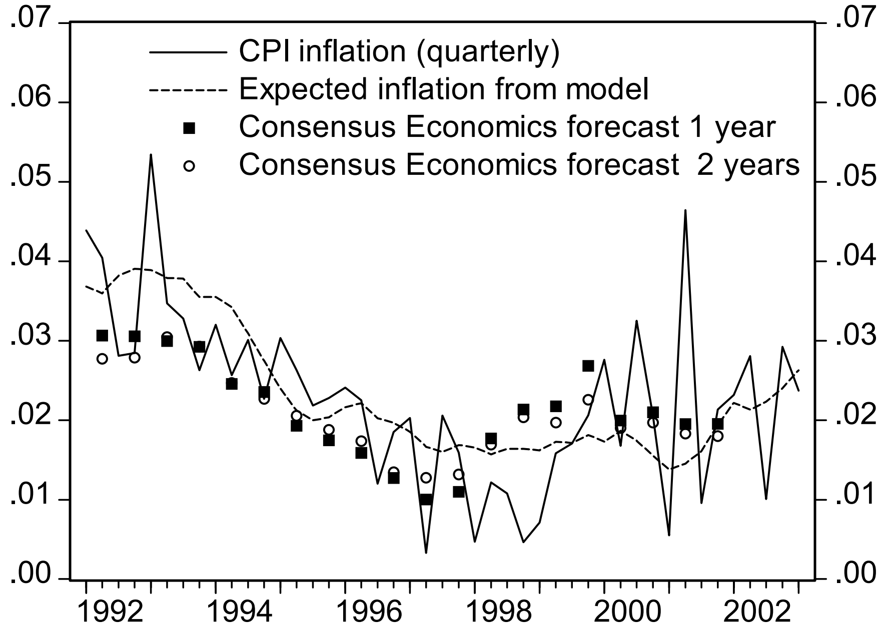
Graph 9



Graph 10



Graph 11


.07
.06
.05
.04
.03
.02
.01
.00
CPI inflation (quarterly)
Expected inflation from model
Consensus Economics forecast 1 year
Consensus Economics forecast 2 years
1992
1994
1996
1998
2000
2002