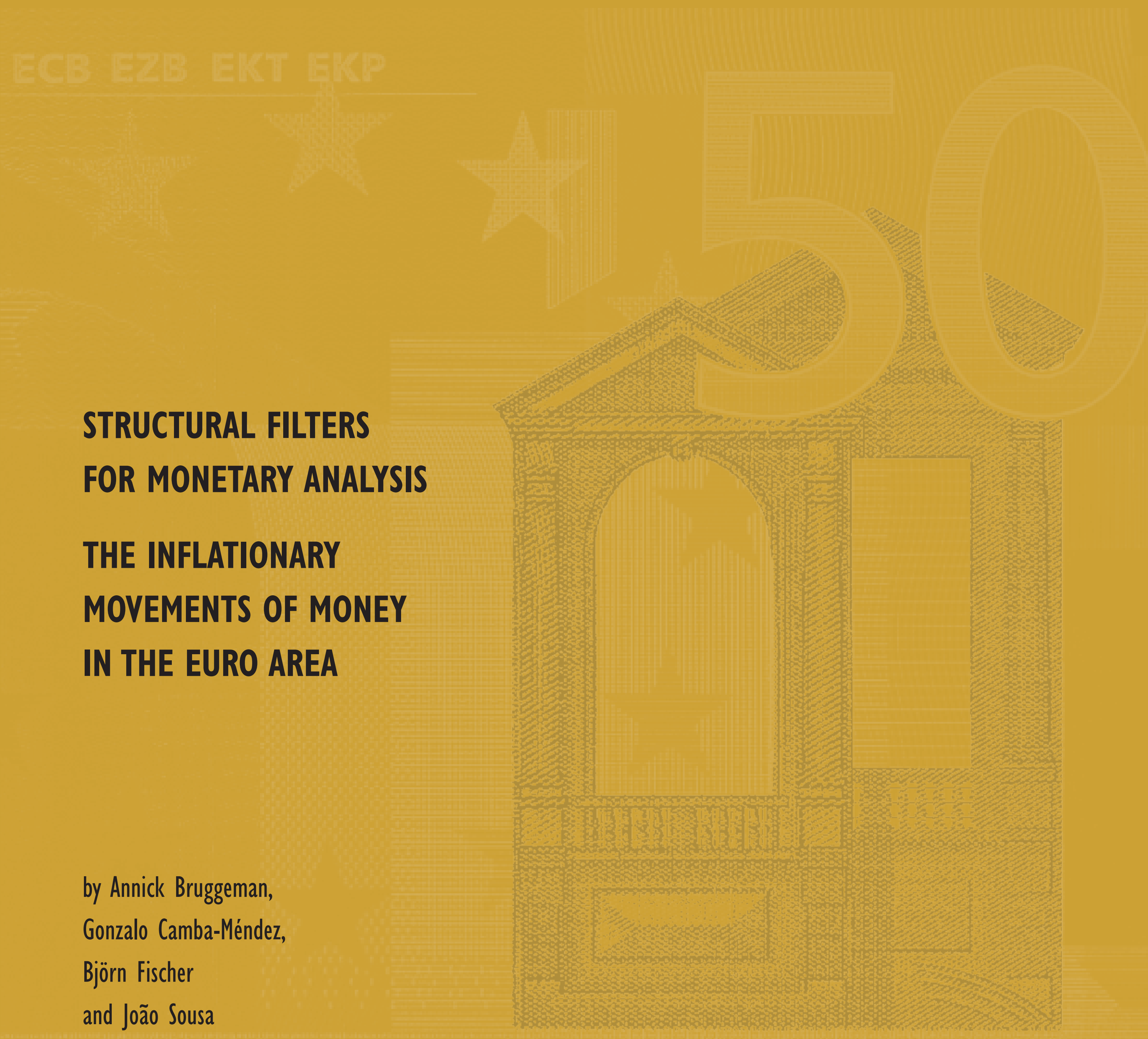
EUROPEAN CENTRAL BANK

WORKING PAPER SERIES
NO. 470 / APRIL 2005



STRUCTURAL FILTERS FOR MONETARY ANALYSIS

THE INFLATIONARY MOVEMENTS OF MONEY IN THE EURO AREA

by Annick Bruggeman,
Gonzalo Camba-Méndez,
Björn Fischer
and João Sousa

EUROPEAN CENTRAL BANK

WORKING PAPER SERIES
NO. 470 / APRIL 2005

STRUCTURAL FILTERS FOR MONETARY ANALYSIS

THE INFLATIONARY MOVEMENTS OF MONEY IN THE EURO AREA [1]

by Annick Bruggeman [2],
Gonzalo Camba-Méndez [3],
Björn Fischer [3]
and João Sousa [4]

In 2005 all ECB publications will feature a motif taken from the €50 banknote.

---

[1] This paper was written while Annick Bruggeman and João Sousa were at the ECB. We thank Gunter Coenen, Jose Luis Escrivá, Stefan Gerlach, Hans-Joachim Klöckers, Huw Pill and Caroline Willeke for useful comments, remaining mistakes are our own.

[2] National Bank of Belgium, Boulevard de Berlaimont 14, B-1000 Brussels, Belgium; e-mail: annick.bruggeman@nbb.be

[3] European Central Bank, Kaiserstrasse 29, D-60311, Frankfurt am Main, Germany; e-mail: gonzalo.camba-mendez@ecb.int and bjorn.fischer@ecb.int

[4] Bank of Portugal, Rua Francisco Ribeiro 2, P-1100-150, Lisboa, Portugal; e-mail: jmsousa@bportugal.pt

Address
Kaiserstrasse 29
60311 Frankfurt am Main, Germany

Postal address
Postfach 16 03 19
60066 Frankfurt am Main, Germany

Telephone
+49 69 1344 0

Internet
http://www.ecb.int

Fax
+49 69 1344 6000

Telex
411 144 ecb d

ISSN 1561-0810 (print)
ISSN 1725-2806 (online)

CONTENTS

Abstract

The quantity theory of money predicts a positive relationship between monetary growth and inflation over long-run horizons. However, in the short-run, transitory shocks to either money or inflation can obscure the inflationary signal stemming from money. The spectral analysis of time series provides filtering tools for removing fluctuations associated with certain frequency movements. However, use of these techniques in isolation is often criticised as being an oversimplistic statistical exercise potentially void of economic content. The objective of this paper is to develop 'structural' filtering techniques that rely on the use of spectral analysis in combination with a structural economic model with well identified shocks. A 'money augmented' Phillips curve that links inflation to money tightness and demand shocks of medium to long-term persistence is presented. It is shown that medium to long-term movements in inflation are mostly associated with the estimated monetary indicators.

Keywords: Inflation and Money.
JEL classification: E31, E50 and C32.

Non-technical Summary

The quantity theory of money predicts a positive relationship between monetary growth and inflation over long-run horizons. However, in the short-run, transitory shocks to either money or inflation can obscure the inflationary signal stemming from money. From a monetary policy perspective it is important to identify those movements in M3 that are associated with inflationary pressures, and discard other movements associated with transitory non-inflationary developments. Communication from monetary authorities often makes references to developments in inflation and money over 'medium-run' or 'long-run' horizons. Furthermore, monetary authorities' mandates are very often defined over these same horizons. This could be taken as an indication that some isolation of the long and medium-run movements of economic time series is implicitly made both by those responsible for setting the mandate and those responsible for the implementation of monetary policy. Spectral analysis techniques provide filtering tools for removing those fluctuations in economic time series associated with certain frequencies, i.e. short, medium or long-run. However, use of these filtering tools in isolation is often criticised as being an over-simplistic statistical exercise potentially void of economic content. The objective of this paper is to develop structural filtering techniques that rely on the use of spectral analysis on well identified structural economic models.

We make use of a money augmented Phillips curve to explain fluctuations in inflation. This may be thought as corresponding to a two pillar view of inflation fluctuations. Namely, that long-run developments in inflation are explained by long-run movements in money, and short to medium term developments by the output gap. The techniques we develop in this paper do not prejudge what frequency-movements in money should be isolated to estimate inflation, but rather provide those movements in money as a by-product of the modelling strategy. Furthermore, we identify those movements in inflation associated with demand shocks and movements associated with money shocks, i.e. monetary looseness or tightness, where these are well identified orthogonal shocks.

Our framework enables us to study separately what drives long-run movements in inflation from factors behind short-run movements. Therefore, it formulates in a quantitative manner a definition for medium to long-run developments, and hence it provides valid quantitative analysis to back communication from policy makers on long-run economic developments. The money series identified by the structural filters developed in this paper provide valid indicators of monetary tightness. They represent that component of money that feeds into inflation movements with a periodicity higher than 9 months.

This paper applies this new structural filter to euro area data for the low inflation period

1986Q1 to 2003Q2. The average rate of growth of euro area M3 over the period 1994 to 2003 was 5.2% with a minimum value of $2\frac{1}{2}$% on the second quarter of 1995 and a maximum of $8\frac{1}{2}$% on the second quarter of 2003. We report measures of monetary tightness exclusively linked with inflation developments, and show that large movements in money over this period were not linked to inflationary pressures. These series of money linked to inflationary pressures displayed a much smoother pattern than the actual series of M3, fluctuating between values of $4\frac{1}{2}$% and $6\frac{1}{2}$% over this same period. This money tightness indicator is also shown to be the key driving force behind fluctuations in inflation.

1 Introduction

The quantity theory of money predicts a positive relationship between monetary growth and inflation over long-run horizons. However, in the short-run, transitory shocks to either money or inflation can obscure the inflationary signal stemming from money. From a monetary policy perspective it is important to identify those movements in M3 that are associated with inflationary pressures, and discard other movements associated with transitory non-inflationary developments. Communication from monetary authorities often makes references to developments in inflation and money over 'medium-run' or 'long-run' horizons. Furthermore, monetary authorities' mandates are very often defined over these same horizons. This could be taken as an indication that some isolation of the long and medium-run movements of economic time series is implicitly made both by those responsible for setting the mandate and those responsible for the implementation of monetary policy. Spectral analysis techniques provide filtering tools for removing those fluctuations in economic time series associated with certain frequencies, i.e. short, medium or long-run. However, use of these filtering tools in isolation is often criticised as being an over-simplistic statistical exercise potentially void of economic content. The objective of this paper is to develop structural filtering techniques that rely on the use of spectral analysis on well identified structural economic models. Among other things, this will enable us to identify that component of inflation associated with monetary shocks and medium to long-run persistency.

We follow Gerlach (2003) in using a money augmented Phillips curve to explain fluctuations in inflation. Gerlach (2003) regards this as a valid interpretation of the ECB's monetary policy strategy, and in his view this corresponds to a two pillar view of inflation fluctuations; namely, that long-run developments in inflation are explained by long-run movements in money, and short to medium term developments by the output gap. Gerlach (2003) used a pre-filtered series of money, where use was made of a low-pass filter to isolate long-run movements. Nelson (2003) also highlighted that studying the relationship between the long-run movements in inflation and long-run movements in money is particularly valuable for central banks because their aim is setting the steady-state rate of inflation. The techniques we develop in this paper do not prejudge what frequency-movements in money should be isolated to estimate inflation, but rather provide those movements in money as a by-product of the modelling strategy. Furthermore, we identify those movements in inflation associated with demand shocks and movements associated with money shocks, i.e. monetary looseness or tightness, where these are well identified orthogonal shocks.

The framework for monetary analysis currently used by the ECB already provides an approach to derive the signal from monetary growth associated with risks to future price stability; see Masuch, Pill, and Willeke (2001). This framework relies on the combination of information obtained from various econometric models with the detailed institutional analysis conducted by experts. This has enabled a thorough understanding of monetary trends in the euro area and the early identification of shocks affecting the information content of monetary data. For example, the close monitoring of monetary data has allowed the timely detection of statistical outliers, e.g. the strong monthly monetary growth in January 1999. This outlier was partly related to the introduction of a new statistical reporting scheme at the start of Stage Three of Economic and Monetary Union (EMU). The analysis has also helped to identify shocks to monetary growth that were related to economic factors not likely to be inflationary. For example, the strong monetary growth between mid-2001 and end 2003 was to a large extent related to the increased liquidity preference of investors in an environment of high economic and financial market uncertainty. In addition, in the context of the economic analysis, shocks to inflation have also been detected that were temporary and unrelated to monetary growth, e.g. oil or food price shocks.

This type of monetary analysis has been highly valuable since the start of Stage Three of EMU. However, there seems to be a case for complementing it with the novel modelling strategy presented in this paper. Our framework enables us to study separately what drives long-run movements in inflation from factors behind short-run movements. Therefore, it formulates in a quantitative manner a definition for medium to long-run developments, and hence it provides valid quantitative analysis to back communication from policy makers on long-run economic developments. The money series identified by the structural filters developed in this paper provide valid indicators of monetary tightness. They represent that component of money that feeds into inflation movements with a periodicity higher than 9 months. It is our view that these indicators could be a useful complement to the analysis of the developments in annual M3 growth in the euro area currently conducted.

Isolation of long-run movements relies on forecasts at the end of the sample. It is thus important to study the real time performance of our methods to assess its usefulness for a central bank. Results presented below will show that extending the original money growth series with forecasts stemming from a money demand model reduces the size of the revisions to our monetary tightness indicators.

The remainder of the paper is organised as follows. Section 2 presents a review of the relevant empirical literature on the long-run link between monetary growth and inflation. Section 3 derives structural filters for monetary analysis. Section 4 discusses issues linked with the real-time use of the proposed filters. Finally, Section 5 concludes.

2 The link between money growth and inflation

The quantity theory of money states that there exists a long-run relationship between monetary growth and inflation that can be formulated as follows:

$$\Delta p = \Delta m - \Delta y + \Delta v$$

where Δp denotes inflation, Δm nominal monetary growth, Δy real output growth and Δv changes in the income velocity of money. If Δv and Δy are constant, a 'one-to-one' long-run relationship between nominal monetary growth and inflation exists. If only Δv is constant a 'positive' long-run relationship between nominal monetary growth and inflation exists.

There is an extensive empirical literature documenting the medium to long-term link between money growth and inflation. Lucas (1980) showed that using transformations that give less weight to the low-frequency components of M1 growth and inflation in the US results in a very weak relationship between these transformed or 'filtered' series. However, giving more weight to the low-frequency components results in an almost proportional relationship, as predicted by the quantity theory of money. Recent examples of this approach for the euro area can be found in Gerlach (2004), Neumann (2003) and Jaeger (2003). Gerlach and Neumann formulate a 'money augmented' Phillips curve model in which the expected inflation rate, or low-frequency component of inflation is approximated by the low-frequency component of the rate of growth of M3 per unit of output, i.e. M3 divided by real GDP. Results in Neumann (2003) show that the rate of growth of this money measure has been the dominant source of inflation in the euro area over the period 1986-2002. Gerlach (2004) also finds that the low-frequency component of inflation is closely related to the rate of growth of M3 per unit of output both over the period 1980-2002 and 1980-1990. Furthermore, Gerlach (2004) concludes that a model in which inflation is explained by lagged trend money growth and a lagged output gap measure fits better when estimated on data covering the low inflation period following 1991 than when estimated over the 1970s and 80s. This may be associated with the more forward-looking nature of current inflation developments.

Gerlach and Svensson (2003) and Vega and Trecroci (2002) included the real money gap as a substitute for or a complement to the output gap in a Phillips curve setting. Both studies concluded that the real money gap and the output gap both help to explain inflation developments in the euro area.

Jaeger (2003) conducted a frequency domain analysis of the link between money and inflation. He showed that the coherence (which can be interpreted as the correlation between two frequency components) between inflation and money growth is very high at the lower frequencies but much less so for frequencies similar to those associated with business cycle fluctuations, i.e. between 2 and 8 years.

Studies conducted with structural vector autoregresive (S-VAR) models also find evidence on a positive link between inflation and money. However, these studies are not conclusive about the appropriate horizon over which money is more correlated with inflation. For instance, Shapiro and Watson (1988) conclude that shocks to money play an important role in explaining the variability of inflation (over 80%) in the US, even at short time horizons. However, results of Christiano, Eichenbaum, and Evans (1999) for the US suggest that the impact of a shock to M2 on prices is clearer at longer horizons. Also the results of Altig, Christiano, Eichenbaum, and Linde (2002) for the US suggest that a shock to M2 only impacts upon prices a year and a half later. A similar result for the euro area is reported in Sousa and Zaghini (2004) who use the same identification strategy of Peersman and Smets (2001). The forecast error decompositions of prices in both models show that shocks to euro area M3 do not explain much of the forecast error variance in prices at relatively short horizons. However, the cumulative effect of the shocks to M3 to the variability in prices increases significantly with the horizon.

Other studies relied on data for a large group of countries over a relatively long time span. The main problem common to most of the panel data studies is that they disregard the fact that the behaviour of velocity and real output growth may not be similar across countries. One way to handle this problem is to rely on a panel of pooled time series and cross section data and to use a fixed effects specification, which allows the constant of the regressions to differ across countries. In this context, de Grauwe and Polan (2001) find that these fixed effects tend to increase more than proportionally with the growth rates of money, suggesting that the long-run developments in velocity and real output do indeed differ across countries. At the same time, allowing for these fixed effects does not alter the authors' conclusion that the link between monetary growth and inflation is much stronger for high inflation countries (with an average inflation rate above 20%). Nelson (2003), however, suggests that De Grauwe and Polan's rejection of the long-run link between monetary growth and inflation for low inflation countries is unjustified. His main critique is that they do not allow inflation to respond to monetary growth with a lag. Nelson shows that allowing for dynamics in a satisfactory manner leads to results that are "decidedly more favourable to the quantity theory".

A major critique that can be voiced on all these studies is that they do not give any indication on the out-of-sample forecasting performance. However, Nicoletti-Altimari (2001) replicates the analysis of Stock and Watson (1999) for the euro area and concludes on the basis of the out-of-sample forecasting performance that M3 growth is a valid indicator of future inflation in the euro area. After comparing the out-of-sample forecasting performance of a whole range of monetary, financial and real variables he comes to the conclusion that quarterly M3 growth provides valuable information on developments in inflation over the medium to long term, i.e. between 9 and 12 quarters ahead, whereas this is not the case for shorter lags. The interpretation of these results is however somewhat complex concerning the link between money growth and inflation, as the forecasting horizon and the smoothness of the signal are indistinguishably linked in this exercise. However, it is likely that both factors contribute to this result. First, monetary growth seems to lead inflation by around 1 to $1\frac{1}{2}$ years. Second, monetary growth seems to have information content for the longer-term inflation trend rather than for short-term fluctuations in inflation. This might explain why for short horizons monetary growth does not play a role, as short-term shocks to inflation, that are mostly unrelated to short-term shocks in monetary growth, contribute importantly to the overall variance of inflation over that horizon. By extending the forecasting horizon, one automatically smoothes inflation, thereby increasing the signal to noise ratio.

3 Structural Filters for euro area M3

We use a money augmented Phillips curve as the underlying model to describe fluctuations in inflation.

$$\pi_t = \Phi_m(L)\,\Delta m_t + \Phi_y(L)\,gap_t + \boldsymbol{\varepsilon}_t$$

where π_t denotes the inflation rate, Δm_t denotes money growth, gap_t an output gap indicator, $\boldsymbol{\varepsilon}_t$ an iid shock, and where $\Phi_m(L)$ and $\Phi_m(L)$ are polynomial operators of leads and lags. The structure of these polynomial operators will depend on the type of filter we choose. Two choices will be made, namely a double-sided filter and a one-sided filter. In the technical sections below $\boldsymbol{y}_t$ should be understood as π_t and $\boldsymbol{x}_t$ corresponds with the vector series $(gap_t, \Delta m_t)'$. Note also that gap_t is an economic variable which by construction displays a zero mean. Therefore, the model above satisfies long run homogeneity resctritions, namely that the steady state inflation rate does not depend on the output gap, but exclusevely on money growth.

3.1 Double-sided filter

The modelling framework presented in this section is an extension of that in Brillinger (1981, ch. 8). Let $\{\boldsymbol{y}_t\}_{t=1}^{\infty}$ and $\{\boldsymbol{x}_t\}_{t=1}^{\infty}$ be $m \times 1$ and $n \times 1$ vector-valued second order stationary series with mean $\boldsymbol{c}_y$ and $\boldsymbol{c}_x$ respectively and cross spectral density matrices given by $\boldsymbol{h}_{yy}(\lambda)$, $\boldsymbol{h}_{xx}(\lambda)$ and $\boldsymbol{h}_{xy}(\lambda)$ for $0 \leq (\lambda) \leq 2\pi$. The problem to be addressed is that of searching for the $m \times n$ filter $\{\boldsymbol{b}_u\}_{u=-\infty}^{\infty}$ such that $\boldsymbol{y}_t^*$ is near $\boldsymbol{y}_t$ where:

$$\boldsymbol{y}_t^* = \boldsymbol{\mu} + \sum_{k=-\infty}^{\infty} \boldsymbol{b}_{t-k}\boldsymbol{x}_k \tag{1}$$

The minimum of $E\left\{\boldsymbol{\varepsilon}_t'\boldsymbol{\varepsilon}_t\right\}$ for $\boldsymbol{\varepsilon}_t = (\boldsymbol{y}_t - \boldsymbol{y}_t^*)$ is achieved for:

$$\begin{aligned} \boldsymbol{\mu} &= \boldsymbol{c}_y - \left(\sum_{u=-\infty}^{\infty} \boldsymbol{b}_u\right)\boldsymbol{c}_y \\ \boldsymbol{b}_u &= \boldsymbol{\psi}\left(\boldsymbol{B}\left(\alpha\right), u\right) = \frac{1}{2\pi}\int_0^{2\pi} \boldsymbol{B}\left(\alpha\right) e^{iu\alpha} d\alpha \end{aligned} \tag{2}$$

where the transfer function $\boldsymbol{B}(\lambda) = \boldsymbol{h}_{yx}(\lambda)\boldsymbol{h}_{xx}^{-1}(\lambda)$. The function $\boldsymbol{\psi}\left(\boldsymbol{B}\left(\alpha\right), u\right)$ is simply the inverse Fourier transform associated with the transfer function $\boldsymbol{B}(\lambda)$. Model (1) provides a representation for the movements of $\boldsymbol{y}_t$ as a function of $\boldsymbol{x}_t$ and $\boldsymbol{\varepsilon}_t$, where $\boldsymbol{\varepsilon}_t$ is orthogonal to the other inputs by construction.

Identification of shocks. The inputs $\boldsymbol{x}_t$ are not orthogonal, but in certain instances it might be possible to identify orthogonal input shocks by incorporating further restrictions possibly based on economic theory in the manner which is standard in the structural VAR literature. In what follows we will use the denotation $\overline{\boldsymbol{A}}$, to denote the transpose conjugate of a complex matrix $\boldsymbol{A}$. Identification of the shocks requires to identify a structure such that $\boldsymbol{h}_{xx}(\lambda) = \boldsymbol{P}(\lambda)\boldsymbol{\Psi}(\lambda)\overline{\boldsymbol{P}(\lambda)}$, and where the spectral density matrix $\boldsymbol{\Psi}(\lambda)$ is diagonal, i.e. coherencies are always zero. This would allow to rewrite the decomposition of the variance of $\boldsymbol{y}_t$ as:

$$\boldsymbol{\Sigma}_{yy} = \int_0^{2\pi} \boldsymbol{h}_{yy}(\lambda)d\lambda = \sum_{k=1}^{n}\int_0^{2\pi} \boldsymbol{\mathcal{B}}_j(\lambda)\overline{\boldsymbol{\mathcal{B}}_j(\lambda)} + \int_0^{2\pi} \boldsymbol{h}_{\boldsymbol{\varepsilon}\boldsymbol{\varepsilon}}(\lambda)d\lambda \tag{3}$$

where $\boldsymbol{\mathcal{B}}_j(\lambda)$ denotes the j-th column of $\boldsymbol{\mathcal{B}}(\lambda)$ and $\boldsymbol{\mathcal{B}}(\lambda) = \boldsymbol{B}(\lambda)\boldsymbol{P}(\lambda)\boldsymbol{\Psi}(\lambda)^{\frac{1}{2}} = \boldsymbol{B}(\lambda)\boldsymbol{\mathcal{P}}(\lambda)$. Retrieving the signal from these identified shocks is easily accomplished by using an appropriate decomposition of the transfer function. The transfer function to extract the signal of the k-th identified shocks is defined as

$$\boldsymbol{O}^k(\lambda) = \boldsymbol{B}(\lambda)\boldsymbol{\mathcal{P}}_k(\lambda)\left(\boldsymbol{\mathcal{P}}(\lambda)^{-1}\right)_{k,\cdot} \tag{4}$$

where $\boldsymbol{\mathcal{P}}_k(\lambda)$ denotes the k-th column of $\boldsymbol{\mathcal{P}}(\lambda)$, and $\left(\boldsymbol{\mathcal{P}}(\lambda)^{-1}\right)_{k,\cdot}$ denotes the k-th row of $\left(\boldsymbol{\mathcal{P}}(\lambda)\right)^{-1}$. Computation of the filters $\left\{\boldsymbol{o}_t^k\right\}$ corresponding to this transfer function is accomplished in the usual manner, i.e. $\boldsymbol{o}_u^k = \boldsymbol{\psi}\left(\boldsymbol{O}^k\left(\alpha\right), u\right)$.

Band pass filtering. It is easy to show that the minimum of $E\left\{\boldsymbol{\varepsilon}_t'\boldsymbol{\varepsilon}_t\right\}$ for components of a certain frequency is achieved for $\tilde{\boldsymbol{b}}_u = \boldsymbol{\psi}\left(\boldsymbol{F}\left(\alpha\right)\boldsymbol{B}\left(\alpha\right), u\right)$ where $\boldsymbol{B}\left(\alpha\right)$ is defined as above and $\boldsymbol{F}\left(\alpha\right)$ for $0 \leq \alpha \leq 2\pi$ is the transfer function of a band-pass filter, i.e. for given values for α_0 and $\mathcal{K}$ it is given by:

$$\boldsymbol{F}\left(\alpha\right) = \begin{cases} \boldsymbol{I} & \text{if} \quad \left|\alpha \pm \alpha_0\right| \leq \mathcal{K} \\ \boldsymbol{0} & \quad\quad \text{otherwise} \end{cases}$$

or what is the same the integration to compute $\{\boldsymbol{b}_t\}$ in (2) is run over the relevant frequencies.[1] This allows us to isolate that component in money exclusively related with fluctuations in inflation with a periodicity larger than 9 months. In our application below, this filter would be simply defined as $\tilde{\boldsymbol{o}}_u^k = \boldsymbol{\psi}\left(\boldsymbol{F}(\alpha)\,\boldsymbol{O}^k(\alpha), u\right)$, for values of $\alpha_0 = 0$ and $\mathcal{K} = 1.99$.

3.2 One-sided filters

Let $\{\boldsymbol{y}_t\}_{t=1}^{\infty}$ and $\{\boldsymbol{x}_t\}_{t=1}^{\infty}$ be $m \times 1$ and $n \times 1$ vector-valued second order stationary series. We estimate the model

$$\boldsymbol{\alpha}(L)\,\boldsymbol{y}_t = \boldsymbol{\delta}(L)\,\boldsymbol{x}_t + \boldsymbol{\varepsilon}_t \tag{5}$$

where $\boldsymbol{\alpha}(L)$ and $\boldsymbol{\delta}(L)$ are standard polynomial lag operators. The implicit one-sided filter in the model above is given by $\boldsymbol{\alpha}(L)^{-1}\,\boldsymbol{\delta}(L)\,\boldsymbol{x}_t$. The roots in the polynomial lag $\boldsymbol{\alpha}(L)^{-1}\,\boldsymbol{\delta}(L)$ determine what kind of filter will be applied to the right hand side variables. If the roots are positive the weights are exponentially decaying. This filter can be understood then as a Cogley (2002) type of filter. If additionally, one of the roots is close to one, this translates into substantial smoothing (the weight of the filter for distant observations is still significant), whereas a value close to 0 leads to little smoothing (the weight of the filter goes to 0 very quickly).

3.3 Empirical Results

The Data. Use is made of euro area quarterly data over the period 1986Q1 to 2003Q2. The choice of this relatively short period was based on a number of considerations. First, the period of the 70s and early 80s was characterised by high and volatile inflation and may therefore not be so informative about the current situation of low and stable inflation rates, see Figure 1. This is suggested by de Grauwe and Polan (2001) and Gerlach (2003) who conclude that the link between monetary growth and inflation is only valid for countries or periods with high inflation. By concentrating on a sample period with low inflation rates this paper therefore takes a cautious approach. Without explicitly addressing the issue of the possible different regimes, we avoid that our results could be solely driven by the 'high inflation part' of the sample considered. At the same time, this implies that we run the risk of introducing a bias against the role of money. Second, standard unit root and stationarity tests suggest that within this shorter sample period inflation can be treated as a stationary process, while this is not the case when the sample period starts in 1970 or 1980. Indeed, the null hypothesis that inflation for the above-mentioned period is stationary cannot be rejected

---

[1] It is also easy to show that this solution is equivalent to the solution obtained by a two step method in which the series $\boldsymbol{y}_t$ and $\boldsymbol{x}_t$ are both prefiltered with the same band-pass filter and use as inputs in the model.

at the 5% significance level with the Kwiatkowski-Phillips-Schmidt-Shin test. Furthermore, the null hypothesis of a unit root can be rejected at the 5% significance level using the Phillips-Perron test. The output gap has been computed using the Hodrick and Prescott (1997) filter with $\lambda = 1600$.

Identification of Shocks for the double-sided filter. In order to identify a double-sided structural filter of monetary tightness it simply remains to formulate a structure for the spectral density matrix $\boldsymbol{h}_{xx}(\lambda)$, and where, as indicated above, $\boldsymbol{x}_t = (gap_t, \Delta m_t)'$. We pursue the following strategy. First, we derive the Wold representation $\boldsymbol{x}_t = \boldsymbol{C}(L)\,\boldsymbol{\varepsilon}_t$, where $\boldsymbol{\varepsilon}_t$ is a 2×1 iid process with mean zero and covariance matrix $\boldsymbol{\Sigma} = \boldsymbol{P}\boldsymbol{P}'$. The spectral density matrix of $\boldsymbol{x}_t$ will then be written as $\boldsymbol{h}_{xx}(\lambda) = \boldsymbol{\mathcal{P}}(\lambda)\overline{\boldsymbol{\mathcal{P}}(\lambda)}$; where $\boldsymbol{\mathcal{P}}(\lambda) = \boldsymbol{C}\left(e^{-i\lambda}\right)\boldsymbol{P}$. For this definition of $\boldsymbol{\mathcal{P}}(\lambda)$, computation of the transfer function of the structural filter follows from equation (4). Second, in determining the structural shocks, i.e. in identifying matrix $\boldsymbol{P}$, we follow a procedure similar to the one used in the structural VAR literature. The specification implies that both the output gap and the rate of growth of M3 are explained by demand and money 'tightness' shocks. We impose the necessary restrictions for identification using a Choleski decomposition, thereby obtaining monetary shocks which are orthogonal to demand shocks. Thus, the identification strategy assumes that demand shocks respond only with a lag to money shocks. By contrast, monetary authorities can respond to contemporary demand shocks by tightening or loosening monetary conditions. In addition, money growth responds contemporaneoulsy to demand shocks because liquidity requirements fluctuate with the state of the economy.

Results. Figure 2 shows the multiple coherence of money growth and the output gap with respect to inflation for the time period 1986Q1 to 2003Q2. This measure can be understood in a simplified way as the multiple correlation between these two series and inflation at different frequencies or cycle lengths. Figure 2 reveals that the multiple coherence is very high for the low and business cycle frequencies. Figure 2 also plots the coherence between inflation and the output gap once the impact of money growth is removed from both these series, i.e. the 'partial' coherence. It reveals that the output gap provides additional information to explain inflation with respect to money growth for movements associated with business cycle frequencies. However, it provides little additional information to explain the very long-run movemements of inflation.

A first issue that has to be solved in the double-sided approach is how to find an appropriate length of the window for which the filter is defined. In this paper the choice of the appropriate length of the window is based on the results of the Akaike Information Criterion.

The results suggest that a window length of 8 quarters is desirable. A second issue relates to the end-point problem. Since the equation for inflation also includes eight quarters of leading money growth, monetary data have been extended up to 2005Q2, using forecasts, see section 4 below for more details.

Figure 3 shows the filter weights for the annual rate of growth of money stemming from the applied double-sided structural filter. As stated above it is useful for policy to isolate the medium to long run movements. We have thus implemented a structural double-sided filter that identifies money shocks of a persistency larger than 9 months. Figure 4 shows the resulting smoothed series of monetary growth. The double-sided filter smooths money growth considerably. For example, the strong portfolio shifts affecting M3 growth in the 1993-1996 episode, which had no impact on inflation, are basically completely smoothed out by the filter. The decomposition of inflation into the contributions of money and demand shocks as described in equation (3) is displayed in Figure 5. It clearly illustrates that most of the movements in inflation are associated with money shocks.

For the estimation of the one-sided filter, the general to specific approach of Hendry and Krolzig (2001) was used to arrive to an optimal lag structure, allowing for lags up to order seven. The resulting equation of the modified Phillips curve including money growth is shown below (standard errors in brackets):

$$\pi_t = \underset{(0.1)}{0.62}\pi_{t-3} + \underset{(0.1)}{0.21}gap_{t-3} - \underset{(0.1)}{0.22}gap_{t-6} + \underset{(0.04)}{0.07}\Delta m_{t-3} + \underset{(0.04)}{0.09}\Delta m_{t-7} + \varepsilon_t$$

where π_t is the annualized quarter-on-quarter inflation rate, gap_t is the output gap and Δm represents the annualized quarter-on-quarter money growth. All coefficients are significantly different from zero. Lag 7 for money is significant, in line with the expectation that money is leading inflation by around $1\frac{1}{2}$ years. The filter weights corresponding to the Phillips curve type of equations with M3 growth are shown in Figure 6. The weights show a relatively slow decay over time, e.g. money contributes mainly via long-term movements to inflation. This is further illustrated in Figure 7, that shows the implied smoothed series of the annual growth rate of money, mean and phase shift corrected.[2]

The decomposition of inflation into the contributions of money growth, the output gap and the unexplained part can be derived following the principles outlined in subsection 3.2. Figure 8 shows that money growth is the main contributor to the smooth underlying trend of inflation.

---

[2] The phase shift correction was performed using cross-correlation analysis between the original money growth series and the filtered series. In addition, the annualised quarter-on-quarter rates of growth were transformed into annual rates of growth.

4 Real-time use of structural filters

The previous section suggests that smoothed series of monetary growth may serve as an additional tool for monitoring those monetary developments that may lead to inflation. However, such a tool is only useful for policy purposes, if several conditions are fulfilled in real time. First, given the time lag of the transmission of a monetary policy shock to inflation, it is important that the well known leading signal of money growth to inflation, see for example Nicoletti-Altimari (2001), is preserved. Second, revisions of the filters over time should not lead to major distortions in detecting the relevant signal, especially around turning points. This has several consequences for the filtered series for money growth, both for the one-sided and the double sided filter. In order to extract the signal from current monetary developments for future inflation, the considerable phase shift induced for the money signal stemming from the one-sided filter of the augmented Phillips curve has to be counterbalanced with a considerable reliance on forecasts. The double-sided filter is additionally dependent on such forecasts because the weighting scheme relies not only on past and contemporaneous values but also on future values. Therefore, when new data become available, and forecasts are partially replaced by actual figures, the filtered series are revised.

We assess the ‘real time’ performance of the filters by studying the size of the revisions caused by a) the replacement of forecast values with observed values and b) the recursive estimation of the filter weights. This definition is therefore only partial, as it ignores revisions of the underlying raw data, which can also distort the results.

In order to construct the structural filters in real time, we compare two different scenarios for the computation of the eight quarters of forecasts:

1. Use of ARIMA models.[3]

2. Use of a structural model. Money growth is forecasted from the money demand model of Calza, Gerdesmeier, and Levy (2001), and where use is made of an ARIMA(1,1,1) for forecasting real GDP, and an ARIMA(0,2,1) for forecasting the GDP deflator. Additionally, interest rates and oil prices are assumed to be constant during the forecast horizon.

In order to reproduce the real-time procedure, the models are estimated recursively and forecasts are made each time for the next eight quarters. First, they are estimated for the period 1986Q1-1991Q4 and used to predict M3 over the following 8 quarters. Then they are re-estimated up to 1992Q1 and another 8 quarters of forecasts are produced, and so on and

---

[3] An ARIMA(0,1,1) model was used to forecast money growth; the characteristics of the other ARIMA models are described in the second scenario.

so forth until 2001Q2. The money demand equation from 2001Q2 onwards is fixed at the 2001Q2 estimates to avoid short-run instability problems in the money demand model.

Due to the small sample size and the relatively low number of turning points, a formal analysis of revisions and especially of the speed in detecting turning points in real time is not possible. However, one can present the main stylised facts in a more heuristic way. In order to have a visual assessment of the impact of the two different strategies on the real-time analysis, Figure 9 shows filtered M3 growth in real time for the double-sided as well as the one sided filter. Some very clear stylised facts can be detected for both filters. First, revisions, especially around turning points, are substantial for the first variant of using only ARIMA models for extending the series. Second, those revisions are substantially reduced, especially around turning points, when the series of monetary growth is extended with forecast from the money demand model.

Our analysis revealed that revisions start to be insignificant after ten quarters, so that we considered the filter to be final when the end point of money growth was $t + 10$. Table 1 shows the size of the mean squared revisions t to $t + 10$ for the time period 1992Q1 to 2001Q4, e.g. a measurement of the size of the revision from the information available in real time to the final information. It is clear from the table that relying on forecasts from a money demand model reduces the relative mean squared revision considerably for both filters.

5 Conclusions

This paper developed structural filtering techniques that relied on the use of spectral analysis on well identified structural economic models. This enabled us to identify that component of inflation associated with monetary movements which have a medium to long-run persistency. In deriving the filters we control for the influence of the output gap. It is our view that our structural filters could serve as valid quantitative analysis to back communication from policy makers on long-run monetary developments.

We applied these filters to euro area data for the low inflation period 1986Q1 to 2003Q2. The average rate of growth of euro area M3 over the period 1994 to 2003 was 5.2% with a minimum value of $2\frac{1}{2}\%$ on the second quarter of 1995 and a maximum of $8\frac{1}{2}\%$ on the second quarter of 2003. We have shown that large movements in money over this period were not linked to inflationary pressures and reported measures of monetary tightness exclusively linked with inflation developments. These series displayed a much smoother pattern, fluctuating between values of $4\frac{1}{2}\%$ and $6\frac{1}{2}\%$ over this same period. This money tightness indicator was also shown to be the key driving force behind fluctuations in inflation. The analysis conducted in this paper is founded on a money augmented Phillips curve and some simple identification assumptions. To the extent that this represents an oversimplistic view of the economy, our results may be subject to criticism. Use of the modelling strategy presented in this paper with a more elaborate model of the economy is currently pursued by the authors.

The one-sided as well as the double-sided structural filters for money rely on forecasts at the current end of the time series. In that respect, we concluded that using structural forecasting models substantially reduced the size of the revisions of our money tightness indicator, especially around turning points, and provide policy relevant information.

References

Altig, D., L. Christiano, M. Eichenbaum, and J. Linde (2002): “Technology Shocks and Aggregate Fluctuations,” Mimeo.

Brillinger, D. (1981): *Time Series: Data Analysis and Theory.* Holden-Day, San Francisco.

Calza, A., D. Gerdesmeier, and J. Levy (2001): “Euro area money demand: Measuring the opportunity costs appropriately,” IMF Working Paper, No. 01/179.

Christiano, L., M. Eichenbaum, and C. Evans (1999): “Monetary Policy Shocks: What have we Learned and to what end?,” in *Handbook of Macroeconomics*, ed. by J. Taylor, and M. Woodfoord. North Holland.

Cogley, T. (2002): “A simple adaptive measure of core inflation,” *Journal of Money, Credit and Banking*, 34(1), 94–113.

de Grauwe, P., and M. Polan (2001): “Is inflation always and everywhere a monetary phenomenon?,” CEPR Discussion Paper Series, No. 2841.

Gerlach, S. (2003): “The ECB's two pillars,” CEPR Discussion paper, No. 3689.

——— (2004): “The two pillars of the ECB,” http://home.netvigator.com/ gerlach/sgerlach.htm.

Gerlach, S., and L. Svensson (2003): “Money and inflation in the euro-area: A case for monetary indicators?,” *Journal of Monetary Economics*, 50, 1649–1672.

Hendry, D., and M. Krolzig (2001): “Automatic econometric model selection using PcGets,” Timberlake Consultants, London.

Hodrick, R., and E. C. Prescott (1997): “Postwar U.S. Business Cycles: An Empirical Investigation,” *Journal of Money, Credit, and Banking*, 29, 1–16.

Jaeger, A. (2003): “The ECB's money pillar: An assessment,” IMF Working Paper, No. 03/82.

Lucas, R. E. (1980): “Two illustrations of the quantity theory of money,” *American Economic Review*, 70, 1005–1014.

Masuch, K., H. Pill, and C. Willeke (2001): “Framework and tools of monetary analysis,” in *Monetary Analyis: Tools and Applications*, ed. by H. Klckers, and C. Willeke. ECB, Frankfurt am Main.

Nelson, E. (2003): “The future of monetary aggregates in monetary policy analysis,” CEPR Discussion Paper Series, No. 3897.

Neumann, M. J. M. (2003): “The European Central Bank’s first pillar reassessed,” Mimeo.

Nicoletti-Altimari, S. (2001): “Does money lead inflation in the euro area?,” ECB Working Paper, No. 63.

Peersman, G., and F. Smets (2001): “The Monetary Transmission Mechanism in the Euro Area: More Evidence from VAR Analysis,” ECB Working Paper, No. 91.

Shapiro, M. D., and M. Watson (1988): “Sources of Business Cycle Fluctuations,” *NBER Macroeconomics Annual*, pp. 111–148.

Sousa, J., and A. Zaghini (2004): “Monetary policy shocks in the euro area and global liquidity spillovers,” ECB Working Paper, No. 309.

Stock, J. H., and M. Watson (1999): “Forecasting inflation,” *Journal of Monetary Economics*, 44, 293–335.

Vega, J. L., and C. Trecroci (2002): “The information content of M3 for future inflation,” *Weltwirtschaftliches Archiv*, 138, 22–53.

Figure 1: Euro Area Monetary Growth and Inflation (in percent).

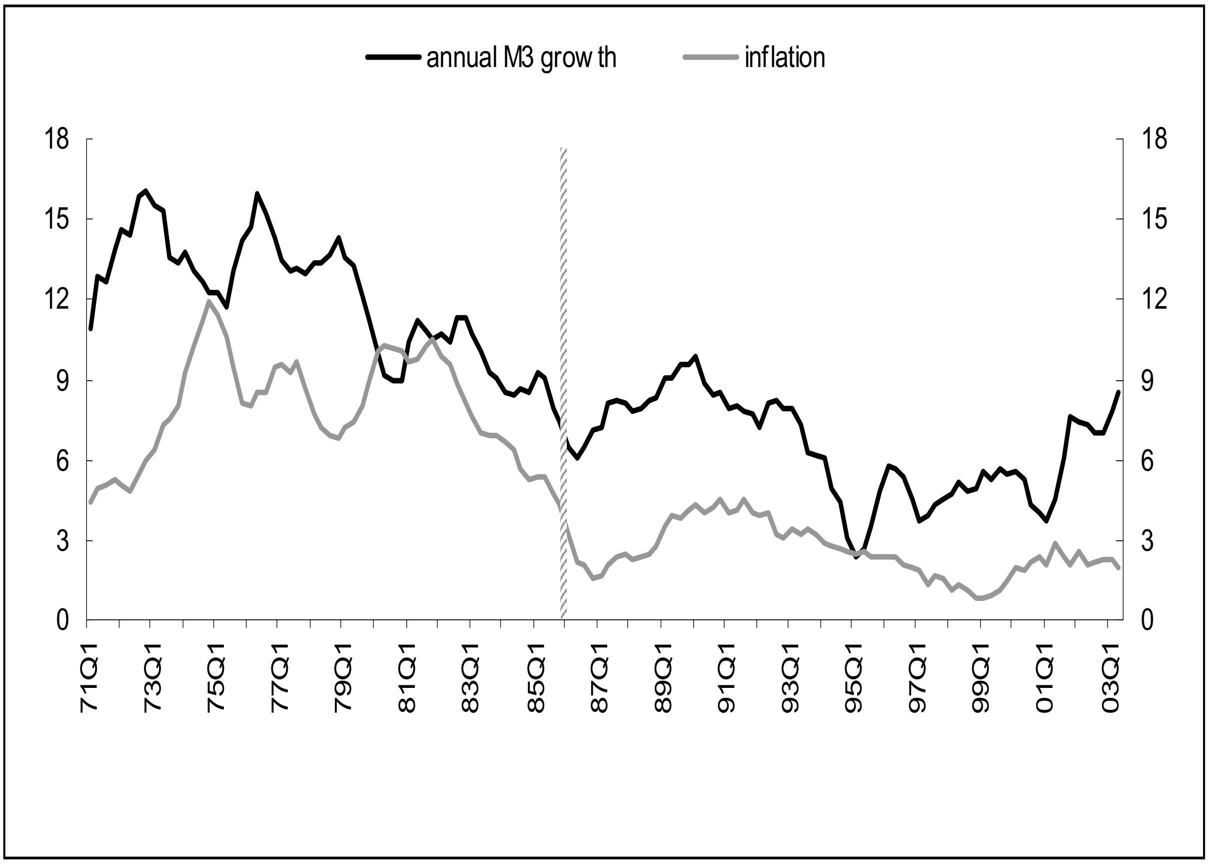


Figure 2: Multiple Coherence between Inflation and M3 Growth and the Output Gap.

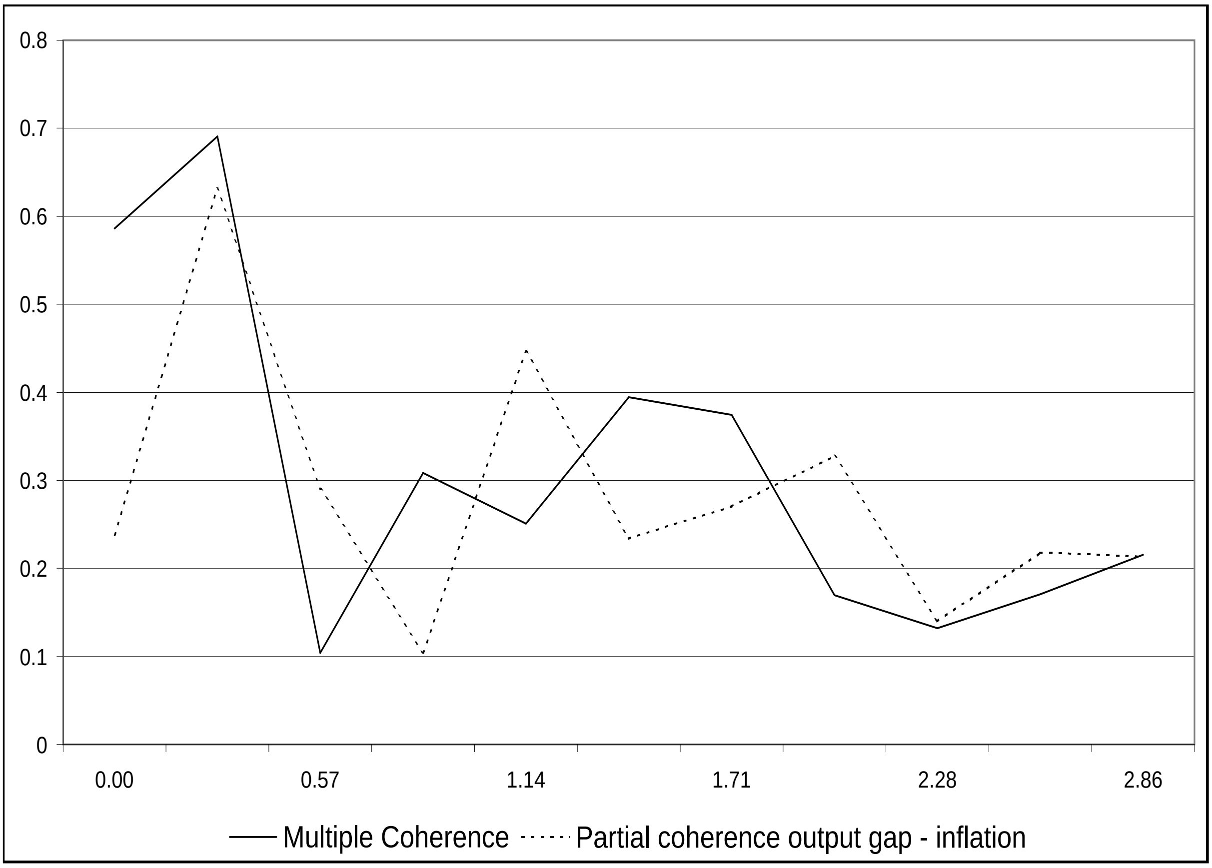
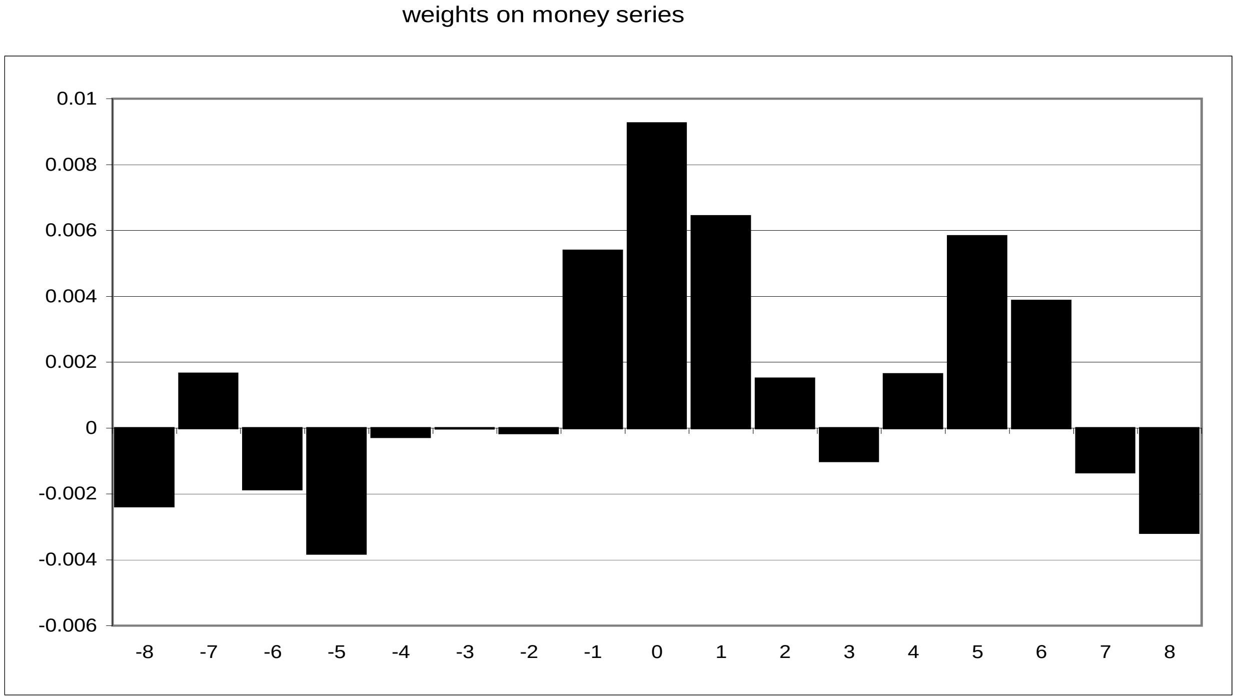


Figure 3: Weights for Double-sided Monetary Tightness Filter. (> 9 months).



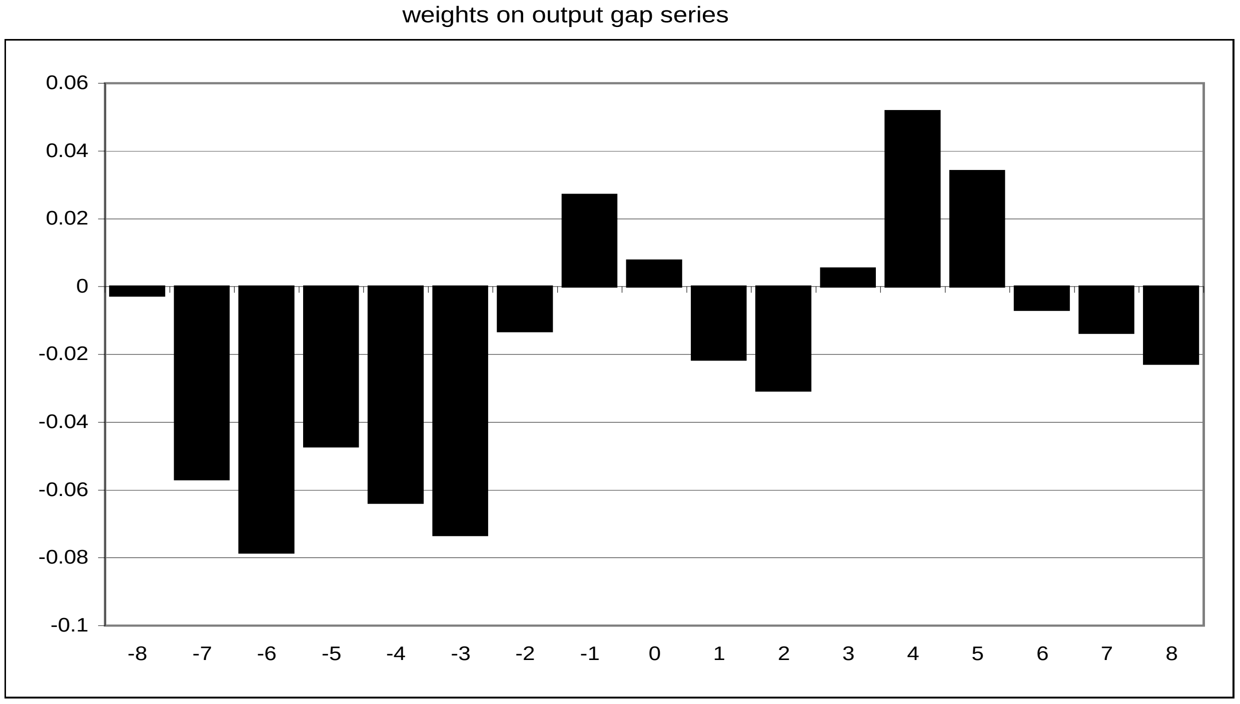


Figure 4: Money and Inflationary (> 9 months) Money Movements. Double-sided.

Figure 5: Decomposition of Shocks to Inflation (>9 Months Movements). Double-Sided.

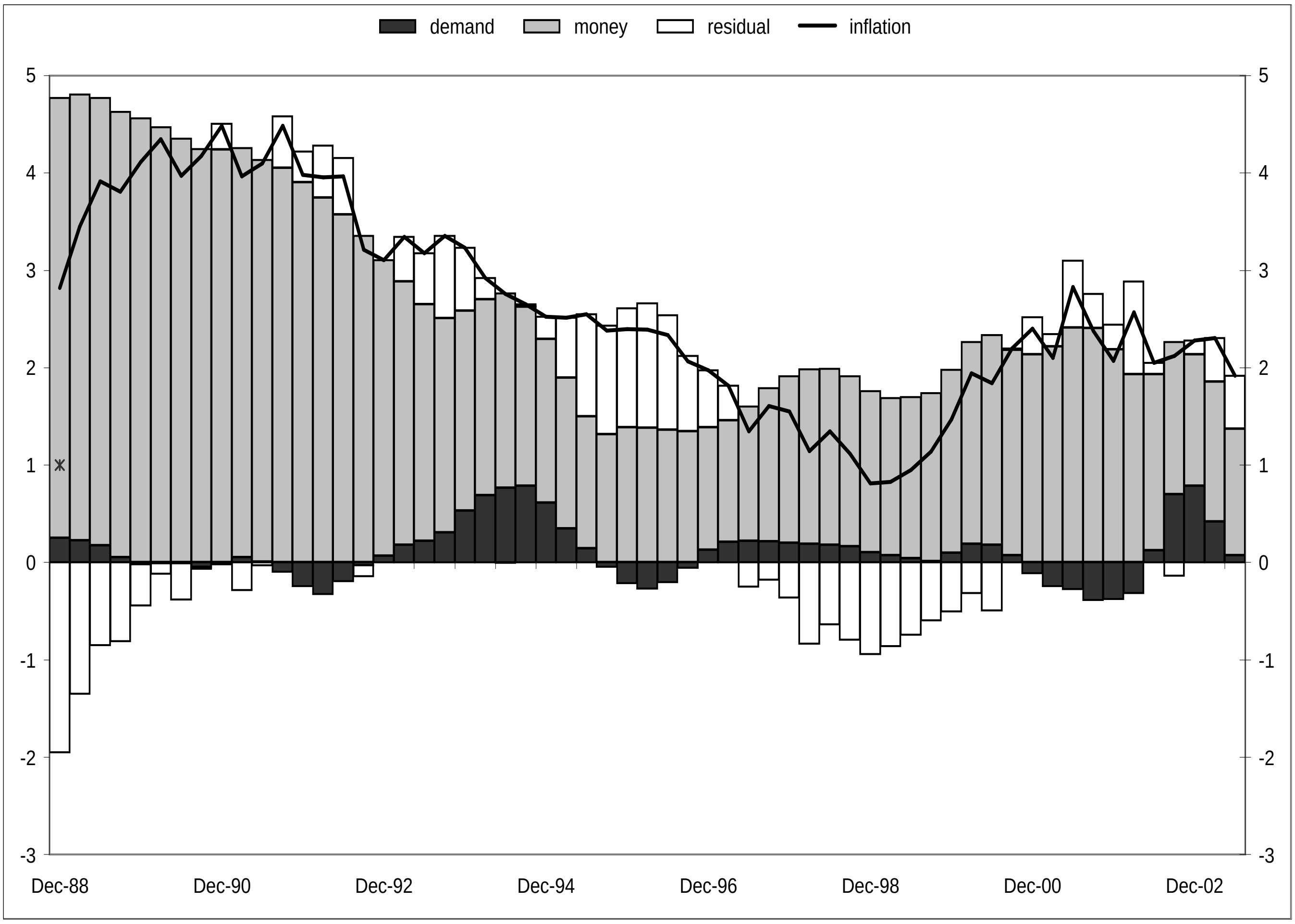


Figure 6: Weights for One-sided Monetary Tightness Filter.

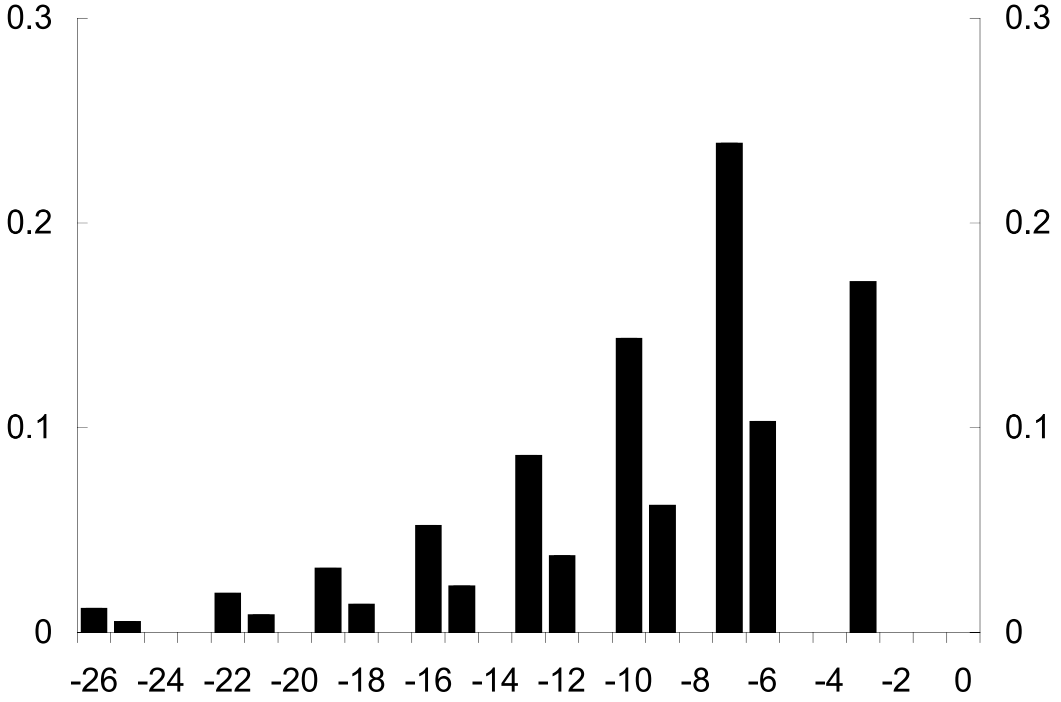


Figure 7: Money and Inflationary Money Movements. One-sided.

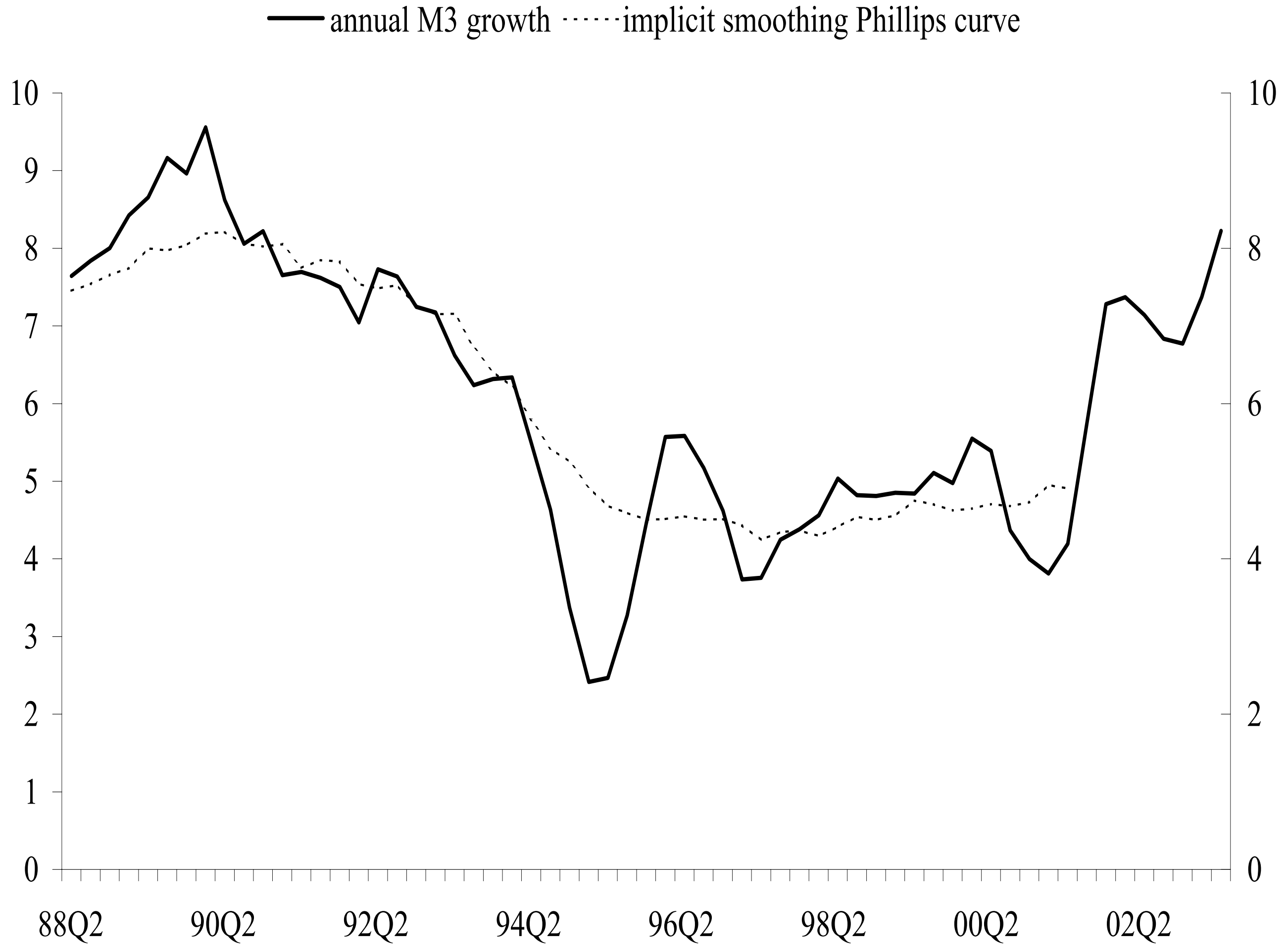


Figure 8: Decomposition of Shocks to Inflation. One-Sided.

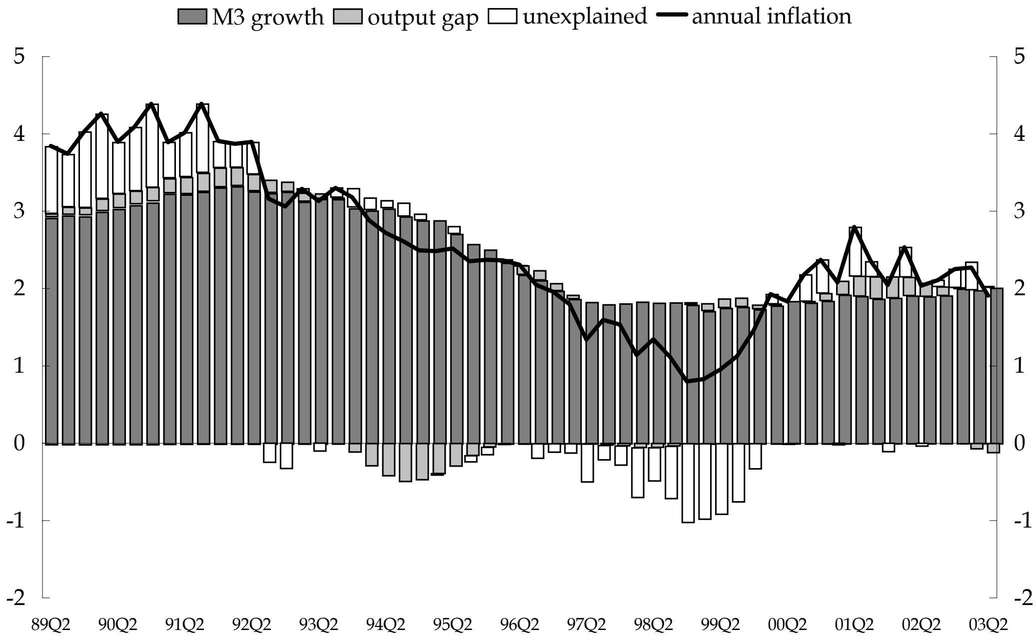
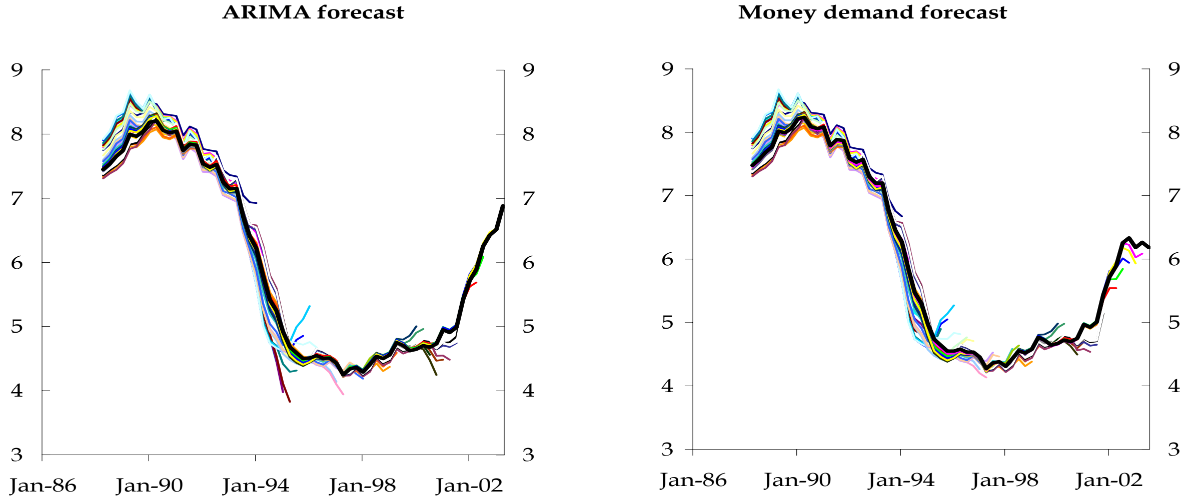


Figure 9: Real Time Estimation of Monetary Tightness Filters.

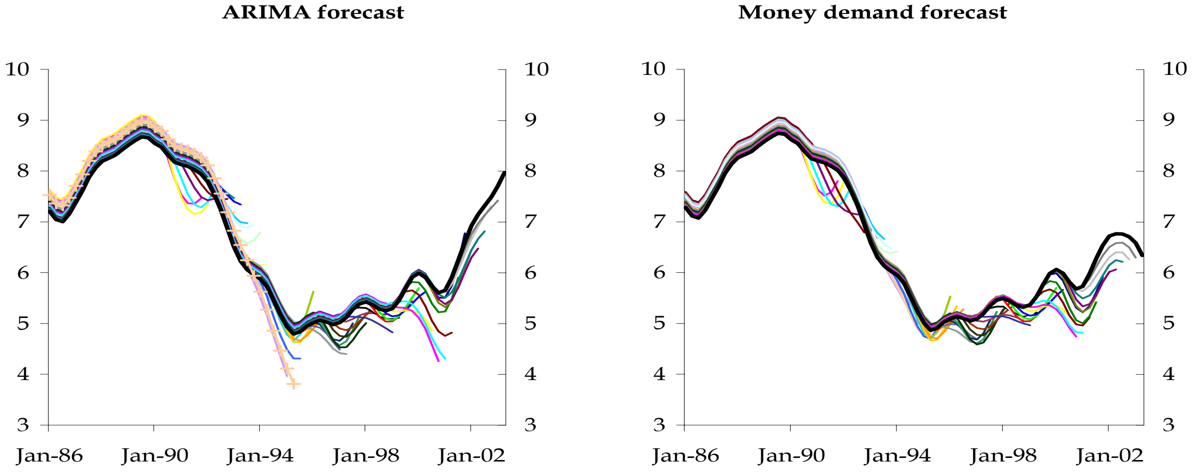
One-sided Filter



ARIMA forecast

Money demand forecast

Two-sided Filter



ARIMA forecast

Money demand forecast

Table 1: RMSE of Real-Time Estimated Monetary Tightness Filters.

	One sided Filter	Two Sided Filter
ARIMA Forecast	0.09	0.12
Money Demand Forecast	0.05	0.03

European Central Bank working paper series

For a complete list of Working Papers published by the ECB, please visit the ECB's website (http://www.ecb.int)

425 "Geographic versus industry diversification: constraints matter" by P. Ehling and S. B. Ramos, January 2005.

426 "Security fungibility and the cost of capital: evidence from global bonds" by D. P. Miller and J. J. Puthenpurackal, January 2005.

427 "Interlinking securities settlement systems: a strategic commitment?" by K. Kauko, January 2005.

428 "Who benefits from IPO underpricing? Evidence form hybrid bookbuilding offerings" by V. Pons-Sanz, January 2005.

429 "Cross-border diversification in bank asset portfolios" by C. M. Buch, J. C. Driscoll and C. Ostergaard, January 2005.

430 "Public policy and the creation of active venture capital markets" by M. Da Rin, G. Nicodano and A. Sembenelli, January 2005.

431 "Regulation of multinational banks: a theoretical inquiry" by G. Calzolari and G. Loranth, January 2005.

432 "Trading european sovereign bonds: the microstructure of the MTS trading platforms" by Y. C. Cheung, F. de Jong and B. Rindi, January 2005.

433 "Implementing the stability and growth pact: enforcement and procedural flexibility" by R. M. W. J. Beetsma and X. Debrun, January 2005.

434 "Interest rates and output in the long-run" by Y. Aksoy and M. A. León-Ledesma, January 2005.

435 "Reforming public expenditure in industrialised countries: are there trade-offs?" by L. Schuknecht and V. Tanzi, February 2005.

436 "Measuring market and inflation risk premia in France and in Germany" by L. Cappiello and S. Guéné, February 2005.

437 "What drives international bank flows? Politics, institutions and other determinants" by E. Papaioannou, February 2005.

438 "Quality of public finances and growth" by A. Afonso, W. Ebert, L. Schuknecht and M. Thöne, February 2005.

439 "A look at intraday frictions in the euro area overnight deposit market" by V. Brousseau and A. Manzanares, February 2005.

440 "Estimating and analysing currency options implied risk-neutral density functions for the largest new EU member states" by O. Castrén, February 2005.

441 "The Phillips curve and long-term unemployment" by R. Llaudes, February 2005.

442 "Why do financial systems differ? History matters" by C. Monnet and E. Quintin, February 2005.

443 "Explaining cross-border large-value payment flows: evidence from TARGET and EURO1 data" by S. Rosati and S. Secola, February 2005.

444 "Keeping up with the Joneses, reference dependence, and equilibrium indeterminacy" by L. Stracca and Ali al-Nowaihi, February 2005.

445 "Welfare implications of joining a common currency" by M. Ca' Zorzi, R. A. De Santis and F. Zampolli, February 2005.

446 "Trade effects of the euro: evidence from sectoral data" by R. Baldwin, F. Skudelny and D. Taglioni, February 2005.

447 “Foreign exchange option and returns based correlation forecasts: evaluation and two applications” by O. Castrén and S. Mazzotta, February 2005.

448 “Price-setting behaviour in Belgium: what can be learned from an ad hoc survey?” by L. Aucremanne and M. Druant, March 2005.

449 “Consumer price behaviour in Italy: evidence from micro CPI data” by G. Veronese, S. Fabiani, A. Gattulli and R. Sabbatini, March 2005.

450 “Using mean reversion as a measure of persistence” by D. Dias and C. R. Marques, March 2005.

451 “Breaks in the mean of inflation: how they happen and what to do with them” by S. Corvoisier and B. Mojon, March 2005.

452 “Stocks, bonds, money markets and exchange rates: measuring international financial transmission” by M. Ehrmann, M. Fratzscher and R. Rigobon, March 2005.

453 “Does product market competition reduce inflation? Evidence from EU countries and sectors” by M. Przybyla and M. Roma, March 2005.

454 “European women: why do(n’t) they work?” by V. Genre, R. G. Salvador and A. Lamo, March 2005.

455 “Central bank transparency and private information in a dynamic macroeconomic model” by J. G. Pearlman, March 2005.

456 “The French block of the ESCB multi-country model” by F. Boissay and J.-P. Villetelle, March 2005.

457 “Transparency, disclosure and the Federal Reserve” by M. Ehrmann and M. Fratzscher, March 2005.

458 “Money demand and macroeconomic stability revisited” by A. Schabert and C. Stoltenberg, March 2005.

459 “Capital flows and the US ‘New Economy’: consumption smoothing and risk exposure” by M. Miller, O. Castrén and L. Zhang, March 2005.

460 “Part-time work in EU countries: labour market mobility, entry and exit” by H. Buddelmeyer, G. Mourre and M. Ward, March 2005.

461 “Do decreasing hazard functions for price changes make any sense?” by L. J. Álvarez, P. Burriel and I. Hernando, March 2005.

462 “Time-dependent versus state-dependent pricing: a panel data approach to the determinants of Belgian consumer price changes” by L. Aucremanne and E. Dhyne, March 2005.

463 “Break in the mean and persistence of inflation: a sectoral analysis of French CPI” by L. Bilke, March 2005.

464 “The price-setting behavior of Austrian firms: some survey evidence” by C. Kwapil, J. Baumgartner and J. Scharler, March 2005.

465 “Determinants and consequences of the unification of dual-class shares” by A. Pajuste, March 2005.

466 “Regulated and services’ prices and inflation persistence” by P. Lünnemann and T. Y. Mathä, April 2005.

467 “Socio-economic development and fiscal policy: lessons from the cohesion countries for the new member states” by A. N. Mehrotra and T. A. Peltonen, April 2005.

468 “Endogeneities of optimum currency areas: what brings countries sharing a single currency closer together?” by P. De Grauwe and F. P. Mongelli, April 2005.

469 “Money and prices in models of bounded rationality in high inflation economies” by A. Marcet and J. P. Nicolini, April 2005.

470 “Structural filters for monetary analysis: the inflationary movements of money in the euro area” by A. Bruggeman, G. Camba-Méndez, B. Fischer and J. Sousa, April 2005.