# The Preferences of the Euro Area Monetary Policymaker

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## Abstract

The aim of this paper is to uncover the aggregate monetary policy preferences in the Euro Area. This is pursued under the assumption of optimising policy behaviour subject to a simple model of the macroeconomic structure, following a procedure recently proposed in the literature, in which GMM estimation stems from the optimal control solution to the optimisation problem.

Instead of waiting for more quarterly data of ECB policymaking, the sample goes as far back as possible into the pre-EMU years. Through a combined analysis of facts, data and literature on European integration, 1995 is identified as the beginning date of a Euro Area notional policy regime, later sustained by the ECB.

The policy preferences are estimated as a loss function with strict inflation targeting at 1.6% and interest rate smoothing, during 1995-2002.

**Keywords:** Central Bank Preferences, Euro Area, Optimal Control, GMM.

**JEL classification:** E52, E58, C32, C61.

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# The Preferences of the Euro Area Monetary Policymaker

## 1. Introduction [1]

The purpose of this paper is to estimate the monetary policy preferences in the aggregate Euro Area. The loss function of the Euro Area policymaker is estimated with data on output gap, inflation, short-term interest rates, and imported inflation, assuming an optimising policy behaviour subject to a macroeconomic structure that can be modelled with a small aggregate-supply and aggregate-demand dynamic model. In addition to the challenging study of the aggregate Euro Area case, a more technical contribution of the paper is the use of a *quasi-real-time* output gap, notionally closer to the information available to policymakers when deciding policy, than the official *ex-post* gaps routinely used in research of, for instance, the U.S. FED preferences.

At this stage it is not yet possible to extract econometrically the parameters of the loss function of the European Central Bank (ECB), because of the scarcity of quarterly data since the launching in January 1999 of the European Monetary Union (EMU), and in view of the shortcomings of monthly data - excess of volatility and inability to parsimoniously account for the cyclical condition of the economy.

Instead of waiting for further data on policymaking by the ECB, we extend the estimation period as far back as possible in order to achieve a satisfactory estimation of the policy preferences. That is, in addition to the actual time of ECB's operation, we include a previous period during which it is reasonable to consider the group of central banks of the current EMU as if they were a single monetary authority. In this view, the preferences of this notional central bank, founded since 1992 in the consensus over the Maastricht criteria for EMU initial membership, are the driving force behind each country's monetary policy during the process of successful convergence towards January of 1999.

Within the time span between the Treaty and the actual Union, we determine the beginning of the estimation period - 1995 - through a combination of analysis of facts, data and literature. Facts are on European integration, data on the aggregate Area and its

[1] We thank comments and suggestions from Fabio Canova, and Richard Dennis for sharing the *Gauss* code of his study of the policy preferences of the US Federal Reserve.

main countries, and literature on the convergence of macroeconomic structures and cycles in the EMU countries.

The main findings are that this Euro Area policymaker sets interest rates aiming at an inflation target of around 1.6 percent, with no direct concern over output gap stabilisation, and significantly smoothing the policy instrument. This result is subject to some sensitivity checks, concerning the beginning date of the sample, the procedure for deriving the interest rate equation describing the central bank optimising behaviour, and the econometric technique used to estimate the model parameters.

The rest of the paper is outlined as follows. Section 2 reviews data, facts and literature in order to define the beginning of the sample for estimation of the monetary policymaker's preferences, and identifies a stable aggregate demand - aggregate supply structure of the Euro Area. Section 3 sets up the optimising model for monetary policy analysis, explains the estimation procedure, and presents the results for the Euro Area. In section 4 some sensitivity checks are conducted. Finally, Section 5 offers concluding remarks.

## 2. Macroeconomic Structure and Monetary Policy

This section inspects Euro Area and nation level data, as well as facts and literature, in order to establish since when it is reasonable to view the Euro Area as an homogeneous and stable macroeconomic entity, showing strong enough traces of a common, even if notional, monetary authority.

### Volatility, Structure and Monetary Policy

Along the last thirty years, the performance of the current Euro Area in terms of the main stabilisation policy objectives has changed markedly, as measurable by the aggregate time-series in the Area Wide Model Database (AWMD) of the ECB. Figure 1 illustrates this change, showing five years averages of the variability of quarterly inflation and output gap of the aggregate Area between 1972:I and 2002:IV around currently consensual desired levels – 2 percent of annual inflation and a null gap. While the volatility of aggregate inflation decreased systematically since the creation of the European Monetary System, in 1979, the figure suggests that the largest part of its fall has occurred during the 1980s. Furthermore, during the disinflationary period the volatility of the Area aggregate output gap increased, and in fact kept on increasing during the first half of the 90s. In contrast, the second half of the 90s and the first two years of the XXI$^{st}$ century witnessed a fall in the volatility of both inflation and the output gap of the aggregate Euro Area.

Figure 1 relates to the well-known Taylor's (1979) assertion that the transitory Phillips trade-off between the levels of inflation and unemployment gap implies a permanent trade-off between their variability around desired levels. As further developed by Taylor (1994) and Fuhrer (1997), the permanent variability trade-off depicts an efficiency policy frontier for any given monetary policy regime, which is negatively sloped and convex to the origin. Its locus depends on the policy regime and on the variability of the shocks hitting the economy, and its slope is a function of the structure of the economy, including the elasticity of the short-term Phillips curve. The optimal policy choice yields a specific combination in the efficiency frontier, which is a function of the relative weight attached to inflation and activity gap volatility in the policymaker's loss function. The distance between actual macro performance and the frontier may be interpreted as a measure of the policy inefficiency.

Taken at face value, figure 1 seems to indicate a shift in policy preferences from output stabilisation to inflation stabilisation during the 80s, possibly together with some decline of supply shocks, and the existence of a stable regime during the second half of the 80s and first half of the 90s targeting a low rate of inflation. During the second half of the 90s and the two first years of the XXI$^{st}$ century the policy regime and/or the intensity of supply shocks may have changed further, leading the Area to remarkably low levels of volatility of both inflation and output gap.

However, suggestive as the picture may seem, it allows for a coherent interpretation of the aggregate Euro Area monetary policy preferences only if it is not a spurious result of the aggregation of heterogeneous national macro structures, supply shocks, and/or monetary policy regimes. To this respect, the fact remains that the institutional economic and monetary union of the Area member states only exists since 1999:I, and there seems to exist no wide consensus as to when did the Area's national economies become homogeneous. In order to determine to what extent – *ie* since when – the information in figure 1 may actually be read within Taylor's framework, we now look at national data, at the main events of European monetary integration, and at results from the literature on convergence of structures and cycles in the Area countries. The section is then closed with tests for structural stability of a small macro model for the aggregate Area.

The charts in figure 2 show the variability of inflation and the output gaps, in periods comparable to those of figure 1, for 8 EMU member states – Austria, Finland, France, Germany, Italy, the Netherlands, Portugal and Spain – that together account for almost 95 percent of the aggregate Euro Area economic activity (see the weights used for computing the time-series in the AWMD in Fagan *et al*, 2001, p.53, Annex 2, table 2.1).[2] Nearly all the pictured countries share with the aggregate Area the fact that in the last two periods, 96:I-00:IV and 01:I-02:IV, the volatility of both inflation and the output gap fell, attaining their historically smallest levels. The only clear exception to this rule is France, which experienced a visible increase in the output gap volatility, when compared to the previous 86:I-90:IV and 91:I-95:IV periods, but still preserving very small levels of inflation volatility – while the increase in the Netherlands inflation volatility is negligible. The dispersion (standard deviation) between the volatilities of these 8 countries' output gaps fell from around 15 in the 70s to around 11 in the 80s, 6.6 in 91-95, 3.6 in 96-2000 and 1.4 in 2001-02. The dispersion between the volatilities of inflation increased up to 10.2 in 86-90, but then fell sharply to 1.2 in 91-95, 0.6 in 96-2000 and 0.4 in 2001-02. Overall, the national data support the pattern shown in figure 1 for the aggregate Euro Area. We then conclude that it is not a spurious result, but rather a group one, at least since the mid-90s.

The events in European integration further strengthen our conclusion of harmonization of nation-level macroeconomic volatilities during the 90s. All along the first half of the 90s, the European Single Market has been deepening economic integration between the Union member states. After March 1995 there has been no parity realignments in the exchange-rate mechanism of the European Monetary System, and the actual fluctuation of market exchange rates inside their theoretical bands has been almost imperceptible, especially since 1996. Given that capital movements in the European Union had been fully liberalised by 1992 – see European Commission (1997,

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[2] Ireland, Luxembourg and Greece were not pictured because of insufficiency of data, and Belgium because of problems with the data resulting in difficulties in fitting the Hodrick-Prescott filter that has been used to detrend output for all the countries. The original time series are the quarterly GDP deflator and real output (both with basis 1995=100) published by the International Monetary Fund in its International Financial Statistics.

pages 25-46 and Appendix C) – the exchange rate stability means that monetary policy has been *de facto* unified from the mid-90s.

The recent literature on the synchronisation of business cycles in the Euro Area seems to confirm a significant economic harmonization within the Area. Agresti and Mojon (2001) find nation-level cycles of quarterly real GDP that very significantly correlate with the aggregate Area cycle throughout 1972-98 and that, moreover, practically overlap the aggregate cycle since the mid-90s, with the exception of a very small number of periphery countries. Luginbuhl and Koopman (2003) model the convergence in per capita real GDP of Germany, France, Italy, Spain and the Netherlands as a gradually evolving unobserved variable, and find that the growth component converged by 1985, the cycle component converged by 1990, and the overall variance had reached half of convergence by 1995. Artis *et al* (1999) find high correlations between the smoothed probabilities of changes in the growth rate of monthly industrial production of the individual Area countries, except for the UK, during the last three decades of the XX$^{th}$ century, and estimate an aggregate Area cycle. Artis *et al* (2003) compare results from several alternative methods and time-series and, notably, find a systematic tendency for the cross-sectional dispersion of the industrial production cycles of the Area countries to shrink over time, arriving at very low dispersions during the second half of the 1990s.

The analysis so far suggests that a common macroeconomic structure for the aggregate Euro Area may be well defined since the mid-90s. In order to identify it and determine its beginning as a stable structure, we next formulate a small dynamic macro model and test its stability with Euro Area data spanning from 1972 until 2002.

**Aggregate Demand - Aggregate Supply**

The structure of the Euro Area aggregate economy is modelled as a simple backward-looking aggregate demand - aggregate supply system similar to the one applied by Rudebusch and Svensson (1999) to US data, where aggregate demand is an IS equation expressed in terms of output gap, and aggregate supply is an expectations augmented Phillips equation.

Rudebusch and Svensson's motivation for using this model was threefold: tractability and transparency of results; good fit to recent US data; and proximity to many policymakers' views about the dynamics of the economy, and to the spirit of many policy-oriented macro-econometric models, including some used by central banks. In addition, we have three reasons of our own.

First, it has been widely used in recent empirical studies of monetary policy rules or regimes. That is the case, among many others, of Favero and Rovelli (2003), Dennis (2003), and, for European countries, Peersman and Smets (1999), Taylor (1999), and Aksoy *et al* (2002). While the intensive use does not necessarily mean that the model entirely represents the structure of actual developed economies - see Cukierman (2001) -, it reflects, though, its sensible theoretical and empirical properties, from which Goodhart (2000) stresses the realistic inclusion of monetary transmission lags.

Second, even though most of the uses of the model relate to the US, it seems reasonable to expect the structure of the Euro Area to be broadly similar, since both are large and relatively closed economies – as argued, for instance, by Rudebusch and Svensson (2002). In support of this belief, Agresti and Mojon (2001) find that the business cycle of the aggregate Euro Area is similar to the US in several respects, and Angeloni *et al* (2002) show that the responses of the Area's output and inflation to monetary actions are quite close to those typically reported for the US. In fact, both Peersman and Smets (1999) and Taylor (1999) have successfully estimated this model with aggregate data of a core of EMU countries. Moreover, our assumption that the Euro Area may be studied following approaches already used for the US economy is also backed by analysis from alternative theoretical frameworks. For instance, Smets and Wouters (2003) estimate a dynamic structural general equilibrium model for both the US and the Euro Area over 1974-2002, finding remarkably similar characteristics in the two areas concerning the type of shocks, their propagation mechanisms, and the responses of monetary policy to shocks.

Third, the output gap series that we use has been computed within a system that features a similar Phillips equation - specifically, an unobserved components model with the Phillips and the Okun relation as measurement equations, see Aguiar and Martins (2003).

Following a thorough process using standard model identification criteria, we assume the following specific version of the Rudebusch-Svensson model:

$$\begin{cases} x_t = c_1 + c_2 x_{t-1} + c_3 x_{t-2} + c_4 x_{t-3} + c_5 (i_{t-3} - \pi_{t-3}) + \varepsilon_t^d \\ \pi_t = c_6 \pi_{t-1} + c_7 \pi_{t-2} + c_8 \pi_{t-3} + (1 - c_6 - c_7 - c_8) \pi_{t-4} + c_9 x_t + c_{10} (Im\pi_{t-1}) + \varepsilon_t^s \end{cases} \quad (1)$$

where the equations are, respectively, the IS function - aggregate demand, linking the output gap to its past and to real interest rate - and the Phillips function - aggregate supply, relating inflation to its past, the output gap and exogenous supply shocks. We impose dynamic homogeneity into the Phillips curve, as that hypothesis is not rejected in unconstrained estimation and has the advantages of reducing the number of coefficients, and comply more clearly with the natural rate hypothesis. Model (1) implies a transmission of monetary actions to the output gap similar to Peersman and Smets' (2001) and is compatible with Angeloni *et al*'s (2002) extensive reading of the evidence on the Euro Area transmission of policy.

The inflation rate - π - is the first difference of the log of quarterly GDP deflator, in percent, and the nominal short-term interest rate - i - is the quarterly average of the 3-month interest rate EURIBOR, in percentage points. The proxy for exogenous supply shocks is the lagged deviation of imported from domestic inflation - Imπ, in percentage points. The output gap - x, in percentage points - is computed as the actual quarterly real GDP minus a stochastic trend real output estimated in Aguiar and Martins (2003).

The data are quarterly time-series for 1972:I-2002:IV for the aggregate Euro Area. For inflation, interest rate and imported inflation the source is the European Central Bank: for the period 1970-1998, the data source is the Area Wide Model Database (AWMD) published in Fagan *et al* (2001), whilst for subsequent periods compatible updates are taken from several issues of the ECB Monthly Bulletin. The output gap has been estimated by the authors in a separate paper, with an unobserved components model estimated by maximum likelihood using the Kalman filter – see the data sources and other details in Aguiar and Martins (2003).[3] Still, it deserves further discussion here.

The output gap measure we use is not the end of sample estimate given by the Kalman smoother, but rather the estimate given by the filter updating equations at each period. Thereby, this output gap series can be interpreted as *quasi real-time* estimates, as each output gap is the optimal estimate in each time period, given the identified

[3] All data and replication files are available from the authors upon request, including the Gauss codes for computing the output gap used as data in this paper.

model, but only using the information available up until that period.[4] We use these *quasi real-time* estimates of the gap because they are conceptually closer to the policymakers' real-time perceptions about the state of the economy than the *ex-post* official gap series available at the time of research that have typically been used by researchers estimating the US Federal Reserve policy preferences, like Favero and Rovelli (2003) and Dennis (2003).

Our preference for using gap estimates as close as possible to real-time data is motivated by recent literature showing that the assumptions about the timing of information gathering can be quite relevant for policy analysis. The importance of using data available to policymakers in *real-time* in *ex-post* evaluations of monetary policy has been profusely shown, for the US case, by Orphanides (2001a and 2002). Nelson and Nikolov (2001) also report a pattern of official real-time output gap misperceptions in the UK during the 70s similar to the one identified by Orphanides for the US. In both cases, the authors inspected the information actually used at the meetings of monetary policy committees.

Here, however, we cannot use proper real-time information, because, for almost the whole sample period, there is no aggregate Euro Area real-time statistical data and we are evaluating the policy of a notional central bank.[5] Hence the option for using the *quasi real-time* approach explained above. Figure 3 illustrates, for our case, the discrepancies between *ex-post* and *quasi real-time* estimates, showing the output gap series given by the Kalman smoother and the series given by the Kalman filter.

In order to determine the beginning date of a stable macroeconomic structure in the Euro Area we test the stability of system (1) over the entire sample. As there is no precise *a priori* about the timing of possible structural breaks, one appropriate test is based on Andrews' (1993, equations 4.1 and 4.2, page 835) sup-Wald statistic. Figure 4 reports the results of this test, for a joint full information maximum likelihood

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[4] Assuming that the policymaker uses our trend-cycle decomposition model and limits its information to the series in the model, there are essentially two differences between our quasi real-time estimates and strict real-time estimates. First, real-time estimates are published with a lag and are subject to subsequent revisions. Second, real-time estimates may be affected by changes in the model identification and parameter estimates.

[5] Coenen et al. (2001) study the profile of revision of the main macroeconomic variables in the Euro Area during 1999 and 2000, using the numbers published in the ECB Monthly Bulletin - an approach that may be highly helpful in future research on EMU policymaking with real-time data.

estimation of the system with the standard 15 percent trimming. The null hypothesis of no structural change is rejected, at the usual significance level of 5 percent.

Next, we set out to estimate the dates of structural break. Due to the well-known problems with the Wald test for such a task, we follow Hansen's (2001) suggestion, which consists of identifying the sample split that minimises the sum of the standard errors of the regressions of the two sub-samples, before and after the break date. As figure 5 shows, it turns out that the dates of structural breaks in both the IS and the Phillips equation are estimated at near the end of 1994 – respectively 1994:IV and 1994:III – with no signs of any other breaks.

Hence, within this data set, we conclude that system (1) is structurally stable in the Euro Area as of 1995:I. This finding is quite consistent with the analysis of aggregate and national data in figures 1 and 2, as well as with the events of economic and monetary integration and the results on business cycle convergence elsewhere in the literature.

Now that a stable macro structure has been identified, the paper sets out to estimate the policy preferences of the Area's policymaker, assuming an optimising behaviour constrained by the macro structure (1), during 1995:I-2002:IV. If well-defined monetary policy preferences are successfully estimated, two suggestions are to be drawn. First, the common policy preferences have a role in explaining the fall in output gap and inflation volatility at the mid-90s. Second, the estimated preferences are the ones taken by the ECB, meaning that in spite of the institutional change at 1999 there seems to exist no discontinuity in the conduct of monetary policy. The hypothesis of a notional monetary regime since 1995 - anticipating the formal 1999 EMU - is compatible with arguments put forth previously, although in a different context, by McCallum (1997), who noted that in many episodes of monetary history institutional changes lag behind actual policy changes.

## 3. Estimating the Policy Preferences of the Euro Area policymaker

In this section, after specifying the central bank loss function, the optimisation problem faced by the policymaker, and its solution, are presented. Then, the econometric technique is described, and the main results are reported. We follow Favero and Rovelli (2003) deriving the optimality conditions for the policy instrument – short-term interest rate – using optimal control, and then jointly estimating the interest rate equation with the dynamic macro structure of the economy by GMM.

**Central Bank's Preferences**

Following fairly standard assumptions in the literature, we model central bank's preferences as an intertemporal loss functional. In each period the loss function is quadratic in the deviations of inflation and the output gap from their desired levels ($\pi$* and zero, respectively), as well as in the change in the interest rate, which is the policy instrument. Future values are discounted at rate $\delta$, and the weights $\lambda$ and $\mu$ are nonnegative.

$$L_t = E_t \sum_{\tau=0}^{\infty} \delta^{\tau} \frac{1}{2} \left[ (\pi_{t+\tau} - \pi^*)^2 + \lambda x_{t+\tau}^2 + \mu (i_{t+\tau} - i_{t+\tau-1})^2 \right] \tag{2}$$

The inclusion of the output gap variability in $L$ is generally considered compatible with the statutes of modern central banks, such as the US Fed. Even inflation targeting regimes, which have a formally quantified commitment to price stability, have a second order objective concerning growth and employment - see Svensson (2003). However, the ECB statutes, similarly to the Bundesbank's, are not entirely clear on the significance that real activity stabilisation has in its legal mandate, as they merely state in the 2$^{nd}$ article of its Chapter II, that (ECB, 2002, page 2)

> "[…] the primary objective of the ESCB shall be to maintain price stability. Without prejudice to the objective of price stability it shall support the general economic policies in the Community […]"

The ECB Governing Council, when announcing its stability-oriented monetary policy strategy, established that (ECB, 1998, article 2º)

> "As mandated by the Treaty establishing the European Community, the maintenance of price stability will be the primary objective of the ESCB. Therefore, the ESCB's monetary policy strategy will focus strictly on this objective."

This led some authors - for instance, Goodhart (1998) - to argue that output is not supposed to enter the true ECB objective function. In general, McCallum (2001a) also argues that, for uncertainty reasons, monetary policy should not respond strongly to output gaps. All summed-up, we specify our baseline loss, $L$, as a flexible inflation targeting regime, which nests the strict inflation targeting case - no concern with the variance of the gap -, letting the evidence discriminate which of these systems better fits the revealed preferences of the Euro Area policymaker.

In what concerns the inclusion of the changes in the interest rate, we follow a relatively standard practice in the empirically oriented literature, which is to consider that the policymaker also dislikes variations in the policy instrument - the so-called interest rate smoothing. Even though theoretical central bank loss functions do not include the instrument as part of the final goals of policy, the fact is that optimal interest rates simulated from models with such loss functions are substantially more volatile than actual short-term interest rates - Sack (2000). Central banks seem to prefer to change interest rates in small discrete steps in the same direction over extensive periods, and reverse their path infrequently - for a review see Sack and Wieland (2000).[6] Although several authors have argued that the evidence of policy inertia has little structural content, mostly reflecting econometric problems - see Rudebusch (2002), for instance -, recent simulations and estimations in Favero (2001) and English *et al.* (2002) reiterate the evidence in favour of intentional smoothing.

Before proceeding to the optimisation solution and the estimation, a brief reference to the exclusion of money and exchange rates is in order. Following the currently consensual monetary policy analysis framework - see McCallum (2001b) -, no monetary aggregate is included in our model, implying that money is neither an instrument nor an intermediate target of policy.[7] As a result, though, the estimates should be interpreted with some caution, since no distinction between money supply and money demand surfaces in the model and, thus, some coefficients may be reflecting mixed effects from demand and policy changes.

As for the absence of an exchange-rate variable as an intermediate or final target, it is grounded in two arguments. On one hand, exchange rates are likely to matter less in a policy rule of a large and relatively closed economy like the Euro Area than in a small open economy - see Peersman and Smets (1999). On the other hand, the evidence in Clarida and Gertler (1997) indicates that the Bundesbank's concerns with the DMark

[6] Further motivations for interest rate smoothing are put forward by Goodhart (2000) and Rudebusch (2001).

[7] This is seemingly at odds with the ECB first pillar, which is a monetary aggregate growth targeting - see ECB (1998). However, several recent studies have found no evidence that money has been relevant in the ECB's policy decisions - Mihov (2001) and Begg *et al.* (2002).

exchange-rate when conducting monetary policy were essentially related to its importance as a determinant of domestic inflationary pressures rather than as a final target *per se*. This seems to be the case for the ECB as well, as recently put forward by Gaspar and Issing (2002). And this role of the exchange-rate as determinant of inflationary pressures is already implicitly considered in our model, through the lagged deviation of imported from domestic inflation.

**Estimating Policymakers' Preferences**

For the sake of realism and estimation feasibility, we circumscribe the optimisation problem to a discretionary policy regime, in which the policymaker solves for the optimal closed-loop system, *ie* sets its policy sequentially, in each period, given the then observed state of the economy. In this case, the monetary authority chooses in each period the interest rate that minimises the loss functional subject to the dynamic economic structure:

$$Min(L_t) = \underset{i_t}{Min}\, E_t \sum_{\tau=0}^{\infty} \delta^{\tau} \frac{1}{2} \left[ (\pi_{t+\tau} - \pi^*)^2 + \lambda x_{t+\tau}^2 + \mu (i_{t+\tau} - i_{t+\tau-1})^2 \right], \quad \forall t \tag{3}$$

subject to system (1).

As the policy control variable is the short-term interest rate, the solution is an expression describing the optimal interest rate as function of the state variables of the system. Once supplemented by an innovation, that expression joins the system describing the dynamics of the economy, and estimation of the structural parameters of the model may be carried out.

The approach devised by Favero and Rovelli (2003) is based on the Euler equation of the system – the first order condition -, which in this case takes the form

$$E_t \sum_{\tau=0}^{\infty} \delta^{\tau} \left[ (\pi_{t+\tau} - \pi^*) \frac{\partial \pi_{t+\tau}}{\partial i_t} \right] + E_t \sum_{\tau=0}^{\infty} \delta^{\tau} \lambda \left[ x_{t+\tau} \frac{\partial x_{t+\tau}}{\partial i_t} \right] + \left[ \mu (i_t - i_{t-1}) - \mu \delta E_t (i_{t+1} - i_t) \right] = 0 \tag{4}$$

This equation is then truncated at four quarters ahead, and the partial derivatives in it are expanded and written as function of the relevant aggregate-supply and aggregate-demand coefficients in (1). At this stage, the expression of the first-order condition conveniently includes the cross-equation restrictions of the system, ensuring that the loss function is properly minimised subject to the constraints given by the economy structure. Further supplemented with an innovation, the Euler equation, in estimation form, becomes

$$\begin{aligned}&\delta^3 E_t(\pi_{t+3}-\pi^*)[c_9.c_5]+\delta^4 E_t(\pi_{t+4}-\pi^*)[c_9.c_2.c_5+c_6.c_9.c_5]+\\&\lambda\delta^3 E_t x_{t+3}[c_5]+\lambda\delta^4 E_t x_{t+4}[c_2.c_5]+[\mu(i_t-i_{t-1})-\mu\delta E_t(i_{t+1}-i_t)]+\varepsilon_t^p=0\end{aligned} \tag{5}$$

Favero and Rovelli justify truncation at four quarters with two arguments. First, discounting in the infinite-horizon loss function means that expectations about the state of the economy carry less relevant information for the present conduct of policy, as they relate to periods further ahead. Second, expanding the horizon would complicate the equation and bring collinearities to the system, causing great difficulties to estimation. We argue, in addition, that the four-quarter forecast horizon seems to be in line with the forecasting needs and abilities of real world policymakers - see, for instance, the macroeconomic projections in IMF (2001), and in the Greenbook available at each FED open market committee meeting as discussed in Perez (2001). Moreover, evidence from estimated policy rules suggests that actual policy involves forecast horizons of inflation not beyond four quarters – see, for example, Orphanides (2001b).

Equation (5) is jointly estimated with system (1), generating estimates of the coefficients describing the monetary policy regime - $\mu$, $\lambda$, and $\pi^*$ - as well as of the aggregate-demand and aggregate-supply coefficients, and the system's innovations. Because expectations are replaced by actual observations, estimation uses GMM, as it seems reasonable to assume that policymakers use efficiently the information available when forming expectations. We use the second, third and fourth lags of all the system's variables as instruments, and base inference in a heteroescedasticity and auto-correlation-consistent variance-covariance matrix.[8] Employing this method in the more restricted loss function of strict inflation targeting with interest rate smoothing is straightforward, setting $\lambda$ to zero in equation (5).

Table 1 summarises the results of estimation, both for a central bank loss function of flexible (left-hand side) and of strict inflation targeting (right-hand side).

[8] The system is first pre-whitened, and then a Bartlett Kernel is used to weight the auto-covariances, with a Andrews estimator of the bandwith. We employ the two-step estimator, which is a one-step weighting matrix version of GMM. Covariance estimation is difficult in cases, like ours, of serially correlated moment conditions and small samples - see Hansen *et al* (1996) and the other articles in that special edition of the Journal of Business and Economic Statistics (vol. 14, n. 3). The choice of GMM estimator draws largely upon Florens *et al*'s (2001) Monte Carlo results indicating that the two-step estimator generates estimates close to maximum likelihood and is not strongly biased in the estimation of forward-looking Taylor rules.

The key coefficients of the structural equations – the aggregate-demand and aggregate-supply slopes, representing the sensitivities of the gap to the real interest rate and of inflation to the output gap - are estimated with the expected signs, reasonable magnitudes, and quite good precision. In addition, they do not change markedly when flexible inflation targeting is replaced by strict inflation targeting. In terms of magnitude, the estimates are close to those found by Smets (2003) with a different sample of aggregate Euro Area data.

The real equilibrium interest rate - given by $c_1/(-\ c_5)$ - is estimated at around 2.1 percent, which is compatible with the conventional wisdom on the long-run economic growth attainable in the Euro Area.

As to the parameters revealing the preferences of the monetary policymaker, the inflation target - $\pi^*$ - and the relative weight of interest rate smoothing - $\mu$ – are reasonably and precisely estimated. In contrast, the weight of the output gap in the loss function - $\lambda$ in the left-hand side of table 1 - is not statistically significant. Thus, the hypothesis of flexible inflation targeting is rejected in favour of strict inflation targeting.

In short, this model successfully extracts the preferences of the Euro Area policymaker throughout 1995-2002 - inflation targeting at around 1.6 percentage points, no direct concern for stabilisation of the output gap, and significant smoothing of the policy instrument.

## 4. Sensitivity Checks

This section reports two sensitivity exercises to which we submitted the results, the first one concerning the beginning date of the notional monetary policy regime, and the second using an alternative method of solution and estimation.

### Sensitivity to the date of emergence of the monetary policy regime

In view of the non-institutional basis for identification of 1995:1 as the beginning date of the Euro Area notional policy regime, it is prudent to check the sensitivity of the preferences parameters to changes in the starting quarter of the sample period.

Figure 6 shows the main results for all possible samples ending in 2002:IV and beginning from 1992:I to 1995:IV. The check does not proceed after 1995:IV due to the reduced number of observations.

The first chart in the figure reveals that the weight of interest rate smoothing in the central bank loss function, $\mu$, is not well estimated before 1994:IV. In the samples beginning at that and subsequent quarters, the p-value remains within acceptable levels and the estimates concentrate in the short range from 0.0265 to 0.03.

The second chart in figure 6 – which does not picture the p-values because the estimates are always significant - shows the inflation target oscillating around 1.6 in the samples beginning at 1993:I and thereafter. The apparent decline of the inflation target estimates throughout the samples beginning between 1992:I and 1993:I suggests that the framework has a good capability of capturing the intensity of the disinflation policies towards the EMU in the first half of the 90s.

Overall, the checks in figure 6 essentially imply that we could not have begun our sample period more than a quarter before 1995:I, and that if we had chosen to begin estimation at 1994:IV or any of the subsequent quarters through 1995:IV, the estimated policy preferences would be quite similar to those in table 1.

**An alternative solution with maximum likelihood estimation**

The optimal control solution to the policymaker's optimisation problem yields an Euler equation that requires lead-truncation in order to be usable in estimation, which has been done in section 3 above. We now check the robustness of the results to an alternative method that does not need truncation.

We follow the dynamic programming – maximum likelihood procedure recently designed by Dennis (2003) after the inverse control strategy used by Salemi (1995). This method is based on the result that with a quadratic objective function and linear stochastic constraints, the policymaker's optimisation fits into the stochastic linear regulator problem, and, as such, Chow's (1997) Lagrangean solution applies.

The Lagrangean solution yields an optimal linear policy rule, which in this case takes the form

$$i_t = g_0 + g_1\pi_t + g_2\pi_{t-1} + g_3\pi_{t-2} + g_4\pi_{t-3} + \\ g_5 x_t + g_6 x_{t-1} + g_7 x_{t-2} + g_8 i_{t-1} + g_9 i_{t-2} + g_{10} Im\pi_t \quad (6)$$

where the coefficients $g$ are functions of the macroeconomic structural parameters in (1) and of the central bank's preferences in (2) - see Chow (1997, sections 2.3-2.4, pages 22-25.

Dennis' (2003) procedure consists of a sequence of steps involving a component of dynamic solution and another of estimation. At each step, the solution component consists of solving for the optimal linear policy rule (6), given starting values of the structural coefficients $c_1$ through $c_{10}$ in (1) and $\lambda$ and $\mu$ in (2). Then, in the estimation component, this optimal policy rule, supplemented with an innovation, joins the aggregate demand and aggregate supply equations (1), in a three equations system, from which all the structural coefficients of the model - macroeconomic and preferences - are re-estimated by full information maximum likelihood. Solution and estimation are sequentially repeated until satisfactory convergence is attained.[9]

The inflation target $\pi^*$ can be computed from the final optimal policy rule coefficients in steady-state (*ie* with $x_t$=0), given that the nominal equilibrium interest rate equals the sum of $\pi^*$ with the real equilibrium interest rate – given by $c_1/(- c_5)$. In the case of strict inflation targeting, $\lambda$ is set to zero in the solution equations leading to the optimal linear policy rule.

Table 2 reports the results of estimation of the model both for flexible and strict inflation targeting, with interest rate smoothing.[10]

As in table 1, the left-hand side of table 2 rejects the hypothesis of flexible inflation targeting in the Euro Area, since the output gap weight - $\lambda$ - is not statistically significant.

The right-hand side of table 2 confirms our previous results that a central bank loss function of strict inflation targeting with interest rate smoothing ($\mu$ becomes statistically significant) fits well the aggregate Euro Area monetary policymaking. Furthermore, the estimates of the inflation target ($\pi^*$ = 1.5 percent) and the real equilibrium interest rate ($r^*$ = 2.2 percent) are quite close to those reported in table 1. In

[9] We have used Richard Dennis' Gauss code as the basis for ours', which implements the numerical solution by linear approximations described in Chow (1997).

[10] Due to the convergence requirements of the method, the sample must include four additional periods - 1994:I through 1994:IV.

contrast, the estimate of the relative weight of interest rate smoothing - $\mu$ - differs substantially from the one in table 1. This discrepancy may be caused by differences in the solution procedures - such as the truncation -, or in the estimation methods. Its explanation, however, is beyond the scope of this paper – see Dennis (2003) and Soderlind *et al* (2002) for some discussion of the US case.

## 5. Concluding Remarks

This paper estimated the aggregate monetary policy preferences in the Euro Area in the form of a loss function with strict inflation targeting at 1.6% and interest rate smoothing.

Through a combined analysis of facts, data and literature on European integration, the paper has identified 1995 as the beginning date of a Euro Area notional policy regime, in the sense that it is reasonable to consider the group of central banks of the current EMU as if they were already a single monetary authority. In this view, the common policy preferences have a role in explaining the fall in the volatility of both the output gap and inflation since the mid-nineties.

Our strategy of going as far back as possible into the pre-EMU years, instead of waiting for more evidence of ECB policymaking, seems to have been fruitful. Of course, its validity will be further put to test once enough new data allow for the estimation of strictly post-1999 monetary policy preferences.

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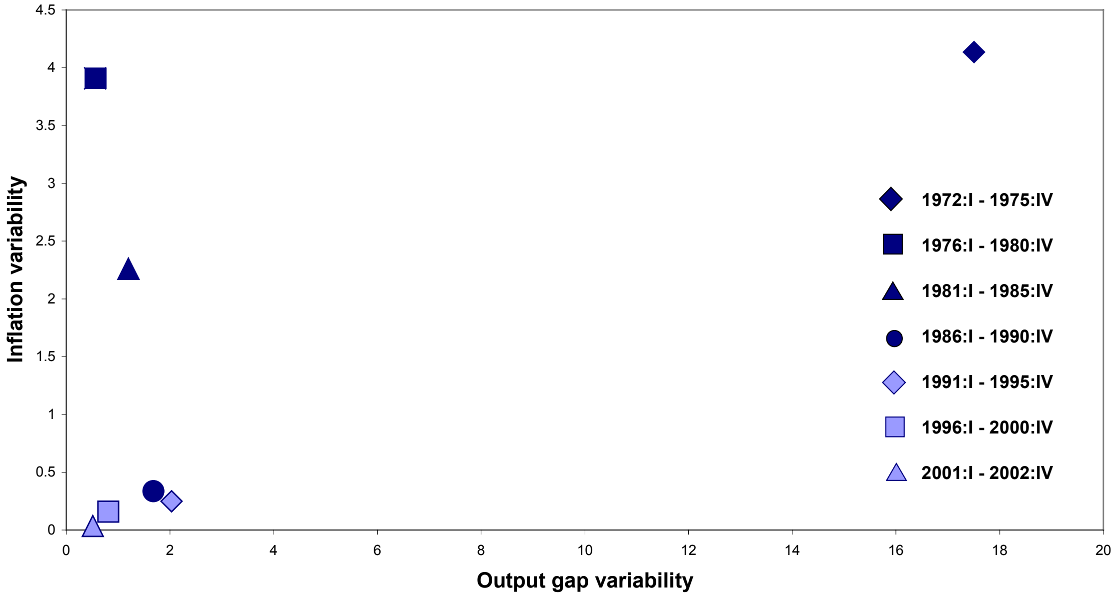
# Figure 1. Macroeconomic Volatility in the Aggregate Euro Area 1972:I-2002:IV

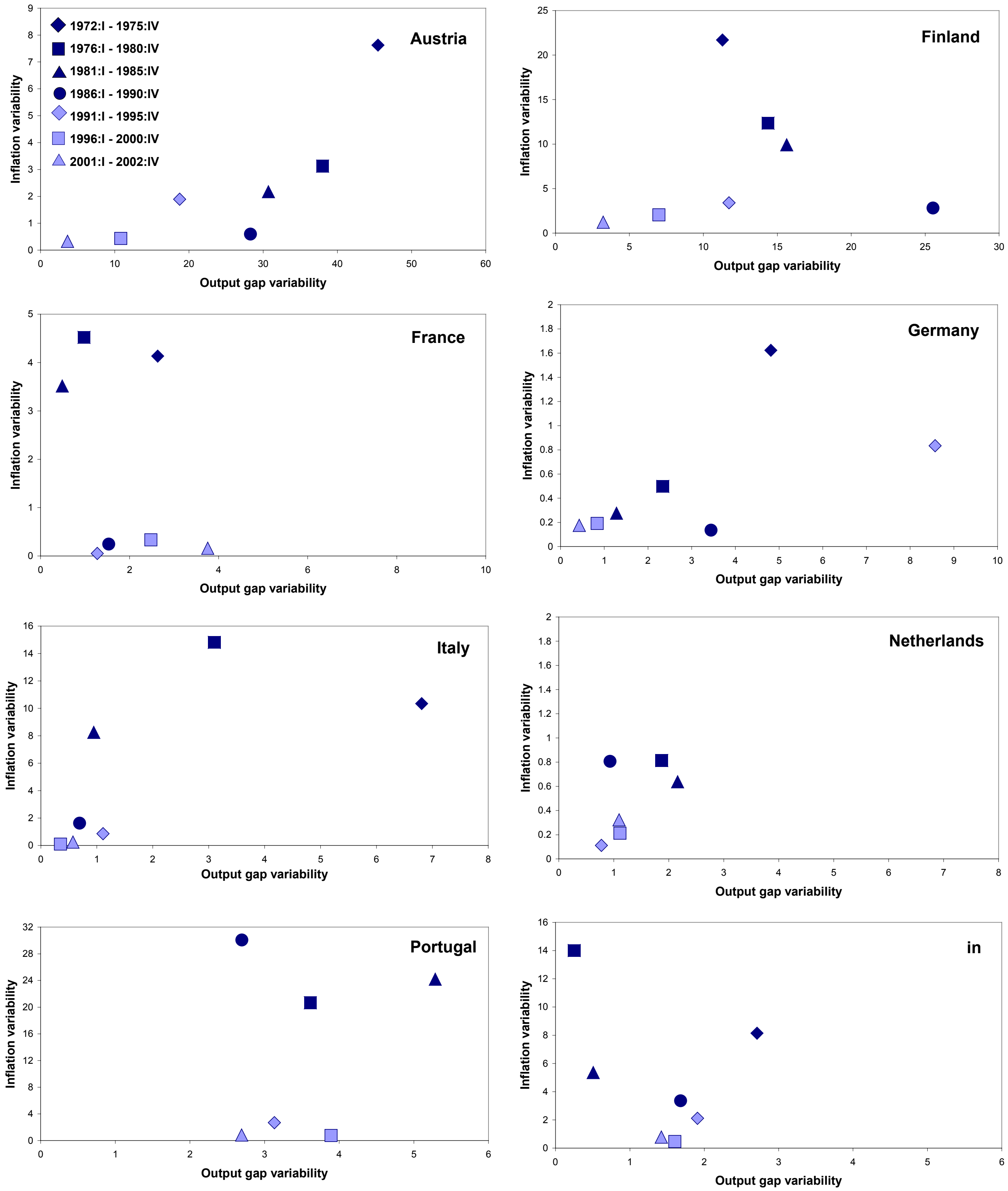



Notes: Data sources - Area Wide Model Database (AWMD, published in Fagan *et al*, 2001), European Central Bank Monthly Bulletin, and authors' calculations.

Inflation variability is the average of the square deviations of the quarterly inflation rate from 0.5 (2 percent annual inflation). The inflation rate is the first difference of the log of the GDP deflator.

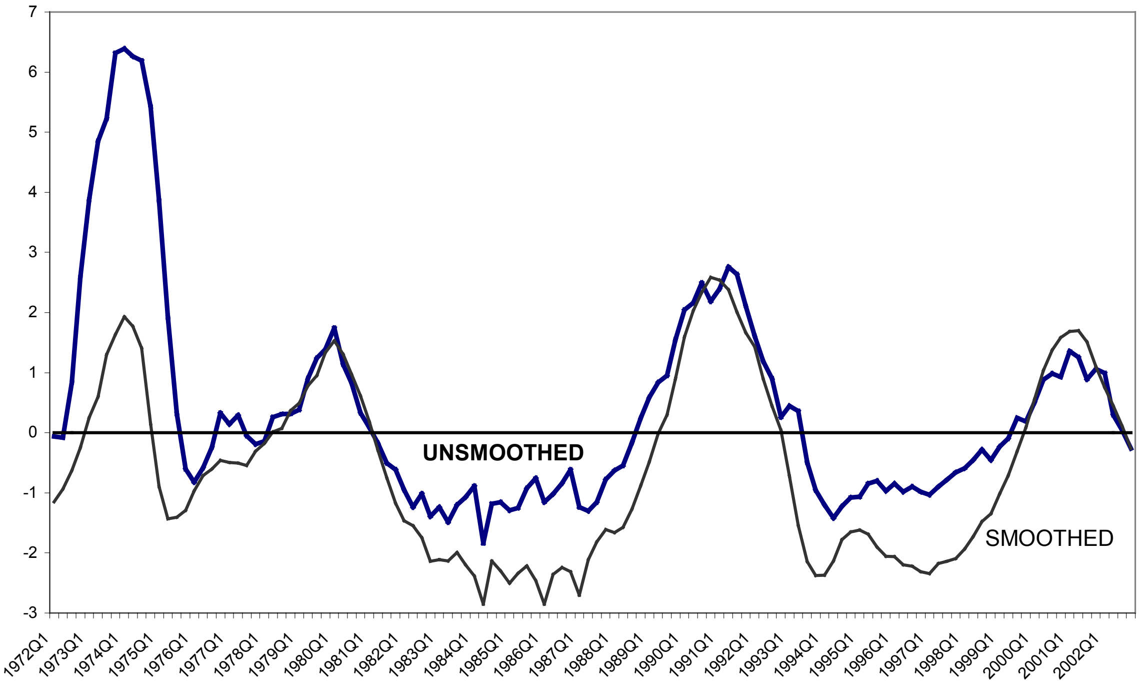
Output gap variability is the average of the square deviations from zero of the quarterly output gap, in percent. The output gap has been computed with a trivariate unobserved components model of stochastic NAIRU and trend GDP - see Aguiar and Martins (2003).

## Figure 2. Macroeconomic Volatility in Euro Area Countries, 1972:I-2002:IV



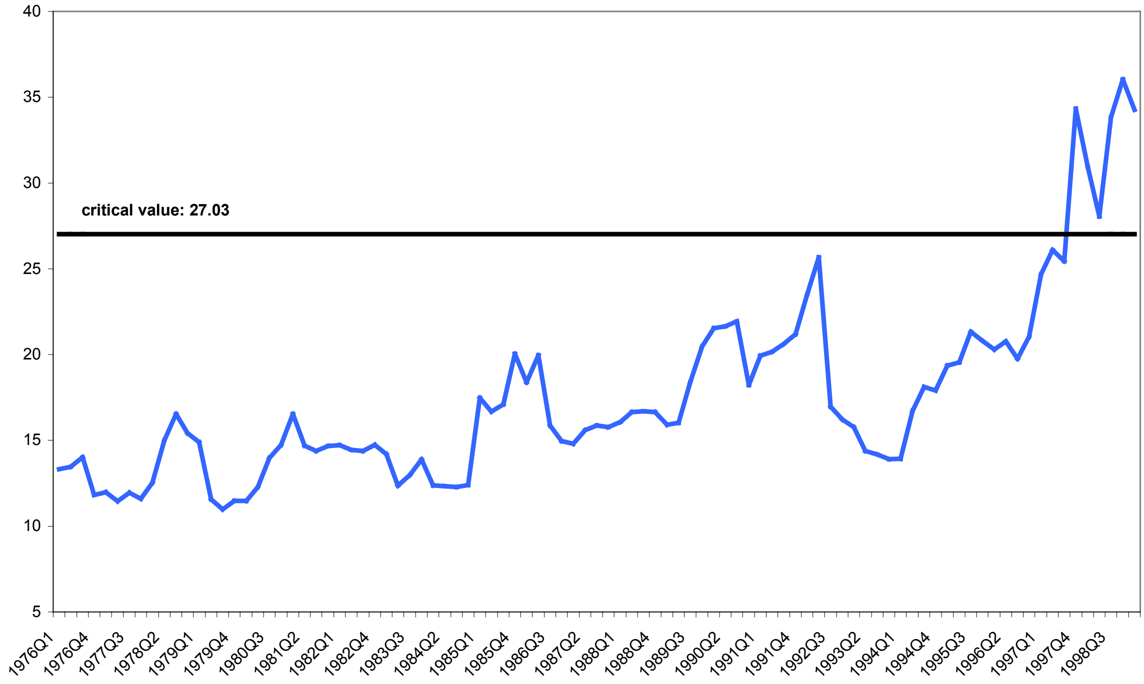

Notes: Data sources – International Financial Statistics of the International Monetary Fund, and authors' calculations. Inflation variability is the average of the square deviations of the quarterly inflation rate from 0.5 (2 percent annual inflation). The inflation rate is the first difference of the log of the GDP deflator (IFS, 1995=100). Output gap variability is the average of the square deviations from zero of the quarterly output gap, in percent. The gap is the deviation, in percent, of real output (IFS, 1995=100) from its trend, which has been computed with the Hodrick-Prescott filter (λ=1600).

**Figure 3. Unsmoothed *versus* Smoothed Output Gap**
**Euro Area 1972:I-2002:IV**



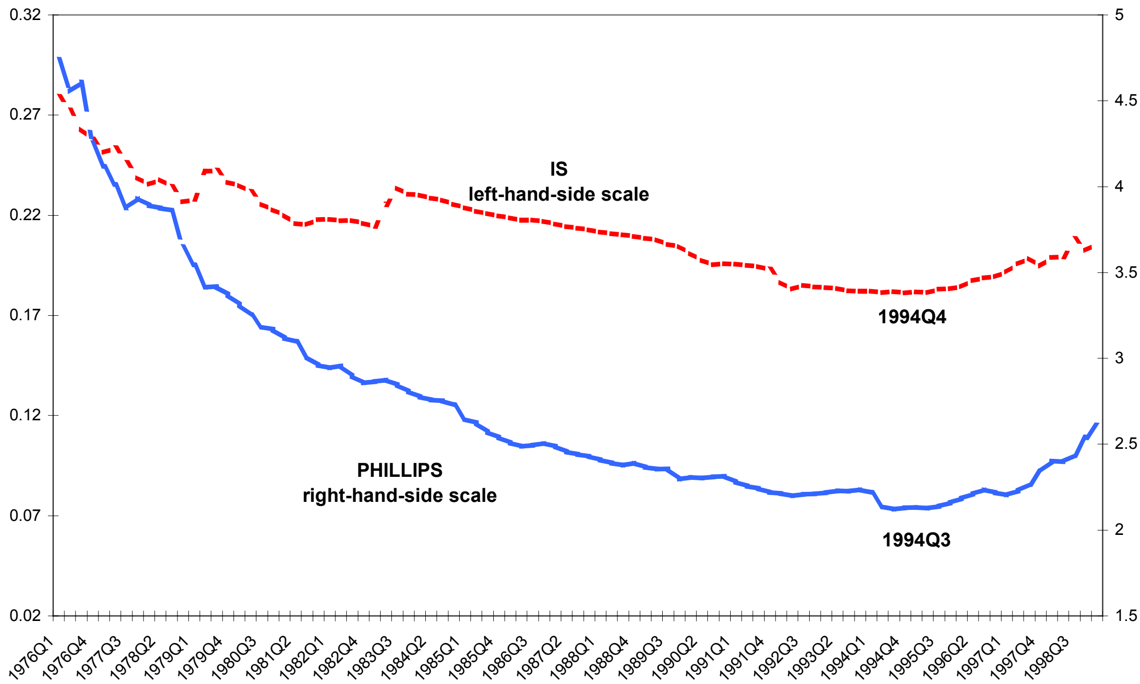

Notes: The unsmoothed line is the output gap estimates given by the Kalman filter (Harvey, 1989, equations 3.2.1 - 3.2.3, pages 105-106), while the smoothed line is the estimate given by the fixed-interval Kalman smoother (Harvey, 1989, equations 3.6.16, page 154).

**Figure 4. Test of the Stability of the Macroeconomic Structure**
**Euro Area 1972:I-2002:IV**



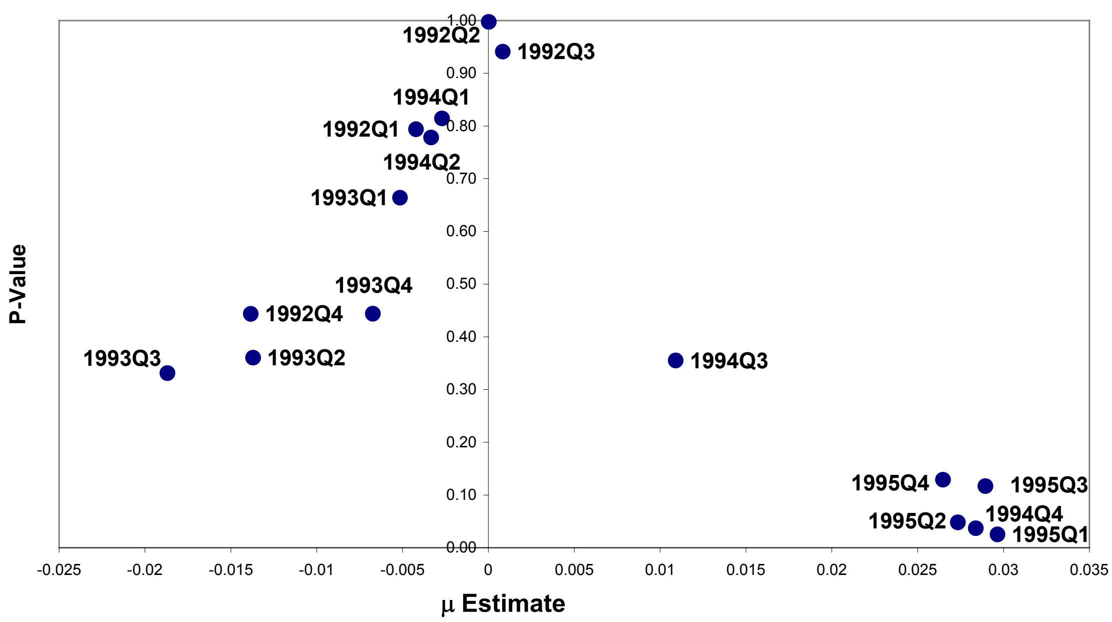

Notes: Andrews (1993) sup-Wald test for a pure structural break in the AS-AD system (1) estimated by FIML.
Critical value – Andrews (1993, table I, p. 840), model with 10 parameters, 15% of trimming and 5% significance.

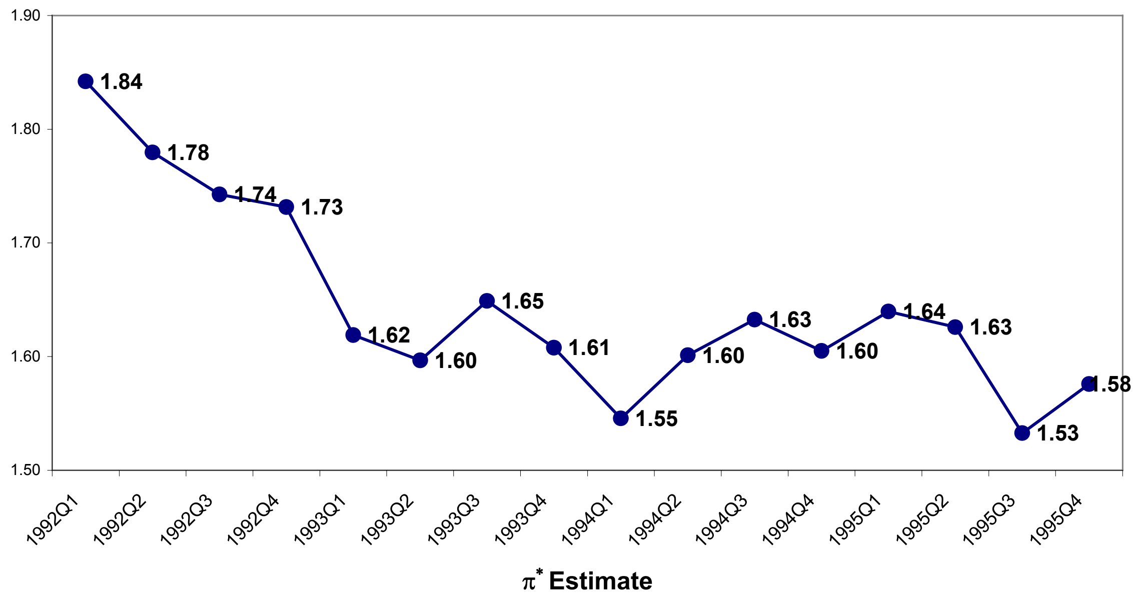
## Figure 5. Dating of Break in the Macroeconomic Structure
## Euro Area 1972:I-2002:IV




Notes: Hansen's (2001) break-date estimation for the AS-AD system (1) estimated by FIML.
Trimming - 16 obs (15%). Each point in a curve depicts the sum of the square standard errors of the regressions applied to two sub-samples obtained by splitting the sample at that quarter.

# Figure 6. Sensitivity to the Beginning Date of the Notional Monetary Policy Regime in the Euro Area




Notes: The dates are the beginnning of each sample period, which ends in 2002:IV.
Solution-estimation method – see notes to table 1.

## Table 1. Macroeconomic Structure and Policymaker's Loss Function Euro Area 1995:I-2002:IV

| | Flexible Inflation Targeting with Interest Rate Smoothing | | | Strict Inflation Targeting with Interest Rate Smoothing | | |
|---|---|---|---|---|---|---|
| | Estimates | T-stats | P-values | Estimates | T-stats | P-values |
| **AD** | | | | | | |
| $c_1$ | 0.183 | 5.35 | 0.00 | 0.180 | 5.83 | 0.00 |
| $c_2$ | 1.672 | 18.87 | 0.00 | 1.721 | 25.00 | 0.00 |
| $c_3$ | -0.540 | -5.29 | 0.00 | -0.530 | -5.20 | 0.00 |
| $c_4$ | -0.241 | -5.14 | 0.00 | -0.291 | -6.26 | 0.00 |
| $c_5$ | -0.088 | -6.25 | 0.00 | -0.084 | -6.74 | 0.00 |
| $\sigma(\varepsilon^{AD})$ | 0.256 | | | 0.260 | | |
| **AS** | | | | | | |
| $c_6$ | 0.460 | 4.78 | 0.00 | 0.438 | 6.56 | 0.00 |
| $c_7$ | -0.127 | -1.63 | 0.11 | -0.082 | -1.16 | 0.25 |
| $c_8$ | 0.381 | 6.55 | 0.00 | 0.380 | 6.66 | 0.00 |
| $c_9$ | 0.136 | 2.75 | 0.01 | 0.145 | 3.16 | 0.00 |
| $c_{10}$ | 0.164 | 9.00 | 0.00 | 0.170 | 9.60 | 0.00 |
| $\sigma(\varepsilon^{AS})$ | 1.123 | | | 1.147 | | |
| **CB Loss** | | | | | | |
| $\pi^*$ | 1.496 | 9.95 | 0.00 | 1.640 | 12.62 | 0.00 |
| $\lambda$ | -0.026 | -0.74 | 0.46 | -- | -- | -- |
| $\mu$ | 0.028 | 1.88 | 0.06 | 0.030 | 2.28 | 0.03 |
| $\sigma(\varepsilon^{IR})$ | 0.034 | | | 0.034 | | |
| **r*** | 2.069 | | | 2.142 | | |
| **J Statistic** | 0.612 | 19.57 | 0.81 | 0.704 | 22.52 | 0.71 |

Notes: Discount factor - $\delta = 0.975$.
Optimal control solution - (two-step) GMM estimation.
HAC variance-covariance matrix - pre-whitening, Bartlett kernel, Andrews bandwidth.
[Prob.] - one-sided significance probabilities.
J Statistic – value function (1st column), ×nobs (2nd column).
$\varepsilon^{IR}$ - residuals of the Euler equation.
Instruments - constant, $\Delta\pi_{t-i}$, $x_{t-i}$, $i_{t-i}$, $Im\pi_{t-i}$, i=2, 3, 4.

## Table 2. Sensitivity to Dynamic Programming Solution - FIML Estimation

| | Flexible Inflation Targeting with Interest Rate Smoothing | | | Strict Inflation Targeting with Interest Rate Smoothing | | |
|---|---|---|---|---|---|---|
| | Estimates | T-stats | P-values | Estimates | T-stats | P-values |
| **AD** | | | | | | |
| $c_1$ | 0.066 | 1.35 | 0.09 | 0.102 | 1.63 | 0.05 |
| $c_2$ | 1.305 | 8.78 | 0.00 | 1.531 | 9.60 | 0.00 |
| $c_3$ | -0.199 | -0.95 | 0.17 | -0.333 | -1.37 | 0.09 |
| $c_4$ | -0.244 | -2.19 | 0.01 | -0.336 | -2.70 | 0.00 |
| $c_5$ | -0.029 | -2.15 | 0.02 | -0.046 | -2.41 | 0.01 |
| $\sigma(\varepsilon^{AD})$ | 0.214 | | | 0.236 | | |
| **AS** | | | | | | |
| $c_6$ | 0.824 | 4.28 | 0.00 | 0.902 | 4.62 | 0.00 |
| $c_7$ | -0.160 | -1.04 | 0.15 | -0.188 | -1.19 | 0.12 |
| $c_8$ | 0.372 | 2.35 | 0.00 | 0.378 | 2.32 | 0.01 |
| $c_9$ | -0.076 | -0.33 | 0.37 | 0.191 | 1.91 | 0.03 |
| $c_{10}$ | 0.133 | 5.95 | 0.00 | 0.137 | 6.40 | 0.00 |
| $\sigma(\varepsilon^{AS})$ | 1.013 | | | 1.027 | | |
| **CB Loss** | | | | | | |
| $\pi^*$ | 2.088 | -- | -- | 1.522 | -- | -- |
| $\lambda$ | -15.880 | -0.19 | 0.42 | -- | -- | -- |
| $\mu$ | -1.676 | -0.23 | 0.41 | 1.568 | 2.36 | 0.01 |
| $\sigma(\varepsilon^{IR})$ | 0.354 | | | 0.329 | | |
| $r^*$ | 2.278 | | | 2.239 | | |

Notes: Discount factor - $\delta = 0.975$.
Dynamic programming solution - FIML estimation.
Sample - Aggregate Euro Area 1994:I-2002:IV.
Variance-covariance matrix - inverse of the square-root of the Information Matrix.
[Prob.] - one-sided significance probabilities.
$\varepsilon^{IR}$ - residuals of Optimal Policy Rule.